BeOS: Porting UNIX Applications

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Preface to 2012 Release

A few years ago, Scott McCreary contacted me about releasing my book to the Haiku community. It's taken some time to get everything together.

I first published this book back in 1997, and it's been a very popular resource, for BeOS and BeOS programmers alike. Of all the books I've written (which now number almost 30), the BeOS book is still the one that either gets mentioned or asked about. Usually prefixed by 'Hey, you're the guy that wrote that BeOS book' and a long discussion about how great BeOS is and what happened.

I've released this book, which is now back under my copyright (thanks to Elsevier) to help porting applications.

The book content itself is unchanged; I haven't updated or corrected any of the content, and many things have moved on since 1997.

If you have any issue, or any questions, please find me at my website, MCslp.net. You can reach me by email using MC at that domain.

Have Fun

MC

Preface

Dedication

To my wife, Sharon, who let me stay at my computers long after bedtime.

Acknowledgements

As tempting as it is to list everybody who might have been involved, I'll try to keep this list as short as possible.

First of all, I'd like to thank the publishing people for getting me started, and more importantly asking me in the first place. Those people include Simon Hayes, Angela Allen, Paul Hardin, Mark Stone and Meghan Keefe. Thanks should also go to Chris Herborth, my technical editor who managed not only to correct my mistakes, but also kept me abreast of developments in the rest of the Be community when my time was taken up writing.

Lots of thanks to Christoph Droulers at Be, who managed to supply me with a replacement motherboard within a few days of the Advanced Access release, and thanks to William Adams and Jake Hamby at Be for providing me with timely information about the new OS version.

I can't really get by without thanking all the people who write great software and supply the source code to the public. This includes Richard Stallman who wrote emacs the first UNIX application I ever bought, and Larry Wall who wrote perl, the first package I ported to the BeOS.

Finally, I'd like to thank all the people in the Be community who have continued to encourage me to complete this port or that port and thanked me for doing so. I don't have enough space to name you all, but you know who you are!

Preface

Welcome to the practical guide for porting applications to the BeOS. This guide will, I hope, provide you with all the information you need to guide you through the process of porting off-the shelf-utilities like emacs and perl and your own programs and tools to the new OS.

Who should use this book

Anybody who is porting or writing software for the BeOS. Although this book primarily concentrates on porting software from the range of UNIX works, such as those from the Free Software Foundation, this book can be used as a reference work for all porting activity.

I have written this book with both beginners and advanced programmers in mind, but I've made some assumptions about your abilities. You should be able to program in C, and it would be to your advantage if you had had experience of using UNIX. I have catered for Windows and Mac users where possible, and experience of a command line interface would be a significant advantage. Whatever your background, I would hope you are familiar with using the BeOS even if you don't know how to program with it.

How to use this book

The book is split into three parts:

Part 1: Preparation - This section deals with getting to know the BeOS, making the best use of the available tools and preparing yourself for the porting process. If you already know UNIX fairly well you may wish to skip some of the chapters in this section. Alternatively you might want to read them anyway, in which case you might find some new techniques you weren't aware of.

Part 2: The Porting Process - We cover the entire process of porting software from the moment you download it to release your work to the unsuspecting public. This process includes configuration, identifying and using the various build techniques, building the package and identifying what to fix and testing the package to make sure it built correctly.

Part 3: Writing for BeOS - This last section is for reference purposes and contains a comprehensive guide to the POSIX functionality and how it affects the porting process within the BeOS.

The dialogue throughout the book is geared towards to providing you with a s birds eye view of the porting process and so I make extensive use of examples. In most cases these are examples from my own experience and I've often included the output and code from live ports that I'm working on. However, in some cases I've had to modify the code or the text contained in this book. Not everything from the monitor travels well to the printed page!

I have used the following conventions:

This is standard text, used throughout the book.

Names of programs, command line options, functions and other related items within the text are in <u>this style</u>

```
Whilst program listings and shell examples are in this style
```

In all cases, I've used the standard shell supplied with the BeOS which is based on the bash shell from the Free Software Foundation. For UNIX users this is similar to the Korn and Bourne shells and uses the same prompt symbol of the dollar sign, '$'.

Keyboard combinations are explained using the terms Alt (generally next to the spacebar, also called 'Option' on Macs) and Ctrl for the control key. We exclusively use the 'Return' key throughout the book, especially when using the shell. On Mac keyboards this key is the one with the main character keys usually with an arrow of some kind on it. This is not to be confused with the 'Enter' key which is on the numeric keypad.

I tend to use the terms application, package and software throughout the book to mean essentially the same thing. This is because in most situations a package (for example, gawk) creates only one application which is the software. However, in some situations I make the distinction that a package includes all the elements (source code, documentation, support files etc) whilst the application is the result of building the package.

Why and How to contact the author

Hopefully this book should help you through every step of porting Unix-style applications to the BeOS. If you are having problems, the best place to start is by talking to other programmers working on the project or the author, these details are usually kept within one of the many README files supplied with package. You may also want to try any mailing lists or usenet newsgroups that cover the package you are working on, or one of the general BeOS mailing lists such as bedevtalk, details are in the appendix at the end of this book.

As a last resort, or if the book doesn't mention something which you think it should (and for that I apologize in advance!), you can e-mail me on mc@whoever.com. For more details on me and the other projects I'm working on, my website is at http://www.prluk.demon.co.uk.

Chapter 1. - Introduction to the Porting Process

For those of you who picked this book up expecting to find out what the 'BeOS' in the title meant, I'll explain. BeOS is the new OS from Be Inc. It runs on the now extinct BeBox hardware and on Apple Mac and compatibles such as those from Power Computing and Motorola.

The operating system itself is based around a brand new design and some brand new ideas in order to provide a OS for the future, rather than one stuck with the standards of the past. Dealing with this compatibility issue makes existing OS slow and clumsy. Consider Windows 95, which still supports and in some cases uses DOS which itself was based on CP/M. Alternatively, take a look at MacOS, previously System 7. This is still a supported OS on some of Apples first Macs such as the Mac Plus. The compatibility works in reverse too, the new PowerPC based Macs support 68k code. All these issues go to make up a slower OS requiring ever faster machines with more memory and more hard disk space just to support the same basic functions.

With the BeOS, the entire OS was built from scratch. To use techno-babble it's a multi-threaded, pre-emptive multi-tasking OS supporting multiple processors. For the lay-person, this means an OS able to do lots of things simultaneously. Better still, it's able to do lots of things simultaneously much faster than existing OS, and it takes up less disk space and memory when doing so. The OS also supports two interfaces as standard, the familiar windows style interface and also a UNIX like command line interface. This helps it to appeal to Mac, Windows and UNIX users and provide the best of all worlds.

The core of the programming effort around the BeOS will be the object-oriented C++ programming environment. This is fine for new software, and it's something that Be themselves encourage, but the environment is geared towards the windows based interface. For people who want to port their software to the BeOS there has to be an easier way, and this is why the BeOS also supports POSIX. Porters and programmers alike can now move their UNIX style software to the BeOS. People porting other applications can also use the same POSIX interface to port the internals of their software whilst using the C++ environment to support their interface.

This is where this book fits in, it's a guide to porting the core of applications and packages to the BeOS. This includes the wealth of 'free' software available on the UNIX platform (for example, <u>emacs</u> and <u>perl</u>) and software from Macs and Windows PCs that use a UNIX or POSIX like interface to the outside world.

Porting is a structured and recursive process. By following some simple rules and steps it's possible to port most packages relatively simply. However, there are some packages which require a less rigid approach. Although a lot of porting has less to do with programming skill than writing the program in the first place, you still need to know about the machine to which you are porting. This includes knowing how to use the machine itself, as well as making the best use of the tools and features of the OS. Finally, you need to know what it is about the OS that makes it different and similar to other operating systems so that you can configure the finally port the software.

This book aims to provide you all the information you should need but shouldn't be taken as a complete solution to the solution. There are many steps to porting, including extracting the software, configuring, building and installing the software, and then communicating all your efforts to the original authors. I cover all of this, and more, in this book giving you a complete breakdown of the processes involved, and all the information you need.

Your success when porting will be governed by a combination of your programming ability and your understanding of the principles in this book.

Lifecycle of a Port

There are several stages to the porting process. Once you have decided what application to port, you need to follow the steps below:

1. Transfer the package to your machine and then decompress and extract the sources..
2. Configure the package by defining the local environment. This includes setting directory names and file locations. You will then also need to tell the configuration system what OS you are using, and in some cases provide information about individual functions and data structures within the BeOS..
3. Building or compiling the package, usually using a development tool such as make and a suitable Makefile. This is probably the longest part of the process, as you will undoubtedly need to make modifications to the original configuration and perhaps even to the source code to get the program to compile properly. In extreme circumstances you may also need to write more code or supply additional functions and features to plug the gaps in abilities and requirements.

4. Testing using the supplied test suite or building your own. If you find any problems, you'll need to return to building the package and make the modifications to get the program to work as desired.
5. Converting the documentation. Under UNIX this is traditionally been easy; most implementations included the nroff/troff typesetting system, which is what supplies the formatting for man pages. Increasingly, however, online help and documentation is being done in HTML. Indeed, with the BeOS, the standard documentation system is HTML.
6. Creating a new package to supply to the public. This should include everything the old package includes, plus any additional items required for your version of the port.
7. Communicating the changes back to the author.

This is vital and it's often forgotten by porters. In fact, unless you thoroughly enjoy the porting process, not telling the author of the changes you made will mean you have to repeat all the steps above with the next version he releases. Providing this information also means that new versions should automatically work on the BeOS without requiring you to change anything.

Choosing an Application to Port

The Unix world abounds with an interesting collection of free tools and software, any of which could make good candidates for porting to the BeOS.. Most of the software available for Windows or the MacOS is supplied precompiled and ready to use. In part this is because you can make certain assumptions about the machine on which the program will be run. Almost certainly the processor will be the same. For PCs this is an Intel x86 (including the Pentium series) and for Macs this is a Motorola 68k or more recently a Motorola/IBM PowerPC.

Machine Code

All programs used on computers are in machine code, this is code which makes up the instructions sent to the microprocessor which control the execution of the program. The instruction itself is represented by a number, and it is this number, combined with the data, that makes a program work. Each instruction is a low level function that the processor must perform. For example, most processors have an instruction to add two numbers together. However, the use of different processors means that the numbers for instructions, and the format of the instructions and data is different. It is these binary code differences, combined with differences in the OS that mean we can't move applications between, Apple Macs and PCs.

When dealing with a group of processors, such as the Intel x86 group which includes the original 8086, the 80286, i386, i486 and newer Pentium, each processor is just an expanded and updated version of the previous model. This retains backwards compatibility and saves everybody recompiling every application ever written to allow it to work. Any application which will work on a 80286 chip will work on a Pentium, but the reverse is not always true because the Pentium uses instructions not found on the 80286 chip.

UNIX is a different matter altogether. There are hundreds of different varieties of UNIX, and all of them can be attributed to a variety of different processors, which doesn't help the situation. Solaris, for example, is now available on both SPARC and Intel hardware, but although this provides OS compatibility it doesn't retain binary compatibility. Even within Sun there is diversity; six years ago the current OS for the SPARC platform was SunOS 4, a stable and still widely installed version of the OS. As part of the march of technology and progress, five years ago Sun introduced Solaris. This was a new OS, and though still based on UNIX and still incorporating support for SunOS applications, for the real benefits of the operating system software needed recompilation.

UNIX, Processors and Flavours

The history of UNIX goes back much further than people think. Much of the history has helped to form the features and facilities with which we are familiar today, including multitasking, multiprocessing and protected memory spaces. One of the advantages of UNIX is that at it's core it is relatively simple, and so the range of processors on which it runs is varied. This makes the compatibility more complex because not only do applications need to be aware of the OS on which they run, but they also need to be in the binary machine code format for the processor to understand the commands. Taking just the lead players in the market today, Sun already support Solaris on the SPARC processor, the Intel 486 and Pentium processors and the PowerPC. Despite the compatibility between Solaris at an OS level, it's not possible to take a program compiled with Solaris on Intel and use it on a machine running Solaris for SPARC. The code is not binary compatible, even if though the OS is essentially identical.

If we broaden the range, Linux runs on Intel processors. Here we have a different problem. We cannot assume that a Windows Intel application can be moved to the Linux Intel machine simply because of the same underlying hardware. The OS is now the incompatibility. All of the libraries and functions on which an application relies will not exist in identical forms on two different OS, even if they both run on the same processor and therefore have the same machine code. The other two major UNIX vendors, HP and Silicon Graphics, both run yet another version of UNIX.

Even taking POSIX, a standard interface to the underlying OS that makes porting between UNIX flavors easier, into account doesn't help. The underlying differences between the OS can still make portability a problem.

When you compare the market share of UNIX and it's various processors and the market share of Windows with it's identical Intel processor family, you begin to realize why so much of the free software is available as source code for UNIX and as compiled applications for Windows. The precompiled binaries that are available under UNIX work on such a small range of machines that supplying source is the only practical solution to supporting all flavors of Unix. This is the opposite of the Windows and Intel world, where a binary compiled on one machine will generally run on the whole range of machines.

The choice of code to port depends on several factors.. Make sure there is a demand for the package you are going to take the time to port. You also want to make sure that your work isn't redundant with somebody else'. . My first work on the BeOS was to port the sed utility, something which Be was introducing in to the next version of the BeOS. I learnt a great deal about porting software to the new OS by choosing a small, and relatively simple application. Choosing a similar package to port at the outset gives you a lot of practical experience, and if the package has already been ported then you have something to benchmark against.

If possible, determine that it is possible for you to do it. Even using this guide, porting is difficult and requires experience programming the OS before you can even start. If you're new to porting, choose something small, as I did with sed, before moving on to something larger like sendmail or emacs.

One thing you should do is to check the dependencies. A dependency is a requirement of the package to have access to a library or other application before you can start working on the main package. For instance, porting RCS, the revision system, would require the diff utility, which in GNU form requires the regex regular expression library. In this example, to compile the single package would actually require you to port two other packages before you even started on the original work. These dependencies are important, and the README file normally includes the information you need to know.

Since there is no point in porting an application if you don't actually know how to use it, you should pick a package you know — otherwise you won't be able to test the package. If possible, choose one where you at least know the basic principles of how the program works, even if you are not completely sure of the programming steps involved.

With all this in mind, pick an application from those available. A good selection is available from GNU (see sidebar), who are endeavoring to provide all the programs available for the typical UNIX platform and eventually an entire cross-platform UNIX clone. GNU software has the advantage of being highly portable. There are several reasons for this. First, the software is developed and released, via GNU, to the computing community. Because the software and the source code is free, the packages are then ported from the original code to many different platforms, and each time a new platform has been 'cracked' and the port achieved, the information is relayed back to GNU and the development team so that the next version of the package is compatible with a larger number of platforms.

Out of all this work, all done for free by the members of the Internet and computing community, GNU has developed a configuration script which takes a lot of the guesswork out of the porting process. This guesswork includes checking core things such as byte ordering and variable sizes, right up to checking the existence of specific functions within the OS you are porting to. Unfortunately, the configuration script is not infallible, and one of the goals of porting software is to make sure that the configuration works on all the platforms it's been ported to, and that the information is sent back to the developers.

The Free Software Foundation and GNU

GNU, which stands for the recursive 'GNUs Not UNIX' is a project which produces a wide range of software aiming to plug the gaps in the market of free software already available. The projects most famous export is emacs a very powerful editor with built in scripting based on the LISP programming language. The GNU project is one of the many projects supported by the Free Software Foundation. Most people consider the two entities to be identical. In fact, the Free Software Foundation do not write or support any software, but they do support the GNU project with financial and administration support in their cause to provide free software for everyone whilst simultaneously battling the super-corporations such as Microsoft to encourage them to reduce the cost of their software.

Difficulties with the BeOS

Every OS has its own individual peculiarities and problems.There are some things which are the same in the BeOS as they are in other OSs, and these will help you quickly jump into the BeOS. Because of the POSIX compatibility, libraries and header files and their contents will be familiar, if not exactly the same to what you're used to. The same shell programs and utilities that regular UNIX users use are also available, as those used to gawk, cut, paste and so on will be happy to know. For Windows and Mac users, finding a common reference point is more difficult, but you should be familiar with the windows based environment, and those used to DOS will find the UNIX like command line much easier to use.

The biggest difficulty with the BeOS as a target OS for your port is that it's new. Other platforms have the advantage of having been around for a few years, if not more. UNIX is decades old, and although it's now fragmented into a number of different varieties and flavors, the principles behind the OS are the same. You can also be pretty sure that most flavors of UNIX come from one of two stables—BSD or System V—and that makes the process easier still. Part of the BeOS closely resembles UNIX. I've already mentioned the UNIX like command line interface and tools. A number of the terms and frames of reference are also similar, such as threads and processes.

To be more precise, BeOS supports the POSIX 1003.1-1990 standard for communication between applications and the operating system, and that at least gives us something to work with. This standard specifies the functions, header files, data structures and other information which applications utilize to access the abilities of the underlying operating system. Most UNIX flavors now support the POSIX standard. Even if they don't support POSIX directly, the chances are a number of their functions are actually supported within the POSIX framework. This is because many of the functions that are now part of the POSIX standard actually came from UNIX in the first place.

With POSIX support, - porting applications is made easier, because any application written with POSIX standards in mind should be relatively easy to port to another POSIX compliant OS.

At the time of this writing, the first public release of the OS has been made, and the Intel version is now out on the shelves.. That makes the OS just over 2 years old, a mere baby compared to monoliths like UNIX, DOS, Windows, and MacOS. The youth of the BeOS means that its functions and abilities are limited. Some of the 'standard' libraries and support applications to aid in the porting process don't exist. For example, UNIX programmers will be used to a choice of editors, either emacs or vi. While ports of these tools exist, there may be minor differences in the way they operate and in the features they provide, although this shouldn't cause a huge problem..

We will look more closely at some of the specific problems with the BeOS as we move through the different chapters, but a brief discussion of the main issues will illustrate the nature of problems you will encounter.

Differences of Terminology

Even when the functionality of the BeOS is the same, the terminology may be different. Although the POSIX interface helps to shield you from this to an extent, you will find references to terms that you don't recognize. For example, where UNIX uses threads, processes, and process groups, the BeOS uses threads and teams. In addition, UNIX uses filesystems to describe the individual areas of a disk which go to make up the filesystem. Under BeOS (and indeed MacOS), individual disks or partitions of disks are called volumes. Under Windows and DOS they are called drives. Essentially, they all refer to the same thing, a partition of a physical storage device.

Missing Features

Not all the features of all the UNIX variants are here—in some cases not even all the features of just one variant. For example, the standard (and in fact only) shell is bash, the sh/ksh/csh amalgamation from GNU; there aren't separate versions of each shell available. This shouldn't cause any major problems because most shell scripts are written in the Bourne or Korn shells. However, missing utilities such as find (which is available for the BeOS) are of greater concern when porting. Many such utilities now have versions available within the BeOS porting community but it can be quite a shock to not find the tool incorporated as part of the basic OS.

Fundamental OS Differences

The BeOS structure is different to most OS, from the general directory and file layout to the core processes that run. There is still a kernel, but rather than a large kernel providing all of the functionality for the entire operating system, there is a smaller kernel which supports the multithreading, multitasking and memory services. All the other facilities normally provided by a single kernel are instead supported by a collection of "servers". Each server is responsible for a specific area of functionality. The Network server for example is primarily responsible for communicating over the network. Unlike UNIX, where such servers provide additional services, if the server isn't running then you don't have access to the network or any related network services.

The advantage of individual servers for these services is that if the servers crash, you merely need to restart the server and the entire OS to regain the services.

The BeOS really isn’t any different from any other OS when it comes to problems and difficulties. Although I’ve painted a fairly negative picture here, you’d have just much difficulty porting applications to other OSs. Porting is complicated. The processes in any instance remain the same: You need to bridge and plug the gaps and find the compatible parts you need to resolve the differences.

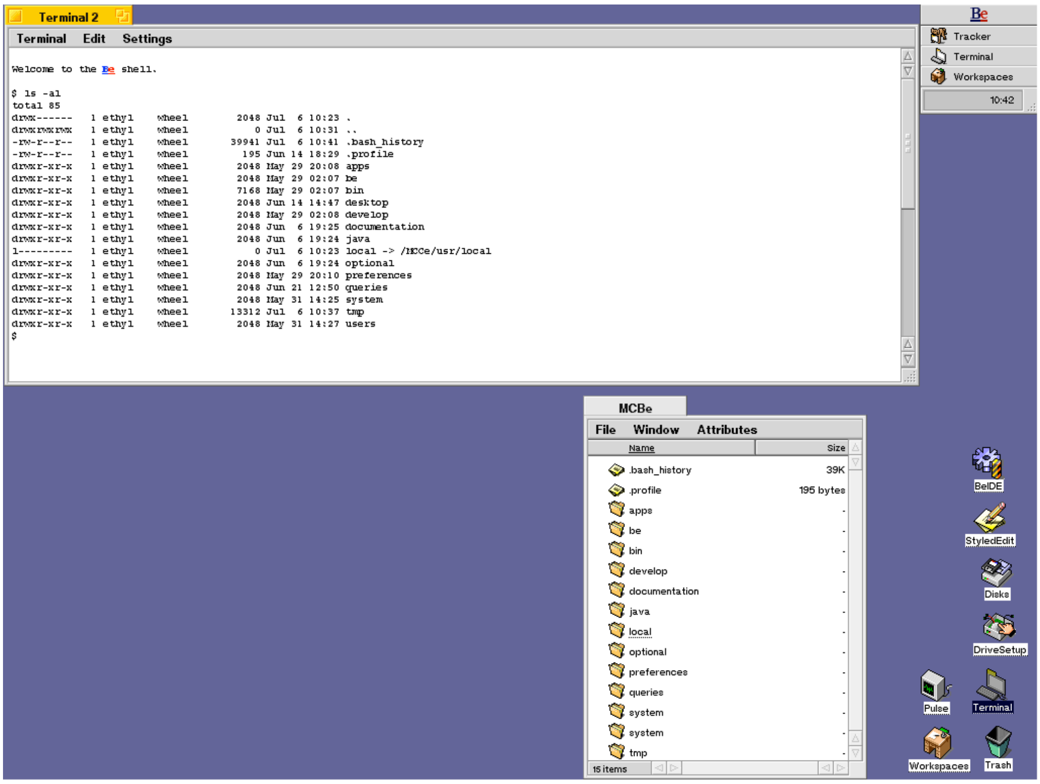
Chapter 2. : BeOS Structure

We'll start by taking a quick look at the interface. The BeOS can be split into two types of interface. One is the now-familiar windows interface similar to the Mac OS, The X Window System on UNIX, and Microsoft Windows in its various incarnations; this main interface is called the Tracker and is similar to the Finder on the MacOS. The other is a command-line interface similar to MS-DOS or UNIX and is accessed via a program called the Terminal using a shell called bash.

In this book we'll deal largely with the terminal interface because it is the preferred interface of software porters, particularly those coming from the UNIX stable. Where necessary we'll look into BeOS programs such as the Integrated Development Environment (IDE) and Debugger.

The two interfaces are compatible. It's possible to list contents of a directory using the Tracker interface or using the ls (list files) command in a Terminal window (Figure 2.1). By the same token, you can run a BeOS (windows) program from the command line as you would run a UNIX command, or you can double-click on the application's icon in the Tracker. Running a UNIX command from the Tracker has no effect since the Tracker is incapable of accepting any input or output to the program you run.

Figure 2.1
Accessing directories from the Tracker and the Terminal



The BeOS File System

The BeOS filesystem has changed a lot in the relatively short life of the operating system. In it's first incarnations, the filesystem was actually a database, with the UNIX like interface built on top of it. This worked in tandem with the rest of the OS which used the notion of databases as a way of storing information about the system, preferences etc, much like the Windows 95 registry. However, the filesystem was slow in comparison to others when used for storing the files everybody was used to. It it also meant the OS was slow to start when it might take just 15 minutes to get to a point where you could use the machine.

In the latest release, the filesystem is now based on a UNIX style Journalling File System. The JFS is much more robust and much faster than most other forms of UNIX OS. Instead of writing filesystem information (directory entries, allocation blocks, etc.) directly to the disk each time, writes and changes are written to a journal. In the background, the OS then updates the files on the disk using the information in the journal. The most significant advantage of this is is that it is almost impossible to corrupt the filesystem information, even during a crash. Because the journal is written instantly to the disk at the time of the request, making modifications to files after a crash is just a case of working through the journal.

This saves running an fsck like utility to recover a disk at startup, saving time. My BeBox, which has dual 66Mhz 603 processors and 6.5Gb of space, starts up in less than 30 seconds.

The database system from the original filesystem still exists and in addition each file can now have a number of attributes attached to it. For example, an email message could be stored as a file with attributes specifying the sender, subject and other information. These attributes can be read without having to open the file because they are stored along with the other filesystem information, such as the files name, size and creation date. For POSIX style programs, this information is not needed as it is in deference to the abilities of other POSIX style OS.

The advantage to most people though will be that the OS now operates like all other OS, and in particularly like UNIX, with the same basic file and directory formats without the information having to be processed by the OS first.

Basic Structure

Let's look at the directories, folders, and files on the disk and their layout. Initially the basic format looks like a cross between Mac OS and UNIX, and anybody familiar with these platforms will be able to identify some of the areas quite easily.

The different elements of the BeOS pick up on different aspects of various other operating systems. The top level of the structure is the *Disks* icon which is equivalent to "My Computer" under Windows 95 and similar to the Desktop of the MacOS. There is no direct analogy with UNIX. UNIX structure is based around the root filesystem, which itself is a place to store files and directories. In that respect the Disks icon equates to the physical machine.

Under each of these operating systems the different disk drives and other storage devices (including networked drives) are referred to differently.

Volumes

Each physical drive under BeOS is classed as a volume. This is true for hard-disk drives, CD-ROM drives, or floppy disks. Each volume has its own name, and these volumes are immediately available under the Disks icon. Within each volume there are a number of directories.

As with UNIX, you can mount a volume at a specific directory location, but most people will probably want to retain a match of different volumes to different disk drives.

Like UNIX, the “root” directory is still valid, and can be referenced using the “/” (forward slash) character. You can then reference individual volumes by specifying the volume name after the slash.

For example, to access a volume called “MCBe” you would refer to it as:

```
$ cd /MCBe
```

If you are referring to a volume whose name has spaces in it, enclose the name in quotes:

```
$ cd "/Be Hard Disk"
```

However, be warned that using

```
$ cd /
$ ls -l
```

does not just provide you with a list of additional volumes, it also lists some top level directories such as /dev (for devices) and some links to important directories such as system which contains the OS kernel and configuration files.

This is very different from both Mac OS and DOS/Windows. Under Mac OS each hard disk has its own icon on the Desktop, each of which is referred to as a volume. The Desktop displays the available volumes and so is equivalent to the root directory under BeOS. The principles used for handling volumes in the BeOS’s Tracker interface are very similar to the MacOS style, but you must access the individual disks using the Disks icon on the desktop.

Under DOS and Windows, the method for handling volumes is the same but the terminology is slightly different. Each disk is referred to with a letter and is equivalent to the BeOS volume. Each directory within each disk drive can then be described by prefixing it with the drive letter in the same way that directories on specific disks can be prefixed by the volume name under BeOS.

The Boot Volume

Under the BeOS there is a special volume named *boot* that refers to the disk containing the active operating system and the OS applications. Items such as preferences and commonly used applications should also be stored on the boot volume.

The bootvolume is always available, because it will always equal the disk which contains the currently running OS, regardless of the actual name of that disk. In fact, it is really an alias to the disk that contains the OS. The boot volume should be your preferred option when you set default directories in applications. We'll look at using the boot reference as an alternative to missing directories later in this chapter.

MacOS uses the term "Start-up Drive" for the equivalent functionality. It is possible to work out which drive has been used to boot up the machine by finding the active System Folder, which is also where most of the preferences and system information can be found. DOS and Windows do not have a specific way of finding out which drive started up the OS, but it is generally fair to assume that it is the C: drive.

Directories

Using directories under the BeOS is not very different from UNIX or DOS, which makes the transition fairly easy for most people. For those coming from the MacOS the differences are more marked. Directories in the BeOS are equivalent to folders on the Mac. These directories can be accessed via the Tracker in the same way that folders are accessed on the Mac using the Finder.

Directories are separated by the UNIX-style "/" character. As with UNIX, directories can also be referenced using "." (dot, meaning the current directory) and ".." (dot dot, meaning the parent directory). For example, using

```
./foo
```

will select the file called foo in the current directory, while

```
../foo
```

will select the same file in the parent directory. You can also specify files and directories absolutely (e.g. /MCBe/foo), but remember that the first item must be either a volume name or the boot alias.

Default Directories

The basic contents of the boot volume are

```
$ cd /boot
$ ls -l
total 4651
drwxr-xr-x   1 ethyl    wheel        2048 May 29 20:08 BeOS
drwxr-xr-x   1 ethyl    wheel        2048 May 29 02:07 apps
drwxr-xr-x   1 ethyl    wheel        7168 May 29 02:07 common
drwxr-xr-x   1 ethyl    wheel        2048 Jun 14 14:47 home
drwxr-xr-x   1 ethyl    wheel        2048 May 29 20:10 preferences
drwxr-xr-x   1 ethyl    wheel       13312 Jul  6 10:37 tmp
$
```

You'll notice that the list shown here doesn't match the Tracker version of this same directory. This is because the Tracker shows all files, while the Terminal listing (which is what we get with ls -l) "hides" any files whose first character is ".". Refer back to Figure 2.1 to see the difference between the Tracker and Terminal output of the boot volume.

., .. and .file

Many people find the differences between the single dot, double dot and files starting with dot to be confusing. This is understandable, it takes some time to get used to terms which mean very different things but use the same basic symbol.

A single dot *always* refers to the current directory, this is especially useful when you want to refer to the program in the current directory, and to one of the of the files in your directory path. The double dot *always* refers to the parent of the current directory. This is useful when you are a number of directories down, and don't want to specify the full path of the file you are referring to. IT is also the only way to traverse back up a directory structure when you have traversed down it using cd. Using:

```
$ cd ..
```

changes the current directory to the parent of the one you were just in.

Any file beginning with a dot is usually a configuration or preferences file for an application, particularly when in a users home directory. For example, the file .profile is executed by the shell each time it is run from a Terminal window and specifies things such as the prompt to use on the command line, and the search path to use for applications.

In all cases, ls will hide any file name beginning with a single dot. This means that ., .. and files with a name beginning with . are ignored in the standard listing. Using ls -a will show all files, including those beginning with a ".".

There are a number of basic directories including beos, bin, system, apps, preferences and home.

The beos directory is the location of the OS, including the kernel support applications and configuration information. It is further subdivided to include the rest of the necessary files in a structured format. In particular /boot/beos/bin is a link to /bin, which contains the command line utilities used in the Terminal, /boot/beos/apps contains the programs supplied by Be as part of the BeOS. The /boot/beos/system contains the OS files, libraries and servers essential to the operation of the machine..

The /boot/beos/documentation directory, as the name suggests, contains documentation on a number of aspects of the BeOS, including online manuals for all of the software, tools, and BeOS application kits (but not including documentation on the POSIX libraries and functions). The documentation is supplied in the form of HTML (Hypertext Markup Language) and can be viewed using the supplied Web Browser, NetPositive.

The contents pages are linked to the other parts of the document, making it an invaluable and easy-to-use reference.

The apps directory is for BeOS applications. These are applications used by the BeOS as a whole, as opposed to the /boot/bin directory, which is used to store the UNIX-like tools such as ls and compress. The applications directory is further subdivided into software vendors. For example, apps/Metrowerks contains the user software supplied by Metrowerks (the C compiler and other tools).

The home directory contains files, applications and libraries for the user.

/boot/home/config should contain servers, libraries, fonts and configuration files that are not directly related to the kernel of the core operating systems operation.

Contributed software (non-system software) should ideally be placed into the /boot/apps directory structure or for command line applications, /boot/home/config/bin. This organization prevents you from overwriting the OS-supplied software, and makes it easier for you to find the software and update it when you need to.

The /develop directory contains the headers, libraries and other files that you use to develop applications. The details of using the compiler and other development tools will be discussed in Part 2 of the book.

The next top level directory, preferences, contains links to the programs in /boot/beos/preferences required to change the machine's configuration. These are small applications which set program options, much like the control panels under Windows and MacOS, rather than files used by the operating system to specify the preferences, as you'd find in UNIX.

Take some time to look around these directories, particularly the /boot/develop directory. We'll be using that directory and its contents regularly during the porting process.

Applying UNIX Structure to the BeOS

It is possible with some thought to apply the basic file-system structure used on most UNIX machines to the BeOS. The layout is very similar; the only major differences come from the change in the way physical drives are handled and the names and locations of familiar directories.

We still have a root directory, but unlike UNIX this directory is incapable of holding files, just directories and symbolic links. The BeOS has dispensed with top level directories being the sole source of information about the current operating system because the boot volume implies the location of the OS files.

In Table 2.1 you can see how many of the standard UNIX directories are equivalent to their BeOS counterparts. I've used Sun's Solaris variant of UNIX for the directory names, although many of these names are common to most UNIX flavors. Beyond the standard UNIX directories, there are also well-recognized extensions to the layout. For example, the GNU project specifies the /usr/local directory for installing additional pieces of software. The /boot/home/config/bin directory structure should be used for the contributed software, libraries, and support files.

Table 3.2

UNIX Directory Equivalents

UNIX (Solaris)	BeOS
/	/boot
/dev	/dev
/var	/boot/var
/etc	/boot/beos/etc
/lib	/boot/beos/system/lib
/bin	/boot/beos/bin
/usr	/boot/home/config
/usr/bin	/boot/home/config/bin
/usr/lib	/boot/ home/config/lib
/usr/include	/boot/ develop/headers

Once you've gotten used to these minor differences, using BeOS directories is as easy as using directories under UNIX. You can't change the standard layout: for example, removing or renaming the beos directory has catastrophic effects, much as removing the /usr or the /etc directory would on a UNIX machine. The use of the /beos directory should make upgrades as easy and painless as possible. To prevent any problems, no user files should be stored in these directories.

Beyond that, however, you can re-create whatever structure you prefer or are familiar with within your own home directory. However, it is best to try to keep to the basic layout outlined here, as the BeOS is selective about where it expects to find things like libraries and other files during program execution. If you want to recreate a particular layout, use symbolic links to refer to the equivalent items as I've outlined them above.

Missing Links and Other Goodies

The BeOS is missing some familiar features and a number of useful utilities from the standard range available on most UNIX variants.

The most obvious, and perhaps most annoying, missing feature is that the BeOS has no concept of hard links, although it is aware of symbolic links. The absence of hard links can cause you a number of problems when porting, as some programs rely on hard links to compile and run correctly. This affects the use of the machine as well. Aliases, introduced into the Mac's System 7, are now a common feature of the operating system; aliases were copied in Windows 95 and renamed shortcuts. Both are different terms for the same thing: links.

Links are essentially just pointers to a file or directory. They are used under UNIX to create a duplicate name for the same file, perhaps in a more convenient place. For example, contributed software usually has the current version number appended to the program or folder name. A link is then created whose name is just the base name of the program, which is much more convenient to type. A good example of this is perl. The real program name might be perl-4.036, but a hard link is created which enables the user to refer to the same program simply as perl. Thus when the program is upgraded to perl-4.037, the user can still access the most up-to-date (and freshly linked) version by simply typing perl.

In most cases, these links are introduced using hard links. A hard link is just a duplicate name entry in the directory list. A hard link takes up no additional disk space (it doesn't duplicate the file). A symbolic on the other hand is really just a special type of file. Rather than adding an extra name to the directory list, and then linking that name to the real location of the file, as in hard links, a symbolic link is a pointer to the file. This is the same basis as aliases and shortcuts, and so it should be more familiar to everybody.

It is often possible to get around the hard link requirement by using a symbolic link, or by truly duplicating the file or directory, but this is a less than ideal solution.

For those attached to a particular type of shell interface to UNIX, you will be disappointed to find that the BeOS currently only supports bash. Although bash is an amalgamation of the best features of the Bourne, Korn, and C shells, those who prefer the individual shell interfaces will have to cope with bash. You can find out how to make the best use of bash in Chapter 4.

Many of the familiar commands that you expect to find when using the command-line interface are also missing. The more command doesn't exist, but it has been symbolically linked to the GNU software equivalent less. This isn't a bad thing because less provides much better functionality, including the ability to go back through a document as well as forward.

Chapter 3: We’re Not in UNIX Anymore

In the last chapter we saw the differences between the BeOS directory structure and those of DOS, Windows, MacOS, and the various flavors of UNIX. There are a number of similarities between the layouts of BeOS and UNIX, but now we’ll concentrate on the more specific differences between the core of the BeOS and UNIX. This chapter will help those readers with a UNIX background to learn how the BeOS differs from UNIX, and help those with Windows or Mac experience to understand how the BeOS's UNIX-like elements work.

From very early in its life, UNIX was designed with multiple users in mind. Each user has a specific ID number and can be a member of a number of different groups. Each group also has its own unique ID. Finally, there is a special set of users called “other” which is considered to be everybody else (who isn't you or a member of your group). These sets—user, group, other—affect the ways in which files, directories, and processes can be modified and accessed.

This approach is very different from that taken in both DOS/Windows and MacOS, where the user's access to the machine is absolute. There is no separation on a single machine between what you have access to and what you don't; you have access to everything. However, most people have come across the user and groups concepts when accessing servers on a network, where the same terminology is used. You can try this on MacOS by setting up file sharing on your machine, selecting a volume, and then choosing Sharing from the File menu. For file sharing, the main user (owner) has access to anything on the machine, but can grant specific rights to individuals who connect over the network, and can group these individuals with others who share similar access rights.

Any individual user on the network will therefore have access to the resources they own, to the resources which are owned by a group of which they are a member, and finally to all those resources which are available to everyone.

The BeOS is a hybrid of the multiuser approach of UNIX and the single-user approach of the Mac. A BeOS machine is, in essence, a single-user machine like a Mac, but the UNIX-style (POSIX) interface offered by the Terminal provides a UNIX-style set of file permissions. This UNIX influence extends to the way processes are handled and how the core of the OS operates, but we’re not in UNIX anymore—there are some important differences.

The BeOS's Concept of Users

To gain access to a UNIX machine you must log in with your user name. The name identifies you to the system and sets up the environment (stored in the /etc/passwd file) that will control your access to the resources on the machine. Each user is unique, with their own unique number. Each file and directory has an owner identified by the user ID.

User names and user IDs

The relationship between usernames and user IDs is controlled by the /etc/passwd file under UNIX. User ID's are numbers, and must be unique to each individual user. User names are just text aliases to the individual numbers. The OS only stores the ID against a file, not the name. This means that you can change the name assigned to a specific number by modifying the passwd file, but it doesn't adjust the actual ID of the files concerned, just the name that is reported back.

Really, the names are only there because humans are useless at remembering numbers but much better at remembering words.

Under the BeOS, which was designed as a single-user OS rather than a UNIX-style multiuser OS, no such system exists. This lack causes a few problems during the porting process and in providing a working version of the application you are porting. Many UNIX-bound applications use this multiuser model to control access to files by different programs within an entire application, and others require specific permissions on files and directories to work properly.

The BeOS is now beginning to introduce a multiuser type environment, and the changes to the directory structure reflect this progression.

Permissions

File and directory permissions are based around three bits: read, write and execute. The combination of the file owner and the permissions controls access to files and directories. When you do an ls -l (long listing) of a directory, the first column of output shows you the permissions for each file using a ten-character string:

```
$ ls -l
total 258
-r--r--r--   1 ethyl    wheel       17982 May 29 20:42 COPYING
-r--r--r--   1 ethyl    wheel       25263 May 29 20:42 COPYING.LIB
-r--r--r--   1 ethyl    wheel       47750 May 29 20:42 ChangeLog.Z
-r--r--r--   1 ethyl    wheel        6915 May 29 20:42 INSTALL
```

```
-r--r--r--   1 ethyl    wheel         4038 May 29 20:42 Makefile.be
-r--r--r--   1 ethyl    wheel         4000 May 29 20:42 Makefile.in
-r--r--r--   1 ethyl    wheel         4699 May 29 20:42 NEWS
-r--r--r--   1 ethyl    wheel         4607 May 29 20:42 README
-r--r--r--   1 ethyl    wheel         3555 May 29 20:42 acconfig.h
-r--r--r--   1 ethyl    wheel         8785 May 29 20:42 config.h.be
-r--r--r--   1 ethyl    wheel         8287 May 29 20:42 config.h.in
-r-xr-xr-x   1 ethyl    wheel        92914 May 29 20:42 configure
-r--r--r--   1 ethyl    wheel        11374 May 29 20:42 configure.in
drwxr-xr-x   1 ethyl    wheel         2048 Jul  6 18:28 doc
-r-xr-xr-x   1 ethyl    wheel         4771 May 29 20:42 install-sh
drwxr-xr-x   1 ethyl    wheel         5120 Jul  6 18:28 lib
-rw-r--r--   1 ethyl    wheel            0 Jul  6 18:29 lsl.out
drwxr-xr-x   1 ethyl    wheel         2048 Jul  6 18:28 man
-r-xr-xr-x   1 ethyl    wheel          649 May 29 20:43 mkinstalldirs
drwxr-xr-x   1 ethyl    wheel         2048 Jul  6 18:28 src
-r--r--r--   1 ethyl    wheel            1 May 29 20:43 stamp-h.in
```

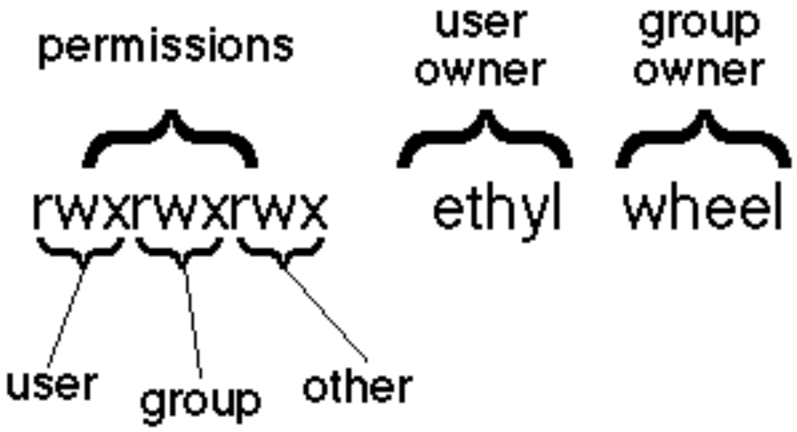
The first character shows you the file type, using "d" for directory, other possible characters can be seen in the sidebar.

The possible file types (indicated by the first character of the permissions column) are as follows:

d	the entry is a directory
l	the entry is a symbolic link
b	the entry is a block special file
c	the entry is a character special file
p	the entry is a named pipe
-	the entry is an ordinary file

The next three characters show the permissions for the owner of the file; the three after that show the permissions for the group owner; and the last three show the permissions for everyone. Each character is called a permission bit, and the combinations of different bits specify the mode. See Figure 3.1.

Figure 3.1
Users, Groups and Permissions



The third and fourth columns (ethyl and wheel) relate to the user and group respectively. The user and group specify the registered users of the file. Access to the file or directory is granted based on this information, and the permissions.

For example, a read bit (the "r") in the second column of the permissions indicates that the owner can read the file. In the third column, a write bit (the "w") indicates that the owner can modify (write to) the file. An execute bit ("x") in the fourth column shows that the file is executable (a program or script) by the owner. For example, a file with "-r-x" in the first four columns has read and execute permissions set for the owner, and is therefore likely to be an application or a script. The dash (-) indicates that the write bit is not set. A file that has the read and write bits set ("rw-") is more likely to be a regular file.

UNIX uses the execute bit to decide whether a file is executable or not; that is, whether it's a script or program. Under the BeOS, it is not necessary to set the execute bit for a file to be recognized as executable, though this shorthand is useful in helping you identify executable programs in directory listings. Instead, the BeOS uses MIME (Multi-purpose Internet Mail Extension), a system borrowed from the Internet which records information about the files contents and format. The basic MIME list has been expanded to cater to BeOS applications, but the principle remains the same.

There are some special cases with respect to permissions for directories. If a directory that has the read bit set, the user can list its contents, but won't be able to obtain details about the contents (size, date created, and so on) or open the contained files unless the execute bit is also set. If a directory only has the execute bit set, the user will have access to the files contained in the directory, but only if they know the file name! This can be useful for incoming FTP directories where you may want to allow people access to file with a given URL, without providing them access to the rest of the directory.

A user who has write permission to a directory can delete anything contained within it. This is true even if the files themselves don't give the user write permissions. Many applications use these and other features to control access to files and directories by users in multiuser situations.

File permissions represent one area in which the BeOS copies the appearance of UNIX, but not the functionality: while the BeOS currently makes any requested changes to the permissions of files and directories, it generally ignores the permissions when it comes to separating access by users, groups or everybody else. There are, under certain circumstances, ways of getting around this, but you should keep in mind that the BeOS is not currently a multiuser-aware machine. This doesn't mean that it can't be used by more than one user, neither does it stop the machine from being a viable server platform, but it does affect how the machine responds to multiuser-aware applications, particularly in regard to file access and permissions.

Processes

Windows and MacOS users can think of a *process* as a currently running application (the OS itself is also a process). Under UNIX and the BeOS, when you list the current processes there appear to be a greater number of processes running than you might expect. What is actually happening is that different elements of the OS are split down into individual processes, whereas under Windows and MacOS they are simply treated as part of the overall system in one single process. The BeOS uses a slightly different model for processes than UNIX does, as we will see later in this chapter.

We will consider those privileges that directly affect the multi-user model we find under UNIX. Under UNIX a process that is executed is owned by the user who created it, and this user has special privileges over the control of the process. Since there is no concept of users within the BeOS, running a process does not assign a user and therefore the user has ultimate control over all processes running, including the system processes. For example, it's possible (but not recommended) to kill a system process—after all, you own the process, so you should be able to kill it.

Execution

Under UNIX you can set the user permissions and the user ownership of a file so that anybody running the program will execute the program as the owner of the file, rather than the user. It is the combination of the owner of the file and a special bit called the setuid (set user ID) bit which allows you to force an application to execute as a specific user. The setuid bit appears in the place of the execute bit as an "s" instead of the usual "x".

Executing as a specific user is a technique often used by OS-level software to give the user file access that they would not normally have. The passwd command is set to execute as the superuser so that, for example, the user running the program can change their password. Under the BeOS, the setuid bit can be set, although currently it has no effect (since the BeOS is not truly a multi-user system).

In UNIX all processes that are executed by a specific user can be listed using the ps command, and it's also possible to list the processes that have been executed within the current shell. Again, on the BeOS the lack of user specifications means that all the processes are owned by the same user, which is the only user on the system.

Running the ps command therefore produces the same output regardless of the options you specify. Once more the unneeded options are included to allow programs that use the ps command to execute without being interrupted by an error condition.

The BeOS's Concept of Groups

A *group* is a collection of users. Groups allow all users within that group access to a resource. Access to processes, files, and directories can be controlled and restricted by group ownership in the same way that user ownership affects access by individual users.

Permissions

Under UNIX, as with user permissions, it is the combination of the group ownership and group permissions which control the access to files. All members within a group are considered to have group ownership, but while user ownership is absolute, group ownership is always shared between all members.

This doesn't mean that a group member automatically has the same rights as the owner of the file or directory. Group members are unable to change the permissions of a file, even the group permissions to which, logically, they should have access. They can delete a file or directory, though, if the group has write permission. The BeOS does not support the concept of groups and so group permissions make no difference to the access rights of the individual user. It does, however, still honor any changes to the group permissions, even though they have no effect.

Processes

Under UNIX the group under which a process has been run affects the files and directories to which that process has access. However, because the BeOS does not distinguish between different groups, in fact there is only one group, so groups have no effect on a process's access rights to files. This means that regardless of the group (and user) permissions on a file, e the BeOS all processes have access to all files and directories.

This is a different mechanism from the process group ID under both the BeOS and UNIX. A process group ID controls which processes are attached to a specific parent process. Under the BeOS this is handled via the UNIX (or more correctly POSIX) compatible interface interface, which we will look at more closely in the coming chapters The BeOS also uses a different mechanism for grouping processes together, as we will see later in this chapter.

Execution

Because the BeOS is not group-aware, no facility to change group ownership of applications exists. This affects the setgid (set group ID) bit, since without a group owner setting the setgid bit will have no effect. Under UNIX, though, the setgid bit allows a program to be run with the group ownership as defined by the group owner of the file, in much the same way that the setuid bit allows programs to be run as the owner of the application.

Effects on Porting

The absence of a users or groups concept in the BeOS can affect the porting process, both in the code and in the processes required to port the application. Because of the lack of the /etc/passwd and /etc/group files it is impossible to set a file or directory's owner or group.

For example, consider the following:

```
$ ls -l
drwxrwxrwx   0 elvis    1             0 Feb 24 23:02 t
drwxrwxrwx   0 elvis    1             0 Feb 24 23:02 t.c
drwxrwxrwx   0 elvis    1             0 Feb 24 23:02 t.o
```

Now try changing the owner:

```
$ chown martinb t.c
$ ls -l
drwxrwxrwx   0 elvis    1             0 Feb 24 23:02 t
drwxrwxrwx   0 elvis    1             0 Feb 24 23:02 t.c
drwxrwxrwx   0 elvis    1             0 Feb 24 23:02 t.o
```

You probably expect it to fail. The BeOS accepts the command as valid, but actually does nothing. This keeps programs and shell scripts from failing because the chown command, as we know, doesn't work. The same is true for chgrp, which also does nothing, but still returns a successful exit status to the calling program. This silence doesn't always solve the problem during the porting process, as it is possible that the installation program may not only attempt to set the ownership of files, but also check the ownership to ensure correct installation. Unlike attempting to set ownership, checking ownership *will* return an error condition.

The BeOS's chmod program, which adjusts the permissions on a file or directory, does work identically to the UNIX command, and so it should produce the correct exit status to the calling program and have the expected effect on the file or directory concerned. Keep in mind, though, that the execute bit does not have to be set on the file for it to be an executable program.

Also, setuid and setgid programs won't have any effect—there are no users or groups for processes to execute as other than the default user. Again, this lack can cause problems at various stages of the porting process, so it is important to be aware of them right from the start.The problems of setting permissions and ownership usually only occur during a packages installation process, and it is a very rare occurrence when it happens.

You will also find that when you extract sources (which is discussed further in Chapter 5), the files are recovered using the standard user and group. Permissions, though, are extracted correctly.

Perhaps the best equivalent for the BeOS when using UNIX is the *superuser*, or *root*. Under UNIX, the superuser has access to everything, without exception and without restriction. The BeOS effectively gives you permanent root access to the OS. This has some advantages, since you are never restricted by the files you have access to. You should never end up in the situation where the file you really need to have access to is unavailable because you don't have the required permissions.

Unfortunately, all the dangers of root access come with the privileges. It is possible, and dare I say easy, to accidentally delete a file, overwrite the OS files, or delete entire directories. So be careful when deleting and moving files and directories. We're not in UNIX anymore, and the same safety mechanisms don't exist.

Processes

Each program running on a UNIX machine is called a process, and each process has a number of attributes. We've already seen how some of these attributes are missing in the BeOS, and how that affects the porting process. The BeOS's process structure is very different from that found under most UNIX variants. Let's have a look at the output of the ps command:

Listing 3.1

Output from the ps command

```
 thread           name      state prio   user  kernel semaphore
----------------------------------------------------------------------
-
kernel_team(team 2)
      1        idle thread 1  rdy   0       0   41750
      2        idle thread 2  run   0       0   42541
      3        psycho_killer  msg  10       0    1596
      4        kernel_daemon  zzz   5       0    2944
      6         1 idle angel  sem  10       0       0 debug idle
thread 1(30)
      7         2 idle angel  sem  10       0       0 debug idle
thread 2(34)
      8              dprintf  zzz  10       0      16
      9                dgets  sem  10       0       0 request for
input(48)
     63       syslog_cleaner  zzz   5       0       0
/boot/system/app_server (team 7)
     15           app_server  sem  15     837    1670 Bpcreate(288)
     23             keyboard  sem 100      23      98 kbsem(209)
     24             joystick  sem 100       0       0 Joystick poller
lock(297)
     25               mouser  sem 100     229     424 mssem(210)
     26              updater  zzz 100     364     469
     27              picasso  msg  15       0       4
     28      mouse_down_task  sem  15      14       9 Bpcreate(290)
     35             app_task  sem  15       2       8 CR_SRV_PORT(386)
     59             app_task  sem  15       2       5 CR_SRV_PORT(608)
     60             app_task  sem  15     866    1475 CR_SRV_PORT(616)
     62             app_task  sem  15      86     193 CR_SRV_PORT(691)
     64             app_task  sem  15       2       5 CR_SRV_PORT(715)
     65             app_task  sem  15       2       5 CR_SRV_PORT(721)
     66             app_task  sem  15       2       5 CR_SRV_PORT(730)
     67           #wt Deskbar  sem  15      94      65 Bpcreate(763)
     73    #wt Tracker Status  sem  15       2       3 Bpcreate(813)
     76           #wt desktop  sem  15     251     201 Bpcreate(855)
     81              #wt MCBe  sem  15     850    1109 Bpcreate(887)
     90             app_task  sem  15       1       4 CR_SRV_PORT(991)
    129             app_task  sem  15      74     136
CR_SRV_PORT(1536)
    131       #wt Terminal 1  sem  15    1043    1151 Bpcreate(1572)
/boot/system/registrar (team 11)
     29      _roster_thread_  sem  10     138     221
_roster_port_(380)
     36            main_mime  sem  10      29      80 main_mime(397)
     37           pulse task  zzz  10     202     106
/boot/system/syslog_daemon (team 15)
     38 syslog_daemon_wrapper  sem  10      15      55
AppLooperPort(602)
     61        syslog_daemon  sem  10       1     109
syslog_daemon_port(699)
/boot/system/Tracker (team 17)
     40              Tracker  sem  10     109     447
AppLooperPort(610)
     74       Tracker Status  sem  15       0       0 Tracker
Status(761)
     75         TrashWatcher  sem   5      17     218
TrashWatcher(833)
     77            w>desktop  sem  15     358     431
TrackerWindow(846)
     82               w>MCBe  sem  15     709    1060
TrackerWindow(874)
     83           pulse task  zzz  10     313     182
/boot/system/Deskbar (team 19)
```

```
     43              Deskbar  sem  10      84     249
AppLooperPort(684)
     79            w>Deskbar  sem  15     118     125 Deskbar(750)
     80           pulse task  zzz  10     232     136
/boot/system/audio_server (team 21)
     45         audio_server  sem  10      25     120
AppLooperPort(701)
     69           DAC Feeder  sem 120       0       0 first
subscriber(787)
     70           ADC Feeder  sem 120       0       0 first
subscriber(797)
     71           pulse task  zzz  10     184     105
/boot/system/print_server (team 23)
     47         print_server  sem  10      68     379
AppLooperPort(703)
     72           pulse task  zzz  10     196     113
/boot/system/debug_server (team 25)
     49         debug_server  sem  10      24      73
AppLooperPort(706)
     68      kernel listener  sem  10       0       0 msg from
kernel(773)
/boot/system/net_server (team 29)
     84           net_server  sem  10      16      61
AppLooperPort(969)
     91             net main  sem  10      26     176 timeout-
cancel(1038)
     92         ether-reader  sem  10       0       2 ethercard
input(1017)
     93        loopip thread  sem  10       0       0 loop wait(1025)
     94        socket server  msg  10       2      19
    105           socket[33]  sem  10       3       3 client-
read(1183)
    106           socket[35]  sem  10       2       2 client-
read(1187)
/boot/bin/ftpd -E (team 33)
     96                 ftpd  sem  10      10      48 server-
read(1189)
/boot/bin/telnetd -E (team 35)
     98              telnetd  sem  10       8      46 server-
read(1203)
/boot/apps/Terminal (team 44)
    128             Terminal  sem  10      75     172
rAppLooperPort(1503)
    132           Terminal 1  sem  15     474     330 Terminal 1(1563)
    133         RNodeManager  sem  10     327     216 LooperPort(1582)
    136                       sem  10      62     108 wchan(1587)
    137                       sem  10      40      48 LooperPort(1608)
    138               BTimer  sem  10      15      15 BTimer(1625)
/boot/bin/sh -login (team 45)
    135                   sh  sem  10     512     385 Wait for dying
teams(1588)
/boot/bin/ps (team 49)
    142                   ps  run  10      34     104

32768k (33554432 bytes) total memory
17388k (17805312 bytes) currently committed
15380k (15749120 bytes) currently available
53.1% memory utilisation
```

You should notice almost immediately that the layout of the list is very different from the analogous UNIX output. There is no user listed for each entry and while the process ID exists, it has instead been called a thread. Also, no parent process ID is listed, nor should we expect one given the already discussed differences. There are a number of new columns giving each thread a name, a state, and a priority. Each entry also has two memory columns: The first displays the user memory allocated by the thread, and the second the kernel memory allocated by the thread. The final column shows the semaphore for each thread. A *semaphore* is the identifying flag which controls when the thread should be executing or idle.

Threads

What should, I hope, have been immediately obvious is that processes appeared to be split into a number of sub-elements. This is because the BeOS multithreading architecture, which I'll discuss in more detail in Chapter 16, causes BeOS applications using the BeOS GUI, such as the Tracker and Terminal, to be split into at least two individual elements called *threads*.

Threads are not a new feature; UNIX has had multithreading capability for some time, although it is implemented very differently in each different UNIX flavor. All BeOS applications have two threads: one controls the main function of the program, and the other controls the interface to the window (menus, buttons, and so on). You can create more threads within an application to allow a single program to be multitasking, rather than relying on the multitasking features of the OS.

Note, however, that this feature is available to BeOS-GUI programs as standard, and to UNIX style commands only with some special programming. The UNIX-like commands (those run in a Terminal) run in a single thread, as you can see if you look at thread number 135, which lists the sh shell thread. This use of threads, and more to the point the inclusion of the threads into the process list, is an important difference between UNIX and the BeOS.

Teams and Killing Processes

Looking back at the output of the ps command again, hopefully you should have noticed that threads were in fact grouped together by the term team. A *team*, at its most basic level, is a collection of threads; but it is simpler to compare a BeOS team to a UNIX process. A thread is just an extra level of detail which the BeOS is able to provide because of its threaded nature.

Threads, Teams and Processes

The relationship between Threads, Teams and Processes is relatively simple. A process is any application that is currently running. An individual process can be split into a number of individual threads. A team is just another name for a process.

If you want to kill a thread under the BeOS, you specify the thread ID to the kill command or the kill() function. In the case of POSIX programs, there is only one thread and this is therefore equivalent to killing the entire process.

The BeOS differs from standard UNIX, although many of the basic principles of the OS are the same. In general the same terms are used, but the same functionality does not always stand behind that terminology. Keep in mind that:

- The BeOS and UNIX are different at the core
- They differ in handling users and groups, and this affects file permissions, processes, and how applications are executed
- The lack of meaningful users or groups in the BeOS affects the porting process, rather than the software you are porting

Chapter 4: Useful Tools

Porting an application to a new OS is a complicated process. Knowing the tools described in this chapter can significantly reduce the time it takes to port an existing application or write a new one. Wherever possible, I've provided some specific examples which you can adapt for your own purposes. If you're familiar with UNIX, you might find that much of this chapter covers familiar territory.

As we are already aware, the Terminal interface of the BeOS provides a basic shell much like the UNIX shell or the DOS command prompt. The shell is what provides the command line interface between the user and the operating system. While each of the tools presented here is a separate program, none of them would be available if it weren't for the shell.

Despite the friendly and easy to use environment of the GUI, there are some things that can be done (and probably should be done) in the command line interface (CLI). A good example is deleting files with a wildcard. This is very difficult, although not impossible, using a GUI. Using a command line interface it is as easy as typing the command and the wildcard.

bash

The bash shell was developed by GNU, itself part of the Free Software Foundation, as a replacement for the UNIX shells that were previously available. Actually, bash stands for Bourne Again SHell, and is an amalgamation of the better features from the Bourne shell (sh), the C shell (csh), and the Korn shell (ksh). It inherits its great ease of use from the Bourne shell while still providing a number of useful extensions.

Let's cover some basics to acquaint ourselves with bash. The *prompt* provides the interface to the shell. There are two levels of commands that we can type in. Some are built into the shell; others are programs executed when you press Return. Commands are generally of the form

```
command [-options] [arguments] [files]
```

Each command you type in is executed when you press Return. When you press Return, bash goes through a series of expansions, including aliases and file selectors, before executing the expanded command and its arguments. You'll learn more about aliases, file selectors, and other types of expansion later in this chapter.

Command History

Life would get tedious if you had to retype every command every time you needed to use it. With bash, you can use shortcuts and substitutions for commands you've typed already, thanks to its *command history*, a record of all the commands you've typed during this shell session.

You can see all the commands you've typed by typing history at the prompt. But just listing the commands isn't very helpful—you need to know what you can do with this history list.

The History of the Command History

In DOS you have a very simple way of repeating the last command. The function keys F1 and F3 provide character-by-character and entire line repetition which you can edit, delete, or insert as required. This functionality only works on the previous line entered and is difficult to use because typing any characters automatically replaces the corresponding contents of the buffer.

In UNIX the command history interface is worse. All commands typed into sh are executed once and forgotten, so there is no way of either listing the commands entered or editing any previous commands. The C shell was the first to provide a basic level of editing, but it works on substitution of text on previous commands and is tricky to use at best.

The Korn shell provided a better interface, allowing commands to be stored and recalled. The commands could also be edited using the familiar vi commands (the default option) or emacs style commands.

bash provides a similar editing feature, but the default option is to use Emacs command keys. These bindings can be changed, but most people use the default, and it's good practice to understand what the default settings are should you plunged into a foreign environment.

Navigation

You can navigate through the list of commands using the Up and Down Arrow keys. These select the previous and next history command, respectively. For example, if you've previously run the commands

```
$ cd /boot
$ cd /boot/develop/headers
```

you can press the Up Arrow key once to get

```
$ cd /boot/develop/headers
```

Press it again, and you get

```
$ cd /boot
```

Because the arrow keys do not work on all keyboards, it is useful to know that ^p and ^n have the same previous/next effect. You can go to the start of the history list by using M-< and to the end of the list by using M->.

Note. *The Meta prefix (as in M-<) means "press and release the Escape key, then press and release the next character." This obscure Emacs terminology is based on some UNIX keyboards that had a key marked "meta," which you won't find on your Macintosh, Windows, or BeBox keyboard.*

Editing

Once we have found the command line we are looking for, we can edit the line. This ability saves a lot of retyping of similar commands or of commands you typed in incorrectly first time around.

We can use the Left and Right Arrow keys to move through the line, or use the equivalent ^b and ^f to go backward and forward between individual characters. You can also go backward and forward between individual words (made up of alphanumeric characters) with the M-b and M-f key combinations.Use the ^e key combination to move to the end of the line and ^a to move to the beginning of the line.

You can delete areas of the line with either the Backspace key, which deletes the character immediately to the left of the cursor, or ^d, which deletes the character under the cursor. You can also delete to the end of the line using ^k.

With all of these commands in mind, you should be able to change the following line:

```
$ mwcc -DBEOS -DSVR3 -i- -I/boot/local/include -c foo.c
```

Note. The C compiler on the BeOS is called mwcc.

to

```
$ mwcc -DBEOS -DSVR4 -i- -I/boot/local/include -c bar.c
```

without too much difficulty. And you can see why it's convenient to be able to edit the line!

After editing a command line, you just press Return to execute the command. You don't need to be at the end of the line to press Return to run the edited command line.

Note. *The history lines recorded are the lines as typed, not as expanded. This allows you to change a file specification or other definition while retaining the remainder of the command. The shell can then re-expand the modified line at the time of execution. You'll learn about file expansion later in this chapter.*

Searching

You can also search the history list for a specific string using an *incremental search.* This type of search looks through the history list for each character you type until it finds a match. To start a reverse incremental search on the history list, press ^R. For example, say that you've typed the following commands during this session:

```
$ cd /boot
$ ls d*
$ cd /boot/develop/headers
$ ls
```

Now the history list contains these commands. If you press ^R here then start typing **ls**, you will go back to the most recent command (which was just ls). Add a space and you'll go back two more lines to the only line that has "ls" then a space ("ls d*").

If you had typed "d" to start with, you would have gone back to

```
$ cd /boot/develop/headers
```

which is the most recent command line containing a "d".. If we continue the reverse search by typing a space we should go back to

```
$ cd /boot
```

selecting the next nearest line matching the pattern. Searching continues until we have fully expanded the line, matched the last possible line matching our search, moved the cursor, or pressed Return to execute the command.

Pressing ^r again will take us back to the next previous line matching the typed text, and we can continue pressing ^r until the string no longer matches.

Table 4.1

Command History Navigation

Key Combination	**Function**
^p, Up-arrow cursor key	Go to previous line in history
^n, Down-arrow cursor key	Go to next line in history
M-<	Go to top of history list
M->	Go to bottom of history list
^b, Left cursor key	Go backward by character through current line
^f, Right cursor key	Go forward by character through current line
M-b	Go Backward by word through current line
M-f	Go forward by word through current line
^e	Go to end of line
^a	Go to beginning of line
^k	Delete to end of line
^d	Delete character under cursor
Backspace	Delete the character to the left of the cursor
^r	Start reverse incremental search

File Selectors

The ability within the shell to refer quickly to a single file or multiple files is based around the use of file selectors. Most DOS and UNIX users will be familiar with these concepts. For Mac and Windows users, the concept of file selectors and wildcards may well be new.

A file selector is a string made up of a combination of specific characters and wildcards. A wildcard matches a selection of characters. For example, the wildcard '?' matches any single character, whilst the '*' wildcard matches any number of characters.

File names given as command-line arguments are passed verbatim to the program you are running. However, file selections and wildcards are expanded by the shell and it is this list of files which is then passed to the command as the arguments. This is different from DOS, which takes the command-line arguments and uses functions within a given program to expand the wildcard.

The expansion of file names occurs anywhere within the shell command line where a file selector specification is made. This ability to expand any string to a list of files is used within other parts of the shell, as we will see later in this chapter.

**** and ?***

The * (asterisk) and ? (question mark) operators match multiple characters and single characters, respectively. These are what most people call "wildcards":, they match any single (?) or multiple (*)character, regardless of whether it is a letter, number, or other symbol. Using these operators in combination with characters enables you to select groups of files very easily. Consider the following directory list and series of commands:

> **Note.** Remember, ls is the command to list files and directories.

```
$ ls
INSTALL       Porting       bar.c         foo           foo.o
Makefile      README        bar.h         foo.c         foobar
Makefile.bak  bar           bar.o         foo.h         fooby
$ ls *.c
bar.c  foo.c
$ ls foo.*
foo.c  foo.h  foo.o
$ ls foo*
foo     foo.c   foo.h   foo.o   foobar  fooby
$ ls foo??
foo.c  foo.h  foo.o  fooby
```

Note: It is possible to use wildcards in any command, not just ls. As you can see, it is possible to select a wide range of different files using these two characters. However, you can be more precise in your file specifications.

Square Brackets

Going back to the previous example, imagine if you had wanted to list all of the files starting with a capital letter. It would be very difficult to do using the two wildcards * and ?: you'd have to specify each capital letter with a trailing asterisk. There's an easier way. You can use square brackets ([and])to match any of the characters enclosed in the brackets.

```
$ ls
INSTALL       Porting       bar.c         foo           foo.o
Makefile      README        bar.h         foo.c         foobar
Makefile.bak  bar           bar.o         foo.h         fooby
$ ls [MRIP]*
INSTALL       Makefile      Makefile.bak  Porting README
```

As you can see, using brackets to specify the capital letters that you know are there (M, R, I, and P) matches all of the files you want, which gets around the problem in the current directory. What it doesn't solve is the problem of listing all files starting with any capital. The solution? A pair of characters separated by "-" (hyphen) matches any character alphabetically between the pair. With this information you can now use

```
$ ls
INSTALL       Porting       bar.c         foo           foo.o
Makefile      README        bar.h         foo.c         foobar
Makefile.bak  bar           bar.o         foo.h         fooby
$ ls [A-Z]*
INSTALL       Makefile      Makefile.bak  Porting README
```

to match what you want. Because the "-" character works this way, you can also use

```
$ ls [a-z]*
```

to match all files starting with lowercase letters, and

```
$ ls [0-9]*
```

for those starting with a number.

Combinations of the above examples can be used for complex matching. For example, the expression [A-Za-z] will match any single upper- or lowercase character. Notice, however, that brackets only match a single character. To match multiple characters using square brackets, repeat them as necessary. For example,

```
$ ls [A-Z][a-z]*
```

lists all the files starting with a capital whose second letter is lowercase.

Finally, using a "^" (caret) character as the first character in the expression reverses the meaning, causing it to match any character *not* enclosed. So

```
$ ls [^A-Z]
```

will match all files not starting with a capital letter, which effectively means files starting with lowercase characters or numbers.

Brace Expansion

Brace expansion allows us to produce arbitrary strings. It is similar to file-name expansion, as outlined above, but you can use it to create new files, in addition to referring to existing files. The format of a brace expansion expression is an optional prefix, a set of comma-separated strings between a pair of braces ({}), followed an optional suffix. The result is a group of strings with the prefix and suffix appended to each string.

Using the above example again, we could describe the "foo" files by:

```
$ ls
INSTALL       Porting      bar.c        foo          foo.o
Makefile      README       bar.h        foo.c        foobar
Makefile.bak  bar          bar.o        foo.h        fooby
$ ls foo.{c,h,o}
foo.c foo.h foo.o
```

Note. The mkdir command creates a directory.

The ability to create such strings can be used to shorten command lines quite considerably. Imagine creating a number of directories:

```
$ mkdir /boot/local/lib /boot/local/bin /boot/local/etc
```

Using brace expansion, you could shorten the process to

```
$ mkdir /boot/local/{lib,bin,etc}
```

Caution. *Brace expansion presents an incompatibility with shell scripts expecting sh commands instead of bash. A string of the form file{1,2} parsed by sh will generate file{1,2}, whereas bash will produce file1 file2.*

Tilde Expansion

The tilde character (~) is often used in UNIX to represent the home directory of the user or the home directory of another user on the system. A single tilde character expands to the value of the HOME environment variable or, if this isn't set, to the home of the user executing the shell. When the tilde precedes the name of a valid user of the system, it is expanded to the home directory of the specified user. For example, if your username is lskywalker, for you the ~ would expand to /u/lskywalker (your home directory). To get to hsolo's directory, you'd use ~hsolo, which is equivalent to /u/hsolo.

Both cases are affected by the BeOS's lack of a user mechanism. Instead, tilde expansion defaults to /boot/home. You can change the default by specifying the home directory you want to use in the HOME variable. You can assume, however, that using tilde expansion is a safe way to represent the home directory and provides for the future compatibility of the BeOS when multi-user features are added.

File-Name Completion

Typing the names of files you want when using the shell is a tiresome process, especially if the file is in a another directory. It is also sometimes difficult to remember the exact path to the file or directory you are looking for, and you constantly find yourself either going down level by level or listing the path first before you try to type it in.

Simpler methods are available. Within UNIX you can specify files and directories with the wildcard characters. Although this is neither as precise nor as reliable as typing the whole thing, it can sometimes save time.

With bash you can go one stage further, using file-name completion with the Tab key to automatically complete and select a given name.. Say you want to get to /boot/develop. You can type

Note. Use cd (change directory) to move between directories.

```
$ cd /boot
$ cd de
```

then press the Tab key, and bash automatically completes the file name

```
$ cd develop
```

based on the names of the files and directories that you might intend. Any unique match to the letters already typed is automatically completed. If an exact match isn't found (for instance, if you had a documentation directory in addition to develop), bash doesn't complete the name. In this instance, when you typed

```
$ cd /boot
$ cd d
```

and press the Tab key, bash would display

```
$ cd d
```

You'd then press the Tab key again to display a list of possible completions:

```
$ cd d
develop        documentation
```

Now you can type the next character (either "e" or "o") to select one of the directories.

When completing directories, bash automatically appends a slash to the end of the name. If you saw

```
$ cd /boot/de
```

then pressed the Tab key, bash would display

```
$ cd /boot/develop/
```

Adding this character seems fairly trivial, but as you start to use completion you will find that it saves you a lot of typing and makes your life easier in the process.

Job Control

Running commands in the background on UNIX enables you to multitask by letting you work actively on one thing while the machine is doing some other, non-interactive, task. The BeOS provides the same functionality. To run a command in the background, simply append the ampersand (&) character to the end of it.

Note. *Both the Mac and Windows GUIs are multitasking systems,but there is no equivalent to the UNIX and BeOS ability to start applications running in the background without some form of intervention by the user. However, if you can imagine starting a long, complicated macro in Word, then switching to an Excel window to work on something else while Word churns away at your macro, you have the idea of a background process.*

Sometimes, however, you might decide in the middle of things that you want to interrupt or suspend the current task, or even put the entire task into the background, to enable you to type a different command. bash provides this facility via the job control functions, which are similar to the functionality of ksh and csh, but they are often wanted feature of sh.

Running Jobs in the Background

As already outlined, running commands in the background in the BeOS is the same as it is in UNIX. Append an ampersand to the command line and the process is automatically run in the background.

```
$ mwcc -c foo.c &
[1] 180
$
```

The number enclosed in the square brackets is the job number of the background task within the current shell. The number after that is the process ID, independent of the shell. You can use either of these to track the status of the job. If you run another job:

```
$ mwcc -c bar.c &
[2] 194
$
```

the job number and process ID have increased, as you should expect!

Listing Running Jobs

You can list the running background jobs by using the jobs command:

```
$ jobs
[1]- Running mwcc -c bar.c &
[2]+ Running mwcc -c foo.c &
```

The job number is shown first, followed by a "+" (plus) or "-" (minus) character signifying the previous and current job, respectively. The status is next, showing whether the job has finished, is waiting for input or output, or has completed. The command line is then shown for reference. If you need the process ID numbers instead of the job numbers, you can list them by using jobs -l.

Redirection

Porting a new application, particularly when running a compilation process, can cause a large number of errors. While the Terminal remembers some of this output, it is useful to have a permanent record you can refer to later. Sometimes it is also useful to have the input for a command come from a file rather than from the keyboard.

Both of these situations are examples of *redirecting* output (and input) to (and from) files rather than the keyboard or screen. Redirection works on the three basic input/output streams from applications. These are

- stdin (0), the standard input, which is usually the keyboard
- stdout (1), the standard output, which is usually the screen or terminal
- stderr (2), the stream dedicated to displaying error messages, which is usually the same destination as stdout

Notice the numbers in parentheses. These are the file numbers, as used by C's open() command set. The use of numbers allows you to specify precisely which stream you want to redirect to/from. If your program uses multiple streams (beyond those listed), you can select the correct one by specifying the number, as we will see below. However, when using redirection on the command line, you'll use shortcut characters (such as ≤ and ≥) to indicate which stream you're referring to.

Redirecting Output

To redirect your output to a file you use the ">" (greater than) character followed by a file name. The file name can be local, relative, or absolute. For example,

```
$ mwcc -c -DBEOS foo.c >comp.errs
```

is a local redirection, as it creates the new output file in the current directory. If the file does not exist, it is created before any output is written to the file. If the file does exist then the entire contents are replaced with the redirected output. This is only true if the noclobber option is not set. Setting the noclobber option, using

```
$ set -o noclobber
```

the redirection will fail if the file already exists.

Alternatively, we could place the output in the parent directory

```
$ mwcc -c -DBEOS  fooc >../comp.errs
```

An absolute example would be

```
$ mwcc -c -DBEOS foo.c >/boot/tmp/comp.errs
```

which redirects the output to a file in the /boot/tmp directory.

Redirecting Input

You can redirect input using the "<" (less than) character; for example,

```
$ cat <comp.errs
```

Note. The cat command displays files on the screen, and is used (with output redirection) to concatenate files together.

would use the comp.errs file as input to the cat command instead of the standard input (from the keyboard). Input redirection is useful in situations where it is not possible to specify the file name as an argument to the program itself. Most programs which do not allow you to specify the file name accept input from standard input by default.

Note. *The redirection of input and output relies on or creates a number of files. It can often be quicker and easier to supply the same information via pipes, discussed later in this chapter, if the files you are creating are only for temporary purposes. However, don't let this dissuade you from using redirection when you need permanent records of output from programs.*

Appending Output to Files

You don't always want to create a new file for each redirection command you run. Sometimes it would be more useful to append the output to an existing file. The >> twin redirection operator causes the output to be appended to the specified file rather than creating or replacing the contents.

```
$ mwcc -c -DBEOS foo.c >comp.errs
$ mwcc -c -DBEOS bar.c >>comp.errs
```

Multiple Redirections

Because programs treat stdout and stderr as different streams, redirecting the stdout to a file won't always capture all of the information generated by a program. Although both the program output and errors might normally go to the screen, they're different output streams. To get around this division you can redirect both stdout and stderr to files, either two different files or the same file.

You can use the stream numbers to control which output stream is redirected to which file. Consider the command

```
$ make >comp.errs
```

Note. You'll learn about the make command in Chapter 10.

which would send all of stdout to the file comp.errs. In the example, the stream number sent to the file is assumed to be stream number 1. This style is shorthand for

```
$ make 1>comp.errs
```

where the leading number before the redirection operator defines the stream number.

Hopefully you will have already realized that we can use the same command, but with stream 2 instead of stream 1,

```
$ make 2>comp.errs
```

to correctly send stderr to the comp.errs file (but leave stdout for the terminal display). If you wanted separate versions of the stdout and stderr output you would just specify both redirections:

```
$ make 1>comp.out 2>comp.errs
```

The result is two files, one with information about what commands have been run, the other with information about the errors produced. We can make the output more useful by sending both stdout and stderr to the same file:

```
$ make 1>comp.errs 2>&1
```

The ampersand character followed by the stream number specifies which existing redirection definition to redirect the output to. Note that you don't have to specify twin redirection operators, because you are sending two streams to the same file, not appending to an existing file. However, if you wanted to append to an existing file you could do it this way:

```
$ make 1>>comp.errs 2>&1
```

Using Pipes

Whilst redirecting files is a useful feature, you can sometimes find yourself redirecting output only to view it again with another program. Consider the following example which generates an error file which is then viewed using less

```
$ make >comp.errs 2>&1
$ less comp.errs
```

It would be much easier to just pass the output from the command through the comp.errs file without generating it in the first place. We can do this using pipes.

A pipe is a logical connection between the standard output of one command and the standard input of another command. For example

```
$ make >&1| less
```

is identical to the previous example, but it doesn't create the file between the two commands, which, more often than not, you will probably delete anyway. You can chain together as many commands as you like so that a single line reproduces the effect of a number of commands. We'll see pipes used throughout the rest of this chapter, and through much of the rest of the book.

The for Loop

The for loop within bash is similar to the for loop within C. However, the loop does not work with an increasing or decreasing numerical variable as it does in C.

Syntax

The syntax for the for command is

```
for variable in words ...
do
COMMANDS
done
```

For each item in the list of *words*, the *COMMANDS* are processed once, placing the word into the *variable*.

The list of words can be used to specify files using the file selectors (* and ?) described above, making the for loop a good mechanism for running the same set of commands on a specific set of files.

For a simple example, these lines would list the contents of a directory using the for loop:

```
$ for file in *
> do
> echo "Filename: $file"
> done
```

This method is more complicated and slower than simply using the ls command, but it demonstrates the expansion of the words (file names) and execution of the loop.

Compilation Example

Makefiles, which we cover later in this book, provide a controlled way of compiling an application, you can use the for loop to quickly try a different method without having to change or write a makefile. You can compile a list of files very quickly using the for loop, as follows:

```
$ for file in *.c
> do
> echo "Compiling $file:"
> mwcc -c -DBEOS $file
> done
```

The advantage of using a for loop is that compilation can continue even if a particular file fails to compile because of an error. This seems backward, but compiling as many source files as possible helps you to focus in on those that don't compile. This approach helps to reduce frustration, especially on large projects.

Consider the following sequence:

```
$ for file in *.c
> do
> ci -l $file
> mwcc -c -DBEOS $file
> done
```

which uses RCS (Revision Control System) to check in the latest version of the file and then compile it. We will find out more about RCS in Chapter 7. More uses of the for loop will appear throughout the remainder of the book.

Using the for Loop with Redirection

You need to approach redirection carefully when using it in combination with the for command. Let's revisit the above example to demonstrate how redirection works within a loop:

```
$ for file in *.c
> do
> ci -l $file
> mwcc -c -DBEOS $file
> done
```

If you wanted to record the output of the compilation, you could change the compilation line to

```
> mwcc -c -DBEOS $file >comp.errs 2>&1
```

But this would recreate the comp.errs file for each cycle of the loop. You would get the last compilation results, but not the results for all of the compilations.

A quick way to get around this is to use

```
> mwcc -c -DBEOS $file >>comp.errs 2>&1
```

instead, which will append the output to the comp.errs file for each iteration of the loop. There is a problem with this, though: what if you need the output from all of the programs executed within the loop. Adding the redirection to each line would be cumbersome. A much better way of producing the results desired is to change the entire sequence to

```
$ for file in *.c
> do
> ci -l $file
> mwcc -c -DBEOS $file
> done >comp.errs 2>&1
```

which sends the results of the entire for command to the comp.errs file, including both stdout and stderr.

You should find that using a for loop, with or without redirection, can save you significant amounts of time when porting applications.

Aliases

The word *alias* means "assumed name," which is a good indication of precisely what an alias is in bash. Those familiar with other UNIX shells should have already come across the alias command. It allows you to set up an alias or nickname for a command or command line. Ordinarily when you enter a command at the shell, the first word of each command is checked to see if it matches an existing alias. If one is found, bash substitutes the alias for the alias value.

New Aliases

The format for creating a new alias is as follows:

```
alias aliasname=realname
```

where *aliasname* is the nickname you want to create, and *realname* is the string which will be substituted in its place. For example,

```
$ alias ll='ls -l'
```

allows you to shorten the command for a long directory listing. For the rest of this shell session, you can now type ll when you want to run the command ls -l.

Alias Expansion

Aliases are expanded so that they replace the existing command. This means that you can specify additional options to most commands even when using an alias. For instance, once you had made ll the alias for ls -l,

```
$ ll -aF
```

would expand to

```
$ ls -l -aF
```

Because expansion is based on the logical start of a command, we can use aliases within any command string, including after pipes.

```
$ alias grbe='grep be'
$ cat *.c |grbe
```

Aliases are not expanded beyond the first word in a command string, so

```
$ alias ll='ls -lF'
$ ls ll
```

does *not* expand to ls ls -lF.

Aliasing is not recursive either, so an alias is expanded only once. If you create an alias which replaces an existing command,

```
$ alias ls='ls -F'
```

the expansion doesn't continue indefinitely until all occurrences of the alias name have been expanded. Only full words (those separated by a space) are expanded. Typing the command:

```
$ alias ll='ls -lF'
$ llc
```

won't expand the ll component of the llc command.

You can remove an alias by using the unalias command:

```
$ unalias ll
```

and you can list the current aliases by simply running alias without any options:

```
$ alias
alias l='ls -m'
```

```
alias lc='ls *.c *.o'
alias ll='ls -lF'
alias which='whence -v'
```

Aliasing only substitutes a string for a single word. You cannot use arguments within an alias; any arguments used with an alias are just passed on to the expanded program. You cannot, therefore, use an alias to replace a shell script. Aliases are usually used to either provide familiar names for existing commands or make typing repetitive commands easier.

TIP. *Aliases only last for a single shell session. If you find you're making the same aliases over and over, add them to your profile, see the section later in this chapter for more information..*

The Directory Stack

When using a command-line interface, even under a windowed environment like the BeOS, you may want to change directories briefly and go back to the directory you were in before. You can do this manually, but if the name of the directory you are currently in is long, complicated, or difficult to type, moving can be tiresome.

In bash you can get around this tedium by using the directory stack, whose LIFO (last in, first out) model enables you to push the current directory into the stack. Using the complementary command you can then pop the directory and your location within it off the stack.

Pushing and Popping

The terms pushing and popping refer to the physical notion of putting things on top of a pile. For example, imagine a pile of cards. When you a card on the top of the file, you are *pushing* the card onto the stack. When you take a card off the pile, you are *popping* the card off the stack.

This process is called Last In First Out (LIFO), because the last card put on the pile will be first card you take off the pile again.

FIFO, First In First Out, simulates the same stack of cards, but this time, when you take a card it is not taken from the top of the stack, but from the bottom.

The two commands are:

```
pushd directory
popd [ + | - ]
```

For an example, try the following:

Tip. The pwd (print working directory) command allows you to easily see what directory you're in.

```
$ cd /boot/develop/headers/posix/sys
$ pushd /boot/system
$ pwd
/boot/system
$ popd
/boot/develop/headers/posix/sys
$ pwd
/boot/develop/headers/posix/sys
```

As you can see, popd pops the most recently pushed directory from the top of the stack, and takes you there. Because you have to specify the directory that is placed onto the stack, you could also have typed in

```
$ pushd /boot/develop/headers/posix/sys
$ cd /boot/system
$ popd
```

Usually, though, you don't just arbitrarily change directories! Once a directory has been placed onto the stack, you can pop it off the stack at any time, but once it's popped, it's no longer in the stack. Directories placed onto the stack are only remembered for the period a shell is open. You can't use directories pushed onto the stack in an earlier session.

You can see the list of directories currently in the stack with the dirs command. Directories are shown left to right in the order they were put into the stack, as this example shows:

```
$ pushd /boot/develop/headers/posix/sys
$ cd /boot/system
$ dirs
/boot/develop/headers/posix/sys /boot/develop/headers/posix/sys
$ pushd .
$ dirs
/boot/system /boot/system /boot/develop/headers/posix/sys
```

If you place more than one file onto the directory stack, you can use the popd command to select a specified directory in the list by referencing the directories in the order they're listed by the dirs command. For example, , +0 references the first directory put into the stack, +1 references the second, and so on. Conversely, the -0 option to popd selects the most recent directory put into the stack, -1 the next most recent, and so on.

Using aliases you can make the process even simpler. Set up two aliases:

```
alias pu='pushd .'
alias po='popd'
```

Now you can push and pop directories to and from the stack with only two characters.

Shell Scripts

Shell scripts are, like the DOS batch files, just a collection of commands which you could ordinarily run from the command line. However, their utility comes from the fact that the collections of commands can be run again and again using all of the commands and functions outlined in this chapter, and throughout the rest of the book.

To create a shell script, create a text file that contains the list of commands you want to run. Save the file, change the file permissions so that the text file is executable (mode 755), and your shell script is ready to use using a command such as

$ chmod +x foo

Although the BeOS uses a different method to track whether a file is an application, bash uses the file permissions to identify an application.

The real advantage of a shell script is that you can write a collection of commands that are executed against a specified argument on the command line. To use command line arguments within a script, you use the special variable name $x where x is a number. For example, a shellscript with the following command in it

```
echo $1
```

Would just print the first argument back to the screen. If you want to use all the arguments, you can use the special variable $*

ls $*

We will use a variety of shell scripts throughout the rest of this book. Although they can look daunting, often, they are simple to follow compared to C source code!

The .profile file

Under UNIX, each shell has it's own initialization file called a profile or login script. This is a small shellscript file that sets up certain environment variables at the time the user logs onto the machine.

For the Bourne shell, this file is named .profile, and under bash this is called .bash_profile. As an extension of this facility, bash also uses a run command file called .bashrc which is executed each time the shell is run.

Under the BeOS, the file /boot/home/.profile is used as both the .bash_profile and .bashrc files and is executed each time an instance of the shell is run. In general this will be each time an instance of the Terminal is run.

Because the file is run for each bash process, it can be used to incorporate aliases, file paths and other variables. However, be warned that any changes to the file will not be seen until either you read the file in again, or a new instance of the shell is started.

You can force a read of the file by using the source command, for example

```
$ source ~/.profile
```

The source command can also be specified using a single period:

```
$ . ~/.profile
```

Grep

The search command, grep, which searches a text file for a particular string or expression, is probably the most-used shell command (except the C compiler) in the application porting process. It is an invaluable tool to be able to find the context or the file in which a particular string is contained.

When we talk about grep we're actually talking about a collection of commands: grep, egrep and fgrep. If you are searching for strings in a particular file it is best to use the simpler, and generally faster fgrep. For finding simple expressions over multiple files, use grep. When searching for a complex regular expression search use egrep.

On its own, grep accepts a string to match and a list of file names to search. Each line within the file or files that matches the string is output to the screen (stdout). This output can be redirected or used with a pipe. If no file is specified, grep accepts input on stdin via either the keyboard or a pipe.

This example would produce a list of all of the lines which match the string "BEOS" in any file ending in .c or .h:

```
$ grep "BEOS" *.c *.h
foo.c: #ifdef BEOS
```

Because we searched on multiple files, each line will be preceded by the name of the file the line was found in. If only one file is specified, grep just displays the lines that contain your search string.

To list just the files that contain the string (without the lines from within the files), use the -l option:

```
$ grep -l "BEOS" *.c *.h
```

Sometimes you'll want to search for all occurrences of a string whether they're upper- or lowercase (especially when you're porting someone else's code and you don't know their capitalization style). For that functionality you can use the -I option, which causes grep to ignore the case of the string being searched for. For example,

```
$ grep -i beos *.c *.h
```

will find "BEOS", "beos", beOS, and so on.

You may have noticed that I excluded the quotes around the search string in the last example. You don't need to specify the string by surrounding it with quotes unless the string you're looking for contains a special character which would otherwise be interpreted by the shell. Special characters include the space character, which would signify an end to the string argument.

Output Options

As we have already seen, you can display the results of your search in a number of ways. By default each matching line is copied to the standard output. If you are searching multiple files, then the appropriate file name is prepended to each matching line. You can use the -l option to display just the names of the files which contain the search string;. this lists each file separated by a newline.

You can obtain the line numbers which contain the matching text by using the -n option, which can be used in combination with an editor to go directly to the line you are looking for.

Regular Expressions

Both grep and egrep accept regular expressions, although to varying degrees of complication. A *regular expression* can be defined as a string made up of both static characters and special characters, which together define a series of rules. Regular expressions are often used with search tools (such as grep) to customize the search terms. We have already seen some simple regular expression-style strings in the file selectors used to choose a list of files.

Special Characters

The simplest regular expression is one that contains only static text. For example, "BEOS" is an example of a regular expression, although it is so simple as to be trivial.

Regular expressions can help with more complicated searches, such as trying to find all the words containing three letters starting with "an". When selecting files at the shell we used the "?" character to match any single character. Within a regular expression we use the "." (period) instead. The period matches any character except newline. The regular expression string for our example therefore becomes "an.".

We can use the period in conjunction with the "*" (asterisk) character. The asterisk means "match the previous regular expression for zero or more repetitions." Therefore, to return to our previous example, the regular expression an.* would match the words "an", "ant", or even "analysis".

Because the * repeats the . wildcard for zero or more repetitions, we can now match the two-character word "an" in addition to any word starting with "an" that has three characters or more.

The "+" (plus) character matches the previous regular expression for one or more repetitions. In our example, an.+ would match "ant" and "analysis", but not "an", because unlike the *, the + requires at least one match.

Using these special characters, we can now select some quite complex strings. Table 4.2 offers some examples of regular expression matching that you might find illustrative or useful.

Table 4.2

Examples of Regular Expression Matches

Expression	Matches
.*tion	Anything ending with "tion"
ac.+tion	Anything beginning with "ac" and ending in "tion" with one or more characters between the two; matches "actuation" but not "action"
a..t.*	Anything starting with "a" followed by any two characters, "t", and then any string
M.* B.*	Any string starting with a capital "M", then any number of characters followed by a space and another word beginning with capital "B" with any string of characters after it
printf(.*);	Any printf statement
#define .* .*	Any #define statement with two or more arguments

Note: You might want to refer to the documentation on regular expressions and the sed and grep commands for a full list of the characters and sequences used in regular expressions.

If you want to use a special character as part of the regular expression, you can precede it with the "\" (backslash) character. The \ forces the regular expression to match the next character as an absolute, a process called *escaping* the next character. Special characters include regular expression commands, spaces, some punctuation marks, and any non-printable character. For example, use the \ when you want to search for the . character itself (as in foo\.c), rather than allowing the . to have its regular expression meaning.

Within egrep and grep you have the facility to match a regular expression "or" another regular expression. The "|" (vertical bar) character is used to specify the "or" option within a regular expression. An example would be:

Note. In this example, the * character is a wildcard for the files to search on, not part of the regular expression itself.

```
$ grep "printf|scanf" *.c
```

which matches text strings. We could also conduct an "or" search using a regular expression.

Square Brackets

When selecting files we found we could use square brackets ([]) to define a range of characters to match, rather than selecting specific (static) characters or any character at all (wildcards). The use of square brackets in file selection is based on their use in regular expressions; they work in exactly the same way in regular expressions as we saw previously.

For example, you could use the command

```
$ grep "[a-z]printf" *
```

to select lines which contain one of the special printf commands. You could try a wider search by using

```
$ grep "[a-z]*printf" *
```

which would look for zero or more occurrences of the lowercase characters appearing before the printf. You could also be more specific and use

```
$ grep "[sfv]printf" *
```

to search for just sprintf, fprintf and vprintf.

You can also combine square brackets with the * and + operators, as in this example:

```
$ grep "[a-zA-Z]*" *
```

which looks for any word containing multiple of upper- and lowercase letters, or basically any line containing a letter. Square brackets allow you a much greater level of control over the strings you search for and can help you when you want to specify words of a particular length.

The above example would match any string that contained zero or more repetitions of upper- or lowercase characters. This is messy as you will end up with a large number of matches. If you instead wanted to match any word with at least four characters in it,

```
$ egrep "[a-zA-Z][a-z][a-z][a-z]" *
```

would work, but is still likely to match a lot of words. You can append an expression which specifies that the fifth character should NOT be a letter or number, causing the egrep command to look only for four-letter words:

```
$ egrep "[a-zA-Z][a-z][a-z][a-z][^a-zA-Z0-9]" *
```

This command terminates the regular expression search on anything that isn't an alphanumeric character.

Reverse Matches

Sometimes you'll want to select all the lines which *don't* match the specified search string, rather than those that do. You can use the -v option to select the non-matching rather than the matching lines. The command

```
$ grep -v "\/\*" foo.c
```

would match all lines that didn't contain an opening comment string (/*).

More Regular Expressions with egrep

All of the above examples are supported by both grep and egrep, but not by fgrep, which only searches on simple strings. You can execute more complex regular expressions using egrep, which expands all the regular expressions available. It is beyond the scope of this book to cover them all in detail, but here are some examples which may be useful to you during the porting process.

The "^" (caret or circumflex) character can be used at the beginning of a regular expression to specify that the remainder of the expression should be matched relative to the beginning of the line. Essentially, this means that the ^ can be translated as "if the line starts with..." For example, to match any line that starts with a #define, followed by a word to define and the number that it expands to, use the command

```
$ egrep "^#define [a-zA-z]* [0-9]*" *
```

A "$" (dollar sign) character has special meaning at the end of a regular expression. This character causes the expression to be matched against the end of a line. For example, to match the string "break;" only if it occurs at the end of the line, use

```
$ egrep "break;$" *
```

Finally, the special characters "\<" and "\>" cause the expression to match the beginning and end of a word, respectively (in this case, a *word* is defined as a string with alphanumeric or underscore characters). This simplifies one of our earlier examples ("printf(.*);") to

```
$ egrep "\<printf\>" *
```

which would match any occurrence of "printf", but not "vprintf", "sprintf" and so on.

Grepping Effectively

Knowing what to search for is only one part of the process of extracting the lines of text you want. Sometimes it is necessary to do some post-processing, or more usually post-grepping, to find what you're looking for.

Before rushing into composing the grep command, you should first consider precisely what it is you want to find and how specific you can be in defining what you're looking for. For example, say you have a number of files in a program you're porting, and one of them has a problem with the variable definition. You need to find where this variable is defined, but you don't know which file it's in. It is pointless to look for "#define", since the average search will list far too many lines and too many files to be useful.

Selecting the Text

A much better way to look for a definition would be to use the definition text. However, this approach has its own dangers, in that you will get all of the lines that use the definition as well as those that define it. You might think this is an obvious example, but many people choose the wrong item to search for when they are looking for a specific item.

Specifying the text string correctly is very important; otherwise you will end up with a useless list that doesn't contain what you want, or such a large list of entries that it is impossible to find what you are looking for.

Knowing the correct strings and regular expressions to use can help you to select the correct text. Once it's selected, you can use further searches to get what you want. Going back to the example above, suppose you're specifically looking for the definition statement for a variable (DIR).

You could do this using grep as follows:

```
$ grep "#define DIR" *.h *.c
```

However, this example implies that the definition is specified precisely as in the match string. Very rarely are definitions so tidily described. You could try a regular expression match, like this:

```
$ egrep "^#define[]+DIR" *.h *.c
```

which returns nothing; so this method is still far from perfect. It still relies on a pretty tight definition of the define command, and not everybody programs with such precision.

Using Pipes

Rather than using regular expressions or rough approximations of the text you're looking for, you can use pipes to reduce the eventual output. The reduction works by effectively sub-searching the lines output by an earlier command.

Here's an example of reduction using a pipe:

```
$ egrep "^#define" *.h *.c | grep "DIR"
fileio.c: /* #define DIRECTORY_PAGES */
ndir.h: #define IS_DIRECTORY_SEP(_c_) ((_c_) == DIRECTORY_SEP)
ndir.h: #define DIRBLKSIZ 512 /* directory block size */
…
```

You now get to see the matching lines, including the file names. There is still a lot of extraneous information, though. Using the -v option you can define your search even further to get precisely the list you want:

```
$ egrep "^#define" *.h *.c | grep "DIR" |grep -v "\/\*"
config.h: #define DIR "/boot/stat.config"
```

The final command selects everything piped to it that doesn't contain an opening "/*". Note that you have to escape each of these characters so that grep doesn't try to parse them as a regular expression. This will strip the comments out of the list of lines, generating a reduced list which you can use to identify the file containing the real definition of the variable. This is the file you need to change to complete the port.

This is a specific example, but typical enough that you should be able to adapt the processes outlined here for your own needs.

Searching Multiple Files

Since you'll often use grep to search for a string in a large number of files, you'll want to know the tricks of handling the output in these situations, and how you can use pipes and grep's options to make your searches fast and refined.

Listing multiple files when using the grep commands generates a list of matching lines with the file name prepended to the matching lines. The following command is a good example. It quotes one line from the stat.h file and one line from the types.h file:

```
$ grep uid_t *
stat.h:     uid_t    st_uid;
types.h:typedef unsigned int uid_t;
```

When looking through multiple files, you aren't always interested in the name of the file that contains what you're looking for. Sometimes you just need to see the line that contains the text.

Text without File Names

You can use grep with the -h option to produce a list of lines containing the string you're searching for but not the names of the files: ,

```
$ grep -h uid_t *
     uid_t    st_uid;
typedef unsigned int uid_t;
```

File Names without Text

Alternatively, sometimes all you want is a quick list of the files that contain a string. You can use this string to sub-divide and sub-search a particular range of files. The -l option produces a list of files separated by newlines: :

```
$ grep -l uid_t *
stat.h
types.h
```

Even if a file contains more than one occurrence of the string, this option lists each file only once. This is a fast method, as the program stops searching the file as soon as a suitable match has been found. When porting you should find that you regularly use this command to quickly tell you where a particular item of text is.

Counts

One final grep option you can use when searching multiple files is -c, which displays a count of the number of lines containing the matching string. We can use this feature to help give us a rough estimation of how long a port will take and whether it would be quicker to make the individual modifications to each file or change the compilation to automatically substitute for the differences. Here's an example:

```
$ grep -c uid_t *
dir.h:0
dirent.h:0
fcntl.h:0
file.h:0
ioctl.h:0
param.h:0
stat.h:1
sysmacros.h:0
time.h:0
times.h:0
types.h:1
utsname.h:0
wait.h:0
```

Rather inconveniently, this option also displays files which contain no matches. Using pipes, you can filter this information by ignoring all "0" entries:

```
$ grep -c uid_t *| grep -v ":0$"
stat.h:1
types.h:1
```

Using for with grep

You can use for with grep to search multiple files for a specified piece of text. A quick example would be:

```
$ for file in *
> do
> grep uid_t $file
> done
```

This example doesn't list the file names, but it's easy to change the command to display the file name before each list of matching lines:

```
$ for file in *
> do
> echo $file
> grep uid_t $file
> done
```

Both of these examples essentially recreate the behavior of grep itself, with marginally less useful output. The second example will list all the files searched, not just those with matching elements. However, the real advantage of using for to do searches is that you can do sub-processing within each cycle of the command.

In the example below I use sed to do some processing before conducting the search of a file. More details on sed can be found later in this chapter.

```
$ for file in `grep -l "#include" *.h`
> search=`echo $file|sed -e "s/\.h//g/"`
> rfilename=`echo $file|sed -e "s/\./\\\./g/"`
> grep "rfilename" *.h >>header.depend
> grep -iv "__$search__" $file >> header.define
> done
```

The example shows a script which checks to see which header files are defining which other header files, sending the output to header.depend. We also list header files that do not define the code which ensures that a header file is not included twice. All the files selected are those which only contain a #include line, which we can safely assume are those which have dependencies on other include files.

Again, we have given a specific example here, but like previous examples, you can see the pattern and adopt it for your own use.

Multiple Directories

The ability to search for a specific item of text in a range of directories is invaluable when you port applications. It is often necessary to find a particular definition or function, and not everybody puts all of the source code into one folder.

As I have already mentioned, it's not easy to search multiple directories via the command line under the BeOS. Using one of the available find ports, it is possible to run a search for a piece of text across a number of files and directories using a command of the form:

```
$ find /boot -exec fgrep -il "string.h" {} \;
```

However, you can simulate this ability using a shell feature, albeit with some loss of functionality. You may remember that in the bash section earlier in this chapter I explained how bash, like other shells, expands the file-name specification and passes the expanded list to the program, rather than simply passing the specification and letting the program sort the file-name matching.

This ability to match a range of files, whether outside of or within the current directory tree, allows you to run commands like this:

```
$ ls */*.h
```

which would list all of the files matching *.h in all the directories under the current directory. This command doesn't match files in the current directory, however, so you must include an option for that too. Let's look at the output from within the /boot/develop/headers/posix directory:

```
$ ls *.h */*.h
CPlusLib.h        grp.h               stdarg.h          sys/time.h
alloca.h          limits.h            stddef.h          sys/times.h
ansi_parms.h      locale.h            stdio.h           sys/types.h
assert.h          malloc.h            stdlib.h          sys/utsname.h
be_math.h         malloc_internal.h   string.h          sys/wait.h
bsd_mem.h         math.h              sys/dir.h         termios.h
ctype.h           memory.h            sys/dirent.h      time.h
dirent.h          null.h              sys/fcntl.h       typeinfo.h
div_t.h           parsedate.h         sys/file.h        utime.h
errno.h           pwd.h               sys/ioctl.h       va_list.h
exception.h       setjmp.h            sys/param.h       wchar_t.h
float.h           signal.h            sys/stat.h
getopt.h          size_t.h            sys/sysmacros.h
```

By combining this listing with grep you can search all of the matching files for a matching piece of text:

```
$ grep "string" *.h */*.h
malloc.h:#include <string.h>
memory.h:#include <string.h>      /* they really want memcpy() and fri
parsedate.h:   ascii string such as:  Mon, June 10th, 1993 10:00:03 am
parsedate.h:   Input:  char *datestr - pointer to the string containin
parsedate.h:           time_t now    - the time with which the datestr
parsedate.h:   Input:  char *table - pointer to an array of strings co
parsedate.h:format of these strings is descri
parsedate.h:   Return: char **  - pointer to the array of strings curr
parsedate.h:   An example format string is:
parsedate.h:   Which handles date strings such as: Mon, June 10th, 199
parsedate.h:   which is the specification for strings like:  1994-01-2
stdio.h:  __string_file,
string.h: *  string.h
string.h:#ifndef __string__
string.h:#define __string__
string.h:/* prototypes for some useful but non-standard string routine
```

The */ specification only branches down one level of directories, but you can repeat the process for as many directory levels as you require:

```
$ grep "string" *.h */*.h */*/*.h */*/*/*.h ...
```

sed

Editing files, particularly a lot of files where you are changing the same information, can be time-consuming and frustrating. It would be much easier if you could script the process in some way, and then run the script on all of the files you needed to edit. The problem is finding a scripting editor that provides a flexible enough process to do what you need.

The streams editor, sed, is such an editor. sed is based around e, ed, and vi, all of which are editors based on the same core code. The difference between sed and most other editors is that sed takes input from a file, processes a number of commands taken from the command line or another file, and outputs the results to the screen.

This means that you can use sed as that scriptable editor to make changes to multiple files easier. What's more, sed is scriptable from the command line, so you can use it from the shell or within shell scripts. The best way to use sed is as a filter for converting, replacing, or deleting text. The format for the sed command is:

```
sed [-e script] [-f sfile] [file ...]
```

If no files are specified, sed uses stdin for input. The script is the list of sed commands to run on each file; or you can specify that the list of commands comes from a script file that you prepare (sfile in the example). Basically, sed copies the each line (separated by the newline character) into a pattern space, then each command in the script is executed sequentially on the pattern space. When the last command has been completed the pattern space is written to stdout.

Commands are of the form:

```
function [ arguments ]
```

where *function* is one of the commands listed in Table 4.3. There are many more commands than appear in the table; this are just a selection of the commands regularly used during the porting and programming process.

Table 4.3

Selected sed Commands

Command	Function
a\ text	Append: write the pattern space, append the text, then read the next input line
i\ text	Insert: write the text, write the pattern space, then read the next input line
r *rfile*	Write the pattern space, then read the contents of the file, placing them in the output before reading the next input line
s/*re*/*rt*/*flags*	Substitute the replacement text *rt* for the regular expression *re* in the pattern space Flags are: g – Replace all occurences in the pattern space p - Print the pattern space if a replacement was made w *wfile* - Append the pattern space to the file *wfile* if a replacement was made
y/*s1*/*s2*/	Transform: replace all occurences of characters in the string *s1* with corresponding characters from *s2*
=	Place the current line number on the standard output as a single line

For an example of using sed, you can use the line number function to identify the line number for each line in a file:

```
$ sed -e "=" foo.h
1
#include <stdio.h>
2

3
#define DIR "/boot"
...
```

The output is not as useful as it first appears, because line numbers appear on their own lines before the lines in the file. We could get better output by using grep to list the line numbers, but if we stick with sed, we can combine this simple line-numbering function with more complicated searches and replacements. The advantages of making these changes all within the same program are that we can reduce the amount of intervention necessary and hopefully improve the processing time.

It is important to note that when using sed you must redirect the output to a file. sed does not support the notion of an output file and would generally be used within a piped command line or as a filter with redirection to produce one file from another. A simple replacement statement thus becomes part of a shell script, since you have to redirect sed output to a new file, copying the new file over the old file. You can see an example of such a shell script later in this chapter.

The operation of sed with a script file is really no different from command-line operation, although you can use some of the more complex commands shown above as well as selective and repetitive search/replace mechanisms. To use a script, first create the script as a text file (you can use an editor or some quick redirection, as below):

```
$ cat >change.sed
s/\/\//\/\*/g
s/printf(/sprintf(tempstr,/g
(Ctrl-D)
```

This first replaces any occurrence of '//' with '/*', useful for converting C++ source code comments to C, and then it changes references to the printf command with a version using sprintf. Once you have finished creating the script file, run the desired sed command:

```
$ sed -f change.sed foo.c >foocomm.c
```

The process of execution is similar to running sed from the command line, except this time the pattern space is matched and replaced each time for each line in the script, before finally being written to stdout (and then redirected to foocomm.c). Processing files this way requires some careful thought, as you must ensure that the process of execution replaces the desired strings. If you make a mistake, it will be repeated in any number of files! We will cover some examples of this later in this chapter.

Search and Replace

You can use sed with a regular expression to replace text in a file with some specified other text. The regular expression is matched against the current contents of the pattern space, then any changes or substitutions are made and the results written back to the pattern space. You can supply multiple search and replace commands to perform a number of replacements on the line. This feature provides a lot of flexibility when it comes to making replacements.

A search/replace command takes the form:

```
s/RE/RT/[flags]
```

where RE is the regular expression to search for, RT is the text to replace with (which can itself be a regular expression), and [flags] are the optional flags to control the action of the replacement. The RE/RT *expression pair* is the pair of regular expressions that defines both the text to search for and the text to replace.

For example, a simple search/replace would be

```
$ echo "hello world" |sed -e "s/hello/goodbye/"
```

which would replace a single occurrence of "hello" with "goodbye" from stdin, an echo command, to the screen (remember that sed by default sends output to the screen).

Note the closing "/" character, which is required to define the end of the replacement text. Because / is one of the special characters interpreted by the regular expression engine, if you wanted to find a string that actually contained a / you would need to escape it using the "\" character.

If the file had contained two instances of "hello" in a single line, only the first occurrence would have been replaced. When you know that there will only be one occurrence of the search text, this is not a problem. However, when you need to control replacement over an entire line you can use the g flag after that trailing slash mark to cause the replacement to be executed globally on all the found instances:

```
$ echo "AAAAAA"|sed -e "s/A/BA/g"
BABABABABABA
```

The output seen here has replaced each occurrence of ""A" with "BA". Note that the replacement is not recursive, despite the way sed works. The g flag causes sed to search the entire line for instances of the search text to replace. However, once it reaches the end of the line, sed doesn't go back and run the search and replace command again. If you wanted to do this you would need to specify multiple search/replace commands.

If sed did run the specified command recursively on the line, then in our previous example, sed would be stuck in a loop forever replacing 'A' with 'BA'.

Heres another example of a replacement operation, this time using a regular expression rather than plain text:

```
$ sed -e "s/[Mm][Rr]\ /Mr/" foo.txt
```

One common use of sed is replacing a piece of text which can be either lower- or uppercase with a fixed-case string. For instance, in most programming languages, the compiler is case sensitive. You can use sed to change the case of a function, variable, or other string so that it is in the same case throughout a file:

```
$ sed -e "s/[pP][rR][iI][nN][tT][fF]/printf/" foo.c
```

You should already be able to see that sed can be an invaluable tool for correcting text quickly and easily, enabling you to script the changes rather than having to use an editor.

Sending Selected Text to a New File

One sed feature that often gets overlooked is the capability to print just the changes made to a particular file, rather than printing the entire contents of the file including those lines where no replacement was made.

This feature is useful because you can not only extract desired text using complex regular expressions (as you can with egrep), but also modify the found text to create a completely new file based on the changes. For example, consider a simple header file, foo.h:

```
#include <stdio.h>
#include <stdlib.h>
#include <strings.h>
#define MYDIR "/usr/local/mydir"
```

When porting this header file over to the BeOS you can use a sed script to produce a file of the changed text. In the example, say you want to change the strings.h and MYDIR definitions to the BeOS equivalents. Using the a script file conv.sed that contains these commands:

```
s/strings\.h/string\.h/p
s/\/usr\/local\//\/boot\/local\//p
```

we can run sed on this file with the -n option (which switches off automatic printing of the pattern space):

```
$ sed -n -f conv.sed foo.h
```

to end up with the following output:

```
#include "string.h"
#define MYDIR "/boot/local/mydir"
```

You have now produced an alternate header file that you can use to help configure and port an application.

The Dangers of Replacing Text

You have already seen some very good examples of how sed can be used to replace text in a file. There are some issues regarding the replacement process that you should be aware of, however. We have covered some of the more obvious ones, such as always redirecting output. An equally important element is how you specify the text to be used as the search item.

One of the problems with any search is that it is only as good as your search terms. Computers are logical and precise about what they look for; if you specify "hello" and the file you are searching actually contains "HELLO", the computer will ignore the entry because it doesn't match.

Getting around the problem is simple in this case: you can either specify the search string as uppercase or use square brackets to force a case insensitive search. How about if you're looking for the name of a function? Logically the same rules apply, but if you extend the search criteria to find the function definition, you start to have problems. Searching for a function name would find more entries than you were looking for, and adding a simple bracket doesn't solve the problem. More significantly, functions can be defined in a variety of different ways without affecting how the code is compiled.

A function definition can be written as

```
void foo(int bar) {
```

or

```
void foo ( int bar )
```

or

```
void foo(bar)
int bar;
{
```

Each of these declarations would match different search expression.

When using multiple search/replace expressions you need to think very carefully about what you are replacing. Before we look into this, let's recap the process. First you create a file that contains a line-by-line script of the replacements to be made. For each line in the input file, each line in the script is executed.

The repetitive action of the script can be used to your advantage to make recursive changes on lines of text. It can also work against you to introduce errors into the resultant output.

Imagine the simple task of reversing the order of the following list using sed:

```
bert jones
larry jones
albert jones
simon jones
```

The script

```
s/bert/simon/g
s/larry/albert/g
```

should do what you want; it swaps Albert with Larry and Bert with Simon. Or does it? In fact, you end up with:

```
simon jones
albert jones
```

```
alsimon jones
simon jones
```

Because you didn't carefully check the information beforehand, you have replaced all instances of "bert" with "simon", which affects the names Bert and Albert. In this simple example, the ramifications aren't that great, but in a source file these unintended changes could take hours of work to resolve. We can't change the file back by performing the inverse of the original script because doing so would replace the real Simon as well as putting "bert" back into Albert.

Avoid inadvertent changes by finding the right text in the first place. You can use complex expression searches or careful selection of text equivalents to do so.

More Regular Expression Characters

All of the expressions we have used so far with sed have been very similar to those we used in grep to find text. You can define each of these regular expressions using a standard set of recognized characters to effectively select the level and type of search you need along with the text to search for.

Table 4.4 shows the complete list of the characters and formats you can use when specifying regular expressions. You can also use this table to determine which characters are special and therefore need to be escaped in a regular expression.

Table 4.4

Regular Expressions

Expression	What It Matches
. (dot)	Any single character except newline
*	Zero or more repeats
+	One or more repeat
[...]	Any character in the set
[^ ...]	Any character not in the set
^	Beginning of a line
$	End of a line
\c	Escape special character c
|	Alternative ("or")
\(... \)	Grouping
\n	nth group (in output text)
\‘	Beginning of buffer
\’	End of buffer

\b	Word break
\B	Not beginning or end of a word
\<	Beginning of a word
\>	End of a word
\w	Any word-syntax character
\W	Any non-word syntax character
\sc	Character with syntax c
\Sc	Character with syntax not c

Replacing Selected Elements

When using standard regular expression matching to do a search and replace you have to be careful what you opt to search for and what you say to replace it with. For example, lets try to change any number followed by a lower case ‘mb’ to be an upper case ‘MC’. The command

```
$ sed -e “s/[0-9]*[mM][bB]/99\ MB/g”
```

would replace any number followed by the letters “Mb” with “99 MB”. This represents a problem, because to find the string you are looking for you need to specify that it contains numbers. By default, sed replaces whatever text it finds, so in this example we have accidentally replaced and therefore lost that number information.

Grouping regular expressions into logical blocks enables you to logically split a regular expression into a number of subdivisions. This only affects how readable the search expression is to humans, not how it actually operates. The format for grouping regular expressions is

```
\( ... \)
```

The group can contain any number of regular expression constructs. For example, the expressions [a-zA-Z0-9] and \([a-zA-Z0-9]\) would be interpreted identically during the search phase.

Each new group is given a unique number. Within the replacement text you can reference the group by its number. This allows you to use the found group in the replacement text. Let’s use the previous example to demonstrate:

```
$ sed -e “s/\([0-9]*\)[mM][bB]/\1\ MB/g”
```

The above command would replace any number followed by “mb” with the number found followed by “ MB”. For example, the lines

```
123mb
56MB
3Mb
```

would be converted to

```
123 MB
56 MB
3 MB
```

The problem caused by the previous version of the search has been solved. Not only can you make sure that you search for the correct information at the outset, you can ensure that the entire text found won't be replaced with the replacement text, only the selected elements of the search text will be replaced.

Another example of replacing selected elements would be to change all printf commands to sprintf commands. This task requires inserting a string name into the function specification. A text replacement won't work, since the arguments to the function will be different depending on the situation. Since you can't lose this argument information you must use grouping to find the arguments and include them in the replacement text.

You can use grouping to find the function and change the arguments like this:

```
$ sed -e  "s/\(printf(\)\(.*\)\();\)/s\1tempstr,\2\3/g"
```

Splitting out the elements we get:

Group	**Search For**	**Replace With**
1	printf(	sprintf
-		tempstr,
2	.*	Found text
3	);	Found text

Parsing the following text:

```
printf("Hello World\n");
printf("Value is: %d\n",intval);
```

would produce

```
sprintf(tempstr,"Hello World\n");
sprintf(tempstr,"Value is: %d\n",intval);
```

You should be able to see from this example how the grouping in the search text is used to make up the replacement text.

Using sed with grep

We can use sed to do some processing before conducting the search of a file. For example, a common part of the porting process is to find out which header files rely on other header files. We could use the following code:

```
$ for file in `grep -l "#include" *.h`
> do
> search=`echo $file|sed -e "s/\.h//g/"`
> rfilename=`echo $file|sed -e "s/\./\\\./g/"`
> grep "rfilename" *.h >>header.depend
> grep -iv "__$search__" $file >> header.define
> done
```

The example shows a script that first generates a list of files containing the #include statement. The script then checks to see which header files are defining which other header files, sending the output to header.depend. I've used sed to strip the filename in the first line, and sed again to create a search string for the dependency check. It also lists header files that do not define code to ensure that a header file is not included twice. The files selected are those which contain a #include line, which we can safely assume are those which have dependencies on other include files.

From this specific example you can see the pattern and adapt it for your own use.

Using sed with bash

Like most shell commands, sed can be used with other commands to provide extended functionality. Combining commands can also simulate some missing functions or facilities in the shell. The most common example is combining sed with a built-in function, such as a for loop, to produce the necessary effect on a number of files. A single-file problem usually already can be solved via the available tools!

Renaming Files

One of the most frustrating omissions from the UNIX mv (move/rename) and cp (copy) commands is the ability to rename a collection of files all at once. For example, within DOS, it's easy to rename all files ending in .c so that they end in .h instead:

```
c:\> ren *.c *.h
```

Within UNIX and the BeOS, the same type of command will usually produce an error because both the mv and cp commands expect multiple files to be moved or copied to a single directory, not to a selection of other files. This is because in UNIX and the BeOS, unlike DOS, the wildcards are expanded by the shell and then passed as arguments to the program, rather than the program being responsible for the wildcard matching.

To get around this limitation on renaming using wildcards, you can use sed and some simple shell scripting to create the same effect:

```
$ for file in *.c
> do
> new=`echo $file|sed -e "s/\.c/\.h/g"`
> mv $file $new
> done
```

The process is very simple: for every file matching *.c, make the variable new equal the variable file, replacing the ".c" with ".h"; then rename each file called file to new.

Global Replacements

Another combination of sed with bash uses a similar style to the renaming example above. When replacing text in files, though, you have to be careful. The safest way to use sed is to redirect the output to another file before replacing the existing file:

```
$ for file in *.c
> do
> sed -e "s/printf/myprintf/g" $file >$file.out
> mv $file.out $file
> done
```

However, sed's "limitation" can become an advantage in this situation: Because you have to redirect to another file, you can easily introduce a backup mechanism. If something goes wrong, you can go back to a previous version and use that. For example, consider the following example, which uses the cp command to produce a backup of the file:

```
$ for file in *.c
> do
> sed -e "s/printf/myprintf/g" $file >$file.out
> cp $file $file.bak
> mv $file.out $file
> done
```

The above example still makes the assumption that the replacement was successful and the file produced is in the desired format. But in case there's a problem, the .bak backup file is still intact.

Using sed for global replacements in a number of files raises some important issues concerning how you are conducting the port. In particular, it is bad practice to make sweeping changes within a collection of files. Even with the best of intentions you can introduce more errors than you hope to solve by replacing the wrong item, or forgetting to make changes in a particular file.

It is best therefore to make use of the other tools available to check your search criteria and your replacement text to ensure that the desired effect is obtained.

A real-world example can be taken from the source code for gawk. In the gawk code, the same name, token, was used for both a structure and a union. During compilation the compiler produced an error because there were two entities with the same name. Using sed, the name was changed in the required files from token to dfatoken. However, the word "token" was also used as part of other variable names, which were also inadvertently changed.

A better plan would have been to use grep to produce a list of the lines in which token was referenced. This list could then have been used to generate a suitable search strategy to replace the required name.

Like most of the examples we have already seen, this case is fairly specific and the answer seems obvious enough. In the heat of porting, however, the answer is rarely obvious and it is easy to spend hours on a port and be in worse shape than when you started!

Be aware, then, of the dangers of making replacements using sed, particularly in multiple files. Make sure you use the tools available to make backup copies of the files before you overwite them with the versions parsed by sed.

less

Note. Use the less command to quickly display the contents of a file.

The less command is similar to the more standard more command found on both UNIX and DOS, except that it allows backward as well as forward movement through the file that it displays to the screen.

You can use less as a stand-alone command, supplying it with the name of a file to display. For example,

```
$ less foo.c
```

will display the first screenful of information, and provide a prompt at the bottom of the screen. You can move through the file, search for specific strings, and select other files from this prompt, all without leaving the less command.

You can also open multiple files at once with less:

```
$ less *.c
```

While viewing these files, you can move through them by using :n and :p for next and previous file, respectively. In each case, less moves to the start of the file selected.

Use the q key to exit the less program.

Movement in less

You can move forward through an individual file page by page by using the spacebar, ^v, the f key, or ^f. You can move forward line by line by using either the Return key or ^n. You can move backward page by page using M-v, the b key, or ^b, or line by line using ^p.

Like more, less can be set to move any desired number of lines; just put the number before the command specifying the direction. You can also skip forwards through a file by typing the number of lines to skip, followed by s'.

Searching in less

To search for a particular pattern, precede the text to search for with the "/"(slash) character. This automatically searches for the next occurrence of the string in the file and advances the display to two lines before the string. That way the string can be seen in the context of the lines around it. You can also specify the text to search for on the command line:

```
$ less +/printf foo.c
```

You can change the search from case-sensitive to case-insensitive by specifying -i as a command line option when starting less.

When viewing source code it is often useful to be able to match open and close brackets. Pressing { or (when a corresponding bracket is shown on the top line of the screen will cause less to find the next matching close bracket,) or } as appropriate. The last line on the screen will be the line containing the closing bracket.

The reverse is also true. When a } or) is on the bottom line and you press that key, the corresponding open bracket will be shown on the top line of the screen.

Other Features in less

Line numbers are sometimes useful if you want to use the reference in an editor. The option to display line numbers before each line is -N.

The = command will show you details about the current location within the current file (or output), including the line, percentage through the file (if known), and file name (if known).

You can adjust the page size to display a different number of lines. The default setting is the number of lines available on the terminal. To change this option you use the *-n* option, where *n* is the number of lines; for example,

```
$ less -25 foo.c
```

would adjust the output to scroll backward and forward by 25 lines.

Tabs are often displayed incorrectly onscreen, but you can use another less feature to expand individual tabs into a number of spaces. By default this figure is eight spaces; to change it to ten, for example, specify the figure on the command line:

```
$ less -x10 foo.c
```

Another useful feature of the less command is the ability to set a mark within a file at particular position so that you can easily return to that position. For example, imagine viewing a source file that references a function used elsewhere in the file. You need to find the other occurrences of the function name, but you want to be able to quickly jump back to the current line. You can save the current location using the "m" character, followed by a letter (such as "a"). This sets a mark (like a bookmark) named "a" at that point in the file. After you conduct a forward search through the file to find the function; then, rather than quitting or painstakingly moving backward through the file to your last position, type ' (single quote) followed by the letter you used (a) to mark the position, and less will take you straight back.

Using less with Pipes

Piping output through less is no different than piping output through the more command. You'll often use less with a pipe to page through the results of some other command. For an example of this, we will use a grep command to extract the lines of the file containing the printf function, passing the output through less:

```
$ grep "printf" foo.c |less
```

You get all of the benefits of the less command when doing so, of course. When viewing this output, you can page forward and back, search, match brackets, or whatever you normally do when you call less on a file.

The more command is a symbolic link to the less command, so there should be no need to use the less command directly.

touch

When you use make, files are compiled based on whether their modification time is more recent than the compiled version. With most editors and editing processes the modification time is updated correctly, but there are exceptions. You'll also find that even with the most comprehensive of makefiles, make won't always work as you expect.

Note. You'll learn all about make and makefiles in Chapter 9.

To adjust your modification times and force make to work properly, you can use touch to change the modification time of a file. The format of the command is:

```
touch [ -amc ] [ mmddhhmm[yy] ] filename...
```

Where the string *mmddhhmm* specifies the month, day, hour and minute with the option of also specifying the year (*yy*). If you don't specify a time in this way, the current time will be used. For example, to update the modification time to the current time you would use

```
$ touch foo.c bar.c
```

Now both of those files show that they've been modified recently, without your having to open them in an editor and risk introducing errors.

Sometimes it is useful to do the opposite and change a file's modification time so that it's earlier than the current time, which you can do by specifying the month, day, hour, minute, and if necessary year:

```
$ touch 0228133897 foo.c bar.c
```

This file now shows that it was last modified on 2/28/97, at 1:38 P.M..

One other feature of touch is useful for faking the existence of a file when you can't get rid of the dependency elsewhere. If the specified file that you are touching doesn't exist, touch will automatically create an empty file with the current timestamp.

tr

It's quite common to need to replace characters in files. Many programmers find that they suddenly need to change the name of a variable because they have duplicated the name of one that comes from elsewhere. You could use your editor to do this or, as we've seen, you could use sed to make the replacement.

But how about replacing individual characters within a file with other characters? Using an editor would be slow and would be overkill for what appears to be a simple task. The same could be said for sed (!); after all, writing out those expressions to match characters is complex and time consuming. This is even more difficult when you want to replace special characters, especially when those special characters could include a newline, which sed uses to separate lines.

The ideal thing would be a program that replaces (or deletes) characters without being limited by individual lines: tr is just such a program.

The format for the tr command is:

```
tr [ -cds ] [ string1 [ string2 ] ]
```

Without any options, tr replaces the characters in *string1* with the corresponding characters in *string2*. For example,

```
$ tr "eo" "ai"
```

would change "hello world" to "halli wirld". You'll notice that it has replaced the first letter of the match string with the first letter of the replace string, and the second letter of the match string with the second letter.

To specify a special character, use the \xxx notation, where xxx is the octal number for the character; for example,

```
$ tr "\012" "\015"
```

will change an ASCII newline to a carriage return. This is quite a useful command and often much quicker than using an editor to make the same change.

We can also use tr to delete characters:

```
$ tr -d "\012"
```

would strip all the newlines from a file.

Another trick is

```
$ tr "abcdefghijklmnopqrstuvwxyz" "ABCDEFGHIJKLMNOPQRSTUVWXYZ"
```

which converts all lowercase characters to uppercase. A quicker version of this is to use the square brackets we used earlier to define the range of characters. This shortens the above example to

```
$ tr "[a-z]" "[A-Z"
```

Note. You must use tr either as part of a pipe or with redirection. tr only reads and writes from stdin and stdout.

uniq and sort

When you are porting it is sometimes useful to generate lists from different sources. Take definitions, for example; we will see in Chapter 8 how #defines can help the porting process, but it is often the case that a single application uses a number of source files for its configuration information. To look at that information properly, excluding all the duplicates where things have been defined, could be a long editing process.

Instead, it would be easier to have a program remove duplicates from the file (thus "deduping" it), which is precisely what uniq does. You need to use uniq in tandem with sort because of how uniq works: It reads in the input, outputs the first line, then compares each input line with the previous one; if it matches, the line is not output again. If the list isn't sorted in the first place, uniq is incapable of deduping since it compares line-by-line.

Here's an example taken from the port of perl:

```
$ egrep -h "^#define" *.h|sort|uniq >defines.out
```

This uses grep to generate a list of all the definition statements in all .h files, then sorts those definitions so they're in alphabetical order, then uses uniq to strip out all the duplicates:

```
#define BIN "/boot/local/bin"    /**/
#define CAT2(a,b)a ## b
#define CAT2(a,b)a/**/b
#define CAT3(a,b,c)a ## b ## c
#define CAT3(a,b,c)a/**/b/**/c
#define CAT4(a,b,c,d)a ## b ## c ## d
#define CAT4(a,b,c,d)a/**/b/**/c/**/d
#define CAT5(a,b,c,d,e)a ## b ## c ## d ## e
#define CAT5(a,b,c,d,e)a/**/b/**/c/**/d/**/e
#define MEM_ALIGNBYTES 8   /**/
#define STRINGIFY(a)"a"
#define _config_h_
```

The result is a list of all the definitions used in the program. This list was used to manually configure perl because the configuration script supplied doesn't work on the BeOS (we'll discuss this more this in Chapter 11).

All of these tools are really compliments to, rather than replacements for, the one tool programmers rely on the most: an editor.

Editors

There are a number of editors available on the BeOS. For those people used to GUI style editors, the StyledEdit program is a basic editor which can be used for most tasks. As an alternative, you can use the editor as part of the BeIDE (Integrated Development Environment). This provides the same basic functionality of StyledEdit, but also incorporates additional features such as syntax styling and complex search and replace options.

For command line users, there are a number of ports of vi and similar editors available, including vim and which is supplied with the BeOS. A version of elvis is in production which includes the ability to syntax style documents, in the same way as the editor that comes as part of the BeIDE.

There is also a port of emacs available as part of the GeekGadgets utility set. If you prefer to use emacs I suggest you obtain a copy of this, details are provided in Appendix A.

You can find many of the editors mentioned here on the BeOS CD-ROM in the "optional" and "3rd Party Software" folders.

Chapter 5: Sources

Once you have some familiarity with the BeOS and the programming tools it makes available to you, you're ready to begin the porting process.

Getting the Sources

UNIX software in general and GNU software in particular is traditionally made available over the Internet via anonymous FTP.

Using one of the many archive sites around the world is still the recommended way of getting software for porting. Indeed, Be Inc. supports the use of the Internet as the preferred support mechanism for their developers. In BeWare they have provided a simple way of listing any software produced for the BeOS, which can be a useful place to find support files for your own porting process.

Some of the best archive sites on the Internet and other ways of obtaining sources and support material are described in Appendix A.

Networking is still an underdeveloped aspect of the BeOS. The BeOS doesn't directly support any filesharing options, so you can't copy files off your MacOS or PC server using a file sharing system. There is a port available for supporting NFS to copy files from a UNIX server though. FTP is also supported, and this should let you transfer files from just about any machine as the Internet takes off. It has some shortcomings, as even the best programs do. Most annoying is that if a transfer gets interrupted it is impossible (under the BeOS) to restart a transmission midway through a file. On very large files this can be frustrating as you try for the nth time to transfer a particular file. There are versions of ftp which get round this by enabling you to continue a transfer after it has broken. Look for the ncftp port from the BeWare pages (see Appendix A for more information).

Removable Storage

You can also use floppy disks to get information onto a BeOS machine. Putting the file on floppy requires that you format a 1.44MB disk and create a tar archive straight onto the disk. You can do this under MacOS using suntar and under DOS using a program such as djtar.

You can also use UNIX to write a floppy, provided the flavor of UNIX you use supports the standard 1.44MB format. Most modern Unices do, more to provide compatibility with DOS than anything else. However, transferring a file which is larger than a single floppy by creating a multiple disk tar file is terribly unreliable.

If you created your floppies with a PC, the standard BeOS supports the mtools interface, which enables the user to access and read files off DOS floppies. The only problem with mtools is that it is sometimes unreliable and doesn't work with all disks, even those formatted on the same machine.

To use, simply insert the DOS formatted floppy disk, and then use the commands shown in table 5.1 to access, copy and navigate your way around the disk.

Table 5.1

Common mtools commands

Command	Description
mcd	MS-DOS cd (change directory)
mcopy	MS-DOS copy (copy files)
mdel	MS-DOS del (delete files)
mdir	MS-DOS dir (directory listing)
mformat	MS-DOS format (formats a disk)
mren	MS-DOS ren (rename a file)

In addition, there is a newer version of the mtools interface which also supports other media such as ZIP disks, the Windows 95 long file names and even hard disk partitions. You can even obtain a filesystem plugin that will mount DOS disks natively just as the BeOS mounts MacHFS disks. However, this is currently read only.

Finally for floppy access, the BeOS supports MacHFS floppy disks of 1.44Mb, but not the older 800k format.

The latest version of the BeOS now supports the use of Mac HFS and ISO 9660 (PC/High-Sierra) formatted CD-ROMs. Transferring files is now a lot easier, and you also have access to a wide range of source code CD-ROMs such as the GNU Source Code CD-ROM (see Appendix A).

Working with Archives

An *archive* is a collection of files combined into a single file. This makes it easy to transfer the file around, as the entire contents required to produce an application are all in one place. Archives contain a variety of files, in the case of UNIX, the contents are the usually the sources of the application, which are then compiled to produce the finished product. Under Windows and MacOS, the archives usually contain the application and support files, often with some kind of installer to make the process easier for the lay user.

There are two sides to working with archives, extraction and creation. Once you have obtained the sources you require and identified (or sometimes changed) the archive type, the next stage is to decode, decompress, and extract the archive into the files you will need to port the application. This process assumes that you have been able to identify the archive type by the name. Sometimes, however, you will have to resort to trial and error to discover what type a particular file is.

When it comes to distributing the files and your ported application to the public, you need to collect up the files into a new archive and compress it. Within UNIX, the tool used to do this is tar combined with gzip. Under the BeOS, the standard is to use the Info-ZIP tools for BeOS applications because it supports the extended attributes on the BeFS. Since most Posix style ported applications don't use extended attributes, you can continue to use tar/gzip. For those users used to cpio there is a version available in GeekGadgets, details of which can be found in Appendix A.

Within this section we'll take a look first at how to identify what type of archive a particular file is, and then how to decode it. Also, because we are working the BeOS in it's UNIX like guise, we will take a look at using the tar program to produce archives which we can distribute to other people.

Identifying Archives

Over the years different people have developed different systems for creating archives. Some include only the files; others include the files along with the associated directory structure. In both cases the files can be compressed to save space and the all-important transmission time. The identification of an archive's type, including its compression system, is essential because without the correct decompression software you won't be able to read the file!

There are three levels of archiving that you will see regularly, and each level uses its own recognized set of extensions:

- The archive itself, which contains the files (and directory tree, if appropriate) that make up the archive
- The compression mechanism, which helps to reduce the size of the file. This may, or may not, be part of the same file as the archive.
- An optional encoding system, usually used to encode and decode binary files for transfer over e-mail

Usually the name of the archive has a version or revision number appended to it, followed by the extension identifying the archive type. For example, the archive name emacs-19.29.tar tells you that this an archive containing Emacs and that the revision number is 19.29.

The extensions used to identify the contents are sometimes concatenated to show the nesting of the archive, including the compression and encoding system. Working in reverse, a package called foo-1.0.tar.gz.uue tells us the following:

1. The package was encoded using uuencode.
2. It was compressed using gzip.
3. The archive format is tar.
4. The version number is 1.0.
5. The program is foo.

Table 6.2 lists recognized extensions and the program or method to use to extract them. In some cases, the best method of extraction is to go back to the platform the file originated on and recreate the archive in a format that you can use on any platform. If you get to choose the archive format used to pack the source code you are obtaining, the best format to look for is tar; and if compression is required look for GZip.

Table 6.2

Recognized Extensions

Extension	Method	Source
.arc	Created by ARC, extractable under DOS.	Usually DOS, also Atari, Amiga, and some UNIX variants.
.arj	DOS arj format, extract under DOS.	DOS
.cpio	Created by and extract using cpio under UNIX.	UNIX
.cpt	Compact Pro format, extract under MacOS using StuffIt Expander.	MacOS
.gz	Created using gzip, extractable under BeOS.	Any
.hqx	BinHex format, extract under MacOS using StuffIt Expander. Also extractable under BeOS using mcvert, see Appendix A for more details.	MacOS
.lzh	LHarc format, extractable under BeOS with the xlharc tool, see Appendix A for more details.	DOS, Windows, Amiga, Atari
.shar, .sh	A shell archive, extractable under BeOS using bash or unshar.	UNIX
.sit	StuffIt, extract under MacOS using StuffIt Expander.	MacOS

.tar	tar format, extractable under BeOS.	Any
.uu, .uue	uuencoded file, extractable under BeOS.	UNIX
.Z	compress format, extractable under BeOS using gunzip.	UNIX
.z	Old gzip format, extractable using gunzip. Could also be pack format, a former alternative to compress; extract under UNIX and recreate.	UNIX
.zip	Zip format, extractable under BeOS.	DOS
.zoo	Zoo format; extract under DOS and recreate.	DOS

While the BeOS is a new platform, and hence does not have methods for handling every compression and archive format, new ways of extracting files under the BeOS are appearing every day. We already have access to gzip, lharc, zip, and tar formats.

Encoding Systems

One of the difficulties of using e-mail over the Internet is that many parts are still working on old 7-bit technology. This use of 7 bits for transferring messages only allows standard punctuation, letters, and numbers to be transferred. Binary files, including those made as a result of any compression program, are 8-bit and cannot be transferred reliably over the 7-bit e-mail systems.

Because of this need for transferring 8-bit files over 7-bit systems a number of encoding mechanisms were developed that converted 8-bit characters into 7-bit compatible strings. This creates a file that is larger than its 8-bit cousin but is compatible with the 7-bit e-mail systems.

In general, the space saved by compressing the 7-bit file is significantly more than the space used up by encoding the 8-bit version that you create from the 7-bit. So while the use of encoding is a double-edged sword, one side is significantly sharper than the other!

The first thing to do when working with an encoded file is to try to determine the encoding used. If the method is not apparent from the filename, then the first few lines of a file should identify the method. You can identify each encoding type (UUencode, BinHex, MIME and shar) as follows:

- The first line of a uuencoded file contains begin 644, followed by the filename enclosed in the file.
- The line of a BinHex file states the version number of BinHex to use to decode the file, the latest version (for some time now!) is 4.0.

- A shar file has the text ‘This is a shell archive’ in the preamble before the encoding starts.
- A MIME file will have been referenced by specifying that the enclosure is MIME encoded. In some cases, the email message a full description of the location to get a program to extract the file for most platforms as part of the header before the encoded files.

If, when you look at the header of a file, you get get a lot of weird characters or blank spaces, then the file you are displaying is not encoded. You need to move on to the compression section to identify the program you need to use to decompress the archive.

uuencode

One of the most popular encoding systems on UNIX is uuencode, a system developed to work with the uucp (UNIX to UNIX Copy) system used to exchange e-mail. This converts 3-byte strings to 4-byte strings, creating an increase of 35% in the size of the encoded file over the original.

To encode a file, you use the uuencode command. This reads in the binary file, and sends the encoded version of the file to the standard output:

```
$ uuencode foo.tar foo.tar > foo.tar.uue
```

You must specify the name of the file you are encoding, and the name of the file that you want the encoded file to bed decoded into. In this example, I’ve just used the same name twice. If no file is specified, uuencode defaults to using the input from stdin, and this is where the specification of the decoded filename becomes useful. The line

```
$ tar cf foo.tar ./foo|gzip|uuencode foo.tar.gz >foo.tar.gz.uue
```

would create a file that when decoded produces a file called foo.tar.gz, which could then be extracted using gunzip and tar in the normal way. Notice that the uuencode command only has one filename, this is the destination name, as the standard input was used as the source file name.

Decoding a file is just as simple, you use the uudecode command, specifying the name of the file to decode. For example, to decode the file we create in our last example you would use:

```
$ uudecode foo.tar.gz.uue
```

which would create the foo.tar.gz file as specified when we created the encoded version.

shar

Files created using shar are really just shell scripts that have files incorporated into the script, but they can function like encoded files. Like uuencoded files they are used to transfer files over mail systems that only support 7-bit transfers. They are slightly smaller than uuencoded files, but have the disadvantage of requiring a UNIX-like shell and sometimes a C compiler to extract the contents.

To extract a shar file, strip all the information up to the line which reads:

```
# This is a shell archive
```

Save the file, and then pass the filename as an argument to a shell, as follows:

```
$ sh foo.shar
```

The shell will execute the various commands in the shellscript and generate the necessary files as it goes. In some cases, you may find more than one source shar file, all of which must be extracted in the same way in the same directory as the rest of the package.

This should, in theory, work without any problems. However, sometimes the extraction will fail because of a bad line, or a problem decoding a binary file. We can usually get round them, but let's quickly cover the format of a shar file before we look at ways of solving the problem. A shar file starts off with a preamble about the contents, followed by the first file. If the file is in a directory other than the current directory, then the full directory path is created.

Any file incorporated into the shar file is then enclosed verbatim if the file is text, or uuencoded if the file is binary. The enclosures are marked by the line containing the "<<" symbol and some sort of end marker (for example, SHAR_EOF). This method uses a shell feature which allows the standard input to be taken from the next lines in a script up until the specified marker.

If you needed to you could manually extract files, even encoded ones, by cutting and pasting the necessary sections from the shar into new files. This is difficult, and prone to errors. An easier option is to locate a version of the package in some other format or use the machine it was created on to extract the file and regenerate the archive using tar.

While shar's need for a UNIX-like shell does not adversely affect BeOS users, its occasional requirement of a C compiler presents some problems. Some versions of shar, notably HP-UX, create shar files which include the program required to decode binary files. The shar file goes through the same process, but the first file to be created is the source file for the decoding program, which is then compiled and used to help extract the remainder of the enclosed and encoded files.

This introduces extra levels of complication. Not only will you have to contend with difficulties of extracting the files using the shell, but you may also have to port and compile the enclosed application. If you are unable to extract the file under BeOS, then extract it on the UNIX machine it came from and then re-package it as a tar file.

MIME (Multipurpose Internet Mail Extensions)

MIME files can be encoded and decoded using the mpack toolkit. Generally, the process of encoding and decoding files into MIME documents is performed by the email package you are using. However, not all packages support MIME yet and sometimes it is easier to save the message as a text file, and then extract the files using a package such as mpack. Using the package is straightforward, much like the other encoding tools.

To decode files supplied in MIME format, use the munpack utility, specifying the name of the save e-mail message:

```
$ munpack mail.mime
```

This will extract the files into the current directory, providing a running commentary of the process.

split

Splitting is not really a type of encoding, but encoding is often the point at which files are split for transmission. The split is made to make transferring large files over mail systems easier by creating a number of smaller files from one big one.

To rejoin split files, you need to concatenate the files before running them through any program to decode, decompress, and extract them.

You can do this using cat to create the file:

```
$ cat foo.* >foo.tar.gz.uue
```

or using cat with pipes to join and decode in one step:

```
$ cat foo.* |gunzip -c |tar xf -
```

which achieves the same result without creating a large file in the process.

Compression Systems

There are a number of compression systems available. The most popular and familiar are ZIP (if your background is DOS/Windows), StuffIt (if your background is MacOS), and gzip and Compress (if your background is UNIX). Each has its own merits and depending on the program some compression systems not only compress but archive files, including the directory structure, into a single file.

The two most popular systems you will find on the Internet when considering UNIX files are gzip and compress. gzip was created by GNU Software as a cross-platform compression system. Supplied as standard with the BeOS, it is easy to use and allows you to use both the native gzip and compress formats.

Using compress

For a long time compress was the standard compression system available on UNIX systems. Even with modern systems the standard compression package supplied is often still compress. This makes compress the program of choice as any UNIX flavor should be able to expand the files.

compress uses a modified version of the Lempel-Ziv algorithm identical to that used in most compression programs. The advantage of compress is its simplicity, which helps to make it both versatile and reliable.

Compressing a file using compress

To compress a file, use the compress command:

```
$ compress foo.tar
```

which creates a new file, foo.tar.Z, and removes the original. The new, compressed version is only written out if the compression has saved some space.

Decompressing a compressed file

To decompress files, use the uncompress command:

```
$ uncompress foo.tar.Z
```

If the .Z is not specified, uncompress looks for a file that matches the file name given with the .Z appended to it. If no file name is specified, both compress and uncompress default to reading input from stdin and sending the output to stdout.

Using zip

Zip is the standard format for transferring files on PC's with it's roots firmly in DOS, and more recently with utilities such as WinZip under Windows 95 and NT. It uses the same compression algorithm as gzip, but the difference comes from the ability to include more than one file, and even better, a whole directory structure of files into the file all as part of the same application. With the latest version of the Info-ZIP tools, a free version ported to most platforms, you have the advantage that BeOS attributes are also stored in the archive file.

To extract a zip file, you use the unzip tool supplied with BeOS, specifying the zipped filename on the command line:

```
$ unzip foo.zip
```

Alternatively, you can double-click on the file in the Tracker and it will automatically be extracted.

Using gzip

gzip also uses a modified version of the Lempel-Ziv compression algorithm, but usually produces smaller files than compress. It's used in a very similar way: two different programs are used to compress and decompress.

Compressing a file using gzip

Gzip compresses a file by creating a new file of the same name with .gz appended to it. Once the compression has been completed the original file is removed.

```
$ ls
foo.tar
$ gzip foo.tar
$ ls
foo.tar.gz
```

Decompressing a gzip file

You can use gunzip to decompress a gzipped file back to its original form:

```
$ gunzip foo.tar.gz
```

As with compress, you can use gzip and gunzip via pipes to make compressing and decompressing files easier. When decompressing you need to use the -c option with gunzip to force it to output the decompressed file to stdout instead of a file:

```
$ gunzip -c foo.tar.gz|tar xf -
```

The gzcat program is a simpler version of gunzip and is identical to the gunzip -c command:

```
$ gzcat foo.tar.gz|tar xf -
```

Gzip is also capable of decompressing files created using compress, zip, and pack. There are some limitations, though. The zip compatibility only works on zip archives containing single files compressed using the "deflation" method. If you want to decompress zip files it is better to use the unzip utility, which has been ported to the BeOS.

The tar Archiving System

Under UNIX, tar (short for tape archiving program) is used primarily for backing up and archiving files to tape. Actually, though, tar can be used to create archives on tape, disk, or any other device. You can also use tar to create a file rather than having to write to a physical device. The file created is called a tar file and can be used to transfer an entire collection of files (including the directory structure) into one large file.

A tar file is not compressed in any way, so once created the file can then be compressed and optionally encoded using your preferred compression and encoding programs. While tar is primarily a UNIX file format, compatible programs can be found on MacOS and DOS/Windows. Most Unices now come with tar as standard because it is such a universally accepted way of transferring an entire directory tree as a single file.

Creating and using tar archives

tar is easy to use once you get to know the principles and some of the little tricks and traps of the program. There are three basic commands: c creates new tar files; x extracts existing tar files; and t provides a table (list) of the files contained in the archive.

So, for example, the line

```
$ tar t
```

would provide a list of files from… well, from where? Most Unices use the first tape device as the default to read from; in the example the command would try /dev/mt/0 or /dev/mt0. Under the BeOS, tar looks to the floppy drive as the default device. If you try this without a floppy in the drive, or with a floppy that does not contain a valid tar file, you will get an error:

```
$ tar t
tar: read error on /dev/floppy_disk : No space left on device
```

which is just a cryptic way of saying that tar couldn't identify the device as containing a valid tar file. If you had inserted a floppy disk into the floppy drive you could use this to transfer files between the machine running the BeOS and another machine.

You can specify a file (or other device) for tar to use with the f option:

```
$ tar tf foo.tar
```

The f option means "use the next argument as the file or device to...". When used with the t or x option this description completed with "read from". For example, the command:

```
$ tar tf myfile
```

lists the contents of myfile.tar.

When used with the c option the sentence for describing the operation becomes "use the next argument as the file or device to write to". This is the most common way of using a tar file. You will have transferred it to the machine, probably via FTP, and you need to use tar to extract the files from the archive.

Using our example again, the resultant output will be a list of the files (with their paths) in the order in which they are stored in the tar file.

```
$ tar tf foo.tar
./foo/foo.c
./foo/bar.c
./foo/foobar.h
./foo/Makefile
```

I will cover the path and order issue shortly, but looking at the list you'll see that it doesn't really contain any useful information. You can use the v option to provide more verbose (detailed) output about the files.

```
$ tar tvf foo.tar
drwxrwxrwx 1/1       0 Feb  6 12:13 1995 ./foo/
-rwxrwxrwx 1/1    2257 Feb  6 12:18 1995 ./foo/foo.c
-rwxrwxrwx 1/1     629 Feb  6 12:18 1995 ./foo/bar.c
-rwxrwxrwx 1/1     463 Feb  6 12:18 1995 ./foo/foobar.h
-rwxrwxrwx 1/1    8194 Feb  6 12:18 1995 ./foo/Makefile
```

An extra line has appeared at the top of the archive. This is because it is now showing not only the files, but also the directories which go to make up the archive. Using the verbose option it lists the directory in addition to any files within the directory, showing the same permission, size and date information.

The specification of the directory in the archive is important. When it comes time to extract the archive, tar needs the directory information to create the directory before it creates the contents.

When creating tar files you should always specify files or, preferably, entire directories from their parent:

```
$ tar cf foo.tar ./foo
```

This helps to keep all of the files that you are including in one place, so that when they are extracted they will be extracted into a new directory called foo.

Extracting files from tar archives

When you're extracting files using the x option to tar, the path of the directories and files is important. Consider the following example:

```
$ tar xf bar.tar
/usr/local/contrib/bar/bar.c
```

The leading / (slash) would force most UNIX versions of tar to extract the file to the absolute directory. This would create the directories if they didn't exist and overwrite any existing files in the process. Under the BeOS we use GNU tar, which automatically strips the leading slash and extracts the archive within the current directory. For example, the above archive would be extracted to ./usr/local/contrib/bar.

Not all archives follow this model, and it is a good idea to get into the habit of listing the contents of a tar file before extracting it, or better still just looking at the first few lines using the head command:

```
$ tar tf foo.tar|head
```

By default, head lists the first ten lines of any piped output. If you need to, you can create a directory, change to it, and then extract the archive:

```
$ tar tf foo.tar |head
./foo.c
./bar.c
./foobar.h
./Makefile
$ mkdir foo
$ cd foo
$ tar xf ../foo.tar
```

You can extract a particular file from an archive by specifying it on the command line. The only caveat is that the file specification must be relative to the archive directory structure.

In the previous example, you could have extracted the file using

```
$ tar xf bar.tar /usr/local/contrib/bar/bar.c
```

which would still extract it to the absolute directory. The line

```
$ tar xf bar.tar bar.c
```

wouldn't have worked, though, because there is no file matching that path in the archive.

During extraction the directories and files in the archive are created in the order in which they were added to the archive. This can cause problems if files have been added to the archive which would supersede earlier entries.

When dealing with compressed files, you can pipe the output through tar to decompress and extract the archive contents without requiring an intermediary file:

```
$ gunzip -c foo.tar.gz| tar xf -
```

The single "-" character causes stdin to be used as the file and can be used in the same way during the archive-creation process to create a ready-compressed tar archive:

```
$ tar cf - ./foo|gzip > foo.tar.gz
```

Alternatively for compressing and decompressing archives, you can use the z option. This automatically compresses the file using gzip or uncompress it using ungzip. This shortens the creation of the above compressed tar file to

```
$ tar zcf foo.tar.gz ./foo
```

To uncompress and extract the archive, the command is shortened to

```
$ tar zxf foo.tar.gz
```

Listing the contents is also much quicker, using the command

```
$ tar ztf foo.tar.gz
```

Archive Contents

Once you have extracted an archive it is useful to be able to identify the contents. There is no general standard for what an archive should contain, but usually it is made up of a series of source files, documentation, and text files. In some cases, you may also find that the package includes binaries and libraries, along with other support files such as graphics and databases.

Sources

You might think it is easy to identify the source files in an archive. Usually it is—you should find a lot of the familiar .c and .h files—but there are exceptions. Depending on the source of the archive, you can sometimes find sources in the root directory, and sometimes in other subdirectories.

In addition to the sources, you need to find the mechanism you'll use to build them into a package. Invariably this is the Makefile, but some packages use different methods to configure and build the package, create the necessary scripts and/or Makefiles, and then finally build the package. We'll cover this in more detail Part 2 of this book.

Let's look at the root directory of GNU Emacs:

```
$ ls -F
BUGS                  configure.in         mkinstalldirs*
ChangeLog             cpp/                 move-if-change*
GETTING.GNU.SOFTWARE  etc/                 msdos/
INSTALL               info/                nt/
Makefile.in           install.sh           oldXMenu/
PROBLEMS              lib-src/             site-lisp
README                lisp/                src/
config.bat            lock/                update-subdirs*
config.guess*         lwlib/               vms/
config.sub*           make-dist*           vpath.sed*
configure*            man/
```

There are a number of subdirectories combined with text files and scripts at the top level. It would be safe to assume that most of the directories contain the source, and the obvious one is src, which in the case of Emacs contains nearly all of the source required to build the entire package.

The Makefile isn't apparent, but you can see a Makefile.in. This file is a template file which will be filled in by some configuration program (configure, in this case) to generate the real Makefile that will be used during the build process. We will look closer at how to recognize build types and configuration systems in Part 2 of this book. If you can't see either a Makefile or some form of template to produce a a Makefile, then you need to read the documentation!

In fact, the .in suffix indicates that the file is a template and will be used to generate any sort of file. Emacs and other GNU packages use template files as the basis for the automatic configuration program, which we take a close look at in Chapter 10.

Documentation

There are a number of conventions, but again no general standards, about the documentation that should be supplied with an archive. Usually, however, you will find a number of files whose names are all-uppercase or start with an initial capital letter. This causes the files to stand out in a UNIX-style directory listing, since files are listed in ASCII (not dictionary alphabetical) order.

The most obvious documentation file is README, which includes information about the archive itself and what programs it provides. Before you start porting or working on any package you should read the README file to ensure that you know the package and its limitations.

Some archives will contain a README file for each platform; for example, README.SYSV would explain any specifics for porting the package to UNIX System V.

Note: SYSV is usually a good sign, as POSIX (the functions and header files used to support the UNIX part of the BeOS) was largely based on the SYSV OS.

The next file you should acquaint yourself with is the INSTALL file, which contains information about how to configure, compile, and install the program. This should provide you with some useful pointers about the difficulties you might face when porting the package. The BeOS is based on POSIX, a standard which uses elements of the two main UNIX OS, BSD and System V. This support, combined with the use of the GNU utilities as the base utility package, can make the porting process easier.

In some packages you may find that a directory has been created to hold the different versions of the README and INSTALL files for the different operating systems. In these cases of multiple files you should look, at least briefly, at each one just so you know what tricks and traps other porters have found while working on the package.

You may not find a README or INSTALL file in every archive or package you wish to port. In these cases your next step is to look for some documentation about how to use the package.

man

Documentation can be found in a number of forms. The most popular form for UNIX-based packages is the man format. man is a program available on nearly all UNIX variants which provides online documentation about all aspects of the OS. This includes everything from introductory information to command-line programs, function and procedure calls, and even file formats. It is therefore common to find one or more man files in a package.

There are some problems with man. It was never designed to be a complete manual for the OS but it is frequently treated as such. Descriptions are often short and cryptic, or worse. Examples are sometimes included to show you how at least some of the features described work, but they rarely go into enough detail to teach you much about the item you're reading about.

The man files are viewed using nroff, which converts the codes in the file into a format that can be viewed onscreen, including underlining and bold if the terminal device supports it. The nroff formatting is sometimes simple enough to be ignored when you view the files in an editor, providing you don't mind consciously filtering out the formatting commands.

Note: There is a port of the GNU groff utility package which supports the nroff style formatting. See Appendix A for more information.

A man page can be identified in a number of different ways. Invariably it has a name ending in .man or ending in a number and optional letter. This numbering system corresponds to the different sections within the man system. Each section deals with a different element of the operating system. You can see the section numbers and the corresponding section titles for System V Unices in Table 6.3. Other variants of UNIX have similar, but not identical, structures. For example, man section 1 always means command-line programs, but SunOS uses section 8 for maintenance commands while System V uses section 1m.

Table 6.3

man Sections

Section Number	Description
1	Basic commands (programs)
1m	Maintenance (superuser) commands
2	System (kernel) calls
3	Library functions
4	Special files, file formats
5	Conventions, file formats and miscellaneous information
6	Games
7	Macro packages

Under UNIX, documentation is supplied as source files which are installed then accessed using the man command. The man program finds the document in the tree structure and then uses nroff to display the formatted version onscreen. The documentation supplied with the BeOS is formatted in HTML and can be viewed using the NetPositive web browser. This fact doesn't help though when most supplied software will use the man formatted documents. The nroff tool doesn't exist on the BeOS, but a groff tool (the GNU version) is available as part of GeekGadgets.

GNU has a package called groff which provides all the functionality of both nroff and troff (the program used to print man files). You can use groff to view man files onscreen using the following command:

```
groff -eptsR foo.man|more
```

You can also use the groff package to create PostScript files which can then be printed on a printer, or, as you will see shortly, viewed onscreen.

Info and TeX

Another format often used, particularly by GNU projects, is the info file.. Info files can be viewed onscreen and also can be used to produce documentation in hard-copy format using the TeX package.

TeX files (identified by their trailing .tex) can be formatted using the TeX formatting system into printable documentation. TeX is really a typesetting system, and the details of its operation are beyond the scope of this book. Despite the fact that TeX has been around for a good many years, it is still one of the most difficult programs to use.

If you own a Mac and find that you are using a lot of TeX files, it might be worth obtaining a copy of OzTex, which is a complete package of software that can process TeX files and display them onscreen, convert them into DVI files for transfer elsewhere, or even print them out to any valid printer attached to the machine.

On the BeOS, Fred Fish has ported the UnixTex package, which can create the necessary DVI files or PostScript files from TeX source.

Using makeinfo it is possible to convert the texinfo files into info format. Info is a menu-driven browser. It follows a basic tree structure, and individual pages within the tree are called *nodes*. You can view the pages within Emacs (useful when you are programming) or use a stand-alone browser to access the information.

If one is available, you should use an info file in preference to a man page. Info files allow you to read the contents and also to use the cross-referencing mechanism to view references in other info files, a facility not found in man pages. This provides much greater flexibility and as a result info files usually contain more information.

Preformatted Documentation

If you are lucky enough to come across preformatted documentation, such as PostScript or DVI files, it is probably easiest to print these out. There are a number of programs which convert DVI files into files suitable for printing on a number of printer types, including PostScript.

Alternatively, you can use the ghostscript package to view PostScript files onscreen. ghostscript can also be used to print PostScript files on non-PostScript devices such as inkjet and even dot-matrix printers.

With all these different formats for supplying documentation for a package it is amazing to think that anybody ever uses any program. It is often easier to convert it to a format that can be printed out than to attempt to view it onscreen.

Text Files

Beyond the introductory files such as README and INSTALL and the documentation there are a number of other files which you will often see included in an archive. Looking at a typical GNU package again, you will remember that Emacs had the following layout:

```
$ ls -F
BUGS                   configure.in       mkinstalldirs*
ChangeLog              cpp/               move-if-change*
GETTING.GNU.SOFTWARE   etc/               msdos/
INSTALL                info/              nt/
Makefile.in            install.sh         oldXMenu/
PROBLEMS               lib-src/           site-lisp
README                 lisp/              src/
config.bat             lock/              update-subdirs*
config.guess*          lwlib/             vms/
config.sub*            make-dist*         vpath.sed*
configure*             man/
```

The BUGS file is used to describe the method for submitting bugs to the author. Submitting bugs to the original provider of a package helps ensure that the bug will be eliminated. Even better is supplying the fix for the bug. We'll discuss this further in Appendix B, "Releasing the Software."

In GNU packages there is always a ChangeLog file which contains a list of all the changes made to the package. These include adding new functionality, fixing bugs, and so on. Information is provided about what was changed, who changed it, and when the change was made. During the porting process it is useful to read this file, as it may provide pointers to any known bugs, problems, or difficulties.

The ChangeLog file can also help you when you port the next revision of a piece of software by listing the things that have changed, including some of the fixes you need to complete your port.

We have already covered the INSTALL file and its uses, but to recap it is the first thing you should read before you start to port the software. Many packages have very simple rules for their build processes; others, like GCC for example, are very complicated. Porting a piece of software to a new platform without knowing how it is supposed to build and install on another platform should be futile.

The PROBLEMS file contains a list of known problems that have been encountered when building, compiling, and testing the package on different platforms. This file is another piece of essential reading, as it provides more pointers on how well the porting process might go on a new OS.

In the Emacs package there is a special etc directory which contains a lot of the ancillary documentation. On other packages these files can often be found at the root level of the package directory.

MANIFEST is a list and description of all of the files included in a package, and can be used to test the integrity of a package you have just received. It is not included in larger packages such as Emacs and gcc because the list would be too long to make it practical. A simple script to check the contents of the package against the MANIFEST file would look like this::

```
$ for file in `cut -f1 MANIFEST`
> do
> if [ ! -f $file ]
> then
> echo Cant find $file
> fi
> done
```

Occasionally a package will include a Todo file, which is just a list of everything the author would like to include in the features of the program.

The Copying file is supplied with most packages, especially those from GNU. While all software is free from GNU (which is part of the Free Software Foundation), they use a rights license for legal reasons to protect themselves against misuse or misrepresentation and from legal proceedings following the use of the program.

The Copying file should always be included in a port of a package, as it outlines all of the details of how to distribute the program and what restrictions there are on its distribution. It is a good idea to get to know the contents of this file, but it’s not essential as long as you remember to include it in any ports you provide to other people.

You should be able to see from this that there is more to a package than just the source files. It makes sense to look around at least the first package you are going to port to get to know the files and formats. Once you know the basics, getting to know new packages should not be a problem. Knowing the contents and identifying their use should be your first priority in all cases.

Chapter 6: Revisions and Backups

When writing an application it is often useful, and sometimes vital, to be able to go back to an old version; usually this is done to return to a more stable version of the software. For this you need to use a revision system which keeps individual versions of sources and the changes between, combined with notes about the changes for yourself and other programmers. Sometimes, however, nothing will do but a complete and verified backup copy. Backups are discussed at the end of this chapter.

Revision Control System (RCS)

The Revision Control System (RCS) is an easy-to-use package that automates the storing and retrieval of revisions. Its capabilities include adding logging and identification information to the revision files. It is suited to text rather than object files and so can be used on all elements of a package, from the source code to the documentation.

Note: RCS is incapable of storing revisions of binary files. However, since it stores the source files that go to make up a binary, this isn't usually a problem.

You can use RCS at two levels, basic and advanced. The basic level only requires simple knowledge of two commands, ci and co. These two commands use (or create) RCS files which contain an archive of the revisions made. The "check in" command, ci, adds a file revision to an RCS archive. co "checks out" a revision from an RCS archive.

For the more advanced user there are a variety of programs which enable you to control and manage the revisions you create. We will learn both levels in this section.

Checking In/Out

The process of recording a revision is called *checking in*. For this we use ci, which compares the file you are checking in against the last version recorded. The changes are recorded in an RCS file which contains the original source, the changes, and any description or logging information attached to each version. Each version you check in automatically increments the version number by 0.1 units after the main revision. When the counter gets to 1.9, the next revision becomes 1.10, rather than 2.0.

For example, a revision checked in when the revision version is currently 1.2 will be incremented to 1.3. It is possible to manually change the revision.

The name used for an RCS file is usually the name of the source file followed by ,v.We will use the following directory for our examples in this section:

```
total 11
-rw-rw-rw-   0 elvis    1           464 Nov 30 14:10 Makefile
-rw-rw-rw-   0 elvis    1          4190 Nov 30 14:10 calc.y
-rw-rw-rw-   0 elvis    1            86 Nov 30 14:10 const.c
-rw-rw-rw-   0 elvis    1           628 Nov 30 14:10 fmath.c
-rw-rw-rw-   0 elvis    1          1087 Nov 30 14:10 lex.l
-rw-rw-rw-   0 elvis    1           345 Nov 30 14:11 tmath.c
```

If an RCS file doesn't already exist, one will be created. Let's check in the tmath.c file:

```
$ ci tmath.c
tmath.c,v  <--  tmath.c
enter description, terminated with single '.' Or end of file:
NOTE: This is NOT the log message!
>> Text text based math library for in-line calculator
>> .
initial revision: 1.1
done
```

The first line describes the process about to be executed. The file tmath.c will be added to the RCS file tmath.c,v. You are then asked for a description for this revision. This should really be just a short description of what you have changed. In this case, since it is the first revision, I've given a description of what the file contains. Once you have entered your description you end the entry using a single "." as the first character of a line. ci then tells you the revision number and finishes.

You have just added revision 1.1 of the tmath.c file to the RCS file. If you now look at the directory again, the original tmath.c file has disappeared and a RCS file is there in its place.:

```
total 11
-rw-rw-rw-   0 elvis    1           464 Nov 30 14:10 Makefile
-rw-rw-rw-   0 elvis    1          4190 Nov 30 14:10 calc.y
-rw-rw-rw-   0 elvis    1            86 Nov 30 14:10 const.c
-rw-rw-rw-   0 elvis    1           628 Nov 30 14:10 fmath.c
-rw-rw-rw-   0 elvis    1          1087 Nov 30 14:10 lex.l
-r--------   0 elvis    1           345 Mar 16 07:43 tmath.c,v
```

What has happened to the original file? By default, ci assumes that you are permanently adding the file you are checking in as part of the revision process.

Checking out extracts either the latest or the specified revision from the RCS file and recreates the source file by processing all of the changes between the original revision (1.1) and the version you requested. To get the latest revision (1.1) of the file back you need to use the co command to check out the current revision back into a file you can compile:

```
$ co tmath.c
tmath.c,v  -->  tmath.c
revision 1.1
done
```

which automatically recovers the last revision (the revision with the highest version number) from the RCS file into the genuine source file.

To speed up the process of checking a file in and out we can use -u option to ci to check in a revision and immediately check it back out again for further editing:

```
$ ci -u tmath.c
tmath.c,v <-- tmath.c
new revision: 1.2; previous revision: 1.1
enter log message, terminated with a single '.' Or end of file:
>> Added bincplx() function.
>> .
done
```

If you now update the file and check it in again, the revision number will have been updated automatically to 1.2:

```
$ ci tmath.c
tmath.c,v  <--  tmath.c
ci: tmath.c,v: no lock set by elvis
```

The check in process has returned an error because the file was not checked out properly. When you check out a file without any options the file created is simply a copy of the latest version. The RCS system doesn't expect you to make modifications to the file, because thats not what you asked for. Then, when you try to check a new revision in, it returns an error because it wasn't expecting any updates.

What you need to do when working with revisions is to lock the revision. This places a logical lock on the revision file that allows you, as an individual user, to update and resubmit a later version. The reason for requiring the lock is that without it, anybody checking out a revision could potentially update it and check it back in again. With a single user working with source code this isn't a problem, but if two people checked out a revision, worked on it, and then submitted the changes back, you would end up with two additional versions of the file, and both would probably conflict with each other. Whilst the lock is in place, it is impossible for anybody except the user who checked out and locked the revision to check in another version.

To lock a file, you can check it in as normal, then check out a locked version:

```
$ co -l tmath.c
```

or at the point of checking in you can automatically check out a locked version by specifying the -l option:

```
$ ci -l tmath.c
```

This command also provides you with an editable version of the file.

If you do make the mistake of not locking a revision when you check it in or out, you can use the rcs command to lock the current revision:

```
$ rcs -l tmath.c
RCS file: tmath.c,v
1.1 locked
```

```
done
```

Now try checking in the modified version of tmath.c again:

```
$ ci -l tmath.c
tmath.c,v  <--  tmath.c
new revision: 1.2; previous revision: 1.1
enter log message, terminated with a single '.' Or end of file:
>> Added the bintodec function
>> .
done
```

This time you are prompted for the log message for the revision. This should be a description of the changes you have made to the file. You will see later how to view the contents of the revision log.

Using ci with make

This method of checking a file out from a locked version is what enables you to control revisions. Ideally, you should be using ci and co every time you modify the file. That way you can go back to any revision you like at any point.

Perhaps the best way of doing this is to make the check-in and check-out process part of the build process for the application. We'll cover the use of make in more detail in Chapter 9. To use the ci program with make, you just need to add a line similar to the previous example before the compilation line for the source file:

```
.c.o:
	@ci -l $<
	$(CC) $(CFLAGS) -c $< -o $@
```

which will prompt you for the log information for each version.

Backing Out a Revision

Using a simple extension to the basic commands, you can either specify a revision to add to the RCS file during check-in, or check out a particular revision. This is useful if you need to go back to an earlier version, or if you want to specify a new revision sequence. For example:

```
$ ci -l2.0 tmath.c
```

would lock version 2.0 of tmath.c into the RCS file rather than allowing RCS to choose the next revision number. To check out an earlier version,

```
$ co -l1.1 tmath.c
```

would create a file containing version 1.1 of tmath.c.

This has effectively overwritten the existing file, replacing it with the previous version. The newer version still resides in the RCS file. The easiest way to supersede this with the previous version is to check in the old version with a new revision number. This has the added advantage of allowing you to return to the additions or changes you made if you want to do so.

Checking the Contents

We can check the contents and log entries of an RCS file using the rlog program. The name suggests that it just prints out the contents of the log, but in fact the program can provide a number of useful reports on the status of RCS files.

To view the revision log for a file, just specify the file on the command line:

```
$ rlog tmath.c |less

RCS file: tmath.c,v
Working file:  tmath.c
head: 1.2
branch:
locks:
access list:
symbolic names:
keyword substitution: kv
total revisions: 2;     selected revisions: 2
description:
First version of the text based math library
----------------------------
revision 1.2
date: 1997/03/18 20:37:33;  author: elvis;  state: Exp;  lines: +5 -0
Added the dectobin function
----------------------------
revision 1.1
date: 1997/03/18 20:30:19;  author: elvis;  state: Exp;
Initial revision
=============================================================
```

As you can see, this provides a lot of information about the file itself, including its current state, along with details of all the revisions and modifications made to the file (in the form of the log messages entered when the different versions were checked in).

Merging Revisions

You can use the rcsmerge program to create a new source file based on two (or more) revisions of the source file from the RCS file. This provides a way to list the source code modifications to a file across more than one revision number. For example, you could create a new version (v2.0) of a source file for which someone has supplied you updates to a previous version (v1.0). Using the file supplied you can update the source, taking into account your revisions from the old version to the new version in addition to those supplied.

To do this, put the supplied revisions in the live source file, then run the command

```
$ rcsmerge -p -r1.0 -r2.0 tmath.c >tmath.out.c
```

The -p option tells rcsmerge to output the final file to stdout, which will then be redirected to a new file.

rcsmerge also allows you to reverse changes made to files by specifying the revisions in reverse order. For instance,

```
$ rcsmerge -r2.0 -r1.0 tmath.c
```

would change the current tmath.c from version 2.0 to version 1.0.

Cleaning a Revision

During the RCS process you can create a number of files that you don't need, or keep locked and unlocked versions of source files in the source tree. Sometimes you need these files, but you should ensure that any changes you make are recorded in the RCS files. Checking in a revision every time you make a modification ensures that the RCS files contain the source tree and that any source files can be recreated from their parent RCS files.

To get around this problem, you can use the rcsclean program to remove any source files from the current directory which are not locked or which do not contain any changes between the current and the previous version.

For each file you specify, rcsclean tries to check in the file, any file which cannot be checked in (because it is not a locked version), or any file which during the check in does not create a new revision number is deleted.

For example,

```
$ rcsclean *.c
```

would remove all files which hadn't been changed since they were last checked out.

Warning: rcsclean can be a dangerous command. Many people find they have made the mistake of not locking out a revision. Then, when they use rcsclean it deletes the file that they have been making changes to. Care should be taken to ensure that the files you specify are safe to be deleted.

Creating a Complete Source Tree

Once you have made all your modifications to the source and checked them all in, you now need to generate the full set of files for the package based on the contents of the RCS files. The files create during the process will make up the *source tree* for the package, which should include all the files necessary to build the entire package.

Creating a complete source tree using RCS can be complex, although the principles are very simple. The first step is to check out the required revision of the source files into a new directory. You can then use the new directory to generate the source tree for the complete package.

A simple script to do this is

```
$ mkdir tmath
$ cd tmath
$ for file in ../tmath.build/*,v
> do
> co -l $file
> done
```

This checks out the latest file from the RCS files contained in the tmath.build directory.

Once the files have been generated, the only thing left to do is to check the compilation, package the files up, and release them. These steps are described in Chapter 16.

Concurrent Version System (CVS)

The Concurrent Version System (CVS) is a front end to the RCS system. In essence it has extended the revision control of RCS which uses a single RCS file in a single directory to refer to a number of revisions to a single file. The extensions use a hierarchical structure of files and directories for storing multiple revisions to a single file. The hierarchical structure allows different people to work on a file simultaneously, expanding the usability of the RCS system.

RCS was designed to enable a single person to work on a single source file. While that source file was locked, nobody else could edit the file, and therefore it provided the security required to ensure that multiple edits didn't supersede or override each other.

Unfortunately, it is precisely this locking mechanism that stops more than one person from working on the same source file. CVS allows multiple users to edit the same file via complex branching. They can all then add their revisions to the CVS file, which in turn creates a final version suitable for compilation.

The process still needs some manual management; two people making modifications to the same part of the file would of course cause a problem. The method used is branching. This allows an individual to create a branch from the main revision source and update the parts of the program. Meanwhile, other users create their own branches and make the modifications. Using the multiple branches the source can then merged back up the revision tree by comparing the differences at different levels to create the new final version.

Many would argue that the simpler RCS model is the better of the two, since it forces programmers to use multiple files for a single project. This style of programming is not a bad way to work, and in fact most people naturally use different files for different areas of programming. These files can turn out to be quite large, though. In Perl, for example, the utility source file (util.c) is 35K and it contains hundreds of different functions. Two people could not work on the file with RCS, even to update two different functions. With CVS you can still use multiple files, but you can also accommodate multiple programmers.

Beyond the multiple-user model, in its basic operation CVS is the same as RCS. You still have to go through the same checking in and checking out procedure, although this time it is via a set of utilities and interfaces to the base RCS package.

Using Multiple Files

When developing a new piece of software, even a relatively small project is usually made up of a number of separate functions. As the project grows, a single source file will increase in size, and every time you make a modification the whole file needs to be recompiled just to create the application. If you separate the file out into a number of smaller files, then each time you make a change to the source, only the file you changed needs to be recompiled, speeding up the compilation process.

When working with a revision system, the advantages of using separate files are even more marked. It allows different people to work on different parts of the entire application at the same time. However, in the case of some packages, the individual files for the different areas turn out to be quite large, and this makes using RCS impossible, you need to work with a more suitable revision system such as CVS.

There are some other features notable in CVS.

You can use CVS to track third-party sources, and also local modifications to those sources. This allows you to work on a contributed archive such as Perl without affecting the original source code. Even if the source is contained on CD-ROM, you can extend the modifications by storing them on a local hard drive, whilst still using the sources on the CD-ROM as the base source code to which the different revisions are related.

The logs which are appended to each revision can be recorded either in the CVS revision file, a separate notes file or even a Usenet news database. This is useful in a public source situation or in a large cooperative project. For example, the ChangeLog file which is supplied with most GNU packages could be created by logging the changes for individual revisions directly into the file.

You can create tags that mark a set of revisions in a number of source files. You can then use CVS to release, at any time, a single version of a software package based on the different revisions of the individual source files. This is true even when files and directories have been added or removed between revisions. Alternatively a specific date can be used to identify a similar package version release.

CVS can directly create a patch file between two revisions, again across multiple files and directories if necessary. This is similar to the rcsdiff command, except for the range of files and directories on which it operates.

CVS over RCS

CVS is really just an extension to the RCS system using a collection of scripts and programs to make better use of the core RCS engine. There are no differences at core level between the operation of the two systems, but there are some differences in how the two systems should be used.

If you are the only person working on a project and you are happy to produce static versions and revisions of software, then the simpler and easier-to-use RCS is probably the right solution for you.

If, however, you are managing a larger project with many source files, multiple source files spread across a number of subdirectories, or you are collaborating with other people working on the same project at the same time, then you should consider using CVS.

CVS should also be the revision system of choice if you are doing collaborative work over the Internet, where the ease with which you can work on the same file and produce final revisions based on all of the changes will save you hours of manual labor. This can be done directly over a TCP/IP link or you can use the ability to produce patch files of any revision. Using CVS in this way will help you communicate with the other programmers working on the package, enabling you to send updates easily and keep the download times as short as possible.

Using diff for revisions

You can create a list of the differences between two files using the diff command. The file created by the process is called a diff file, and the format of this file depends on the type of diff you create. You can use a diff file to create one version of a file from another, but usually diff is used to record the changes between the current and previous versions of a source file. The process of updating a source file is called “patching” and will be covered it later in this chapter.

diff compares two files and outputs a concise list of the differences between them. Each difference is grouped into a collection of *hunks*. A hunk is a collection of differences which are within a specified number of lines of each other, otherwise known as *relatively local differences*. There are a number of different formats that diff can output to, and it is useful to be able to identify them in case you need to make manual modifications to files. There is an easier way, of course, which we will see later in this chapter.

For the examples we will compare the following file (A):

```
This is the first line in both files A and B. However, the next line
only appears in file A. You won't find it in B at all. The third line
is the second line of file B, but the third of file A. We can
show the difference between these two files in context.

   This is the start of paragraph two in both files. This paragraph
is exactly the same in both files across all the lines except the
last. In file A we finish with this line.
```

With this file (B):

```
   This is the first line in both files A and B. However, the next
line
is the second line of file B, but the third of file A. We can
also put a line in B that does not appear in A. The diff command will
show the difference between these two files in context.

   This is the start of paragraph two in both files. This paragraph
is exactly the same in both files across all the lines except the
last. In file B, we make the change even more prominent by also
adding a fourth line to this second paragraph.
```

Standard diffs

A standard diff file is produced when you run the command without any arguments:

```
$ diff file.a file.b

2d1
< only appears in file A. You won't find it in B at all. The third
line
4c3,4
< show the difference between these two files in context.
---
> also put a line in B that does not appear in A. The diff command
will
> show the difference between these two files in context.
8,9c8,9
< last. In file A we finish with this line.
<
---
> last. In file B, we make the change even more prominent by also
> adding a fourth line to this second paragraph.
```

The first line specifies the location of the first modification. The line is of the form:

```
x[,y]{acd}i[,j]
```

Here, x specifies the start line and y the optional end line. The characters a, c, and d specify that lines have been added, changed, or deleted. The numbers following show for how many lines in file B the change should occur, or alternatively the line range.

In the above example, therefore, line 2 in file A should be deleted. The next line shows the line to be deleted for reference purposes. The leading “<” character indicates the removal of the quoted line from the first file.

The second hunk in the file specifies that line 4 in file A should be replaced with lines 3 to 4 of file B. This is followed by the line to change in file A, a divider (---), and the replacement lines preceded by the “>” character. Finally, lines 8 and 9 in file A are replaced with 8 and 9 from file B.

The resultant file shows all the changes required to make file A match file B.

ed Format diffs

An ed format diff creates a script that can be used by the editor ed to produce file B from file A. You can produce this file by using the -e option with diff:

```
$ diff -e file.a file.b
8,9c
last. In file B, we make the change even more prominent by also
adding a fourth line to this second paragraph.
.
4c
also put a line in B that does not appear in A. The diff command will
show the difference between these two files in context.
.
2d
```

While this appears to be a good idea, ed is not a reliable program and is not supported on every platform. The diff file produced doesn’t contain any information about the previous contents of the file and so it impossible to check, even manually, that the replacement text is being inserted in the right place.

Context diffs

As the name suggests, a context diff contains the changes to the file with context information. This can be used by patch or a programmer to verify that the changes are being made to the correct part of the file.

To create a context diff use the -c option:

```
$ diff -c file.a file.b
*** file.a   Wed Mar 19 21:20:00 1997
--- file.b   Wed Mar 19 21:19:25 1997
***************
*** 1,9 ****
     This is the first line in both files A and B. However, the next
line
- only appears in file A. You won't find it in B at all. The third
line
```

```
  is the second line of file B, but the third of file A. We can
! show the difference between these two files in context.

     This is the start of paragraph two in both files. This paragraph
  is exactly the same in both files across all the lines except the
! last. In file A we finish with this line.
!
--- 1,9 ----
     This is the first line in both files A and B. However, the next
line
  is the second line of file B, but the third of file A. We can
! also put a line in B that does not appear in A. The diff command
will
! show the difference between these two files in context.

     This is the start of paragraph two in both files. This paragraph
  is exactly the same in both files across all the lines except the
! last. In file B, we make the change even more prominent by also
! adding a fourth line to this second paragraph.
```

Here we are given significantly more information than in a standard diff file. The first two lines show the names and date/time stamps of the files in question. These provide a backup reference point to the base files. Note the *** by the first file, and the corresponding --- by the second file. These denote the files to reference as each hunk is processed.

The next line is a separator, followed by the first hunk. This shows, because of the surrounding asterisk characters, that this is a change to the first file from lines 1 to 9. The following lines in the diff file show which lines should be changed, including some additional lines used only for context purposes (to ensure that even if the line numbers are not correct we can still find the correct place in file A to make the changes). By default, diff uses two lines of context information on either side of any changes, although this can be changed if you desire.

Each line preceded by a minus sign (-) is a line to be deleted from the source file. An exclamation point (!) signifies a change to the quoted line. The next section shows the replacement text to be added to file B. This is denoted by the "---" characters around the line reference. Exclamation points again denote which lines to modify. A plus sign (+) denotes a line that should be added to the destination file.

Overall, a context diff is much more reliable than the previous two formats because of the context information. You should try to use a context diff wherever possible. If you can, it's even better to use a unified context diff.

Unified diffs

A unified context diff is similar to the context diff format and is created using the -u option:

```
$ diff -u file.a file.b
--- file.a   Wed Mar 19 21:20:00 1997
+++ file.b   Wed Mar 19 21:19:25 1997
@@ -1,9 +1,9 @@
```

```
    This is the first line in both files A and B. However, the next
line
-only appears in file A. You won't find it in B at all. The third line
 is the second line of file B, but the third of file A. We can
-show the difference between these two files in context.
+also put a line in B that does not appear in A. The diff command will
+show the difference between these two files in context.

    This is the start of paragraph two in both files. This paragraph
 is exactly the same in both files across all the lines except the
-last. In file A we finish with this line.
-
+last. In file B, we make the change even more prominent by also
+adding a fourth line to this second paragraph.
```

As you can see, the format is almost identical. The difference is that changes made between the two files are noted next to each line. These can be interpreted simply as "remove the lines prefixed by the minus sign and replace them with the lines preceded by the plus signs."

If you are in the position of passing the files to a human, rather than a program such as patch, most people prefer to "read" context diffs, largely because the text can be cut and pasted between the difference file and the source file. Unified context diffs are more difficult to use manually because the leading character needs to be stripped.

Preparing for patch

The purpose of the patch command is to use the output of the diff command to make the necessary changes to one version of a source tree to get it to match a newer version. patch can accept a number of formats, but the most reliable is a unified context diff.

Obviously, you don't want to run the diff command on each file individually. diff provides a way around this by allowing you to select two directories to compare rather than two files:

```
$ diff -u emacs-19.34 bemacs-1.0 >bemacs.diff
```

This will create a full list of differences between the two directories, but only for those files immediately inside the two directories. To do it recursively throughout the entire source tree you need to specify the -r option:

```
$ diff -ru emacs-19.34 bemacs-1.0 >bemacs.diff
```

This produces a single file containing everything you would need to change the basic Emacs source tree into the BeOS-compatible source tree. Next, you'll see how to use patch to do this.

patch

To minimize time-consuming downloads, you will often have the option of downloading diff or patch files from the same location as the full packages.

The files usually contain the string "diff" or "patch" and specify which version the patch updates and what version you will end with. These patch files contain the output of the diff command and detail the differences between versions of a program. These files are much smaller than whole packages and therefore quicker to download. Once you have the diff files you can read them and patch the files manually, but it would be much easier if a program existed which did the patching of the files from the diff contents for you. This is what patch does.

Patching Packages

patch processes a diff file and performs the following processes before finally making the changes detailed in the file:

6.1. Checks for and ignores any irrelevant header information in the file. If it can, it uses what information it can from the header to identify the type of diff used in the patch file.

7.2. Renames the old file, adding a suffix to the name (by default, .orig).

8.3. Produces a new file with the name of the old file, incorporating the patches from the patch file directly into this new file.

The precise method used by patch depends on the type of diff contained in the patch file. As we have already seen, the most reliable type of diff is the unified context diff, in which both the line numbers and the text are referenced and patch can check these two items against the file to patch. A "fuzz factor" is used when the line numbers and text don't match, and patch can usually make corrections even when extra lines have been added or dummy lines removed.

ed-style diffs are the most dangerous, as changes are made to the file irrespective of the existing contents. For example, an ed-style diff could specify that line 12 was to be replaced. If additional lines had been inserted into the file, patch would still replace line 12, even if that line was now line 15. At all costs, ed-style diffs should be avoided..

If, under any circumstance, patch is unable to identify a place in the old file where it is supposed to make a patch, it will report an error. The entire hunk is then written out to a corresponding .rej file which will contain all the rejected hunks.

To perform the patching process, you usually move to the top of the package's source tree, the collection of files and directories that go towards making up the entire package. The easiest way to find out at which point within the package to apply the patch is to check the header information usually included with the patch file. Let's have a look at the header for the bash patch from version 1.14.5 to 1.14.6:

```
$ gunzip -c bash-1.14.5-1.14.6.diff.gz | more
diff -Nrc2 bash-1.14.5/.patchlevel bash-1.14.6/.patchlevel
*** bash-1.14.5/.patchlevel      Sat May 20 15:24:57 1995
--- bash-1.14.6/.patchlevel      Mon Oct  9 14:42:45 1995
***************
*** 1 ****
! 5
--- 1 ----
! 6
diff -Nrc2 bash-1.14.5/NEWS bash-1.14.6/NEWS
*** bash-1.14.5/NEWS       Wed Jul 12 10:08:44 1995
--- bash-1.14.6/NEWS       Tue Nov 28 13:21:17 1995
***************
*** 1,64 ****
! This file documents the bugs fixed between this release,
bash-1.14.5,
! and the last public bash release, 1.14.4.
```

In this example, the patch file isn't very helpful because it doesn't tell you where to apply the patch from. But what you can see from the header information of the diff file is what files it expects to change. The file in question is bash-1.14.5/.patchlevel. If you don't specify any options to patch the preceding path information, bash-1.14.5 is skipped.

Let's try patching the file:

```
$ cd bash-1.14.5
$ gunzip -c ../bash-1.14.5-1.14.6.diff.gz |patch
Hmm...  Looks like a new-style context diff to me...
The text leading up to this was:
--------------------------
|diff -Nrc2 bash-1.14.5/.patchlevel bash-1.14.6/.patchlevel
|*** bash-1.14.5/.patchlevel    Sat May 20 15:24:57 1995
|--- bash-1.14.6/.patchlevel    Mon Oct  9 14:42:45 1995
--------------------------
Patching file .patchlevel using Plan A
```

patch proceeds to patch the file using the information provided:

```
Hunk #1 succeeded at 1.
```

patch will continue through the file making modifications to all of the necessary files until it either hits a problem it can't get around or reaches the end of the patch file.

You can reduce the amount of information provided by specifying the -s option. This still allows patch to describe what it is doing, but not in as much detail as before.

Better still, you can redirect the output to a file:

```
$ gunzip -c ../bash-1.14.5-1.14.6.diff.gz |patch -s >patch.log
```

Sometimes, it is useful to strip the subdirectories specified in the patch file. This is especially useful if you've changed the directory name of the package. The -pn (where n specifies the number) option enables you to specify how many directories to strip off each individual file:

```
$ gunzip -c ../bash-1.14.5-1.14.6.diff.gz |patch -s -p1 >patch.log
```

This would strip the first directory off the name of any of the files being patched.Problems

While using patch appears straightforward, there are a number of tricks and traps that can catch you out and cause more problems than patch is designed to solve.

If you cancel a patch process partway through you can cause problems because some of the files will already have been patched, while others are yet to be patched. If patch identifies that it has already patched the file, it will ask you if you want to reverse (or roll-back) the patch or ignore the patch changes and continue on to the next file.

The best solution to this problem is to quit the patch process again and check the log from the first patch procedure you ran. By checking the log you will be able to identify any problems (or successes!) in the first patch process. You can then opt to skip over the patches or reverse the patches previously applied as required.

For bad hunks (those that fail during the patch process) it is probably easier to study the log file for the rejected pieces and manually patch the files. Use the previous sections on diff to help you identify the sections that need to be modified. Hopefully, the patches will be in context or unified context style diffs which are much easier to work with.

Occasionally you will come across these lines when patching a file:

```
$ gunzip -c ../bash-1.14.5-1.14.6.diff.gz |patch -p
Enter the name of the file to patch:
```

The cause of this is usually a mismatch between the file name of the current file and the name expected in the patch file. This is common when you change the name in order to fix a problem during the porting process or if you have started the patch process from the wrong directory.

If you are in the parent directory of the package you are porting you can specify the -p option to force patch to use the directory name included in the patch file.

Sometimes you may run the patch process on what appears to be a patch file but get a message like this:

```
$ patch <foo.diffs
Hmm...  I can't seem to find a patch in there anywhere
```

You can assume from this that the file isn't a patch file at all. In UNIX this usually points to an outdated version of the patch program (older versions don't support the more modern unified context diffs). In the BeOS this shouldn't be a problem.

Backups

Any programmer knows about the importance of keeping backups, but many people fail to back up their files often enough. Sometimes they end up doing it only once in the course of a project—halfway through, or worse, only at the end. Such backups are not always useful, though. By their very nature, backups are static, snapshots in time.

Revision systems do form a basic backup system by keeping a copy of your files in another place. That way if you accidentally delete a file you can recover the last revision you checked in. However, what if you delete the directory? Worse, what happens when your hard disk drive dies? What happens when your entire machine fails? While the latter examples sound dramatic, they do happen, and usually it's just before a deadline. A revision system won't help you; you need a full-scale backup.

When making a backup you need to decide what you want to back up, and what you are going to back up to. For most situations backing up the entire directory tree of the application you are porting is a good idea. This is wasteful of space, but it does ensure that you can go back to an exact point in time when your sources and object files matched.

If you want to conserve space, you can get away with just backing up the source files. In theory these should contain the information required to create any object or application files, but you should ensure that you back up everything you need. Always remember to include any Makefiles, scripts, configuration files, and so on.

Once you have decided what you want to back up, decide on the medium you are going to back up to. At the worst you can consider backing up to another folder on the same drive as your source, but ideally you should consider backing up to a different drive, floppy disk, or even tape. The BeOS supports removable mass-storage devices like Jaz and Zip cartridges, and these are a quick and easy medium to back up onto.

If the size of the backup is small you could consider using floppy disks. These don't store much (1.44Mb per disk) but still might be adequate for the sources of a small program. Using tar you can also backup onto multiple floppy disks. For example, the command

```
$ tar cM ./foo
```

will back up the directory foo to as many floppies as are required. The GNU tar program handles the disk labeling and ensures that files can be retrieved off the disks again providing they are inserted in the correct order. The disks need to formatted, as tar is unable to format the disks itself. Use the command

```
$ tar xM
```

to restore from multiple floppies.

If you use another disk or removable media of some kind, you can back up to a file using tar. The advantage of using tar over simply copying files to other directories is that tar is usually more reliable, makes it easier to extract a single file from an archive, and often uses less space. Also, when using a tar file with a compression program like compress, zip or gzip you will get a better compression ratio than if you compressed individual files.

To back up an entire directory to another directory, use the following command:

```
$ tar cf - ./foo| gzip - /boot/backups/foo-backup.tar
```

This example would create a gzipped tar file on the backups directory of the boot disk.

One other advantage of the GNU tar command is that you can specify that only files which have been modified since a particular date should be backed up. Using this feature you can do incremental backups, which use less space, allowing you to perform backups on different days.

Backup levels

Backups can be separated into a number of levels. The top level is a *Full* backup, this backs up all files, directories regardless of the date they were created. Subsequent backups are then classed as incremental. There are many different definitions of incremental. At it's most basic level, an incremental backup backs up all files which have changed since the last full backup. This is an efficient model, and is the one used by most backup systems. However, as you change more files, the longer the period between the full and the incremental backup, the larger the number of files that will be stored.

GNU tar uses a modified version of the incremental backup which allows you to back up all the files which have changed since a specific date. This model allows you to backup files based on the last time any backup was run, rather than just the last full backup.

An extension to the incremental model is to use different level numbers for each incremental backup. A level 1 incremental backup backs up all files since the last level 1 or full backup was performed. A level 5 backup only records files that have changed since the last level 5, or higher (1-4, including full) backup has taken place. The higher backup supersedes the lower backup, recording all the files that have changed since the last backup of the same or higher number. These different levels can be combined to make an efficient system for incrementally backing up files.

For example, lets say you do a full backup every Friday. On Monday, you perform a level 5 incremental backup, which backs up all the files changed since the full backup on Friday. On Tuesday, you do another level 5 incremental backup which only records the files that have changed since Mondays level 5 backup.

On Wednesday, you do a level 3 backup, this backs up all the files changed since the full backup on Friday, including those files that were backed up on Monday and Tuesday. On Thursday you do a level 5 backup again, but this time, it only records the changes since Wednesdays level 3 backup. On Friday, you perform a full backup, and the whole process repeats again.

Using this model, you have a full backup and a half week backup safely stored in a safe or offsite. You can also use the different levels to back up files throughout the day (using, for example level 9), then have a tape back up all the files changed throughout the day during the night (using level 5), and then repeat the model outlined above.

Finally, the last level is "x". An x level incremental or true incremental backup is similar to a standard incremental. However, the guide time for the file is not the last full backup, nor is it measured against whether the file has changed since a specified date. Instead, the file is only backed up if it has been modified since the last time the file was backed up.

I use the script below to back up my files (stored in /MCCe/Projects/InProgress). You can modify this script for your own backups, or write your own.

```
#!/boot/bin/sh
bdir="/MCCe/Projects/InProgress"
date=`date|sed -e "s/\ .*//" |sed -e "s/\//./g"`
bdate=$1
bhead="/MCCe/Backups/Projects"
cd $bdir
bref=1
bfile="$bhead.$date.$bref.tar.gz"
while [ -f $bfile ]
do
       bref=`expr $bref + 1`
       bfile="$bhead.$date.$bref.tar.gz"
done
tar cfN - $bdate ./*|gzip - >$bfile
```

To use this script, adjust the directories you want to back up from and to (specified in bdir and bhead), and then run the command

```
$ backup mmddyy
```

where *mmddyy* is a date you specify in month-day-year format with no punctuation). All files modified after that date will be backed up.

The script should be easy to follow. It automatically creates an incremental backup to a different disk drive, compressing the archive and labeling the file with the date of the backup. An incremental number is also attached to ensure that multiple backups on the same day do not overwrite each other.

Chapter 7: Getting Started

Once you understand the basics of the tools available on the BeOS, you can start porting your chosen application.

The steps involved depend largely on the package you are porting and the complexity of the source code. Preparation is the key to success: make sure that you understand the steps involved in configuring and installing the package. Every package, even those supplied by GNU, is installed a different way. Reading the documentation should be your first step; this should provide you with all the information you need to start the porting process.

Reading the Documentation

The well-used acronym RTFM (Read the "Fine" Manual) applies as much to programmers as it does to users, and probably more. User applications are usually supplied precompiled, with the configuration for a specific machine already worked out. The most difficult decision required during installation is which disk and which directory to install the software into. This is to protect the user from what is (behind the scenes at least) a complicated process.

Programmers, porters, and system administrators are expected to be more knowledgeable about the machines and the packages they are installing. In the case of UNIX software, source files are supplied and the person installing is expected to have a basic knowledge of the build process. This is true for many programs, from free software distributed by organizations like GNU to Oracle database products.

You must read the documentation supplied with a software package before you do anything else. I don't mean the entire documentation; CVS, for instance, has almost a thousand pages of documentation, including the user manual and sample guides.

Key elements typically are installation guides and the "Read me" files found in most packages. In Chapter 5 we looked at the contents of a typical package directory. Lets have another look at the base directory for Emacs. What we are looking for is a file called README or INSTALL:

```
$ ls -F
BUGS                    configure.in        mkinstalldirs*
ChangeLog               cpp/                move-if-change*
GETTING.GNU.SOFTWARE    etc/                msdos/
INSTALL                 info/               nt/
Makefile.in             install.sh*         oldXMenu/
PROBLEMS                lib-src/            site-lisp/
README                  lisp/               src/
config.bat              lock/               update-subdirs*
```

```
config.guess*          lwlib/                 vms/
config.sub*            make-dist*             vpath.sed
configure*             man/
```

Emacs has grown from an advanced editor to something which almost resembles an entire operating system. This makes the sources large. Version 19.34b of Emacs is 10.5Mb even when compressed; uncompressed it is almost 40Mb. Part of this is the base package itself: the elisp files, the documentation, and the core source code. A sizable amount, though, is composed of the compatibility files which make Emacs work on a number of different platforms.

As with all GNU software, and most other supplied packages, the INSTALL file should be the place to start looking for information about how to configure and install the package. Let's have a look at the start of the INSTALL file supplied with Emacs:

```
$ more INSTALL
GNU Emacs Installation Guide
Copyright (c) 1992, 1994 Free software Foundation, Inc.

   Permission is granted to anyone to make or distribute verbatim
copies
   of this document as received, in any medium, provided that the
   copyright notice and permission notice are preserved,
   and that the distributor grants the recipient permission
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BUILDING AND INSTALLATION:

(This is for a Unix or Unix-like system.  For MSDOS, see below; search
for MSDOG.  For Windows NT or Windows 95, see the file nt/INSTALL.)

 1) Make sure your system has enough swapping space allocated to
handle
a program whose pure code is 900k bytes and whose data area is at
least 400k and can reach 8Mb or more.  If the swapping space is
insufficient, you will get an error in the command `temacs -batch -l
loadup dump', found in `./src/Makefile.in', or possibly when
running the final dumped Emacs.

Building Emacs requires about 70 Mb of disk space (including the Emacs
sources).  Once installed, Emacs occupies about 35 Mb in the file
system where it is installed; this includes the executable files, Lisp
libraries, miscellaneous data files, and on-line documentation.  If
the building and installation take place in different directories,
then the installation procedure momentarily requires 70+35 Mb.
```

After the initial copyright notice and excerpt from the GNU General Public License, we leap straight into the installation process, starting with requirements and prerequisites. Let's continue through the file for another page:

```
2) Consult `./etc/MACHINES' to see what configuration name you should
```

```
give to the `configure' program.  That file offers hints for
getting around some possible installation problems.

3) In the top directory of the Emacs distribution, run the program
`configure' as follows:

    ./configure CONFIGURATION-NAME [--OPTION[=VALUE]] ...

The CONFIGURATION-NAME argument should be a configuration name given
in `./etc/MACHINES'.  If omitted, `configure' will try to guess your
system type; if it cannot, you must find the appropriate configuration
name in `./etc/MACHINES' and specify it explicitly.

If you don't want X support, specify `--with-x=no'.  If you omit this
option, `configure' will try to figure out for itself whether your
system has X, and arrange to use it if present.

The `--x-includes=DIR' and `--x-libraries=DIR' options tell the build
process where the compiler should look for the include files and
object libraries used with the X Window System.  Normally, `configure'
is able to find them; these options are necessary if you have your X
Window System files installed in unusual places.  These options also
accept a list of directories, separated with colons.
```

Step 2 tells us to check the ./etc/MACHINES file for more information on the platforms Emacs has been ported to. Step 3 tells us how to configure the package, which must be done before we can build it. In this case it describes how to run the configure program, something we'll look at in more detail in Chapter 10.

Let's look at a different INSTALL file, this time from the wu-ftpd package:

```
INSTALLATION INSTRUCTIONS

1.  edit src/pathnames.h to conform to your needs.

    _PATH_FTPUSERS  "/etc/ftpusers"
        The file that lists users that can never ftp in.  Usually
contains
        root and all usernames not connected to a real person (eg.
bin, sync,
        nobody, etc.)
    _PATH_FTPACCESS "/usr/local/etc/ftpaccess"
        The configuration file for the server.
    _PATH_FTPHOSTS  "/etc/ftphosts"
        The individual user access configuration file.
**  _PATH_EXECPATH  "/bin/ftp-exec"
        The directory that contains additional binaries for use with
the
        SITE EXEC command.
    _PATH_PIDNAMES  "/usr/local/daemon/ftpd/ftp.pids-%s"
        The filename template for pid files.  The %s gets
automagically
        replaced by the proper classname.  There will be as many pid
files
        as there are classes in your ftpaccess.
    _PATH_CVT       "/usr/local/etc/ftpconversions"
        The file that contains the conversion (file -> file.Z, etc)
        configuration.  See ftpconversions.5 for a description of the
format.
```

This time we launch straight into the configuration information. This is less useful than the Emacs file; there are no notes about installation requirements, or details on how to find out what platforms this software has already been installed on.

If the INSTALL file is not available try the README, which is sometimes used to describe the installation process. You might also find that some packages use different installation instructions for different platforms, and these details can be found in files with the OS name appended to either README or INSTALL. In all cases you should read all the files completely and make sure that you understand what is involved.

In general, you should try to identify the following key elements:

- **What is required to compile the package.** This includes prerequisite items. For example, RCS requires that diff and diff3 be installed. Other packages may rely on specific libraries to function, such as dbm or the GNU readline library. It also includes any other pertinent information, such as the space required to build and install the package.
- **How to configure the package.** Beyond using a configuration script, many options are specified in one or more header files. In particular, the config.h and paths.h files contain the bulk of such information and are common to most packages. You should also be aware of any changes that may be required to the Makefile.
- **What steps are required to compile and build the package.** After configuration, you must know the process for actually compiling the source code. For most packages this is a simple case of running make; for others it may require more complex steps. GCC, for example, requires at least three steps after configuration just to compile the base product. This process is deliberately not automated to ensure that the compilation proceeds correctly.
- **How to install the package.** This is often as simple as typing make install, but some packages have special steps and processes in addition to, or instead of, the make command.

You can use this checklist to help you decide if you are prepared to compile a package.

If the application hasn't already been ported to the BeOS you should also be looking for any references to:

- **POSIX compliance.** The BeOS is mostly POSIX-compliant, and any package that supports POSIX commands will probably be easier to port.
- **SVR4 or SYSV compatibility.** SVR4 (System V Release 4) forms the basis of many UNIX OSs, including Sun Solaris and HP-UX. Although the BeOS isn't SVR4-compliant, a lot of SVR4 code is actually POSIX-compliant.

- **AIX compatibility.** Usually this only matters with applications that are affected by the processor type you are running on. Compilers are a good example. AIX is the most stable of the UNIX flavors which are supported on PowerPC equipment.
- **Linux compatibility.** Because the BeOS is also available on the Intel platform, Linux is the obvious choice for Intel based BeOS porting and should help to alleviate some of the difficulties experienced when the processor type is required by the package being ported. Linux is also very close to the POSIX specification. Since the BeOS is also POSIX compatible it should be a good platform to start from.

Identifying the Build Type

If you're lucky, reading the package's installation instructions will provide you with all the information you need. Unfortunately, not everybody is as diligent as the GNU team in describing the processes required to build a package. If an installation guide is enclosed it will sometimes be incomplete. There are even some packages that don't come with any documentation at all, in which case you need to use other methods to reveal the build type.

There are many different ways to build an application, but there are four main steps common to each:

9.1. **Configure the package for your OS (often automatic).** This usually includes making decisions about the libraries to use, the header files to use, and the definitions required to compile the source correctly. Although I've described this as configuring for your OS, it can sometimes be machine-specific depending on the additional programs and libraries you might have installed.

10.2. **Configure the package for your machine (often manual).** This should include information like the location of your libraries, where to install the completed package, and so on. Often this level of configuration only requires specifying a few directories, but sometimes it includes more detailed information such as host names and network types. This isn't the same as the user configuration; the information you supply here will be hard-coded into the program and won't constitute part of the configuration files once the package is installed.

11.3. **Build the package.** Building is usually controlled by a make program or a clever compilation script that does the work for you. make-based builds are easiest to understand; scripts aren't always so easy to follow. In all cases, what you're looking for is a program which runs the compiler that builds the software.

12.4. **Install the package.** This is usually relatively straightforward and is often handled by the same system (Makefile or a script) as the build process. In other cases you need to manually install the software and support files.

Depending on the package, different programmers will have implemented these steps in different ways.

To identify the build type you need to start by looking at the package directory again. Let's assume that Emacs doesn't come with any documentation describing how to go about installing and configuring the package. You should be able to spot some things automatically. There are a number of scripts (denoted by the trailing asterisk) which are probably involved in at least one part of the process. There is also a Makefile, and although it doesn't have the normal name, the trailing suffix denotes that it will probably be used during the configuration process.

```
$ ls -F
BUGS                   configure.in          mkinstalldirs*
ChangeLog              cpp/                  move-if-change*
GETTING.GNU.SOFTWARE   etc/                  msdos/
INSTALL                info/                 nt/
Makefile.in            install.sh*           oldXMenu/
PROBLEMS               lib-src/              site-lisp/
README                 lisp/                 src/
config.bat             lock/                 update-subdirs*
config.guess*          lwlib/                vms/
config.sub*            make-dist*            vpath.sed
configure*             man/
```

Tip: The -F option displays a trailing asterisk (*) for executable files and a slash (/) for directories.

This is a fairly typical example from the GNU project; nearly all GNU software follows the same general idea and is supported by a configure script generated by the autoconf package, also from GNU. We'll cover configuration scripts in more detail in Chapter 10.

Even perl follows the same basic idea, albeit with different file names. Here's the directory of v4.036:

```
$ ls -F
Artistic        cflags.SH       h2ph.SH         perly.fixer
Configure*      client          h2pl/           perly.y
Copying         cmd.c           handy.h         regcomp.c
EXTERN.h        cmd.h           hash.c          regcomp.h
INTERN.h        config.H        hash.h          regexec.c
MANIFEST        config_h.SH     hints/          regexp.h
Makefile.SH     cons.c          installperl     server
PACKINGLIST@36  consarg.c       ioctl.pl        spat.h
README          doSH            lib/            stab.c
README.ncr      doarg.c         makedepend.SH   stab.h
README.uport    doio.c          makedir.SH      str.c
README.xenix    dolist.c        malloc.c        str.h
Wishlist        dump.c          msdos/          t/
arg.h           eg/             os2/            toke.c
```

```
array.c          emacs/           patchlevel.h     usersub.c
array.h          eval.c           perl.c           usub/
atarist/         form.c           perl.h           util.c
c2ph.SH          form.h           perl.man         util.h
c2ph.doc         gettest          perlsh           x2p/
```

Instead of the lowercase configure script, we have a single Configure script with a number of non-executable shell scripts (config_h.SH and makedepend.SH, for example) supporting the main one.

Not all applications have a configuration script. For some you will need to manually configure a file with information about both the OS you are using and the individual setup of your machine. In these cases you need to look for a header file which is common to the majority of the source files. Usually this is called config.h, or there will be a header file whose name matches the name of the package, as in the case of the Apache Web server software, where the configuration file is called httpd.h.

There are also some applications which don't have a configuration file of any sort. Often the entire build is controlled by a single Makefile which includes information about the configuration in the form of define options to the compiler. We'll look at these in some detail in Chapter 9.

For a short period of time many packages were configured using imake. This was an attempt to standardize the configuration information required to build X applications using a number of OS-specific files which, when processed with the supplied imakefile using the C preprocessor, produced a normal Makefile which was then used to build the package. A BeOS version is now available as part of the X Windows port. If you want to avoid using imake, you can usually use make because most packages were also supplied with a traditional Makefile.

Identifying the Build Process

You may be under the impression that once you have identified the build type, the build process is the same. This should be true for most applications. If you find a Makefile it's reasonable to assume that the build process requires you to run the make command. However, many porting exercises involve other programs, scripts, and processes behind the scenes. In these situations you need to be able to identify what happens when you type make, or what happens during the configuration process.

This may sound like reverse logic. Surely if the INSTALL file says to run configure, followed by typing make, then this is the build process, right? Wrong! For some packages typing make does nothing more than execute a script which in turn builds the package. In other cases, a script is wrapped around an execution of make.

Knowing what goes on behind the scenes is vital if you need to identify why the build failed. Not all problems are caused by a fault with the source files. In the case of the BeOS some shell scripts fail because of incompatibilities in the shell itself, or because programs that the script expects to find are missing. There are also some packages that supply a Makefile which actually does nothing more than tell you how to configure and build the package.

The best course of action in any situation where you can't decipher the build process is to actually read the Makefile, configuration scripts, and any other files that are obviously not source-related. This is time-consuming, but sometimes necessary.

Chapter 8: Configuring the Package

We saw in the last chapter how we can identify the build type by looking at the document and the files that are supplied with the package. The build type will be one of three distinct options. Either the configuration is automatic, coupled with a Makefile or build script; the configuration is interactive, coupled with a Makefile or build script; or the configuration needs to be performed manually, combined with either a Makefile or build script.

Once you have identified the build type, you should be in a position to start the porting process. Different packages have different build types, but there are some common elements in all packages which you will have to modify or find workarounds for in order to proceed.

In this chapter we will take a closer look at the options you will need to change to help port the package, including the the tools, directory locations and other information. We will also investigate the use of #include and #ifdef to control the configuration of the package.

Preparation

We have already covered in Part 1 the different tools you will need to use whilst porting, including editors, revision systems, and backup systems. The previous chapter should have helped you to identify the build type and the build process. All of this is in preparation for the final assault, as it were, on the actual process of porting.

If you've gotten this far, the package should by now be unpacked, and you should be in the base directory eager to start. In Chapter 6 I explained how best to go about making backups. Before you even start a port, make backup copies of the configuration scripts, files, Makefiles, and anything else which you feel you may need to refer to at some later stage.

You will always find during the course of a port that you suddenly need to refer to a file that you have modified. This is a problem if you have modified the file so much that the configuration no longer works; you may have to back out that revision and go back a version or two. If you aren't using a revision system then you will need to return to the original supplied version of the file, or perhaps even the original package.

If we take a look at one of my build directories where I keep some of my current porting projects you can see that I keep multiple copies of each package (in this case perl) and each one is in a different stage of development.

```
$ ls
drwxrwxrwx   0 elvis    1           0 Dec 11 15:29 beperl5.8.1/
drwxrwxrwx   0 elvis    1           0 Dec 11 15:29 beperl5.8.1-src/
```

```
drwxrwxrwx   0 elvis    1            0 Dec 11 15:32 beperl5.8.1-
src.bak/
drwxrwxrwx   0 elvis    1       336403 Dec 11 15:35
beperl5.8.1.tar.gz
drwxrwxrwx   0 elvis    1            0 Dec 11 15:35 beperl5.8.2-src/
drwxrwxrwx   0 elvis    1            0 Dec 11 15:38 beperl5.8.3-src/
drwxrwxrwx   0 elvis    1            0 Dec  3 14:16 beperlm/
drwxrwxrwx   0 elvis    1            0 Dec 11 17:41 perl-5.003/
```

One directory, perl-5.003, is the directory created by extracting the GNU package. The other perl directories, those starting with beperl, show the different versions I have in production. If at any time I need to return to the original files as supplied then I can simply open the version in the perl-5.003 directory.

This is wasteful on space, but ultimately more useful than only keeping a few of the files. I don't make any changes to the default directory; any modifications during the build process are made in the corresponding build directory, keeping the packaged versions fresh.

The first version I worked on was v5.001. I had completed this port when I decided to do a test port of v5.003, contained in the beperl5.8.2-src directory. I then progressed to do a full version, which is contained the beperl5.8.3-src directory. Finally, the beperlm directory is a reference directory, this time from a build on a Sun SPARCstation running Solaris 2.4. This is an extensive set of directories for a package which has a very complicated build process, and so the different versions become a vital reference throughout the life cycle of the port.

If you do not have much disk space (and remember to ensure you have enough space the build the package) then you can make copies of just the most important files. Check the documentation, but a good starting list is:

- Makefile
- Makefile.in
- config.h
- configh.in

I tend to use a suffix of .supp to show that the copy is the "supplied" version of the file. Alternatively, you may decide to check in the supplied versions using RCS. Remember, however, that you cannot easily then refer to the file if you need to without checking in the current version and checking out the first revision. This can be a problem if you need to make comparisons between versions of the file.

The final step before proceeding is to check the documentation again. I really can't stress enough the importance of reading the README, INSTALL, and other relevant files before proceeding to do a port. Without the information supplied in these files, knowing how to configure the package and what to change to configure it properly will be difficult at best, impossible at worst.

Take time to double-check that you have everything you need:

- The extracted package in suitable directory on your hard drive
- A backup copy of the important files, or better still of the entire package
- Paper and pen, to make notes whilst you are working
- Coffee, tea, or your preferred beverage!

Now you are ready to proceed.

Expect to Change

Even in well-ported and well-configured packages, such as those from GNU, you can expect to change at least some basic items during the process of a port. Your typical software package includes a number of elements that stipulate how the program should be compiled, including the libraries, library locations, and header file locations required during the build process.

The changes to these vital pieces of information may be in header files or configuration files, may be entered during an interactive configuration script, or may even be in a Makefile. What is important is not where the change takes place, but that you must change the information for the package to be built and configured correctly.

Whatever the method of configuration, there are three core items you will need to change:

- **Directories.** You'll need to specify directories for header paths, configuration information, and the final installation destinations.
- **Tools.** The BeOS doesn't support all of the tools supported by UNIX, and those it does support may have different names. For example, lex been replaced by the GNU version, called flex.
- **Libraries.** Different machines have different libraries, and usually different library locations

Directories

Though there are many standards in the UNIX community there is no adhered-to standard for the location of anything. In particular, supplied software can be, and often is, installed in a variety of places.

You therefore need to be prepared to modify the directories used for the installation and any hard-coded configuration information used by the package. If you have a look at the extract below of the httpd.h header file, taken from the Apache WWW server package, you can see the directory specification required for the root installation directory of the httpd application.

```
#ifdef __EMX__
/* Set default for the OS/2 file system */
#define HTTPD_ROOT "/os2httpd"
#else
#define HTTPD_ROOT "/usr/local/etc/httpd"
#endif
```

This information is hard-coded, using C definitions, into the source code because there is no accepted location for a preferences directory. We will see the effect of defines and how they are used later in this chapter.

You will also find that you need to change the definitions for the installation directory. A typical GNU package uses a standard system under the /usr/local directory. Within this directory the model then follows the basic layout of the UNIX file system, with /usr/local/etc used for configuration information, /usr/local/bin used for the executables and /usr/local/lib used for the library and support files.

Check the directory specifications of any tools used during the build process. GNU make uses the PATH environment variable to search for any tools required. Some packages specify the tools with absolute directory references, which will cause a problem under the BeOS because it is not like a standard UNIX system. For example, specify that the C compiler should be /usr/bin/cc will cause problems because not only does the directory not exist, but the compiler is called mwcc not cc. Although a script called cc will allow you to use the cc in place of mwcc, it is probably a good idea to change the entries to mwcc anyway. If you do make the change, you will need to specify some additional search directories for the header files. As standard, mwcc does not include the current directory for header file files, so you need to include -I- -I. in the compiler definition.

Finally, check the directory specification of any header files or library paths. This is particularly important if you are using any third-party-supplied libraries. It is not uncommon to come across a line like this:

```
CFLAGS =       -O -g -I/usr/local/include -L/usr/local/lib
```

You should double-check to make sure the specified directories exist, and if they don't, either change the references or remove them altogether.

Warning: Removing directory references can cause more problems trhan it solves. This is particularly the case when it comes to testing. Not having a directory that the package deems vital could cause it to fail for some unknown reason, and you then spend hours trying to identify the bug in the code!

Tools

In some of the earlier chapters I explained about some of the tools that are missing in the BeOS and described ways of producing similar, if not identical, results. During the build process you will usually find that some tools either do not exist or don't work in the desired fashion.

The most commonly missing tool is the C compiler, which is called cc under most UNIX variants. Some packages specify that you should use the GNU C compiler, rather than the vendor-supplied compiler. This is gcc, a port of which for the BeOS has recently been completed by Fred Fish (see Appendix A for more information).

The specification of gcc by a package usually signifies that it relies on gcc's compiler features. gcc supports the concurrent use of debugging symbols and optimization;, the two are mutually exclusive on most C compilers. Under some OSs gcc is known to be more reliable or to produce better code. For example, under the SunOS the alloca() library function is notoriously unreliable; gcc, however, includes its own version of alloca(), resolving the problem quickly and easily. In addition, gcc supports non-standard C expressions, such as variable length array declarations such as

```
void foo(int a)
{
	int bar[a];
}
```

These types of expression will need to modified under the BeOS, as mwcc doesn't support this option.

Under the BeOS, the C compiler is mwcc, short for Metrowerks C compiler. All of the basic options for C compilers are supported by mwcc and we will learn more about the specifics of mwcc in Chapter 13. Using any C compiler you can therefore simply change the cc specified to mwcc, or gcc if you have it.

A close second in the missing tool list is the linker. Under UNIX this is usually ld, although most C compilers will act as an interface to the linker. Under the BeOS, the same tool is mwld, and a script called ld is also supplied, but unless the linker is specifically required you can usually replace ld with mwcc.

When you're building libraries, there is no ar command for assembling them but there is an ar script which emulates the functionality. It is not ideal, and because of some of the limitations of using mwcc as a replacement for ar not all of the features are supported. We will have a look at an alternative version of the ar script later in this book. A POSIX version of ar that is BeOS compatible has also been released by Chris Herborth, and details are available in Appendix A for how to obtain this application.

The ranlib command doens't convert libraries into the random library format required either. Most UNIX flavors don't use the ranlib command either, and the BeOS is supplied with a script that does nothing to aid in the build process. Instead of using ar and ranlib you need to use an option with the C compiler to produce either a static or dynamic library; we'll see what command to replace these two commands with in Chapter 13.

The tools yacc, the source code generator for compilers, and lex, the lexical analyzer, do not exist in the BeOS either, but we do have their GNU equivalents, bison (in fact, you use bison -y) and flex. There are some differences in the operation of these two commands compared to the standard UNIX versions, but usually you can simply substitute the commands without causing too many difficulties. Chapter 12 covers these differences in greater detail.

Most other commands used during the build process—cp, install and others—have BeOS equivalents. However, it is worth familiarizing yourself with the commands found on the BeOS so that you can quickly identify the commands a package is asking for, and the probably equivalent and it's location.

Libraries

While it is unlikely that you will need to change the actual names of libraries required during the build process, there are some differences in the libraries available and the directories in which they can be found.

The standard BeOS library locations are specified by the BELIBRARIES environment variable, which by default points to the system libraries in /boot/beos/system/lib and the developer libraries which come as part of the C compiler in /boot/develop/lib. These libraries contain most of the core functions in just a few files. It is especially important to note that, unlike in some UNIX variants, you do not need to include extra libraries for access to networking and other OS extensions.

Unlike Solaris, where a typical command to compile a network tool would contain all of the libraries:

```
$ cc nettool.o -o nettool -lsocket -lnsl
```

we can get away under the BeOS with just

```
$ mwcc nettool.o -o nettool
```

without causing too many difficulties. Of course, this relies on the functions existing and working correctly, something we'll cover in the last part of this book.

We do still need to specify utility libraries such as the lex library (-lfl) The full list of utility libraries is as follows:

Library Name	**Description**

libdll.a Glue code, startup functions and dynamically loadable library support

libfl.a Flex support library

libtermcap.a Termcap (see Chapter 21)

Using #include in the Configuration Process

Header files, or include files, help to provide the necessary data structures, definitions, and function prototypes for OS, utility, and library functions. They are split into well-defined groups, and beyond some standard C header files, each UNIX variant (even those based on the same major variant of BSD and USG versions of UNIX) has a different name for essentially the same file.

This can cause a number of problems during the porting process. The BeOS is POSIX compliant which makes our lives significantly easier. The names of the different header files, and the contents of those files have been standardized.

The most likely way of modifying this information is to change a configuration option to cause a different header file to be included. In extreme circumstances, you may need to change the header files actually referenced in the source code. Most packages use the identity of the OS to automatically select the required include file, but knowing the available header files should help you to spot any problems before they occur.

BeOS Headers

BeOS header files are stored in the /boot/develop/headers directory. This is subdivided into three further directories: be, which contains the files used by the Be C++/GUI environment; gnu, which contains the supplied GNU utility headers; and finally posix, which contains all of the POSIX headers. This last directory is the one we are most interested in as it contains the files responsible for the POSIX-compatible layer, the closest thing to UNIX-style header files we can get.

The full list of files in the Preview Release of the BeOS is as follows:

```
-r--r--r--   1 baron    users        4056 Jun 28 03:13 CPlusLib.h
-r--r--r--   1 baron    users         157 Jun 28 03:13 alloca.h
-r--r--r--   1 baron    users        1281 Jun 28 03:13 ansi_parms.h
-r--r--r--   1 baron    users         737 Jun 28 03:13 assert.h
-r--r--r--   1 baron    users        1211 Jun 28 03:13 be_math.h
-r--r--r--   1 baron    users         532 Jun 28 03:13 bsd_mem.h
-r--r--r--   1 baron    users        3406 Jun 28 03:13 ctype.h
-r--r--r--   1 baron    users         671 Jun 28 03:13 dirent.h
-r--r--r--   1 baron    users         359 Jun 28 03:13 div_t.h
-r--r--r--   1 baron    users        1666 Jun 28 03:13 errno.h
-r--r--r--   1 baron    users        1699 Jun 28 03:13 fcntl.h
```

```
-r--r--r--   1 baron    users        4099 Jun 28 03:13 float.h
-r--r--r--   1 baron    users        4762 Jun 28 03:13 getopt.h
-r--r--r--   1 baron    users         458 Jun 28 03:13 grp.h
-r--r--r--   1 baron    users        1031 Jun 28 03:13 limits.be.h
-r--r--r--   1 baron    users        1134 Jun 28 03:13 limits.h
-r--r--r--   1 baron    users        1157 Jun 28 03:13 locale.h
-r--r--r--   1 baron    users        5206 Jun 28 03:13 malloc.h
-r--r--r--   1 baron    users        6256 Jun 28 03:13
malloc_internal.h
-r--r--r--   1 baron    users        2361 Jun 28 03:13 math.be.h
-r--r--r--   1 baron    users       11274 Jun 28 03:13 math.h
-r--r--r--   1 baron    users         133 Jun 28 03:13 memory.h
-r--r--r--   1 baron    users         239 Jun 28 03:13 null.h
-r--r--r--   1 baron    users        3452 Jun 28 03:13 parsedate.h
-r--r--r--   1 baron    users         522 Jun 28 03:13 pwd.h
-r--r--r--   1 baron    users        1534 Jun 28 03:13 setjmp.h
-r--r--r--   1 baron    users        5406 Jun 28 03:13 signal.be.h
-r--r--r--   1 baron    users         940 Jun 28 03:13 signal.h
-r--r--r--   1 baron    users         453 Jun 28 03:13 size_t.h
-r--r--r--   1 baron    users        1130 Jun 28 03:13 stdarg.h
-r--r--r--   1 baron    users         540 Jun 28 03:13 stddef.h
-r--r--r--   1 baron    users        6724 Jun 28 03:13 stdio.h
-r--r--r--   1 baron    users        3074 Jun 28 03:13 stdlib.h
-r--r--r--   1 baron    users         671 Jun 28 03:13 string.be.h
-r--r--r--   1 baron    users        5340 Jun 28 03:13 string.h
drwxr-xr-x   1 baron    users        2048 Jul 20 10:33 sys
-r--r--r--   1 baron    users        6623 Jun 28 03:13 termios.h
-r--r--r--   1 baron    users        3181 Jun 28 03:13 time.h
-r--r--r--   1 baron    users        4448 Jun 28 03:13 unistd.h
-r--r--r--   1 baron    users         243 Jun 28 03:13 utime.h
-r--r--r--   1 baron    users         279 Jun 28 03:13 va_list.h
-r--r--r--   1 baron    users         560 Jun 28 03:13 wchar_t.h
```

with the contents of the sys subdirectory being

```
drwxr-xr-x   1 baron    users        2048 Jul 20 10:33 .
drwxr-xr-x   1 baron    users        2048 Jul 20 10:33 ..
-r--r--r--   1 baron    users         319 Jun 28 03:13 dir.h
-r--r--r--   1 baron    users         289 Jun 28 03:13 dirent.h
-r--r--r--   1 baron    users          92 Jun 28 03:13 fcntl.h
-r--r--r--   1 baron    users          68 Jun 28 03:13 file.h
-r--r--r--   1 baron    users         129 Jun 28 03:13 ioctl.h
-r--r--r--   1 baron    users         161 Jun 28 03:13 param.h
-r--r--r--   1 baron    users         130 Jun 28 03:13 socket.h
-r--r--r--   1 baron    users        3480 Jun 28 03:13 stat.h
-r--r--r--   1 baron    users         358 Jun 28 03:13 sysmacros.h
-r--r--r--   1 baron    users         793 Jun 28 03:13 time.h
-r--r--r--   1 baron    users         502 Jun 28 03:13 times.h
-r--r--r--   1 baron    users         959 Jun 28 03:13 types.h
-r--r--r--   1 baron    users         300 Jun 28 03:13 utsname.h
-r--r--r--   1 baron    users         649 Jun 28 03:13 wait.h
```

This directory structure matches most UNIX variants, in particular the SVR4 layout, very closely. This is due, as we have already noted, because of the POSIX style support.

You will notice that a number of the files seem excessively small. sys/fcntl.h is only 92 bytes. This is the file that normally contains information about the file modes and file locks, and other file-control information. In this case the contents of the file just include the file fcntl.h, which is taken from the /boot/develop/header/be/kernel/fcntl.h file.

Because of the two styles of programming on the BeOS many of the files in the be subdirectory are cross-linked via #include statements to the POSIX directory and vice versa. This can make finding a specific definition or a specific file complicated. The definition of the search path for include files under the BeOS is handled by the environment variable BEINCLUDES.

BeOS Priorities

When you use header files there are always some dependencies where certain header files rely on the contents of another header file. Most OSs, including the BeOS, include any dependent header files as part of the header file contents.

The priorities of header files are important, as they can affect the overall build process. Most errors that occur during the compilation will occur either because the wrong header file has been included, or because a required header file is missing or included at the wrong point.

The most common missing files are those that have to do with setting default variable types and structure definitions. These are:

- ansi_parms.h, which specifies the ANSI C parameter macros
- ctype.h, which is used to specify character types, and to define the macros which support type recognition, isalpha, islower and so on
- limits.h, which is used to define the upper and lower limits for the core variable types
- stddef.h, which defines, via a number of other include files, pointer types, and the NULL macro
- sys/types.h, which defines many of the standard datatypes used throughout the header files

Not all of these are required in all situations, but it often doesn't hurt to include these files as part of the configuration process to ensure that the information is being picked up correctly.

Using Header Files to Control the Configuration

When you configure a package you must supply the configuration information to the sources. The configuration process uses a number of different ways to pass this information on to the package source code. There are in fact two ways of supplying the information; both rely on the use of macro definitions and header files, but they are supplied to the C compiler in two very different ways.

The first method relies on the use of complex and often very long compiler commands specifying the various definitions and options required to build the package. This information is usually supplied and configured by the CFLAGS variable in a Makefile. For example, we might use the following C command to specify the default news host for a package:

```
$ mwcc -DNEWS=news.usenet.net reader.c -o reader
```

While this is not a bad method for configuring a package, it does make the process of tracking bugs and making changes to the configuration very difficult. You can appreciate that a complex configuration may be made up of a number of these definitions. A complex definition could take up multiple lines for the command which makes it difficult to follow and even more difficult to track problems. Some packages help by splitting up the CFLAGS variable into a number of separate lines, but the information is still difficult to track. You also run the risk of changing an option which causes the package not to be rebuilt properly, a problem we will cover in the next chapter.

An easier and now more widely accepted method for passing configuration information to the package sources is the configuration header file (config file for short). A config file uses the combination of the macro definitions, which I'll discuss in following section of this chapter, and the header files to configure and set up the base information required by the rest of the package. Essentially, it is doing nothing more than the CFLAGS variable in a Makefile. Because the configuration information is stored in a header file, it is often surrounded by extensive notes in the form of comments, making the options easier to understand and select.

Usually the config file is easy to spot. GNU packages use the file config.h, while others use header files matching the name of the package, like the httpd.h file used by the Apache WWW server. The example below comes from a ready-configured Emacs config.h file.

```
#ifndef EMACS_CONFIG_H
#define EMACS_CONFIG_H

#define POSIX_SIGNALS

#define EMACS_CONFIG_OPTIONS "BEOS_DR8_BASIC"

#define SIGTRAP 5

/* These are all defined in the top-level Makefile by configure.
   They're here only for reference.  */

/* Define LISP_FLOAT_TYPE if you want emacs to support floating-point
   numbers. */
#define LISP_FLOAT_TYPE

/* Define GNU_MALLOC if you want to use the *new* GNU memory
allocator. */
#define GNU_MALLOC

/* Define REL_ALLOC if you want to use the relocating allocator for
   buffer space. */
#define REL_ALLOC
```

Selecting the different options is as easy as commenting or uncommenting the various options in the header file. The entire configuration of the package can now be controlled from this single file. Updating the configuration is as easy as changing the config file, and then recompiling the source code.

Throughout the config file itself, and the source files which use the config file it is often necessary to make selections based on the different configuration options. This is handled by the #ifdef macro in the source code, which is itself parsed during the compilation process. Lets take a closer look at how this process works, and how it aids the configuration.

Using the #ifdef macro

In addition to the #include preprocessor directive which incorporates header files into source code, there is also the #define directive. You should already be aware of macro definitions; they are used to specify constant information in C programs. The substitution is made at the preprocessing stage of compilation. This means that the information is effectively hard-coded into the source before the actual process of compilation, in much the same way that header files are included into the source during compilation.

Definitions can also be used to describe the abilities or inabilities of a particular platform. Using the #ifdef preprocessor command you can test for different definitions and provide different code samples based on the existence or nonexistence of a specific definition.

The Principles of #ifdef

The #ifdef command is used to test whether a specified definition exists. It is not possible to test the contents of a definition; you can only test whether the definition exists or not. The information is processed at the time of preprocessing, the first stage of any compilation. The format of the command is

```
#ifdef definition
program source
#else
program source
#endif
```

If the specified definition exists, then the test returns true and the text immediately after the command is included in the preprocessor output. You can then optionally specify some text to be included if the test returns false, after the #else line. Finally, you must terminate an #ifdef statement with a corresponding #endif.

To demonstrate this, let's have a look at a simple example. The source file below prints a message on the screen. The message printed depends on the status of the MESSAGE definition:

```
main()
{
#ifdef MESSAGE
       printf("Hello!\n");
#else
       printf("Goodbye!\n");
#endif
}
```

If you run this program through the C preprocessor (using mwcc -e) you get the following output:

```
$ mwcc -e foo.c
main()
{
printf("Goodbye!\n");
}
```

This version of the program was produced because MESSAGE has not been defined anywhere. If MESSAGE had been defined you'd get

```
$ mwcc -e -DMESSAGE foo.c
main()
{
       printf("Hello!\n");
}
```

This very simple demonstration shows how most configuration systems work. The defines, either on the command line or in a header file, determine what functions and program sequences are required. The C compiler in the preprocessing stage then, using the #ifdef command, selects which source code to use. The resultant compiled file should be in the correct format, with the correct function names, programming sequences, and data for the configured system.

You can nest #ifdef tests, and it is normal practice to include a reference to the original test as a comment when continuing or closing the command, as can be seen in this example from Emacs:

```
#ifdef MSDOS
#include "msdos.h"
#include <time.h>
#else /* NOT MSDOS */
#ifndef VMS
#include <sys/ioctl.h>
#endif
#endif /* NOT MSDOS */
```

This example also shows the #ifndef command. This works in exactly the same way, but the test returns true when the definition does not exist.

When using Standard C, which is supported by the Metrowerks compiler, one final format definition is also accepted. This is a more C-like style which supports the same options as #ifdef, and also allows you to combine definitions using bitwise operators, as shown in this example from unzip:

```
#if (defined(ultrix) || defined(bsd4_2) || defined(sub)
#     if (!defined(BSD) && !defined(SYSV))
#            define BSD
#     endif
#endif
```

You can also see that you can use indentation to make the tests more readable.

The process of using definitions is, as you have seen, very simple. The complicated part is knowing which definitions to use and what effect they have on compilation.

Standard Defines

The use of definitions for controlling the build type used to be based on the combination of the OS and the hardware on which you were porting the package. For example, to compile a package under Solaris on a Sun workstation you would define both the operating system, sunos5, and the hardware architecture, sparc.

This presents us a number of problems:

- As we move into a more heterogeneous network environment, the specification of the hardware and OS alone is often not enough. It is a fairly broad assumption to say that a particular machine is running, for example, the i386 architecture. The i386 has been superseded by the i486 and, more recently, by the Pentium and Pentium MMX chips. In the case of the BeOS, it currently runs on PowerPC and Intel.
- Despite the title of this section, there really are no standard definitions. There are some regularly used definitions, but you can hardly call something that is regularly used a standard!
- The definition name doesn't always reflect the true features of the OS. This is particularly true in the case of System V, where the differences between R3 and R4 are fairly fundamental. Some OSs are still based on the older SVR3 core code combined with some SVR4 additional functions. What do you specify as the supported platform? Using SVR3 may prevent you from building the package, or may just cause old, slow code to be created to make an SVR3-compatible version. Alternatively, specifying SVR4 may cause the build to fail because you are missing functions that the package expects to find.
- Functions used in packages are often assumed to be part of the OS. It should already be apparent that in the UNIX community the term "standard tool" just doesn't apply. The same goes for functions. There is a great difference between kernel functionality and the functionality

provided by a C library. Solaris no longer comes with a standard C compiler or any libraries to support it. Porting a piece of software to Solaris therefore requires a C compiler, which will probably also require a set of C library functions which are supplied as part of the standard OS installation. Alternatively, you could use a public library such as the GNU libc. This provides many functions not found in the kernel that a simple solaris definition may not pick up.

This last item causes tremendous difficulty as programmers struggle with the different OSs missing functions that their packages rely on. In the case of Emacs, the sysdep.c file contains versions of hundreds of "standard" functions, each of which can be included in the object file using a specific definition.

Rather than making wildly inaccurate assumptions about which OS has which function, many programmers have moved toward a model where each function required is specified within its own definition. In this instance, specifying the OS does also define those functions that are known to exist. Others can be added in by defining each present function using a HAS_FUNCTION macro definition. For example, you could define the existence of the printf command by placing the code definition in to the configuration file:

```
#define HAS_PRINTF
```

Then, whenever you wanted to use the printf command you could use an #ifdef directive in the source code.

Most programmers, including GNU, are moving toward this model. Indeed, the GNU autoconf system uses this style of definition as a much more reliable way of configuring a package on multiple OSs.

Under the BeOS we don't have any of the advantages of the other OSs; we can't make assumptions about the previous versions because there haven't been any. We can, though, base our code on other UNIX flavors if we know what functions each flavor supports. We already know what functions the BeOS supports (see Part 3 of this book); all we need to do is match the two, or more, versions together to achieve what we want. We can also use the POSIX support as a starting point for selecting which functions are available.

With my earlier comments in mind, let's have a look at some of the regularly used definitions and their overall effect when porting to the BeOS. More precise information about the functions the BeOS supports is contained in Part 3.

- **SVR4.** Short for System V Release 4, the basis for a number of UNIX OSs including Solaris from Sun and UnixWare from Novell. You may also find it defined as SYSV and on older packages USG (for UNIX Systems

Group, the original AT&T and now Novell-based team of developers). SVR4 affects a number of functions, most notably the string handling. The header file is string.h and uses strchr/strrchr instead of the BSDindex/rindex supported by the strings.h. This is a good choice for BeOS porting as many parts of POSIX standard are based on the SVR4 standard. The BeOS also supports an SVR4-based dirent structure.

- **BSD.** Short for Berkeley Systems Division, this defines the other thread of UNIX development. The string functions are different (see above) and are supported by the strings.h header file. The BeOS currently supports a BSD-like time system, although SVR4 should work in most instances. The BeOS supports some BSD-style memory functions using the bsd_mem.h header file, which also includes versions of index/rindex.
- **UNIX.** Usually specified to describe the OS type rather than specifying the actual OS. Specifying SVR4 or BSD should cause UNIX to be automatically defined.
- **POSIX.** Not as frequently seen as the others, this is the ideal definition to use if it is supported by the package. The BeOS's POSIX support, although not complete, is close enough to the full specification for most packages to compile without difficulty.

Double Definitions

When using and selecting definitions you should be very careful about which ones you use and when you use them. Because definitions can be specified in a number of places—on the command, in a header file, or even in the source file—it is necessary to double-check that a definition is not being specified more than is needed. Usually the compiler will fail during a compilation if the same definition is used twice.

This code example produces just such an error:

```
#include <stdio.h>
#include <stdlib.h>

main()
{
#define HELLO "hello"
printf("%s\n",HELLO);
#define HELLO "bonjour"
printf("%s\n",HELLO);
}
```

The error message looks like this:

```
### mwcc Compiler Error:
#      #define HELLO "bonjour"
#                           ^
# macro 'HELLO' redefined
#-----------------------------------------------------------
File "/MCBe/t.c"; Line 8
#-----------------------------------------------------------
```

```
# errors caused tool to abort
```

We can get around this by undefining HELLO using the #undef directive. This particular problem only occurs when you are specifying a definition for a value. The code fragment

```
#define BEOS
#define BEOS
```

does not cause the compiler to fail. This doesn't mean that you should ignore double definitions of this type.

A double definition can have the undesired effect of compiling one piece of source code one way, and another piece of source code in a different, incompatible way. It is always advisable to check for double definitions, particularly if you are defining options in a package like Emacs, which relies on the config.h file to be correct. Normally a double definition error will be highlighted very quickly, and if you ensure that modifications only go into the specified configuration file then the Makefile should handle any dependencies.

The Effects of the Config File on Compilation

You have already seen how a definition and a corresponding definition test can be used to switch a particular section of source code on or off as it were in a source file. During compilation these tests and definitions are parsed by the preprocessor. This is the first stage of compilation and so no sanity, function lookup, or language syntax checks have been carried out. Because of this the process can lead you to one of two conclusions. The first is that the configuration is a success, and so therefore this method provides you with a way to configure and construct a multi-platform application with relative ease. The second conclusion is that a bad configuration file can produce the wrong code, or such badly formatted code that the compiler is unable to compile the source at all. This latter "feature" can often provide you with more problems than any other single element of the porting process.

The configuration process therefore relies on a very flexible, but ultimately unstable method for controlling the code that is produced. Getting the configuration right ultimately affects the way the file is compiled, and this in turn affects whether the package is built correctly and without any bugs.

However, you can use the same principles your advantage without any of the risks. By commenting out code using #ifdef we can avoid enclosing large sections of source code in a C comment, which is generally considered to be bad practice.

The process of including header files often uses this technique to stop the header file being included more than once. If you take a look at any standard header file you should see something like this:

```
#ifndef __stdio__
#define __stdio__
```

During the course of a port it is good practice to use a specific definition to comment out code. I use a definition of BEOS to comment out or select code that I need to use in a source file. This is precisely how other platforms select their different source snippets. The BeOS has a special built in definition, __BEOS__, which we can use to comment out code for the BeOS without affecting other platforms.

Chapter 9. - Makefiles

As programs become more and more complex the complexity of the process which builds the application increases. In large packages, keeping tabs on which files need to be compiled, and more importantly, which files rely on the existence or contents of other files in order to compile correctly. The make program provides a method for maintaining the status of a package by using a file called a Makefile.

The Makefile has been a standard way of building applications for many years. The make system was designed to ease the execution of the build process. By using a set of rules defined in the Makefile make can produce and compile any file by following the defined ruleset. It automatically checks the status of the component files and rebuilds those required to produce the desired target file. This saves you from manually compiling and building a project; the rules have been set up, and all you need to do is type make.

Principles of a Makefile

The Makefile is simply a text file which contains a number of definitions and rules about how to build a particular package. Some packages rely on the use of a configuration script which identifies the necessary options and then builds the Makefile, which is then used to build the application. Most GNU packages follow this model using the autoconf package. The Makefile is simply the file used by make to intelligently run the C compiler, linker and other tools to build the package.

For other packages the Makefile, through a series of defines and other options which are then passed to the C compiler, helps to define and configure the package. In this instance, the Makefile is much more than just a set of rules which build the package, it also defines how the package is configured.

Whether you edit a Makefile or not is entirely up to you. If you feel comfortable modifying the contents, it may be the easiest way to achieve your goal.. However, as I have already explained, some Makefiles are produced automatically by a configuration program and you may choose to follow the advice given at the top of the file:

```
# Makefile automagically generated by Configure - do not edit!
```

Generated Makefiles are typically difficult to read and follow. Even if you can understand the Makefile and then make suitable modifications to it, it is sometimes comforting to know that if you make a mistake they can be rebuilt by running the configuration script again.

If you decide to use the skeleton Makefile that is used during the configuration process it is often not too difficult to follow the format. The GNU autoconf package uses the m4 processing system to generate the real Makefile from Makefile.in, a file which is not dissimilar to the final version. The m4 program is really only doing variable substitution from the skeleton file to the final version using the information obtained during the configuration process.

Whether the Makefile is supplied or is produced during the configuration process, it is useful to know the format and layout of a Makefile and how this relates to the build process and the execution sequence. Additionally, just in case something goes wrong, we will take a look at some common problems encountered when using Makefiles.

Anatomy of a Makefile

A Makefile has two parts. The first part defines the various sources and variables to use throughout the rest of the Makefile. The second part describes the targets, their dependencies (the elements required to produce the target) and the rules and processes required to produce them.

You should be careful when editing a Makefile, as the format of the lines is important. Different make programs from different UNIX flavors have a number of little traps. Under the BeOS the make program is from the GNU project, which is generally more tolerant, but should still be handled carefully.

At the basic level, a Makefile follows the standard format of all UNIX files. Comments can be included by preceding them with the "#" sign and lines can be extended by appending the "\" character to the end of the line. We will see in the final section of this chapter how strict the make program is about the format of the file.

Variables

Variables are used in a Makefile in much the same way as in a program. They help to define information that is used in the rest of the Makefile. In general, the variables are used to list the source files, object files, libraries and even the commands used to build the package. In fact, you can define any piece of information in a variable.

A variable definition in a Makefile is of the form:

```
NAME = definition
```

The definition starts from the first non-whitespace character after the equal sign and continues until the end of the line. You may continue the line by using the backslash (\) as the last character. Defines must be specified at the top the file, before you start using them in the target specifications. The following are valid macro definitions:

```
CFLAGS = -g
SRCS   =      calc.tab.c lex.yy.c fmath.c const.cLIBS =
```

You should have noticed that in the above example, we also specified a list of file against one of the variables, SRCS. This is a useful feature of the variable system within the Makefile, and it allows us to specify the files to use during the build. Depending on the situation, these files will be used individually, in sequence, or as a complete list of files supplied to a particular command. We'll see how this is used in the next section of this chapter.

A definition without a suitable value is treated as null, or empty. There are also some standard definitions that will be overridden if they are specified in the Makefile, some of which are listed below:

```
AR=ar
ARFLAGS=-rv
CC=cc
CFLAGS=-O
LEX=lex
LD=ld
LDFLAGS=
MAKE-make
YACC=yacc
```

Finally, you can also specify definitions on the command line, so the command

```
$ make CC=mwcc
```

will supersede any definition in the Makefile.

To use a definition, you use the format $(NAME). A definition can be used anywhere within the Makefile, including in command lines, target definitions, and dependency lists. Defines are used in the same way as variables, collecting groups of files and commonly used strings together into one file.

In an extension of the earlier example, you can see below how the definitions are used to help specify the a variety of information to the remainder of the Makefile:

```
PROGRAM       =      calc
OBJS          =      calc.tab.o lex.yy.o fmath.o const.o
SRCS          =      calc.tab.c lex.yy.c fmath.c const.c
CC            =      mwcc
CFLAGS        =      -O -c
LDFLAGS       =      -O -s
LIBS          =      -lm -lfl
all:          $(PROGRAM)
.c.o:         $(SRCS)
              $(CC) $(CFLAGS) $*.c -o $@
calc.tab.c:   calc.y
              bison -dv calc.y
lex.yy.c:     lex.l
              flex lex.l
calc:         $(OBJS)
              $(CC) $(OBJS) $(LDFLAGS) $(LIBS) -o calc
```

For example, the $(PROGRAM) variable, which we have set as calc becomes the dependent item for the target all. Meanwhile, the SRCS variable is used to list the sources that need to be compiled. This list is duplicated, albeit with the .c changed to .o in OBJS to reflect the list of objects required to build the final application, calc. We will look at targets and dependencies in the next section.

Using Variables for Configurations

When using the Makefile as the configuration system, you will commonly find the different operating systems listed. You must then comment them out, or create new definition lines based on the build requirements. The example below shows an extract from the Apache Web server source.

```
# AUX_CFLAGS are system-specific control flags.
# NOTE: IF YOU DO NOT CHOOSE ONE OF THESE, EDIT httpd.h AND CHOOSE
# SETTINGS FOR THE SYSTEM FLAGS. IF YOU DON'T, BAD THINGS WILL HAPPEN.

# For SunOS 4
#AUX_CFLAGS= -DSUNOS4
# For Solaris 2.
#AUX_CFLAGS= -DSOLARIS2
#AUX_LIBS= -lsocket -lnsl
# For SGI IRIX. Use the AUX_LIBS line if you're using NIS and want
# user-supported directories
#AUX_CFLAGS= -DIRIX
#AUX_LIBS= -lsun
# For HP-UX       n.b. if you use the paid-for HP CC compiler, use
flag -Ae
#AUX_CFLAGS= -DHPUX
# For AIX
#AUX_CFLAGS= -DAIX -U__STR__
# For Ultrix
#AUX_CFLAGS= -DULTRIX
# For DEC OSF/1
#AUX_CFLAGS= -DOSF1
```

Because the specification of the code to compile is defined by the variables in the Makefile you could easily set up the Makefile to produce Solaris code. Merely by uncommenting the AUX_CFLAGS and AUX_LIBS definitions under the Solaris 2 comment.

Directories

You can specify directories within target definitions, but it is better to specify these directories relatively than to use absolute references. For example, the following target specification automatically builds the application using the source from the subdirectory:

```
calc:  src/calc.o
       mwcc -o calc src/calc.o
```

It is rare to come across a target specification which specifies a subdirectory; the use of subdirectories within a source tree usually involves using sub-

Makefiles. This is a more complex process, as it involves an individual Makefile for each sub directory within the main package directory tree.

However, it is quite normal to find header files in subdirectories. However a complication can arise that is related to the dependencies of the files being compiled requiring the header files contained in the sub-directories.. Dependencies can also be specified using absolute file references rather than the relative references. This causes additional problems during the build process if the files in the dependency list cannot be found. As mentioned elsewhere in this chapter, dependencies can cause more problems than they hope to solve.

Targets

Although the variables can be used to define some useful information, they are not a necessary part of the Makefile. The important part is the target definitions.

The basic operation of make is to update a target file by ensuring that all files on which the target file depends exist and are up to date. The target file is recreated if the files on which it depends have a more recent modification time than the target file. The make program relies on three pieces of information in order to update a a target:

- The Makefile which contains user-defined rules
- Date and Time stamps of the files
- Built-in rules on how to update certain types of files

The target definitions in the Makefile specify the target name, the files which are required to produce the target (the dependents) and the commands required to produce the target. Further target specifications define how the dependent files are created, and so on. The make program then works recursively through the list of targets and dependents to produce the specified target.

As an example, consider the application foobar which is made up of the object files foo.o and bar.o. The foobar application is dependent on these two files for it's creation, and we might use a command like:

```
$ mwcc -o foobar foo.o bar.o
```

to produce the target application, foobar.

In addition, to generate the two files object files we need to specify targets that describe how to produce them from the C source code.

Format

The format of a target, called a rule, is as follows:

```
target: dependencies
        commands
```

Warning: The character before the second line MUST be a TAB!

Using our example, the rule to build the target foobar is composed of the dependency list of object files (specified by the variable $(OBJS)) and the compiler command line used to build it

```
OBJS = foo.o bar.o
foobar:      $(OBJS)
       mwcc -o foobar $(OBJS)
```

As we have already seen, rules are executed recursively until all the dependencies are resolved. Using our previous example again, the rule which builds the object files from the source files could be:

```
foo.o: foo.c
       mwcc -c foo.c
bar.o: bar.c
       mwcc -c bar.c
```

In fact, there is an easier way of specifying the rule for compiling C source into object files. We can use a special rule which is identified by the make program:

```
.c.o:  foo.c bar.c
       mwcc -c $<
```

The $< is a special type of variable which refers to the target dependencies, which in this case are the source files. In this example, make would expand this variable and run two commands as follows:

```
mwcc -c foo.c
mwcc -c bar.c
```

producing the two object files we require to build foobar.

We will take a look at the entire execution process of make later in this chapters.
Dependencies

The dependency list in a target specification lists the files which are required in order to build the specified target. The target is dependent on this list of files, and make uses this list to make decisions about how to build the target..

When you ask make to build a target, the dependency list is used to check the following:

- If a dependency file does not exist on the file system, the list of available targets is checked to see if a rule exists which will build the file. This happens recursively until all the dependent files are produced, or make is unable to find a rule to build a particular file. In the first instance, the specified target is built using the specified commands. In the second instance, make will fail.
- If the date/time stamp of a dependent file (or a component of the dependent file) is later than that of the target, the target is rebuilt using

the same recursion rules. This recursion happens forward, as well as backward; so if a source file is modified, the object file will be rebuilt, and therefore the program will also be rebuilt.

For example, in the Makefile below, which builds a calculator program written using flex and bison, a change to the file lex.l will cause the lex.yy.c file to be rebuilt (using flex). The new source file produce by flex will be compiled, and the object file will be used to generate a version of calc.

```
PROGRAM       =      calc
OBJS          =      calc.tab.o lex.yy.o fmath.o const.o
SRCS          =      calc.tab.c lex.yy.c fmath.c const.c
all:          $(PROGRAM)
.c.o:         $(SRCS)
              mwcc -c $*.c
calc.tab.c:   calc.y
              bison -dv calc.y
lex.yy.c:     lex.l
              flex lex.l
calc:         $(OBJS)
              mwcc $(OBJS) -o calc -lfl
```

The use of dependencies is essential to the way make works. It helps to define the rules which are used to decide which files to rebuild and which files to ignore. However, they can also help to cause a number of problems. The wrong dependencies will cause the wrong files to be rebuilt, or in some extreme cases the entire file to be rebuilt.

Making the Makefile a dependent

In ideal situations changes to the Makefile should cause the package to be rebuilt. After all, the Makefile is as much a part of the source as any other file, and changes to it could cause files to be rebuilt differently.

For example, imagine changing the compiler used to generate the source code. Making such a change would mean that the entire package would need to be rebuilt, otherwise the code produced might not be optimized or produced correctly.

However, imagine simply adding a source file to a dependency list. In this case, we don't need the entire package rebuilt, we just need the source file compiled and then incorporated into the rest of the application.

In both of these examples, we have made changes to the Makefile but only in the former do we really need the package to be rebuilt.If you do make a significant change to the Makefile it is best to do a make clean and rebuild the package again. This is especially true if the Makefile is the method used to configure the package.

Running Commands

Once the dependencies for the target have been resolved, the make command goes on to produce the target using the specified commands. In our basic example, the commands include those that build the sources from the lex and yacc tools, as well as the compiler commands that compile the source files.

A command can be anything you can type in on the command line within the shell. You can use as many lines as you like for the commands; the Makefile continues to execute commands until the next target specification. As well as running specific commands, you also have the option to incorporate a number of variables, including those you specify in the Makefile. For example, you might specify the options you give to the compiler using a variable within the Makefile:

```
CFLAGS = -c -I. -I..
all: $(OBJS)
        mwcc $(CFLAGS) $(OBJS) -o calc
```

Notice that the variable is used by specifying the variable name within parentheses, precede by the dollar sign.

By default, each line is echoed to the screen after expansion of any variables his is useful as it provides us with a running commentary of the commands make is running. You can switch off command line echo on an individual line basis by preceding the command line with the "@" character. For example, using the following Makefile section:

```
.c.o:   calc.c tmath.c
        mwcc -c $< -o $@ -O

calc:   calc.o tmath.o
        mwcc -o $@ calc.o tmath.o
        @echo Build is complete
```

the output from a make command would be:

```
$ make calc
mwcc -c calc.c -o calc.o -O
mwcc -c tmath.c -o tmath.o -O
mwcc -o calc calc.o
Build is complete
```

In addition to the variables which you define in a Makefile, there are some special variable names which have special meaning. The $@ in the example target definition refers to the target name. This is expanded each time the command is run, so in the definition for compiling the two source files the expansion worked for both, correctly specifying the object equivalent. The $< variable expands to the target file on which the command is currently being executed. In our example this equated to calc.c and then tmath.c.

There are occasions when you want a specific targets to execute commands without any dependencies. To do this, you can just leave the section blank:

```
clean:
        rm -f *.o $(PROGRAM)
```

or you can insert a semicolon into the target definition, as in the example below:

```
clean:; rm -f *.o $(PROGRAM)
```

Common Targets

There are some standard, well-recognized targets which you should find in most Makefiles. They don't appear in all Makefiles however, and it is important to remember that the programmer has complete control over the targets and their specification in the Makefile. The typical targets are depend, all, and install.

depend

The depend target creates a list of dependencies for the packages source tree. Most of the time this is produced by running the makedepend command on the source and header files. You can find a script supplied with some GNU packages, but these are usually tailored to the package in question.

Note: The makedepend command does not exist under the BeOS, but the C compiler is capable of emulating this functionality. We'll take a closer look at this in Chapter 13.

Ideally, depend should be the first target made, as it helps in the production of the rest of the package by ensuring that all the necessary files exist and that any modifications to dependent files update the corresponding object file.

Unfortunately, as useful as the depend target is, it doesn't always work as well as you might like. Sometimes the process itself fails even though the package may build correctly. Often this is caused by nonstandard directories (and therefore unfound files), or by the incorrect configuration of the package. In all cases, you should be cautious using the depend target and only use it if the package specifies it as part of the build process. While it can often highlight problems before you get to the build stage, it can also cause errors that become difficult to track.

all

The all target is the usual way to perform a build. Different packages may set this up as the first target, and therefore the default target during the build process. In these cases you simply need to type make. Most packages also use this target only for building the package; installation is handled by the next target, install.

install

Installation is typically handled by the Makefile to aid in the single point of reference for package builds. Installation is carried out based on the directories specified in the Makefile during the configuration process. It may, optionally, also try to install the documentation, but some packages include a separate install-doc target for this process. Others may expand on this idea and also specify install-all to do a complete installation, and install-bin to install the binaries only. Check the documentation and/or the Makefile before using this target.

clean

The clean target is used to clean the source tree of all the files produced during the build process. This should include everything from executables and object files to header and source files produced during the process. Unfortunately, like many other parts of supplied packages, there is no standard for the contents of the make clean process. Therefore you should treat it with care; some clean targets remove more items than they should; others don't remove enough.

Ideally, make clean should remove everything that can be recreated by running make all without removing configuration files. Check the rm commands used in the target to double-check what happens. Some packages include multiple clean targets, from mostly-clean to extra-clean. Avoid using these in preference to the standard clean target unless you are sure that you want the listed files removed.

Execution Sequence

The execution sequence of make, parts of which we have touched on already, is fairly simple:

1. Find the rule to build the target specified, or use the default (first) rule if no target is specified.
2. Check the dependencies, recursively; any files that have changed should be built using the appropriate target rule.
3. For each target, when all the dependencies have been resolved, use the commands to build the file until all the rules have been resolved.
4. Repeat as necessary!

This looks, and is, fairly simple. However, as with all good sequences, there are some special cases and some tricks that can make the process run more smoothly.

Because of the way the rule system within make works, there is no execution order as such; the program simply resolves the required dependencies before building the current target. However, it is useful to be aware of the practical order in which files should be built during the process.

lex and yacc

The lex program is used for the lexical analysis of text. yacc is a rule-based system which is often used to analyze or process the output from lex. yacc actually stands for "yet another compiler compiler," as it is often used for processing program source into assembly language. We'll cover the GNU equivalents, flex and bison, in greater detail in Chapter 12.

Note: A lexical analyser processes text by words or recognised patterns, rather than by individual characters.

The important detail about both programs when used within a Makefile is that they take the input of a specified file and produce a C source file and optionally a header file.If the two programs are used together (and they usually are) yacc should be run first; if it needs to generate a header file, it will be needed by the source file generated by lex.

Headers

Any header files must be generated or built before they are required by the C source. This can be handled under make by a dependency and a suitable rule.

With most packages the header files should already exist, except where a configuration program creates them based on your specific system. A dependency that relies on a preexisting header file may cause problems.

It is best to run a make depend if the depend target is supplied after any reconfiguration. You should also run the dependency check after you have made any modifications to the source files or the Makefile which may have affected the header files you need.

With pre-supplied Makefiles you can sometimes run into problems with the file specifications of "standard" header files. For example, under the BeOS, the directory /usr/include does not exist, and the dependency will fail, causing the entire build to fail. In these situations, just delete the dependency section of the Makefile.

Source Code

Sources can appear in a number of forms, not all of which may be obvious during the build process. The bulk of the source code will have come with the package, and in some cases it will be generated by other programs. We have already covered the production of source files using the lex and yacc tools.

Other tools which create source code directly include any rapid development tools, scripting languages, and utility functions such as the rpcgen program. While rpcgen currently doesn't exist under the BeOS, it is a good example of a code-generating tool similar to yacc.

Some packages create source code dynamically based on the configuration options. Perl 5 is a good example. As part of the build process a shell script called writemain.SH creates the source code based on the current configuration. In fact, in the case of Perl things are a little more complicated. After you run the Configure script, typing make first builds the miniperl program, a smaller and less feature-rich version of Perl. The miniperl program is then used to help configure and create the final version of the source.

The way Perl is built is unusual, but by no means unique. The GCC compiler uses a similar system to help create the core functions used by the preprocessor, and later, the compiler itself. I don't recommend that anybody attempt to build the GCC tool by hand: the Makefile and associated scripts go through some very complicated steps to reach the eventual goal. Even with all its automation, GCC still requires some user intervention, but luckily this is reduced to just typing in a few commands.

Some other programs use a preprocessor or formatter to modify the code before compilation. John Bradley's xv program is a good example; code is parsed by a formatter which converts his ANSI-style C code into Kernighan- and Ritchie-formatted C for use on older (non-ANSI) compilers. This gets round the problem of allowing ANSI compilers to use the stricter code whilst retaining compatibility with the older compilers on some systems.

How a package and its source files are produced is entirely dependent on the programmer and the complexity of the program. I can assure you that for most tools, the sources are already supplied.

Libraries

Once the sources have been compiled into object files, the next step is to generate any libraries. The reason for using libraries can vary from package to package. On the whole, libraries are used to make the build process easier, rather than having any specific role in the build process. In other cases, the library which is produced is the package. For example, the GNU dbm library package produces libraries as the default option.

In the case of Emacs and sed, the readline and regex libraries respectively have now become packages in their own right.

Because of the command-line length limit, some packages use libraries as a way to reduce the overall size of a command line. A command line itself consists of the command, arguments, any file expansions, and also the environment variables. The environment variables alone can make up more than half of the overall command-line length. Creating a library and including the library instead makes for a much shorter command line which therefore is less prone to errors.

The method for creating libraries under the BeOS is very different from that used under most UNIX flavors. Under most versions of UNIX the ar command produces a library archive. For example:

```
$ ar cs libmine.a *.o
```

Instead, under the BeOS you use the mwcc command with the library command-line option, like this:

```
$ mwcc -xml -o libmine.a *.o
```

There are several different types of library that can be created with mwcc, including the default library type, which is an application. We'll cover the different library types and how best to make the libraries in Chapter 12.

Executables

Once make has finished building all the required elements to compile an object and resolved all of the dependencies required to build the default target(including any libraries), make goes on to create the executable. This step is probably the shortest of the entire process as it requires nothing more than collecting all the required elements together into the final target.

Once the make process has completed, you can usually consider the basic build process to have been finished. make has achieved its aim of building the default target by resolving each dependency and producing the final item.

For most packages the final command during the build is the last compiler/linker line, which builds the final application. Other packages may decide to do some post-processing. For example, during the build of Emacs the application generated is called temacs. temacs is then executed and loads up all of the Emacs lisp functions, including any site configuration files. Once the entire contents have been loaded it dumps itself (creates an executable of the current memory image) to a new executable file. This final file is called Emacs.

Documentation

Documentation, as we have already seen, makes for one of the most complicated parts of the build process. The process of producing documentation is dependent on the package and the author, but the process is usually easily identified in the Makefile and therefore easy to reproduce should you decide to do it manually.

Caution: Some packages add a dependency to the install target that the documentation be created, generated or otherwise processed. This may hinder the installation process because the make command will be trying to run software required to make the documentation that doesn't exist on the BeOS.

If you can't generate the documentation (and this may well be the case on the BeOS) then you can get around it by generating the dependency files using the touch command. We'll look at this workaround in more detail in Chapter 15. Since make only checks the existence and date/time stamp of the dependent files, this should be enough to bypass the process and move on to the installation.

We looked at documentation and how best to read it in Chapter 5.

Installation

The final stage is normally the installation. This usually relies on creating a number of directories and copying the required files over, including the documentation. The dependencies usually consist of the final executables, any libraries or header files required for installation, and sometimes the documentation.

To perform a manual installation for most packages, you just need to know where to copy the files and what file permissions to give them. During an automatic installation this is often executed by an install script or program. This program copies the file, including setting the permissions and owners, and can also perform some basic processing options, such as stripping executables.

Stripping a file of its debug and symbol table information does not affect the execution of a file. The resultant file is usually smaller, and therefore takes up less disk space, but there is no change to the load time or optimization. Once stripped, though, a file cannot be symbolically debugged (because you've stripped the symbolic debugging information). Not all files should be stripped; for instance, debuggers, compilers, and other programs which directly access or use their symbol tables should not be stripped. In the case of the BeOS, the debugging symbols are stored in separate files, so installation without such information is a simply a case of not copying the symbol files (those ending in .xMAP and .xSYM). But the installation script will require modification.

As I said at the start of this section, there is no simple order in which make attempts to build an application. It is entirely up to the Makefile contents, the dependencies, and the commands used to build different files which control the execution of the make command. With this rough guide, though, you should have a better idea of the requirements and stages in a typical build, if there can be said to be such a thing.

Coping with Errors

While make should usually run smoothly, there will be times when you will have some difficulties with running the program. You may encounter a variety of problems including:

- A missing Makefile
- The Makefile exists, but make doesn't do anything
- A badly formatted Makefile that make can't understand
- Missing sources required for the build
- make rebuilds everything

Even with a correctly formatted Makefile, you may find that make still complains, producing obscure error messages. We'll take a look at some examples and how to cope with all these errors in the next section.

Missing Makefile

make is a temperamental application at the best of times. The most frustrating thing about make is that it is overly literal. If you try building all you may get an error of the form:

```
$ make all
make: *** No rule to make target 'all'. Stop.
```

If you try running the command without specifying a target,

```
$ make
make: *** No targets specified and no makefile found. Stop.
```

you'll find that you get a much more sensible message. make can't find a Makefile to work with. By default, make looks for a file called makefile (lowercase) first, followed by the uppercase equivalent Makefile.

If you look at the directory contents and can't find a suitable Makefile, try looking for system-specific Makefiles, and then check the documentation (README or INSTALL) to find out how to build the package. For example, a SVR4 Makefile may be called Makefile.sysv, and it can be compiled by specifying it on the command line to make with the addition of the -f option:

```
$ make -f Makefile.sysv
```

Chances are the Makefile doesn't exist for of one of the following reasons:

- The package uses system-specific files such as Makefile.sysv or Makefile.bsd. Check the directory contents again.

- You need to run a configure program. When porting a GNU package, the Makefile.in file is the skeleton file used to generate the real thing. Return to Chapter 7 for details on identifying the build type.
- The directory you're in doesn't require a Makefile. In some larger packages the root of the source tree contains a Makefile which builds the files in the subdirectory by specifying them absolutely.
- There is no Makefile. Different authors have different feelings about Makefiles and the build process may be done by a shell script. Look for a script named build or configure, or read the supplied documentation.

Some programmers prefer to build the package by hand. For simple programs this isn't a problem; you can probably continue to build the package manually. For larger programs, or to help make your life easier, you may decide that a Makefile is a good idea and write your own. Here is a simple Makefile:

```
PROGRAM      =
SRCS         =
OBJS         =
all:         $(PROGRAM)
.c.o:        $(SRCS)
             mwcc -c $*.c

$(PROGRAM):  $(OBJS)
             mwcc $(OBJS) -o $(PROGRAM)

clean:;      rm -f $(OBJS) core *~ \#* $(PROGRAM)
```

You should be able to fill in the gaps with you own information.

Nothing Happens

One of the most heartrending moments during a port is when you type:

```
$ make all
```

and nothing happens. This can be frustrating at the beginning of the porting process and even more annoying during the porting process. There are two likely causes for this: either it is a problem with the dependencies for the specified target, or there are no commands to be run for the specified target. It is not uncommon to find that the default target is specified like this:

```
all:;
```

which of course does nothing. make is not aware of any problem; you have asked to build a target based on a specified rule, but the specified rule does nothing. As far as make is concerned its job is done.

If you are at the beginning of the porting process, check the Makefile to ensure that it includes the necessary rules required to build the target. Some packages deliberately require you to specify the target you want to build. This is often used where Makefiles include the information and define requires to build the package.

Often, though, you will get a message telling you how to build the package, as in the example below taken from the unzip package:

```
$ make
  If you're not sure about the characteristics of your system, try
typing
  "make generic".  If the compiler barfs and says something unpleasant
  about "timezone redefined," try typing "make clean" followed by
"make
  generic2".
  If, on the other hand, it complains about an undefined symbol
_ftime, try
  typing "make clean" followed by "make generic3".  One of these
actions
  should produce a working copy of unzip on most Unix systems.  If you
know
  a bit more about the machine on which you work, you might try "make
list"
  for a list of the specific systems supported herein.  (Many of them
do
  exactly the same thing, so don't agonize too much over which to pick
if
  two or more sound equally likely.)  Also check out the INSTALL file
for
  notes on compiling various targets.  As a last resort, feel free to
read
  the numerous comments within the Makefile itself.  Note that to
compile
  the decryption version of UnZip, you must obtain the full versions
of
  crypt.c and crypt.h (see the "Where" file for ftp and mail-server
sites).
  Have a mostly pretty good day.
```

During the port, after you have configured and perhaps semi-compiled the package, you need to check the dependencies for the files you have changed. It is probably easier to do a make clean and then a make to rebuild the package than to try to modify the Makefile. This should rebuild the package without requiring any further intervention.

Badly Formed Lines

make is not always able to understand the Makefile. Although the GNU make is more tolerant than some UNIX versions, you still need to be careful about the formatting of the lines. Spaces, tabs, and other characters can all contribute to problems and they are often difficult to track down.

One common error looks like this:

```
$ make
Makefile:24: *** missing separator. Stop
```

This cryptic message is reporting a problem with a specific line, placing the problem with a missing character that it expected to see on the line. Checking the line, there doesn't appear to be anything wrong:

```
tmath: tmath.o fmath.o
       mwcc tmath.o fmath.o -o tmath
```

What the message is actually trying tell you is that the command line has leading spaces, when it should have a leading tab character.

When dealing with definitions, the format of the definition needs to be adhered to exactly. GNU make is quite tolerant of leading and trailing spaces (except in the previous example), but it is good practice not to include spaces after definitions.

When spreading information over multiple lines you must remember to include the backslash character and ensure that it is the last character on a particular line. Conversely, also ensure that you do not use a continuation character when it is not required. make will always interpret the next line as a continuation line.

This can be particularly prevalent when you are commenting out lines. For example, in the following extract from a Makefile, I need to comment out the second line:

```
OBJS   =      calc.o tmath.o fmath.o decmath.o \
#             sunmath.o sunfix.o lexpatch.o \
              hexmath.o octmath.o
```

Unfortunately, during the build process this has the effect of commenting out the third line as well. The backslash character on the comment line (2) forces the next line to be interpreted as a continuation of the comment, and so the next line is completely ignored.

Missing Sources

The number of files accessed and controlled by the make process during its execution is very large. Dependencies, definitions, and even commands use files throughout the build process. Sometimes the files genuinely don't exist, in other cases, the opposite is true and make is referencing files which do exist, but you cannot find.In these latter situations you need to do a search for the file in question, or modify the command lines to show what the commands are doing.

In the former case, there are a number of possibilities:

- **Incorrect dependencies.** It is not uncommon to get an error like this:

```
$ make all
make: *** No rule to make target '/usr/include/stdio.h'. Stop.
```

  which is caused by a bad dependency reference. make cannot find the file or a rule describing how to make it. Ensure that the dependencies are correct for a given file; particularly check those generated by a make depend, especially if they were supplied with the Makefile. Run make depend again to recreate them, or simply remove them altogether.

- **The specified program doesn't exist.** The definitions at the top of a Makefile are often used to describe the tools required to build the program, for example:

```
MAKE = /usr/local/bin/make
CC = /usr/local/bin/cc
LD = /usr/local/bin/ld
```

  If you haven't already checked the tools listed exist, double-check the tool names. Use the information provided in the previous chapter to help you identify the tools and their possible replacement. You will also find that some tools are specified absolutely. Particularly in the case of make, it is normal to specify which version to use, either the standard UNIX version or the GNU version.

- **Package has not been configured.** Make sure you have run the configuration program. If the missing file is a header file, create an empty file (using touch) and try the build again. If it fails because of a compilation error, use the information provided in Chapter 15 to track down the problem.

It Rebuilds Everything

Check that you are using the correct Makefile. You may sometimes build a package which goes through and compiles the various files until the package is built. You then run a make install and the whole package is rebuilt again before finally being installed.

Often, as most make problems, the fault lies with a dependency. You need to check that a stamp file, used to mark the progress of a build, is not being checked for and then updated. This would cause a circular rebuild, whereby every time the package is built, the file which causes the rebuild automatically has a time later than the target.

For example, the Makefile fragment below checks for the existence of a file called stamp-done, but also updates the file in the process:

```
calc:  stamp-done calc.c
       mwcc -o calc calc.c
       touch stamp-done

stamp-done:;
```

In other cases, it may simply be that you have updated a file which is used by all the other source files. A good example is a configuration header file, such as config.h.

Some Makefiles are merely the vehicles for a complex build process. None of the selective intelligence of the Makefile is made use of, and so running make just reruns the build script, which is likely to rebuild everything.

Finally, the package may have a number of different Makefiles. Remember that the lowercase makefile is used by default, even though the capitalized Makefile is the normal one supplied with most packages. Check the documentation to figure out the correct Makefile. You can specify a different file to use on the command line using the -f option:

```
$ make -f MAKEFILE
```

Chapter 10: Configuration Scripts

One of the problems encountered by people developing software on the various UNIX platforms was that the different flavors used different names for various elements of the OS, including functions and header files.

We have already seen how the use of macro definitions in C can help to filter out sections of source code and provide alternatives when porting under different OSs. The problem, as I explained in Chapter 8. is that knowing what defines to choose and what files are required is the real task at hand when porting software.

To make the process easier, people have developed a number of ways in which the configuration information and the configuration files can be generated. The most common is the *configuration script*, a shell script which either checks the system automatically to produce the files or asks the operator for some basic information.

Most GNU packages use the autoconf configuration system, which uses the former method. Perl, which is also a GNU package, uses the latter method. Unfortunately, the BeOS is not as UNIX-compatible as it needs to be to run the configuration scripts properly. In this chapter I will demonstrate some ways of getting around this problem.

Running under the BeOS

The BeOS sometimes has trouble running shell scripts because of missing elements and bugs in the shell program itself, and also because of missing support software. The directory layout and structure are also different, which can cause problems when the scripts are looking for specific header files and libraries. Some scripts get around this by trying to compile a file containing an include statement, with success or failure determining whether the file exists or not.

In this section, we will take a look at three different configuration scripts, the fully automatic configuration, the walk through configuration, and a combination of the two which uses supplied files and the responses to configuration questions to configure the package.. All come from the GNU project, but each has its own way of tackling the problem of configuration, and its own list of problems which occur during execution.

Let's look first at the GNU configure program supplied with Emacs. This same configuration script is used by many of the GNU tools that have specific needs, most notably Emacs, gcc, and binutils, all of which need specific information about which platform they are being compiled on. The script follows this basic strategy:

5.1. Identify the OS. If the OS is recognized, use a pre-created machine and OS header file to set defaults. If the OS isn't recognized, quit.
6.2. Identify the C compiler, linker, and any additional programs required for the build (ranlib, install, bison and so on). Test the compiler switch compatibility.
7.3. Find the headers and libraries, and identify the functions recognized by this specific installation of the OS.
8.4. Identify the location for the installed files.
9.5. Write a configuration file, config.h, containing the necessary defines, and produce a corresponding Makefile which can be used to build the package.

This process covers everything required to build the package based on the pre-configured header files supplied and the additional information required for this specific installation. It should be relatively painless to run under the BeOS:

```
$ configure
creating cache ./config.cache
checking host system type... ./dummy: ./dummy: No such file or
directory
rm: dummy: No such file or directory
Configuration name missing.
Usage: /MCCe/Projects/InProgress/emacs-19.34/config.sub CPU-MFR-OPSYS
or     /MCCe/Projects/InProgress/emacs-19.34/config.sub ALIAS
where ALIAS is a recognized configuration type.
Configure: error: Emacs hasn't been ported to `' systems.
Check `etc/MACHINES' for recognized configuration names.
```

The second-to-last line is the important one. It tells us that configure is not aware what this system is, and so cannot continue. The information is actually gleaned by running another script that uses the UNIX uname command to identify the system. With this release of emacs, the configuration files stored in src/s and src/m do not exist for the BeOS, which is why the configuration script can't identify the machine, and therefore continue the process. Before we look at how we can get around this particular problem, let's have a look at a different problem, this time with the configuration script for perl.

The configure process is slightly different from Emacs, although the basic principles are the same. For perl the configuration is interactive after an initial set of checks for some required programs. The sequence of execution is:

10.1. Check the operating environment, including support for the tools required for the configuration process.

11.2. Identify the OS currently running. If the OS is recognized, set default options to match the OS. If the OS isn't recognized, set all defaults to blank.
12.3. Check for supported libraries, functions, variables, and other information, confirming the information with the user if necessary.
13.4. Create the header files and Makefile which go to make up the configuration files

As you can see, the sequence follows the same basic path as the autoconf system, and is fairly typical of other packages which are not supported by GNU, such as INN, the Usenet news server software. Lets try running the script:

```
$ Configure
(I see you are using the Korn shell.  Some ksh's blow up on Configure,
especially on exotic machines.  If yours does, try the Bourne shell
instead.)
```

This is our first warning that something may be wrong. Although we are actually using bash, which is based on the Bourne-shell, the fact that it supports Korn shell-style commands means it is identified incorrectly. This doesn't affect this configuration script because bash is also Korn shell compatible, but other configuration scripts may be more specific about what they like to be executed under.

```
Beginning of configuration questions for perl5.

Checking echo to see how to suppress newlines...
...using -n.
The star should be here-->*

First let's make sure your kit is complete.  Checking...
Looks good...

Would you like to see the instructions? [n]
Checking your sh to see if it knows about # comments...
Your sh handles # comments correctly.

Okay, let's see if #! works on this system...
It does.

Checking out how to guarantee sh startup...
Let's see if '#!/bin/sh' works...
Yup, it does.

Locating common programs...
awk is in /boot/bin/awk.
cat is in /boot/bin/cat.
comm is in /boot/bin/comm.
cp is in /boot/bin/cp.
echo is in /boot/bin/echo.
expr is in /boot/bin/expr.
I don't know where 'find' is, and my life depends on it.
Go find a public domain implementation or fix your PATH setting!
```

The script has now failed one of its own checks and quit. The fact that the find command is missing has been classed as fatal; you need to install a version of the command or provide a workaround. Let's continue examining the script assuming you have used the replacement find command:

> Note: See Appendix A for details on GeekGadgets, which includes a version of the find command.

```
find is in /boot/bin/find.
grep is in /boot/bin/grep.
I don't know where 'ln' is, and my life depends on it.
Go find a public domain implementation or fix your PATH setting!
```

Now you've found another application that the Configure script requires, or rather you haven't found it. What you need to do is somehow fool the configure script into thinking the application it needs is available after all. In actual fact, this is a fake insert, since the ln command does exist under the BeOS. What it does is demonstrate the problems you are likely to come across. We will cover this and the previous problem in more detail in the next section.

Once you have worked your way around these two problems, you should continue to monitor the script for any unexpected behavior. You may be able to solve the problems using techniques similar to those above, or you may even decide to modify the script in an attempt to solve the problems. Common things to look out for are:

- File permissions, particularly on scripts created by the configuration script during the configuration process. Some automatically expect files to be marked with the execute permissions, others set the execute permission but then fail when they can't delete the file. Check the permissions are set absolutely (using mode 777).
- Any temporary files generated by the configuration script created either in the wrong place or with the wrong names. Often these files have names with tmp or temp in them somewhere. If you can't find the files, then search for all files created 'today' and try to identify the files that way.
- Unexpected results from running other programs and applications. Passing the wrong code, text string, or command to an application can produce either the wrong result, or simply an error, neither of which the average script will know how to deal with.

Try running the script specifying the -x and/or -v options:

```
$ sh -xv configure
```

These options echo the commands as they are read and the commands as they are executed respectively, showing the commands, options, and any file names used during the script's execution.

Let's look at our final example of the GNU configure script, this time from the gawk package. Although the configuration system is still based on autoconf, the sequence follows the perl steps:

14.1. Check the operating environment, including support for the tools required for the configuration process.
15.2. Check for supported libraries, functions, variables, and other information, confirming with user if necessary.
16.3. Create the header files and Makefile which go to make up the configuration files.

The big difference is that rather than identifying the OS, the configure process instead attempts to identify the functions and tools supported. This has the advantage of being completely OS independent As long as the script executes without error and finds what it needs it is not concerned with the OS it runs on. If you run the script under the BeOS however, you run into problems straight away:

```
$ configure
creating cache ./config.cache
checking for bison... bison -y
checking whether ln -s works... yes
checking for gcc... no
checking for cc... yes
configure: error: no acceptable cc found in $PATH
```

Lets take a look at that last line. It says that the C compiler is cc, and that it's managed to correctly identify and find it. In fact, cc is a script which points to the mwcc C compiler. It incorporates some basic command line options which help the porting process by making the environment that mwcc uses more compatible with the cc found on most UNIX systems. We'll take a look at this script later in the book when we come to the build process.

As an alternative,, you could modify the configuration script. By default, the autoconf process looks for two C compilers: one is cc, the standard C compiler supplied with most UNIX OSs, and the other is gcc, the GNU C compiler. Although the BeOS (via the script) supports the cc compiler, you could do a search in the configuration file for gcc, replacing it with mwcc. This second workaround is messy; I don't like modifying supplied scripts unless absolutely necessary, and in this instance the cleaner is just to use the cc that does exist. Modifying a re-creatable Makefile after fooling the configuration script is a much safer option however. Alternatively, we could use a feature of the GNU configuration script which allows you to specify the compiler. Use the following line to use mwcc instead of cc:

```
$ CC=mwcc ./configure --without-gcc
```

With all the GNU scripts you have the ability to set various options for the packages when you run the configuration script. A full list of the appropriate options for the package you are installing is usually contained in the documentation. These options are used to control the settings, applications and directory locations but do not normally include settings for alternative compilers or other support software. For example, to set the default installation directory you use the --prefix option:

```
$ configure --prefix=/boot/local
```

This is a quicker solution than manually editing a Makefile after the configuration script has completed execution.

If you are familiar with the GNU autoconf program, a port is available that gets round most of the problems on configuring software. It even gets round the normal configuration tricks of checking for supported functions. The mwcc compiler will ignore the function in code like this

```
int main()
{
     return 0;
}
int test_function()
{
     function_to_test(1);
     return 0;
}
```

because it spots that the function you are testing the existence of is never called.

Faking Options

In order to get past some of the problems created by missing applications and files you need to fake their existence. If you can, you should replace missing applications with a working version, because if the script tries to run the application and nothing happens, you could end up in even greater difficulties.

You can fake applications by creating mini scripts that are run in the place of the real thing, by substituting a similar application (such as bison for yacc), or by modifying the script itself. In the case of the gawk configure script, we could have substituted the cc command with mwcc. You can do this with a script, the example below is the one supplied with the BeOS

```
#!/bin/sh
exec mwcc -I- -I. $*
```

. If you use this method there is a final step which we'll cover in the next section: manual adjustments.

Sometimes a script will fail because of a missing file. It may be not be anything important; it could just be a test file, or a progress file that the script is checking for but can't find. In these cases it is often possible to create an empty file using the touch command to fool the script into thinking the file exists.

Creating empty files

To create an empty file using touch just specify the filename after the command. For example, to create an empty file called myfile:

```
$ touch myfile
```

For more information on touch see Chapter 4.

It is dangerous and definitely not recommended to simulate the existence of header files in this way. Header files are used by the configuration process to identify supported functions and facilities, so faking their existence can lead to further problems.

In the case of our first example (Emacs) the missing element was a recognizable identification of the machine and OS. In Emacs the GNU autoconf program is looking for two files: one specifies information about the hardware platform, and the other specifies information about the OS. These are stored in the m and s directories respectively, which in turn are contained in the src directory.

The way to identify the machine and OS is to run the uname command, which should provide you with everything you need to identify the machine you are currently running on. When asked to print all the information it begins by reporting the OS, then gives the node name, OS release, OS version, and finally the hardware name:

```
$ uname -a
BeOS MCBe 1.2 d7 BeBox
```

Within Emacs recognition is controlled by another script, config.guess, which contains clues and further scripts which can be used to identify the output of uname and convert this into the standard format recognized by the configuration script. Checking the start of the script, you see the following:

```
UNAME_MACHINE=`(uname -m) 2>/dev/null` || UNAME_MACHINE=unknown
UNAME_RELEASE=`(uname -r) 2>/dev/null` || UNAME_RELEASE=unknown
UNAME_SYSTEM=`(uname -s) 2>/dev/null` || UNAME_SYSTEM=unknown
UNAME_VERSION=`(uname -v) 2>/dev/null` || UNAME_VERSION=unknown

trap 'rm -f dummy.c dummy.o dummy; exit 1' 1 2 15

# Note: order is significant - the case branches are not exclusive.

case \
"${UNAME_MACHINE}:${UNAME_SYSTEM}:${UNAME_RELEASE}:${UNAME_VERSION}"\
in
```

The script is trying to match a string made up of the hardware, OS, OS release, and OS version. Inserting the following as the first check should allow the script to identify the BeOS:

```
    *:BeOS:*:*)
      echo be-be-beos${UNAME_VERSION}
      exit 0 ;;
```

After modifying this script, you need to adjust the other scripts to accept this identification. The configure script requires modification so it can recognize which header files need to be used in the final configuration. The final stage is to create the header files in the directories outlined above. We'll look at the best way to approach this problem in the next section. If this whole process looks daunting to you, Fred Fish has produced a patch for the GNU autoconf system which performs all of these steps. In time, these changes will be incorporated into future revisions of the GNU packages. Check Appendix A for details of where to find Fred's patch, and then refer to Chapter 6 to learn how to apply the patch.

Manual Adjustments

The problem with configuration scripts is that, like computers, they are only as intelligent as the people who programmed them. A configuration script will only check what it has been told it needs to check, and will therefore almost certainly fail on a new platform. As a porter, it is your job to make the necessary changes to ensure that the script is intelligent enough to do its job. For that, you will need to make some manual adjustments.

We have already seen how programs which use uname to identify systems need to have their scripts modified. If you do have to make manual modifications to scripts, make sure you know what you are doing and ensure that you have a backup copy of the script as it was supplied. If possible you should use one of the other tricks I have described and then modify the configuration files created. This is safer and less prone to errors and modifications that may cause the script to fail to run.

It will also make your life easier for complicated projects; the larger GNU packages can use many Makefiles, all of which will need to be modified by hand if you cannot make the configure script work. Modifying the script will also make it more difficult when you come to port the software to the next version of the OS, when many of the problems exhibited by the current version may disappear.

If you need to create header files based on the changes you have made to the script (as in the case of our Emacs example), duplicate an existing header file from those supplied. As has been described elsewhere, the best places to start are those close to the setup and abilities of the BeOS. These are POSIX, SVR4, and Solaris, all of which have similar tool sets and library functions.

Even if the configuration scripts work after you have made your manual adjustments, you will need to check the files that were produced in the process and make some minor modifications to get the package to work. Once compiled, you need to test the package configuration using the method described in this chapter, and then make the necessary final modifications to make sure all the features work.

If the configuration scripts fail completely, even after some manual adjustment, see the "Cheating" section at the end of this chapter. In each case, the results will almost certainly require some form of manual massaging, so come back to this section once you have the files you need.

Testing the Configuration

Once you have finished configuring the package using the configure script and any of the tricks I have described here, you should test the configuration before you build it. That might sound a little difficult at first; surely the best way to test whether the configuration has worked is to try building the package?

Not necessarily. There are two elements to the configuration process: one is responsible for ensuring that the package builds correctly, the other is responsible for making sure the program actually does what it was designed to do. We are only concerned at this stage with the first element, making sure the package builds correctly. There are some things you can check and modify before you start:

- Check that any required configuration files exist, including header files, the Makefile, and so on.
- Ensure that the Makefile is in the correct format and doesn't fail because of any layout problems. You can test for this using the "no execute" mode of make specified by using the -n option. In this mode, make processes the Makefile and prints the commands it will execute without actually executing them. You therefore get to test the build process without being required to build the package. Running the test build on the gawk package just configured, you'd get the following output:

```
cc -c -g -DGAWK -I. -I. -DHAVE_CONFIG_H array.c
cc -c -g -DGAWK -I. -I. -DHAVE_CONFIG_H builtin.c
cc -c -g -DGAWK -I. -I. -DHAVE_CONFIG_H eval.c
cc -c -g -DGAWK -I. -I. -DHAVE_CONFIG_H field.c
cc -c -g -DGAWK -I. -I. -DHAVE_CONFIG_H
   -DDEFPATH='".:/usr/local/share/awk"' ./gawkmisc.c
cc -c -g -DGAWK -I. -I. -DHAVE_CONFIG_H io.c
cc -c -g -DGAWK -I. -I. -DHAVE_CONFIG_H main.c
cc -c -g -DGAWK -I. -I. -DHAVE_CONFIG_H missing.c
cc -c -g -DGAWK -I. -I. -DHAVE_CONFIG_H msg.c
cc -c -g -DGAWK -I. -I. -DHAVE_CONFIG_H node.c
cc -c -g -DGAWK -I. -I. -DHAVE_CONFIG_H re.c
cc -c -g -DGAWK -I. -I. -DHAVE_CONFIG_H version.c
cc -c -g -DGAWK -I. -I. -DHAVE_CONFIG_H ./awktab.c
cc -c -g -DGAWK -I. -I. -DHAVE_CONFIG_H getopt.c
cc -c -g -DGAWK -I. -I. -DHAVE_CONFIG_H getopt1.c
cc -c -g -DGAWK -I. -I. -DHAVE_CONFIG_H regex.c
cc -c -g -DGAWK -I. -I. -DHAVE_CONFIG_H dfa.c
cc -c -g -DGAWK -I. -I. -DHAVE_CONFIG_H random.c
```

```
cc -o gawk  array.o builtin.o eval.o field.o gawkmisc.o io.o main.o
missing.o msg.o node.o re.o version.o awktab.o getopt.o getopt1.o
regex.o dfa.o random.o
cd awklib && make  all
make[1]: Entering directory `/gawk-3.0.2/awklib'
cc -g ./eg/lib/pwcat.c  -o pwcat
cc -g ./eg/lib/grcat.c  -o grcat
cp ./eg/prog/igawk.sh igawk ; chmod 755 igawk
(cd ./eg/lib ; \
sed 's;/usr/local/libexec/awk;/usr/local/libexec/awk;' < passwdawk.in)
> passwd.awk
(cd ./eg/lib ; \
sed 's;/usr/local/libexec/awk;/usr/local/libexec/awk;' < groupawk.in)
> group.awk
make[1]: Leaving directory `/MCCe/Projects/InProgress/Porting/
gawk-3.0.2/awklib'
cd doc && make  all
make[1]: Entering directory `/MCCe/Projects/InProgress/Porting/
gawk-3.0.2/doc'
make[1]: Nothing to be done for `all'.
make[1]: Leaving directory `/gawk-3.0.2/doc'
```

- Check the directories and any other defines in the header files used during the build.

Provided everything works OK, the only thing left to do now is build the package, which will be covered in Chapter 15. If you do find any problems, then refer to the relevant sections of this book to identify and solve the problem.

Cheating

"Cheating" is perhaps an ugly word for what is really just a different approach to the problem of configuration scripts that don't work. The purpose of the configuration script is to produce pre-configured and ready-to-use versions of the files you need to build the package; it is not responsible for the actual building or for making sure that the configuration is correct.

What you need to do is somehow fool the configuration script into thinking it is running on a machine it knows about; run the configuration script on a different machine, and use the output generated to help configure the package on the BeOS; or, using the template files provided as part of the configuration program, produce the "real" versions that should have been generated by the script.

The first option, fooling the script, is the most difficult way to cheat the configuration process. The aim is not to produce the correct configuration for the machine first-hand; instead you want to produce as close a configuration as possible with all the configuration files in the correct formats. Depending on the package, you may be able to do this in a number of different ways. For the GNU autoconf scripts that rely on a specific machine/OS combination (Emacs, gcc, gcclib, and so on) you can specify what system you are running on. This eliminates the checking process that attempts to identify the OS and moves straight on to configuring the system for the specific machine and using the predefined header and configuration files.

If you choose to do this, make sure you select a combination that will reduce the amount of manual configuration required. I suggest you use IBM's AIX (use a configuration argument of rs6000-ibm-aix) or Sun's Solaris (sparc-sun-sol2.4) as a starting point. If you have no luck with these OS, try using Linux as another good starting point. You pass this information to the script on the command line:

```
$ configure sun4-sun-solaris2.4
```

This process won't automatically solve all of the problems associated with running the script, so you will need to refer back to this chapter when the configuration fails.

If you have access to another UNIX-based machine you can try the second method of cheating, which is running the configuration program on the alternative machine. Once you have run the script, create a tar file of the configured package directory and transfer this file over to the machine running the BeOS. Once you have extracted the file, you can try building the application. This configuration will probably fail the first time, but it should provide you with the necessary files required for configuration and the pointers you need to make any necessary changes.

In fact, this method was used by Be to port the original set of tools and utilities available on the BeOS. Some of the tools that are in DR9 are still based on the same source files as those original version, so it just goes to show that the method works!

If you know there are some things that need changing after using the package configured on a different machine, change the configuration files directly. The things to look out for are missing functions, directory specifications, and the tools required to build the package. Use Chapters 8 and 9 to help you make the necessary changes before building, and refer to Chapter 15 for help during the build process.

Most of the time the configuration substitutions are made to supplied template files. For the last method of cheating, you can use this fact to your advantage. Using these template files you can produce the configuration files, which in turn can be used to build the package.

If you look at the directory contents of gawk, there are two files you need to investigate. One is Makefile.in and the other is config.h. If you copy the Makefile.in to Makefile and make the necessary substitutions by hand in combination with making similar modifications to the config.h file, you can simulate the process of the configuration script, which is, after all, only trying to this quickly and easily.

I used this method for Perl5 as the scripts used for the configuration process often failed to run. It’s not the easiest method, and it isn’t for the feint hearted, but it can work if you concentrate on changing the necessary elements to get the application to compile. You can sort out details on the specifics of the application one you have the Makefile working correctly.

Configuration scripts are intended to make the build process easier, but when it comes to porting they sometimes help to confuse the issues. The fact is that nobody has invented a way of identifying all of the features of a machine simply and easily, and then producing a configuration around that information.

The GNU autoconf system gets very close, but it still has to obtain and sometimes even guess a lot of information about the machine before it can make any intelligent suggestions about how the package should be configured.

Chapter 11: Smart Compilers

Following in the footsteps of the configuration script is the smart compiler. The principles of the configuration script and Makefile apply to the smart compiler. The aim is to configure and then compile the package for the current platform based on a series of questions and/or some automatic tests to discover the necessary information required to complete the build. A smart *compiler* is written to combine the two processes into a single, unified way of configuring and building the package.

The term "smart compiler" is probably misleading; it is not a compiler at all, just a script that controls the build process. In most instances the process is still managed by some form of Makefile and either the script is a wrapper around the outside of the make process, or the commands used during the make process are scripts instead of straight compiler commands. In some simpler packages the build process is entirely handled by the smart compiler, although this is very rare. With make and gcc being available on such a wide variety of platforms, most people have moved their packages to this model.

In this chapter, we will look at the use of scripts which form the basis of the build process, with and without the use of a corresponding Makefile.

Smart compilers vs. Makefiles

Opinion over the relative merits of smart compilers over a Makefile is split between programmers who like the shell scripts which the smart compilers are written in, and those who prefer the functionality and ease of make and the Makefile.

The advantage of a smart compiler is that, hopefully, it will be one simple command to both configure and build the specified application. This makes the process easier for non-technical people, or for complex build procedures where the steps involved between compiling each file are complex and therefore difficult to reproduce in a Makefile.

A configuration script with a corresponding Makefile is generally easier to work with if you are a programmer. In particular, the ability to automatically compile a source file based on whether it or any of the header files to which it relies have changed is far more convenient when porting software. You don't need an all in one process, your aim is to get the package compiled, not to simulate the sort of installation program you find on Windows or MacOS.

However, all things considered, the upshot of which system the package is using makes a difference as to the approach you need to use to complete the port.The first goal when working smart compilers is to understand what the script is trying to do.

Following the Script

You already know what the execution sequence of a typical build is: configure, build, install. With a smart compiler all three processes are bonded together into a single process. There are basically two types of smart compilation system. The first form of smart compiler, which uses a script to control the entire build process, is the more difficult to work with as you need to know shellscript in order to follow the process. The pine e-mail package uses this sort of smart compiler; if you look at the directory contents you can see the build script and also a makefile (note the use of lowercase):

> Note: A lower-case makefile will be used in preference to a title case Makefile when the make command is run

```
CPYRIGHT   bin/        build.bat   contrib/   imap/     pico/
README     build*      build.cmd*  doc/       makefile  pine/
```

Checking the documentation, you'd find that the build script requires an argument that specifies the OS under which you are compiling. If you check the script, you can see what actually happens during execution of the script. Shown below is the main part of the script that handles the build process:

```
case $maketarget in

   ???)
```

Destination OS is not specified

```
        echo ''
        cd $PHOME
        if [ -s c-client ] ; then rm -f c-client ; fi
        if [ -s imapd    ] ; then rm -f imapd    ; fi
```

Check to see if the applications exist and delete them

```
      ln -s imap/systype/c-client c-client
        ln -s imap/systype/imapd imapd
        echo "Making c-client library, mtest and imapd"
```

Change the directory, and run make

```
        cd $PHOME/imap
        make $makeargs $maketarget
        echo ''
        echo "Making Pico and Pilot"
        cd $PHOME/pico
        make $makeargs -f makefile.$maketarget
        echo ''
        echo "Making Pine".
        cd $PHOME/pine
        make $makeargs -f makefile.$maketarget
        cd $PHOME
        if [ ! -d bin ] ;  then    mkdir bin;        fi
        cd $PHOME/bin
        rm -f pine mtest imapd pico pilot
        if [ -s ../pine/pine ] ;      then ln ../pine/pine
pine      ; fi
        if [ -s ../c-client/mtest ] ; then ln ../c-client/mtest
mtest ; fi
```

```
        if [ -s ../imapd/imapd ] ;    then ln ../imapd/imapd
imapd    ; fi
        if [ -s ../pico/pico ] ;      then ln ../pico/pico pico ; fi
        if [ -s ../pico/pilot ] ;     then ln ../pico/pilot pilot ; fi
```

Link the created applications to versions in the top directory

```
        cd $PHOME
        echo ''
        echo "Links to executables are in bin directory:"
        size bin/pine bin/mtest bin/imapd bin/pico bin/pilot
        echo "Done"
        ;;
```

Once given a suitable target OS on the command line, the script changes to a subdirectory and runs the make command to build the target. There may be an different way to build the package that doesn't require the use of the smart compilation script. The quickest way to find out is to check the other files in the top level directory of the package. As we already know from Chapter 5, the top level directory is the location of the README, INSTALL and other files. It is also the location of the scripts or Makefiles used to build the package.

Usually, we can find some other files in the top directory that can give us pointers to a different mechanism. The most obvious is a Makefile of some description. This may either be a genuine Makefile, or it could be a Makefile template that we can use to recreate the real thing.

Looking back to the original directory listing, you can see a makefile (lowercase, not title case). Checking the makefile, you can see that it actually does nothing more than send a note to the screen about how to build the package:

```
all:
       @ echo 'Use the "build" command (shell script) to make Pine.'
       @ echo 'You can say "build help" for details on how it works.'
```

This isn't very helpful, and wont provide us with any system at all to build the package. Instead, if we look back to the script, the first directory the script moves to is imap, where it runs a make command based on the OS type specified to the smart compilation script. The Makefile in this directory identifies the OS and then using the information contained in the lines of the Makefile selects an ANSI or non-ANSI version of the source code. The Makefile has been pre-configured with the information about which OS uses ANSI or non-ANSI style C code using the following lines:

```
# ANSI compiler ports.  Note for SCO you may have to set LN to "copy -
rom"

a32 a41 aix bsi d-g drs lnx lyn mct mnt neb nxt osf sc5 sco sgi slx
sos:
       $(MAKE) build SYSTYPE=ANSI OS=$@
aos art asv aux bsd cvx dpx dyn epx gas gso gsu gul hpp isc ptx pyr
s40
sol ssn sun sv4 ult vul uw2:
       $(MAKE) build SYSTYPE=non-ANSI OS=$@
```

Following the build information for the target build, the script runs yet another make in another subdirectory:

```
build:
	echo $(OS) > OSTYPE
	$(RM) systype
	$(LN) $(SYSTYPE) systype
	cd $(SYSTYPE)/c-client; $(MAKE) $(OS)
	cd $(SYSTYPE)/ms;$(MAKE)
	cd $(SYSTYPE)/ipopd;$(MAKE)
	cd $(SYSTYPE)/imapd;$(MAKE)
```

This last Makefile is the one which actually compiles the necessary files into the programs being built. The extract below shows the definition for making a Solaris version using the GNU compiler:

```
gso:	# GCC Solaris
	$(MAKE) mtest OS=sol EXTRADRIVERS="$(EXTRADRIVERS)" CC=gcc \
		STDPROTO=bezerkproto MAILSPOOL=/var/mail \
		ACTIVEFILE=/usr/share/news/active NEWSSPOOL=/var/spool/
news \
		RSHPATH=/usr/bin/rsh CFLAGS="-g -O2 -DNFSKLUDGE \
		 $(EXTRACFLAGS)" \
		RANLIB=true LDFLAGS="-lsocket -lnsl -lgen"
```

After some digging, what we actually see here is not a shell script managing the build process but a script-based front end to a collection of complex Makefiles and subordinate make commands. The actual process for compilation is to copy a header file containing the required information and a corresponding source file with the missing functions to a standard osdep.{c,h} file, which is then compiled with the rest of the source files into the library. This is repeated elsewhere in the build to produce the final versions. Like most porting exercises, this porting process concentrates as much on the contents of the OS-dependent files supplied with the package as it does on the script and the Makefiles surrounding the process.

Why use a smart compiler

Beyond the reasons we've already looked at for using a smart compiler over a Makefile, there are some other reasons why software writers prefer this method.

The most obvious reason is the expected simplicity of the process. Despite what you may think, there are some programmers who actually think about the people likely to use their software. Typing build to completely configure and build a package on a machine is obviously easier than typing configure, answering some questions, and then typing make to build it. However, the process is more difficult for the programmer this way, and developing the software without using some form of intelligent compilation system that doesn't remake the software every time you run the build command must make the process significantly longer. The real benefits to this all in one process only apply for those machines to which the software has already been ported.

The all-in-one method works for those packages where the entire process is managed by the one script. What about the hybrid solutions where a combination of a front end script and additional Makefiles or the opposite, Makefiles with executed scripts are used? If you examine some of the scripts used more closely, the reason for the mixture of scripts and Makefiles becomes obvious.

In the case of perl the use of scripts is two fold. The first reason is that the configuration information can be easily stored in a shell script which is then used by the other scripts to tell them what to do. For example, the compiler script (cccmd) used by the Makefile reads in the configuration information about the compiler and the arguments to use. Storing this information in a shell script is easy, and using shell variables means that we don't need to use programs like sed to generate 'configured' versions of the Makefile or a header file from a template. Making changes to the configuration is easy, all we need to do is modify the configuration shell script, and then all the other build scripts will take note of the change.

In the case of the scripts that do some of the more complex work, the second reason becomes apparent. The scripts use the features of the shell to aid them in the compilation process. A Makefile and the make command only provide the use of variables and variable information which can be generated from the rules and targets. You can't use any shell features during the process because a new shell is spawned each time a command is executed.

In other cases, a smart compiler is used because the platform on which the package was originally developed either didn't support make, or, if it did, it was unreliable or didn't support the use of additional Makefiles in subdirectories. In these situations, some form of wrapper to enable multiple Makefiles from different subdirectories was needed, hence the smart compiler.

Lastly, as with all things, it may just be that the programmer in question preferred to program a smart compiler than create a suitable Makefile and the configuration system to go with it. For the programmer, the smart compiler seemed the obvious solution, and with configuration systems as complex as the autoconf system from GNU, it is easy to see why.

The second type of smart compiler uses a Makefile to control the build process, with scripts working behind the scenes to compile and link the package together. This follows the more traditional route and is generally easier to work with. The reason for this is that individual scripts are written to perform specific tasks. For example, a script might be written to run the local compiler on the specified file. You're still using the make command to build the package; what's changed is that scripts are used in place of the more usual compilers, linkers, and other tools.

The qmail package, a replacement for the mail system under UNIX, uses special scripts for compilation, library building, and linking. The scripts make up the core processes behind the Makefile, which is just the mechanism by which the build process is sequenced. Essentially, though, the process is no different from a normal Makefile. When you run make -n, the Makefile begins by producing the following output:

```
cat warn-auto.sh conf-cc.sh make-cmds.sh > make-commands
chmod 755 make-commands
cat warn-auto.sh conf-cc.sh find-systype.sh > find-systype
chmod 755 find-systype
./find-systype > systype
./make-commands "`cat ./systype`" compile > compile
chmod 755 compile
./make-commands "`cat ./systype`" load > load
chmod 755 load
```

The package starts by creating a few scripts to attempt to identify the system, then it goes on to produce the compile and load scripts. The compile script is used as the replacement for the cc command:

```
#!/bin/sh
exec cc -O2 -c ${1+"$@"}
```

and the load script is used to link the applications:

```
#!/bin/sh
main="$1"; shift
exec cc -s -o "$main" "$main".o ${1+"$@"}
```

See the sidebar for reasons why people use this method as opposed to the make command. Later on, it also builds the makelib script. All of these different scripts are created by the combination of earlier scripts and the identification of the OS, which is handled by the find-systype script. All of the options have defaults, which means that the generation of the scripts does not fail even if the system is not identified. Configuring and setting up the package requires only that you change the definitions for these commands.

During the actual build, you will notice a number of lines which appear to be complex compilations, like this example:

```
( ( ./compile tryvfork.c && ./load tryvfork ) >/dev/null 2>&1 \
&& cat fork.h2 || cat fork.h1 ) > fork.h
rm -f tryvfork.o tryvfork
```

The process actually involves running a compilation on a sample file and then producing a header file based on a successful return code. It is probably easier to read the entire line as an if statement. The scripts check the abilities of the OS by checking for specific functions, much like the GNU configure script, see the sidebar for more information. The difference is that the check has now become part of the build process, instead of the configuration process.

Function checking

There are a number of ways to check if a function exists on the system. If you consider where information about functions is stored, it's quite easy to think of a few obvious ways.

The first place to look is in the system header files. The header files should contain a function prototype for each function supported by the operating system. Searching the header files for a specific name is a quick way of finding the information, but not, unfortunately, 100% reliable. What if the prototype is defined, but the function doesn't appear in the libraries? (You may be surprised at how often this happens!).

How about checking the libraries? Well, we could do a search in the different system libraries for the function we are looking for. Some configuration systems use the nm command to extract a list of symbols (data and functions) from a library. This is slow, and still prone to errors. The function may exist, but just be an empty definition or worse, the function name exists, but the result of the function doesn't match what you were expecting.

The best method employed to identify what functions are available is to actually compile a program and view the results. For example, we could check the existence of the printf command by compiling the following program:

```
#include <stdio.h>
void main()
{
       printf("Hello World\n");
}
```

If the compiler fails to compile the program, we can assume the system doesn't support printf, or does support a function *called* printf, but not one that matches the one we tried to compile. If the compilation succeeds, we can also test the programs output and see if it generates the desired result.

This is a failsafe method of checking if a function exists, and goes some way to explaining why the process is so complicated and often takes so long.

Finally, we get to the meat of the compilation process where files are compiled and linked into the final libraries and applications:

```
./compile fmt_strn.c
./compile fmt_str.c
./compile fmt_uint.c
./compile fmt_uint0.c
./compile fmt_ulong.c
./compile scan_nbblong.c
./compile scan_ulong.c
./makelib libfs.a fmt_strn.o fmt_str.o fmt_uint.o fmt_uint0.o \
fmt_ulong.o scan_nbblong.o scan_ulong.o
./compile fd_copy.c
```

```
./compile fd_move.c
./makelib libfd.a fd_copy.o fd_move.o
./load qmail-alias signal.o now.o lock.o \
qqtalk.o myctime.o datetime.o quote.o gfrom.o slurpclose.o \
libfd.a \
libseek.a \
libcase.a \
libwait.a \
libopen.a \
libenv.a libgetopt.a libgetline.a libsubstdio.a libstralloc.a \
liballoc.a liberror.a libstr.a libfs.a
```

The process for building the qmail package on most systems, even those that it doesn't recognize, is to just type make and sit back. This is the Smart compiler working at its best.

Faking Options

Because of the automatic nature of the smart compiler, faking options isn't often required. With a package as complex as qmail, though, some manual adjustment is required in order to allow for the differences between the BeOS and other UNIX variants. The basis for faking follows the same principles as configuration scripts: you are looking for ways in which to fool the scripts into working within the current operating environment.

With qmail the method for faking this is provided in the form of the scripts which go to make up the final build-time scripts compile, load, and makelib. The process for building the compile command, for example, is based on the combination of three scripts. The one we are interested in is the conf-cc.sh, which looks like this:

```
CC='cc -O2'
LD='cc -s'
```

which can easily be modified to

```
CC='mwcc -O2'
LD='mwcc -s'
```

You just need to recreate the compile script, which you can do by running make compile.

You can modify the other scripts in similar ways, although to do this you need to examine the process by which these scripts are built. make-commands is used to generate the different scripts, and the format of this script is to set the default options and then set the options that are different for each OS. For example, in the make-commands script the specifications for SunOS 5.x (Solaris) are

```
sunos-5.*)
  # we can survive without /usr/ucbinclude and /usr/ucblib
  LIBS='-lsocket -lnsl'
  DNSLIBS=-lresolv
  RANLIB=:
  ;;
```

We can see here that the configuration information required is what libraries to supply during the compilation and build process. On the BeOS, it is safe to assume that we don't need to specify any libraries as all the system libraries are included by default.

From the first example, you now know that the process actually uses Makefiles, so you can use the techniques you have already learned to build the pine package.

With many packages, you will find the former technique of modifying the scripts the most reliable method of porting and building your application. Alternatively, you may find that you need to use the techniques mentioned in some of the earlier chapters to build the package properly. If neither of these methods works, you may want to consider the two alternatives covered later in this chapter, hand compilation and generating a Makefile.

Ideally, whatever modifications you make should done in such a way that they can be incorporated into the version of the package distributed over the Internet. For example, if the system uses a configuration script, you should make the changes to the script and the files it uses so that the method of building and installing the package is the same for all platforms. Remember, at all times, that as the porter you doing the same work the programmer has already done, just for a new platform, and you will need to make the package easy to install, and make the differences easy to incorporate into later versions of the software. We will see the best way of tackling this in Chapter 16.

Hand Compilation

Hand compilation is the process of manually producing the required source files (using other files as templates, or using tools such as bison) and then compiling the source, file by file, using the command line. Being interactive in nature, rather than automatic, it provides a number of advantages. Because of the compatible nature of a Makefile, hand compilation is rarely needed when only a single make command is involved in the build process. After all, at it's most basic level the make command only executes the compiler and linker on a list of source files to build a program.

In the case of a shell script however, the process is likely to be more complex, with procedures and sequences in place both before and after the calls to the compiler. A shell script is rarely as compatible or portable as its Makefile because a shell script will rely on a program or function which doesn't exist in the destination OS. A Makefile on the other hand is compatible with any version of make. When using scripts as wrappers to either the make process or the underlying tools used during the build, hand compilation can often save you the hours of work that the scripts were originally intended to save you.

If you can easily identify the build process, as in the pine example at the beginning of this chapter, you may decide that a hand compilation would be a good way of getting around the problem of using multiple makes and the surrounding shell script. In our second example, based on qmail, a better (and easier) option would be to generate a new Makefile to do the compilation, rather than relying on the scripts that make up the current build sequence. Refer to the last section of this chapter for details on how to write a replacement Makefile.

In the case of the pine example, hand compilation is probably the best way to get around the problem of identifying the full process required for the build and the requirements of the Makefiles. Hand compilation is a long and complicated way of producing the same result as using a Makefile, and although it does give you ultimate control over the build process, I don't suggest this method to anybody with a weak heart or a short temper!

If you decide this is the best route, you should consider the following before starting:

- Hand compilation requires thorough knowledge of the Makefile and the processes involved in compiling files. I'm not referring to just the compiler, but also the build sequence and any required libraries, files, and applications.
- You must know the elements and files required to build each of the targets. This includes header files, any manual modifications, and the use of code-generation tools such as bison and flex.
- You must know the entire build process; missing any single element could cause the build to fail—and take a long time to track down. In particular, the configuration and installation processes make a significant difference in the operation of the package, so even if the package builds successfully, it doesn't follow that it automatically runs properly. Use the techniques outlined in Chapter 15 to test the package, and be much more diligent in addressing minor errors if you've had to hand compile.
- Hand compilation takes considerable time. If you are short of time, try the Makefile process described in the next section.

These all sound very negative, and with good reason. Hand compilation is the nasty side of the porting process and should always be avoided if possible, although with some packages it's inevitable.

Generating a Makefile

In should be apparent by now that most smart compilers still use some form of Makefile, albeit in some sort of modified form for use with the shell scripts. If the shell scripts work, the modifications to the Makefile should be fairly minor, but it may be easier to copy and use the script with some packages than it is with others.

If you do need to create a Makefile, many of the problems associated with hand compiling the package also apply. In essence though, a Makefile does no more than the hand compilation, it just does it automatically.

Refer to Chapter 9 for more details on the use of Makefiles.

The Smart compiler is both a step forward and a step backward from the configuration script and the Makefile. At its best, the Smart compiler reduces the build time to mere minutes. At its worst, you end up having to either hand-compile or produce your own Makefile to simulate the operation of the Smart compiler.

The smart compiler works by trying to combine the process of configuration and compilation into one script, for a variety of reasons best known to the original programmer. Either these scripts interface, and protect the user from, a series of Makefiles, or the Makefile is just a facade to a collection of scripts behind the scenes that do the real work.

Whichever system is in use, configuration scripts and Makefiles or smart compilers, the results should be the same. You are trying to get the package to compile, and it needs to work hand in hand with the modifications to the configuration and the source files as part of the overall framework to achieving the build.

Chapter 12: bison and flex

Two of the most regularly used components of the C programmer's toolset are lex and yacc. lex is program that produces the C code necessary for the lexical analysis of simple text strings. yacc, which stands for "yet another compiler compiler," generates the C code for processing free-form text using the information provided to it by lex.

The two are used together to produce text processors such as calculators and command-line environments, as well as for the more complex mechanics of preprocessors and compilers (hence the name of yacc). Under the BeOS, the GNU versions of these tools, flex and bison, are supported.

The GNU tools provide the same functionality as their standard UNIX counterparts, although there are some differences in their operation. It is quite common to come across sources generated by either, or more usually both, tools. With some packages, most notably compilers, you will need to use these tools to generate the sources instead of using the supplied pre-created sources. We will not be covering how to create the files used by the tools, as that is beyond the scope of this book. If you want to learn how to use the features of flex and bison or their counterparts lex and yacc you might want to read 'lex and yacc' by John Levine published by O'Reilly and Associates.

yacc and bison

The two utilities bison and yacc and fundamentally the same, the only difference is in their origin and their available. As a free package, bison is more readily available than it's yacc cousin, but those of you coming from UNIX will recognize yacc, not bison. Before we cover the differences and similarities between bison and yacc, we should first cover the process of compiling source files using yacc and the range of errors and error messages you are likely to get from the package.

yacc works by processing a specification file that includes:

- A set of rules for the pressing of the input text
- C source code to be executed once a rule has been matched
- The code, or a reference to it, for the scanner used to examine the input

This last item is usually handled by lex, although it doesn't have to be. We will cover the use of flex (lex's cousin) later in this chapter.

Each yacc file should have the file extension .y to identify its type. The make command will identify files with an extension of .y as yacc files and automatically process them, even if no specific rule is given. During the compilation process, the yacc file is turned into C source code, based on a finite state machine with a stack (see sidebar).

The finite state machine

Although it has a grandiose name, a finite state machine is really very simple. As the name suggests, it is a machine (or in the case of programming, a program) which has a finite number of states.

For example, consider a switch. The switch has 2 finite states, on and off, and is therefore an example of a finite state machine. Now think about a calculator that only adds numbers together. The calculator can be in one of three states. It is either accepting a number, accepting the operator, or displaying the results.

The processing of the input to the machine is called reduction. Each input token (a number or operator in our example) and the result of more than on token in a specified is described by a rule within the yacc file. These rules are either shifted (to obtain the next operator) or reduced (when a rule has been matched). Going back to our example, the input of:

1+2

would be shifted twice to discover the operator type, and then the second number. The whole expression would then be reduced and calculated to give a result of 3.

Because each state can be defined by pattern which is being matched we can add additional operators, and therefore additional states to the machine to produce a calculator which not only adds numbers, but also subtracts, multiplies and divides numbers.

The finite state machine stores the information that is being supplied to it on a stack. Information is put on, and taken off, the stack to achieve the necessary goal at each state, or to move from one state to the other. For example, in our last example, the first number, 1, would have been placed on the stack before the machine shifted to enable the operator, +, to be accepted. The number 2 would have been placed on the stack with the 1, and then both would be taken off the stack when the expression is reduced to the sum, 3.

To compile a yacc file into C source code, you pass the yacc file as an argument to the yacc command:

```
$ yacc foo.y
```

The yacc program then produces a new file, y.tab.c, which is the source file that will be compiled by a standard C compiler. You will sometimes also have to create a header file containing the token codes used in the yacc file. The command

```
$ yacc -d foo.y
```

produces both the C source file and a new file y.tab.h containing these definitions.

If you want to produce a readable version of the parser that is created during the process, you can also specify the -v option, which creates the information in a file called y.output. This file describes the individual states of the machine that is defined in the specification file. It can prove very useful, particularly when you are trying to identify a bug in the specification.

Developing calculators

When I first started using lex and yacc, like most people, my first tool was a calculator. I decided to work on a RPN, Reverse Polish Notation calculator, which takes the numbers first, and then the operators to produce the result. For example, to add two numbers together, you would type in:

1 2 +

The system uses the stack and is actually easier to program in because you can take in both numbers and then pop them off the stack, using the operator to produce the result. I developed it using the rules in yacc to produce a simple calculator using the four basic operators, +, -, /, *.

My next task was a standard equation calculator, which instead takes in input as you would write the sum in english:

1 + 2

This still uses the stack, although the process is more complex as the rules required to resolve the numbers either side of an operator are more difficult compared to the RPN method I'd used before.

What is interesting though, is that if you replace the source code used to resolve each rule with source code to print the input, an equation calculator produces RPN output. Ie., entering

1 + 2

prints

1 2 +

Meanwhile, if you do the same with the RPN calculator, all you get is RPN output!

Because a yacc file is independent of the machine on which it is run, it is very unusual, if not impossible, for the process to fail on one machine when the same file works elsewhere. In many cases, the C source code is provided with a package, and like the yacc file that was used to produce it, the source code is cross-compatible, as it uses no functions or other machine-specific information.

You will, however, sometimes run into problems because of missing glue functions. There are only two such functions, main and yyerror. All packages should define these two functions, but if not, you can use the source code below:

```
#include <stdio.h>

int main( void )
{
        return(yyparse());
}

int yyerror(const char *s)
{
        (void)fprintf(stderr,"%s\n",s);
        return 0;
}
```

During the compilation, particularly with complicated files such as compilers, you may be warned of a number of conflicts. For example, when compiling gawk (a text processing language, and a version of the UNIX awk program from GNU) you get the following:

```
awk.y contains 62 shift/reduce conflicts.
```

The conflicts exist because the specification file describes a finite state machine that doesn't change states in an orderly manner, or would not parse the input to the machine correctly. A shift/reduce conflict arises when the machine is unable to decide how to process the input because no valid conclusion can be made based on the input. A reduce/reduce conflict arises when the input could be resolved into two states, instead of the expected one state.

These conflicts are normal, in the sense that the programmer either expects or accepts their existence. They arise because of the strict ordering and parsing mode of the source file and don't indicate a problem to a porter. Checking the documentation will usually tell you to expect a certain number of reduce/reduce or shift/reduce conflicts during the build process, and provided the numbers match these warnings can be safely ignored.

Differences of bison from yacc

bison is completely backward-compatible with yacc, but there are some minor differences in the compilation processes of the two commands. The main difference is that the source file created during the source creation process is not called y.tab.c it is instead called the name of the source with a tab.c extension instead of y.

If you process the sample yacc file foo.y with bison you can see the file created has the .tab.c extension:

```
$ bison foo.y
$ ls
foo.tab.c    foo.y
```

During the course of a build this will cause problems, because make will have a rule that expects the normal y.tab.c file created with yacc if you simply replace the yacc command with bison. This will therefore cause make to fail, because the command hasn't produced the file it expected.

Making bison yacc-Compatible

All the command-line options work in an identical manner to yacc. You can therefore create a shell script called yacc which simulates the operation of yacc, but uses bison instead.

```
bison -y $*
```

The -y option forces bison to produce the y.tab.c file and other files using the standard y prefix letter, instead of the prefix of the input file.

lex and flex

flex is the GNU equivalent of lex, a lexical analyzer used to identify regular expressions and pass a token reference for the matched string to the calling function. lex is typically used with yacc to provide the token information that yacc requires to parse text. Like yacc, lex uses the information stored in a specification file to then create C source code which can be compiled into part of a program.

In comparison to yacc, lex is relatively stupid, its prime purpose being to identify strings and perform a simple function. There is no concept of rules, precedence, or sequences, thats what yacc is for. lex does make a good text processor, much like sed, but the lex file would have to be processed into C, and then compiled and linked. Sed, on the other hand, is really a pure editor, and needs no compilation to achieve the same results as lex.

Each lex file must end in .l to be recognized by make and other software. The normal operation of lex is to generate a C source file from the specification file, as in the example below:

```
# lex bar.l
```

The file produced is called lex.yy.c and can be compiled as a normal C source file.

As with yacc, both the original lex source file and the source code produced are cross-platform compatible, although it is best to make a new C source file from the lex source to ensure complete compatibility.

When lex is used with yacc a number of additional elements are added to the lex file to make it aware of the yacc interface. At the most basic level yacc uses the yylex() function to find the next input token. Unfortunately, the function is very dumb, and it is not possible for yacc using this function to match strings or special characters; it can only recognize numbers. Lex on the other hand can identify just about anything you choose, including strings, special characters and can even be set to identify arbitrary strings and differentiate between strings and numbers. Using lex we can pass the matched information on to the yacc rules. This function can be replaced by the lex source code and so the two packages must be aware of the common elements.

This information is contained in the header file produced by the yacc code-generation process, and the glue information required in the lex source is an extra definition at the start of the file:

```
%{
#include "y.tab.h"
%}
```

You also need to be able to pass variable information (arbitrary strings or numbers) to the yacc code. This information is passed in the global variable yylval. The definition of yylval is contained in the yacc source and must be referenced as an external variable in the lex source code. By default this value is an integer, although it can be any variable type, including a union or structure.

The use of a different variable type for the yylval variable can cause a number of problems during compilation because yacc will often define the type of yylval as integer (via the YYSTYPE macro), effectively ignoring the definition in the yacc source file. It is not uncommon to see additional lines in a Makefile the express purpose of which is to add the definition to the source code generated. This is particularly common in the more complex examples.

Differences of flex from lex

flex differs only very slightly from the standard lex in operation. You have more control over the source code generation process than with the standard lex; beyond this, the differences are minimal. It is best to examine the documentation supplied with the BeOS to note the differences, as the facilities provided by flex change with each new version.

One major advantage of flex over lex, particularly on the BeOS, is the ability to produce C++ compatible code instead of normal C code. This can be useful if you are developing BeOS applications that use the BeOS C++ application kits where the use of a C++ object for parsing text will be more useful than the compatibility of C function. Refer to the documentation for more details.

Making flex lex-Compatible

There is no need to write a shell script that simulates the yacc command line as you have to do with bison; instead, you can just substitute the commands directly so that

```
$ lex bar.l
```

becomes

```
$ flex bar.l
```

Exactly the same file, lex.yy.c, is produced by both programs so this should not cause any problems during the build process.

flex Library

Once you have generated the C source and compiled it, at the time of linking you must use the flex library. Without it, programs will fail to build correctly. You can include the flex library with the -lfl command to the C compiler. This is in direct replacement of the corresponding lex library, -ll, as in this example:

```
$ mwcc lwx.yy.c -lfl
```

Alternatively, you can replace the two required commands with the C source below:

```
extern int yylex( void );

int yywrap( void )
{
	return(1);
}

int main( void )
{
	while (yylex());

	return 0;
}
```

For most porting situations these will be supplied, or the library versions will be used in their place.

Chapter 13 - The Compiler and Linker

The compiler and linker are at the heart of the package-building process. The compiler converts the C source code into object code (compiled source) and the linker links the object code together to produce the application. Without a compiler it is impossible to convert the source code supplied in a package into the object code required by the linker. Without the linker, you can't turn the object files into a library or an application. It is therefore safe to assume that without the compiler and linker, it is impossible to port a package to any new platform.

The BeOS is supplied with two applications: mwcc is the C compiler and mwld is the linker. In this chapter we will take a look at how these work, and how to use the features of these applications to complete the port.

How the compiler and linker work

Before we cover the specifics of using the compiler and linker, it is worth covering the steps involved in turning your source file into an executable:

17.1. The first stage, called preprocessing, uses a preprocessor, which reads in the source file, expands any macro definitions (#define), and processes any conditions (#ifdef). Any include files (which consist mostly of directives and function prototypes) are also included and processed. The files produced are called preprocessed source.

18.2. The compiler parses the C code produced from the previous process (including the header files, expanded macro definitions, and so on) and produces assembly language for the processor (PowerPC or Intel on the BeOS). The files produced at this stage are called assembly language source.

19.3. An assembler converts the assembly language produced in stage 2 into the machine instructions used by the processor. The files produced by this stage are called object files.
On the BeOS, the compiler mwcc performs steps 1 to 3 using a single application. Other compilers, such as gcc have different applications which perform each stage.

20.4. Finally, a linker collates the object files and library functions. The file produced at this stage will either be a library (a collection of functions) or an executable application.

The standard compiler under the BeOS is mwcc, and unlike the compilers on other platforms it is a completely self-contained program that performs the entire process from preprocessing to code generation. The linker, mwld, is similarly multipurpose, being able to link object files and create libraries, both tasks normally shared by two or more applications.

The GNU C compiler, gcc has now been ported to the BeOS, but you still need to use the BeOS linker, mwld, to produce an executable.

In this chapter, we will see how to make the best use of the BeOS compiler and linker, and how they differ from those found on many UNIX platforms.

Preprocessing

We have already seen that preprocessing is the first step in the production of an executable. The sub-steps involved in preprocessing are executed in a more or less recursive style with a number of passes (usually three). The first pass reads in the source, including any header files, and any header files which are included by the header files.

The next pass reads in the full source and identifies any macro definitions, including any conditional statements. The third pass then expands the definitions into the final preprocessed version of the source file.

Defining Values

The -Dname option to mwcc allows you to specify additional macro definitions This is compatible with most other compilers, including gcc, so it should not represent a problem when porting.

When using command-line definitions you should keep a few things in mind:

- Try to keep the number of definitions to a minimum; if you find you are using a lot of definitions on the command line, create a header file and include that in the source. Having a lot of definitions on the command line makes the code generally hard to follow because you can’t see a macros value until the source is compiled. It also makes changes more difficult to incorporate, as we have already seen, changing the settings in a Makefile doesn’t ensure that the source is recompiled.
- When specifying definitions that require special characters you will need to escape them using the backslash (\). For example, you would specify a string as follows:

```
$ mwcc -c foo.c -DOUTSTR=\"Hello World!\"
```

- Using a definition on the command line allows you to specify the definition only for a particular file, or for a number of files. Make sure you only use the specification on the files that require it; incorrect definitions can cause porting problems.

It is also possible to undefine macros (using the -Uname option) that may be specified in the file (or any of the header files included by the file). This is equivalent to a #undef directive in the source file. It is unlikely you will use this in general practice. However, if a compilation is failing because a definition causes the use of some incompatible source code, it may be quicker to try your theory by undefining the macro on the command line instead of modifying the source.

Using the Preprocessor

It is common for some packages to use the facilities of the preprocessor to process and format the Makefile and other files before building the package.

Because of the macro definition and expansion capabilities of the preprocessor it can make the process of configuring a package easier without requiring an alternative configuration program. By default, most packages expect to use the -E argument to the compiler to preprocess files and the Metrowerks compiler is no exception. So to preprocess the file foo.c you would type:

```
$ mwcc -E foo.c
```

Output from the command is sent to stdout, so you will need to redirect the output to a file if you want to use it.

Some packages may use the C preprocessor, cpp, directly but there is no separate preprocessor in the Metrowerks toolkit. The commands cpp and mwcc -E are interchangeable. If you want to use the cpp command, you can create a small shell script called "cpp" containing:

```
#! /bin/sh
mwcc -E $@
```

You could use this script to emulate the existence of cpp and therefore trick configuration scripts into thinking that a cpp program exists. In most instances however the configuration script will also try to use mwcc -E to preprocess a file.

Preprocessing can also aid in the porting process by allowing you to generate the file which is actually compiled by the rest of the C compiler, rather than the source file which contains the definitions and conditional statements. When working with a large or complex project identifying a complex expansion can be a mammoth task. In order to achieve the level of cross-platform compatibility, definitions and conditionals are used to decide which piece of source code should be compiled. Using the preprocessor, you can preprocess the source and then identify which macro needs to defined (or indeed, undefined) to compile the source correctly.

Note: When reading preprocessed source dont expect to see tidy C source code. A great deal of the niceties such as tabs, spaces, and the more useful comments will all be missing from the preprocessed version of the file.

Creating a Dependency List

In Chapter 9 we covered the advantages of using a dependency list in a Makefile to aid in the correct compilation and building of a package. On most UNIX flavors, the makedepend program creates the dependency list.

Under the BeOS you use an option to the mwcc compiler to create the dependency list. For example,

```
$ mwcc -make foo.c
```

generates a list of the dependent files for the source file. It is probably a good idea to create a shell script to simulate the makedepend command with the compiler's alternative. The makedepend program is usually run on the entire source tree; you may want to repeat this action for mwcc, which you can do quite easily by passing the command-line arguments straight to the makedepend script:

```
#!/boot/bin/sh
mwcc -make $*
```

Optimization

Optimization allows the compiler to make decisions about how it produces the assembly code that ultimately produces the final application. Normally, optimization is only specified during compilation once an application has been debugged, although some people use optimization throughout the development of a package.

The optimization can be either for execution speed or for size, depending on the final application. Today, the size of an application and the memory and disk space it uses are less of an issue; most people want to squeeze the maximum horsepower out of their machines. In addition, many people want to optimize the application for their processor. Different processors can execute the same compiled C source code in different sequences, and a compatible sequence on one processor does not always execute at the same speed when run on a different processor from the same family.

In general, optimization works by removing additional or extraneous assembly code, or modifying source code to make better use of the processor functions available. For example, using a single specialized CPU instruction instead of two for a particular command will save you an instruction cycle. It doesn't sound like much; after all your average instruction cycle takes only microseconds to execute. But factor it up to the number of lines in a package and you gain a significant increase in speed. emacs, for example, has about 150,000 lines of C source code, not including any header or configuration files.

Other techniques include identifying loops and modifying the assembly code to process the loop faster. For example, the for loop below would be terribly inefficient when compiled, as the process of looping requires jumping from the end of the loop to the beginning again and then testing the value of the counter. This is a number of processor steps, even without the addition of adding up the value of the total variable.

```
for (counter=0;counter<4;counter++)
      total+=4;
```

When optimizing the code, the compiler would convert the loop into just three statements which add up the value of total.

Other techniques used are instruction re-ordering which changes the order commands are supplied to the processor and removing unused, or unnecessary code sections.

Optimization Levels

The GNU C compiler, gcc, supports two basic levels of optimization, -O and -O2. These adjust the number and type of optimization techniques employed by the compiler during its generation stage.

gcc also supports levels -O3 and -O4, but -O2 is the recommended optimization level for most project.s

mwcc accepts a number of different optimization options. The basic level of optimization, -O, supports processor scheduling. This is a technique whereby individual CPU instructions are sequenced in the correct order for efficient operation without the CPU having to load information or instructions from RAM to do its task.

For each level you go up from -O an additional form of optimization is added, up to the top level of -O7 which optimizes all the code, with scheduling and speed optimization using the techniques I described above. This is the highest level you can go to under the BeOS and should only be used for final versions. If you are using a Makefile, add -O7 to the CFLAGS before a final compile. You can also specifically select optimization for size or speed using the -Os and -Op command-line arguments. See Table 13.1 for a full list of optimization levels available on the PowerPC platform and the effects.

There are different levels of optimization and different styles of optimization available on the Intel version of the BeOS. These were not available in full form at the time of writing so check the documentation of mwcc under Intel when it becomes available.

Table 13.1

mwcc optimization levels

Option	Optimization methods used
-O0	Suppress all optimization
-O	Enable instruction scheduling (PPC603)
-O1	Enable peephole optimization
-O2	Enable instruction scheduling (PPC603)
-O3	Enable global optimization
-O4	Enable peephole, speed and instruction scheduling optimization with global optimization level 1
-O5	Enable peephole, speed and instruction scheduling optimization with global optimization level 2
-O6	Enable peephole, speed and instruction scheduling optimization with global optimization level 3
-O7	Enable peephole, speed and instruction scheduling optimization with global optimization level 4
-Op	Optimize for speed
-Os	Optimize for size

Warning: Using level -O7 on some source code will cause the compiler to use huge amounts of virtual memory. If you find that the compilation is taking too long, try reducing the level down to -O5 or below. You may also find that you need to reduce to as much as -O3 if you find problems with 64-bit integers.

Using Optimization with Debugging

Like the GNU C compiler, mwcc can create optimized debuggable code, something many compilers do not handle. This allows you to debug compiler-optimized code rather than debugging a non-optimized version. As you will see, optimizing source code can introduce errors, and the ability to debug the optimized version should help to pinpoint any specific problems.

As a personal preference, I find that I use the two options of optimization and debugging exclusively. The first pass of the porting process I always run with debugging on. This allows me to identify and fix any problems with as much information to hand as possible. Particularly useful when porting is the ability to monitor variable values.

Once I have completed and tested the "debugger" version of the package, I then recompile with optimization switched on to generate the final distributable version. The other advantage to switching debugging off at the final build is that the executable will be that much smaller.

There are some exceptions to this rule; a number of programs that use symbol tables like debugging symbols included to aid the program execution. In particular, debuggers, compilers, and complex programs like emacs like debug information. In all of these cases, the ability to optimize code execution while still retaining this information should make the ported package significantly faster compared to a debugged-only version.

Coping with Optimization Problems

With some applications and packages using optimization can cause a number of problems. On the whole, it is relatively rare, but when it happens it can often be very difficult to trace the problem to the source code. This is because the optimized version of the source code does not match the file which you select to compile.

The most obvious problem with optimized code are the introduction of strange numbers and unexpected modifications to strings and pointers. If you encounter any such problems during a port that you can't pin down to an alternative source (see Chapter 15), try compiling the package without optimization.

In extreme circumstances, you may want to go from one extreme to the other and produce debugged code instead of the optimized version. This should, by default, just compile the source as the compiler finds it, which should hopefully introduce fewer errors into the final source.

Debugging

Debugging software is the process of removing the errors (bugs) from the application. Traditionally, removing bugs meant using manual techniques, such as multiple printf() statements, to print out the status of a program during its execution. Symbolic debuggers take a more interactive approach; they take compiled source combined with additional debug code and provide a structured interface where the compiled code is executed step by step alongside the source code lines.

To perform symbolic debugging additional information is supplied with the object files and applications which describes the stage line by line. The symbolic debugger takes this information, combined with the original source, and displays it interactively to the user. We will see examples of the Be debugger in Chapter 14, and in Chapter 15 we'll look at alternative ways of testing and debugging applications using the manual method.

Debugging under the BeOS is slightly more complicated than it is under most UNIX platforms. Under most platforms the debugging information is incorporated into the object file, and ultimately any libraries or executables created from those object files. You have the option to keep the debug information in the file, or, without recompiling, you can use strip to remove the additional symbol information from the file.

With mwcc and the BeOS, debugging information is generated using the same command-line option, -g, but that is where the similarity between the two ends. All the debugging information is stored in a separate symbolic debugging file with the library or application. The file extension is .xSYM and this is used, in conjunction with the application itself, to debug the code. To create a debuggable version of emacs, for example, you would need to add the -g option to the CFLAGS variable used in the Makefile.

Warnings

Warnings are exactly what they say they are: warnings about the quality of the code you have written, and pointers to possible problems at the time of execution. You can choose to ignore warnings; some packages may even tell you to ignore them during a build because they know of the problem and it doesn't cause any trouble. The point of a warning is merely to notify you that something isn't quite right about the source that you've written, and that you ought to change it. A warning doesn't necessarily point to a problem, but if there is an error in the code that has been produced an unchecked error is a good place to start.

There are a number of reasons why you might get a warning, and you can control the notification level of warnings from the compiler using a number of command-line options. There are three basic levels of warning:

- **None.** No warnings are issued.
- **On.** All warnings are issued, except missing function prototypes.
- **All.** All warnings are issued, including missing function prototypes.

You can switch to each of these levels by using the -w opt1,opt2 argument. For example, to switch warnings to "on," you would type:

```
$ mwcc -c -w on foo.c
```

mwcc also supports the cc/gcc style argument -wn where n is a number. 0 switches warnings off; 1 turns on warnings except command-line options; 2-8 turns on all warnings (except missing function prototypes); and 9 turns on full warnings (including missing function prototypes).

Warnings can also be individually selected on the command line when compiling using the same argument mechanism. The various types of warning are listed in Table 13.2.

Table 13.2

Options to the warning argument, -w

Option	Description
pragmas	Illegal pragma definitions
emptydecl	Empty declarations
possible	Possible (unspecified) errors
unusedvar	Unused (but declared) variables
unusedarg	Unused (but prototyped) arguments
extracomma	Extra commands
extended	More possible (unspecified) errors
params	Suspicious, obsolete, or substituted command line options
largeargs	Large arguments passed to functions without prototypes
hidevirtual	Hidden virtual functions

Warnings do not stop the compilation process; the files will be compiled as usual. You can change this behavior using the iserror option, which causes warnings to be treated as errors, stopping the compilation process and interrupting any make or other build script that's in progress:

```
$ mwcc -c -w iserror foo.c
```

When porting, I suggest you switch full warnings on, which should highlight any OS-specific problems (such as incompatible char, int, or other variable types) as well as highlighting possible problems that the original author missed. Always check the documentation first before acting upon any of the warnings given; they be known but ignorable items. Also, don't always take the warnings as a signal to a problem with the port, it may be nothing to do with the porting process, but should probably be investigated anyway.

Header Files

A header (or include) file serves as the interface between the source code and library functions supported by the system libraries. Essentially, each header file is a list of function prototypes, variables, and macro definitions which are used to supply information to the source file (and ultimately the compiler) and to verify the format and syntax of the required functions or their prototypes. The actual functions are stored in libraries, which we'll cover later in this chapter.

The functions and macro definitions in the header files are used regularly and are supplied in a number of files which can then be called upon by each source file requiring the library facilities. For example, the file stdio.h contains the information required to use printf, scanf, and other I/O functions (hence the name, which is short for “standard I/O”).

A common problem with header files is that although there are some agreed-upon standards for names, over time, a number of the files have changed names and sometimes contents. A complex part of the porting process is matching the requested header in a source file to the actual header file required.

For example, the older UNIX OSs used strings.h to specify the string handling functions (strcat, strcpy, and so on). SVR4 and other recent revisions of the OS now place this information into string.h, a change of only one character, but the compiler is not smart enough to make an automatic decision. We will see in Chapter 15 how the wrong header file can cause all sorts of problems during the building of a package.

The Metrowerks C compiler is ANSI-compatible, which can cause some problems when you use alternative header files from supplied sources. The ANSI specification requests an ANSI-style prototype of each function. Without this prototype function definition, mwcc may issue a warning about incorrect argument numbers or argument types to a function.

The format of the function is also different:

```
int foo(char *bar);
```

instead of the traditional

```
int foo(bar)
char *bar;
```

although this does not cause a problem for mwcc.

If you specify the -ansi strict option then mwcc will report an error.

Finally, in the case of the BeOS, which uses C++ as its core language, the format is slightly different from that of standard header files to account for the way in which C++ handles external functions, as can be seen in this example:

```
#ifdef __cplusplus
extern "C" {
#endif
char *strcpy(char *, const char *);
char *strncpy(char *, const char*, size_t);
#ifdef __cplusplus
}
#endif
```

Obviously, a non-C++ program will just define the functions and other definitions as normal during the preprocessing stage. ANSI C and Kernighan and Ritchie (K&R) C define functions in different ways; for example,

```
char *strcpy(char *, const char *);
```

in ANSI is equivalent to

```
char *strcpy();
```

in K&R. To get around the problem of defining the functions differently for each type of C compiler, functions are defined in the source code by some packages using a macro, __P():

```
char *strcpy __P((char *, const char *));
```

the latter part of which would expand to nothing for K&R C, or (char *, const char *) for ANSI C.

Standard Locations

There are two ways in which a header file can be referenced in source code. Those in angled brackets, like this:

```
#include <stdio.h>
```

are searched for and used from the standard system directories, while those in quotes:

```
#include "foo.h"
```

are searched for in the current directory.

It is usual to find additional directory specifications in large packages, and these are referenced using additional arguments to the compiler, as we will see later.

During preprocessing it is also possible to switch off the default directories used for header file inclusion using the -nodefaults option. This can often be useful if you are building an alternative OS or cross-compiling.

The standard header files can be found in the /boot/develop/headers directory. This is defined in the BEINCLUDES environment variable, which in fact points to this directory and a number of subdirectories, as follows:

```
/boot/develop/headers
/boot/develop/headers/be
/boot/develop/headers/be/add-ons
/boot/develop/headers/be/app
/boot/develop/headers/be/device
/boot/develop/headers/be/drivers
/boot/develop/headers/be/game
/boot/develop/headers/be/interface
/boot/develop/headers/be/kernel
/boot/develop/headers/be/mail
/boot/develop/headers/be/media
/boot/develop/headers/be/midi
/boot/develop/headers/be/net
/boot/develop/headers/be/nustorage
/boot/develop/headers/be/opengl
/boot/develop/headers/be/support

/boot/develop/headers/cpp/boot/develop/headers/gnu
/boot/develop/headers/posix
```

The posix directory contains the files in which we are most interested, as the bulk of the POSIX-compatible support can be found here. We will look at POSIX in more detail in Chapter 17, with further details on the level of POSIX support in the BeOS in the remainder of the chapters.

As a rough guide, Table 13.3 lists some of the facilities that the standard header files provide.

Table 13.3

Header files and their contents

File	Description
assert.h	Program assertion checking
ctype.h	Character handling (isalpha(), toupper())
errno.h	Error conditions/descriptions
float.h	Floating point value limits
limits.h	Other data limits
locale.h	Locale information (currency, thousands separator,and so on)
math.h	Mathematics (constants, sin(), cos(), and so on)
setjmp.h	Nonlocal jump mechanism
signal.h	Signal handling
stdarg.h	Variable arguments (for printf()-like commands)
stddef.h	Common definitions (NULL)
stdio.h	Standard input/output (printf(), scanf())
stdlib.h	General utilities (alloc(), number/string conversions, and so on)
string.h	String handling
time.h	Date and time get/set
unistd.h	System calls (exec*(), fchown(), and so on)

Using Other Locations

mwcc supports the standard -I directive for including additional directories in the search path. For example, to include the /boot/local/include directory, you would use the command:

```
$ mwcc -c foo.c -I/boot/local/include
```

The Metrowerks complier is more strict about which files it includes when, and so the -I option is not always sufficient. An additional header file argument, -i-, forces all include directories specified after this argument to be searched for <> include references and "" references. Specified on it's own though, -i- forces the current directory not to be searched. Effectively, all include files are treated as system-wide files. Like the -nodefaults option this allows you to compile sources using header files *not* in the standard header path.

This can be very useful when porting software, and in fact I would recommend that you use it all the time to prevent any potential header file problems. Because of the strictness of mwcc compared to gcc you need to specify this argument whenever additional header directories are used, as in the example below:

```
$ mwcc -i- -I/local/include foo.c -c
```

More commonly you will want to specify some local directories, in fact it is common practice to specify -I. As part of the build process. When used in conjunction with -i- you need to decide where to place this option as it will affect how the directory is searched. Using

```
$ mwcc -i- -I.
```

forces mwcc to search the current directory for <> and "" header file references. Using

```
$ mwcc -I. -i-
```

will force mwcc to only search for "" header file references.

Libraries

A library is a collection of functions and data supplied in a single file. However, you could make the same statement about standard object files. If I compile foo.c:

```
$ mwcc -c foo.c
```

I automatically create an object file called foo.o. If foo.o contained a function that I wanted to use in another program, bar, I could just link the two files together:

```
$ mwcc bar.o foo.o -o bar
```

There is nothing wrong with this model, until you start using the same file repeatedly in a number of projects. Libraries are a convenient way of collecting together a number of object files into a single file.

Under UNIX, this file is a special format and can be handled by the ar program. Under BeOS, mwcc simply puts all the objects from the object files into one big one that is historically given the same .a filename suffix. At link time, mwcc then extracts the objects it requires for the current application it is building.

All of the functions that you take for granted, for example printf(), are in fact functions contained in the standard library. Under most OSs this is libc; under the BeOS it is libroot.so.

Library Types

There are two basic types of library: static and shared. A static library is the library type most people are familiar with. A static library is created either by using the linker or by using ar to produce a file that contains all of the code and data from the supplied object files. A shared (or dynamic) library is generated by the linker and then only referenced at the time of execution of the application.

There are advantages and disadvantages to each library type. Basically these center around size and speed of execution. As a general rule, statically linked applications tend to be large, but fast in execution, while dynamically linked applications are small, but incur a small overhead each time they are executed.

The use of a shared library also forces a reliance on the library being available when you next run the application. On your own machine this is not a problem, but when supplying the file to another user or distributing the software you must ensure that the shared library will be available on the destination machine.

Static libraries avoid this problem entirely by incorporating all the required functions within the application. This makes distribution easier and more reliable, but also more cumbersome as you have to supply larger and larger applications. In summary:

- Static linking copies the functions required by the application when the executable is created.
- Dynamic linking copies the functions required by the application when the program is executed.

You will find that most libraries supplied with most OSs, including the BeOS, use a combination of the two, and sometimes include both. In the case of the BeOS, the OS libraries are shared, but the additional development libraries (flex, termcap, and so on) are static. This is fairly normal, because it allows the OS libraries to be updated without requiring the additional applications and tools to be rebuilt.

A library name is of the form libname.[a|so], where name is the library's title and the extension specifies the library type. All libraries start with lib , and static libraries always end with .a and shared libraries with .so.

Locations

By default, the mwld linker uses the libraries specified in the BELIBRARIES environment variable. As standard this environment variable contains:

```
/boot/beos/system/lib
/boot/develop/lib
/boot/home/config/lib
```

You can specify additional library directories in much the same way as you would header file directories, this time using the -L option.

For example, within the perl package the additional directories are specified by the LDFLAGS variable in the Makefile:

```
LDFLAGS =      -L/usr/local/lib -L/opt/gnu/lib
```

Using Other Libraries

To use a different library, you specify the library name after the -l argument. For example,to include the math library you would type

```
$ mwcc -lm -o foobar foo.c bar.c
```

The library is searched for in the library path (see above), and if it isn't found the linker will return an error. Refer to Chapter 8 for details on the libraries available under the BeOS.

Making Libraries

In the process of porting various packages it is likely that you will need to build some libraries. Under the BeOS, both types of libraries can only be built using the linker, so you need to adjust the way most packages produce their libraries.

Creating Different Libraries

There are two different types of library, as we've already seen. They are the symbolic and the static library. If you class an application as another type or library, there are really three different types. You specify what type of library to build by specifying the -xm option and the library type (a for application, l for a static library, and s for a shared library).

You will also need to specify the output file name using the -o option. For example, to create a static library called foobar you would use

```
$ mwcc -xml -o libfoobar.a foo.o bar.o
```

or for a shared library

```
$ mwcc -xms -o libfoobar.so foo.o bar.o
```

Most libraries that you will build during porting will be static libraries. Usually static libraries are created using the ar program, which creates an "archive" of the object files and their contents. The command used to generate a static library using ar is

```
$ ar cs libfoobar.a foo.o bar.o
```

Using a script that simulates the functionality of ar will help to reduce the manual modifications required to build the package. I use the script below:

```
#!/boot/bin/sh


if [ $# -lt 3 ]
then
       echo Not enough arguments
```

```
else
	shift
	outfile=$1
	shift
	if [ -f $outfile ]
	then
		echo Remove existing?
		read answer
		case $answer in
			y*)	rm -f $outfile
				echo Removing $outfile
				echo Recreating...
				mwld -xm l -o $outfile $*
				;;
			*)	echo Attempting to rebuild...
				mv $outfile $outfile.tmp
				mwld -xm l -o $outfile $outfile.tmp $*
				rm -f $outfile.tmp
				;;
		esac
	else
		mwld -xm l -o $outfile $*
	fi
fi
```

Provided the number of arguments is greater than three, the script ignores the first argument, takes the next argument as the library name, and any remaining arguments as files to be added to the library. I've included an additional test which checks if the library already exists; if it does, you can select whether to remove it and recreate the library based on the objects you specified. If you don't remove the existing library, then the object files are added to the library file.

There is no standard way of generating a shared library under a variety of OSs, which is probably why most packages build static libraries instead.

When producing a static library, there are no hard and fast rules or tips. Obviously, the smaller and more optimized your code, the faster and smaller your final applications will be.

For shared libraries, you need to keep in mind the way in which the functions and data stored in the library are copied to the executing application. At the point of execution, the OS uses a single copy of the shared library code and data stored in memory. When creating the shared library, it is a good idea to use the -rostr option to the compiler. This forces strings to be marked as read only.

•

During the actual creation process for a shared library, you need to specify which symbols should be exported. This is in deference to the UNIX style shared library where all symbols are automatically exported. The operation of generating the symbol tables is different depending on which processor the BeOS is running on. The process for Intel processors was still being finalized at the time of writing, but is likely to be similar to the process for building DLL libraries under Microsoft Windows. You should check the release notes for the Intel version when it becomes available.

For PowerPC the process you use will depend on the size of your library. If you are only creating a small library, you can simply specify the symbols you want to export on the command line. For example, to export the function foo you would use the following command:

```
$ mwcc -xms -export foo foo.o -o foo.so -ldll -lroot -lbe -lnet
```

Note: The additional libraries listed are the standard BeOS shared libraries, and must be specified. This is because the shared library that is generated must contain references to the functions from other shared libraries that it uses. Under normal circumstances, the compiler does this for you, but it doesn't when generating another shared library.

Any additional functions would also have to specified on the command line. For even a small library this method obviously becomes a time consuming task.

If the library has a corresponding header file with the function prototypes you should insert the following line before the prototypes start:

```
#pragma export on
```

and then

```
# pragma export off
```

where they end. When compiling, you use a command similar to the following:

```
$ mwcc -xms -export pragma foo.o bar.o -o foobar.so -ldll -lroot -lbe -lnet
```

This is a simple solution, but you must ensure that all the prototypes are listed, otherwise the functions will not be exported. Also be careful if you intend to pass the modified code back to the author, it may cause problems for older C compilers.

The final solution is much less straightforward, but it will get round the difficulties of exporting all the functions. Using a different command line option, you can specify a file which contains a list of the functions of you want to export. The command line is:

```
$ mwcc -xms -f foo.exp foo.o bar.o -o foobar.so -ldll -lroot -lbe -lnet
```

If the file doesn't exist, the compiler will create the file with all the functions in it, all you have to do is go in and remove the ones you don't want to export. There are a number of functions that we don't want exported that will be generated as part of the standard compilation process. We can speed up the removal of these standard functions by creating a script which generates the shared library automatically:

```
libname=$1
shift
objects=$*
rm -f tmp.exp
mwcc -o $libname.so -xms -f tmp.exp $objects\
 -ldll -lroot -lbe -lnet >/dev/null 2>&1
```

```
sed -e s:^longjmp:\#longjmp:\
 -e s:__ptmf_null:\#__ptmf_null:\
 -e s:__register_global_object:\#__register_global_object:\
 -e s:__destroy_global_chain:\#__destroy_global_chain:\
 -e s:__global_destructor_chain:\#__global_destructor_chain:\
 -e s:_init_routine_:\#_init_routine_:\
 -e s:_term_routine_:\#_term_routine_:\
 -e s:__start:\#__start:\
 -e 's:^@:\#\1:p' <tmp.exp >libname.exp
rm -f tmp.exp
mwcc -o $libname.so -xms -map $libname.xMAP -f libname.exp\
 $objects -ldll -lroot -lbe -lnet
```

To use, you just specify the library name (without it's extension) and the objects you want in the library. For example, our foobar.so library could be generated by the command:

```
mksharedlib foobar foo.o bar.o
```

Included Symbols

By default, a library file on the BeOS only includes the functions specified. If you want to be able to debug the library functions, you must also specify the debugger options to create the necessary symbol files. The symbol file contains the list of symbols (functions and variables in the object file) and their physical location within the file. It also specifies the location of the source, and in some cases a copy of the source file used to generate the object file. This information is used by symbolic debuggers to move around the application and identify variables and their types, and to display the source code rather than the machine code during the debugging process.

Using a separate is in complete contrast to most OSs, which include the debugger information in the object file, which in turn is stored in the library file. You must specify the debugger argument at the time of creating the library, for example:

```
$ mwcc -g -xms foo.o bar.o -o foobar.so
```

When installing the library file, make sure you also copy across the appropriate symbol file.

Profiling

Profilers are used to monitor the performance of specific functions and areas of code. This includes monitoring the code's speed of execution , and how long specific functions are called.

The process of profiling happens in two stages. First the compiler adds code to the functions it is compiling and uses a library for the support functions. During execution, a file is produced which is processed by the profiling application. Profiling a program can help to improve both its performance and the quality of code you produce.

A profiling library is now available as part of the full Metrowerks CodeWarrior BeIDE, and profiling support is built into the supplied mwcc compiler using the -profile option:

```
$ mwcc -c -profile on foo.c
```

Luckily, this shouldn't pose too much of a problem during porting. Generally the profiling process is only useful when first writing the software, although it can be useful to identify problems in parts of ported code.

Chapter 14: The Debugger

Identifying and removing bugs is an art. You need to locate the problem and find a solution. When programming your own software, this process is relatively easy. You know the problem, and you know the likely reasons for the problem. Most of the time, the problem is a typing error, or a mismatch somewhere between data types, pointers, or other information.

Working with somebody else's program is more difficult, and in porting the focus shifts from the code that constitutes the program to the functions and data types that you are using. We will see in Chapter 15 that a large number of problems with ported software stem more from mismatches between functions and less from the way the program works.

Using a debugger can aid the process by showing, in real-time as it were, precisely what the program is doing, and what the values of the variables are at that point. There are three ways of debugging applications on the BeOS. The first, the OS debugger, is a machine code-level debugger that can sometimes help with tracing a problem. It is the first debugger you will come across when you run a BeOS application that fails, as it automatically loads when a program crashes.

The second debugger is the symbolic debugger, so named because it shows you the symbols within the application, as well as the variables and other data, all in the native format of standard C source code. Of all the debuggers, this is probably the most useful as it provides the most comfortable interface to the insides of an application.

The final method of debugging is the use of printf and other commands to supply you with progress information.

Depending on your experience this is the most useful or the most useless type of debugging. In this chapter, we will take a look at how to use all these methods, and how to get the best out of them in the process. We will also discuss the various merits of each method.

The BeOS Debugger

The BeOS debugger is built into the operating system and allows you to control or examine a running or crashed program. The debugger is what most people would class as an *absolute debugger* because it displays the assembly language and registers of the processor rather the variable names and program lines (symbols) that would be available in a symbolic debugger.

The name Absolute Debugger is a reference to the fact that the code and variables you are seeing are those on the processor. What you are viewing is the absolute, or complete version of the application. You cannot get a more precise or exact view of a running application than the code executing on the processor. Unlike the symbolic debugger, it isn't relating the values in the processors registers back to variables.

It is the BeOS debugger that appears when you run a program that crashes, effectively the same operation as a UNIX machine deciding to dump the core, although on the BeOS you drop into a debugger which can help you resolve the problem instantly, without having to separately run a debugger.

You can also cause the program to drop into the debugger by calling the debugger() function within the source code, or, finally, by running the db program. For example, to debug the application foo, you'd use the command:

```
$ db foo
```

Alternatively, you can debug a running application by specifying the thread (or process) number:

```
$ db 138
```

In all cases, for the program to be debugged properly a symbol file must be available. This should have been created at the compile stage using the -map option, for example:

```
$ mwcc -map foo.xMAP foo.c
```

Note however that this symbol map is different to the symbol file created with the -g option to the compiler. Compiling a program with -g does not create a BeOS debugger .xMAP file, you must specify the option at the time of compilation.

When the debugger starts, you end up in a Terminal window the title of which is the program Team number. We will look at BeOS-specific programs, including teams and threads, in Chapter 16. The first thing that is shown, providing you have generated an .xMAP file, is the function which caused the program to abort. In this example, temacs, the executable generated when emacs is built, has generated an error:

```
data access exception occurred
make_pure_string:
+0074 8000b7ec:  93a70000 *stw       r29, 0x0000 (r7)
temacs:
```

Within the debugger you can run a number of commands to determine why you ended up there, and to find out the status of the machine. db, being an absolute debugger, is pretty useless unless you know what information and data the registers should contain.

Using the sc command you can display a stack crawl. The stack crawl displays the contents of the stack including any called functions, variables or chunks of allocated memory. Depending on how well you know your application this may or may not be useful to you.

The most useful function the debugger is to provide a relatively safe way for the program to quit execution using the exit command. Unfortunately, it isn't completely reliable, and in some cases can bring the entire OS to a halt. For this reason, you should move onto running the application within the symbolic debugger, which will provide you with more useful information about the reason for the crash.

Caution: Make sure that the application you are quitting from is your application, and not one of the systems servers. You can verify this by running ps in a Terminal window and comparing the number at the top of a debug window with the thread number in the process list.

The Symbolic Debugger

The symbolic debugger is supplied with the development tools on the BeOS. Being a symbolic debugger it deals with the debug process at source level and allows you to interactively refer to the variables and program statements by name and line number from the C source code they were compiled from.

In general through a symbolic debugger you should be able to:

- View program execution using the source code instead of the assembly language equivalent.
- Identify the location and function/data which caused the crash. This is usually handled by a "backtrace" command which displays a listing of the functions called that lead to the error. In the BeOS debugger the functions are shown in a separate window; see below for more details.
- View the address space and value of data in both the native (unreadable) form and the "human" (readable) form. Under the BeOS this includes identification of the constituent parts of structures, unions, and arrays.
- View the assembly language equivalent, and the register values.
- Set a breakpoint. A *breakpoint* is a logical reference to a line within a program. The breakpoint causes execution to stop and it's often used within loops to enable you to identify the variable values, and just before points known to cause the program to crash so you can monitor the variables leading up to it.
- Single-step through the program. Sometimes called "step-over," this involves running successive *lines* of the source code individually. Attached to this, the BeOS (and other debuggers, including gdb, not currently supported on the BeOS) also support what is classed as step-into and step-out. Step-into allows you to debug not only the source of main() but also the functions which it calls. Without step-into, you would only be able to identify the line within the main() execution

sequence that caused a problem. Step-out is the reverse of this process. Using both commands allows you to control the level of granularity with which you view the source, and ultimately, the errors.

You control the debugging process via a simple interface which provides access to the program execution sequence, the source code, and other variables and functions within it. All this information is displayed in different windows and allows for easy cross checking. To start the debugger, drag and drop the .xSYM file produced during compilation onto the debugger application which can be found in /boot/develop/debugger/MWDebug-Be.

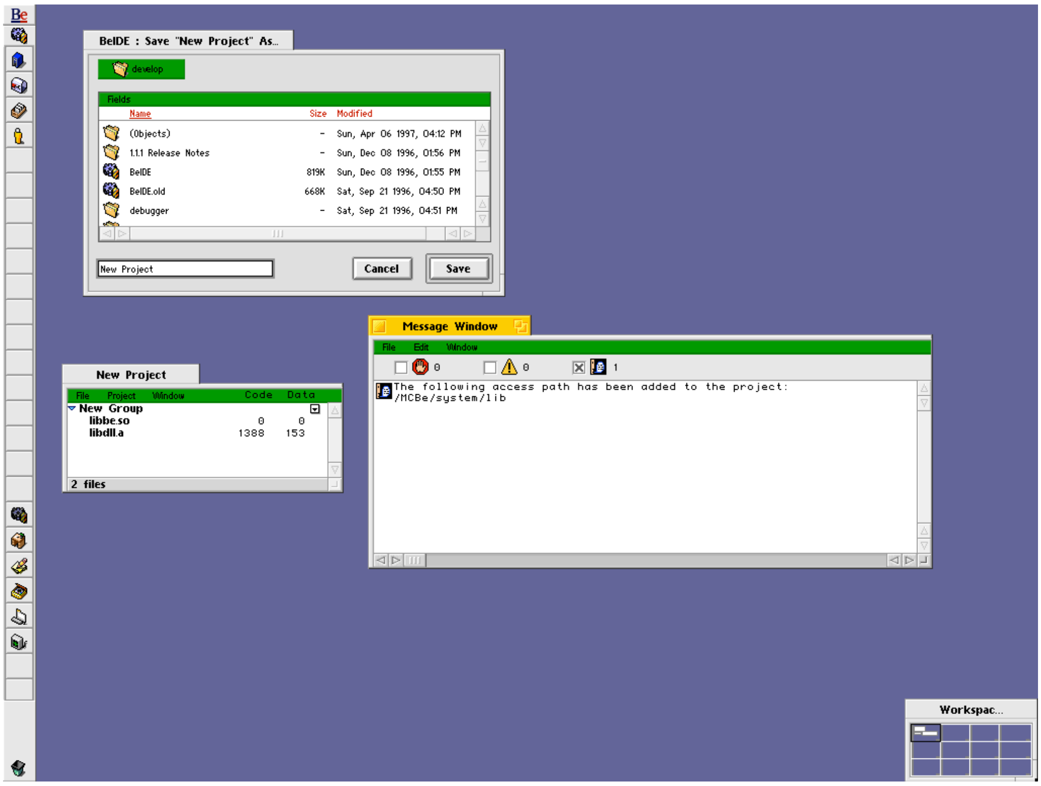
If the program you are debugging normally performs all of it's input/output via a Terminal window, you need to start the Debugger differently.

1. Open a Terminal window
2. Run the debugger from the command line:
3. $ /boot/apps/Metrowerks/debugger/MWDebug-Be.debug
4. Choose "Open" from the File menu and select the symbol file relating to the application you want to debug

Using this method, all the input/output of the application continues to go via the Terminal instead of being lost.

Once the symbol file has been opened, you will be presented with two windows. In Figure 14.1 you can see the main debugger window which contains the name of the application. We will take a look at the second debugger window, which refers to the .xSYM file shortly.

Figure 14.1
The main debugger window

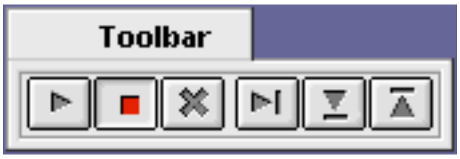


The main window shows the current program and the state of execution. The window has two main panes. The lower one shows the current execution position within the program source. In between these two panes is the toolbar which allows you to control the execution of the program you are debugging. We will take a closer look at this later. The top pane of the main window is split again and shows the function stack in the left pane. This is the list, in order, of the functions that have been called to reach the current point. In the sample window you can see there are only two functions listed. __start is the library function which precedes the main() function and sets up the environment to be ready for the program to start.

The right-hand part of the top pane shows the currently active variables in the application. Numbers, addresses, and pointers show their values. Character strings and structures are displayed by their address in memory space; the blue triangle to the left of the variable name expands this definition to show either the contents of the string or the variables which make up the structure or union. Successive variables can then be expanded again. This allows you to show the contents of, for example, the argv variable usually defined either as char **argv, a list of pointers to pointers which themselves point to character strings or char *argv[], a list of pointers to variable length strings.

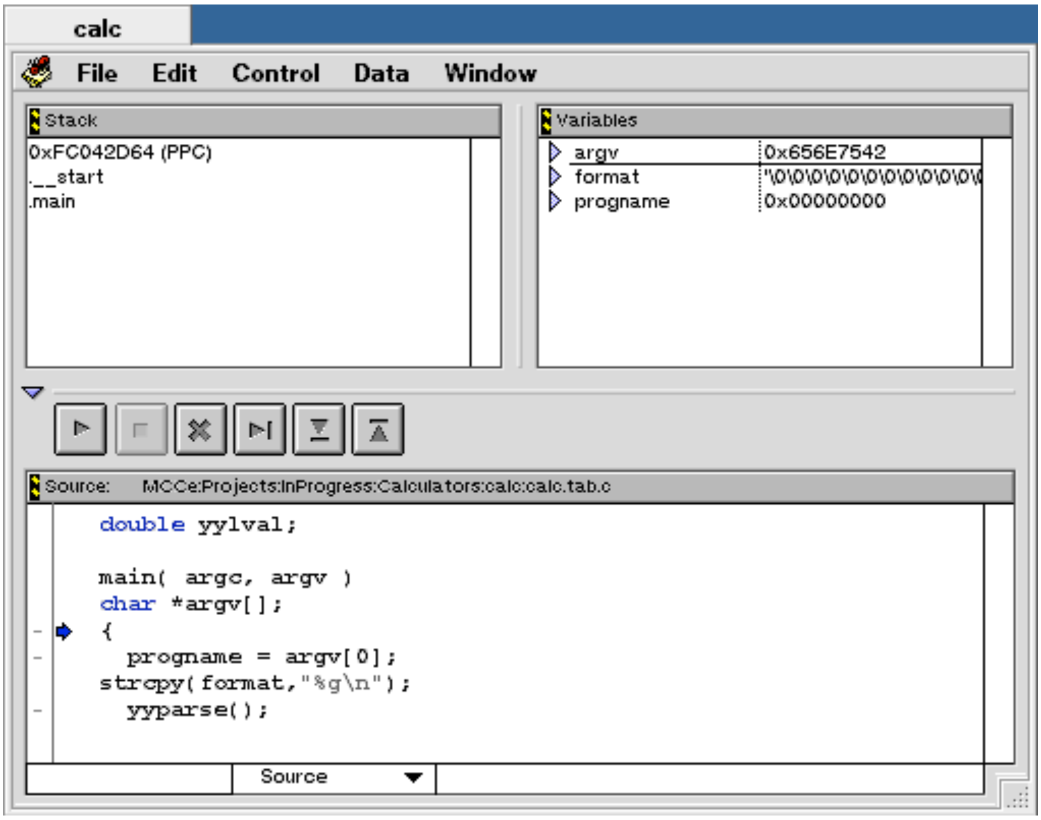
Control is handled by the toolbar window shown in Figure 14.2. Each button controls a different event in the execution of the program. The first will run the program if it is not already running (Alt+R). The second stops the program when it is running (Alt+.), and the next, with the cross on it, kills the program completely (Alt+K). The next three buttons control the execution. The first performs a step-over, executing a single line of source code (Alt+S). The second and third step into (Alt+T) and out of (Alt+U) the code. If the current line is a function within the current application it will move the main window into the file containing the function's source. If the source isn't available, then the assembly language equivalent of the current source line will be shown instead. The last takes you back up the levels to the source for main(). Menu equivalents for all the toolbar buttons can be found under the Control menu in any of the other debugger windows.

Figure 14.2
The debugger control panel



The symbol window, Figure 14.3, is split into two separate panes. The bottom pane shows the source code or assembly language for the selected function or variable. The top pane is split into further sections, with the section on the left listing the source files, the middle section showing the functions within the selected file, and the last section the global variables within that file. You can view individual functions and source files within this window independently of the program window. The contents of this window are basically the output contents of the symbol dump, which itself is contained in the .xSYM file. Selecting functions or variables will automatically display the relevant section of the source file. As with the program window, you get the option to select the display in either source or assembly form by using the pop-up at the bottom of the window.

Figure 14.3
Viewing symbols within the program



Within any window (except the toolbar) if you want to edit a selected file, use Alt+E (or Edit Filename under the File menu) to open the file within the IDE editor window.

For a demonstration of how to use the debugger, let's look at a real example. I've shown the output here as text, instead of multiple debugger windows, to make it easier to read. Going back to our temacs problem above, opening the same file within the debugger and running the program shows us a fault within the make_pure_string function; more specifically, the program halts at the XSETSTRING line:

```
Lisp_Object
make_pure_string (data, length)
     char *data;
     int length;
{
  register Lisp_Object new;
  register int size = sizeof (EMACS_INT) + INTERVAL_PTR_SIZE + length
+ 1;

  if (pureptr + size > PURESIZE)
    error ("Pure Lisp storage exhausted");
  XSETSTRING (new, PUREBEG + pureptr);
  XSTRING (new)->size = length;
  bcopy (data, XSTRING (new)->data, length);
  XSTRING (new)->data[length] = 0;

  /* We must give strings in pure storage some kind of interval.  So
we
     give them a null one.  */
```

```
#if defined (USE_TEXT_PROPERTIES)
  XSTRING (new)->intervals = NULL_INTERVAL;
#endif
  pureptr += (size + sizeof (EMACS_INT) - 1)
           / sizeof (EMACS_INT) * sizeof (EMACS_INT);
  return new;
}
```

Hmmm...XSETSTRING is probably a macro, it's all in capitals. This is where the usefulness of the debugger stops, although it's already provided us with the piece of information we want to know. The problem with a symbolic debugger is that the source code it shows you is the source code that was compiled. It takes no account of any preprocessing and so macro definitions like XSETSTRING have to be traced manually. Just before we leave the debugger, let's check the values for the two variables new and pureptr shown in the right-hand top pane:

```
new = -2146524792
pureptr = 0
```

The value of new looks dodgy, the number is large and it's negative. That doesn't signify a problem as such, since memory is allocated from 2Gb and above in the BeOS. The highest bit will be set, and will therefore display as a large negative number. Printing it as a hex value would make it look less conspicuous. Even so, it still looks wrong. Checking back in the source code the variable was never initialized when it was created, so a random number probably isn't that weird. As for pureptr, it looks equally dubious, but with a value of zero it probably won't cause us too much trouble. Dropping to a Terminal window, we need to look for the definition. We'll try their source file first, in case it's local:

```
$ grep XSETSTRING alloc.c
      XSETSTRING (val,
      XSETSTRING (val,
      XSETSTRING (val,
  XSETSTRING (new, PUREBEG + pureptr);
  XSETSTRING (*(Lisp_Object *)&buffer->upcase_table, buffer-
>upcase_table);
  XSETSTRING (*(Lisp_Object *)&buffer->downcase_table, buffer-
>downcase_table);
  XSETSTRING (*(Lisp_Object *)&buffer->sort_table, buffer-
>sort_table);
  XSETSTRING (*(Lisp_Object *)&buffer->folding_sort_table, buffer-
>folding_sort_table);
                  XSETSTRING (*objptr, newaddr);
                XSETSTRING (*objptr, newaddr);
              XSETSTRING (* (Lisp_Object *) &newaddr->intervals-
>parent,
```

Nope, not there, let's look in the header files instead:

```
$ grep XSETSTRING *.h
lisp.h:#define XSETSTRING(a, be) XSET (a, Lisp_String, be)
```

Doesn't help us much, it's just a macro which references what appears to be another macro. If we look for the XSET macro, we get even more matches:

```
$ grep XSET *.h
config.h:#undef HAVE_XSETWMPROTOCOLS
frame.h:#define XSETFRAME(a, b) (XSETPSEUDOVECTOR (a, b, PVEC_FRAME))
```

```
frame.h:#define WINDOW_FRAME(w) ({ Lisp_Object tem; XSETFASTINT (tem,
frame.h:#define XSETFRAME(p, v) (p = WINDOW_FRAME (***bogus***))
lisp.h:#ifndef XSETTYPE
lisp.h:#define XSETTYPE(a, b) ((a)  =  XUINT (a) | ((EMACS_INT)
lisp.h:   and XSETFASTINT provides fast storage.  This takes advantage
lisp.h:#define XSETFASTINT(a, b) ((a) = (b))
lisp.h:#ifndef XSET
lisp.h:#define XSET(var, type, ptr) \
lisp.h:#ifndef XSETMARKBIT
lisp.h:#define XSETMARKBIT(a,b) ((a) = ((a) & ~MARKBIT) | ((b) ?
lisp.h:#define XSETTYPE(a, b) ((a).u.type = (char) (b))
lisp.h:   and XSETFASTINT provides fast storage.  This takes advantage
lisp.h:#define XSETFASTINT(a, b) ((a).i = (b))
lisp.h:#define XSET(var, vartype, ptr) \
lisp.h:#define XSETMARKBIT(a,b) (XMARKBIT(a) = (b))
lisp.h:#define XSETINT(a, b) XSET (a, Lisp_Int, b)
…
```

Nothing definitive, but lisp.h looks like it might contain a number of these definitions. Any one of these definitions could be the one we're looking for, and each one is probably selected by a configuration option. Rather than wading through the source and then the config files to find the one we're currently using, we can cheat and use the pre-compiler to show us what's actually going on:

```
$ mwcc -E -i- -I. -I.. alloc.c >alloc.cpp.out
```

The other advantage of this is that we will resolve what the values of some of the other macros are. The output for the make_pure_string function looks complicated. I suggest you skip over this output if you have a phobia of parentheses:

```
int
make_pure_string (data, length)
char *data;
int length;
{
register int new;
register int size=sizeof(int) +(sizeof (struct interval *))+length +
1;
if (pureptr + size > ((240000 + 0 + 0) * 1))
error ("Pure Lisp storage exhausted");
((new) = ((int)(Lisp_String) << 28) + ((int) ((char *) pure + pureptr)
 & ((((int) 1)<<28) - 1)));
((struct Lisp_String *) (((new) & ((((int) 1)<<28) - 1)) |
0x20000000))
->size = length;
bcopy (data, ((struct Lisp_String *) (((new) & ((((int) 1)<<28) - 1))
 | 0x20000000))->data, length);
((struct Lisp_String *) (((new) & ((((int) 1)<<28) - 1)) |
0x20000000))
->data[length] = 0;
((struct Lisp_String *) (((new) & ((((int) 1)<<28) - 1)) |
0x20000000))
->intervals = 0;
pureptr += (size + sizeof (int) - 1)
/ sizeof (int) * sizeof (int);
return new;
}
```

Ouch! The line we're interested in is this one:

```
((new) = ((int)(Lisp_String) << 28) + ((int) ((char *) pure + pureptr)
 & ((((int) 1)<<28) - 1)));
```

If we check back with the debugger for what some of the values are, and then calculate them, we can shorten the expression to:

```
new = ((int)(Lisp_String) << 28) + 698540)
```

Alternatively, we can try to evaluate the expression using the debugger's expression window. Open the window using the Expression option in the Window menu and then use New Expression under the Data menu to enter any expression you like. If we try the expression above it will fail because it doesn't recognize Lisp_String as being a variable.

Searching the source code again, we find that Lisp_String is in fact a structure and so the expression doesn't appear to make any sense. To try to make sense of this expression, we can modify the source code to incorporate a printf that displays the value of (int)(Lisp_String) << 28. This is helpful; we get a value of 805306368. Incorporate that into our equation above, and we get a large figure. It's no wonder the program crashes with a data access exception, it's trying to create a variable at an address of 768Mb. We already know that user memory is allocated at an address of 2Gb or higher, and therefore the program is trying to create a memory block within the kernel data area.

Here we hit upon another problem with debuggers: although we now know why the problem exists, it will take us time to work through the header files, and ultimately the configuration files, before we resolve the problem. That's not to put the debugger down; it has provided us with the information about where the problem started, and from that we could fathom what the likely problem was. Of course, there are other ways of finding out this information.

Manual Debugging

There are many people who are against the principle and process of manual debugging. Depending on your experience of debuggers, you may prefer this less complete but often faster method of debugging. The process entails using printf statements to show the progress and/or variable contents during the execution of a program.

Often, this is more useful than using a debugger, particularly if you want to monitor the point or function at which a program is failing, or during long for and while statements where the debugger would have to be stepped through the program lines instead of simply providing a list of the values.

There are some obvious disadvantages to using manual debugging. Each time you make a modification to the information you want to view, the program must be re-compiled. This in itself is not a problem, apart from the time aspect, but it introduces extra levels of complication, and possible error, that you don't need when trying to port an application.

There are no hard and fast rules for deciding whether to use manual debugging or not. You will need to make your own mind up on whether this method is acceptable to you. Personally, I use this method up to a point. The printf statement can only supply so much information before you lose track of where you are, where you should be, or what values you're really looking at.

I've also found on other platforms (not the BeOS, yet!) that using printf on a string seems to correct a value that would otherwise cause a function to crash. The exact reason in each case is something I have never discovered, but it's made me dubious enough to use manual debugging sparingly. The most likely reason is a timing issue (the printf statement inserts a 'wait' which causes the value to end up correct. Alternatively, it could be related to a optimization or compilation error, and introducing the additional printf statement causes a different code sequence to be created.

We will start by looking at how best to use the printf command, or it's cousin the fprintf command which can be used to send the output to a file, rather than to the standard output. We will then move on to look at some sample uses from my own experience that helped me to solve problems very quickly, and some that provided me with no information at all.

Using printf

Using printf and fprintf is a programming art all its own. In the context of debugging, they are used for two main functions. The first is displaying the progress of the application, the second is displaying variables.

The first technique is the easiest; you just add lines into the program like this:

```
printf("Got here!\n");
```

However, it might be useful if you expand on the description somewhat or risk running a program that outputs the following:

```
$ foo
Got here!
Got here!
Got here!
Got here!
Got here!
$
```

which is not exactly useful.

Much better is to provide information about the location of the statement:

```
$ foo
Opened file (input.dat)
Read data (hello)
```

```
Read data (world)
Read data (today)
Closed file
```

You can also use the printf technique to display variables and strings during the execution. I used this technique in the example above to show me the file I was opening and the data I was reading from the file. Although this is useless for some information, it can provide pointers to potential problems. I used this method to identify a bug in one of my own programs. The program would crash when it reached a certain function call, and checking the output with debugging switched on showed me precisely what the problem was. I'd gotten the name of the file wrong, but hadn't checked for this simple mistake in the code:

```
#include <stdio.h>
#include "db.h"

#define IFILE "import.txt"

void main()
{
  int i;
  FILE *import;

  ip_record tmp_ip_rec[40];
  db_file_record newdb;

       printf("Started\n");

  create_db("dbfile.db");

       printf("Created database\n");
       printf("About to open file %s\n",IFILE);

  import=fopen(IFILE,"r");

       printf("Got here\n");

  for(i=0;i<40;i++)
    {
      fscanf(import,"%s%s
\n",tmp_ip_rec[i].ip_addr,tmp_ip_rec[i].name);
      tmp_ip_rec[i].id=i;
    }
  fclose(import);

  for(i=0;i<40;i++)
    write_record("dbfile.db",tmp_ip_rec[i],sizeof(tmp_ip_rec[i]));
}
```

The bad file name specified by IFILE didn't occur to me until after I ran the program:

```
$ ./testdb
Started
Created database
About to open file import.txt
Drop to debugger
```

It took a few minutes for the problem to sink in, but without the mental prompt of the file name, I would never have discovered the problem.

All you are really doing when using printf is providing a running commentary on the progress of the application. Some packages offer an extra level of debugging that provides a similar facility. It's not uncommon to come across statements like this:

```
#ifdef MEMDEBUG
printf("Freeing up %ld bytes of memory\n",net_buffer);
#endif
```

The authors are just using the same manual debugging principles to aid in the porting process. You can switch the debugging on and off at compilation time by defining the macro:

```
$ mwcc -c -DMEMDEBUG lib.c
```

and when the problem is solved, compile the source again without the debugging switched on.

Unfortunately, this technique doesn't always work. When working with emacs I decided to use this technique to identify the point at which a particular function failed. Within emacs a number of the functions are defined as complex internal functions based around a combination of the elisp language and C code, all strung together with complex macros sorting out the data types and complex structures used by the program.

We've already seen the effect of running temacs and how this triggered the OS debugger, and also traced the problem within the symbolic debugger. Before I moved to the symbolic debugger I tried the manual route by adding in the appropriate printf statements describing the current location during execution. All I discovered using this method was that the real problem didn't lie in the emacs.c source file.

I managed to trace the failure to make_pure_string in alloc.c, and then down to a specific line:

```
XSETSTRING (new, PUREBEG + pureptr);
```

I could even display the values of the variables, but I couldn't identify the problem without then checking the source code using a combination of grep and my favorite editor.

OK, so the technique didn't fail, but to get to the point I needed to get to —the macro that caused the problem—I had to hand edit and recompile a lot of different files. I wasted an hour, perhaps 90 minutes trying to identify the problem this way, and it got me to the same conclusion as the symbolic debugger. The difference is that with the symbolic debugger it took seconds.

Creating a Log File

An extension of the printf principle is to create a set of functions which write errors and information out to a log file. This is most useful with text-based programs that send all of their output to the Terminal and extracting your printf statements from the normal text that is sent to the screen as part of the application will be difficult.

I use the small file below to do most of my work for me. The newlog function just creates a file, and the writelog function will take variable-length argument lists to make reporting conditions with additional information as easy as possible.

```
#include <stdarg.h>
#include <stdio.h>
#include <errno.h>

#define LOGFILE "./execlog"

int newlog()
{
  FILE  *new;

  if ((new=fopen(LOGFILE,"w")) == NULL)
    {
      fprintf(stdout,"ErrLog:Fatal Error\nCant open error file\n");
      return(1);
    }
  fclose(new);
  return(0);
}

void writelog(char *format, ...)
{
  va_list args;
  char str[1000];
  FILE *errlog;

  va_start(args, format);

  vsprintf(str,format,args);

  if ((errlog=fopen(LOGFILE,"a")) == NULL)
    {
      fprintf(stdout,"ErrLog:Fatal Error\nCant open error file\n");
      return;
    }

  fprintf(errlog," %s\n",str);

  fclose(errlog);

}
```

To report an error, you can use the same printf format used above:

```
writelog("Got here, value of str is %s, current errno:%d",str,errno);
```

The LOGFILE macro specifies the location of the file for all the information to be written to. You'll need to compile this and then link it with the final executables in each case. It's coded so that a failure to open or write the log file doesn't affect the execution of your program, but obviously you'll lose any errors recorded using the function.

Tracking the progress of a program is not always as easy as it first appears. You may think you know what the program is doing, but until you trace it with a debugger, you can't know for certain. Debuggers take the guesswork out of solving bugs and can save you hours of work. However, they are complex applications that often provide you with more information than you want, or less information than you need.

In these situations, it probably pays to use printf instead. On the other hand, using printf can similarly supply you with mountains of useless information as the program executes, or not enough information to isolate the problem. Often, printf will point to something you could have found much easier using the debugger.

Chapter 15 - Building the Package

Thus far we have focused on the processes and programs used to conduct a port, without actually covering the build itself.

You already know how to extract the package, how to configure it, even how to debug it after it's been compiled. What you don't yet know is how to cope with the error messages produced during compilation, and how to interpret those back to the configuration.

Hopefully, if the extraction, preparation, and configuration have gone correctly, this should be the easiest part of the process. Unfortunately, the truth is that this is the most tiresome part of the process as you grapple with the compiler, the configuration, and the actual source code to produce the goal. Porting is a recursive process, and as such you will return and repeat the same steps and the same commands many times before you actually complete the process.

It can be disheartening to try yet another modification to the program and not achieve the final, desired result. You could build the project by hand as you manually compile the sources, then link everything together, only to find there is still some missing component required at the linking stage. You need to keep a clear head, make plenty of notes, and always consider the simplest possible causes of a problem. It will become apparent as we go through the process in this chapter that the bulk of problems are caused by missing header files, which in turn are usually caused by incorrect configurations. Above all else, testing the code you have produced is vital. We'll take a look at the errors and their likely solutions from the first time you type make up until the point when you install the files.

Keeping a Log

Keeping a log, in whatever form (even paper!), is vital when you are porting software. You must keep track of what you've done, what you've changed, and the different solutions you've tried.

If you decide to use a version tracking system such as RCS the process of logging and returning to any changes you might have made is easy. If you prefer to work without RCS (and I do) then you need to create a file, or a number of files, which show the steps that led you to the final version.

I use a simple script which takes in my input, prepending the date and time, and stores it in a corresponding file depending on the command-line arguments I give it. For example, to write a comment about about the build in general I type:

```
$ writelog
```

and start typing in my comment. The result is stored in the file build-log.general. To comment about a specific file, I use

```
$ writelog config.h
```

The result from this command is written to build-log.config.h where the extension is the file name. Using this technique for file naming means I can very quickly see which files I have modified or made notes on.

The script itself is very simple:

```
#!/bin/sh
if [ $# -lt 1 ]
then
logfile=build-log.general
file=General
else
logfile=build-log.$1
file=$1
fi
echo "Comments for $file@
date >>$logfile
cat >>$logfile
echo "--" >>$logfile
echo >>$logfile

echo "Comments appended to file $logfile"
```

When creating the log, remember to include as much information and detail as would be needed to recreate the same source version again. Your log, in whichever form, is the only way in which you can reliably make the changes necessary to complete the build. It should form your "notepad" of thoughts and ideas on how to progress the port to its final conclusion.

Storing Output

Another vital tip when porting software is to store the output from the build/make/compile process. This is vital not only as an additional reference to your logs, but also to help you make the necessary changes to the source. You need to make sure that you capture all the potential output from a build using redirection; for example,

```
$ make >make.log 2>&1
```

will capture both the standard output produced by make and the errors produced by the compiler.

When using the output that was generated, open the file in an editor and examine the file, then use the section below to identify and resolve the problems. If you need to make a number of modifications, do it in reverse order and that way the line numbering given in the errors will remain the same as you proceed to the start of the file. Remember, however, that some errors early on in the source file will have knock on effects. For example, a missing header file may cause problems and errors throughout the rest of the file. Make sure you check the first few errors and see if you can identify the obvious before making sweeping changes in the code.

You might decide to keep different versions of the output generated, but in general they shouldn't be needed, as the most recent build should have been the most successful. On the other hand, you may find that previous versions aid the logging process by showing both the problems and the method in which you fixed them. You might even decide to use the file to help produce the Changes document you supply with the package.

Compilation Errors

You will find that a large number of the errors reported during compilation are actually caused by simple but fatal errors. From the moment you type make (or its equivalent) there are literally hundreds of reasons for the compilation to fail. The most common ones are missing header files and the absence of structures, datatypes, and macro definitions usually specified in those files. In the following sections we will take a look at some of the more common errors and how to solve them.

Missing Header Files

Because header files are included at the top of a source file during the preprocessing stage they are the first error to be reported. Header files also define and set up many of the definitions, function prototypes, and variables used by the rest of the source code. Because of this, they generate knock-on errors (missing variables or bad functions for example) that can fool you into thinking something else is wrong.

For example, consider this output from building gdbm:

```
cp ./testndbm.c ./tndbm.c
mwcc -c -I. -I. -O  ./tndbm.c
### mwcc Compiler Error:
#      #include <ndbm.h>
#                      ^
# the file 'ndbm.h' cannot be opened
#-----------------------------------------------------------
File "/MCCe/Projects/InProgress/Porting/begdbm1.7.3/tndbm.c"; Line 45
#-----------------------------------------------------------
### mwcc Compiler Error:
#      datum key_data;
#      ^^^^^
# undefined identifier 'datum'
#-----------------------------------------------------------
File "/MCCe/Projects/InProgress/Porting/begdbm1.7.3/tndbm.c"; Line 65
#-----------------------------------------------------------
### mwcc Compiler Error:
#      datum data_data;
#      ^^^^^
# undefined identifier 'datum'
#-----------------------------------------------------------
```

```
File "/MCCe/Projects/InProgress/Porting/begdbm1.7.3/tndbm.c"; Line 66
#-----------------------------------------------------------
### mwcc Compiler Error:
#      datum return_data;
#      ^^^^^
# undefined identifier 'datum'
#-----------------------------------------------------------
File "/MCCe/Projects/InProgress/Porting/begdbm1.7.3/tndbm.c"; Line 67
#-----------------------------------------------------------
### mwcc Compiler Error:
#      char key_line[500];
#      ^^^^
# expression syntax error
#-----------------------------------------------------------
File "/MCCe/Projects/InProgress/Porting/begdbm1.7.3/tndbm.c"; Line 69
#-----------------------------------------------------------
### mwcc Compiler Error:
#      char data_line[1000];
#      ^^^^
# expression syntax error
#-----------------------------------------------------------
File "/MCCe/Projects/InProgress/Porting/begdbm1.7.3/tndbm.c"; Line 70
#-----------------------------------------------------------
### mwcc Compiler Error:
#      DBM *dbm_file;
#      ^^^
# undefined identifier 'DBM'
#-----------------------------------------------------------
File "/MCCe/Projects/InProgress/Porting/begdbm1.7.3/tndbm.c"; Line 72
#-----------------------------------------------------------
### mwcc Compiler Error:
#      char done = FALSE;
#      ^^^^
# expression syntax error
#-----------------------------------------------------------
File "/MCCe/Projects/InProgress/Porting/begdbm1.7.3/tndbm.c"; Line 74
#-----------------------------------------------------------
### mwcc Compiler Error:
#      char *file_name;
#      ^^^^
# expression syntax error
…
# too many errors
# errors caused tool to abort
```

There are 377 lines in the full output, which I've truncated here for brevity. A number of errors are reported, including missing identifies and syntax errors, but the root of all the problems is the missing header file. In this case, the problem can be solved by specifying an additional header directory in the compiler command line. In this example, I need to include some contributed library and header files from the dbm database sources. We looked in Chapter 13 at how to refer to other directories for header files and libraries.

Missing header files usually have one of two symptoms. Either the header file cannot be found, or the header file is mis-referenced or mis-described. The first problem is usually solvable by modifying the include directory options to the compiler. Going back to our gdbm example, all references to the configuration header autoconf.h are made as local references:

```
#include "autoconf.h"
```

emacs on the other hand references the config.h as a system include:

```
#include <config.h>
```

To make sure the header file is found and used correctly we need to specify additional search locations to mwcc:

```
$ mwcc -i- -I. -I.. -c fileio.c
```

The second cause, incorrect header file names, is more difficult to solve. The question of what header files are available and which the package should use should have been resolved at the configuration stage. A very common source of trouble is the header file which defines the string handling routines such as strcpy. On many systems the name of this file is strings.h; on others, the BeOS included, the name of this file is in fact string.h. The two files contain largely identical definitions and function prototypes; it is only the files' names that are different.

In extreme cases you may find that the header files you have just don't contain what the package expects to find. In these circumstances you will need to either search for the real location of the item, or, if it can't be found, attempt to plug the gap with alternative source.

Undefined Defines

Providing you have overcome the problems of header files mentioned above, resolving undefined definitions (the next most common cause of errors) requires a more extensive search. You need to search the header files to make sure the definition isn't hidden elsewhere. Alternatively, you may find that a simple definition requires making substantial modifications to the code to get around the differences.

Martin: Sorry, but the above sentence just isn't clear. Try breaking it down into more than one sentence, and see if you can clarify. -Mark

Better? MC

The problems of an undefined macro definition are difficult to trace because the preprocessor doesn't really know whether the item it's looking for should or shouldn't be a macro. For example, the code fragment:

```
if ((fp=fopen(INFILE,"r"))==NULL)
       return(-1);
```

looks fairly innocent, but compiling it without defining the INFILE macro produces a rather cryptic error:

```
### mwcc Compiler Error:
#       if ((fp=fopen(INFILE,"r"))==NULL)
#                     ^^^^^^
# undefined identifier 'INFILE'
#----------------------------------------------------
File "fileread.c"; line 47
#----------------------------------------------------
# errors caused tool to abort
```

All the compiler tells us is that it doesn't recognize the word as either a variable or a suitable string value.

What we need to do is identify what INFILE should be before we fix the problem. Almost certainly the fact that the name is all uppercase means it is a macro definition, but we should confirm this. The first thing to do when looking for a macro definition is to search the local source files and see if it is used elsewhere. Chances are, if it is, we can get an idea from that file what the definition is and where we can find it. We can do this using grep, and for speed we'll ask grep only to report the files it finds the string in.

```
$ grep -l INFILE *.c
fileread.c
```

We already knew that…

Now let's try looking in the local header files:

```
$ grep -l INFILE *.h
files.h
```

Aha! We do a line search on that file:

```
files.h: #define INFILE "infile"
```

and we've found it. To fix the problem all we need to do is include the header file in the source, or find the configuration option that switches the inclusion of that file on. Usually the configuration is handled by some sort of script, or by one of the header files supplied with the package. Refer to Chapters 9-11 for more information.

If we hadn't found it, the next stage would be to search the system header files.

```
$ cd /boot/develop/headers/posix
$ grep -l INFILE *.h sys/*.h
```

If we could find the definition here then the process is the same, we need to ensure that the file is included in future when compiling. If there isn't a built-in option for specifying this in the configuration system then we will need to add our own. It's best to do this as simply and effectively as possible; remember that your port should also be portable to other machines and eventually you'll be passing the code back to the author.

For this reason, include the header statement within some qualifiers, for example:

```
#ifdef BEOS
#include <ctype.h>
#endif
```

You will need to modify the build commands or the configuration file so that BEOS is defined when it comes to compiling the source again.

If the definition can't be found anywhere, you have to make a decision about the package you are porting. If the package you are porting is important, or required, then you will need to find an alternative source of the definition and almost certainly the functions and variables that go with it. We'll look at this again later in this chapter, and in more detail for specific items in Part 3 of this book.

Undefined Variables

Getting an undefined variable error is generally quite rare. The bulk of source code should be written with variable names "hard-coded" as it were. However, for compatibility and portability reasons some variables are defined within an #ifdef statement, and not having the configuration right will cause the wrong version, or in some cases no version, of the variable to be included.

The trick is to find where the variable is used, and then the function header in which it is defined so you can identify what datatype the variable should be. You can use the same method as before. Use grep to search the source code and header files to look for the original definition.

Undefined Types

Invariably, an undefined type is caused either by the lack of the correct header file, or by a fault in the configuration which fails to either define the type or include the necessary file.

Incorrect/Incompatible Types

The mwcc compiler is notoriously strict at character conversions. If you take a look at my port of emacs you will notice numerous modifications that add a type cast to the strings used. This is not because the strings are defined badly, but because occasionally mwcc doesn't like doing a conversion between const, unsigned, and signed character strings. For example, from fileio.c I have to make a modification to the getpwnam function call:

```
#ifdef BEOS
      pw = (struct passwd *) getpwnam ((const char *)(o + 1));
#else
      pw = (struct passwd *) getpwnam (o + 1);
#endif
```

You can tell mwcc to be more relaxed about it's pointer conversions by using the -relax-pointers command line option.However, it's probably a good idea to make these manual modifications anyway.

In general, incorrect or incompatible types are probably caused by a header file error, which ultimately leads you back to configuration. You have two choices here: either modify the header files to be compatible (dangerous and inadvisable) or use the technique I described above. If there is a configuration option to change the datatype within the package, use it in preference to modifying the source code.

Unexpected End of File

This is an unmatched parenthesis, #ifdef, or similar statement where the compiler is expecting to find a closing statement or character, but instead finds the end of a file. It is unlikely that you would find one of these in a package' it will usually have been picked up by the author before the package was sent out. But, as we'll see in the next section, it is possible to make the mistake yourself.

Introducing New Errors

You should be careful when making changes not to introduce any more errors, or worse introduce any problems which will make the code incompatible with your current system by making it reliant on some other unsupported function.

It's easy to make the situation worse simply by forgetting to add or remove a particular line. For example, a good trick I've already mentioned is to comment out code using macro definitions when compiling. I often use

```
#ifndef BEOS
…
#endif
```

and then pass the BEOS definition via the configuration file. This quickly comments out a particular section without requiring me to edit the file to enable it again. Forgetting the #endif will disable the remainder of the file, and introduce an unexpected end of file error.

Another common problem is adding definitions to the configuration in order to fix a problem in one file, only to make compilation of another file fail. I came across just such a problem when working on a commercial port to the BeOS. The functions for converting between network byte order and host byte order were defined in one source by default. A straight compile produced an error because the functions were already defined.

Changing the configuration successfully commented out the offending functions, only to have a different source file fail because the compiler couldn't find the functions when it came to linking the file.

When building packages, whenever you change the configuration you should recompile the entire package to make sure that your modification doesn't cause a different file to fail during compilation. The easiest way to do this is to run make again specifying clean as the first target:

```
$ make clean all
```

Alternatively, just deleting all the object files should, in a simple package, cause everything to be recompiled:

```
$ rm -f *.o
$ make
```

For more complex packages where source files, object files and the various support files are contained in subdirectories you will need to visit each one and delete the files, or alternatively use a find command such as this:

```
$ find . -name "*.o" | xargs rm -f
```

Compilation Warnings

As we've already covered, compiler warnings can help to point to potential problems. By default, only some of the warnings are produced by the compiler, but these can still help to highlight incompatibilities within the package. You can turn on all warnings using the -w all or -w9 option to the C compiler. Below, we'll take a look at some common warnings and why they occur.

Function Has No Prototype

When a function is used without a prototype, a warning is generated to highlight the fact that no checking can be performed on the format of the function. The error doesn't necessarily point to an immediate problem, but it may mean there is a missing header file. This in turn may be selected by a macro definition in the configuration and therefore point to a badly configured package. The error does however remind you to check the existence of this function when it comes time to link the object code.

The -wlargeargs flag can help you to identify problems with passing large values to functions that have not been prototyped, and may be more useful for identifying problems than using -w9.

Return Value Expected

The function

```
int add(int a, int be)
{
        int c;
        c=a+b;
        return;
}
```

should return the value of a+b, but the return statement doesn't contain the value specified in the function definition. This is sloppy programming, and you will need to modify the source to solve the problem. If you don't do so, the value "returned" to the calling line will most likely be a random value and bare no relevance to the expected value.

Variable *Name* Is Not Used in Function

This error can be caused either by sloppy programming or by code which uses the variable but has been commented out. This shouldn't affect the execution of a program, but will affect the memory used. Obviously with a small variable such as an int it doesn't make any difference, but with a large structure or string it would cause a problem.

Linking Errors

If you get to the linking stage, you have already completed the most difficult part of the build stage. Any file that has compiled correctly without reporting any errors (or warnings) is a major achievement. The problems which manifest themselves during the linking stage are easier to solve and are normally caused by missing functions, libraries, or in some cases even missing object files.

Missing Objects

Most make processes should have failed before they get to the linking stage if a file is missing. The dependency checking should stop the build, but not all Makefiles use dependencies. If you've made your own Makefile you need to check the dependencies.

The mwcc compiler returns this error:

```
### mwcc OS Error:
# can't resolve file path for 'abbrev.o'
# File or directory not found (OSD error -2147454956)
# errors caused tool to abort
```

If you think the file isn't needed, you can get past the problem by faking the existence of the file using touch:

```
$ touch abbrev.o
```

The error will almost certainly disappear. The trick works because make is only concerned with whether the file exists, not its contents. You may find that a different group of linking errors, relating to missing functions, will appear instead. You'll need to check the configuration files and source code to make sure these missing functions are compiled correctly, and we will look at how to identify and fix those problems. Check the Makefile and ensure that the file is in the dependency list; if it isn't, try making the file by hand:

```
$ make foo.o
```

Using make rather than mwcc to build the file initially should force the use of the correct C compiler and options. If this doesn't work, try using the compiler directly. Often you can get away with a simple compiler command:

```
$ mwcc -i- -c -I. -I.. foo.c
```

In other cases you might need to add some more options, such as additional defines, or even additional include directories.

The most likely reason for a missing file, though, is that it didn't compile properly, and that usually points back to a bad configuration and one of our earlier examples.

Missing Libraries

If we look at the remainder of the earlier gdbm example, the build continues to fail because of some missing libraries:

```
mwcc  -o tdbm testdbm.o -ldbm -lndbm -lc
### mwld OS Error:
# can't resolve file path for 'libdbm.a'
# File or directory not found (OS error -2147454956)
# errors caused tool to abort
```

In this particular case the library in question is the basic dbm library, which gdbm aims to replace. The library isn't supplied with the BeOS as standard and so a separate build and port of the dbm library had to take place before I could compile this program.

This behavior demonstrates one of the frustrating elements of the porting process, the "reliant" object code on which the port is based. Admittedly, it is fairly safe to assume that dbm exists on a UNIX system—the dbm libraries are used by many of the core OS programs such as sendmail to store information—but it is also presumptuous to assume *automatically* that the file exists.

Most "missing" libraries aren't missing at all; either they are in different directories, in which case you need an additional -L argument to the compiler command, or you don't need them for the BeOS platform. This latter problem is particularly prevalent in the additional libraries required for functions such as networking. Under Solaris you need to include a number of libraries to provide access to DNS and socket-based services:

```
$ gcc -o foonet foo.o -lnsl -lsocket
```

HP-UX, on the other hand, includes the required functions in the standard C library. Within the BeOS, although the libraries are separate, they are automatically incorporated at link time based on the contents of the $BELIBFILES environment variable. You will still need to remove any specifications for additional libraries from the Makefile because the library names are different.

If the library is supposed to be built during the standard build process, then you have a different problem. Most likely, it's a dependency problem in the Makefile; the build should have failed by now if the library couldn't be built.

Missing Functions

It is quite common to come across missing functions within a package. Dealing with missing functions by matching the functions required by the package with the functions available on the BeOS constitutes a large part of the porting process. The configuration process should have selected the correct functions, and any missing functions, identifiers, or header files which normally go with them should have been identified at the compile stage.

This isn't always the case, however. Particularly in the large, well-ported packages the problem stems not from any missing function in the system library (as such) but from a problem in the source code. A reliance on a specific function is often handled by an additional suite of functions included with the package. emacs and other GNU packages use the sysdep.c file to supply these additional functions. These are then switched on or off by the configuration header file, which specifies which functions are needed. For example, the bcmp function is defined within the sysdep.c file as follows:

```
#ifndef BSTRING
#ifndef bcmp
int
bcmp (b1, b2, length)      /* This could be a macro! */
     register char *b1;
     register char *b2;
     register int length;
{
#ifdef VMS
  struct dsc$descriptor_s src1 = {length, DSC$K_DTYPE_T, DSC
$K_CLASS_S, b1};
  struct dsc$descriptor_s src2 = {length, DSC$K_DTYPE_T, DSC
$K_CLASS_S, b2};

  return STR$COMPARE (&src1, &src2);
#else
  while (length-- > 0)
    if (*b1++ != *b2++)
      return 1;

  return 0;
#endif /* not VMS */
}
#endif /* no bcmp */
#endif /* not BSTRING */
```

As with missing variables and datatypes during compilation, your first task is to find out if the function exists within the current distribution. If it doesn't exist, check the system libraries and headers. In this example, the bcmp function is referenced in the bsdmem.h header file on the BeOS, a header file which is unlikely to be included in the standard configuration.

If you can't find the function, you will need to re-create it. For simple functions you might be able to do this yourself, but an easier option is probably to use one of the available public libraries. A good place to start is the GNU C library package, glibc, which contains all of the functions required by GNU packages. Another alternative is the Linux, FreeBSD and NetBSD sources, either of which should be able to provide you with the information and functions you require.

As with previous examples, if you find you need to modify the configuration or the files required by the entire package, do a make clean and compile the package again. This ensures that the changes you have made do not affect other parts of the build and ultimately cause it to fail.

Duplicate Objects

The opposite of the previous error, a duplicate function or variable, can be caused by similar problems. Specifying that a particular function is required to be built within a package when an OS version exists can be dangerous. Sometimes, however, it is a necessary decision. In other cases, the problem has probably arisen because you have modified the configuration without building the entire project again.

Either way, unless the duplicate is deliberate or necessary (for incompatibility or bug reasons) it is best to get rid of it. The output of the linker should show you where the duplicate was found and where the original is, making identification and elimination easier.

Installation

Generally you can go ahead right now and test the files you have created. However, for many packages, there is yet another step before you test the files, that of installation. Generally, if practical, I install the files before performing any sort of test on what I've created. As we'll see in the next chapter, a number of errors can be generated by the program not finding what it expects to find where it expects to find it.

The process of installation may involve any or all of the following:

- Installation of executables into a location that can be referenced by the shell, that is, a directory in the PATH
- Installation of any documentation and support files, including configuration, preference, and other information

- Setting the correct permissions and ownerships of the files and directories used by the application, including, if necessary, any "blank" directories
- Installation of library and header files in places available for program development

There is also one additional item, often omitted from the process by both systems administrators and package authors:

- Removal of any old versions already installed on the system

Forgetting this last item can cause all sorts of problems, from software that doesn't run correctly or reports spurious errors and problems right through to a messy system.

Depending on the package the installation is either easy and fully automatic or complex and completely manual, or any variation of those limits. We will take a look first at removing the old versions before we move on to installing new versions.

Removing Old Versions

Between different versions of emacs the installation directories and formats do not change much. Looking at the install target in the Makefile it is fairly obvious that a very strict structure exists:

```
### Build all the directories we're going to install Emacs in.
     Since
### we may be creating several layers of directories (for example,
### /usr/local/lib/emacs/19.0/mips-dec-ultrix4.2), we use
mkinstalldirs
### instead of mkdir.  Not all systems' mkdir programs have the `-p'
flag.
mkdir: FRC
	$(srcdir)/mkinstalldirs ${COPYDESTS} ${lockdir} ${infodir} $
{man1dir} \
	  ${bindir} ${datadir} ${docdir} ${libexecdir} \
	  `echo ${locallisppath} | sed 's/:/ /g'`
	-chmod a+rwx ${lockdir}
```

All of the configuration files, lisp code, and support files from emacs are installed into the /usr/local/lib/emacs directory by default. Beneath this directory the different versions are kept, and within each version the architecture-dependent files are kept. This allows multiple versions of emacs on multiple machines to all be stored within the same directory layout.

While this makes installation and the program itself more complicated, it also makes removing old versions very easy. You can just delete the directory tree for the version you no longer require. This is precisely the method used by the uninstall target in the Makefile:

```
### Delete all the installed files that the `install' target would
### create (but not the noninstalled files such as `make all' would
### create).
###
```

```
### Don't delete the lisp and etc directories if they're in the source
tree.
uninstall:
       (cd lib-src;                              \
        $(MAKE) $(MFLAGS) uninstall                     \
           prefix=${prefix} exec_prefix=${exec_prefix}      \
           bindir=${bindir} libexecdir=${libexecdir} archlibdir=$
{archlibdir})
       for dir in ${lispdir} ${etcdir} ; do             \
         if [ -d $${dir} ]; then                  \
           case `(cd $${dir} ; /bin/pwd)` in             \
             `(cd ${srcdir} ; /bin/pwd)`* ) ;;          \
             * ) rm -rf $${dir} ;;                      \
           esac ;                                 \
           case $${dir} in                        \
             ${datadir}/emacs/${version}/* )            \
               rm -rf ${datadir}/emacs/${version}       \
             ;;                                   \
           esac ;                                 \
         fi ;                                     \
       done
       (cd ${infodir} && rm -f cl* dired-x* ediff* emacs* forms* gnus*
info* mh-e* sc* vip*)
       (cd ${man1dir}  && rm -f emacs.1 etags.1 ctags.1)
       (cd ${bindir}  && rm -f emacs-${version} $(EMACS))
```

For other packages, it is more difficult to identify their installation location. Your average package is likely to be split over at least two directories, and you need to remove the files without upsetting any of your other packages. This process doesn't make the BeOS (or UNIX for that matter) unique. It is a well-accepted fact that software on UNIX machines is generally difficult to install properly, and more often than not impossible to uninstall completely.

The decision you make about removing old versions of software depends on your own circumstances. It is possible when working with different versions of packages and with your own different builds of software to have multiple, but incompatible, executables all trying to use the same folder structure and configuration files, which makes it almost impossible to work with the version or abilities of the one you want.

As a general rule, unless you need to use the previous version of the package for compatibility reasons, I suggest you remove it. If possible, make sure you have a compiled version available, or the old sources (including any modifications you made), before removing the package. This way, should you need to reinstall it, it will hopefully be a less painful process than having to repeat the porting exercise all over again.

The problem of removing old software remains to be solved; even with emacs the uninstall target only removes the current build version, not the previous one. For that, you'll need to go back to a previous release of emacs, and older releases didn't include the uninstall option at all.

Removing a package without such an option is a laborious process, made worse by the availability or otherwise of the relevant source tree. If the old Makefile is available you need to find the install target to find out which files were installed, and where. The example below is relatively simple and comes from gdbm:

```
install: libgdbm.a gdbm.h gdbm.info
	$(INSTALL_DATA) libgdbm.a $(libdir)/libgdbm.a
	$(INSTALL_DATA) gdbm.h $(includedir)/gdbm.h
	$(INSTALL_DATA) $(srcdir)/gdbm.3 $(man3dir)/gdbm.3
	$(INSTALL_DATA) $(srcdir)/gdbm.info $(infodir)/gdbm.info
```

We can duplicate this entry and replace the $(INSTALL_DATA) with rm -f, producing

```
uninstall: libgdbm.a gdbm.h gdbm.info
	rm -f libgdbm.a $(libdir)/libgdbm.a
	rm -f gdbm.h $(includedir)/gdbm.h
	rm -f $(srcdir)/gdbm.3 $(man3dir)/gdbm.3
	rm -f $(srcdir)/gdbm.info $(infodir)/gdbm.info
```

For other packages the process is not as simple. emacs, for example, has an extensive install target which has to copy the executable, support files, lisp, and info files to the corresponding directories.

If you don't have access to the original Makefile then the process is more long-winded. You need to find the executable and all the files that go with it. The easiest way to do this is to find the executable:

```
$ which perl
perl is /boot/home/config/bin/perl
```

and then search the probable locations for files modified within minutes of the executable's modification date and time. You can use ls -lt to list the date/time stamp sorted in time order.

If, and however, you decide to remove an already installed package you must be careful not to remove software you actually need, or to disable other packages by removing a required configuration file. Removing a library, for example, is probably a bad idea. Removing an application can be less traumatic, but it is possible that another application or script requires the file you have just deleted.

Installation of the Files

For most applications, the install target is the ultimate goal. The normal target specification for install is for the all target to be built first, and for the compiled software to then be copied to appropriate directories, like this:

```
install: all
	cp foo /boot/home/config/bin
```

while others are more complex:

```
BINDIR=             /boot/home/config/bin
ETCDIR=             / boot/home/config/etc
MANDIR=             / boot/home/config/man
MANEXT=             8

all:
	@ echo 'Use the "build" command (shell script) to make ftpd.'
```

```
	@ echo 'You can say "build help" for details on how it works.'

install: bin/ftpd bin/ftpcount bin/ftpshut
	-mv -f ${ETCDIR}/ftpd ${ETCDIR}/ftpd-old
	@echo Installing binaries.
	install -o bin -g bin -m 755 bin/ftpd ${ETCDIR}/ftpd
	install -o bin -g bin -m 755 bin/ftpshut ${BINDIR}/ftpshut
	install -o bin -g bin -m 755 bin/ftpcount ${BINDIR}/ftpcount
	install -o bin -g bin -m 755 bin/ftpwho ${BINDIR}/ftpwho
	@echo Installing manpages.
	install -o bin -g bin -m 755 doc/ftpd.8 ${MANDIR}/man8/ftpd.8
	install -o bin -g bin -m 755 doc/ftpcount.1 ${MANDIR}/man1/
ftpcount.1
	install -o bin -g bin -m 755 doc/ftpwho.1 ${MANDIR}/man1/
ftpwho.1
	install -o bin -g bin -m 755 doc/ftpshut.8 ${MANDIR}/man8/
ftpshut.8
	install -o bin -g bin -m 755 doc/ftpaccess.5 ${MANDIR}/man5/
ftpaccess.5
	install -o bin -g bin -m 755 doc/ftphosts.5 ${MANDIR}/man5/
ftphosts.5
	install -o bin -g bin -m 755 doc/ftpconversions.5 ${MANDIR}/
man5/ftpconversions.5
	install -o bin -g bin -m 755 doc/xferlog.5 ${MANDIR}/man5/
xferlog.5
```

Even after this extensive list of files to install, wuftpd still requires some manual intervention to complete the installation. Herein lies a problem: In much the same way that removing old versions causes a problem, there is no standard way of installing a package after it has been compiled and built.

This presents us with something of a problem, because we know that installing the wrong files—or, worse, installing the right files in the wrong place—presents us with a problem not only when we come to use the package, but also when we come to replace or remove it later.

With all these negative points, it is hard to imagine that anything gets installed correctly. In fact, the situation is not as bad as I've portrayed it; most installation processes supplied with most packages are adequate, in that they install the files in the specified place. The full sequence of events during installation should be:

1. Create any necessary directories
2. Copy across the application files into the directories
3. Copy across the support files and documentation
4. Set permissions on the files and directories

Most packages make the process simpler (even within the scope of a Makefile) and use the install program, which is supplied as standard with the BeOS, or a shell script equivalent. The install program has advantages over cp in that files can be copied to their locations with the permissions and file ownership already set correctly. This shortens the overall process and simplifies the commands make has to run.

In addition to the standard install target some packages split the installation process between a number of smaller targets. It is not uncommon to find targets such as install-man and install-doc in addition to, or as part of, the main install target. Other packages don't include any options for installing documentation, and still others don't include any form of installation at all.

In all cases the basic process is the same; all you need do is ensure that the process runs smoothly and does not generate any errors. As a warm-up, here is an extract from the emacs Makefile, which pretty much does everything required to install the package. It is annotated, and should be relatively easy to follow.

```
### We do install-arch-indep first because
### the executable needs the Lisp files and DOC file to work properly.
install: ${SUBDIR} install-arch-indep install-arch-dep blessmail
	@true

### Install the executables that were compiled specifically for this
machine.
### It would be nice to do something for a parallel make
### to ensure that install-arch-indep finishes before this starts.
install-arch-dep: mkdir
	(cd lib-src; \
	  $(MAKE) install $(MFLAGS) prefix=${prefix} \
	    exec_prefix=${exec_prefix} bindir=${bindir} \
	    libexecdir=${libexecdir} archlibdir=${archlibdir})
	${INSTALL_PROGRAM} src/emacs ${bindir}/emacs-${version}
	-chmod 1755  ${bindir}/emacs-${version}
	rm -f ${bindir}/$(EMACS)
	-ln ${bindir}/emacs-${version} ${bindir}/$(EMACS)

### Install the files that are machine-independent.
### Most of them come straight from the distribution;
### the exception is the DOC-* files, which are copied
### from the build directory.

### Note that we copy DOC* and then delete DOC
### as a workaround for a bug in tar on Ultrix 4.2.
install-arch-indep: mkdir
	-set ${COPYDESTS} ; \
	for dir in ${COPYDIR} ; do \
	  if [ `(cd $$1 && /bin/pwd)` != `(cd $${dir} && /bin/pwd)` ] ;
then \
	    rm -rf $$1 ; \
	  fi ; \
	  shift ; \
	done
	-set ${COPYDESTS} ; \
	mkdir ${COPYDESTS} ; \
	chmod ugo+rx ${COPYDESTS} ; \
	for dir in ${COPYDIR} ; do \
	  dest=$$1 ; shift ; \
	  [ -d $${dir} ] \
	  && [ `(cd $${dir} && /bin/pwd)` != `(cd $${dest} && /bin/
pwd)` ] \
	  && (echo "Copying $${dir} to $${dest}..." ; \
	      (cd $${dir}; tar -cf - . )|(cd $${dest};umask 022; tar -
xvf - ); \
	      for subdir in `find $${dest} -type d ! -name RCS -
print` ; do \
	       rm -rf $${subdir}/RCS ; \
	       rm -rf $${subdir}/CVS ; \
	       rm -f  $${subdir}/\#* ; \
	       rm -f  $${subdir}/.\#* ; \
	       rm -f  $${subdir}/*~ ; \
	       rm -f  $${subdir}/*.orig ; \
	       rm -f  $${subdir}/[mM]akefile* ; \
```

```
              rm -f  $${subdir}/ChangeLog* ; \
              rm -f  $${subdir}/dired.todo ; \
             done) ; \
       done
       -rm -f ${lispdir}/subdirs.el
       $(srcdir)/update-subdirs ${lispdir}
       -chmod -R a+r ${COPYDESTS}
       if [ `(cd ./etc; /bin/pwd)` != `(cd ${docdir}; /bin/pwd)` ]; \
       then \
          echo "Copying etc/DOC-* to ${docdir} ..." ; \
          (cd ./etc; tar -cf - DOC*)|(cd ${docdir}; umask 0; tar -xvf
- ); \
          (cd $(docdir); chmod a+r DOC*; rm DOC) \
       else true; fi
       if [ -r ./lisp ] \
          && [ x`(cd ./lisp; /bin/pwd)` != x`(cd ${lispdir}; /bin/
pwd)` ] \
          && [ x`(cd ${srcdir}/lisp; /bin/pwd)` != x`(cd ./lisp; /bin/
pwd)` ]; \
       then \
          echo "Copying lisp/*.el and lisp/*.elc to ${lispdir} ..." ;
\
          (cd lisp; tar -cf - *.el *.elc)|(cd ${lispdir}; umask 0; tar
-xvf - ); \
       else true; fi
       thisdir=`/bin/pwd`; \
       if [ `(cd ${srcdir}/info && /bin/pwd)` != `(cd ${infodir} && /
bin/pwd)` ]; \
       then \
         (cd ${infodir};  \
          if [ -f dir ]; then \
            if [ ! -f dir.old ]; then mv -f dir dir.old; \
            else mv -f dir dir.bak; fi; \
          fi; \
          cd ${srcdir}/info ; \
          (cd $${thisdir}; ${INSTALL_DATA} ${srcdir}/info/dir $
{infodir}/dir); \
          (cd $${thisdir}; chmod a+r ${infodir}/dir); \
          for f in ccmode* cl* dired-x* ediff* emacs* forms* gnus*
info* message* mh-e* sc* vip*; do \
            (cd $${thisdir}; \
             ${INSTALL_DATA} ${srcdir}/info/$$f ${infodir}/$$f; \
             chmod a+r ${infodir}/$$f); \
          done); \
       else true; fi
       thisdir=`/bin/pwd`; \
       cd ${srcdir}/etc; \
       for page in emacs etags ctags ; do \
         (cd $${thisdir}; \
          ${INSTALL_DATA} ${srcdir}/etc/$${page}.1 ${man1dir}/$${page}
${manext}; \
          chmod a+r ${man1dir}/$${page}${manext}); \
       done

### Build Emacs and install it, stripping binaries while installing
them.
install-strip:
       $(MAKE) INSTALL_PROGRAM='$(INSTALL_PROGRAM) -s' install

### Build all the directories we're going to install Emacs in.
       Since
### we may be creating several layers of directories (for example,
### /usr/local/lib/emacs/19.0/mips-dec-ultrix4.2), we use
mkinstalldirs
### instead of mkdir.  Not all systems' mkdir programs have the `-p'
flag.
mkdir: FRC
       $(srcdir)/mkinstalldirs ${COPYDESTS} ${lockdir} ${infodir} $
{man1dir} \
```

```
    ${bindir} ${datadir} ${docdir} ${libexecdir} \
    `echo ${locallisppath} | sed 's/:/ /g'`
  -chmod a+rwx ${lockdir}
```

Even if the installation process doesn't work as advertised, doing the installation by hand is as easy as copying any file. Whichever way you decide to install the package, you will know when you come to test whether the installation, and more importantly the compilation, have failed. We will take a closer look at this in the next chapter.

Testing the Build

Most programming is testing. Ideally, you need to test the application in every single possible combination and sequence of events that could happen. Of course, this isn't always feasible. What you can do, though, is check the basics, check the high and low figures, and run some spot checks on procedures and functions that you know are likely to cause problems.

There are quite literally thousands of reasons why a program may not work, even after it has been compiled correctly. Your job as a porter is made significantly easier because you are not writing the software from scratch, you are only porting it to a new platform. Most, and hopefully all, of the core C code should work on any platform; your job is to make sure that the links to the OS and the outside world work as they should. What you need to do is to create a test harness, a collection of tests and spot checks through which the bulk of the problems will not be able to escape.

Checking the Created Files

There is one, probably obvious, test to make sure that a program has compiled correctly. Run it!

However, before you rush to the keyboard and try to run the software, make sure that you've created everything you need. For many packages, this is just a single application file, but for others the package may be made up of a number of smaller files and scripts, all of which may be interdependent. You may need to install the application(s) you have just compiled, support files, and configuration files before testing. Check the documentation to see if this is required.

List the files built during the build process and make sure they are executable, and of a reasonable size. Anything that isn't executable probably hasn't been generated and output by the linker properly. Check the logs created during the build process to ensure that the linker didn't return any errors.

The size is also important; some packages create an empty application file before the linker generates the real version. Alternatively, your linker may have tried to generate the application file, but failed because of a missing object file or library, leaving behind an incomplete application file. Anything that looks excessively small has probably not compiled correctly. It could be a shellscript, but this is unlikely to have been generated as part of the build process.

Creating Your Own Harness

A test harness is a set of scripts, tests or other applications that test the functionality of the code you have produced. The term harness is an analogy that implies that a function that fails the test harness manages to break through the tests you have developed.

Creating your own test harness is a complicated process. You know what you need to achieve: as much testing as possible on the various elements of the program. The problem is how to go about it. When writing your own programs testing is easy; if you're like me you probably test the software after each additional feature has been added. When you run your program and something doesn't work as you expect, you can almost immediately identify the problem.

Working with somebody else's code can be mind-numbing, but you can apply the same basic principle: subdivision. If you subdivide the program into component parts it should be easier to identify the source of the problem. Subdivision also works on the superficial level of determining what the problems might be. The range of errors for a ported application is relatively small; you can concentrate on a number of specific areas to reduce the time it takes to test. The main reasons for ported software failing are differences in the library implementations of functions, or genuine bugs in the source code.

Differences between the libraries on the OS from which the program was ported and those on the BeOS can cause significant problems. Hopefully the configuration process will have ironed out most of the differences, or identified the difference and proposed an alternative solution. It is possible however that the configuration you've selected isn't the perfect selection for the BeOS. Minor things can cause a tremendous number of errors. For example the BeOS doesn't support flock() although the function exists returns a useless number as the result. The configuration found the function, and ran a test program to check the existence, but this wasn't picked up as either a fault or a successful return; the program (gdbm) just failed during startup with an unknown error.

Bugs which were ignored on the development system because they didn't cause any problems suddenly manifest themselves. This is particularly apparent with pointers and character strings.

This reduces the amount of code you have to test because many of the lines within a package don't fall into the two categories above.

The subdivision approach to testing is the same way that packages such as gawk and perl test themselves. They start by testing the basic features, and then move on to testing the more complicated features and built-in functions. You can apply this process to other packages by concentrating on the area of the package affected.

For this approach, you really need to use some form of debugging if you don't want to get into the bowels of the package. As I have already described in Chapter 14, I find manual debugging with printf statements showing the progress and location the easiest way to track down the locality of the problem. Usually, this is enough to isolate the function or line of code causing the problem. When working on the BeOS port of emacs, for example, I used this method to trace me back to a function which initialized the memory system.

The program would freeze when it reached this point, and I used multiple printf statements to isolate the function call. Using grep I was then able to identify the source file containing the function init_alloc_once, which pointed in the direction of the alloc.c source file, which in turn pointed me towards the malloc() system call.

emacs, like many of the large packages, is virtually impossible to understand without months of reading the code, and so subdivision is the only way you will discover where the problem is. Even so, there is no practical way of testing every function of the program; even using the built-in lisp language, testing would be difficult and time consuming. Therefore, once you have emacs or similarly large software running, the best way to test the package is just to use it. If you think it is stable enough, release it to the public. You will find out soon enough from the users of the software whether there is a problem with it.

In fact, your users probably are the only ones who will be able to test the full range of features and functions in the ports you provide to them.

Using the Supplied Harness

GNU packages, and some others, come with their own test suites which you can use to verify the quality of the port. Using the supplied test harness can save you a considerable amount of time and effort. The harness should cover all the core operations and may, with more complex programs, even cover all the functions required for operation (but not necessarily all the variables).

Certainly with alternative languages such as gawk and perl the harness supplied is comprehensive enough to test the vital parts and provide information on possible problems, or at least pointers to problems, very quickly. We will look at some possible errors returned by tests and how to identify and fix the problems in the next section of this chapter.

The perl test suite is located in the t subdirectory and contains an extensive array of tests and a script (also written in perl) to execute and monitor their output. You may think that a problem with perl could cause the main script to fail, but you can test items individually to identify the source of the error. The output from the tests is fairly sparse, but it does give an indication of whether the tests completed as expected:

```
$ TEST
base/cond......ok
base/if........ok
base/lex.......FAILED on test 12
Failed a basic test--cannot continue.
base/pat.......ok
base/term......ok
comp/cmdopt....FAILED on test 12
comp/cpp.......FAILED on test 0
comp/decl......ok
```

The test file base/lex produced an error on test 12. Because the TEST script is just another perl script, we can run the scripts individually:

```
$ perl base/lex
1..24
#1      :x: eq :x:
ok 1
ok 2
ok 3
ok 4
ok 5
ok 6
ok 7
ok 8
ok 9
ok 10
ok 11
ok 12
ok 13
ok 14
ok 15
ok 16
ok 17
ok 18
ok 19
ok 20
ok 21
ok 22
ok 23
ok 24
```

We find that, in fact, there is nothing wrong with the script; it must be in the TEST script instead. We can verify this by running another script which also failed on test 12, comp/cmdopt:

```
$ perl comp/cmdopt.t
1..40
ok 1
ok 2
ok 3
…
ok 38
ok 39
ok 40
```

Again, the test doesn't return any errors. This is almost certainly a problem with the parent TEST script. Unfortunately, this doesn't get us off the hook; we need to find out what the problem in this script is because it still points to a bug in the perl we have created.

The best way to approach this is to write our own test script which progressively works through the tests and stores the output so we can track down the problems later. Using the output we can identify the problem, make the necessary changes to the sources, and then try again until all the faults are eliminated.

perl is a complicated package to use as an example, although it is one of the few packages to come with such an extensive test suite. Another good example of a supplied test harness is gdbm, the GNU version of the database management system. Within the gdbm package is a suite of programs which test the functionality of the various library functions. Here the tests need to be performed manually, but you should still be looking out for the same pointers to possible problems as before.

An alternative to the gdbm test programs is to use perl to test the dbm functions. However, you run the risk of reporting and trying to solve errors that may be in the wrapping or the contents. Trying to fix perl when the problem is gdbm, or vice versa, may cause you to tear your hair out.

Pointers to Problems

During the tests you will undoubtedly come across a problem or event, and you need to be able to trace that back to the source code and a possible incompatibility. You could use a debugger, or one of the debugging techniques I have already shown you. The problem is that using a debugger doesn't always answer your questions about the cause of a problem.

Certainly, debugging will show you the sequence of events leading up to the problem, and the values of the variables that may have caused it, but it doesn't always show you the actual cause, only where the cause made the program crash.

There are, though, some obvious things you can look out for when running and testing your program which will help you to identify the problem and its probable source.

Memory Overflow

A memory overflow is highlighted by a core dump, or a drop into the debugger. The error can indicate a variety of problems, most of which, with good programming, shouldn't appear. However, often the result is caused by an incompatibility between OSs that causes a problem which would otherwise have been picked up on a different platform.

The most likely shape this problem will take is the program trying to access a variable outside of the current memory space. The most likely cause of this is a badly aligned string, or a failed alloca() call that was never checked. You should be able to trace the fault to a specific line using a debugger, but it may take further investigation, tracking back through the source, to find the real fault.

If you're building a GNU package, try altering the configuration to use the GNU memory routines. The ALLOCA definition usually controls this action.

Signed/Unsigned Numbers

The BeOS is a 32-bit OS, which means that by default an int is 32 bits long, which is the same size as a long. This bitsize gives a maximum value for an int of (2^32)-1. A char is eight bits long. Whereas a short is sixteen bits. Some packages use specific types for different variables, which can cause problems as you move between OSs.

For example, if a particular variable is specified as a short but returns a negative instead of the expected positive number then you need to specify a larger type. It should probably be changed to an int. You can do this by manually modifying the source code using a search and replace. Be careful not to define an int int though.

A better solution is to redefine short in a header file as long:

```
#define short long
```

A good example of this problem can be seen in the compiler mwcc, although the error number is returned by the OS:

```
# File or directory not found (OS error -2147454956)
```

which returns an unfeasibly large negative number for what is a relatively simple number. We will see why this number is the value it is, and also look at the full range of datatypes in Part 3 of this book.

Character Order

The byte order of an operating system can be described as "big-endian" or "little-endian." Big-endian OSs store the larger portions of the number in the lower bytes, so the number 0x12345678 would have digits 1 and 2 in byte 0, 3 and 4 in byte 1, and so on.

In little-endian OSs the reverse is true: 1 and 2 would be stored in byte 3, 3 and 4 in byte 2, and so on ending with 78 in byte 0. You can see the difference more clearly if you take a look at Table 18.1. For the storage of numbers this shouldn't matter, as number types are defined only within the compiler.

Table 18.1

Big-endian and little-endian numbers

Byte	Little-endian value	Big-endian value
0	78	12
1	56	34
2	34	56
3	12	78

You can test the behavior of your system using the program below, taken from the perl Configure script:

```
#include <stdio.h>
main()
{
        int i;
        union {
                unsigned long l;
                char c[sizeof(long)];
        } u;

        if (sizeof(long) > 4)
                u.l = (0x08070605L << 32) | 0x04030201L;
        else
                u.l = 0x040302010L;
        for (i = 0; i < sizeof(long); i++);
                printf("%c",u.c[i]+'0');
        printf("\n");
        exit(0);
}
```

If you compile and run this program on the BeOS on a PowerPC processor you will find it is big-endian, reporting "4321". For BeOS on Intel processors it should report "1234".

Missing Files/Directories

When you run an application it may return a "configuration file not found" or "missing directory" error. These are simple problems with the configuration where you have not adjusted the directory or file names to match the BeOS layout. Chapter 2 covered the basic layout of the Be file system.

In some cases, these problems may manifest themselves as more serious errors, although the problem remains the same. I have even seen one program (a commercial Internet tool) report "Fatal error: cannot continue." After debugging the source, I found a problem with a file name, where the specification had been hard-coded into the source instead of using a "public" definition. Though easy to solve, the problem caused my heart to skip a beat after some weeks of porting other parts of the program.

The File System Interface

When porting a program which uses file locking as a mechanism of accessing and controlling the contents of files, you need to check the file locking mechanisms and functions. Most programs should report an error when they come across such a problem; it usually affects the execution enough that the program has to shut down. Some programs will just report a "Can't read file" error, even though you are sure the file exists and is readable.

You may also come across programs which expect to use hard links, so you will need to change the references to link() to symlink(). In addition, the off_t datatype is 64 bits in the BeOS, not 32 bits. We will look at these and other file system specifics in Part 3 of this book.

Testing the software and making sure it works properly is the last stage of porting before supplying your changes to the author and distributing the package to the rest of the OS community. It is vital, not just for the program's success, but also for your own credibility, that the program work correctly.

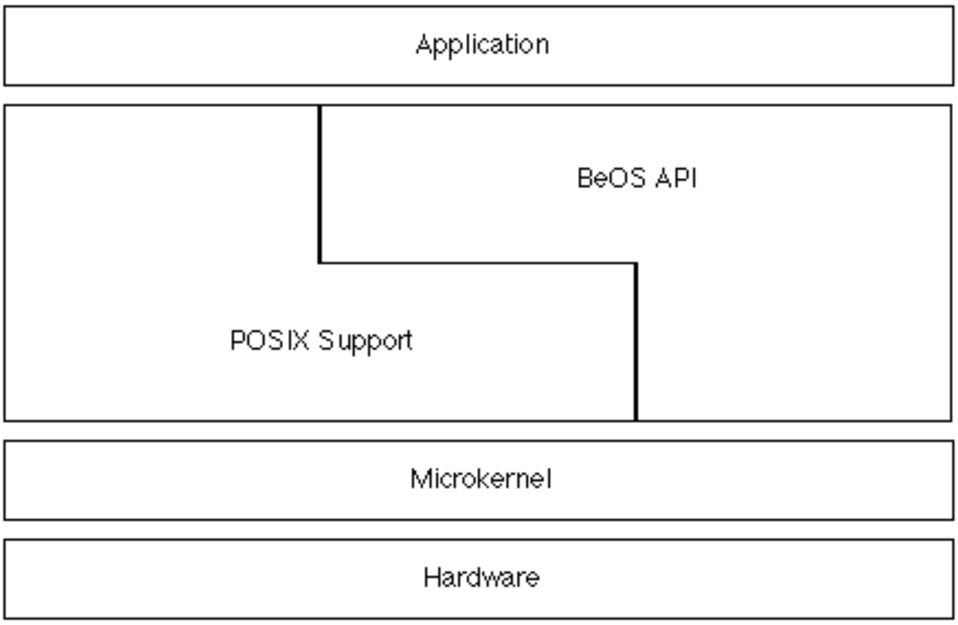
Chapter 16 - Overview of BeOS Programming

When writing a program for the BeOS, as opposed to porting a program to the BeOS, you have two styles to choose from. One is the POSIX style which resembles the UNIX environment and the other is the object-oriented BeOS API (application programming interface). As porters of mostly UNIX software, we are more interested in the POSIX compatibility layer. Before we take a closer look at the POSIX support provided by the BeOS we will take a brief look at both styles, how the two can be used together, where the differences and similarities are apparent and where the two styles cross over.

Program Styles

If you take a look at the diagram of how the BeOS works in Figure 16.1, you can see how the two programming interfaces interlock with each other. The BeOS API attaches itself directly to the kernel, as does the POSIX support. You will also notice that the BeOS API covers some of the POSIX support, and in some cases is actually built on the POSIX functions.

Figure 16.1
The BeOS application structure



This is a fairly simplistic representation; the entire application support is slightly more complex and sophisticated. We can, however, make some analogies between the BeOS and other OSs. We already know there are two different styles of programs within the BeOS: those based on the BeOS API and those based on the POSIX-style interface.

The main difference between the two from the user's point of view is the interface that will be used. A BeOS application is more than likely to be based within the Windows-style environment for the OS and use the same multiple windows, menus, and so on for interaction with the user. A POSIX-style application is more likely to work within a text-based interface. emacs or perl are both good examples of POSIX-style applications and are more similar to the two packages on a UNIX machine or DOS on a PC. We also know that a POSIX application can really only be started from within a Terminal window (the command line) because of the restrictions on the I/O. A BeOS application on the other hand can be executed from the command line, but can also be executed from within the Tracker by double-clicking on it. All these differences, while fairly invisible to the user, are much more dramatic behind the scenes, both when the application is written and developed and when it is executed.

It is possible to double-click on a POSIX application in the Tracker, but you will not see any output, even if it is produced.

A good example of an application which is based on a GUI API that can be run from the command line is the BeOS browser, called NetPositive. This is a GUI based application built on the BeOS API, and can be run from the command line, as well as by double clicking it from the Tracker.

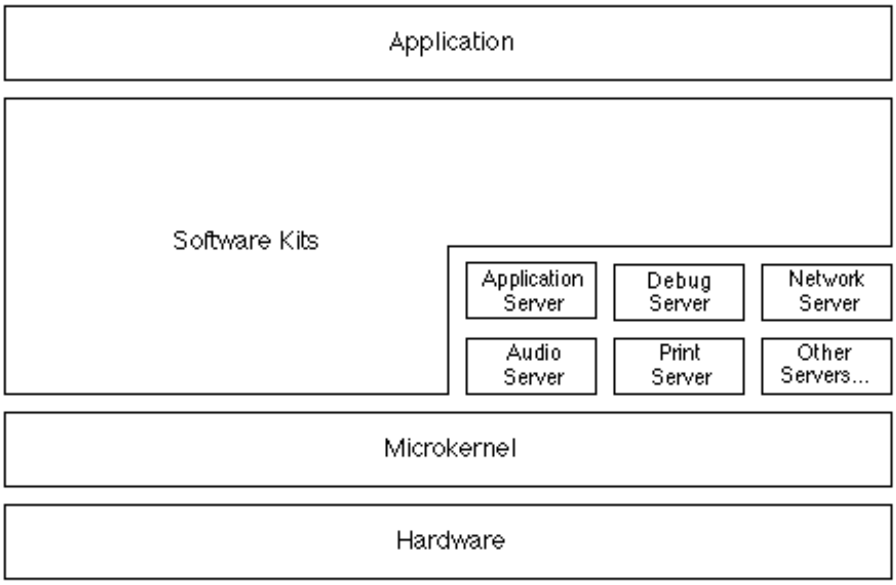
Be Style

Programming for the BeOS is unlike writing application software for any other platform. Thinking about Be programming style requires an open mind and a fresh approach.

A Closer Look

If you take a closer look at the structure of the BeOS API (Application Programming Interface), as seen in Figure 16.2, you can see that the underlying structure of a BeOS program is supported by a number of servers. A BeOS application is, put simply, a client application to a number of supporting servers, all of which are automatically started up at boot time. Access to the servers is controlled via a number of software kits, and it is this combination of multiple APIs and the client/server model that makes programming on the BeOS so unique.

Figure 16.2
The BeOS API



If we start from the bottom of the diagram and work our way up, we can investigate the internals a little more closely. At the base level is the hardware, the physical equipment required to run the OS. On top of this is the kernel. The *kernel* sits on top of the hardware and is the core unit that controls the OS. It provides the interface functions between the next level—the servers—and the hardware. At a CPU level, this encapsulates the support of multiple processors and supports the notion of threads, the basic building blocks of a running application. The kernel is highly optimized and very small in comparison to other bulky OSs. The MacOS System file, for example, is 6.5Mb in its latest revision, Mac OS 8, this is without support for networking or anything other than the basic system and interface. In comparison, the BeOS kernel, also without any additional components, is just 452K.

The use of a kernel allows the core of the OS to be ported to a number of platforms, and also allows a variety of hardware to be supported using software drivers which are dynamically loaded when required. The kernel can be accessed either directly using system calls (as in UNIX) or via the abstraction layer, which is the object-oriented interface supported by the servers.

Each server is responsible for supporting a different set of services. For example, the network server supports networking protocols on top of the physical device. Each server is multithreaded, much like the kernel, and so is able to handle a number of requests and operations almost simultaneously.

Fitted onto the servers is the API, which in Be terminology is the software kits. The software kits (and the servers) are written in C++, whilst the kernel is written in C. The object orientation of C++ provides a number of benefits, not least of which is the speed with which programs and applications can be written. Most significantly, they support the model of ever-expanding support for basic structures.

For example, using the principles of inheritance it is possible to create a base class of a window, and then a new class which uses the features of the window combined with the additional features of a text entry box. This is similar to the building blocks used to describe animals. The specification of a mammal is a creature that has fur and is warm blooded; within this you get dogs, which have the basic features combined with extended canines and a tail, and also kangaroos, which follow the same basic features of being furry and warm blooded, and include the addition of a pouch.

Finally, communication between the servers, threads, and other applications takes place via messages. These messages can be any piece of information you might want to exchange, or they may be the control codes which run, pause, or stop an application. We'll see how this works in the "Program Structure" section, below.

All of these abilities fit together within the BeOS to make the development of a multithreaded, graphical application very quick and easy. In addition, behind the scenes you are able to access the core of the OS and the underlying hardware.

Program Structure

If you take a look at a sample BeOS application you can see its main differences from a standard C application. The main function seems to contain a lot of code that doesn't really do anything, and an additional function has been defined that does the work:

```
#include <Application.h>
#include <Window.h>
#include <View.h>

class HelloView : public BView {

public:
       HelloView(BRect frame, char *name);
virtual void    AttachedToWindow();
virtual void    Draw(BRect updateRect);
};

class HelloWindow : public BWindow {
```

```
public:
      HelloWindow(BRect frame);
virtual bool    QuitRequested();
};

class HelloApplication : public BApplication {

public:
    HelloApplication();
};

void set_palette_entry(long i,rgb_color c);

HelloView::HelloView(BRect rect, char *name)
       : BView(rect, name, B_FOLLOW_ALL, B_WILL_DRAW)
{
}

void HelloView::AttachedToWindow()
{
        SetFont(be_bold_font);
        SetFontSize(24);
}

void HelloView::Draw(BRect)
{
        MovePenTo(BPoint(10, 30));
        DrawString("Hello, World!");
}

HelloWindow::HelloWindow(BRect frame)
      : BWindow(frame, "Hello", B_TITLED_WINDOW, B_NOT_RESIZABLE)
{
}

bool HelloWindow::QuitRequested()
{
        be_app->PostMessage(B_QUIT_REQUESTED);
        return(TRUE);
}

int main(void)
{
        HelloApplication *myApplication;

        myApplication = new HelloApplication();
        myApplication->Run();

        delete(myApplication);
        return(0);
}

HelloApplication::HelloApplication()
                                  : BApplication('HLWD')
{
        HelloWindow             *aWindow;
        HelloView               *aView;
        BRect                   aRect;

        // set up a rectangle and instantiate a new window
        aRect.Set(100, 80, 260, 120);
        aWindow = new HelloWindow(aRect);

        // set up a rectangle and instantiate a new view
        // view rect should be same size as window rect but with left
top at (0, 0)
        aRect.OffsetTo(B_ORIGIN);
        aView = new HelloView(aRect, "HelloView");
```

```
        // add view to window
        aWindow->AddChild(aView);

        // make window visible
        aWindow->Show();
}
```

If you compile and run this application, with the associated files supporting the view and window functions, you get a window displaying:

```
Hello World!
```

Beyond the obvious use of C++ as the programming language, you should notice that the main() function, which is the function that by default is the entry point and also the controlling element in the execution of the rest of the program, has simply become a container.

The HelloApplication object defines the action of the program, which in this case involves opening a window and printing a message to the screen. The other statement in the definition tells the application to quit using the BMessage system.

The sequence of execution is then as follows:

5.1. Open a connection to the application server
6.2. Create the application, window and print the message.
7.3. Run the application created, thereby actually displaying "Hello world!".
8.4. When the window close button is clicked, send the B_QUIT_REQUESTED message to the applications message queue.
9.4. The B_QUIT_REQUESTED message is received and we check whether we should actually quit.
10.5. The program quits.

You can now see how this differs from a standard application. A standard application would immediately start executing code and making calls to the library function printf. Under the BeOS API the application is first "created" and then executed as a client to the application server. If the user had not click the close window button, the application HelloApplication would have continued running indefinitely.

Although the main() was still the top function in the execution stack, in real terms it was no longer the controlling function within the program. In fact, the program, per se, actually finished when the Run() command was sent to the application server. It was only the application which finished executing on receiving the BMessage.

Threads

Under standard UNIX an application or program that is running is called a process, under Windows it is called a task, and on the MacOS it is simply an application. Within all of these OSs you have the ability to multitask.

Multitasking is the ability to run more than one application at a time, and have each application continue to run in the background while you are using the foreground application.

The different OSs all handle this with varying degrees of success. UNIX as an OS was designed to be multiuser, and therefore had to be multitasking. Both the MacOS and Windows (even NT and 95) approximate multitasking with varying degrees of success. In all these cases, OSs have grown out of the previous model and hardware, and the requirement to be backward-compatible with previous versions of the software and OS.

Threading is the ability to not only multitask with many applications running at the same time, but to subdivide a single application into a number of smaller parts. This threading is useful when you have large, complex programs and you don't want to introduce complex mechanisms for simulating the effect of multiple threads in a single application.

The overall impression a user will get from threading is of a much faster, much more responsive system. Within the BeOS the threading occurs at the OS level, right from the kernel through the servers and on to the software kits. It is so extensive and largely automatic that the threading occurs naturally. At creation time a BApp (an application written using the BeOS API) using BWindow will automatically have two threads created. One controls the underlying program in the application server and the other controls the client functions of the window that is created. The window can then be moved around the desktop, resized, and so on without affecting the operation of the program controlling it.

The other advantage of threading over multitasking is that it allows the OS to switch the threads of an individual application between different processors. In a single-processor machine this makes no difference to multitasking, but within a multiprocessing machine you get true symmetric multiprocessing and therefore a much faster overall system. Using threads on a true multi-processing machine allows you to run a thread simultaneously on each processor. Using a four processor machine, and you have 4 threads executing at the same time.

You can see multiple threads in action just by looking at a process list. I've taken the extract below from my system, and you can see the multiple Tracker threads, each one related to a single window. Because each window has it's own controlling thread, updates occur immediately, instead of waiting for the next scheduled update of the entire Tracker program. The controlling process is number 72:

```
   72   #wt Tracker Status  sem  15       2       3 Bpcreate(804)
   73          #wt Deskbar  sem  15    4701    3103 Bpcreate(810)
   76          #wt desktop  sem  15    1425    1287 Bpcreate(853)
  156            #wt Disks  sem  15     633     511 Bpcreate(103402)
  158             #wt MCBe  sem  15    2226    2009 Bpcreate(103424)
```

```
161          #wt develop  sem  15      587      495 Bpcreate(103454)
164          #wt headers  sem  15      314      210 Bpcreate(103484)
167            #wt posix  sem  15     1050      814 Bpcreate(103511)
```

Software Kits

Each interface to the server is accessed by a C++ *software kit*. The kits define the object classes and therefore the data and functions required to access the various servers. Each kit is targeted for supporting a different server, or a different base of functionality. For example, the application kit contains everything required to communicate with the application server, whilst the device kit controls access to and communication with physical devices. It is difficult to make a comparison to a UNIX-style system, as a combination of the system and C libraries go to make up the functions that allow you to program and control the OS.

Application Kit

The application kit describes the core application objects. These include the base BApplication object, which is the building block for all applications, and the BRoster object, which keeps track of the running applications. The BMessage object is used to pass objects and data between threads, and the threads are controlled and managed by the BLooper objects. The clipboard functionality is supported through the BClipboard object class.

The application kit is the most important of all the software kits as it defines the set of objects which allow applications to be built. Without the application kit, the notion of BApplications would not exist.

Device Kit

In order to write device drivers you need to use the device kit to extend the functionality of the kernel. This includes hardware drivers, display drivers, and other hardware-based interfaces. The device kit also provides support for the standard devices of the OS, which vary depending on the machine you are working on, but include serial devices (BSerial).

Device drivers can also be used to define elements which are not physical devices, but that you want to access in a set way. For example, Osma Ahvenlampi has developed the /dev/random device which returns a random number based on the hardware interrupts in the kernel.

Game Kit

The game kit provides a simple interface to support full-screen rather than window-based graphics, an essential level of support for fast full-screen animation.

3D Kit

Using the 3D kit it is possible to construct and control fully rendered 3-D objects in real time. The 3D kit also includes support for the industry-standard OpenGL libraries.

Interface Kit

The interface kit provides the objects that support the windows (BWindow) and container objects for laying out information within windows (BView). The supported objects include the standard check boxes (BCheckBox) and text boxes (BTextView). For those who are used to working with X, the interface kit is defines the widgets used top display information within a window. For example, the Motif window manager specifies the xmBulletinBoardWidgetClass widget, which is roughly equivalent to the BView object in the interface kit. It is the interface kit which also supports the graphic and drawing objects. The whole kit is generally used with the application kit to provide the required objects to the whole of the application.

Kernel Kit

Unlike the other kits, the kernel kit is C-based instead of C++-based. It provides low-level access to the kernel functions. This allows a programmer to create and manage multiple threads. Ports are the in/out box of the message world and allow different threads to pass messages to each other. Semaphores can be used to control the execution time and sequence of threads and other pieces of code. Areas are roughly equivalent to the shared memory system available under most UNIX flavors. They allow large areas of memory to be allocated and then shared between threads. The same blocks of memory can also be forced to remain in the system memory of the machine, rather than being shunted to the disk as with normal virtual memory.

Finally, the last major part of the kernel interface is the image system. An *image* is the code which is produced by the compiler and can be an entire application, a dynamically loadable library, or an add-on image. This last item is the mechanism used by various programs within the OS to support the notion of add-ons to their functionality. The kernel kit also provides a number of utility functions such as time access, system information, and datatype operations.

Media Kit

The media kit supports the sound and video abilities of the OS. At its base level, the media kit provides mechanisms for the generation, monitoring, and manipulation of media-type information. Much like technologies such as MPEG and Quicktime, the media kit also supports synchronization between different media formats, which is useful for broadcast and video editing. The synchronizing mechanism is built into the media kit; all you need to do is select the data streams you want to synchronize, and the media server does the rest of the work.

The features of the media kit are extended slightly through the use of subscriber technology. The notion of *subscription* to a media stream means that audio or video data can be monitored and manipulated in real time between the input and output of the data. For example, you could produce an electronic graphic equalizer that subscribes to an audio stream and modifies the signal before outputting it to the computer's speaker. This is a fairly complex example; at its simplest level, subscription allows audio and video data to be read in and written direct to disk, and vice versa. This allows the BeOS to support a very fast I/O system for audio and video information, which can be seen very readily when you view the optional videos. Better still, try viewing lots of the videos supplied on the CD simultaneously.

Midi Kit

MIDI (Musical Instrument Digital Interface) is used by musicians to control, communicate, and sequence musical information. For the most part, when involved with computers MIDI is used to control external instruments by a sequencing program. A sample BeOS MIDI application is included with the OS. The midi kit will read, write to, and control musical instruments using the MIDI standards and MIDI interfaces connected to the BeBox. On the Mac, the MIDI kit uses the serial ports, assuming they are connected to suitable MIDI devices, and on the Intel version the MIDI kit interfaces to the MIDI support on a sound card, or to none if no sound card is installed. In the later versions of the BeOS the MIDI kit can also be used to interface to a software based MIDI synthesizer.

Network Kit

As the name suggests, the network kit provides access by BApps to the network. Access is currently supported through the use of BSD-style sockets and TCP/IP. The network kit is also the location for the BeMail library, which supports Internet-style e-mail messages. From PR onwards Be has developed an Appletalk library for compatibility with Apple computers. At present this only supports interfacing to Appletalk printers, but longer term this may provide network access to Appletalk servers.

Storage Kit

Access to directories, files, and the file systems is achieved via the storage kit. This defines the structures and functions used to access the core components of the storage system on the BeOS. Using the storage kit it also possible to expand the functionality and supported file system types. Some of the functions provided are roughly equivalent to UNIX functions (dirent() and statfs(), for example).

Support Kit

The lowest levels of the BeOS application system are accessed via the support kit. Using the object model it is possible to organize and arrange information using the BList object class, and access the errors and base data types within the entire object model. In essence, the support kit provides you with access to the very building blocks (or objects) that go to make up the Be object-based development environment. In addition, the support kit also provides a syslog-style system for logging errors (almost identical to the UNIX model), a StopWatch toolkit, and a system for caching memory, which is useful for large data throughput applications.

Headers and Libraries

All the headers are stored within the /boot/develop/headers/be directory:

```
total 620
drwxr-xr-x   1 baron    users        2048 Jul 20 09:33 .
drwxr-xr-x   1 baron    users        2048 Jul 20 09:33 ..
-r--r--r--   1 baron    users         448 Jun 28 02:13 AppKit.h
-r--r--r--   1 baron    users         509 Jun 28 02:13 Be.h
-rw-rw-rw-   1 baron    users      589776 Jun 28 02:59 BeHeaders
-r--r--r--   1 baron    users         313 Jun 28 02:13 BeHeaders.pch++
-r--r--r--   1 baron    users         309 Jun 28 02:13 DeviceKit.h
-r--r--r--   1 baron    users         224 Jun 28 02:13 GameKit.h
-r--r--r--   1 baron    users        1014 Jun 28 02:13 InterfaceKit.h
-r--r--r--   1 baron    users         346 Jun 28 02:13 KernelKit.h
-r--r--r--   1 baron    users         381 Jun 28 02:13 MediaKit.h
-r--r--r--   1 baron    users         399 Jun 28 02:13 MidiKit.h
-r--r--r--   1 baron    users         289 Jun 28 02:13 NetKit.h
-r--r--r--   1 baron    users         638 Jun 28 02:13 StorageKit.h
-r--r--r--   1 baron    users         461 Jun 28 02:13 SupportKit.h
drwxr-xr-x   1 baron    users        2048 Jul 20 09:32 add-ons
drwxr-xr-x   1 baron    users        2048 Jul 20 09:32 app
drwxr-xr-x   1 baron    users        2048 Jul 20 09:32 device
drwxr-xr-x   1 baron    users        2048 Jul 20 09:33 drivers
drwxr-xr-x   1 baron    users        2048 Jul 20 09:33 game
drwxr-xr-x   1 baron    users        2048 Jul 20 09:33 interface
drwxr-xr-x   1 baron    users        2048 Jul 20 09:33 kernel
drwxr-xr-x   1 baron    users        2048 Jul 20 09:33 mail
drwxr-xr-x   1 baron    users        2048 Jul 20 09:33 media
drwxr-xr-x   1 baron    users        2048 Jul 20 09:33 midi
drwxr-xr-x   1 baron    users        2048 Jul 20 09:33 net
drwxr-xr-x   1 baron    users        2048 Jul 20 09:33 nustorage
drwxr-xr-x   1 baron    users        2048 Jul 20 09:33 opengl
drwxr-xr-x   1 baron    users        2048 Jul 20 09:33 support
```

Each of the top-level header files contains #include statements to incorporate the contents of the software kit folders. This enables you to incorporate the entire software kit with one single #include statement in your own source.

The libraries are stored within the /boot/beos/system/lib folder and are split into a number of files, mostly by the software kit or server.

Naming Conventions

The more observant of you will have already spotted a trend in the naming of objects and functions within the BeOS API. Nearly all objects within the BeOS API start with the letter "B," for example, BApplication.

All names start with an uppercase character, and a mixed case is used throughout the API to help distinguish API code from POSIX code. Within C++, object-based functions are attached to their parent objects, and so you can reuse names throughout a project.

The rules for symbol names are identical to those of the UNIX style (see below), and there are the additional reserved names of the C++ language to avoid. These include:

catch	inline	protected	virtual
class	new	public	
delete	operator	template	
friend	private	this	

Interfacing with the POSIX Libraries

If you refer back Figure 16.1, the BeOS API not only sits on top of the servers and the kernel, it also partly covers the POSIX interface.

C++ is merely a superset of the standard C programming language, and is backward-compatible with C-style functions and data. In my first example of a BeOS application I used the printf function to display a message on the screen. This is actually a C library function, as opposed to a POSIX library function, but the principles are the same. Any C function can be used within a C++ application providing it is available in a library. This means you can use POSIX functions, supplied libraries (such as gdbm), and your own C code to support the functions and abilities you need.

For hardened C programmers, this is preferable to rewriting code in C++, but it loses the advantages of reusable code and expandable objects. Many people would argue, however, that well-written C code has been reusable for years and that C++ is just the latest programming fashion, as Java is rapidly becoming, and as Pascal and BASIC have previously been.

UNIX Style

UNIX-style programs are those run within a Terminal window and are the type most people would expect to use on a DOS or UNIX machine.

Overview

UNIX-style programs (it is wrong to call these programs POSIX-style, as POSIX doesn't define how a program is written, only some of functions that are used to write it) are much simpler than Be-style programs.

For a start, we can remove all of the additional features that are supported by the C++ libraries.

Program Structure

With UNIX-style programs, the format and layout is much easier and simpler. To duplicate the functionality of our BApp program we can use the following source:

```
#include <stdio.h>

void main(void)
{
	printf("Hello World!\n");
}
```

When we run this we get, once again:

```
Hello World!
```

There's no textual difference in the result. The real differences for the user are really aesthetic. The execution sequence starts with the function main() after the first opening brace, then it runs the library function printf, and execution stops when it reaches the closing brace. There is no application which is separate from the program, we don't need to contact the application server to generate the application, window and other information, but the message is still displayed to the user.

The main differences in the programming are:

- Calls to system functions are made straight to the kernel or the supported libraries; functions are not accessed via the software kits or the kernel.
- The execution is direct; there is no communication to the application or any other servers.
- We don't have access to the window environment of the BeOS.

On the whole the program is much simpler, but we have also lost a lot of flexibility, the most significant part of which is the ability to use the graphical interface.

Under the BeOS, there really isn't a lot of distinction between the two styles. A BApplication can use POSIX functions in the same way as a POSIX program can, and many of the function calls to the core of the operating system are supported in C as well as C++ via the software kits. However, there is a difference in the way the program is constructed with the use of BApplication objects compared to the simple straightforward C style. The major difference is the interface, where POSIX style programs will use the text based interface and BApplication applications will use the windows environment.

Headers and Libraries

Back in Chapter 8, we took a look at the header files and how they affect the porting process. Now let's look again at the headers and their role in programming a UNIX-style application.

First, let's start by taking a look at the directory contents of /boot/develop/headers/posix:

```
total 129
drwxr-xr-x   1 baron    users        2048 Jul 20 09:33 .
drwxr-xr-x   1 baron    users        2048 Jul 20 09:33 ..
-r--r--r--   1 baron    users        4056 Jun 28 02:13 CPlusLib.h
-r--r--r--   1 baron    users         157 Jun 28 02:13 alloca.h
-r--r--r--   1 baron    users        1281 Jun 28 02:13 ansi_parms.h
-r--r--r--   1 baron    users         737 Jun 28 02:13 assert.h
-r--r--r--   1 baron    users        1211 Jun 28 02:13 be_math.h
-r--r--r--   1 baron    users         532 Jun 28 02:13 bsd_mem.h
-r--r--r--   1 baron    users        3406 Jun 28 02:13 ctype.h
-r--r--r--   1 baron    users         671 Jun 28 02:13 dirent.h
-r--r--r--   1 baron    users         359 Jun 28 02:13 div_t.h
-r--r--r--   1 baron    users        1666 Jun 28 02:13 errno.h
-r--r--r--   1 baron    users        1699 Jun 28 02:13 fcntl.h
-r--r--r--   1 baron    users        4099 Jun 28 02:13 float.h
-r--r--r--   1 baron    users        4762 Jun 28 02:13 getopt.h
-r--r--r--   1 baron    users         458 Jun 28 02:13 grp.h
-r--r--r--   1 baron    users        1031 Jun 28 02:13 limits.be.h
-r--r--r--   1 baron    users        1134 Jun 28 02:13 limits.h
-r--r--r--   1 baron    users        1157 Jun 28 02:13 locale.h
-r--r--r--   1 baron    users        5206 Jun 28 02:13 malloc.h
-r--r--r--   1 baron    users        6256 Jun 28 02:13
malloc_internal.h
-r--r--r--   1 baron    users        2361 Jun 28 02:13 math.be.h
-r--r--r--   1 baron    users       11274 Jun 28 02:13 math.h
-r--r--r--   1 baron    users         133 Jun 28 02:13 memory.h
-r--r--r--   1 baron    users         239 Jun 28 02:13 null.h
-r--r--r--   1 baron    users        3452 Jun 28 02:13 parsedate.h
-r--r--r--   1 baron    users         522 Jun 28 02:13 pwd.h
-r--r--r--   1 baron    users        1534 Jun 28 02:13 setjmp.h
-r--r--r--   1 baron    users        5406 Jun 28 02:13 signal.be.h
-r--r--r--   1 baron    users         940 Jun 28 02:13 signal.h
-r--r--r--   1 baron    users         453 Jun 28 02:13 size_t.h
-r--r--r--   1 baron    users        1130 Jun 28 02:13 stdarg.h
-r--r--r--   1 baron    users         540 Jun 28 02:13 stddef.h
```

```
-r--r--r--   1 baron    users        6724 Jun 28 02:13 stdio.h
-r--r--r--   1 baron    users        3074 Jun 28 02:13 stdlib.h
-r--r--r--   1 baron    users         671 Jun 28 02:13 string.be.h
-r--r--r--   1 baron    users        5340 Jun 28 02:13 string.h
drwxr-xr-x   1 baron    users        2048 Jul 20 09:33 sys
-r--r--r--   1 baron    users        6623 Jun 28 02:13 termios.h
-r--r--r--   1 baron    users        3181 Jun 28 02:13 time.h
-r--r--r--   1 baron    users        4448 Jun 28 02:13 unistd.h
-r--r--r--   1 baron    users         243 Jun 28 02:13 utime.h
-r--r--r--   1 baron    users         279 Jun 28 02:13 va_list.h
-r--r--r--   1 baron    users         560 Jun 28 02:13 wchar_t.h
```

The /boot/develop/headers/posix/sys directory contains:

```
total 21
drwxr-xr-x   1 baron    users        2048 Jul 20 09:33 .
drwxr-xr-x   1 baron    users        2048 Jul 20 09:33 ..
-r--r--r--   1 baron    users         319 Jun 28 02:13 dir.h
-r--r--r--   1 baron    users         289 Jun 28 02:13 dirent.h
-r--r--r--   1 baron    users          92 Jun 28 02:13 fcntl.h
-r--r--r--   1 baron    users          68 Jun 28 02:13 file.h
-r--r--r--   1 baron    users         129 Jun 28 02:13 ioctl.h
-r--r--r--   1 baron    users         161 Jun 28 02:13 param.h
-r--r--r--   1 baron    users         130 Jun 28 02:13 socket.h
-r--r--r--   1 baron    users        3480 Jun 28 02:13 stat.h
-r--r--r--   1 baron    users         358 Jun 28 02:13 sysmacros.h
-r--r--r--   1 baron    users         793 Jun 28 02:13 time.h
-r--r--r--   1 baron    users         502 Jun 28 02:13 times.h
-r--r--r--   1 baron    users         959 Jun 28 02:13 types.h
-r--r--r--   1 baron    users         300 Jun 28 02:13 utsname.h
-r--r--r--   1 baron    users         649 Jun 28 02:13 wait.h
```

We can actually separate these listings into two groups. The UNIX style of programming uses C, which has its own set of headers. Any OS will also have its own collection of headers which define the functions used to access the system. We already know that the BeOS uses the POSIX standard, something we'll look at in the next chapter.

The standard C library consists of the following header files:

assert.h Diagnostics
ctype.h Character class tests
float.h Floating point limits
limits.h Integer and string limits
math.h Mathematical functions
setjmp.h Non-local jumps
signal.h Signals
stdarg.h Variable argument lists
stdio.h Input and output
stdlib.h Utility functions
string.h String functions
time.h Date and time functions
The remainder of the header files are therefore Be- and/or POSIX-specific.

Under UNIX, there is essentially no such thing as a standard library, but the file libc.a contains all the C functions, with additional libraries supporting additional OS or utility functions. Under the BeOS, the standard C library does not exist; it has been split into a number of files spread across the OS. See Chapter 8 for more information.

Naming Conventions

Defined within C and POSIX are a number of naming conventions. Within this superset there are a number of subset conventions relevant to each element of the program. The basic difference between writing a BeOS API application and a UNIX style application when it comes to naming conventions is the use of upper- and lowercase.

Traditionally all functions, keywords, and variables are referenced within C as lowercase names. Uppercase is used very rarely within normal programs, except for macro definitions, but is sometimes used to indicate a difference between two major sets of program functions. For example, X and window managers such as Motif use titlecase so that you can distinguish the window functions and variables from the rest of the application.

First in the lists of reserved words are the defined keywords as used within the standard C language. These are:

auto	double	int	struct
break	else	long	switch
case	enum	register	typedef
char	extern	return	union
const	float	short	unsigned
continue	for	signed	void
default	goto	sizeof	volatile
do	if	static	while

There are also a number of standard functions defined within the C language, using these as names for your own variables and functions should be avoided. All are defined within the C headers listed in the previous section:

abort	fprintf	longjmp	strcat
abs	fputc	malloc	strchr
acos	fputs	mblen	strcoll
asctime	fread	mbstowcs	strcpy
asin	free	mbtowc	strcspn
atan	freopen	memchr	strerror
atan2	frexp	memcmp	strftime
atexit	fscanf	memcpy	strlen
atof	fsetpos	memmove	strncat
atoi	ftell	memset	strncmp
atol	fwrite	mktime	strncpy
bsearch	getc	modf	strpbrk

ceil	getchar	perror	strrchr
calloc	getenv	printf	strspn
clearerr	gets	putc	strstr
clock	gmtime	putchar	strtod
cos	isalnum	puts	strtok
cosh	isalpha	qsort	strtol
ctime	iscntrl	raise	strtoul
difftime	isdigit	rand	strxfrm
div	isgraph	realloc	system
exit	islower	remove	tan
exp	isprint	rename	tanh
fabs	ispunct	rewind	time
fclose	isspace	scanf	tmpfile
feof	isupper	setbuf	tmpnam
ferror	isxdigit	setlocale	tolower
fflush	labs	setvbuf	toupper
fgetc	ldexp	sin	ungetc
fgetpos	ldiv	sprintf	vfprintf
fgets	localeconv	sqrt	vprintf
floor	localtime	srand	vsprintf
fmod	log	strcmp	wcstombs
fopen	log10	sscanf	wctomb

Next are the naming conventions used within the POSIX standard. There is some crossover between the C library functions and those supported by POSIX, and also some omissions because of the lack of support of these functions by the BeOS:

access	fdopen	mkfifo	sigsetjmp
alarm	fork	open	sigsuspend
asctime	fpathconf	opendir	sleep
cfgetispeed	fstat	pathconf	stat
cfgetospeed	getcwd	pause	sysconf
cfsetispeed	getegid	pipe	tcdrain
cfsetospeed	getenv	read	tcflush
chdir	geteuid	readdir	tcgetattr
chmod	getgid	rename	tcgetpgrp
chown	getgrgid	rewinddir	tcsendbreak
close	getgrnam	rmdir	tcsetattr
closedir	getgroups	setgid	tcsetpgrp
creat	getlogin	setjmp	time
ctermid	getpgrp	setlocale	times
cuserid	getpid	setpgid	ttyname
dup	getppid	setuid	tzset
dup2	getpwnam	sigaction	umask

execl
execle
execlp
execv
execve
execvp
_exit
fcntl
getpwuid
getuid
isatty
kill
link
longjmp
lseek
mkdir
sigaddset
sigdelset
sigemptyset
sigfillset
sigismember
siglongjmp
sigpending
sigprocmask
uname
unlink
utime
waitpid
write

In addition to these names there are some conventions that can be used, but are best avoided if at all possible. Here are some good rules to follow:

- Avoid naming functions with a leading underscore (_). Many of the C internal support functions use one or two leading underscores.
- Only use uppercase names for macro definitions, and try not to use mixed-case names within UNIX/POSIX-style programs.
- Don't use any names beginning with "sa_" or "SIG", which are related to the signal functions.
- Don't use symbols starting "l_", "F_", "O_", or "S_", all of which are used within the fcntl system.
- Symbols starting with "E" should also be avoided as they are used to define errors.

This is not an exhaustive list, and you should refer to a C manual such as *The C Programming Language* by Kernighan and Ritchie.

The vagaries of programming on the BeOS can make programming, and more specifically porting, interesting. Because the BeOS supports the two different styles you have to take these items into consideration when porting software. For the purposes of the porting you are only concerned with two elements: the supported headers and functions, and the reserved names used throughout the OS.

The BeOS API provides a different of programming to that which you are used to. However, the POSIX style interface provides a much more familiar environment, and for porting purposes is a much needed element of the operating system.

Chapter 17. - POSIX

We’ve covered the relevance of POSIX in the makeup of the BeOS a number of times. While a large majority of the software written for the BeOS will use the BeOS C++/ object-based environment, a significant proportion is expected to be made up of UNIX-style tools and utilities.

In order to make this possible, Be needed to build a UNIX-like interface to the complex BeOS system, and that presented a problem. There is no such thing a single UNIX OS. Most commercial UNIX operating systems, including HP-UX, Solaris, and SCO, are made up of elements from the two main schools of UNIX software, BSD and AT&T (System V). Even different versions from the same vendor are not tied to one particular variety. If any UNIX limited itself to only the ‘standard’ functions, we wouldn’t have access to the tools and utilities most people consider to be the standard, such as NIS, DNS, and NFS at a network level, and sockets and streams at an OS level.

Rather than trying to adhere to a specific UNIX standard, Be decided to reverse the position and instead follow the standard that UNIX vendors, and vendors of other OS, use as their guide to developing their OS. This standard is POSIX, and we will take a brief look at the effect of POSIX on UNIX and how the POSIX support has been implemented on the BeOS, and how this pertains to the porting process.

What Is POSIX?

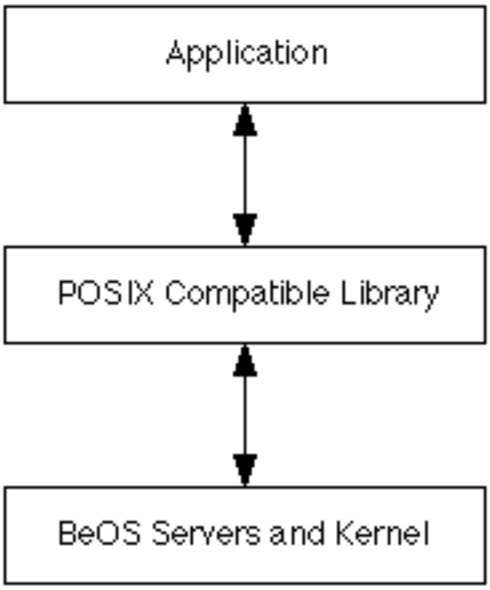
POSIX is a set of standards that apply to OSs, utilities, and programming languages. The standards are wide-ranging and cover everything from “standard” function calls and what they should return, to the capabilities and features of the OS on which those functions rely. In relation to the BeOS, the standard we are most interested in is known as POSIX 1003.1 and defines the interface between the applications and the OS (we’ll look at this abstraction layer later). The standards were set by the IEEE and have been adopted by a number of other organizations including the American National Standards Institute (ANSI) and the International Standards Organization (ISO).

There are many POSIX standards other than POSIX 1003.1 (POSIX.1), including real-time extensions (POSIX 1003.1b), threads (POSIX 1003.1c), and a shell command language based around the System V shell with features from the C and Korn shells (POSIX 1003.2). This last standard not only specifies the shell and its abilities, but also the commands that the shell should be able to find (POSIX 1003.2a). This specification was intended to make shell scripts more portable, and it's understandable why the additional commands were added to the specification.

The POSIX standard is also endorsed and supported by a number of organizations, including the leading UNIX vendors such as Sun Microsystems, Microsoft, IBM, Digital, and Hewlett-Packard, the less well-known UNIX and mainframe system developers like Bull and Data General, and organizations such as the Free Software Foundation. Endorsement by such companies, as well as acceptance by both ANSI and ISO, virtually guarantees the use and support of the standard by all information systems companies, and this provides us with a suitable base to work from when developing new software and porting existing software.

As I have already stated, the POSIX.1 standard defines the interaction between applications and the OS, although this communication is strictly organized into the two sides of the requirements. An application needs to make a call to the OS and uses a specific function; the OS performs the functions and returns a result code. The POSIX.1 standard defines the function name used by the calling application and the arguments to the function and what they represent. The expected response from the OS, including it's format and range of values is also defined. How the OS implements the function call is not defined, because it doesn't need to be. In fact, the standard deliberately avoids specifying the OS functions; only functions used by typical applications are included. You can see how the different parts interact in Figure 17.1.

Figure 17.1
POSIX interaction



While POSIX has its history in UNIX, this abstraction of the function definition allows the POSIX standard to be implemented on a variety of machines and OSs. For example, the function call chdir() changes the directory specified in the first and only argument. The implementation level of this within the OS could be within the libraries or within the OS itself and could rely internally on hooks, traps, or events which force the directory change. As programmers and porters, how this function is implemented doesn't concern us. The function should work as described in the POSIX.1 standard, and therefore allow us to compile and use the program on a number of POSIX-compliant OSs.

```
int chdir( const char *path );
```

The core of the POSIX.1 standard is aimed at the portability of applications, rather than abilities or functionality. A number of areas were identified that include processes, execution environment, files/directories, input/output, and terminal communication. Extensions to the POSIX.1 standard define some of the additional support standards required for using the functions, and for the use of the standard within a programming environment. This helps to define the format of tar and cpio files at a utility level, and the requirement for the use of either traditional or ANSI C as the programming language of choice.

POSIX and UNIX

The features, functions, and specifications of the POSIX.1 standard have come about from an amalgamation of functionality from both System V UNIX (originally developed by AT&T) and BSD UNIX (developed at the University of California, Berkeley). Although both flavors of UNIX are based around the same ideals and features, they have grown up with very different sets of functions and system calls. This is what causes the bulk of the difficulties in porting between OSs.

Unlike UNIX, POSIX is not an operating system. The definition of a standard set of functions and functionality has caused some problems when it comes to porting. Because POSIX uses functions from both varieties of UNIX porting a UNIX application that has been developed with either BSD or SYSV in mind to a POSIX-based OS can be difficult. However, if the package uses POSIX compliant functions, the porting is relatively easy.

If we have a look at a simple example of a function you will see that the differences are minor but also significant. The function localtime() converts a timer value to the local time format. Within BSD, the function prototype was contained in the header file sys/time.h, and in SYSV, the header file time.h. Within POSIX the full definition is

```
#include <time.h>
struct tm *localtime(const time_t *timer)
```

This definition matches the full SYSV specification, including the use of the time_t datatype; BSD on the other hand uses a long.

This helps to demonstrate two of the major differences between POSIX and other flavors of UNIX when it comes to configuration and porting. The first is the use of standard directories and headers, a problem which affects every program you will ever port. The second is the use of standard datatype names; in this example it was time_t, but other functions and function sets use similar datatypes. This hides the underlying type of the data from the user, while providing the level of compatibility required when programming multiple platforms.

A more complex example of the differences can be found in the ioctl command, which has been implemented in a variety of different, and often incompatible, ways on all the UNIX flavors. Under POSIX the ioctl command, which was generally used to control terminals, has been replaced by a number of functions, all beginning with the prefix tc. For example, the command

```
ioctl(fildes, TIOCGPGRP, ...)
```

has been replaced by the function

```
tcgetpgrp(fildes)
```

All of these differences add up to make your life harder or easier, depending on the OS you are porting from or the OS that the package relies on. In general, I've found that SYSV or a SYSV-based flavor of UNIX is the best place to start when porting POSIX applications. This includes Solaris, SCO, and AIX and excludes SunOS, Linux, and, of course, FreeBSD or NetBSD.

The BeOS and POSIX

With the latest public release of the BeOS, the attitude toward the POSIX interface has changed. Up to DR8 of the BeOS, the importance of POSIX was played down and the support was built as a compatible library, rather than forming an integral part of the OS. However, the wealth of free software out there for the UNIX platform has caused a marked change in focus.

The new POSIX libraries were written by the Be team with a copy of *POSIX Programmers Guide* by Donald Lewine (O'Reilly) in front of them. This difference means that the POSIX compatibility has been built in from the start, and the functions are no longer a user library, but instead a proper POSIX support layer with calls direct to the OS. For example, in the past one of the major frustrations was the lack of support for the fork() call, which never worked properly under DR8. It's now a proper system call.

Despite all the work that has been done, though, the BeOS support for POSIX is not absolute, and there are many elements missing from the full POSIX specification. Rather than be negative about the situation, let's look briefly at what parts of the specification the BeOS does support:

- **Signals** Full signal support, including SIGHUP and SIGWINCH. There is also support for interrupts and alarms within the signal system.
- **Terminals** Support for the termios system, including control characters.
- **Variable argument**s Using the stdarg.h header file.
- **File system control** chmod, chown, and so on.
- **File control** Using the standard fcntl and other utilities. File locking however is not supported by fcntl.
- **Directory entries** opendir and related functions from the dirent set.
- **Non-local jumps** Both longjmp and setjmp, with support for signal-based jumps.

This is not an exhaustive list, and we'll cover the specifics of each set of functions in the coming chapters.

Effects on Porting

The POSIX standard is all about portability of software at a source code level. Most authors already support the POSIX standard as an option, and this helps to make the process significantly easier. There are two ways in which you can use this support to your advantage.

The first method, and the most significant of the two is the direct support for the POSIX standard. Most packages provide a level of POSIX support in a number of different ways. emacs, for example, is not too concerned about POSIX except when it comes to signals. This is because the emacs distribution includes most of the required support functions that make up the POSIX library within the sysdep.c file. The second method affects those packages which are less specific about their support. In these cases you may have to use a POSIX-compatible OS to start the process off.

On the whole, POSIX support should make the process easier if the package supports the POSIX standard. If the package doesn't support POSIX directly, then you can use the UNIX equivalents of the commands to produce a POSIX version. For example, we've already seen how ioctl is not a POSIX function (although, rather confusingly, ioctl is still supported by the BeOS), but it does have POSIX equivalents of all the features.

How you implement such a change is entirely up to you, but if you're planning on supplying the change back to the author you should use the #ifdef technique described in Chapter 8 of this book.

•

In the remaining chapters we'll look at the specific areas of the POSIX standard as implemented within the BeOS. We will also take a look at the common UNIX functions and how you can emulate them using POSIX or by writing the code yourself.

Chapter 18. - Kernel Support

The core of most programs revolves around a number of functions that directly access the kernel, or a layer of kernel functionality. Without many of these basic functions, most applications simply wouldn't be able to work, even if you had managed to replace some of the functions we discuss in later chapters.

This chapter covers the core limits and datatypes, memory access, accessing users and groups, processes, interprocess communication, and then the core kernel functions for spawning new jobs. Later in this chapter, I've included information on a number of the utility support functions, including non-local jumps and string handling. Although not strictly kernel related, they do affect the core routines of many applications.

Datatypes

The Metrowerks compiler specifies a number of a base datatypes based on the Standard C definitions. Additionally it defines some datatypes able to cope with larger numbers. The header limits.h defines the minimum and maximum values. The types, their byte sizes and minimum/maximum values are:

Table 18.1

BeOS Datatypes and ranges

Type	Size	Minimum	Maximum
short	2 bytes	-32766	32767
unsigned short	2 bytes	0	65535
int	4 bytes	-2147483646	2147483647
long	4 bytes	-2147483646	2147483647

unsigned long	4 bytes	0	4294967295
long long	8 bytes	-9223372036854775806	9223372036854775807
unsigned long long	8 bytes	0	18446744073709551615
float	4 bytes	1.17549e-38	3.40282e+38
double	8 bytes	2.22507e-308	1.79769e+308
long double	8 bytes	2.22507e-308	1.79769e+308
char	1 byte	-126	127
unsigned char	1 byte	0	255

As you can see, the BeOS is all set for 64-bit processors, already being able to handle huge numbers.

Note: Some operating systems and C compilers support a double double this is the same as a long double.

When porting or writing software to be cross-platform compatible right from the OS up, a number of types are defined in the header files. These datatype macros can be used both for building the kernel and for writing applications, and so regardless of the origin of a package, when it is recompiled the underlying datatypes will remain the same and no type casting or conversion will be necessary.

A number of standard datatype macros are defined using typedef and the BeOS supports a subset of these, which are defined as follows:

Table 18.2

BeOS datatype macros

Name	BeOS type	Description
caddr_t	char *	Core address value
cc_t	unsigned char	Control character
clock_t	long	Clock tick
cnt_t	int	Count type
daddr_t	int	Disk address
dev_t	long	Device number
fpos_t	long long	File position
gid_t	unsigned int	Group ID
ino_t	long long	Inode number
mode_t	unsigned int	File permissions
nlink_t	int	Link count
off_t	long long	File offset
pid_t	long	Process ID

ptrdiff_t	long	Difference between two pointers
sigset_t	long	Signal set
size_t	unsigned long	Memory/variable size
speed_t	unsigned char	Line speed/baud rate
ssize_t	long	Byte count or error indication
tcflag_t	unsigned long	Terminal modes
time_t	unsigned long	Time of day in seconds
uid_t	unsigned int	User ID
umode_t	unsigned int	File mode
wchar_t	char	Wide character type

These macros are used throughout the headers and function definitions as a standard way of specifying the necessary datatypes. The above list represents an almost complete subset of the full POSIX standard. Wherever possible you should use these macros, and not the datatypes shown. This will avoid problems when the package is ported to a different platform.

Resource Limits

All computers and OS have limits — the figure or range above which a variable can not exceed. These affect the operation of a program or application by restricting the range of the variables they need to use. Resource limits also stop applications for overusing the machine or exceeding practical limits on the machines capability.

Accessing the resource limit values is important to many programs so they can limit themselves without affecting the OS. There are two ways of getting hold of this information, using the macros supplied in the headers, or using a function to return the limits for the current OS.

Default Values

There are many limits spread across the header file structure used throughout the OS. Some of them, as we will see, are available not only at the time of compilation but also during execution using the sysconf command.

The following limits are specified within the POSIX standards and are defined when you include the limits.h. All these limits can be preceded by _POSIX_; for example, ARG_MAX becomes _POSIX_ARG_MAX:

Table 18.3

POSIX and BeOS limits

Macro	Value	Notes

ARG_MAX	131024	Maximum size for the arguments and environment to an exec call.
CHILD_MAX	666	Maximum number of processes per real user ID. This is considerably higher than in most implementations because the BeOS is not yet multiuser in the true sense.
LINK_MAX	1	Maximum number of hard links to a single file.
MAX_CANON	255	Maximum bytes in a line for canonical processing.
MAX_INPUT	255	Maximum number of bytes in the character input buffer.
NAME_MAX	256	Maximum length of a file name.
NGROUPS_MAX	32	Maximum number of groups a single user can be a member of.
OPEN_MAX	128	Maximum number of files open by one process.
PATH_MAX	1024	Maximum length of a path name.
PIPE_MAX	512	Maximum number of bytes written to a pipe in a single write command.
SSIZE_MAX	32767	Maximum value of ssize_t.
TZNAME_MAX	32	Maximum number of bytes in a time zone name.
SYMLINKS_MAX	16	Maximum number of links to be followed. (This is not a POSIX macro, there is no POSIX definition.)

Using sysconf

The sysconf function allows you to obtain some of the system limits from within an application at runtime, rather than using the predefined macros, which only define the values at compilation time. The synopsis of the command is

```
#include <unistd.h>
long sysconf(int name);
```

The returned value is the limit you have requested. The BeOS defines the following values for name:

Table 18.4

Limits available when using sysconf

Macro	sysconf Name	Description
_POSIX_ARG_MAX	_SC_ARG_MAX	The maximum length of arguments to the exec() call.

_POSIX_CHILD_MAX	_SC_CHILD_MAX	The number of simultaneous threads.
CLK_TCK	_SC_CLK_TCK	The number of clock ticks per second.
_POSIX_JOB_CONTROL	_SC_JOB_CONTROL	Job control functions are supported.
_POSIX_NGROUPS_MAX	_SC_NGROUPS_MAX	Maximum number of simultaneous group IDs per user.
_POSIX_OPEN_MAX	_SC_OPEN_MAX	Maximum number of files open by one thread simultaneously.
_POSIX_SAVED_IDS	_SC_SAVED_IDS	Indicates that each thread has a saved set-user-ID and a saved set-group-ID.
STREAM_MAX	_SC_STREAM_MAX	Maximum number of streams available to one thread at one time.
_POSIX_TZNAME_MAX	_SC_TZNAME_MAX	Maximum number of bytes in a time zone name.
_POSIX_VERSION	_SC_VERSION	Shows the year (first four digits) and month (last two digits) that the POSIX standard used was approved.

For example, the code fragment below would print the maximum number of simultaneous streams available to a thread:

```
printf("%ld\n",sysconf(_SC_STREAM_MAX));
```

setrlimit and getrlimit

getrlimit and setrlimit allow you to set system-based resource limits on the current process. It is not possible to control these limits within the BeOS and so neither command exists. The limits that are defined are specified in the limits.h file, which in turn includes the limits.be.h header file. The synopsis for the two commands is:

```
#include <sys/time.h>
#include <sys/limits.h>
struct rlimit {
     int rlim_cur;  /* current (soft ) limit */
     int rlim_max;  /* hard limit */
};
int getrlimit(int resource, struct rlimit *rlp);
int setrlimit(int resource, struct rlimit *rlp);
```

Each function works by passing an rlimit structure to the function. The getrlimit function returns this information for the limit specified in the resource argument, and the setrlimit function attempts to set a new current value. The full list of limits that should be available using these functions is shown in table 18.5.

Table 18.5

Limits available with getrlimit/setrlimit

Resource	BeOS Limit	Description
RLIMIT_CORE	Unknown	The maximum size of a core image file, in bytes
RLIMIT_CPU	Unknown	The maximum amount of Cpu time that a process may consume
RLIMIT_DATA	Unknown	The maximum size that the data segment of an application can be
RLIMIT_FSIZE	Unknown	The largest size of a file
RLIMIT_MEMLOCK	Unknown	The largest amount of memory that a process can lock into physcial memory
RLIMIT_NOFILE	128	The maximum number of files a process can have open at any one time
RLIMIT_NPROC	Unknown	The maximum number of processes that a single user can have running at the same time.
RLIMIT_RSS	Unknown	The maximum size that the resident set of a process (physical memory) can consume.
RLIMIT_STACK	262144	The maximum size of the stack segment of a process, in bytes.

Memory Handling

There are two ways of allocating specific areas of memory. One is to use the stack space, which is used by all applications to store the values of local variables, arguments to functions, and the callbacks to previously called functions. There is a limit to stack space, and so using it for large memory allocation does not work.

The other method is to use dynamic memory allocation, which allocates blocks of memory in the heap, an almost unlimited supply of memory available to all applications. The limit itself is restricted only by the maximum memory size plus the swap space.

There are two basic sets of commands. The alloca function takes memory from the stack space. The malloc, calloc and realloc functions take memory from the heap. The free function releases heap memory allocated using one of the malloc family of functions.

alloca

The alloca function allocates space from the stack during runtime. It's designed so the space will be reclaimed when the calling function or the entire program exits; there is no other way to free the memory once allocated:

```
#include <alloca.h>
void *alloca(size_t size);
```

alloca returns a pointer to the memory area if successful, or NULL if the allocation failed. Within the BeOS, alloca is a builtin function with the name __alloca. To use it, you must include the alloca.h header file, which uses a macro definition to point alloca references to the internal version.

Most GNU tools come with a version of the alloca function supplied within alloca.c. This version was originally designed to overcome a performance problem in the emacs package, but has now been extended and expanded to be supported on a number of platforms and is used across the entire GNU package set. I advise you to use the BeOS-specific version; it is more reliable and less prone to errors than the GNU version because of the specialties built into the BeOS.

Stack space is finite on the BeOS, currently set to 256K. The GNU alloca is not subject to this limit, but it is good practice to check the size being allocated by alloca if the program drops into the debugger with a "data access exception" error. In my experience, alloca is unreliable on the BeOS, particularly when allocating memory close to or beyond the stack size. Instead of returning NULL the allocation will cause a drop into the debugger. If possible, and if you are willing to accept the performance decrease, I would replace alloca with malloc but remember to incorporate the necessary free statements to fee up memory after use.

malloc, calloc, and realloc

These three functions allocate or reallocate memory. They are slower than alloca because they take memory from the heap, rather than from the stack. This means that the functions must find a suitable "blank" space, and then keep a record of the free blocks in memory that are available to be used, hence the performance degradation. On the other hand, these functions can allocate almost unlimited amounts of memory to be used by an application.

The malloc function is used identically to alloca to allocate a block of space:

```
#include <stdlib.h>
void *malloc(size_t size);
```

A pointer to the allocated memory is returned, or NULL if malloc was unable to find a suitable block for allocation. The contents of the memory space are not zeroed, and therefore the contents are completely random. If you need to zero the memory, either use calloc or use memset on the returned block to zero the contents.

The calloc function is identical to the malloc function, except that the memory is set to zero on allocation. You also have the ability to specify the size of the elements and the number of elements to be stored within the memory block. This doesn't produce a different type of memory allocation, the calloc function still allocates a set number of bytes:

```
#include <stdlib.h>
void *calloc(size_t nmemb, size_t size);
```

The code fragment below demonstrates the use of malloc to allocate a zeroed area of memory:

```
#include <stdio.h>
#include <stdlib.h>

void main(void)
{
	char *myblock;

	myblock=malloc((16*1024*1024));
	if (myblock==NULL)
	{
		printf("Couldn't allocate memory block\n");
		return;
	}
	else
	{
		memset(myblock,0,(16*1024*1024);
		printf("Allocated 16Mb\n");
	}
}
```

The same code in calloc is:

```
#include <stdio.h>
#include <stdlib.h>

void main(void)
{
	char *myblock;

	myblock=calloc(16,(1024*1024));
	if (myblock==NULL)
	{
		printf("Couldn't allocate memory block\n");
		return;
	}
	else
		printf("Allocated 16Mb\n");
}
```

The realloc function reallocates an area of memory. This can be an increase or a decrease:

```
#include <stdlib.h>
void *realloc(void *ptr, size_t size);
```

The pointer returned is the new location of the memory block, which may or may not have moved. The ptr is the pointer returned by a previous call to malloc, calloc, or realloc. If the size requested is larger than the previous block then the extra memory will not have been initialized. If it is smaller, the memory block will be truncated (no checks are made to ensure the memory block is empty). If you specify a pointer that hasn't been returned by one of the allocation family of functions, it could have disastrous results.

Most applications use alloca to specify buffer spaces for reading in files (compilers for example) where speed is essential. The remainder of the block memory allocation is via one of these functions. If a program uses a lot of local/global variables of significant size, use malloc and free in place of alloca to avoid crashes.

free

Once a block has been allocated using malloc, calloc, or realloc it can be freed using the free command:

```
#include <stdlib.h>
void free(void *ptr);
```

The ptr is the pointer to the previous allocation command. No value is returned, so it is impossible to tell whether the memory has been freed or not without attempting to access the previous pointer. You can also simulate the operation of free using realloc with a size value of 0:

```
realloc(mybuffer, (size_t) 0);
```

This is considered by most to be bad programming, especially since there is a special free function available, but some packages use this method.

> Note: Using export MALLOC_DEBUG=true in the shell will provide debugging information for the malloc function. This may help to isolate problems in memory allocation if used in combination with the debugger to trace the faults.

Users and Groups

Although the BeOS is not a multiuser system, the POSIX definition states that the system must have a concept of users, even if multiple users aren't available. This means that an OS supporting the POSIX standard must have the ability to return a valid user ID. This appears to be a trivial item, but even simple operations like listing files cause the user and group information to be shown.

Results from get Functions

The basic get functions retrieve information from the OS about the current user and group, the effective user and group, and the user's name:

```
#include <sys/types.h>
#include <unistd.h>
uid_t getuid(void);
uid_t geteuid(void);
char *getlogin(void);
gid_t getgid(void);
gid_t getegid(void);
```

The getuid and getgid functions return the user ID and group ID respectively. In both cases, the BeOS will always return a figure of 0 (zero), since there is only one user on the system. Traditionally under UNIX, the superuser, or root, is the only user to have an ID of zero. However, since root has access to all parts of the OS and this is effectively the level of access you have to the BeOS, it makes sense to do it this way.

This may, however, cause you a number of problems with programs that specifically ask to be run by a user other than root. In these cases, the best solution is to remove the level of protection by commenting the section out completely, or by using macro definitions to remove it from the code at compile time.

Considering what we have already found, it is normal to expect that the getlogin function, which returns the name of the current user, would return root. Wrong! Let's try it:

```
#include <sys/types.h>
#include <stdio.h>
#include <unistd.h>
void main(void)
{
       printf("%s\n",getlogin());
}
```

If we compile and run this program, it returns:

```
baron
```

There is some mystery over exactly where this name comes from. Needless to say, the origin is not important; what is important is that getlogin didn't return what we expected. Worse, the source of this information isn't where we would expect it to be either. Under UNIX all user information is stored within the /etc/passwd file. This contains the user name, ID, real name, and so on. This file does not exist under the BeOS, and so the information must come from elsewhere.

If you check the environment variables of the shell you will see the standard variable USER. To check this, either type set, which displays all the information, or better, type:

```
$ echo $USER
```

The name returned by default is baron. If you change this name within the shell, subsequent calls to the getlogin command will return the name you specified:

```
$ cd /boot/develop/headers
$ ls -l
drwxr-xr-x   1 baron    users        2048 Jun  8 08:03 be
drwxr-xr-x   1 baron    users        6144 May 29 02:08 cpp
drwxr-xr-x   1 baron    users        2048 May 29 02:08 gnu
drwxr-xr-x   1 baron    users        2048 May 29 02:08 posix
$ export set USER=martinb
$ ls -l
drwxr-xr-x   1 martinb  users        2048 Jun  8 08:03 be
drwxr-xr-x   1 martinb  users        6144 May 29 02:08 cpp
drwxr-xr-x   1 martinb  users        2048 May 29 02:08 gnu
drwxr-xr-x   1 martinb  users        2048 May 29 02:08 posix
```

To make matters even more confusing, this is true only for the current shell, and then only for commands run within or from that shell or its descendants. You can change this setting permanently by putting the command in the file /boot/home/config/boot/UserSetupEnvironment. This difference in the source of the information could, potentially, be used to "create" a number of different user names. Of course, all the names would refer back to the same user ID!

The whole system just succeeds in creating confusion by allowing different names to be returned in different shells, even though they are all being run by the same user. However, looking longer term, it is a quick solution, dirty though it may be, to providing full multiuser support at some later stage without introducing new commands, while also allowing software that expects to find these commands to get real data back.

The effective user and group IDs are provided under UNIX to allow programs, and therefore users, access to information they wouldn't normally have access to. A number of core commands use this feature to provide information to the user. The ps command traditionally needs access to the kernel and the running processes in order to extract the information required. This presents a problem, because only root has access to this information normally.

To get around this, using the owner of a file and a special permission bit, an executable will run as the owner of the file, and not the user executing it. For example, a file owned by root with the standard set of execute permissions will be executed as the current user, bob. With the set user ID bit set on the same file, the program will have all the privileges of the superuser. In the former situation, the effective user ID was bob, the executor of the program. In the latter example, the effective user ID was root. The same mechanism can also be used on groups, with the group execute bit defining the execution status.

This is a necessary evil in UNIX to provide basic users with access to information and abilities they wouldn't normally have access to. Under the BeOS, of course, there isn't any user except root. The effective user ID is therefore zero, which matches the standard user ID. To demonstrate this, try compiling the following code:

```
#include <sys/types.h>
#include <unistd.h>

void main (void)
{
       printf("UID: %d\n", getuid());
       printf("EUID: %d\n", geteuid());
       printf("GID: %d\n", getgid());
       printf("EGID: %d\n", getegid());
}
```

This should report the following:

```
UID: 0
EUID: 0
GID: 0
EGID: 0
```

In order to aid the user and group model, and further support the POSIX standard, the BeOS also supports the functions for obtaining user and group information straight from the databases:

```
#include <sys/types.h>
#include <unistd.h>
#include <grp.h>
int getgroups(size_t size, gid_t list[]);
struct group *getgrgid(gid_t gid);
struct group *getgrnam(const char *name);
struct passwd *getpwuid(uid_t uid);
struct passwd *getpwnam(const char *name);
```

The getgroups function places the list of group IDs of groups which the current user is a member of into the array specified. With a size of zero, the function returns the number of groups the current user is a member of, and therefore the number to be specified in the next call to the function. In the current release, this function always returns zero.

This paves the way for the remainder of the functions, all of which would return a similarly sparse response in the absence of any real user or group information. If they existed. Although the definitions appear in the header files, the functions themselves do not appear in the standard BeOS libraries. If the functions return invalid values, it may be necessary to comment out the functions and replace the values with fixed entries.

Results of set Functions

If we return to our earlier set user ID example, it would be useful to set a specific user or group ID during execution. The commands for this are setuid and setgid:

```
#include <sys/types.h>
#include <unistd.h>
int setuid(uid_t uid);
int setgid(gid_t gid);
```

Both commands return 0 (zero) on success, and -1 on failure. In both cases, the BeOS returns a zero, regardless of the user or group ID specified.

Processes

Aside from the users and groups under which an application is executed, processes can also be collected into process groups. These are different from the execution groups, and allow you to group collaborating processes together. This is especially useful when running a program which spawns a number of children. They should all be members of the same process group, and therefore easy to identify and later kill when you no longer need them.

Process Groups

The following functions allow you to create new process groups and add processes:

```
#include <sys/types.h>
#include <unistd.h>
pid_t getpgrp(void);
int setpgid(pid_t pid, pid_t pgid);
pid_t setsid(void);
```

The setpgid function adds the process specified by the pid argument to the group specified by the pgid argument. The function returns a 0 on success and -1 on failure. The error number is returned in errno.

If the pid is 0, it will add the current application to the specified process group. The BeOS supports the System V ability to also specify pgid as 0, which automatically creates a new group and adds the current application to the group. This is identical to the setsid function.

setsid creates a new process group. The calling application is the group leader and is automatically added to the new group. You can find out which group the calling process is a member of by using the getpgrp function.

The setpgrp function has been implemented differently under BSD and System V. Under BSD, it has now been replaced by the setpgid function. The function definitions are identical:

```
int setpgrp(pid_t pid, pid_t pgrp);
```

For System V, the setpgrp function used to support the functionality now provided by setsid; again, the definitions are basically identical:

```
int setpgrp(void);
```

The most common use of this function was to create a new process group before forking off a number of subprocesses. The functions are completely interchangeable in both cases, and should you need to use setpgrp, use a macro to substitute the function. The example below comes from the source for apache, which tries to identify the level of support provided:

```
#ifndef NO_SETSID
	if ((pgrp=setsid()) == -1) {
		fprintf(stderr,"httpd: setsid failed\n");
		perror("setsid");
		exit(1);
	}
#else
…
```

Process IDs

A process ID is the number given to each running process on the machine. It is sometimes useful to obtain this information within an application for control purposes. For example, a server process may record it's parent ID in a file that can then be referenced by other packages. Many web servers use this method to make shutting them down easier. You can gain information about the current process IDs using a small number of utility functions. They are all defined by the POSIX standard and so should be fairly portable among OSs.

```
#include <sys/types.h>
#include <unistd.h>
pid_t getppid(void);
pid_t getpid(void);
```

The getppid function returns the parent process ID of the calling application. The parent process is the program that called the application. For example, when you run ls the parent of that application is the shell you are using. This information is reported by the ps program as the thread ID.

The getpid function returns the current process ID of the application. In an example of both functions, the following program reports the parent process and process ID:

```
#include <sys/types.h>
#include <unistd.h>

void main(void)
{
	printf("PPID:%d\n",getppid());
	printf("PID:%d\n",getpid());
}
```

Signals

Signals provide a method for interrupting the normal course of program execution. They are very difficult to port because so many different implementations have evolved over the years. This doesn't extend only to implementations on different platforms. Even between versions of the same OS, the implementation has changed enough that signal code has to be rewritten. For the porter, this creates no end of problems. Under the BeOS, of course, we're using POSIX-based signals, but not everybody supports POSIX, and POSIX doesn't provide all the functions and facilities of signals within System V or BSD.

Signals allow you to call functions outside of the normal sequence of execution. In effect the execution sequence is interrupted. When a process receives a signal a call is made to a signal handler, a special function designed to execute a number of commands on receipt of a specific signal. Most people's experience of interrupting is killing an errant process using the kill command.

If no function is attached to a particular signal, then the results will default to one of two possibilities. Either the signal will be ignored and execution will continue, or the program will terminate. In the latter case, under UNIX the program would have exited, and in some cases created a core file, an image dump of the process before it quit. Under the BeOS, the likely result of a signal that would normally cause a termination is that the program will simply quit, usually with a warning.

Apart from the kill command, signals can also come from the keyboard (Control-C, for example, sends a SIGINT to the current process), from internal timers (such as alarm()), and from terminal windows, which receive a SIGWINCH signal when a window is resized.

We'll start by looking at the signals supported by the BeOS and their default responses before moving onto the data structures and functions that enable us to control and manage signals.

Supported Signals

From the signal.be.h file (which is included when using signal.h) we get the following list of supported signals:

```
#define SIGHUP     1    /* hangup -- tty is gone! */
#define SIGINT     2    /* interrupt */
#define SIGQUIT    3    /* `quit' special character typed in tty  */
#define SIGILL     4    /* illegal instruction */
#define SIGCHLD    5    /* child process exited */
#define SIGABRT    6    /* abort() called, dont' catch */
#define SIGPIPE    7    /* write to a pipe w/no readers */
#define SIGFPE     8    /* floating point exception */
#define SIGKILL    9    /* kill a team (not catchable) */
#define SIGSTOP    10   /* suspend a thread (not catchable) */
#define SIGSEGV    11   /* segmentation violation */
#define SIGCONT    12   /* continue execution if suspended */
#define SIGTSTP    13   /* `stop' special character typed in tty */
#define SIGALRM    14   /* an alarm has gone off (see alarm()) */
#define SIGTERM    15   /* termination requested */
```

```
#define SIGTTIN    16   /* read of tty from bg process */
#define SIGTTOU    17   /* write to tty from bg process */
#define SIGUSR1    18   /* app defined signal 1 */
#define SIGUSR2    19   /* app defined signal 2 */
#define SIGWINCH   20   /* tty window size changed */
#define SIGKILLTHR 21   /* be: kill just the thread, not team */
```

The signals closely match most UNIX variants by name. Not all packages use the macro definitions here (even though it is bad practice not to do so) but the basic numbers (for example 9 for SIGKILL and 15 for SIGTERM) are identical.

There has always been an unwritten policy of supporting user-defined signals for specific applications. If you need to use a special symbol, use the numbers from 32 in reverse order, just in case the standard set is expanded. The maximum number of signals supported is currently 32; specifying a signal number above this just doesn't work.

Under UNIX, the result of a signal may be an immediate exit (kill); an exit and a core dump (core); the program may pause (stop); or the signal may simply be ignored (ignore). The full list of signals, actions, and their descriptions as extracted from the sys_siglist variable can be seen below:

Table 18.6

BeOS signals and actions

Signal	Action	OS Description
SIGHUP	Kill	Hangup
SIGINT	Kill	Interrupt
SIGQUIT	Kill	Quit
SIGILL	Kill	Illegal instruction
SIGCHLD	Ignore	Child exited
SIGABRT	Kill	Abort
SIGPIPE	Kill	Broken pipe
SIGFPE	Kill	Floating point exception
SIGKILL	Kill	Killed (by death)
SIGSTOP	Stop	Stopped
SIGSEGV	Kill	Segmentation violation
SIGCONT	Ignore	Continued
SIGTSTP	Ignore	Stopped (tty output)
SIGALRM	Ignore	Alarm
SIGTERM	Kill	Termination requested
SIGTTIN	Stop	Stopped (tty input)
SIGTTOU	Stop	Stopped (tty output)
SIGUSR1	Ignore	User-defined signal 1
SIGUSR2	Ignore	User-defined signal 2

SIGWINCH	Ignore	Window size change
SIGKILLTHR	Kill	Kill thread

Signals are sent to individual threads, except SIGKILL which is sent to all threads of the specified process. All of the signals can be caught except SIGKILL, which will always cause a program to quit. Even SIGABRT can be caught and acted upon, but it is not advised by Be, who say the effects of doing so are unknown. My own tests haven't shown anything specific as a result of catching the signal, but it's probably best to avoid it if you can.

Signal Data

The text versions of each of the signals are stored in the sys_siglist. There is no limit, theoretically, but only the first 32 signals are given a description. These are the standard OS ones and the user-definable signals:

```
#include <signal.h>
extern const char * const sys_siglist[];
extern const char *strsignal(int sig);
```

Ironically, accessing beyond 32 will cause a SIGSEGV. The function strsignal() returns the string matching sig and gives the descriptions for the signals, as outlined in table 18.6 above.

Under System V, the sys_siglist is also subdivided into messages for the different actions; these aren't supported under POSIX, and therefore aren't supported by the BeOS either. You should use strsignal rather than relying on the sys_siglist variable in any case.

Signal Functions

The BeOS supports the standard POSIX functions, with some additions from both BSD and System V. The BeOS also supports some additional arguments to the signal handlers.

```
#include <signal.h>
#include <unistd.h>
int raise(int signal);
int kill(pid_t pid, int sig);
int send_signal(pid_t tid, uint sig);
unsigned int alarm(unsigned int sec);
typedef void (* __signal_func_ptr)(int);__signal_func_ptr signal(int
signal, __signal_func_ptr signal_func);
```

The signal function traps the specified signal and attaches a function to be executed at the time the signal is received. The code below will execute until a SIGQUIT has been sent to the program, either from a kill command or from one of the signal functions which we will see later.

```
#include <signal.h>

void myfunc(int signum)
```

```
{
       printf("Im quitting now...%s\n",strsignal(signum));
       exit(0);
}

void main(void)
{
       signal(SIGQUIT,myfunc);
       raise(SIGQUIT);
       while(1);
}
```

The signal function is part of Standard C, and not POSIX. It provides a simple but effective way of trapping signals, but ideally we should be using the sigaction functions to be POSIX compatible. I also used the raise function, also part of Standard C, to send the SIGQUIT function to the current process. The raise function simply sends the specified signal to the current process and I could have just as easily used the kill function had I specified the process ID, perhaps using getpid(). The send_signal function is identical to the kill function. However, kill returns -1 and sets the errno variable in the event of an error, but send_signal returns a Be style error.

The alarm function sends SIGALRM to the current process after the number of seconds specified in sec. You can use it as a simple way of creating a recurring event. I use it within a system monitoring program as the interval timer between updates. To do this, you need to re-register the SIGALRM trap on each call of the function handler:

```
void update_now(void)
{
       treadstats();
       signal(SIGALRM,(void *)update_now);
       alarm(30);
}
```

Some OS actually require this for all signals. This requires each signal handler to also respecify the signal each time it is executed.

The remainder of the signal functions are used to support the POSIX signal handling. We will start by looking at signal sets.

Signal Sets

Inherited into POSIX from BSD, a *signal set* enables you to define more than one signal to be assigned to signal handler. The set is defined in a variable of type sigset_t which is a bitset of the available signals. If the specified bit is present within the bitset, then the signal is a part of that set. Using a bitset means one variable can be used to specify any number of signals.

```
int sigemptyset(sigset_t *set);
int sigfillset(sigset_t *set);
int sigaddset(sigset_t *set, int signo);
int sigdelset(sigset_t *set, int signo);
int sigismember(sigset_t *set, int signo);
```

```
int sigprocmask(int how, const sigset_t *set, sigset_t *oset);
```

The kernel stores two signal sets as standard. The first defines the signal mask, the second the pending signal set. The signal mask specifies which signals are blocked to the current process (those which are not sent, regardless of any signal handlers). The pending signal set stores the results of any signals sent to the process while they were blocked. The next call to sigprocmask, which resets the bit for a blocked signal, causes the signal to be sent to the process.

The sigprocmask function sets the signal mask for the application. It is a replacement for the sigsetmask and sigblock functions. They were defined under BSD as:

```
#include <sys/signal.h>
int sigsetmask(int mask);
int sigblock(int mask);
```

and can be replaced using sigprocmask and either SIG_SETMASK or SIG_BLOCK, as appropriate. For example, the lines

```
sigset_t newsigset, oldsigset;
memsigset=(1 << SIGQUIT);
sigprocmask(SIG_SETMASK, &newsigset, &oldsigset);
```

would set the current signal mask based on the signal set in newsigset. The old mask is returned in oldsigset. The SIG_UNBLOCK flag resets the bits in the supplied mask. Alternatively you can supply oldsigset as NULL which discards the old mask entirely. There is no equivalent in the BSD function set.

You add signals to a signal set by shifting and logical "ORing" them together. An easier way, however, is to use the set functions that are part of the POSIX standard:

- sigemptyset resets a set so that no signals are specified.
- sigfillset sets all signals. This can be useful if you only want to exclude a few signals from the valid list.
- sigaddset adds the specified signal to the set.
- sigdelset removes the signal from the set.
- sigismember returns a 1 if the specified signal is a member, 0 if it isn't.

Using these functions we can replace code such as

```
sigset_t myset;
myset=(1<<SIGQUIT) | (1<<SIGHUP);
```

with

```
sigset_t myset;
sigaddset(&myset,SIGQUIT);
sigaddset(&myset,SIGHUP);
```

This is a simple example that doesn't work in the functions' favor. Updating a set, however, is easier with these functions, and finding the current signals within a set is also easier.

The reasons for blocking signals are varied. Probably the best reason is to block signals during a signal handler's execution. The last thing you want is for a signal to interrupt a signal handler's progress. This could potentially cause all sorts of problems, especially if the signal handler is responsible for accepting data of a network, or responding to an important event that needs to be reacted on immediately. Remember that if a signal interrupts program execution, the signal handler for the signal gets processed first!

```
#include <signal.h>
int sigpending(sigset_t *set);
int sigsuspend(const sigset_t *mask);
```

You can use the sigpending function to return the currently pending set of signals in the variable set. The signals are those that are currently pending but blocked by the current signal mask. The signals themselves will be delivered when the signal mask is changed. The return value will be 0 if the mask can be determined, -1 if there is some sort of error. The error condition will be returned in errno.

The sigsuspend command sets the mask to the one specified in mask. The function then waits until a signal within the set is received and resets the signal mask to its previous value when the signal handler returns. For example, I may have a signal mask set which ignores all signals. When I want to pause program execution for a period of time using alarm, I can set up a signal set to only respond to the SIGALRM signal. Then, once the signal has been received, the old signal set is reinstated and program execution continues as normal.

The replacement for the POSIX signal function, which is simple in the extreme, is the sigaction function. This provides the same basic functionality, but adds to the information that is passed to the signal handler.

```
#include <signal.h>
int sigaction(int sig, const struct sigaction *act, \
                             struct sigaction *oact);
struct sigaction {
       __signal_func_ptr sa_handler;
       sigset_t          sa_mask;
       int               sa_flags;
       void             *sa_userdata;
};
```

The sigaction structure is used to specify the details of the signal handler when the signal is received. The sa_handler specifies the function to be called. The sa_mask is the signal mask which will be used to block the specified signals while the signal handler is executing. It is "ORed" with the current signal mask and so should form a complete block to the signals specified within the current environment.

The flags stored in sa_flags specify a number of options to the wrapper around the signal handler. They are not currently supported in full by the BeOS implementation. The only flag supported by both the BeOS and POSIX is SIG_NOCLDSTOP. This stops child processes from sending a SIGCLD to the parent process when it stops. SIGCLD will still be sent when a child terminates.

The last field of the structure is a pointer to other data. This is different from the POSIX standard although it is allowed under the POSIX definition. This data option is not currently supported by the BeOS, although it is promised for future versions.

The sigaction function can, and should, be used as a direct replacement for the signal function, save for the addition of the sigaction structure. The sig argument is the signal to be trapped, act is the new sigaction, and the previous sigaction data is returned in the structure oact. We can change the example outlined in "Signal Functions" above to:

```
#include <signal.h>

void myfunc(int signum)
{
       printf("Im quitting now...%s\n",strsignal(signum));
       exit(0);
}

void main(void)
{
       struct sigaction newact = { myfunc, 0, 0 };

       sigaction(SIGQUIT,&newact,NULL);
       raise(SIGQUIT);
       while(1);
}
```

If NULL is specified for oact then nothing is returned. If NULL is specified for act then sigaction returns the current sigaction structure for the specified signal.If NULL is specified for both oact and act then sigaction will return 0 if the signal is valid, or 1 if the signal is not valid.

Signal Handling

The *signal handler* is a function which is executed when a specific signal is received. You're already aware of how to set this up using either signal or sigaction.

The signal handler must not return anything, and can only support one argument, which is the signal number that caused the function to start. You can then use the argument to identify why the function has been called. In the above examples, I've just used it to print out the signal error text when the signal handler is called.

In essence, a signal handler can do whatever is required, although some signals are specific about the behavior of the function that is called. For example, if a handler is trapped against SIGABRT the function should be as short and compact as possible, preferably just writing out an error message and then closing. Other signals can be used to trigger all sorts of actions. The SIGALRM is popular when used with the alarm function as a way of regularly executing a command.

The POSIX standard defines a number of functions which are considered to be safe when used within a signal handler. The reason for the list is that a signal handler is designed to interrupt the normal progress of a program. There are some functions, however, that work on multiple calls, saving some information between invocations. Ideally, the functions should be re-entrant, an ability which is very difficult to program. Within the BeOS, many of the functions supported by the POSIX library are not re-entrant, despite its multithreading, which normally demands such a feature. The only other solution is to block signals during a function's execution. This is less reliable, and can lead to problems if a signal is received more than once. Multiple signals aren't stored in the pending signal set.

Reentrant Functions

A reentrant function is one that can be called by functions it calls. Or, more specifically, a reentrant function is one that can be called again before it has properly returned from it's last call. This means that the function cannot use the values of external variables (since they may change between invocations) and cannot store static information (since this may also change between different invocations).

POSIX defines the following functions as safe:

_exit	access	alarm	cfgetispeed	cfgetospeed
cfsetispeed	cfsetospeed	chdir	chmod	chown
close	creat	dup	dup2	execle
execve	fcntl	fork	fstat	getegid
geteuid	getgid	getgroups	getpgrp	getpid
getppid	getuid	kill	link	lseek
mkdir	mkfifo	open	pathconf	pause
pipe	read	rename	rmdir	setgid
setpgid	setsid	setuid	sigaction	sigaddset
sigdelset	sigemptyset	sigfillset	sigismember	sigpending
sigprocmask	sigsuspend	sleep	stat	sysconf
tcdrain	tcvflow	tcflush	tcgetattr	tcgetpgrp
tcsendbreak	tcsetattr	tcsetpgrp	time	times
umask	uname	unlink	utime	wait

waitpid write

Of those listed, only tcvflowis not supported by the BeOS. The safety of other functions cannot be guaranteed, and it's probably better to avoid using them rather than crossing your fingers and hoping for the best.

Interprocess Communication

Much of the core functionality and usefulness of the UNIX OS is based around interprocess communication (IPC). It allows different applications to talk amongst themselves, thereby making the interoperability of the OS much easier. For example, files are submitted to the printing daemon via interprocess communication. The daemon listens for new jobs, and one or more other applications can submit files for printing simultaneously. This removes the reliance on complex queueing mechanisms and file-based semaphores.

Many systems now implement one or more methods of interprocess communication. We will take a brief look at the three main forms of interprocess communication supported by the BeOS: pipes, sockets, and FIFOs. The problem with porting IPC is that the variety of methods (which go beyond those described here) makes it difficult to find a standard. Even within the POSIX standard both pipes and FIFOs are supported, and socket access is now supported by most OSs (including the BeOS) in order to support network, rather than single-machine, interaction.

This single problem of too many methods for interprocess communication leads to a number of difficulties. The biggest of these problems is that if the method of IPC supported by your package doesn't support the methods available on the BeOS, it will take a considerably large amount of work to convert from one method to another. There are implementations available in FreeBSD and NetBSD that may be portable.

Pipes

You should already be familiar with the theory of a pipe. In Chapter 4, we looked at how pipes were to channel information from one process to another. For example, when viewing the directory listing, we might want to pipe the output through the more program, which presents us with information a page at a time:

```
$ ls -l | more
```

Most people's experience with pipes is at this level, when using the commands within the shell.The same basic principles apply in IPC, a pipe is used to communicate, or channel information from one process to another.

However, the restriction with IPC is that the pipe function is only really useful within a single application that has created a number of subprocesses using fork. Using pipe and fork the subprocesses can communicate with each other, and, if necessary with the parent application. We'll take a closer look at fork in the next section.

```
#include <unistd.h>
int pipe(int fildes[2]);
```

The function returns a zero on success. The file descriptors of the read end of the pipe are placed in fildes[0] and the write end of the pipe in fildes[1].

The file descriptors will be available to all processes forked from the parent process, but they cannot be shared among more than one invocation of an application. The file descriptors are also unidirectional, which means you must always read from and write to the correct file descriptors.

Pipes are often employed as a way of running an external command. This is a fairly long process because the application has to fork a new process before using exec to the run the external program. This is messy, and can get complicated and laborious if you do have to do it frequently.

The popen function is an extension of the pipe command which opens a pipe, forks a process, and then executes a shell with the specified command, turning the entire process into a single function:

```
#include <stdio.h>
FILE *popen(const char *cmd, const char *type);
int pclose(FILE *fp);
```

The type is either "r" or "w" based on whether you are reading from or writing to the command you are executing. You cannot do both, as a pipe file descriptor is unidirectional. In general, popen is a quick way to spawn and read from or write a command from within some C code. For example, the program below prints the date as returned by the OS /boot/bin/date command:

```
#include <stdio.h>

void main(void)
{
	FILE *fp;
	char buf[1024];

	fp=popen("date","r");

	printf(fgets(buf,1024,fp));

	pclose(fp);
}
```

You could open the pipe as write- rather than read-enabled and then controlled an external application. For example, you could use popen to control an editor by writing the commands to the command from within another application. Once the program stream has been opened with popen, providing the program does not exit immediately, you can continue reading from the command until either it quits or the pclose function closes the stream. The file descriptors will also be closed if the program exits normally.

Sockets

Sockets are a BSD invention, based on the TCP/IP networking system for communicating between machines. If you open a socket to the same machine you are calling from you effectively have an interprocess communication system. We will deal with sockets and their use in networking in Chapter 22.

The socket system is defined within posix/sys/socket.h, which itself includes the file be/net/socket.h. As we shall see later, the implementation is far from perfect, but it does support the basic socket functions. It doesn't, however, support the socketpair function, which simulates the pipe command using sockets.

FIFOs

A FIFO is a special type of file often referred to as "named pipe." FIFO stands for "first in first out" and refers to the method of communication between different processes. Because the FIFO is a file, it can be opened and read using standard commands by a number of processes; we are no longer restricted to one process or reliant on networking systems.

If we return to the earlier example of the printing system under UNIX, it is often implemented as a FIFO. The FIFO file is read from by the printing daemon, and the lp program writes files to the FIFO. The FIFO system is supported by the sys/stat.h header:

```
#include <sys/stat.h>
int mkfifo(const *path, mode_t mode);
```

mkfifo returns a 0 on success and -1 on failure.

Despite the support professed in the header file, FIFOs do not work under the BeOS. Any call to the mkfifo function will return a -1, indicating a failure.

Others Forms of IPC

There are a number of other forms of IPC which are currently missing on the BeOS. As far as I am aware, there are no plans to update the support to include any of these additional forms of IPC in later versions. This may cause some problems for those already using a specific type of IPC. Let's take a look at System V IPC, a much-maligned but very useful form of IPC.

System V IPC is based around one or more blocks of shared memory, a selection of message queues, and semaphores. It's supported by all System V variants of UNIX, and also SunOS 4, FreeBSD and NetBSD. However, it's not supported to any level by most other BSD style unices. Despite its acceptance by a number of major companies, many people still have an aversion to this technique of IPC because it is very buggy and difficult to work with effectively. Oracle, for example, uses System V IPC if it's available as a quick way of buffering access to the database. Requests are supplied via the message queues, and the data is returned in the shared area of memory. It's fast and convenient for this sort of operation, but often buggy, as any Oracle DBA will tell you.

There is a free version (by Daniel Boulet) available, but to use it you may need access to the kernel source code to provide the necessary core code.

System Calls

Beyond standard kernel functions are a number of functions that are classed as *system calls*. These are functions which make direct calls to the OS, rather than using some form of library or other layer on build on top of the OS. They are used to execute other programs, as in system and exec, to create subprocesses, as with fork or to get information about the current environment in which a program is running, as with getenv.

In addition, there are a number of functions that allow you to abort the current program, or to exit the current program. The difference being the response returned to the calling application.

system

system is more of a macro than a real function and is not part of the POSIX definition, although it is part of Standard C. In general, use of system is actively discouraged because it's nonstandard and non-portable across systems, with each one defining a different implementation. On the BeOS, system closely matches the SVR4 libraries, executing a command within the standard shell:

```
#include <stdlib.h>
int system(const char *command);
```

What happens behind the scenes is that system forks off a new process using fork and then uses exec to run a shell, which is then used to execute the application specified in command. The return value is that of the shell which is executed, not the application which is executed within the shell. If you specify a NULL string then the standard shell /boot/bin/sh will be run instead.

exec

The exec family of commands is a friendlier way of executing other applications from within an application. The exec command itself has long since been forgotten, and is now replaced by a number of functions offering varying levels of additional environment and argument support. The full list supported by the BeOS is:

```
#include <unistd.h>
int execve(const char *path, char *argv[], char **envp);
int execl(const char *path, const char *arg, ...);
int execv(const char *path, char **argv);
int execlp(const char *file, const char *arg, ...);
int execle(const char *path, const char *arg , ...);
int exect(const char *path, char **argv);
int execvp(const char *file, char **argv);
```

In all cases, a call to exec will replace the current process with the application specified in the path or file arguments. Using a path-based function assumes that you are specifying an absolute pathname for the entire application. Use of the file argument causes the application to be searched for in the current PATH set in the environment.

The additional arguments allow you to specify arguments (either as a series of strings, arg, or as a pointer to a list of NULL terminated strings, argv). Using the envp variable you can specify a list of environment settings, or if envp is not available the environment of the calling application is used instead. Both argv and envp are NULL terminated lists of NULL terminated strings.

In all cases, the maximum size of the environment, command, and arguments should not exceed the value specified by ARG_MAX.

The exec series of functions is part of the POSIX specification, except for exect. This function is from the BSD libraries and enables program tracing, although this option is not supported by the BeOS. In all other respects, exect is identical to execv.

fork

fork creates a new process which is identical in nearly all respects to the parent process. The only difference is that the subprocess has a new process ID and the parent process ID of its parent. All file descriptors are duplicated from the parent, but signals and alarms are not inherited:

```
#include <sys/types.h>
#include <unistd.h>
```

```
pid_t fork(void);
```

The process ID of the child is returned on success, or -1 if the fork failed. The maximum number of children that can be forked by any one process is defined by the macro _POSIX_CHILD_MAX.

fork is often used to create a subprocess which is then used to call exec and execute another program. As such, it is inefficient because the function must copy the parent's environment and descriptors before processing can continue, and the exec functions will automatically replace this information with that from the called application. For this reason the vfork process was written. This simply creates a subprocess without copying the information, therefore improving the performance for executing sub-programs. In programs like make this can produce a significant increase in performance. Unfortunately, the BeOS does not support the vfork function, but this shouldn't cause any serious problems.

wait

Once you have forked a subprocess, you may want to check the status of the process before proceeding. This is especially true when you come to the end of a program. Using the wait command you can wait for all forked subprocesses to finish executing before continuing:

```
#include <sys/wait.h>
pid_t wait(int *statloc);
```

The status argument should be an integer which you pass to the command for the status of the process to be returned in. The information is returned as a bit field and the information can be extracted by using a number of macros:

- WIFEXITED(status) returns true if the process exited normally; WIFEXITSTATUS(status) will return the exit value.
- WIFSIGNALED(status) returns true if the process exited because of a signal.
- WTERMSIG(status) evaluates to the signal number that caused the process to exit.
- WIFCORED(status) is true if the program caused a core dump (not applicable to the BeOS).

An additional command, waitpid, allows you to monitor a specific process ID:

```
#include <sys/wait.h>
pid_t waitpid(pid_t pid, int *stat_loc, int options);
```

where pid is the process number to wait for, stat_loc is the variable to return the status in, and options is a bitwise variable (values should be inclusive

"ORed" together) which defines what to monitor. The WNOHANG option will cause the function to return immediately if the status cannot be determined. The WUNTRACED option reports whether the process has been stopped and is used by shells to handle job control.

When you use waitpid these status macros are available:

- WIFSTOPPED(status) returns a non-zero value if the process is currently stopped.
- WIFSTOPSIG(status) will return the signal that caused the process to stop.

unexec

The unexec command is used most notably by emacs to create an executable version of the application from the combination of the base application and the loaded LISP programs. It is defined by the emacs package source and is not a standard function, but, as emacs is such a major package, I thought it worth a mention. The problem is that the linking method used to create applications on the BeOS is called PEF (Preferred Executable Format) and is protected under copyright, hence the problem developing a set of public domain routines to generate the necessary executables. This will affect alternative linkers for exactly the same reason. Even the gcc port by Fred Fish uses the Metrowerks linker to create the final executable. This should only affect PowerPC versions of the BeOS, as Intel versions will use the publicly available PE format.

getenv and putenv

The getenv function retrieves the value of an environment variable by its name:

```
#include <stdlib.h>
char *getenv(const char *name);
```

The data is returned as a character string, or NULL if the variable name isn't found. For example, to print the value of the variable PATH you could use this code fragment:

```
printf("%s\n",getenv("PATH"));
```

If you are copying the value to a string, you should ensure that the string is large enough to contain the value. The maximum size possible is specified by the macro ARG_MAX. See "Resource Limits," earlier in this chapter.

The function putenv is the opposite of getenv and places a variable into the program's environment. The function comes from the SVR4 implementation of UNIX. putenv is not part of Standard C or POSIX, but is supported under the BeOS:

```
#include <stdlib.h>
int putenv(const char *string);
```

The function works by accepting a string of the form

```
VAR=VALUE
```

and therefore works the same as creating a variable within the shell.

abort

The abort command causes abnormal program termination:

```
#include <stdlib.h>
void abort(void);
```

The only exception to the rule is if the SIGABRT signal is being caught by a signal handler. In this situation the signal can be acted upon, but the program should exit soon after the signal has been called. Functions registered with the atexit function are not called.

exit and atexit

exit is a Standard C function which immediately quits a program, supplying a return code (specified by the status argument) to the calling application:

```
#include <stdlib.h>
void exit(int status);
void _exit(int status);
```

The function causes normal program termination, calling the functions defined by atexit() (in reverse order), flushing and closing all open streams, and then calling the function _exit().

The _exit function closes all open files, sends the appropriate signal to the parent if it is waiting using wait, sends a SIGCHLD signal to the parent process, closes all associated process groups (if it is controlling any) and then closes itself.

The atexit function registers a list of functions to be executed when the program terminates normally (via the exit() command), or at the end of the main() function if the exit() function is not used.

```
#include <stdlib.h>
int atexit(void (*func)(void));
```

Within the BeOS you can specify up to 63 functions to be called, with atexit returning a 0 for success and a 1 for failure.

Regular Expressions

The regular expression library, which consists of the functions compile, step, and advance, is not supported by the BeOS. However, the GNU regex regular expression library does compile with little trouble on the BeOS. It is slightly more complicated to use, but supports the GNU standard regular expressions that you will be familiar with from using gawk, perl, and such, and is therefore a better solution to most needs.

Non-Local Jumps

Although they are almost as taboo as the infamous goto statement, non-local jumps are a sometimes-used necessary evil. The advantage of non-local jumps is that, as the name suggests, they can span more than one source file. A goto statement is only applicable within a single source file.

The principle is that the settings—specifically the registers—or the current instance are recorded using setjmp and then recalled at some later stage using longjmp. The BeOS supports this as part of its POSIX support with some minor differences from the standard implementations.

setjmp and longjmp

The setjmp function records the current instance into the specified jump buffer:

```
#include <setjmp.h>
typedef long *jmp_buf[70];
int setjmp(jmp_buf buffer);
void longjmp(jmp_buf buffer, int val);
int sigsetjmp(jmp_buf buffer);
void siglongjmp(jmp_buf buffer, int val);
```

As you can see, the buffer is just an array of long numbers used to record the register, program counter, and other processor-specific values.

The longjmp command is used to return to the point at which the buffer was recorded. This effectively returns program execution to the point at which the setjmp call was invoked. The val argument is used as the number returned by the setjmp function, and this is how you identify whether this is the first call to the setjmp function or not.

For example, consider this code:

```
#include <setjmp.h>

void main(void)
{
       jmp_buf mybuf;
       if ((setjmp(mybuf))==0)
```

```
            longjmp(mybuf,1);
}
```

The first time the function is called, setjmp returns 0 and the longjmp function is called. This returns execution to the setjmp function, this time causing the setjmp command to return 1. The if test has failed and the program exits as normal.

It should be remembered that a setjmp function records the settings of the current function, so writing a wrapper to go around the setjmp call will not work as expected.

One of the problems with setjmp is that although it restores all the processor values, it doesn't restore any local variables and, more specifically, doesn't restore the current signal mask. Two other functions specified by the POSIX standard allow the signal mask to be recorded and restored. They are sigsetjmp and siglongjmp respectively.

Under the BeOS, the sigsetjmp and siglongjmp commands are supported, but do not currently record the signal mask.This is identical to SVR4, which does not save the signal information as standard. You may have to provide a workaround for the signal mask problem if you want the code to work on other platforms. When working with source code from other packages, they should have already taken into account the effects of BSD style and SVR4 style jumps.

Moving and copying memory

There are two basic trains of thought on copying sections of memory. The first is the BSD style, using bcopy to copy the binary information from one variable or area of memory to another. The second, is to use memcpy to copy the information. The BeOS supports both, but there are some minor differences in their operation and expected use.

bcopy and bzero

bcopy copies an area of memory from one location to another. The name arises from the term "binary copy." It is essentially identical to the memmove function (see below). The synopsis of the command is:

```
#include <bsd_mem.h>
void bcopy( const void *src, void *dst, size_t len);
```

Although bcopy isn't supported directly by the BeOS, you can access it by using the bsd_mem.h header, which defines it as:

```
#define bcopy(s, d, l) memmove(d, s, l)
```

This maps it to the memmove function; note the difference in the order of the arguments. Don't use memcpy as a substitute; both bcopy and memmove ensure that overlapping areas of memory are copied correctly.

Alternatively, you can use the source code below:

```
void bcopy(register char *src, register char *dst
       register int length)
{
       while (length-- > 0)
              *dest++ = *src++;
}
```

The bzero command is used to set an area of memory to zero:

```
#include <bsd_mem.h>
void bzero(void *b, size_t len);
```

It is identical to the memset command and is defined in the bsd_mem.h header as:

```
#define bzero(d, l) memset(d, '\0', l)
```

The source code is similar to bcopy:

```
void bzero(register char *b, register int length)
{
       while (length-- > )
              *b++ = 0;
}
```

memcpy, memmove, and memset

The memcpy function copies an area of memory:

```
#include <string.h>
void *memcpy(void *dst, const void *src, size_t len);
```

It can be destructive on overlapping areas of memory and you should use memmove, which copies the information from low to high or high to low order in order to prevent destroying any information in the destination:

```
#include <string.h>
void *memcpy(void *dst, const void *src, size_t len)
```

memset sets an area of memory to a specific value:

```
#include <string.h>
void *memset(void *dst, int val, size_t len);
```

The POSIX specification uses memcpy, memmove, and memset instead of the BSD-style bcopy. If a program specifies bcopy then use the config files to include the bsd_mem.h header file, which should also get you out of some other pickles.

memchr

You can search for a byte in a block of memory using the memchr function:

```
#include <string.h>
```

```
void *memchr(const void *s, int c, size_t n);
```

The function searches the memory pointed to by s for the byte c for n bytes, returning a pointer to the found byte.

String Handling

You can't very far in programming without having to use a string or collection of characters somewhere. A number of string functions exist which convert strings to and from numeric values. There are also a number of utility functions which provide information on the length of a string (strlen) and enable you to separate a string into component parts (strtok). Finally we'll look at the strerror function, and the errors reported and available under the BeOS.

Data Conversions

The BeOS supports the full range of Standard C conversions of strings to numbers, with the addition of two further functions for converting strings to type long long:

```
#include <stdlib.h>
double atof(const char *str);
int atoi(const char *str);
long atol(const char *str);
double strtod(const char *str, char **end);
long strtol(const char *str, char **end, int base);
unsigned long strtoul(const char *str, char **end, int base);
long long strtoll(const char *str, char **end, int base);
unsigned long long strtoull(const char *str, char **end, int base);
```

strlen and Other Basic String Functions

The basic string functions are part of Standard C, and not part of POSIX. Those supported by the BeOS are:

```
#include <string.h>
size_t strlen(const char *);
char *strcpy(char *dst, const char *src);
char *strncpy(char *dst, const char *src, size_t len);
char *strcat(char *dst, const char *src);
char *strncat(char *dst, const char *src, size_t len);
int strcmp(const char *str1, const char *str2);
int strncmp(const char *str1, const char *str2, size_t len);
int strcasecmp(const char *str1, const char *str2);
int strncasecmp(const char *str1, const char *str2, size_t len);
int strcoll(const char *str1, const char *str2);
size_t strxfrm(char *str1, const char *str2, size_t len);
char *strchr(const char *str, int chr);
char *strrchr(const char *str, int chr);
char *strpbrk(const char *str, const char *set);
size_t strspn(const char *str, const char *set);
size_t strcspn(const char *str, const char *set);
char *strtok(char *str, const char *set);
```

```
char *strstr(const char *str, const char *pat);
int strcasecmp(const char *str1, const char *str2);
int strncasecmp(const char *str1, const char *str2, unsigned nchars);
char *strdup(const char *str);
char *stpcpy(char *dest, const char *src);
```

In the following sections, we will take a closer look at the more regularly used functions and how they differ from other OSs implementation of the same function. If I don't specifically mention a function, then it forms part of the basic functionality of most OSs and you shouldn't have any compatibility problems.

strcasecmp and strncasecmp

These two functions compare two strings, returning a value that is less than, equal to, or greater than zero, based on whether str1 is less than, equal to, or greater than str2:

```
#include <string.h>
int strcasecmp(const char *str1, const char *str2);
int strncasecmp(const char *str1, const char *str2, unsigned nchars);
```

The strncasecmp function is identical, but only checks the first nchars characters. You may also find references to the functions stricmp and strnicmp, which are identical to their respective cousins.

These functions are not part of the POSIX or Standard C definitions.

stpcpy

This function is identical to strcpy except that it returns a pointer to the end of the string, rather than the beginning:

```
#include <string.h>
char *stpcpy(const char *str1, const char *str2);
```

You can use this to make the process of concatenating strings together much easier than using strcpy and strcat:

```
#include <string.h>
#include <stdio.h>

void main(void)
{
       char mystring[20];
       char *strptr=mystring;
       strptr=stpcpy(strptr, "Hello ");
       strptr=stpcpy(strptr, "World");
       printf("%s\n",mystring);
}
```

This function is not part of either Standard C or POSIX, although it is usually defined in public C libraries such as GNU and NetBSD.

strdup

strdup allocates a block of memory using calloc and then copies the string into it, returning the pointer to the memory block. This effectively duplicates the string without using the clumsy strcpy function, making it especially useful on larger strings:

```
#include <string.h>
char *strdup(const char *str);
```

This is not part of POSIX or Standard C.

strtok

The strtok command provides a simple way to separate strings using a specified set of characters:

```
#include <string.h>
char *strtok(char *s1, const char *s2);
```

With the first call to the strtok function, it returns the string of characters from s1 up to, but not including, the first matching character from s2. If no character from s2 is found then NULL is returned. Subsequent calls to strtok with a NULL value for s1 will match further strings from the position of the last match to the next matching character from s2. For example, the program below separates the string "Hello World again!" with spaces:

```
#include <stdio.h>
#include <string.h>

void main(void)
{
       printf("%s\n",strtok("Hello world again!"," "));
       printf("%s\n",strtok(NULL," "));
       printf("%s\n",strtok(NULL," "));
}
```

which produces:

```
Hello
world
again!
```

strtok is used as a quick way to extract or separate information from strings, and many of the kernel functions use it to determine information in configuration files. The function is not supported under BSD and so you may find that some packages will try to introduce their own versions.

strchr, index, strrchr, and rindex

strchr and strrchr search a string forwards and backwards, respectively, for a specified character:

```
#include <string.h>
char *strchr(const char *str, int chr);
char *strrchr(const char *str, int chr);
```

In both functions, the return value is the pointer to the first or last character specified by chr in the string str. For example:

```
printf("%s\n",strchr("Hello World",'o');
```

prints

```
o World
```

whereas

```
printf("%s\n",strrchr("Hello World",'o');
```

prints

```
orld
```

The index and rindex commands are alternative versions of strchr and strrchr respectively. They work in identical ways and even use the same arguments to the functions. The compatibility header bsd_mem.h defines macros for these as:

```
#include <bsd_mem.h>
#define index(str, chr) strchr(str, chr)
#define rindex(str, chr) strrchr(str, chr)
```

The POSIX standard uses strchr in preference to index. Most packages will prefer to use the POSIX definition. Some older packages will actually request to use the index version (perl v4, for example). Since both functions are essentially identical there is no reason not to substitute or mix and match, providing this doesn't upset other functions by the inclusion of the bsd_mem.h header. Of course, if you are writing new code, then you should use the POSIX compatible versions to remain as portable as possible.

strerror

You can print the string associated with an error using strerror:

```
#include <string.h>
char *strerror(int errnum);
```

Where errnum is the error number, the string equivalent of the error is returned. If no error message is found, NULL is returned. The error messages are stored within the libraries in a character string array:

```
extern int sys_nerr;
extern char *sys_errlist[];
```

The sys_nerr variable specifies the maximum number of errors represented, and the sys_errlist contains the error messages. However, on the BeOS these structures don't contain the error messages or the figures you expect. The variables are only made available for identification purposes and so you need to use the strerror command wherever possible. For example, the code fragment

```
#include <stdio.h>
#include <string.h>
#include <errno.h>

void main(void)
```

```
{
printf("%s\n",sterror(EACCES));
}
```

prints

```
Permission denied
```

Using a simple program it is possible to identify the error range and their errors. In PR, errors are calculated from LONG_MIN upwards, and so the program takes a significant amount of time to execute:

```
#include <stdio.h>
#include <string.h>
#include <errno.h>
#include <errno.h>

void main(void)
{
       register long I=0;

       for (i=LONG_MIN;i<=LONG_MAX;i++)
              if ((strncmp(strerror(i),"Unknown Error",13))!=0)
                     printf("%ld: %s\n",i,strerror(i));
}
```

To save you time, the program equates to the following list in PR:

```
-2147483648: No memory
-2147483647: I/O error
-2147483646: Permission denied
-2147483645: General file error
-2147483644: File not found
-2147483643: Index not in range for the data set
-2147483642: Bad argument type passed to function
-2147483641: Bad value passed to function
-2147483640: Mismatched values passed to function
-2147483639: Name not found
-2147483638: Name in use
-2147483637: Operation timed out
-2147483636: Interrupted system call
-2147483635: Operation would block
-2147483634: Operation canceled
-2147483633: Initialization failed
-2147479552: Bad semaphore ID
-2147479551: No more semaphores
-2147479296: Bad thread ID
-2147479295: No more threads
-2147479294: Thread is inappropriate state
-2147479293: Operation on invalid team
-2147479292: No more teams
-2147479040: Bad port ID
-2147479039: No more ports
-2147478784: Bad image ID
-2147478528: Debugger already installed for this team
-2147475456: Invalid or unwanted reply
-2147475455: Duplicate reply
-2147475454: Can't send message to self
-2147475453: Bad handler
-2147475452: Already running
-2147475451: Launch failed
-2147475450: Ambiguous app launch
-2147475449: Unknown MIME type
-2147475448: Bad script syntax
-2147467264: Stream not found
-2147467263: Server not found
-2147467262: Resource not found
-2147467261: Resource unavailable
-2147467260: Bad subscriber
```

```
-2147467259: Subscriber not entered
-2147467258: Buffer not available
-2147467257: Last buffer
-2147454975: Argument too big
-2147454972: Bad file descriptor
-2147454971: Device/File/Resource busy
-2147454970: No child process
-2147454969: Resource deadlock
-2147454968: File or Directory already exists
-2147454967: Bad address
-2147454966: File too large
-2147454964: Invalid argument
-2147454962: Is a directory
-2147454961: Too many open files
-2147454960: Too many links
-2147454959: File name too long
-2147454958: File table overflow
-2147454957: No such device
-2147454956: No such file or directory
-2147454955: Not an executable
-2147454954: No record locks available
-2147454953: No space left on device
-2147454952: Function not implemented
-2147454951: Not a directory
-2147454950: Directory not empty
-2147454949: Too many symbolic links
-2147454948: Not a tty
-2147454947: No such device
-2147454946: Operation not allowed
-2147454945: Broken pipe
-2147454944: Read-only file system
-2147454943: Seek not allowed on file descriptor
-2147454942: No such process
-2147454941: Cross-device link
-2147454940: File Position Error
-2147454939: Signal Error
-2147454938: Domain Error
-2147454937: Range Error
-2147454936: Protocol wrong type for socket
-2147454935: Protocol not supported
-2147454934: Protocol family not supported
-2147454933: Address family not supported by protocol family
-2147454932: Address already in use
-2147454931: Can't assign requested address
-2147454930: Network is down
-2147454929: Network is unreachable
-2147454928: Network dropped connection on reset
-2147454927: Software caused connected abort
-2147454926: Connection reset by peer
-2147454925: Socket is already connected
-2147454924: Socket is not connected
-2147454923: Can't send after socket shutdown
-2147454921: Connection refused
-2147454920: No route to host
-2147454919: Protocol option not available
-2147454918: No buffer space available
-2147450880: No mail daemon
-2147450879: Unknown mail user
-2147450878: Wrong password (mail)
-2147450877: Mail unknown host
-2147450876: Mail access error
-2147450875: Unknown mail field
-2147450874: No mail recipient
-2147450873: Invaild mail
-2147446784: No print server
-2147442688: Invalid device ioctl
-2147442687: No device memory
-2147442686: Bad drive number
-2147442685: No media present
```

```
-2147442684: Device unreadable
-2147442683: Device format error
-2147442682: Device timeout
-2147442681: Device recalibrate error
-2147442680: Device seek error
-2147442679: Device ID error
-2147442678: Device read error
-2147442677: Device write error
-2147442676: Device not ready
-2147442675: Device media changed
-1: General OS error
0: No Error
```

These numbers are useful for debugging purposes, and in this list you'll find a number of BeApp error messages; most applications use the error macros defined in errno.h. Under the BeOS the error numbers are remapped using the header file contained in be/support/Error.h. The full list of error macros under the BeOS (which matches the full POSIX specification) supported under the BeOS is shown in Table 22.7.

Table 22.7

POSIX error macros

Macro	Message
E2BIG	The combined size of the argument and environment lists has exceeded ARG_MAX bytes.
EACCES	Search permission is denied on the directory.
EAGAIN	On file operations, the O_NONBLOCK flag is set and the program would be delayed if the operation took place. When using fork it indicates that the system is unable to spawn another process.
EBADF	Bad file descriptor.
EBUSY	The directory, file or device is in use.
ECHILD	There are no children of this process.
EDEADLK	Deadlock; file has been write locked with F_SETLKW.
EDOM	Argument was out of the mathematical range.
EEXIST	File name already exists. Can also be returned by rmdir() when the directory is not empty.
EFAULT	Invalid address or argument out of memory range.
EFBIG	File exceeds maximum file size.
EINTR	Function was interrupted by a signal.
EINVAL	Invalid argument to function.
EIO	I/O error.
EISDIR	Attempted write to a directory instead of a file.
EMFILE	Process has too many open file descriptors.
EMLINK	Number of links to actual file location exceeded.

ENAMETOOLONG	File name too long.
ENFILE	System has too many open file descriptors.
ENODEV	Device does not exist, or bad operation for selected device type.
ENOENT	File/directory does not exist.
ENOEXEC	File cannot be executed.
ENOLCK	No locks available.
ENOMEM	No memory available for execution.
ENOSPC	File system full.
ENOSYS	Function not implemented.
ENOTDIR	Argument not a directory.
ENOEMPTY	Directory is not empty (when using the rmdir() command).
ENOTTY	Not a terminal.
ENXIO	Device does not exist, or device is not ready.
EPERM	Operation not permitted.
EPIPE	Pipe or FIFO has no read channel available to allow the write operation.
ERANGE	Result is too large.
EROFS	Attempted an operation on a read-only file system.
ESPIPE	An lseek() operation was attempted on a pipe or FIFO.
ESRCH	No such process.
EXDEV	Attempt to link a file to another file system.

Unfortunately, for its POSIX compatibility the BeOS scores well, but other UNIX platforms and therefore other packages will expect a different or additional set of macros. Solaris, for example, specifies no less than 119 different macros as opposed to the 37 specified here. When you can't find a matching macro, it is best to look for the next best guess. If there still isn't anything suitable, check the code and see if it's something that can be checked some other way or, in extreme examples, ignored completely. A lot of the time the additional macros are OS- or functionality-dependent. In these cases, you may be missing more than the macro and so writing or sourcing additional code should enable you to plug the gap.

It is also possible, but highly unlikely, that a package is checking for error numbers directly without using the macros for the post-error checks. In these situations you need to compare the error numbers (found in the header files, usually errno.h or sys/errno.h) for the platform the package was originally written on. This will mean a lot of manual modifications to the source code, but it might be the only way to resolve the problems.

Note: Remember to tell the author when you make such a significant modification.

The strerror function is an SVR4 invention, now part of Standard C. Most packages, however, expect to use the function, or provide a simulation where it's not available. If the configuration system incorrectly identifies the existence of the function, or rather the non-existence of the function, you should set the configuration manually

Variable Argument Lists

Variable argument lists allow you to recreate the variable-length functions like printf within your own programs. The method for doing this is different on most platforms, although the principles remain the same.

The prototype of a function using variable argument lists is

```
void myvafunc(int realarg, ...)
```

The three periods indicate the start of variable arguments. You can place as many fixed arguments as you like before the variable arguments list, but you cannot place any arguments after the variable argument list.

Under POSIX (and the BeOS) the use of variable arguments is supported by the stdarg.h header file. A range of commands can then be used to support the use of variable arguments:

```
#include <stdarg.h>
#include <stdio.h>
void va_start(va_list ap, parmN);
void va_end(va_list ap);
type va_arg(va_list ap, type);
int vfprintf(FILE *stream, const char *format, va_list arg);
int vprintf(const char *format, va_list arg);
int vsprintf(char *s, const char *format, va_list arg);
```

Before using variable arguments you have to initialize the variable argument list using va_start. The parmN specifies the last argument before the variable list. Once the list is initialized, calls to va_arg return the next variable in the list in the specified type. Usually the reason for using variable arguments involves reformatting or repackaging a string with the variable information using vprintf, vsprintf, or vfprintf, which are compatible versions of printf, sprintf, and fprintf respectively. Once the function has completed, you should call va_end to finish the variable arguments.

For example, here's a function which writes an error message to a file:

```
#include <stdio.h>
#include <stdarg.h>

void writelog(char *filename, ...)
{
	va_list args;
	char *format;
	char str[1000];
	FILE *errlog;
```

```
        va_start(args, filename);

        format=va_arg(args, char*);

        vsprintf(str,format,args);

        if ((errlog=fopen(filename,"a")) == NULL)
        {
              fprintf(stdout,"Fatal Error\n");
              exit(1);
        }

        fprintf(errlog,"%s\n",str);

        fclose(errlog);
        va_end(args);
}
```

BSD UNIX and nonstandard C compilers use the header file varargs.h and a slightly different layout for initializing the variable argument list. Here's the same function from a BSD version:

```
#include <stdio.h>
#include <varargs.h>

void writelog(char *filename, va_alist)
va_dcl
{
  va_list args;
  char *format;
  char str[1000];
  FILE *errlog;

  va_start(args);

  format=va_arg(args, char*);

  vsprintf(str,format,args);

  if ((errlog=fopen(filename,"a")) == NULL)
    {
      fprintf(stdout," Fatal Error\n");
      exit(1);
    }

  fprintf(errlog," %s\n",str);

  fclose(errlog);

}
```

Most SVR4- and POSIX-compatible packages will use the stdarg.h header file and format.

Porting the core of any application will touch on at least one of the sections within this chapter. The BeOS supports the POSIX standard relatively closely, and it also supports the complementary Standard C libraries, which are also now defined within the same set of POSIX standards. Unfortunately, it doesn't support the standard as fully as possible, and in many places it is even missing core components of the POSIX standard.

Chapter 19. - Time Support

Time on most computers is handled by some simple variables and structures, and these have been built upon using a number of functions to produce what we call time under UNIX and now POSIX. The BeOS supports the basic POSIX types, with some additional UNIX functions thrown in for good measure.

Standard Variables and Defines

The *epoch* is the point at which time began. As far as UNIX and most other operating systems are concerned this is January 1st, 1970, otherwise known as the epoch. The value is the basic unit of time and is stored as an long which has been typed:

```
#include <time.h>
typedef long time_t;
```

Using a 32-bit integer should make the counter last about 68 years because it is a signed integer value (2^{31}). This allows the timer to specify a time up to January 18th, 2038 based on the epoch.. This is more than long enough to last most people!

The difficulty with time_t is that the figure is calculated in seconds when it is often useful to be able to count in milliseconds. The timeval structure is used to describe the same basic figure as that described using time_t, but the granularity has been reduced to milliseconds:

```
#include <sys/time.h>
struct timeval {
       long tv_sec;
       long tv_usec;
}
```

The clock_t type is used to specify the number of clock cycles used by the current process. The CLOCKS_PER_SEC defines the number of clock cycles per second. The clock_t type can used in combination with clock() to calculate the amount of time of spent calculating by a particular process.

The tm structure defines specific information about the date and time:

```
struct tm {
int tm_sec;
int tm_min;
int tm_hour;
int tm_mday;
int tm_mon;
int tm_year;
int tm_wday;
int tm_yday;
int tm_isdst;
};
```

The individual members are specified as follows:

Table 19.1

Time types and value ranges

Type	Member	Range	Description
int	tm_sec	0-61	Seconds after the minute
int	tm_min	0-59	Minutes after the hour
int	tm_hour	0-23	Hours after midnight
int	tm_mday	1-31	Day of the month
int	tm_mon	0-11	Months since January
int	tm_year		Years since 1900
int	tm_wday	0-6	Days since Sunday
int	tm_yday	0-365	Days since January 1st
int	tm_isdst		Daylight Savings Time flag: >0 if DST is in effect =0 if DST is not in effect <0 if DST status cannot be determined
int	tm_gmtoff		Number of hours offset from GMT.
char *	tm_zone		Timezone abbreviation

The tm_gmtoff member is not included in all implementations, but is within the BeOS. Others define it not as tm_gmtoff but as a long called tm_isdst which specifies the offset value.

The last member is the time zone abbreviation. This is stored as the character pointer tm_zone.

Time Zones

The problem with worldwide use of computers is that different countries and even different areas of the same country have different time zones.

Each time zone specifies the number of hours difference between the current location and UTC. UTC stands for the French equivalent of "coordinated universal time." It used to be called GMT (Greenwich mean time) after Greenwich, UK, the location of the atomic clock at the Greenwich Observatory. When it was agreed that Greenwich should continue being the point of reference, the name was changed from GMT to UTC. Although many believe it was political decision to put the name in French, it probably has more to do with the fact that French is the language of and France is the home of the European standards. It is here that the reference items used to specify the length of a meter, and the weight of a gram, and other measurements are stored, so it's fitting that the measure of time should also have a French bias.

Time zones are named by a three-letter abbreviation describing the location. We already know two of them, GMT and UTC but you will also come across BST (British summer time), PST (Pacific standard time), and EST (eastern standard time).

The tzset function does actually work on the BeOS, but it makes little difference to the operation of the machine:

```
#include <time.h>
void tzset(void);
extern char *tzname[2];
```

Upon execution, the tzset function should set the time conversion information used by the time functions localtime, ctime, strftime, and mktime based on the information provided in the environment variable TZ. If the TZ variable is not set (as is always the case under BeOS), the default time zone is used instead. We can check the result using the tzname variable, which stores two strings: tzname[0] specifies the standard time zone and tzname[1] the daylight savings time zone. The following code will display the results:

```
#include <time.h>

void main(void)
{
       tzset();
       printf("Standard: %s, Daylight Savings: %s
\n",tzname[0],tzname[1]);
}
```

The time zone structure is used by gettimeofday to store the current time zone information:

```
#include <sys/time.h>
struct timezone {
     int tz_minuteswest;
     int tz_dsttime;
};
```

The tz_minuteswest member contains the number of minutes west of UTC of the current time zone. The tz_dsttime member shows whether the current zone supports daylight savings time, and how many hours to advance.

Time Calculations

Calculating time involves a number of problems. We already know that the basic form of time calculation is to take the number of seconds elapsed from January 1, 1970. This is not a perfect calculation, but it has been inherited from the older UNIX variants where recording the time relied on counting the number of clock cycles produced by the processor and then dividing that by a suitable number to generate the number of seconds.

As time progressed, the external clocks (or Real Time Clocks) became more complex, but the legacy system for calculating time remained the same. It is for this reason that time is so complicated a product to extract from a machine, and there isn't a standard function available on all machines which can be used to return a time value.

The process is made even more complicated by two other factors, time zones and daylight savings time. Time zones are relatively easy to handle, providing you know what the numbers are for a given time zone. Daylight savings time, however, is more difficult to work with.

The principle behind daylight savings time is to make the days last longer in the summer by putting the clocks forward in the spring, and putting the clocks back again in the autumn. Not all countries, and therefore not all timezones actually support the notion of daylight savings time (or Summer time as it is referred to in some countries) and this makes the time implementation even more difficult to handle.

Taking all of this into account you can see why the calculation of time is slightly more difficult than it first appears. Internally, every time a user requests the time from the kernel, it has to find out how many seconds have elapsed since the epoch, add or take off the necessary time difference based on the time zone, and then calculate when daylight savings time comes into force and how many hours to add or take away from the figure.

All of this happens instantaneously, but it can lead to problems with software that has to be aware of the different time zones and the effects on the times displayed.

It also affects the operation of the kernel, and most of the operations of the libraries and functions built around the kernel. For example, files are stored with both an access time and a modified time. The values stored are based on the number of seconds since the epoch. In other words, they are completely unaware of the time zone or daylight savings in operation at the time they were saved. It is only when the dates are printed that the calculations are made to show them in the local time format.

The method of calculation also affects the outside operation of programs, and you need to make sure you are aware of the limits and effects when using the various time functions.

Probably the hottest topic in the computer world at the moment is the millennium time bomb. The "year 2000 problem" is another name for the fear currently afflicting systems managers around the world.

Many of the old legacy systems have stored the year value as only two digits, rather than using a four-digit figure. The original reason for this was that data storage was expensive and processor time was sparse. The extra space required and additional processor time needed to process four digits instead of two caused the programmers to ignore the first two digits. It didn't seem to matter, since most people only use two digits anyway (for example, writing 97 instead of 1997), , and in the 60s, the thought of the year 2000, some 30 or so years hence, felt like the distant future.

But can it really affect us now? Well, imagine your date of birth is 1972 but is entered into a computer using only two digits, 72. When you come to the year 2000, the computer will take 00 from 72 and calculate that you are -72 years old, not 28.

You are probably thinking that all modern systems account for this, and you are right, but that doesn't mean you can blindly program your machine without being aware of the dangers. The way to stop this is to ensure that you store all four digits of a date. More to the point, you need to be aware of the limits on calculations made on your behalf internally. Calculations from the epoch are from January 1, 1970. Add 30 years and you should be showing the year 2000, not the year 30.

When calculating numbers using the tm structure, you should remember that calculations of the year work forward from the year 1900. Therefore, to enter the year 2010, the value needs to be 110.

In all cases, the BeOS and most other new systems are aware of the millennium problem and what happens at 23:59:59 on December 31, 1999, but make sure your programs are aware of it as well.

Granularity

As we have already seen, most systems base their time calculation on the number of seconds that have elapsed since a particular date. Many systems are now required to be 'real-time' based, especially with the modern requirements of multimedia systems. Although this is not a direct concern under standard UNIX, the use of real time operating systems is expanding as companies introduce modern computers in to time critical applications such as manufacturing and control.

Under the BeOS, the smallest time unit is the microsecond, supported by bigtime_t datatype. However, the BeOS is not designed for operating in a real time environment without some work in the kernel. Real time operation relies on timing and adjusting the time of certain functions and system calls.

Getting the Time

There is no standard way of extracting the current, local time from the array of OSs available. There are, however, some functions which will help you along the way.

The function you use will depend greatly on the number and format you are trying to get. For most people, strftime does everything they need, supplying them with a formatted string of the time specified by the tm struct, which itself can be gleaned from the localtime function.

time

The time function returns the number of seconds since 00:00:00 on January 1, 1970:

```
#include <time.h>
time_t time(time _t *timer);
```

The timer value is returned and stored in the variable pointed to by timer if specified. A call of the form time(NULL) simply returns the time value.

gmtime and localtime

Most programmers will have come across the problem of calculating a specific day or date based on a reference date and a number of seconds, minutes, hours, and so on. To avoid having different programmers develop a range of such functions, two standard functions were developed. The gmtime function returns the time in struct tm format based on the UTC time. The localtime function returns the local time, also in a struct tm based on the current time zone. In both cases, the calculation is made based on the supplied time_t value:

```
#include <time.h>
struct tm *gmtime(const time_t *timer);
struct tm *localtime(const time_t*timer);
```

The struct tm type was described earlier in this chapter.

difftime

The difftime function returns the difference between time1 and time2 as a double:

```
#include <time.h>
double difftime(time_t time1, time_t time2);
```

It's part of Standard C, but may have previously been expressed with a cast:

```
double timediff;
timediff=(double)(time1-time2);
```

mktime

The complete reverse of the localtime function, mktime converts a struct tm variable into time_t format:

```
#include <time.h>
time_t mktime(struct tm *timeptr);
```

The mktime function can also be used to calculate the day of the week on which a particular date falls. This is because it ignores the values of tm_wday and tm_yday. You can use this trick by passing mktime a struct tm variable containing the specified date, and then checking the values again. For example, the code below works out what day the specified date falls on:

```
#include <time.h>

void main(int argc, char **argv)
{
       struct tm t;
       char *days[7] = {"Sunday", "Monday", "Tuesday",
              "Wednesday", "Thursday", "Friday", "Saturday" };
       t.tm_sec = t.tm_min = t.tm_hour =0;
       t.tm_mday=(int)atoi(argv[1]);
       t.tm_mon=(int)atoi(argv[2])-1;
       t.tm_year=(int)atoi(argv[3]);
       t.tm_isdst = -1;
       mktime(&t);
       printf("That date falls on %s\n",days[t.tm_wday]);
}
```

Note that you have to take one off the month specified because the range of tm_mon is 0 to 11. Also note that because of the way the time calculation works the year has to be specified as a number from 1900, so to put the year 2000 in you would type:

```
$ timeday 1 1 100
```

not

```
$ timeday 1 1 0
```

We looked at the effects of the millennium in "Time Zones," earlier in this chapter.

The effects of passing mktime bad dates make it something to avoid. While mktime checks the values to make sure the figures are not outside the range, (the function returns -12 if they aren't), leap year calculations are not checked. Under the BeOS a date like 2/29/97 causes a data exception and a drop into the debugger. This isn't really very useful; giving mktime an invalid date should return an error.

ctime and asctime

ctime returns a formatted string version of the time value specified by timer in the following format:

```
Sat Jun 21 21:08:35 1997\n\0
```

asctime returns the same value, but bases its calculation on the supplied struct tm variable:

```
#include <time.h>
char *ctime(const time_t *timer);
char *asctime(const struct tm *timeptr);
```

We can use either function to help us calculate the upper and lower limits of the timer values:

```
#include <time.h>
#include <limits.h>
#include <stdio.h>
void main(void)
{
       const time_t high=LONG_MAX,low=0;
       printf("%s to ",ctime(&low));
       printf("%s",ctime(&high));
}
```

This example will display the latest date support by the BeOS. More usually, however, it is used with the time function to return a string containing the current time:

```
#include <time.h>
#include <stdio.h>
void main(void)
{
       time_t now = time(NULL);
       printf("%s",ctime(&now));
}
```

You will notice that the string returned includes a newline character (\n) as well as the terminating null. This is frustrating, and more than likely you'll want to remove this before printing it. Better still, use strftime with either localtime or gmtime, returning the necessary tm structure based on the timer value given.

strftime

Both asctime and ctime print the same string, formatted in a standard format. This isn't very useful, as it is highly likely that you will want to format your string, and at the very least you will want to remove the newline appended to each string.

Older UNIX variants used the cftime and ascftime functions to format the string in much the same way that printf formats other information for printing. Under POSIX, the standard defines a new function, strftime:

```
#include <sys/types.h>
#include <time.h>
#include <string.h>
size_t strftime(char *s, size_t maxsize, char *format, struct tm *tm);
```

The strftime function is basically identical to the cftime and ascftime functions except that it allows you to supply a maximum length for the string. The date and time, taken from tm, are formatted using format and copied to the string pointed to by s up to the length specified by maxsize.

The list of specifiers used within format is shown in Table 19.2.

Table 19.2

String specifiers in strftime

Specifier	String It Is Replaced By	Example
%a	Abbreviated weekday name	Mon
%A	Full weekday name	Monday
%b	Abbreviated month name	Aug
%B	Full month name	August
%c	Date and time	Sun Aug 17 16:56:37 BST 1997
%d	Day of the month as a decimal number	17
%H	Hour as a decimal number, 24-hour format	16
%I	Hour as a decimal number, 12-hour format.	4
%j	Day of the year as a decimal number	229
%m	Month as a decimal number	08
%M	Minute as a decimal number	56
%p	AM/PM	PM
%S	Second as a decimal number	37
%U	Week of the year as a decimal number, using the first Sunday as day 1 of week 1	34
%w	Weekday as a decimal number (0=Sunday)	0
%W	Week of the year as a decimal number, using the first Monday as day 1 of week 1	33
%x	Date	8/17/97
%X	Time	16:56:37
%y	Year without century	97
%Y	Year with century	1997
%z	Time zone	BST
%%	The % character	%

Using these specifiers you can produce a number of the standard formats that are used regularly:

Format	Result
%Y%m%d	19970622
%H:%M	15:55
%c	Sun Jun 22 15:55:23 1997
%a %b %d %H:%M:%S %Y	Sun Jun 22 15:55:23 1997
%x	6/22/97
%X	3:55 PM

gettimeofday

The gettimeofday function returns the current time in the timeval structure pointed to by tv.

```
#include <sys/time.h>
#include <time.h>
int gettimeofday(struct timeval *tv, struct timezone *tz);
struct timezone {
     int tz_minuteswest;
     int tz_dsttime;
};
```

The function also returns the current timezone information in the timezone structure pointed to by the variable tz, although this information isn't really all that useful.

Setting the Time

POSIX doesn't define any specific functions for setting the time on a system. This is probably because different systems, and specifically different hardware, all manage their time differently; but it doesn't help programmers who need to set the time. This makes it particularly difficult to port packages such as xntpd, an implementation of the Network Time Protocol (NTP), which is used across networks and the Internet to set the dates and times of machines.

Most UNIX implementations include a small collection of functions used for setting the time, but the BeOS doesn't support any of them. It does, however, support two functions as part of the Kernel kit:

```
#include <OS.h>
void set_real_time_clock(uint32 secs_since_jan1_1970);
void set_timezone(char *str);
```

The set_real_time_clock sets the number of seconds from the epoch into the real-time clock. The set_timezone function sets the current timezone using the 3 letter timezone abbreviations.

The settimeofday function as defined in SVR4 is the opposite of the gettimeofday function (which, for some curious reason, does exist under the BeOS):

```
#include <sys/time.h>
int gettimeofday(struct timeval *tv, struct timezone *tz);
int settimeofday(struct timeval *tv, struct timezone *tz);
```

The replacement code could look as follows:

```
#include <sys/time.h>
#include <OS.h>
int settimeofday(struct timeval *tv, struct timezone *tz)
{
       set_real_time_clock(tv->tv_sec);
       return(0); /* Always return 0, set_real_time_clock
                     doesn't give us any feedback. /*
}
```

The stime function is also part of System V, and is supported by the BeOS:

```
#include <time.h>
int stime(time_t *t);
```

The last function, adjtime, gradually changes the time, rather than simply jumping forward or back by a number of hours or days. This is most useful in a networked environment where all the clocks of individual machines will drift slightly. It's also safe when used on machines running cron where skipping ahead or back by a number of hours could cause the same program to be run twice, or never to be run at all.

The problem with adjtime is that it's a UNIX daemon, and therefore doesn't lend itself to porting to the BeOS very easily. A daemon usually uses some form of messaging system between itself and the outside world to perform it's tasks, and it is the messaging which causes the most problems. There is a version of adjtime supplied with xntpd for those systems that are missing it (such as HP-UX). However, the implementation uses System V messages to confer information between requests and the daemon that does the work. Under the BeOS, this messaging system isn't supported, although it could probably be implemented under a BApp.

Timers

Timers are used in a number of programs where you probably don't expect to see them. Essentially, a timer provides a way of either pausing execution of a program or part of a program, or as a way of delaying the execution of a particular element until a set point. For example, the egg timers (on Windows) and watch (on MacOS) both use timers to set the interval between different elements of the animation.

One of my first porting exercises was to port the xv image editor to HP-UX. The most trouble I had with the package was getting the mouse cursor to display properly. It used a rotating fish to show that the program was busy and required timers to animate the fish smoothly without interrupting the processing of the images.

alarm

We already looked at the alarm function in the last chapter. Although it doesn't pause execution of a program as such, it can be used to generate repeating events. The timer can only be specified in seconds and so isn't thoroughly useful.

Also, the alarm function relies on a signal handler, a simple function which is executed at the time the alarmsignal is received by the program. This can cause difficulties as it really only lends itself to simple operations, or complex signal handlers to respond to the alarm signal.

itimers

An interval timer can be used to pause execution for a very specific period of time. It's more reliable and precise than alarm or sleep, but unfortunately not supported by the BeOS as yet. There are versions floating about the Internet; you can try porting the versions from NetBSD or the GNU libc package.

sleep and usleep

The sleep function is part of the POSIX standard and pauses execution for the number of seconds specified.

```
#include <unistd.h>
unsigned int sleep(unsigned int seconds);
```

The function is far from perfect and it is likely that the timer pause will be longer than the number of seconds specified.

The usleep function suspends execution for the number of microseconds specified, instead of seconds. It is not supported under the BeOS and although a version exists under the NetBSD distribution, it uses the itimer function. It is also possible to fake the usleep function using select, but this doesn't work under the BeOS because the select function has not been implemented properly. We take a closer look at select in Chapter 22.

There is a BeOS specific timer function that can be used as a substitute to the usleep function. The function is called snooze and uses the bigtime_t variable type to specify the wait time.

```
#include <OS.h>
typedef long long bigtime_t;
long snooze(bigtime_t microseconds);
```

The snooze period is specified in microseconds, and, using an long long the delay period could be as much as 2^61-1 seconds, which equates to over 73 million years!

System Information

Getting information about how long a particular part of a program has taken can be useful. The classic application is to use it for timing how long a calculation takes. Of course, the real reason behind that is to test the performance of a machine. A much less critical reason, though, can be found for timing the execution of certain functions.

The profiling library for the Metrowerks C compiler, uses these to test the execution speed of a program, or indeed parts of a program.

Other programs also use similar functions to test the execution time of a program as a whole. The time and timex functions, both part of System V, can be used for exactly this purpose. Since they are not related to the actual date or time, these operations are really obtaining information about the system's execution.

There are two functions that can aid us in timing. The clock function returns the number of clock ticks since the clock was reset. Each process has its own clock, but there is no specification (or information) about when the clock is reset. The difference between the point at which the program was loaded and when the main() function was executed could be seconds on a slow system and so the function is not really reliable:

```
#include <time.h>
clock_t clock(void);
```

The value returned can be divided by the CLOCKS_PER_SEC macro to get the number of seconds. Note that the name is different from the CLOCKS_PER_SECOND macro, which is what the POSIX standard defines. A better use of the function is to run it once at the start of the timed function and once at the end. Calculating the difference between the two should give a much better representation of the time taken. The example below tests the time taken to perform a relatively simple integer calculation:

```
#include <stdio.h>
#include <time.h>

void main(void)
{
       register  long i=0;
       long cplxres;
       clock_t end,start;
       float total;
```

```
        start=clock();

        for (i=0;i<2000000;i++)
               cplxres=((i*(i-99))/((i*i*i)-(i*i)));
        end=clock();

        total=(float)end-(float)start;
        printf("Time was %f seconds\n",(float)(total/CLOCKS_PER_SEC));
}
```

The problem with <u>clock</u> is that it only tells us the time taken for the user portion of the application. It doesn't include the time taken for functions and calls that are part of the kernel. Calls made to system libraries are still counted as user time however..

If we were trying to time the execution time of our part of an application, not the time taken to execute system functions, it would be very difficult to get the time information we needed. For this, however, we can use the <u>times</u> function. Also POSIX-specified, it is related to the <u>clock</u> function in that it calculates time from the point of execution of a program.

However, the function is more reliable, and generally more useful, because it times the user CPU time, the system CPU time, and the user and system CPU times for any child processes.

```
#include <times.h>
struct tms {
clock_t tms_utime;
clock_t tms_stime;
clock_t tms_cutime;
clock_t tms_cstime;
};
clock_t times(struct tms *buffer);
```

User time is calculated as the time taken to execute user processes and functions. System time is calculated as the time taken executing system functions and processes on behalf of the process. There is no standard for defining what is classed as a system process, and so its only an approximate value. We can modify the above example to look like this:

```
#include <stdio.h>
#include <time.h>
#include <sys/times.h>

void main(void)
{
        register  long i=0;
        long cplxres;
        struct tms start, end;

        times(&start);

        for (i=0;i<2000000;i++)
               cplxres=((i*(i-99))/((i*i*i)-(i*i)));

        times(&end);

        printf("User %.2f, System %.2f\n",
                (((float)end.tms_utime-(float)start.tms_utime)/
CLOCKS_PER_SEC),
```

```
                (((float)end.tms_stime-(float)start.tms_stime)/
CLOCKS_PER_SEC));
}
```

This gives us a far more useful figure. Using both these functions, it would be possible to build a substantial timing engine for executing individual processes, and in fact this is precisely what profiling systems do when the compiler adds in the profiling options.

Chapter 20. - Terminals and Devices

Devices can take a number of different forms. The strict definition of a device is any hardware component attached to the computer. Generally, devices are further subdivided into input devices (such as keyboards) and output devices (such as monitors). Some pieces of equipment, such as disk drives and terminals, can be classed as both input and output devices,. There are some exceptions to this general rule. We can also expand the definition of a device to include some special types of program or server which respond to requests in the same way as other devices, but don't transfer the information to or from a specific piece of hardware.

Using and working with devices relies on a few core routines, many of which will be familiar to UNIX programmers. Under the BeOS, UNIX and POSIX models, devices have the same basic interface as files, so using them at a basic level should not be too different from what we are already used to. In this chapter, we will take a general look at using I/O devices before moving on to take an in-depth look at the input/output device most people will encounter when porting software: the terminal. Finally, we will take a brief look at the issues involved in writing device drivers under the BeOS.

Using I/O Devices

Although you may not appreciate it, you use I/O devices all the time. The keyboard is an input device; your monitor is an output device. For most people, using these and other devices requires a simple call to a function provided by the operating system.

For example, to print some information to the screen, you use printf, and to read some information from the keyboard, you probably use scanf or gets. If you are opening, creating, or using files on disk drives, you use the corresponding stream functions such as fopen and fprintf. Occasionally, however, you have cause to read and write to devices directly, or you need more control over the device you are writing to.

In these instances you talk to the device using a set of functions that control the device at a hardware level. These functions may take the form of a single function controlling many separate elements or many functions controlling individual elements. In more extreme examples, you may be required to read or write information to a device directly using the read and write functions.

When you use the latter method of accessing the device directly, chances are you will be using UNIX-style file descriptors to open the device file, rather than using streams. A device file is a special type of file that forms a logical link between a file and the physical device to which the file is attached. Under UNIX and the BeOS, these files are stored under /dev. You can see the directory listing of my BeBox machine below:

```
$ ls -l /dev
total 0
drw-r--r--   1          users           0 Aug 31 07:30 beboxhw
drw-r--r--   1          users           0 Aug 31 07:29 disk
crw-r--r--   1          users      0,   0 Aug 31 07:29 dprintf
crw-r--r--   1          users      0,   0 Aug 31 07:30 ether
crw-r--r--   1          users      0,   0 Aug 31 07:30 flash
crw-r--r--   1          users      0,   0 Aug 31 07:29 hack
crw-r--r--   1          users      0,   0 Aug 31 07:30 kb_mouse
crw-r--r--   1          users      0,   0 Aug 31 07:30 midi1
crw-r--r--   1          users      0,   0 Aug 31 07:30 midi2
crw-r--r--   1          users      0,   0 Aug 31 07:29 null
crw-r--r--   1          users      0,   0 Aug 31 07:30 parallel1
crw-r--r--   1          users      0,   0 Aug 31 07:30 parallel2
crw-r--r--   1          users      0,   0 Aug 31 07:30 parallel3
drw-r--r--   1          users           0 Aug 31 07:30 ports
drw-r--r--   1          users           0 Aug 31 07:30 pt
crw-r--r--   1          users      0,   0 Aug 31 07:30 scsiprobe
crw-r--r--   1          users      0,   0 Aug 31 07:30 sound
drw-r--r--   1          users           0 Aug 31 07:30 tt
crw-r--r--   1          users      0,   0 Aug 31 07:30 tulip
crw-r--r--   1          users      0,   0 Aug 31 07:29 zero
```

The first character in the output shows you the file type, which for all of the device files shown here is "c," meaning that it is a character-based device. The other possibilities are "b" for a block-based device and "p" for a pipe.

UNIX users will have spotted a major difference. Under UNIX the two numbers shown (before the date) for each device file usually point to a *major* and a *minor* device number. The major and minor device numbers can be used to uniquely identify an individual device, and this information is attached to the device file so that the OS can select the correct device driver when the file is used.

Beyond this difference, the files under UNIX and the BeOS are largely identical, although the names may be different:

- The disk directory contains the SCSI (Small Computer Systems Interface) and IDE (Integrated Drive Electronics) device files. They are subdivided into these two categories, and then further divided by number and master/slave respectively. The disk directory also stores the floppy device file. This is equivalent to the /dev/dsk directory under SVR4 for

SCSI devices, and the /dev/fd0 device file for the first floppy drive on a machine.

- The ether device file is the Ethernet adaptor attached to your machine. This is equivalent to /dev/le0 under SVR4.
- The midi1 and midi2 device files refer to the MIDI interfaces supported on the BeBox. Although these files will exist on the Mac, they are simply aliases to the serial ports. On the PC, the MIDI device files will exist if you have one or more MIDI devices, usually a sound card installed in your machine.
- The parallel files refer to the parallel ports on a machine and are synonymous with the /dev/bpp or /dev/lp device under SVR4. For Mac users this device file will not exist.
- The /dev/ports directory contains the device files for the serial ports on your machine, referenced as /dev/ports/serial1 through /dev/ports/serial4 for a BeBox owner, or through to only /dev/ports/serial2 for a standard PC. For a Mac user, the ports are labelled /dev/ports/modem and /dev/ports/printer.
- Finally, the /dev/pt and /dev/tt directories contain the device files for the individual pseudo-terminals. These are the device files used by multiple instances of the Terminal application, or by Telnet connections to the machine. The device files are synonymous with the /dev/pty* and /dev/tty* range of device files under UNIX.

As you can see, the BeOS supports many of the ports and functions of the UNIX world, making it simple to work with devices. When working with terminals, the devices you use will be the stdin and stdout streams or file descriptors, rather than the direct device files.

Working with Terminals

Typically, the device most people will want more control over is the terminal, or a serial device if they are writing a communications program. Although most of the references in this section refer to using terminals, the same principles and functions can be used to communicate with modems and other serial devices.

If there is one single area of UNIX development that has caused porters problems, it is driving terminals. This is a strange occurrence, since many of the early UNIX systems only had one way of communicating with the outside world: the text-based terminal. Such advanced systems as keyboards directly attached to the UNIX machines and built-in video drivers to display the output to a monitor didn't exist.

Over the years, a number of different systems and function sets have been introduced with the specific aim of supporting terminals. The method for driving terminals can be logically split into two basic areas:

- The functions used to control and pass information to and from the terminal drivers. This can be split into termio, as developed for System V, and termios, which was developed for the POSIX standard and is based on the termio functions.
- The data structures used to store information about the abilities and codes of the terminals you are using, and the functions which make use of these codes. The structures are further split into a two groups: a terminal's capability database, better known as termcap, and a terminal info database, better known as terminfo.

In this section, we'll take a look at all four systems and how they interact with each other.

termio and termios

There are three basic systems for using and controlling terminals, Seventh Edition UNIX, System V termio and POSIX termios. The old Seventh Edition UNIX system is no longer in general use, and so in this book we shall ignore it. The termio system was introduced with System V as a coherent way of using terminals. The termio system was built on and expanded and eventually became the termios functions that are defined in the POSIX standard. The BeOS does not support termio either, but some discussion of it will help you understand how to interact with this type of machine.

The BeOS, via its POSIX interface, supports the termios system for working with terminals. However, since many systems still expect to find ioctl, the BeOS also supports the full ioctl terminal functionality. Even so, for compatibility it is best to the use the termios functions rather than the ioctl equivalents.

Basic Principles

It is important to understand some of the basic principles of terminal configuration and use before we move on to actually using the termio and termios systems. There are a number of new terms that you will encounter throughout this section; see the sidebar for a list of these terms and their meanings.

Terminal Terminology

Here are some basic terms you will come across when using terminals and terminal-like devices.

- *Queues* are used by the terminal drivers to buffer the input and output between the machine and the terminal. The input queue buffers all characters typed that have not been read by the currently controlling process. The output queue buffers all characters that have been sent to the terminal but not actually written to the output device. The queues are supported directly by the terminal drivers and are not related to any buffers set up by the programmer on the individual file descriptor or stream.
- *Flush* means to discard the contents of a queue. This erases any data waiting to be read or any data not yet displayed by the terminal.
- *Drain* means to wait for the input or output on a queue to be read or written before continuing.
- *Control characters* are special characters interpreted by the terminal driver on input before passing the data onto the controlling process. A good example is Ctrl-C, which interrupts the progress of a program.
- *Break* refers to the action of "dropping" the physical connection between the machine and the terminal at a hardware level for a fraction of a second.
- *Baud rate* is the number of units of information a modem can send per second. It is not the same as, but is often confused with, the *bit rate,* which refers to the number of bits transmitted by a serial device per second.

The basic settings of a terminal or serial driver are based on the hardware settings (baud rate, hardware/software flow control, and so on) and terminal settings (processed or raw). We will look at setting the terminal driver using the termio and termios function sets shortly, but first let's take a brief look at how characters are interpreted by the terminal drivers.

Both termio and termios specify two settings for how input data is processed as it flows from the terminal. *Canonical* mode processes the input based on a number of rules built into the OS before passing the information to the calling function. The characters processed by the BeOS and their effects are shown in Table 20.1. In *non-canonical* mode, the driver doesn't interpret any characters except a newline. Canonical mode is roughly equivalent to the BSD "cooked" mode and non-canonical mode is roughly equivalent to the BSD "cbreak" mode. The BSD "raw" mode, which differs from the cbreak mode in that newline characters are not interpreted, is not supported by the termio or termios systems.

Table 20.1

Special Characters Interpreted by termio and termios

Name	Keyboard Equivalent	Description
VINTR	Ctrl-C	Generate a SIGINT signal
VQUIT	Ctrl-\	Generate a SIGQUIT signal
VERASE	Backspace	Erase the last character
VKILL	Ctrl-U	Erase the current line
VEOF	Ctrl-D	Send EOF character
VEOL	Ctrl-@	Send alternative end of line
VEOL2	Ctrl-@	Send alternative end of line
VSWTCH	Ctrl-@	Switch shell
VSTART	Ctrl-Q	Resume output after stop
VSTOP	Ctrl-S	Stop output
VSUSP	Ctrl-@	Generate SIGTSTP signal

termio

The termio system relies on the termio structure and a number of supporting functions which control the device you have opened. The termio structure is usually defined in the termio.h header file as follows:

```
struct termio {
     unsigned short  c_iflag;          /* input modes */
     unsigned short  c_oflag;          /* output modes */
     unsigned short  c_cflag;          /* control modes */
     unsigned short  c_lflag;          /* line discipline modes */
     char    c_line;                   /* line discipline */
     unsigned char   c_cc[NCC];        /* control chars */
};
```

Although the BeOS doesn't support termio, the same basic macros and values can be used on both termio and termios. I will list the values here along with the functions that use them so that comparisons can be made between the termios functions used on the BeOS and the termio functions supported on other machines.

The c_iflag variable sets the input modes for the terminal driver. These are described in Table 20.2. The c_oflag variable sets the behavior of data output; its values can be seen in Table 20.3

Table 20.2

Flags for c_iflag

Parameter	BeOS Value	Description
IGNBRK	0x01	Ignore breaks
BRKINT	0x02	Break sends interrupt
IGNPAR	0x04	Ignore characters with parity errors
PARMRK	0x08	Mark parity errors
INPCK	0x10	Enable input parity checking
ISTRIP	0x20	Strip high bit from characters
INLCR	0x40	Map newline to CR on input
IGNCR	0x80	Ignore carriage returns
ICRNL	0x100	Map CR to newline on input
IUCLC	0x200	Map all uppercase to lowercase
IXON	0x400	Enable input SW flow control
IXANY	0x800	Any character will restart input
IXOFF	0x1000	Enables output SW flow control

Table 20.3

Flags for c_oflag

Parameter	BeOSValue	Description
OPOST	0x01	Enable post-processing of output
OLCUC	0x02	Map lowercase to uppercase
ONLCR	0x04	Map newline (NL) to carriage-return (CR), newline on output
OCRNL	0x08	Map CR to NL on output
ONOCR	0x10	No CR output when at column 0
ONLRET	0x20	Newline performs CR function
OFILL	0x40	Use fill characters for delays
OFDEL	0x80	Fills are DEL, otherwise NUL
NLDLY	0x100	Newline delay mask
NL0	0x000	No delay after newline
NL1	0x100	One character delay after newline
CRDLY	0x600	Carriage return delay mask
CR0	0x000	No delay after carriage return
CR1	0x200	One character delay after carriage return
CR2	0x400	Two character delay after carriage return
CR3	0x600	Three character delay after carriage return
TABDLY	0x1800	Horizontal tab delay mask
TAB0	0x0000	No delay after tab
TAB1	0x0800	One character delay after tab
TAB2	0x1000	Two character delay after tab

TAB3	0x1800	Expand tabs to spaces
BSDLY	0x2000	Backspace delay mask
BS0	0x0000	No delay after backspace
BS1	0x2000	One character delay after backspace
VTDLY	0x4000	Vertical tab delay mask
VT0	0x0000	No delay after vertical tab
VT1	0x4000	One character delay after vertical tab
FFDLY	0x8000	Form-feed delay mask
FF0	0x0000	No delay after form-feed
FF1	0x8000	One character delay after form-feed

The c_cflag variable sets up the hardware parameters of the terminal interface. I've split these into the bit rate settings, shown in Table 20.4, and other settings, shown in Table 20.5. Finally, the c_lflag variable sets the line discipline. The values supported by the BeOS are shown in Table 20.6.

Table 20.4

Bit Rate Settings for c_cflag

Parameter	BeOS Value	Description
CBAUD	0x1F	Line speed mask
B0	0x00	Hang up
B50	0x01	50 bps
B75	0x02	75 bps
B110	Ox03	110 bps
B134	0x04	134 bps
B150	0x05	150 bps
B200	0x06	200 bps
B300	0x07	300 bps
B600	0x08	600 bps
B1200	0x09	1200 bps
B1800	0x0A	1800 bps
B2400	0x0B	2400 bps
B4800	0x0C	4800 bps
B9600	0x0D	9600 bps
B19200	0x0E	19200 bps
B38400	0x0F	38400 bps
B57600	0x10	57600 bps
B115200	0x11	115200 bps
B230400	0x12	230400 bps

B31250	0x13	31250 bps (for MIDI)

Table 20.5

Hardware Settings for c_cflag

Parameter	BeOS Value	Description
CSIZE	0x20	Character size mask
CS5	0x00	5 bits (not supported by the BeOS)
CS6	0x00	6 bits (not supported by the BeOS)
CS7	0x00	7 bits
CS8	0x20	8 bits
CSTOPB	0x40	Send 2 stop bits, not 1
CREAD	0x80	Enable receiver
PARENB	0x100	Transmit parity enable
PARODD	0x200	Odd parity, else even
HUPCL	0x400	Hangs up on last close
CLOCAL	0x800	Indicates local line
XLOBLK	0x1000	Block layer output
CTSFLOW	0x2000	Enable CTS flow
RTSFLOW	0x4000	Enable RTS flow
CRTSFL	0x6000	Enable RTS/CTS flow
ORTSFL	0x100000	Unidirectional RTS flow control

Table 20.6

Flags for c_lflag

Parameter	Value	Description
ISIG	0x01	Enable signals
ICANON	0x02	Canonical input
XCASE	0x04	Canonical upper/lowercase
ECHO	0x08	Enable echo
ECHOE	0x10	Echo erase as bs-sp-bs
ECHOK	0x20	Echo newline after kill
ECHONL	0x40	Echo newline
NOFLSH	0x80	Disable flush after interrupt or quit
TOSTOP	0x100	Stop background processes that write to terminal

Using these flags is as easy as setting the individual variables to match the bitmask you require. However, it is good practice to get the existing settings of the terminal. You can then set your parameters before returning the terminal to its previous state.

Using ioctl

Setting up the terminal using the settings shown in the previous tables requires the use of a function to set up the various parameters for the terminal or device you are using. Like the fcntl function that we will see in Chapter 22, ioctl is a catchall function for setting and controlling the parameters on a file descriptor at a device level. The ioctl function performs so many different tasks that it is not possible to go into every single one in this book. However, what we will do is look at the main functionality provided by ioctl, particularly with reference to the support for driving serial and terminal devices with termio structures. As I have already stated, the BeOS does not support termio fully, but it does support some of the abilities of the ioctl function. It should be pointed out that ioctl is not part of the POSIX specification, and although it is found on most systems, it is not really a portable function.

The synopsis for the ioctl command is defined in unistd.h:

```
#include <unistd.h>
int ioctl(int fd, int op, ...);
```

The fd argument is the terminal or device to use. The op argument specifies the operation to perform and, if applicable, the command can also accept further arguments based on the operation. The list of operations supported varies from implementation to implementation. In Table 20.7 you can see a list of operations that you may come across which are supported under the BeOS, and the values of the corresponding third arguments. In Table 20.8, you can see the differences between the operation names used for setting terminal attributes on various OSs.

Table 20.7

Operations for ioctl

Operation	Description	Final Argument
TCGETA	Get attributes	struct termios *
TCSETA	Set attributes	struct termios *
TCSETAF	Drain I/O and set state	struct termios *
TCSETAW	Drain output only and set state	struct termios *
TCWAITEVENT	Get the current wait state	int *
TCSBRK	Drain output and send break	int *
TCFLSH	Flush I/O	int *
TCXONC	Set flow control	int *
TCGETBITS	Return the hardware states of the device	int *
TCSETDTR	Set DTR (data terminal ready)	None
TCSETRTS	Set RTS (ready to send)	None

TIOCGWINSZ	Get window size	struct winsize *
TIOCSWINSZ	Set window size	struct winsize *

Table 20.8

Setting Terminal Attributes under Different OS

Function	**termio request**	**termios request (BSD)**	**termios request (SVR4)**	**termios request (BeOS)**
Get current state	TCGETA	TIOCGETA	TCGETS	TCGETA
Get special characters	TCGETA	TIOCGETA	TCGETS	TCGETA
Set terminal state immediately	TCSETA	TIOCSETA	TCSETS	TCSETA
Set terminal state (drain output)	TCSETAW	TIOCSETAW	TCSETSW	TCSETAW
Set terminal state (drain I/O)	TCSETAF	TIOCSETAF	TCSETSF	TCSETAF
Set special characters	TCSETAF	TIOCSETAF	TCSETSF	TCSETAF

In all the descriptions below, ioctl returns a zero on success and -1 on failure with the error code supplied in the global variable errno.

TCGETA

The TCGETA operation returns the current setting for the specified terminal in the termios structure pointed to by termstat:

```
int ioctl(fd, TCGETA, struct termios *termstat);
```

TCSETA

The TCSETA operation sets the parameters for the specified terminal using the termios structure specified by termstat:

```
int ioctl(fd, TCSETA, struct termios *termstat);
```

TCSETAF

The TCSETAF operation flushes the current input queue. All the characters in the current output queue are written to the terminal. The function then sets the parameters for the specified terminal using the termios structure specified by termstat.

```
int ioctl(fd, TCSETAF, struct termios *termstat);
```

TCSETAW

The TCSETAW operation sets the parameters for the specified terminal using the termios structure specified by termstat after draining the output queue:

```
int ioctl(fd, TCSETAW, struct termios *termstat);
```

TCWAITEVENT

The TCWAITEVENT operation returns the current wait state for the specified device into the int pointed to by event:

```
int ioctl(fd, TCWAITEVENT, int *event);
```

The result can be compared against the following predefined macros:

EV_RING	Ring condition
EV_BREAK	Break condition
EV_CARRIER	Carrier detected
EV_CARRIERLOST	Carrier lost

TCSBRK

The TCSBRK operation sends a break signal (hardware disconnect) to the specified terminal:

```
int ioctl(fd, TCSBRK, NULL);
```

TCFLSH

The TCFLSH command flushes the input or output queue, depending on the options specified in the third argument, queue:

```
int ioctl(fd, TCFLSH, int queue);
```

Options for queue are shown below:

TCIFLUSH	Flush the input queue
TCOFLUSH	Flush the output queue
TCIOFLUSH	Flush the input and output queues

TCXONC

The TCXONC call sets the software flow control for the terminal specified by fd based on the third argument, flow:

```
int ioctl(fd, TCXONC, int flow);
```

Options for flow are shown below:

TCOOFF	Suspend output (Xoff)
TCOON	Restart output (Xon)
TCIOFF	Suspend input (Xoff)
TCION	Restart input (Xon)

TCGETBITS

The TCGETBITS call returns the current status of the serial driver at a hardware level into the int pointed to by bits:

```
int ioctl(fd, TCGETBITS, int *bits);
```

You can check the return value against the following predefined macros:

TCGB_CTS	Clear to send is active

TCGB_DSR	Data set ready is active
TCGB_RI	Ring indicator is active
TCGB_DCD	Data carrier detect is active

This is roughly equivalent to the TIOCMGET operation supported under BSD and SVR4.

TCSETDTR

The TCSETDTR operation sets the data terminal ready signal on the serial hardware:

```
int ioctl(fd, TCSETDTR, NULL);
```

TCSETRTS

The TCSETRTS operation sets the ready to send signal on the serial hardware:

```
int ioctl(fd, TCSETRTS, NULL);
```

TIOCGWINSZ

The TIOCGWINSZ returns the current window size into the winsize structure pointed to by window:

```
int ioctl(fd, TIOCGWINSZ, struct winsize *window);
```

The winsize structure specifies the number of columns and rows in the current window, and, if applicable, the number of pixels (horizontal and vertical). Programs like jove and emacs use the TIOCGWINSZ call to determine the size of the window and format the screen accordingly. The winsize structure is defined as follows:

```
struct winsize {
    unsigned short ws_row;
    unsigned short ws_col;
    unsigned short ws_xpixel;
    unsigned short ws_ypixel;
};
```

TIOCSWINSZ

The TIOCSWINSZ call sets the window size based on the winsize structure window supplied in the third argument:

```
int ioctl(fd, TIOCSWINSZ, struct winsize *window);
```

If the size of the window specified is different from the previous setting, a SIGWINCH signal is sent to the controlling process.

termios

The POSIX standard built on termio and standardized the functions and structures used with the terminals. One fundamental difference between termio and termios is that in termios some of the ioctl functionality has been replaced by a number of individual functions.

The termios system uses the termios structure, which is defined in the termios.h header file. It is almost identical to the termio structure, the difference being that individual variables within the structure have a special variable type:

```
#include <termios.h>
typedef unsigned long tcflag_t;
typedef unsigned char speed_t;
typedef unsigned char cc_t;

struct  termios {
        tcflag_t        c_iflag;        /* input modes */
        tcflag_t        c_oflag;        /* output modes */
        tcflag_t        c_cflag;        /* control modes */
        tcflag_t        c_lflag;        /* local modes */
        char            c_line;         /* line discipline */
        speed_t         c_ispeed;       /* line discipline */
        speed_t         c_ospeed;       /* line discipline */
        cc_t            c_cc[NCC];      /* control chars */
};
```

The POSIX specification of the structure does not include the c_line variable, but some systems (the BeOS included) specify it anyway. The only other difference from the termio structure is that line speeds are set using the two variables c_ispeed and c_ospeed. They control, individually, the line speed for the incoming and outgoing data.

The same macros and values can be used to set the same features that were described for termio above.

tcdrain

The tcdrain function suspends the process until all the data written to a terminal has been sent:

```
#include <termios.h>
int tcdrain(int fd);
```

The function is identical to the ioctl call TIOCDRAIN. The fd argument should be a currently open terminal and the function returns zero on success or -1 on failure. The errno variable stores the reason for the error.

tcflow

The tcflow function suspends and restarts terminal output:

```
#include <termios.h>
int tcflow(int fd, int action);
```

The function is identical to the TCXONC call to ioctl. The fd argument should be a currently open terminal. See the TCXONC section under "termio" for details on the action argument. The function returns zero on success or -1 on failure. The errno variable stores the reason for the error.

tcflush

The tcflush function flushes the input or output queues for the specified terminal descriptor. It is synonymous with the TCFLSH call to ioctl:

```
#include <termios.h>
int tcflush(int fd, int queue_selector);
```

The fd argument should be a currently open terminal, and the queue_selector argument specifies the queue to flush. The values are based on the macros TCIFLUSH, TCOFLUSH, and TCIOFLUSH. TCIFLUSH specifies the input queue, TCOFLUSH specifies the output queue, and TCIOFLUSH specifies that both the input and output queues should be flushed. The function returns zero on success or -1 on failure. The errno variable stores the reason for the error.

tcgetattr

The tcgetattr function corresponds exactly to the TCGETA call to ioctl and returns the current status of the terminal into the structure pointed to by term:

```
#include <termios.h>
int tcgetattr(int fd, struct termios *term);
```

In fact, the BeOS termios.h header defines it as a macro to the ioctl call:

```
#define  tcgetattr(f, t) ioctl(f, TCGETA, (char *)t)
```

The function returns zero on success or -1 on failure. The errno variable stores the reason for the error.

tcgetpgrp

The tcgetpgrp function returns the current process group for the terminal specified by fd:

```
#include <termios.h>
#include <unistd.h>
pid_t tcgetpgrp(int fd);
```

This function is equivalent to the TIOCGPGRP call to ioctl, and returns the process ID. The function returns zero on success or -1 on failure. The errno variable stores the reason for the error.

tcsendbreak

The tcsendbreak function sends a break indication on the line to the terminal. This is equivalent to the ioctl call TCSBRK:

```
#include <termios.h>
int tcsendbreak(int fd, int duration);
```

The function returns zero on success or -1 on failure. The errno variable stores the reason for the error.

tcsetattr

The tcsetattr function corresponds exactly to the TCSETA call to ioctl and sets the current status of the terminal to the structure pointed to by tp:

```
#include <termios.h>
int tcsetattr(int fd, int opt, const struct termios *tp);
```

The function returns zero on success or -1 on failure. The errno variable stores the reason for the error.

tcsetpgrp

The tcsetpgrp function sets the process group specified by pgrpid for the terminal specified by fd :

```
#include <termios.h>
#include <unistd.h>
int tcsetpgrp(int fd, pid_t pgrpid);
```

This function is equivalent to the TIOCSPGRP call to ioctl, and returns zero on success or -1 on failure. The errno variable stores the reason for the error.

Additional termios Functions

In addition to the replacements for the ioctl calls, the POSIX definition of termios also defines six functions specially designed to control the connection speed values in a termios structure. The remaining function resets the termios structure to the default values.

The BeOS supports four of the six functions, those designed to set the input and output speed of the terminal:

```
#include <termios.h>
speed_t cfgetispeed(struct termios *t);
int cfsetispeed(struct termios *t, speed_t speed);
speed_t cfgetospeed(struct termios *t);
int cfsetospeed(struct termios *t, speed_t speed);
```

The cfgetispeed and cfgetospeed functions return the input and output speed, respectively, stored in the termios structure pointed to by t. The cfsetispeed and cfsetospeed functions set the input and output speed in the structures pointed to by t to the speed specified by speed. In the latter case, using the set functions does not actually alter the speed, it only modifies the speed setting the structure. You still need to use the tcsetattr function to change the speed of the connection.

Like most functions designed to manipulate variables, the functions are in fact macros:

```
#define cfgetispeed(tp)  ((tp)->c_ispeed)
#define cfgetospeed(tp)  ((tp)->c_ospeed)
#define cfsetispeed(tp, sp)  ((tp)->c_ispeed = sp)
#define cfsetospeed(tp, sp)  ((tp)->c_ospeed = sp)
```

Moving from termio to termios

Moving from the System V-based termio system to the POSIX termios system is relatively straightforward:

- Change references to termio.h to termios.h
- Change references to the termio structure to termios
- Replace calls to ioctl with the corresponding tc* series of individual functions

- References to the c_line variable in the termio structure should be removed. Although this variable is defined in the BeOS, the POSIX specification doesn't require it.

termcap and terminfo

In the early years of UNIX development, editing was handled by ed. The ed program was advanced for its time, allowing you to edit individual lines of a document. You could even search for text and replace it. Unfortunately, working on a document more than ten lines long when you can only view and edit one line at a time becomes tedious.

Editors progressed in the late seventies with the introduction of vi, the visual version of ed. The same basic functionality remained; what was different was that you were able to view multiple lines of the document, and move around them in a way never before possible. This presented something of a problem for the developer of vi, Bill Joy. The problem was that different terminals used different sets of control characters and control codes to perform even basic tasks like moving the cursor around the screen. Out of the vi project grew the termcap terminal capabilities database. This described the abilities of each terminal and used a set of functions allowed a programmer to access the functions in a standard way.

The termcap system was eventually improved upon and became the curses package. This package offered the same basic functionality, but with some higher-level and more complex functions added to take advantage of the clever features being introduced to the newer terminals. The next development phase was carried out by the UNIX Systems Group (USG) which improved upon the curses package to produce terminfo. Like curses before it, terminfo provided the same basic interface to the terminal as termcap, albeit via a different set of functions. Also like curses, terminfo was intended to eliminate some of the shortcomings of the termcap system.

The ncurses package has been ported to the BeOS, and can be used as a direct replacement for curses. It is available from GeekGadgets, details of which can be found in Appendix A.

The result is that we now have two basic systems for using terminals. The termcap system is found largely on BSD-based UNIX variants. The terminfo package is found mainly on System V-based UNIX variants. Some UNIX systems, such as Solaris, SunOS and HP-UX, supply both termcap and terminfo. Most application software will have chosen a particular system, or if you're particularly lucky will have support built in for both—making them compatible with a number of systems.

The BeOS supports termcap in favor of terminfo. Below we'll take a close look at termcap, and a brief look at terminfo and how it differs from the termcap system.

termcap

The terminal capabilities database relies on the contents of a single data file which describes the functions and features of the terminals you want to use. The identifier used to configure your terminal is the environment variable TERM; this variable is checked when you first start a shell or other application and the terminal specified is checked for within the terminal capabilities database. The BeOS stores the termcap file in /boot/beos/etc/termcap, and the first entry looks something like this:

```
ansi|ANSI BeBox Terminal:\
    :al=\E[L:bs:cd=\E[J:ce=\E[K:cl=\E[2J\E[H:cm=\E[%i%d;%dH:co#80:\
    :dc=\E[P:dl=\E[M:do=\E[B:bt=\E[Z:ei=:ho=\E[H:ic=\E[@:im=:li#25:\
    :nd=\E[C:pt:so=\E[7m:se=\E[m:us=\E[4m:ue=\E[m:up=\E[A:\
    :k1=\E[M:k2=\E[N:k3=\E[O:k4=\E[P:k5=\E[Q:k6=\E[R:\
    :k7=\E[S:k8=\E[T:k9=\E[U:k0=\E[V:\
    :kb=^h:ku=\E[A:kd=\E[B:kl=\E[D:kr=\E[C:eo:sf=\E[S:sr=\E[T:\
    :mb=\E[5m:md=\E[1m:me=\E[m:\
    :GS=\E[12m:GE=\E[10m:GV=\63:GH=D:\
    :GC=E:GL=\64:GR=C:RT=^J:G1=?:G2=Z:G3=@:G4=Y:G5=;:G6=I:G7=H:G8=<:\
    :GU=A:GD=B:\
    :CW=\E[M:NU=\E[N:RF=\E[O:RC=\E[P:\
    :WL=\E[S:WR=\E[T:CL=\E[U:CR=\E[V:\
    :HM=\E[H:EN=\E[F:PU=\E[I:PD=\E[G:\
    :Gc=N:Gd=K:Gh=M:Gl=L:Gu=J:Gv=\072:
```

This entry defines the basic terminal used by the Terminal application under the BeOS. The file itself contains definitions of all the terminals supported by the BeOS. In this case, the file is derived from the GNU termcap package, which is probably as good a starting point as any for aiding the porting process, especially when porting GNU packages. Lets just have a quick look at a more familiar entry for a vt220 terminal:

```
# vt220:
# This vt220 description maps F5--F9 to the second block of function
keys
# at the top of the keyboard.  The "DO" key is used as F10 to avoid
conflict
# with the key marked (ESC) on the vt220.  See vt220d for an alternate
mapping.
# PF1--PF4 are used as F1--F4.
#
vt220|DEC VT220 in vt100 emulation mode:\
        :am:mi:xn:xo:\
        :co#80:li#24:vt#3:\
        :@7=\E[4~:ac=kkllmmjjnnwwqquuttvvxx:ae=\E(B:al=\E[L:\
        :as=\E(0:bl=^G:cd=\E[J:ce=\E[K:cl=\E[H\E[2J:\
        :cm=\E[%i%d;%dH:cr=^M:cs=\E[%i%d;%dr:dc=\E[P:dl=\E[M:\
        :do=\E[B:ei=\E[4l:ho=\E[H:if=/usr/lib/tabset/vt100:\
        :im=\E[4h:is=\E[1;24r\E[24;1H:k1=\EOP:k2=\EOQ:\
        :k3=\EOR:k4=\EOS:k5=\E[17~:k6=\E[18~:k7=\E[19~:\
        :k8=\E[20~:k9=\E[21~:k;=\E[29~:kD=\E[3~:kI=\E[2~:\
        :kN=\E[6~:kP=\E[5~:kb=^H:kd=\E[B:kh=\E[1~:kl=\E[D:\
        :kr=\E[C:ku=\E[A:le=^H:mb=\E[5m:md=\E[1m:me=\E[m:\
        :mr=\E[7m:nd=\E[C:\
        :r2=\E>\E[?3l\E[?4l\E[?5l\E[?7h\E[?8h:rc=\E8:\
```

```
        :rf=/usr/lib/tabset/vt100:\
        :..sa=\E[0%?%p6%t;1%;%?%p2%t;4%;%?%p4%t;5%;%?%p1%p3%|%t;7%;\
         m%?%p9%t\E(0%e\E(B%;:\
        :sc=\E7:se=\E[m:sf=20\ED:so=\E[7m:sr=14\EM:ta=^I:\
        :ue=\E[m:up=\E[A:us=\E[4m:ve=\E[?25h:vi=\E[?25l:
#
# vt220d:
# This vt220 description regards F6--F10 as the second block of
function keys
# at the top of the keyboard.  This mapping follows the description
given
# in the VT220 Programmer Reference Manual and agrees with the
labeling
# on some terminals that emulate the vt220.  There is no support for
an F5.
# See vt220 for an alternate mapping.
#
vt220d|DEC VT220 in vt100 mode with DEC function key labeling:\
        :F1=\E[23~:F2=\E[24~:F3=\E[25~:F4=\E[26~:F5=\E[28~:\
        :F6=\E[29~:F7=\E[31~:F8=\E[32~:F9=\E[33~:FA=\E[34~:\
        :k5@:k6=\E[17~:k7=\E[18~:k8=\E[19~:k9=\E[20~:\
        :k;=\E[21~:tc=vt220:
```

Lines starting with the hash sign (#) are comments and are ignored. The first line of the terminal description gives the terminal name, as it would be matched with the TERM environment variable. Any number of names, separated by the pipe symbol, can be specified. The last entry is the description of the terminal. Fields are then separated by colons, with each field specifying the various capabilities of the terminal. The format of these capabilities is *capability=definition*. The capability is specified by two letters, and the case is significant.

The definition specifies the capability by specifying a true or false value, a number, or a string. In the case of a string, the string specified is the character sequence to be matched, or the character sequence to be sent to the terminal to produce the specified capability.

Part of the problem with termcap is that there is no form or structure to the database. Because of this, there are a couple of pitfalls you should be aware of when using termcap:

First of all, a definition is freeform; it is up to the program using the termcap database to select the right type of value from the capabilities list. For example, the capability could specify a number, but it is up to the program to use the tgetnum function to return a number.

Also, there is no specification that defines what capabilities should be described for all terminals within the database. This means that the potential for using a capability on one terminal that is not available on another terminal is very high. More seriously, if a basic capability is not specified in the termcap database but is requested by the program you may get unexpected results.

Because there is no formal structure, the termcap database is infinitely expandable. As new terminals are developed, you can easily add features to the database specifying the different capabilities without being restricted by standards and required elements. Unfortunately, this unlimited expandability also leads to the problems already discussed—using unsupported features is fraught with difficulties.

A number of functions are supplied as part of overall termcap functionality to support the termcap database. The functions and variables are defined in the termcap.h header file as follows:

```
char *UP;
char *BC;
char PC;
short ospeed;

int tgetent (char *buffer, const char *termtype);
int tgetnum (const char *name);
int tgetflag (const char *name);
char *tgetstr (const char *name, char **area);
char *tgoto (const char *cstring, int hpos, int vpos);
void tputs (const char *string, int nlines, int (*outfun) (int));
```

To use the termcap functions you need to set up two variables. The first is the buffer which will contain the information from the termcap entry. The variable should be a character array of 1K in size. Call this buffer tbuf. You also need a buffer to contain the capability definition. Again, this needs to be a character array of a suitable size (1K should be sufficient); let's call this variable tcbuf. Finally, you also need a character pointer which points to the start of the capability definition variable, which we'll call tcptr.

Using these functions looks complicated, but ultimately it is really very easy and matches the flexible nature of the termcap database. The tgetent function searches the termcap database for the terminal specified in termtype. The result, if found, is returned in the character array pointed to by the buffer argument. This should be the buffer variable (tbuf) we've already discussed. This buffer is used by the rest of the termcap functions by referring to the buffer via an internal pointer. The tgetent function returns 1 on success, zero if the terminal you specified couldn't be found, or -1 if the termcap database couldn't be found.

The tgetnum function looks in the tbuf character array for the capability specified by name and, if it finds it, returns the number stored in that definition. A -1 is returned if the capability can't be found in the buffer. The tgetflag function returns a Boolean value for the capability specified by name. The function returns 1 if the capability is found or zero if it isn't found.

To obtain the string for a specified capability, you use the tgetstr function. The capability is specified by name and is copied into the buffer pointed to by the argument area. In our example this is tcptr. The tcptr pointer is then updated to point to the end of the capability buffer. A pointer to the start of the capability buffer is returned, or NULL if the capability specified is not found.

From this description, we can summarize the basic process of getting terminal information from the terminal database:

11.1. Initialize tbuf with the termcap entry for the specified terminal using tgetent.
12.2. Get specific capabilities from tbuf by using tgetstr to copy the individual entries in tcbuf.

Two final functions provide some additional specific functionality relevant to the termcap database:

- tgoto generates a positioning string which can be used in other programs to place the cursor at a specific location on the screen. The string returned contains the necessary array of characters to move the cursor to the position specified by hpos (column) and vpos (line) using the capability string contained in cstring. All tgoto does is format the string correctly; it doesn't actually output the string to the screen.
- tputs sends the string string to the terminal. The nlines argument specifies the number of lines that will be affected by the string, and outfun is the address of a function which can send individual characters to the terminal. You can usually specify this as putchar.

Whenever you use termcap you must specify the termcap library using the -l option to the compiler, for example:

```
$ mwcc tctest.c -ltermcap
```

to incorporate the termcap functions.

Most problems with termcap center around the terminal description rather than the functions that support them. Since, essentially, the functions perform no useful purpose without the database, getting a package which uses termcap to compile is not usually the problem.

Having said that, of course, I've already explained how the definitions themselves can be misleading, unhelpful, or just plain incomplete. It is the TERM variable that is usually used to specify which termcap entry to use, so ensure that your TERM variable is set to ansi if you are using the Terminal application, or to vt100 or vt220 if you're using Telnet to access the BeOS machine.

terminfo and termcap

At its most basic level, terminfo is identical to the termcap system. The terminfo system also specifies the capabilities of individual terminals in a terminal database. The major difference is that the terminal information has to be "compiled" into files for use by the terminfo functions. The terminal database is also split into individual files, one for each major group of terminals. Below is the terminfo definition for the vt220 terminal:

```
vt220|dec vt220 8 bit terminal,
   am, mc5i, mir, msgr, xenl, xon,
   cols#80, it#8, lines#24,
   acsc=``aaffggjjkkllmmnnooppqqrrssttuuvvwwxxyyzz{{||}}~~,
   bel=^G, blink=\E[5m, bold=\E[1m, clear=\E[H\E[J,
   cr=\r, csr=\E[%i%p1%d;%p2%dr, cub=\E[%p1%dD, cub1=\b,
   cud=\E[%p1%dB, cud1=\n, cuf=\E[%p1%dC, cuf1=\E[C,
   cup=\E[%i%p1%d;%p2%dH, cuu=\E[%p1%dA, cuu1=\E[A,
   dch=\E[%p1%dP, dch1=\E[P, dl=\E[%p1%dM, dl1=\E[M,
   ech=\E[%p1%dX, ed=\E[J, el=\E[K, el1=\E[1K,
   enacs=\E)0, flash=\E[?5h$<200>\E[?5l, home=\E[H,
   ht=\t, hts=\EH, ich=\E[%p1%d@, il=\E[%p1%dL, il1=\E[L,
   ind=\ED, is2=\E[?7h\E[>\E[?1h\E\sF\E[?4l, kbs=\b,
   kcub1=\E[D, kcud1=\E[B, kcuf1=\E[C, kcuu1=\E[A,
   kf1=\EOP, kf10=\E[21~, kf11=\E[23~, kf12=\E[24~,
   kf13=\E[25~, kf14=\E[26~, kf17=\E[31~, kf18=\E[32~,
   kf19=\E[33~, kf2=\EOQ, kf20=\E[34~, kf3=\EOR,
   kf4=\EOS, kf6=\E[17~, kf7=\E[18~, kf8=\E[19~,
   kf9=\E[20~, kfnd=\E[1~, khlp=\E[28~, kich1=\E[2~,
   knp=\E[6~, kpp=\E[5~, krdo=\E[29~, kslt=\E[4~,
   lf1=pf1, lf2=pf2, lf3=pf3, lf4=pf4, mc0=\E[i,
   mc4=\E[4i, mc5=\E[5i, nel=\EE, rc=\E8, rev=\E[7m,
   ri=\EM, rmacs=^O, rmam=\E[?7l, rmir=\E[4l,
   rmso=\E[27m, rmul=\E[24m, rs1=\E[?3l, sc=\E7,
   sgr=\E[0%?%p1%p6%|%t;1%;%?%p2%t;4%;%?%p1%p3%|%t;
   7%;%?%p4%t;5%;m%?%p9%t^N%e^O%;,
   sgr0=\E[0m, smacs=^N, smam=\E[?7h, smir=\E[4h,
   smso=\E[7m, smul=\E[4m, tbc=\E[3g,
```

You can see that the basic information and layout are the same as for termcap. The minor differences are:

- Individual definitions are now separated by commas, not colons.
- Capabilities can be up to five characters long.
- Definitions can extend to multiple lines without requiring the use of the backslash character.
- Individual definitions are terminated using a semicolon, which must be the last character of the definition.

The text file is compiled using a program called tic (terminal info compiler) which converts the definitions into a binary format for faster loading and searching. You can usually also find an untic program which converts a compiled file into an uncompiled (text) version.

The terminfo functions are also very similar to their termcap cousins:

```
#include <curses.h>
#include <term.h>
TERMINAL *cur_term;

int setupterm(char *term, int fd, int *error);
int setterm(char *term);
int set_curterm(TERMINAL *nterm);
int del_curterm(TERMINAL *oterm);
int restartterm(char *term, int fildes, int *erret);
char *tparm(char *str, long int p1 ... long int p9);
int tputs(char *str, int affcnt, int (*putc) (char));
int putp(char *str);
int vidputs(chtype attrs, int (*putc) (char));
int vidattr(chtype attrs);
int mvcur(int oldrow, int oldcol, int newrow, int newcol);
int tigetflag(char *capname);
```

```
int tigetnum(char *capname);
int tigetstr(char *capname);
```

The setupterm function is basically identical to the termcap tgetent function; it sets up the necessary information to be used by the remainder of the functions. The current terminal is stored in cur_term. The setterm function is equivalent to setupterm(term, 1, NULL), setting up the terminal for the standard output device.

The set_curterm function sets the current terminal to the specified terminal entry, resetting the value of cur_term. The del_curterm function deallocates the memory allocated for cur_term. To reset the terminal, you use the restartterm function, which restores the abilities of cur_term, but accounts for differences in the terminal type or the transmission speed of the terminal.

You can use the tparm function to return the string equivalents of up to nine capabilities (specified by p1 to p9). This is similar to tgoto but can be used on any number of parameters, not just setting the cursor position.

The terminfo tputs function is identical to the termcap tputs function, and putp places the specified string on stdout using putchar. The vidputs and vidattr functions set up attributes for video terminals. The mvcur function moves the cursor from the old position to the new position using the best method available on the current terminal.

Finally, the tigetflag, tigetnum, and tigetstr functions are identical to the tgetflag, tgetnum, and tgetstr functions under termcap.

With a little work, it shouldn't be hard to convert a terminfo-based system to termcap. Since terminfo is the more recent of the two systems it is highly likely that a package will support termcap in preference to terminfo.

Moving from /dev/pty to /dev/pt

Many UNIX programs will expect to use the /dev/pty and /dev/tty directories for pseudo-terminals. Most systems, including BSD based and Solaris, use a simple search sequence to find an available pair of terminal files. Others will use a function such as ptyopen to automatically search for and provide the pseudo terminals.

For the BeOS, the former method will have to be used, as no pseudo terminal functions are provided. In this instance, you can simply substitute /dev/pty with /dev/pt/ and /dev/tty with /dev/tt/.

Device Drivers

A *device driver* is a piece of software that drives a hardware device. The driver itself can be as simple as some functions that interface between standard programs and the device, like the terminal drivers discussed above, or as complicated as the function required by the OS to control the hardware device at its lowest level. A good example of this last type is the graphics display driver, which is a core component of the OS, allowing the user to interact with the computer via the normal monitor.

Beyond the "standard" abilities of a programmer, a device driver programmer, must be capable of working on what I class as a different (but not necessarily more difficult) plane of programming.

With a standard program, or even a standard function, you are working within some known limit, probably using nothing more than Standard C functions to provide the functionality you require. The scope of the program probably never includes any of the physical devices or facilities provided by the OS as anything more than an abstraction of the idea—using the functions supported by the OS to control the device. For example, a file can be opened by fopen; what goes on behind the scenes is not your concern.

With a device driver, you are going beyond this and actually writing code that affects the operation of a physical device. You could be writing the code that controls the disk drive that reads the information about the file off the disk. This level of programming requires of the programmer a slightly different view of the world. You need to be on the other side of the fence, no longer a user of core functionality, but a writer of core functionality.

Of course, all this makes the process seem arcane, and open to only a select few. In fact, the truth is that writing device drivers is relatively easy, provided you know how to program and how to control the device you are writing the driver for.

Writing a device driver for the BeOS is no different from writing one for a UNIX machine. The same principles apply to the process, even if the interface to the kernel is different.

The BeOS is supplied (in the /boot/optional directory) with some very good source examples of how to write device drivers for the BeOS. You should also be able to find a number of sample device drivers on the Be website. I have included below the code for the Zero device driver. This is a simple driver that sets up a device file that will always return zero when accessed. This should be compiled and then inserted into the /boot/home/config/add-ons/kernel/drivers. In addition to this file, a server, which is required to answer the requests, is built by the full project, available on the website.

```
/* ++++++++++
     zero.c
     A driver that zeroes things.
++++++++++ */

#include <SupportDefs.h>
#include <KernelExport.h>
#include <Errors.h>
#include <Drivers.h>
#include <string.h>
#include <fcntl.h>

/* -----
     foward declarations for hook functions
----- */

static status_t zero_open(const char *name, uint32 flags,
                             void **cookie);
static status_t zero_close(void *cookie);
static status_t zero_free(void *cookie);
static status_t zero_control(void *cookie, uint32 op,
                             void *data, size_t len);
static status_t zero_read(void *cookie, off_t pos,
                             void *data, size_t *len);
static status_t zero_write(void *cookie, off_t pos,
                             const void *data, size_t *len);

/* -----
     device_hooks structure - has function pointers to the
     various entry points for device operations
----- */

static device_hooks my_device_hooks = {
     &zero_open,
     &zero_close,
     &zero_free,
     &zero_control,
     &zero_read,
     &zero_write
};

/* -----
     list of device names to be returned by publish_devices()
----- */

static char          *device_name_list[] = {
     "my_zero",
     0
};


/* ----------
     publish_devices - return list of device names implemented by
     this driver.
----- */

const char     **
publish_devices(void)
{
     return device_name_list;
}

/* ----------
     find_device - return device hooks for a specific device name
----- */

device_hooks *
find_device (const char *name)
{
```

```
     if (!strcmp (name, device_name_list[0]))
          return &my_device_hooks;

     return NULL;
}


/* ----------
     zero_open - hook function for the open call.
----- */

static status_t
zero_open(const char *name, uint32 flags, void **cookie)
{
     if ((flags & O_RWMASK) != O_RDONLY)
          return B_NOT_ALLOWED;
     return B_OK;
}

/* ----------
     zero_close - hook function for the close call.
----- */

static status_t
zero_close(void *cookie)
{
     return B_OK;
}


/* ----------
     zero_free - hook function to free the cookie returned
     by the open hook.  SInce the open hook did not return
     a cookie, this is a no-op.
----- */

static status_t
zero_free(void *cookie)
{
     return B_OK;
}


/* ----------
     zero-control - hook function for the ioctl call.  No
     control calls are implemented for this device.
----- */

static status_t
zero_control(void *cookie, uint32 op, void *data, size_t len)
{
     return EINVAL;
}


/* ----------
     zero_read - hook function for the read call.  Zeros the
     passed buffer.  Note that the position parameter, pos, is
     ignored - there is no 'position' for this device.

     We use the memset() function exported from the kernel
     to zero the buffer.
----- */

static status_t
zero_read(void *cookie, off_t pos, void *data, size_t *len)
{
     memset (data, 0, *len);
     return B_OK;
```

```
}


/* ----------
     zero_write - hook function for the write call.  This will
     never be called, because we catch it in the open hook.
----- */

static status_t
zero_write(void *cookie, off_t pos, const void *data, size_t *len)
{
     return B_READ_ONLY_DEVICE;
}
```

The basis of all device drivers is the two global functions, publish_devices and find_device. The publish_devices function is used by the kernel to find out what devices are supported by this driver. The find_device function is used by the kernel to find out information about the device when it is being opened by a calling program. Additional functions are then used to initialize, un-initialize and access and control the device. Obviously, the standard set of functions which should be supported are open, close, read, write, and control.

There are some things that need to be considered however when developing device drivers under the BeOS. The most significant consideration is to take account of the multi-threaded operation of the kernel. To help get round this problem you should use re-entrant functions to prevent device driver operation for affecting or interrupting the operation of multiple threads, or even multiple processors. With a more complex driver, you will need to use semaphores to manage the interaction between the client calls and the interrupt handler which marks the read as completed.

With a memory mapped device such as PCI card you will also need to control the interaction between the virtual memory system and the physical memory. This is because the device driver will expect to copy information from a section of system memory to the device. If the memory address has been moved by the virtual memory system you will be copying invalid data to the device.

Since the process of developing device drivers is very closely linked to the core BeOS API, I have not gone in to too much detail in this book. Hopefully this should not cause too much of a problem as there are plenty of resources available on the internet. The chances of you having to write a device driver for use within the POSIX environment under the BeOS are rare, unless you intend to also move some form of hardware over to the new OS as well. Most hardware that you use in everyday situations is probably attached by the serial port of the machine, or one of the other ports, and is therefore easy to communicate with anyway.

There is no arcane magic to using devices, but there is some difficulty and confusion over how you use terminals. Other the years the methods for using and controlling terminals and, more recently, serial and modem connections has changed dramatically.

The differences between the termio and termios support are minimal. For compatibility the BeOS supports both styles of programming, and so porting should not be too much of a difficulty. What will be more difficult is finding a suitable terminal definition in the termcap file to enable you to control the functionality of the terminal you want to use.

Chapter 21 - Files and Directories

In this chapter we will look at directory and file access. The discussion covers five general topics: General Functions; Streams, UNIX File Descriptors, Utility Functions and Filesystems.

The first section deals with the general access functions, which allow you to set ownership and modes and rename files, among many other things. The second section deals with streams, and describes the interface to files using the Standard C stream function set. UNIX-style file descriptors are discussed in the third section. Then we'll take a look at some utility functions for accessing directories, getting information about files, and using file locking. In the last section we'll take a quick look at extracting information about filesystems.

General Functions

Handling files from a user's perspective—renaming, deleting, and navigating around directories—involves a collection of routines not vastly different from the commands used within a shell. All are simple and easy to use, and in the following sections we'll take a brief look at each one.

rename

The rename function is the same as the mv command. If you specify the name of a file or directory it will move it to the new location. The function prototype is specified in the unistd.h header as follows:

```
#include <unistd.h>
int rename(const char *old_name, const char *new_name);
```

The function returns zero on success, nonzero on failure. The error detail is returned in the global variable errno.

Below is the source for a program I use to quickly convert filenames with uppercase characters to be entirely lowercase. This is particularly when working with files from DOS disks. The program itself is easy to follow, taking in a filename, converting each character and then using the rename function to actually rename the file.

```
#include <stdio.h>
#include <string.h>
#include <stdlib.h>

int main(int argc, char **argv) {

  char oldname[255];
  char name[256];
  int n=0;
  int i;

  if (argc>0) {
    for(i=1;i<argc;i++) { /* for each file on the command line */

      oldname[0]=name[0]='\0'; /* Gets round a Sun bug */
      n=0;

      strcpy(oldname,argv[i]); /* Safer to duplicate the arg string
                                * than use it directly */

      do {
            name[n]=tolower(oldname[n]); /* convert each
                                          * character of the
                                          * filename to lowercase */
                 n++;
      } while(oldname[n]!=NULL); /* until we run out of names */
      name[n]='\0'; /* Terminate the string correctly */

       /* Inform the user */

      printf("Changing %s to %s\n",oldname,name);
      rename(oldname,name);     /* Actually rename the file */
    }
  }

}
```

link and symlink

The link function creates a new link to a file. The link created is a hard link (a duplicate name linked to the same physical file), not a symbolic link (which is just a pointer to a file). The function prototype is as follows:

```
#include <unistd.h>
int link(const char *name, const char *new_name);
int symlink(const char *from, const char *to);
```

The BeOS does not currently support hard links, so this function will always return -1 (failure). The error number is returned in errno. The BeOS does, however, support symbolic links which can be created using the symlink function, also prototyped in the unistd.h header file.

The operation of the symlink function is identical to the link function. The from argument specifies the name of the file to link to, and the to argument is the name of the new link. The file being linked does not need to exist for the link to be created — no checking is performed to make sure the file exists. The function returns zero on success, non-zero on failure with the result being placed in errno.

remove

A file can be deleted in two ways. Both are POSIX-specified functions, but they have their roots in two different trains of thought. The first method is to use remove, which deletes the specified file. The second method is to use the unlink function (see below). The function prototype for remove is:

```
#include <stdio.h>
int remove(const char *name);
```

The name argument to the remove function specifies the name of the file to delete. The function returns a zero on success or a nonzero on failure, and returns the error in errno.

unlink

The unlink function is the companion to the remove function. It removes the named link, which under the BeOS deletes the specified file (see sidebar):

```
#include <unistd.h>
int unlink(const char *name);
```

unlink returns zero on success, and nonzero on failure. The error number is returned in errno.

At first glance, the unlink and remove functions perform the same service. In fact, unlink is specially designed to remove symbolic and hard links. Because of this it is unable to delete a directory, but it can be used to remove a file. The remove function can be used for both files and directories. It is identical to the unlink function for files, and the rmdir function for directories.

Why link?

The terms “link” and “unlink” come from the way the original UNIX Seventh Edition file system was organized. The basics of the original file system still exist today, even in systems as advanced as Be’s Journalled File System (BFS). The BFS uses a journal to record all changes to files. The journal is written to a special part of the disk when a write operation is requested, but the modification to the actual file occurs in the background. This allows the write operation to occur when the drive is less busy, thereby freeing up contention for the disk and improving the overall speed. A journal file system also allows a machine to crash and then startup without requiring any special software to fix potential problems such as fsck under or Disk First Aid on the Mac. Instead, the OS can simply update the files when the machine has started up by just processing the outstanding journal entries.

Like other UNIX based file systems, at the lowest point within the file system all files are referred to by a number. This is different from most other OSs, where the file name is the unique identifier. The file number is called an "inode." Each inode specifies the logical location (block number) that the file uses on the disk and the space it uses, and this information is stored in the inode table. This is essentially no different from the desktop databases used by the Mac, or the file allocation tables (FAT) used by DOS and Windows.

At the higher, user, level a directory table links the directory names, as we see them, to the inode numbers, as the OS sees them—hence the term "link." Therefore, linking to an inode creates a file. Adding another link to the same inode generates two file names, both of which point to the same file. Unlinking an inode deletes the link, or if it is the last link it deletes the file and frees the physical space on the storage device. You can see the inode numbers of files by using the -i option to ls, although the information is of little use.

mkdir, chdir, and rmdir

These three functions are identical to the three commands mkdir, cd, and rmdir available in the shell:

```
#include <sys/types>
#include <sys/stat.h>
#include <unistd.h>
int mkdir(const char *path, mode_t mode);
int chdir(const char *path);
int rmdir(const char *path);
```

The mkdir function creates a new directory with the name specified in the path argument. The mode argument is specified using a bitset. See the section on open later in this chapter for more information. The rmdir command only removes "empty" directories, that is, directories with no files in them. The function does not recursively delete directories like using rm -r in the shell. The chdir function changes the current working directory to the directory specified in the path argument for the current process.

With all three functions, the number returned is zero on success and nonzero on failure with the error contained in errno.

getcwd/getwd

pwd, the built-in function available in the shell, runs the getcwd command to return the current working directory:

```
#include <unistd.h>
char *getcwd(char *buffer, size_t size);
```

The getcwd function copies the name of the current working directory into the string pointed to by buffer, up to the maximum size specified by size. The function should return a pointer to the string, or NULL if the function failed. The error is returned in errno.

The getwd function is the older version, but doesn't support a fixed size for the return string. Using a macro you can define the getwd function as:

```
#include getwd(x) getcwd(x, MAXPATHLEN)
```

Make sure if you use this macro that you include sys/param.h so that the MAXPATHLEN macro is available.

Streams

The term "streams" comes from the original functions for accessing files and the data contained in them from the C standard specified by Kernighan and Ritchie. They refer to a stream as "a source or destination of data that may be associated with a disk or other peripheral." In short, at least as far as we are concerned, it is a method of accessing, using, and storing data in files.

The basic variable type when using streams is the FILE structure. This describes the file you have open, its current status, and your position within the file.In this section we'll look at the FILE structure, how to access files, using the setvbuf and setbuf functions, how to create and use temporary files, how to position yourself within a file and how to handle errors.

The FILE Structure

The FILE structure stores information about a stream. The stdio.h header supplies the details of the necessary structures and function prototypes, and contains the following definition for the FILE structure:

```
struct FILE {
     __file_handle          handle;
     __file_modes          mode;
     __file_state          state;
     unsigned char          char_buffer;
     unsigned char          char_buffer_overflow;
     unsigned char          ungetc_buffer[__ungetc_buffer_size];
     fpos_t               position;
     unsigned char *      buffer;
     unsigned long          buffer_size;
     unsigned char *      buffer_ptr;
     unsigned long          buffer_len;
     unsigned long          buffer_alignment;
     unsigned long          saved_buffer_len;
     fpos_t               buffer_pos;
     __pos_proc          position_proc;
     __io_proc          read_proc;
     __io_proc          write_proc;
     __close_proc          close_proc;
     __idle_proc          idle_proc;
};
```

A lot of this information is only of any use to the system calls and system libraries that use the FILE structure. It is very rare to come across a program that wants to use the information stored in the structure, but if you are porting something like glibc you'll need to be able to identify at least some of the fields in the structure. For example, the file positioning functions will need to know the name of the field which describes the position (which, in this case, is position!).

The first three lines are more structures: handle, which defines the system information about the file; mode, which stores the different modes of the file (open, buffer mode, file kind, and so on); and state, which stores the current state of the file (for example, the end-of-file condition is stored in this structure). The current read/write position is stored in the position field. The FILE structure then goes on to specify the buffer information used by the internal functions. Finally, a number of function pointers are defined for describing how the stream is used.

fopen and fclose

You open and close files using fopen and fclose:

```
#include <stdio.h>
FILE *fopen(const char *name, const char *mode);
int fclose(FILE *file);
```

The fopen command opens the file specified by name. It returns the information about the file in the form of a FILE structure, or returns NULL on error. The error number is stored in errno.

The mode is a character string consisting of one or more of the following:

Mode	Description
r	Open file for reading.
w	Open file for writing.
a	Append to file (writes at end of file).
r+	Update, read, and write; all data is preserved.
w+	Truncate to zero length and open for update.
a+	For append update (read anywhere, writes at end of file).
b	Use for binary mode. This is not applicable in the POSIX specification, but is supported for portability reasons. Files are always opened in binary mode on newer systems so the specification is largely invalid.

If you specify append mode, all writes will occur at the end of a file, regardless of the current location returned by ftell. This is true even if you change the location using fseek. So, for example if you open a file with the mode "rwa" when you read in the file, reading will start from the first byte of information. If you start writing to the file, writes will occur at the end of the file.

The fclose function closes the specified file. It flushes any buffer information in the process. See the section on fflush, below, for more information.

An additional function, freopen, will close and then reopen a file. This is useful if you want to change the mode in which the file has been opened, something not otherwise achievable without manually closing and reopening it:

```
#include <stdio.h>
FILE *freopen(const char *filename, const char *mode, FILE *file);
```

The file is the current stream to be modified, filename is the path of the file to open, and mode is the mode to use when opening the new file. Although it is targeted for use when changing stream modes, it's possible to use it to open a different file on the same stream using a code fragment similar to the one below:

```
fp=freopen("newfile","r+",fp);
```

This helps to reduce program size, although it's hard to see how much of a benefit this would be when used with a small number of open files.

fdopen

The fdopen command is regularly used by portable packages. Using fdopen you can open a stream based on an existing, open, file descriptor:

```
#include <stdio.h>
FILE *fdopen(int fildes, const char *type);
```

fildes is the file descriptor, and type is one of the modes outlined above. On error, NULL is returned; otherwise the new FILE structure is returned.

fileno

The fileno function returns the file descriptor for a given file:

```
#include <stdio.h>
int fileno(FILE *fd);
```

fd must be a valid FILE. The function returns the file descriptor number on success or zero on error.

fflush

You can force a flush using the fflush command. Any pending data to be written to a file is written, and data to be read in from a file is lost:

```
#include <stdio.h>
int fflush(FILE *stream);
```

The function returns EOF (End of File) on error and zero on success. Any error is returned in the errno variable.

You can also specify NULL to the fflush command, which flushes the buffers of all the open streams which support buffers.

setbuf and setvbuf

The setbuf and setvbuf commands are used to set up the I/O buffering on individual streams:

```
#include <stdio.h>
int setvbuf(FILE *file, char *buff, int mode, size_t size);
int setbuf(FILE *file, char *buff);
```

The setvbuf command sets up the buffering for the stream file. buff should be a pointer to an area of memory that can be used as the buffer, the size being specified by size. The mode describes how the buffer should be used and is one of the following macros:

_IOFBF	Full buffering
_IOLBF	Line buffering
_IONBF	No buffering

If you specify NULL as the buffer, but a nonzero value for size, then setvbuf will allocate its own buffer of the size specified. If buff is NULL and size is zero, then buffering is switched off. In all cases, a zero is returned for success and nonzero for failure.

Using setvbuf is straightforward, but you need to be careful. It should be used after the stream has been opened, and before any data has been read from or written to the stream. The effects of modifying the buffer after reading to or writing from the stream aren't documented, but it's not difficult to hypothesize about what would happen. Modifying the contents of a buffer before it has been written, for example, would result in the wrong information being stored on disk, and quite probably some loss or even corruption of information.

The setbuf command is a simpler version of the setvbuf command and is roughly equivalent to:

```
if (buff ==NULL)
     return(setvbuf(file, NULL, _IONBF, 0));
else
     return(setvbuf(file, buff, _IOFBF, sizeof(buff));
```

Both functions are replacements for the BSD function setbuffer and setlinebuf commands:

```
#include <stdio.h>
```

```
void setbuffer(FILE *stream, char *abuf, size_t size);
void setlinebuf(FILE *stream);
```

The setbuffer command is equivalent to setvbuf command, although it automatically sets up full buffering. The setlinebuf command sets up a line-based buffer. Both are supported by the BeOS, but are not part of POSIX or Standard C.

The most common problem with all these functions is incorrectly specifying a buffer. If we look at the function open_file below, it sets buffering using a local variable.

Everything works, until the function returns to the calling function. The buffer has been lost, because the variable used to store the buffer, mybuf is longer in memory. The results of reading or writing a stream with a nonexistent buffer could be catastrophic. The code may actually start writing to areas of memory that it shouldn't do, including the program itself. Because the BeOS uses a protected memory space for the kernel, it is safe to assume that this would remain intact, but the contents of the calling program, or indeed any other program or data in use by the user is open to being overwritten by an overzealous buffering system.

```
FILE *open_file(char *file);
{
     FILE *fp;
     char mybuf[1024]; /* Local buffer */

     if ((fp=fopen(file,"r+"))==NULL)
          return(NULL);

     setvbuf(fp,mybuf,_IOFBF,1024);
     return(fp);
}
```

There are three possible solutions. Define the buffer as static, which will cause the block used by the variable to permanently remain in memory; use malloc to point to a general area of memory that won't get lost when the function exits; or use a global variable to store the buffer. Of all these, option two is preferred, and it has the added advantage of allowing you to specify large buffers without affecting stack size. The other two methods are prone to possible problems. Either memory area could be overwritten by another process, although it's unlikely. In addition, the latter case is considered to be bad programming and adds an unnecessary memory overhead to the entire program, not just when the buffer is being used.

Temporary Files

Creating and using temporary files always causes problems. Ignoring the portability issues for the moment, you still need to find a location to store the file. You could use /tmp under UNIX, but the file system has limited space on most systems and you don't want to cause a file system error. Once you've found a suitable directory, then you need to generate a random and unique name.

If we include the portability issues, then finding a suitable location that works across a number of platforms is difficult. Not all versions of UNIX allow users access to /tmp, although they should, and /var/tmp or /usr/tmp are equally difficult to get access to as they often preserved for OS or SuperUser access only.

To get around this problem, a number of functions were developed as part of the original C specification to provide a simple way of either supplying a pathname to a unique temporary file or opening a temporary file directly.

tmpnam returns the name of a temporary file that is both in a valid directory and not the name of an existing file:

```
#include <stdio.h>
char *tmpnam(char *s);
```

The name will be returned and copied into the string pointed to by s. If NULL is specified, then the function returns a pointer to a static string. Using this function, it's possible to quickly open and use a temporary file. However, because the function only returns the name, the file is not automatically deleted when you close it. You will need to use remove to delete the file.

Although tmpnam is roughly equivalent to the mktemp BSD command, it isn't possible to specify a template for the files name to the function.

The tmpfile function is an extension of the tmpnam function that automatically opens a temporary file returning a FILE structure:

```
#include <stdio.h>
FILE *tmpfile(void);
```

The file is opened with a mode of "wb+", and is automatically deleted when you close the file with fclose.

File Positioning

There are five basic commands for positioning a stream within a specific file. The three that most people are familiar with are

```
#include <stdio.h>
void rewind(FILE *file);
long ftell(FILE *file);
int fseek(FILE *file, long offset, int mode);
fpos_t _ftell(FILE * file);
```

int _fseek(FILE * file, fpos_t offset, int mode);The rewind function rewinds the specified file, and clears the end-of-file error (see "Error Handling," below). ftell returns a long representing the current position within the stream, and fseek searches to the position specified by offset using the reference point specified by mode. The values for mode are:

SEEK_SET	Move to the offset relative to the beginning of the file
SEEK_CUR	Move to the offset relative to the current location
SEEK_END	Move to the offset relative to the end of the file

For example, the call

```
fseek(fp, 0L, SEEK_SET);
```

would move to the start of the file, but

```
fseek(fp, 0L, SEEK_END);
```

would move to the end.

```
fseek(fp, -100L, SEEK_END);
```

would move to 100 bytes from the end of the file (note the negative offset value), and finally

```
fseek(fp, 100L, SEEK_CUR);
```

would move 100 bytes forward from the current position. In all cases, fseek returns nonzero on an error.

Using these three commands it is possible to move around a file very accurately, and because we use longs to record the location, we can store this information easily and portably for use later.

The versions of ftell and fseek that start with an underscore work with the fpos_t data type. This is defined as a long long and therefore allows us to specify very large (i.e. larger than LONG_MAX) offsets for large files using the familiar functions.

The less well-used functions for getting and setting the position within a stream are fgetpos and fsetpos. They work in much the same way, but the position is returned in a variable of type fpos_t as defined in Standard C. However, there is no standard variable type for fpos_t. In the original C specification it was a long; under BeOS it is a long long in preparation for support of very large files.

```
#include <stdio.h>
int fgetpos(FILE *stream, fpos_t *pos);
int fsetpos(FILE *stream, const fpos_t *pos);
```

fgetpos returns the current location into the variable pointed to by pos and returns zero on success or nonzero on failure. fsetpos sets the position to the value of the object pointed to by pos, returning zero on success or nonzero on failure. fsetpos always clears the end-of-file condition on the stream.

The disadvantage of fgetpos and fsetpos is that they can only be used in conjunction with one another. Unless you know the position of the start or the end of the file, you can't use fsetpos to set the location to either of them. However, for very large files, using fgetpos and fsetpos is a much faster and more effective way of moving about a stream.

Error Handling

Most errors that occur in using streams can be identified by a combination of the return value and the value of errno.

As a generalization, any return of NULL or EOF can be considered an error; any other value is a success. On an error, you need to decide how to handle the situation based on the error returned in errno.

Here is a common mistake that is made when using fgets:

```
FILE *fp;
char buf[256];
fp=fopen("myfile","r");
while (!feof(fp))
{
     fgets(buf,256,fp);
…
}
```

Run the program with a file that isn't a multiple of 256 bytes, and it will crash on the last block it reads from the file when you try to use it. The problem is simple enough: The programmer hasn't checked the result from fgets, and expecting the feof command in the while statement to identify the end of file just doesn't work.

Instead, what you need is:

```
FILE *fp;
char buf[256];
fp=fopen("myfile","r");
while (!feof(fp))
{
     if (fgets(buf,256,fp)==NULL)
          break;
     else
          …
}
```

The error here, highlights one of the basic misconceptions that people have when using streams. An end of file on a stream is not automatically identified even if you surround the program section in a catchall statement like the one I used above.

Once the end-of-file (EOF) condition has been set the stream cannot be used until you clear the condition. This is true even when you move the pointer using ftell or fsetpos—it doesn't reset the EOF condition. For rewind it's a different matter; rewind automatically clears the EOF condition as part of the return to the start of the file. The full list of error handling functions is:

```
#include <stdio.h>
int feof(FILE *file);
int ferror(FILE *file);
void clearerr(FILE *file);
```

The feof function, as you already know, returns nonzero if the specified stream has the EOF condition set. The ferror function returns a nonzero if the error condition (including EOF) is set on the specified stream. Using clearerr clears all error conditions for the specified stream.

Other regular errors you'll come across when opening and accessing files are problems with file permissions (EPERM), problems with access permissions to directories in the file's path (EACCES), no space left on device errors (ENOSPC), or trying to create a new file on a read-only file system (EROFS). Checking for these is easy; just compare the value of errno with one of the predefined error conditions. A full list was given in Chapter 18 when we looked at the use of strerror.

```
#include <errno.h>
extern int errno;
if ((errno==EPERM)||(errno==EACCES))
     printf("Panic!: %s\n",strerror(errno));
```

Unix File Descriptors

A UNIX file descriptor is another way of accessing and using the data in files. In practice, the UNIX-style file descriptors are the basis for most forms of communication. This is true not only for files, but also for networking (sockets use UNIX file descriptors) and for the basic access to streams, although generally you are not aware of this when you open a stream.

When you open a file descriptor you establish a link between the file or network connection and the file descriptor, which is an integer. There are three basic file descriptors available in all applications:

Number	Stream Equivalent	Description
0	stdin	Standard input, usually the keyboard or the redirected input from a file
1	stdout	Standard output, usually the monitor or terminal
2	stderr	Standard error, usually the monitor or terminal

All other file descriptors are given a number above these three basic file descriptors. Further calls to open new file descriptors increase the number until the maximum is reached (128, as specified by OPEN_MAX in limits.h).

As you close a file descriptor, it is marked as free, and the next time you open a new file descriptor it will be given the lowest available free number. For example, take the code below, which opens 128 file descriptors, and then closes the descriptors 45 and 67. The next two descriptors opened are 45 and 67, in that order.

```
#include <stdio.h>
#include <fcntl.h>

void main(void)
{
     int basefd;
```

```
    int lastfd;

    basefd=open("fdtest.c", O_RDONLY);

    while ((lastfd=dup(basefd))>0)
         printf("%d\n",lastfd);

    close(45);
    close(67);

    while ((lastfd=dup(basefd))>0)
         printf("%d\n",lastfd);
}
```

If you compile and run this program you should get output identical to this:

```
4
5
6
7
…
126
127
45
67
```

You can see how the descriptors are opened, then the two specific descriptors are closed (45 and 67). The next two opened have the two 'free' numbers.

open and creat

The two basic commands are open and creat, which open an existing file or create a new file. respectively:

```
#include <sys/types.h>
#include <sys/stat.h>
#include <fcntl.h>
int open(const char *pathnames, int oflags, ...);
int creat(const char *path, mode_t mode);
```

The oflags argument is a bitwise OR of some predefined macros. You must specify only one of the following:

- O_RDONLY Open for reading only
- O_WRONLY Open for writing only
- O_RDWR Open for reading and writing

You can then add any number of the following macros:

O_APPEND Set the mode to append; this is equal to the "+" symbol when used with streams. It sets the file pointer to the end of file prior to each write operation.

O_CREAT If the file doesn't exist, allow it to be created. This adds the mode argument as used by the creat function to the end of the function definition. See below for the mode specifications.

O_EXCL	This can only be used with O_CREAT and causes the open call to fail if the file already exists.
O_NOCTTY	Not currently supported, but it is defined. If set and the file is a terminal, the terminal will not be allocated as the calling processes controlling terminal. AU: So, what does it do normally? How the heck should I know! :))
O_NONBLOCK	Do not wait for the device or file to be ready or available.
O_TRUNC	This truncates the file to zero length before opening it.

The open command returns -1 if there is an error, with the error number being placed in errno. Otherwise, a valid, positive file descriptor is returned. For example, to open a file for reading and writing:

```
int outfile;
extern int errno;
if ((outfile=open("out.txt",O_RDWR))>0)
     printf("Cant open file: %s\n",strerror(errno));
```

The creat function creates a new file with the specified mode, which is a bitwise OR of one or more of the macros shown in table 21.1.

Table 21.1

Permissions for creat

Macro	Value	Description
S_ISUID	04000	Set user ID on execution
S_ISGID	02000	Set group ID on execution
S_ISVTX	01000	Save swapped text even after use (forces data or an application to be stored in physical memory, even after the application may have quit)
S_IRWXU	00700	Read, write, execute: owner
S_IRUSR	00400	Read permission: owner
S_IWUSR	00200	Write permission: owner
S_IXUSR	00100	Execute permission: owner
S_IRWXG	00070	Read, write, execute: group
S_IRGRP	00040	Read permission: group
S_IWGRP	00020	Write permission: group
S_IXGRP	00010	Execute permission: group
S_IRWXO	00007	Read, write, execute: other
S_IROTH	00004	Read permission: other
S_IWOTH	00002	Write permission: other
S_IXOTH	00001	Execute permission: other

For example, to create a new file with read permissions for all users:

```
creat("out.txt",S_IRUSR|S_IRGRP|S_IROTH);
```

The creat command can be written in terms of the open command, where

```
creat(path, mode);
```

is equivalent to

```
open(path, O_WRONLY|O_CREAT|O_TRUNC, mode);
```

close

The close function closes the file associated with a file descriptor and deallocates the file descriptor to be used by the system again:

```
#include <unistd.h>
int close(int fildes);
```

The function returns 0 on success and -1 on failure.

read and write

The read and write functions read to and write from the file associated with the specified file descriptor:

```
#include <unistd.h>
ssize_t read(int fd, void *buf, size_t count);
ssize_t write(int fd, const void *buf, size_t count);
```

The read function reads count bytes from the file associated with the file descriptor pointed to by fd into the buffer pointed to by buf. The function returns the number of bytes read, which will be less than count if the number of bytes left in the file is less than count or if the function was interrupted by a signal. A -1 is returned on error, with the error returned in errno.

The write function writes count bytes of buf to the file associated with fd. The function returns the number of bytes written. If the value returned is -1 or less than count there was an error which will be returned in errno.

If blocking is set on the file descriptor, write will wait until the data can be written. If blocking is not set, write will write as many bytes as possible and return the number of bytes written. If blocking is not set and no bytes could be written, write will return -1 with errno set to EAGAIN.

dup and dup2

It is often useful to duplicate a file descriptor. The dup function duplicates the specified file descriptor, but just returns the next available number that isn't being used. The dup2 command duplicates a file descriptor with the new number matching the number specified. The dup functions are often used when creating sub processes with fork so that open files can be shared among many different processes.:

```
#include <unistd.h>
int dup(int fd);
int dup2(int fd1, int fd2);
```

dup2 first closes fd2, and returns the duplicate file descriptor or -1 on error.

fpathconf

You can use fpathconf to get configuration limits for a specified file or directory. It works in much the same way as sysconf does on system limits:

```
#include <unistd.h>
long fpathconf(int fd, int name);
long pathconf(char *path, int name);
```

The corresponding pathconf returns the information for the file specified by path.

The predefined macros for returning the limits of the file specified by fd are:

Table 21.2

Macros for pathconf

Name	Description
_PC_CHOWN_RESTRICTED	Modifications by chown are not allowed on this file or directory.
_PC_MAX_CANON	Maximum length of a formatted line.
_PC_MAX_INPUT	Maximum length of an input line.
_PC_NAME_MAX	Maximum length of a file name for this directory
_PC_NO_TRUNC	Creating a file in the named directory will fail if the file name would be truncated, placing ENAMETOOLONG in errno.
_PC_PATH_MAX	Maximum length of a relative pathname from the specified directory.
_PC_PIPE_BUF	Size of the buffer used with the specified pipe.
_PC_VDISABLE	Special character processing can be disabled.
_PC_LINK_MAX	Maximum number of links to this file.

fcntl

Like its cousin ioctl, fcntl is a catchall function for all the facilities not supported by other functions. It's prototype and use is a little more complicated than your average function too.

```
#include <sys/types.h>
#include <fcntl.h>
#include <unistd.h>
int fcntl(int fd, int op, ...);
```

The descriptor on which to act is specified by fd, and op specifies the operation to be performed. Each operation is selected using a set of predefined macros:

F_DUPFD Duplicates the specified file descriptor, returning the lowest-numbered file descriptor not currently in use. This is equivalent to the dup function.

F_GETFD Returns the FD_CLOEXEC flag associated with fd. The FD_CLOEXEC flag forces calls to exec to close the file descriptors with the flag set. This is useful when you don't want certain file descriptors to be inherited by the program called by exec.

F_SETFD Sets the state of the FD_CLOEXEC flag based on the third argument. The correct way to set the flag is to check the flag first and then set it based on the result. This solves any problems if other flags are already set on the file descriptor that we may not want to upset. The *POSIX Programmers Guide* by Donald Lewine suggests the following code:

```
flags=fnctl(fd, F_GETFD);
flags |= FD_CLOEXEC;
fcntl(fd, FSETFD, flags);
```

F_GETFL Gets the current flags for the specified file descriptor. The flags returned match those supplied when the file was opened or created:

O_APPEND File is opened in append mode.

O_NONBLOCK File does not block when writing data.

O_RDONLY File is open in read only mode.

O_RDWR File is open in read/write mode.

O_WRONLY File is open in write only mode.

F_SETFL Sets the flags for the file descriptor. Only O_NONBLOCK and O_APPEND can be set in this way. You should use the same technique as outlined under F_SETFD above.

We will look at the last three, F_GETLK, F_SETLK, and F_SETLKW, when we look at file locking later in this chapter.

mmap

The mmap function maps the contents of a specified file descriptor into memory. This allows you to access the file directly without using read and write. The full range of functions supporting this is:

```
#include <sys/types.h>
#include <sys/mman.h>
caddr_t mmap(caddr_t, int len , int prot, int flags, int fd, off_t
offset);
void msync(caddr_t addr, int len);
```

```
void munmap(caddr_r addr, int len);
```

Memory mapped files using mmap are part of the POSIX standard, but are not part of the supported functions of the BeOS. Unfortunately, it is a function often used by database code, as it allows memory style access to files, making database code faster in operation.

It is impossible to simulate the function, and very difficult to provide a set of functions to support the notion, of memory-mapped files. Even glibc tends to skip over the functionality, although a version is a supplied with the package. The mmap functions major disadvantage, and the reason it's not often seen, is that it can be memory-hungry and is an incompatible model when used with devices instead of files.

lseek

lseek is the file descriptor version of the fseek command:

```
#include <unistd.h>
off_t lseek(int fd, off_t offset, int whence);
```

The offset argument specifies the position in bytes from the location specified by whence, which is set using one of the predefined macros:

SEEK_SET	Offset from beginning of file
SEEK_CUR	Offset from current position
SEEK_END	Add offset to end of file

It is identical to the fseek function in every respect except from the specification of the offset. The fseek function takes a long offset argument, allowing you to specify 4 terabytes (a terabyte is equal to 1024 gigabytes) of information. The lseek function uses the off_t type for the offset which is specified as a long long. This provides a maximum addressable size of 16384 exabytes (an exabyte is equal to over a million terabytes!). Neither limit is likely to present too much of a problem in the short term.

Utility Functions

Beyond the standard functions for controlling files, using streams and using file descriptors, there are some utility functions which can help to provide further useful operations. Accessing and using directory entries is something that DOS, Windows and MacOS users have to do all the time if you want support wildcard filenames in your programs. For the UNIX user, much of this funcationality is supported via the shell and not the via the programs which are used on top of it.

Once we have found our files, getting information about them, and protecting the files for being used by other applications is an important consideration. We will look at the functions, supported and otherwise, that support these operations in this next section.

Under the BeOS, we also have the added functionality of the attributed file system. We will take a greater look at file attributes and how to access and use them at the end of this section.

Directories

Accessing directories is like many functions of the modern UNIX-like OS. It looks complicated, but is in fact simplicity itself. Everything is controlled by just four functions, and using them couldn't be easier.

We'll look briefly at older implementations of the same functions later, but it's worth comparing the simplicity of these functions to the very much older method of accessing directory contents.

In the original Seventh Edition UNIX, every directory entry was 16 bytes long, and consisted of the 2-byte inode number and the 14-byte file name. The Berkeley Fast File System was the first alternative to this original file system format. As well as increasing the number of bits in an inode from 16 to 32, it also increased the length of a file name from 14 bytes to 255 bytes. The change led to the introduction of the direct structure, which itself evolved into the dirent structure now endorsed by the POSIX standard.

Even today, this is still considered a relatively recent invention, although not many UNIX variants are now supplied with 14-character file name limits.

dirent

A directory is defined by the DIR structure specified in dirent.h; also in this header file is dirent, the specification for a directory entry:

```
typedef struct {
     int     fd;
     struct     dirent     ent;
} DIR;

struct dirent {
     dev_t               d_dev;
     dev_t               d_pdev;
     ino_t               d_ino;
     ino_t               d_pino;
     unsigned short          d_reclen;
     char               d_name[1];
};
```

As far as we are concerned, the only useful piece of information in either structure is the d_name member of dirent. This is the name of the file within the directory.

opendir, readdir, and closedir

Accessing the directories is relatively simple. You first open a directory using opendir, which returns a DIR structure, and then this structure is passed to readdir, which returns a dirent structure containing the file name. Each subsequent call to readdir returns the next file within the directory. There is a problem with this method of accessing directory entries. If another application is creating and/or deleting files in the same directory, you may miss new files, or try to open a deleted file. This is because you are selecting individual directory entires, instead of getting an entire listing.

```
#include <dirent.h>
DIR          *opendir(const char *dirname);
struct dirent      *readdir(DIR *dirp);
int          closedir(DIR *dirp);
void          rewinddir(DIR *dirp);
```

NULL is returned by readdir when there are no more files to be read. Once you've finished reading the directory names, you can go back to the beginning using rewinddir or close the directory using closedir.

A simple version of ls can be produced in just a few lines:

```
#include <dirent.h>

void main(int argc, char **argv)
{
     DIR *dirp;
     struct dirent *direntp;

     if (argc<2)
          dirp=opendir(".");
     else
          dirp=opendir(argv[1]);
     while ((direntp=readdir(dirp)) != NULL)
     {
          printf("%s\n",direntp->d_name);
     }
     closedir(dirp);
}
```

Of course, all this does is output the list of files in the current or specified directory, and we haven't included any of the additional file information normally supplied by ls. Those of you who are expecting to see some form of pattern matching have to remember that it is not ls that generates the names of files based on wildcards, it's the shell which generates this information and passes it on to ls as command-line arguments. Getting the additional information is a little more difficult, but still uses some relatively basic functions.

Most programs now expect to use the POSIX-compatible dirent structures and functions. The functions themselves were taken almost without modification from the System V libraries. Even between System V and BSD, which eventually agreed on the use of dirent, there are differences in the structure contents. Going even further back, BSD used to specify direct, not dirent, although I doubt that you will find many packages using the older direct structures.

stat, fstat, and lstat

The stat group of functions provide you with information about the status of files:

```
#include <sys/stat.h>
int stat(const char *path, struct stat *buf);
int lstat(const char *path, struct stat *st);
int fstat(int fd, struct stat *buf);
```

stat returns the status of the file specified by path into the structure pointed to by buf. Each function returns a zero on success or nonzero on failure, with the error being recorded in errno. The stat structure is defined within the BeOS as follows:

```
struct stat {
    dev_t                st_dev;
    ino_t                st_ino;
    mode_t                st_mode;
    nlink_t                st_nlink;
    uid_t                st_uid;
    gid_t                st_gid;
    off_t                st_size;
    dev_t                st_rdev;
    size_t                st_blksize;
    time_t                st_atime;
    time_t                st_mtime;
    time_t                st_ctime;
};
```

The description of each member is as follows:

Table 21.3

Members of the stat structure.

Member	Description
st_dev	ID of the device containing the file
st_ino	Inode number
st_mode	File mode (permissions)
st_nlink	Number of hard links to this file
st_uid	User ID of file's owner
st_gid	Group ID of file's owner
st_size	File size (not the physical space it uses on the disk)
st_rdev	ID of device for character special or block special files (that is, the devices in /dev)
st_atime	Last access time (equal to st_mtime under the BeOS)
st_mtime	Last modification time
st_ctime	Last status change time

To extract the information about certain elements of the stat structure you will need to perform a logical AND against the file mode with the file modes we've already looked at such as ST_ISLINK.

The lstat command is identical to the stat command except when used on a file that may be a symbolic link. If you use stat on a symbolic link it will return the information about the file the link points to, but if you use lstat, it returns the information about the link. fstat is also identical to stat, but it returns the information about an open file descriptor.

Using fstat it's possible to expand our simple ls to include information about the file's size, modes, and times and the other information we are familiar with from the normal ls. I've modified our original ls example to also display the modification time. It's not the quickest, or cleanest, piece of code, but it does demonstrate how easy it is to re-create the functionality of ls:

```
#include <dirent.h>
#include <sys/stat.h>
#include <time.h>

void main(int argc, char **argv)
{
  DIR *dirp;
  struct dirent *direntp;
  struct stat mystat;
  char namebuf[255], filename[255];
  time_t *mtime;

     namebuf[0]='\0';
     filename[0]='\0';

     if (argc <2)
     {
       dirp=opendir(".");
       strcat(namebuf,"./");
     }
     else
     {
       dirp=opendir(argv[1]);
       strcat(namebuf,argv[1]);
     }
  while ((direntp=readdir(dirp)) != NULL )
    {
     strcpy(filename,namebuf);
     strcat(filename,direntp->d_name);
     stat(filename,&mystat);
     *mtime=mystat.st_mtime;
     printf("%-20s %s",filename,ctime(mtime));


    }
  closedir(dirp);
}
```

Obviously, there's lots more to the ls command than I've demonstrated here; even using the stat commands doesn't give us all the information we need. If you'd like to know how the ls command works, check out the fileutils package from GNU, which includes ls and a number of other shell tools you use regularly such as chmod and chown.

Locking Files

In a multiple-process or multiuser situation you need to be able to lock files to prevent the same file being written to simultaneously by more than one process or user. A number of such systems exist, but it's worth covering how locking works and what types of lock exist.

There are two basic ways in which you can implement some form of locking system. The first method is to use *lock files*, the traditional method of locking files between processes. First introduced in the Seventh Edition of UNIX, it was primarily used with the uucp package to prevent more than one dial-out connection from using the same modem. It operates very simply. For each file that you want to edit, a lock file is created, either in the same location with an LCK appended or prepended to the file name, or in a different directory location altogether.

An application which also wants to open the file first checks for the existence of the the lock file before attempting to open the real file. If the lock file exists, the program either exits with an error, or waits a set period of time before trying again. This method is still in use today and both public packages (such as emacs) and commercial packages (including Netscape Navigator) use lock files to prevent multiple accesses to the same file or multiple instances of a single application.

The second method for locking files is to use a collection of system functions which set and query the lock status of individual files. This requires a greater system overhead, as the OS has to keep track of the files that have locks on, but using the functions is quick and easy. They also provide the ability to lock sections of a file instead of the entire file.

Lock files have the advantage that, apart from the call to open the lock file, there is little overhead in the application and the operating system, which doesn't have to keep a 'mental' track of files with and without locks. However, the filesystem needs to be accessed to discover the status of the lock. Although this isn't a major problem, on a busy filesystem this may slow down access. Lock files also offer the best cross-platform portability; the ability to create new files and open them once created is supported on all platforms.

On the other hand, lock files are difficult to use effectively and not really very system friendly. They don't stop another process from opening the file, either, and so an application could simply ignore the lock file altogether. For each file you might have to open, you also need to open a lock file, and with lots of users opening lots of files this could get messy. Using a locking function which comes as part of the system is a much cleaner idea, and has slightly less effect on the the filesystem because it doesn't need to be interrogated to discover the lock status. The downside is that the OS must be capable of storing the lock status, and of responding to requests for the information. However, a locking system is not very portable; not all systems support all the locking functions, and some don't support any of them.

When using locks there are a number of terms you should be aware of. All relate to the type of lock you want to use on a file, and they can be almost hierarchically arranged. At the top level we have file and record locking. A *file lock* applies to the entire file. A *record lock* applies to a record within a single file. A record specifies a range of data (specified in bytes) within a single file and so record locking should really be referred to as *range locking*.

At the next level is the type of lock. Again these are split into two, and locks are either *advisory* (the lock is made, but not enforced) or *mandatory* (the lock is made and enforced). The enforcement method involves blocking the process when it tries to place a lock on a file with an existing advisory lock, or blocking read/write access if the lock on the file is mandatory.

At the last level you have the opportunity to either share locks on a file or make a lock exclusive. An *exclusive lock* can only be held by one process. A *shared lock* can be held by multiple processes, but does not allow exclusive locks to be placed on the file.

So, to recap, it is possible for a process to have an advisory shared lock on a file or a mandatory exclusive lock on a range of data within that file, or any combination thereof. Not all lock types are supported by all functions, however.

Lock files are easy to implement, so next we'll take a look at the three system functions commonly used to lock files under UNIX and see which of these are supported under the BeOS.

flock

The flock function provides an advisory lock on the specified file descriptor.

```
#include <sys/file.h>
int flock(int fd, int operation);
```

It supports both shared and exclusive locks on the specified file, but is not able to enforce the locks by setting an exclusive lock on the file. The operation is specified by one of the predefined macros:

LOCK_SH Shared lock

LOCK_EX Exclusive lock

LOCK_NB Don't block when locking

LOCK_UN Unlock

flock is not supported by the BeOS, and most would consider that it wasn't a great loss. However, it is used by most of the database libraries, such Berkeley DB and gdbm.

lockf

From System V comes lockf, a function which allows you to set exclusive locks on records (or ranges) within a file.

```
#include <unistd.h>
int lockf(int fd, int function, long size);
```

The locks can be mandatory or advisory. The function sets the lock from the current position (you have to use lseek to search to the start point) for size bytes. Like flock, function is a combination of a set of predefined macros:

F_ULOCK	Unlock the range specified
F_LOCK	Exclusive lock
F_TLOCK	Set lock, or return status if lock cannot be set
F_TEST	Test range for locks

Also like flock, lockf isn't currently supported by the BeOS.

Using fcntl

We looked earlier at the catchall function fcntl, but one of the features we didn't look at was file locking. fcntl is actually the best method of locking files or ranges. Although the BeOS allows the use of the fcntl command for file locking it will return -1 for all calls. File locking with fcntl is due to be supported in a future version. For reference, the full range of file-locking facilities within fcntl is as follows:

```
#include <fcntl.h>
int fcntl(int fd, int op, ...);

struct flock
{
     short l_type;
     short l_whence;
     off_t l_start;
     off_t l_len;
     pid_t l_pid;
};
```

You set the various locks by specifying the necessary operation to fcntl, with the third argument being the flock structure outlined above. Within this structure the l_type member specifies the type of lock:

F_RDLCK	Read (shared) lock
F_WRLCK	Write (exclusive) lock
F_UNLCK	Clear either lock

The range is specified using l_whence, which uses the lseek function macros. l_start is the offset from l_whence and l_len is the number of bytes in the range. Specifying a length of 0 (zero) causes the lock to be made across the entire file. Three fcntl operations control the use of locks: F_GETLK, F_SETLK, and F_SETLKW.

F_GETLK returns information about any locks on the range specified in the flock structure. For example, the code below checks the locks on the first 100 bytes of a file:

```
struct flock filelock;
filelock.l_type=F_RDLCK;
filelock.l_whence=SEEK_SET;
filelock.l_offset=0;
filelock.l_length=100;
status=fcntl(file,F_GETLK,&flock);
```

If any part of the range specified is already locked, the flock structure contains the information about the lock set and the range using the l_whence and l_offset members. The l_pid member specifies the process ID of the process owning the lock. If the lock can be set, l_type is set to F_UNLCK; the rest of the structure is not modified in any way.

F_SETLK attempts to set or release the lock using the information in the flock structure. It returns zero on success, or nonzero on failure with the error supplied in errno.

F_SETLKW sets the lock specified, as with F_SETLK, but waits until any existing lock has been removed before continuing.

readv and writev

The use of readv and writev isn't specified in either the Standard C or POSIX definitions, and in general you don't see them used. They are intended to perform a *scatter read* and a *gather write*. A scatter read takes a collection of memory blocks spread about the memory space and consolidate them into one block to be written to a file. A gather write is the opposite, taking a single block and placing it in a number of smaller blocks of memory. readv and writev aren't supported by the BeOS, but are a relatively popular set of functions, particularly in the networking applications. The function prototypes are as follows:

```
#include <unistd.h>
#include <sys/types.h>
#include <sys/uio.h>
int readv(int fd, struct iovec *vector, int count);
int writev(int fd, struct iovec *vector, int count);
```

The sys/uio.h header file contains the specification of the iovec structure:

```
struct iovec {
     caddr_t iov_base;
     int iov_len;
};
```

The two functions are quite easy to write yourself, but the extracts shown below are taken from glibc, the free C library supported by GNU, and modified to be BeOS compatible:

```
#include <stdlib.h>
#include <unistd.h>
#include <string.h>
#include <sys/uio.h>
#define min(a, b)     ((a) > (b) ? (b) : (a))


int readv(int fd, struct iovec *vector, int count)
{
     char *buffer;
     size_t bytes;
     int bytes_read;
     register size_t i;

     bytes = 0;
     for (i = 0; i < count; ++I)
          bytes += vector[i].iov_len;

     buffer = (char *) alloca(bytes);

     bytes_read = recv(fd, buffer, bytes);
     if (bytes_read <= 0)
          return -1;

     bytes = bytes_read;
     for (i = 0; i < count; ++i)
     {
          size_t copy = min(vector[i].iov_len, bytes);

          (void) memcpy(vector[i].iov_base, buffer, copy);

          buffer += copy;
          bytes -= copy;
          if (bytes == 0)
               break;
     }

     return bytes_read;
}

int writev(int fd, struct iovec *vector, int count);
{
     char *buffer;
     register char *bp;
     size_t bytes, to_copy;
     register size_t i;

     bytes = 0;
     for (i = 0; i < count; ++i)
          bytes += vector[i].iov_len;

     buffer = (char *) alloca(bytes);

     to_copy = bytes;
     bp = buffer;
     for (i = 0; i < count; ++i)
     {
          size_t copy = min(vector[i].iov_len, to_copy);

          (void) memcpy(bp, vector[i].iov_base, copy);

          bp += copy;
          to_copy -= copy;
          if (bytes == 0)
```

```
                break;
        }

        return send(fd, buffer, bytes);
}
```

File Attributes

The Be File System (BeFS) incorporates a new feature not seen in most file systems, even the more modern ones. This feature is file attributes. These are additional pieces of information that are stored with a file as part of the file system, without actually being part of the file itself. These attributes are user level pieces of information, and are in addition and separate to the standard pieces of file information such as modification date, and access permissions.

For example, a file containing an email message would consist, physically, only of the email message text. File attributes would store the information on the sender, recipient, and subject. Data is stored as a series of key/data pairs. For example, a mail message could have the following attributes:

```
To = "Martin Brown"
From = "Bob Fisher"
Subject = "Foo"
```

On a simpler level, file attributes could be used to store keywords about a file or access control lists, a more specific and superior level of file access control. The information is stored as part of the filesystem and is indexed. The information can be searched for and accessed without having to access the file itself, thereby bypassing the need to use file locking when storing and searching for simple pieces of information.

Each attribute is given a name, a data type and the data itself and is contained in a directory accessible in a similar way to the dirent directory structures. The data can be a string of any form, including information. The functions and definitions are defined in the be/kernel/fs_attr.h header file as follows:

```
typedef struct attr_info
{
     uint32 type;
     off_t size;
} attr_info;

ssize_t fs_read_attr(int fd, const char *attribute, uint32 type,
                        off_t pos, void *buf, size_t count);
ssize_t fs_write_attr(int fd, const char *attribute, uint32 type,
                        off_t pos, const void *buf, size_t count);

int fs_remove_attr(int fd, const char *attr);

DIR *fs_open_attr_dir(const char *path);
DIR *fs_fopen_attr_dir(int fd);
int fs_close_attr_dir(DIR *dirp);
struct dirent *fs_read_attr_dir(DIR *dirp);
void fs_rewind_attr_dir(DIR *dirp);
```

```
int fs_stat_attr(int fd, const char *name, struct attr_info *ai);
```

The fs_read_attr function reads the data from position pos of the attribute called attribute of the file specified by fd, returning the information in the variables pointed to by the remainder of the call. The fs_write_attr function performs the opposite, writing the attribute information into the attribute specified by attribute. Using the pos argument you can write information to selected sections of the attribute data. The write operation will add a new attribute if the name does not already exist, or update an existing attribute.

The fs_remove_attr command removes the specified attribute from the file entirely.

The fs_open_attr_dir and fs_fopen_attr_dir open the attributes for the file specified by path or fd respectively. Subsequent calls to fs_read_attr_dir return the attribute names in a dirent structure. To rewind to the start of the directory, use fs_rewind_attr_dir and to close the directory listing use fs_close_attr_dir.

Finally, the fs_stat_attr function call returns the type and size of a specified attribute.

Although the attribute system will not be compatible with any other filesystems, you may need to use the above functions to retain compatibility between the POSIX and BeOS applications. For example, some compression programs are using the above interface to allow Be files, including their attributes, to be stored correctly within a standard compressed file.

File Systems

A number of applications need to know the available space on a particular file system. For example, Usenet news servers such as inn need to know how much space is left before accepting new news messages so they don't cause the OS to crash because of a lack of space.

There are two basic functions which return information about a specific file system into a predefined structure: statfs and statvfs. The BeOS does not support either function at the moment, and extracting information about the file systems requires that you delve into C++ and the BeOS Storage Kit to gain information about the mounted volumes.

I won't go into the details here of how to use the Storage Kit and interface it to your POSIX-style application. The one thing I will say, however, is that it does not provide you with the same level of information as either structure and function combinations available with statfs and statvfs.

select and poll

The select and poll functions allow you to use non-blocking I/O in your programs. This reduces the waiting time, and enables you to accept input from devices that may not be constantly supplying information. For example, you would use select to wait for some information on a serial line.

The current implementation of the BeOS does not support the select function, except on network sockets, and doesn't support the poll command at all. We'll take a look at the select support in the next chapter.

File handling forms the core of many applications, and it is essential that you know how to use the functions that are available and fill the gaps left by those functions which don't exist.

The BeOS is not completely POSIX-compliant, nor is it very UNIX-compatible when it comes to file support, and particularly some core functionality. The select and poll commands especially make it difficult to port some of the more complex titles.

Chapter 22. - Networking

Networking was once an expensive extension to the operation of computers. Not only were the cabling difficult to fit and the cards expensive to purchase, the software available for communicating between machines was unreliable and difficult to use and didn't really provide much benefit over the traditional "sneaker-net" method of carrying disks around the office.

Today the network forms an integral part of the whole computing experience.

The implementation of network services relies on some very simple principles and some basic protocols that define how machines communicate. Depending on how and what you want to communicate, there may be further layers above these protocols that make the implementation easier. The main protocol in modern use is the *socket*, a simple channel which allows two-way communication between machines, using Standard C functions for transferring information. Sockets are the basic level of communication on the Internet.

In this chapter, we will take a look at the BeOS implementation of sockets and the utility functions used to support them. Sockets are not specified in the POSIX specifications, the closest standard is the original BSD implementation.

Sockets

Sockets were first introduced in the Berkeley 4.2 version of UNIX in 1981. They have since become a major component of the network protocols that govern the Internet and a large part of the general network communication methods. They are now supplied as part of all variants of UNIX, and numerous implementations are available on the PC, the Mac, and other platforms. They provide a basic level of communication service over a network, while also being flexible enough to adapt to almost any task.

Sockets can be adapted both for internal communication on the same machine and for communication across a network to other machines. Sockets are opened and created in much the same way as UNIX-style file descriptors —under UNIX you can even use the same functions to read and write to a socket. Under the BeOS, you use a different set of functions to send and receive data over a socket. They are not specific to BeOS (they are also defined under UNIX), but they are specifically for use on sockets. The difference is that the socket you open is to a remote machine, not to a local file.

A socket is essentially just a logical point of reference for connecting to a machine. The socket itself is no more than a number, but the information bound to the socket describes its format and unique address. One of the features that make sockets so versatile is that multiple sockets (to multiple machines) can be open at any one time. This is because each socket has its own unique port number. Therefore a network connection using sockets needs to be described by the address of the machine you are connecting to and the port number on that machine. Specific ports are used for specific protocols; for example, port 25 is used by the Internet SMTP (Simple Mail Transfer Protocol) for exchanging e-mail between machines.

When a socket is opened it is of one of three types: stream, datagram, or raw. A *stream socket* provides a stable bidirectional flow of information. A stream socket is not reliant on records for transferring information and so data can be streamed in large chunks over the network to the recipient machine. It is possible to use a pair of stream sockets to emulate the functionality of pipes (see Chapter 18).

Datagram sockets are less reliable. They work on the premise of individual packets of information being exchanged, although the packets received may be duplicated or in a different order than that in which they were sent. Although at first glance this seems to provide a less stable communication medium, it is a useful implementation when you're working with packet-switched networks such as Ethernet. This is because the packet structure for the underlying and application level protocols is very similar.

Raw sockets provide low-level access to the underlying communication protocols used on the specific network. Although they are not of interest to the general user, they can sometimes be used to gain access to the more obscure features of an existing protocol. Raw sockets are not currently supported under the BeOS networking implementation.

In the following sections we'll walk through the sequence of events required to set up sockets by looking at the individual functions that make up the process. As a rough outline, the basic steps are:

13.1. Create the socket
14.2. Bind to the socket you have just created
15.3. Connect to a remote machine or listen for a connection, using the socket as the channel through which to connect or listen.
16.4. Read or write the information from or to the socket
17.5. Close the socket

socket and closesocket

As we have already seen, a socket is simply a reference number, in much the same way that a UNIX file descriptor is just a number. The information attached to the socket number specifies the address format to use for interpreting names, the socket type (as outlined above), and the protocol to use. The socket function returns a valid socket number (descriptor) and the closesocket function closes the specified descriptor. They are both prototyped in socket.h as follows:

```
#include <socket.h>
int socket(int family, int type, int proto);
int closesocket(int fd);
```

The family argument to socket specifies the address family to use when interpreting addresses. The standard specification for this is via the macro AF_INET, which specifies the Internet address type. The type argument relates to the socket type, as outlined above. You specify the type using the macros SOCK_STREAM (for stream sockets) and SOCK_DGRAM (for datagram sockets). Raw sockets are not currently supported by the BeOS.

The last argument, proto, specifies the protocol to use for the socket. You can use the default protocol, zero, if you don't want to specify a particular protocol; otherwise, a number of protocol options exist. The BeOS supports three types: UDP (User Datagram Protocol), TCP (Transmission Control Protocol), and ICMP (Internet Control Message Protocol).

The UDP protocol (specified by the macro IPPROTO_UDP) is only applicable to datagram sockets. It helps to support the packet-based transmission of information over the socket. It uses the same address format as TCP and is a protocol layer on top of the basic Internet Protocol (IP) networking layer. Once opened, UDP sockets use the send and recv family of functions to transfer information.

The TCP protocol (IPPROTO_TCP) is what most people recognize as the Internet protocol (the Internet is specified as using TCP/IP). Like UDP, TCP sits on top of the basic IP protocol layer and supports streaming sockets. Because the TCP-based sockets are streaming, under UNIX we could use the standard read and write C functions to transfer information over the network. However, the BeOS defines sockets and file descriptors differently, so you will need to use the send and recv functions to transfer data. This is similar to Windows NT.

The ICMP protocol (IPPROTO_ICMP) is an error and control message protocol used to check the status of a remote machine or the networks used to reach the remote machine. It is ICMP packets that support the ping application that reports if a machine is accepting connections or not. ICMP is also used by tracing programs to discover the route packets take to reach a particular destination. Like TCP and UDP, ICMP is a protocol placed directly on top of the IP layer. Because the ICMP protocol is not generally used to send or receive information, there are no standard functions used with this protocol.

The returned value from the socket function is a valid file descriptor (non-negative number), or -1 if an error occurs. The error type is returned in the external variable errno. For example, to create a valid stream-based socket we would use the following piece of code:

```
int fd;
fd = socket(AF_INET, SOCK_STREAM, IPPROTO_TCP);
```

To close an open socket we can use the close function under UNIX. This function is not supported under the BeOS, we need to use the socket-specific closesocket function. The only argument to this function is the open socket. Because the closesocket function is specific to the BeOS and you should use the close function to remain compatible with other operating systems. Use the code similar to the following to use the correct function:

```
#ifdef BEOS
closesocket(s);
#else
close(s);
#endif
```

Windows has similar 'broken' sockets. You may find in some packages that the Windows definitions already exist, so finding and using the Windows workarounds should speed up the porting process.

bind

Creating a socket using the socket function does not open a connection, it merely reserves a file descriptor for use when the connection is created. The bind function binds a socket's file descriptor to a particular name. The name you bind to is the name of the remote machine and is specified in the name argument, which is a variable-length structure. To compensate for this you also have to specify the length as the last argument to the function:

```
#include <socket.h>
int bind(int s, struct sockaddr *name, int namelen);
```

The function returns -1 on error with the error number specified in errno; otherwise, the function returns a zero.

When specifying a network address for use with the function you actually use the sockaddr_in structure to specify the address and port required. The structure is defined in the socket header file as:

```
struct sockaddr_in {
     unsigned short sin_family;
     unsigned short sin_port;
     struct in_addr sin_addr;
     char sin_zero[4];
};
```

The enclosed in_addr structure specifies the Internet address and is defined as:

```
struct in_addr {
     unsigned int s_addr;
};
```

The address should be the Internet address (in dot notation) of the machine you are connecting to. See "Utility Functions," later in this chapter, for details on converting Internet addresses. If you are creating a socket to be used by a server of some kind, you can specify that the socket should bind to any valid Internet address by specifying the macro INADDR_ANY.

The sin_port member of the sockaddr_in structure is the port number of the service you are connecting to. The code below is extracted from a socket-based server application. It creates a new stream socket called listen_socket and binds the socket to port 12000 on any address:

```
struct sockaddr_in sin, conn_addr;
int listen_socket;

if ((listen_socket=socket(AF_INET,SOCK_STREAM, 0)) < 0)
{
     writelog("Unable to get socket");
     exit(1);
}

sin.sin_family=AF_INET;
sin.sin_addr.s_addr=INADDR_ANY;
sin.sin_port=htons(12000);

if (bind(listen_socket, &sin, sizeof(sin)) < 0)
{
     writelog("Unable to bind on socket");
     exit(1);
}
```

Although the bind function sets up a socket with a specific address and port, it doesn't actually open a connection. It is intended for use by servers to set up the socket file descriptor to accept connections. To open a socket connection to a remote machine we need to use the connect function.

connect

The connect function connects to the remote machine and opens the socket. The basic format is identical to that of the bind function:

```
#include <socket.h>
int connect(int fd, const struct sockaddr *addr, int size);
```

As in the previous example, the addr structure specifies the remote machine address and port number. The function returns 0 on success or -1 on failure with the error recorded in errno.

listen

When setting up the server end of a socket connection you need to configure the application so that it listens for requests on the specified port. The listen function sets the socket to be listened to:

```
#include <socket.h>
int listen(int fd, int backlog);
```

The fd argument is the file descriptor as returned by socket. The backlog argument specifies the number of pending connections to queue before refusing any further client connections. There is currently no limit for the backlog variable, but there are constraints to consider in setting limits. Too low, and you may ignore connections that are pending. Setting the value too high may cause too much server latency when accepting requests. A figure of 8 or 16 is probably the most useful, although you may wish to increase this on a busy machine to 32 or perhaps even 64.

A value of zero is returned on success, and -1 on failure. Once a connection request has been received, it must be accepted by the accept function.

accept

The accept function accepts a connection on the specific socket and file descriptor.

```
#include <socket.h>
int accept(int fd, struct sockaddr *addr, int *size);
```

The fd argument is a socket that has been created by socket and bound using bind, and is being listened to by listen. The function extracts the first pending connection on the queue and creates a new file descriptor socket based on the setup of the fd socket. The function returns the new file descriptor, or -1 on error.

The new file descriptor that is returned is used to communicate with the client machine that connected to this socket; the socket is not used to accept further connections on the original socket port.

As an extension of our previous example, the full code for a server listening on port 12000 would look something like this:

```
#include <socket.h>
#include <stdio.h>

int news, on=1;

int main( void )
{
  struct sockaddr_in sin, conn_addr;
  int addrlen;
  int listen_socket;

  if ((listen_socket=socket(AF_INET,SOCK_STREAM, 0)) < 0)
    {
     writelog("Unable to get socket");
```

```
      exit(1);
    }

  sin.sin_family=AF_INET;
  sin.sin_addr.s_addr=INADDR_ANY;
  sin.sin_port=htons(12000);

if (bind(listen_socket, (struct sockaddr *)&sin, sizeof(sin)) < 0)
    {
      writelog("Unable to bind on socket");
      exit(1);
    }

  if (listen(listen_socket, 5) == -1)
    {
      writelog("Unable to listen on socket");
      exit(1);
    }


  switch(fork())
    {
    case -1: writelog("Unable to fork");
      exit(1);

    case  0: close(stdin);close(stderr);

      for(;;)
        {

          addrlen=sizeof(struct sockaddr_in);

news=accept(listen_socket,(struct sockaddr *)&conn_addr,&addrlen);

          if (news == -1) exit (1);
          switch(fork())
            {

            case -1: exit(1);

            case  0: recv_mesg();
              exit(0);

        default: close(news);
            }
        }

    default: exit(0);
    }
}
```

The code creates the socket, which listens for new connections on port 12000. When a connection request is received a new process is forked with the specific purpose of responding to the request of the client. However, before you use this code, be aware that this *doesn't* work under BeOS.

The reason we use the fork function is that the file descriptors are duplicated, and we can therefore pick up the pending connections on the listening socket. As we've already seen though, the BeOS does not treat a network socket and a file descriptor in the same way. This means that when the process forks, the BeOS does not inherit the socket, and is therefore unable to attach itself to the incoming connection. This makes porting networking code using sockets very difficult.

Under UNIX, this system also allows us to accept multiple connections on the specified port without upsetting the core listening process. Most server applications, such as FTP servers or Web servers, use this method to handle multiple connections simultaneously. They can also fine-tune the number of requests they accept by controlling the maximum number of forked processes, and by controlling the backlog argument to the listen function.

getsockname and getpeername

The getsockname and getpeername functions return information about the local socket and remote socket, respectively.

```
#include <socket.h>
int getsockname(int fd, struct sockaddr *addr, int *size);
int getpeername(int fd, struct sockaddr *addr, int *size);
```

The getsockname function returns the name information for the socket specified by fd, returning the information in the structure pointed to by addr with the size returned in the integer pointed to by size. Zero is returned if the call succeeds, or -1 if it fails.

To find out the name of the machine connected to a specific socket you use the getpeername function. This returns the name information of the connected machine in the same structure as getsockname. The same values of zero for success and -1 for failure apply.

Once the information has been returned in the sockaddr structures you can use the gethostbyaddr function to obtain the host's name.

setsockopt

You can manipulate the options on a specific socket using the setsockopt function. The setsockopt function is defined within the socket.h header file as follows:

```
#include <socket.h>
int setsockopt(int sd, int prot, int opt, const void *data,
unsigned datasize);
```

The getsockopt function, which returns the options for the specified socket, is not supported by the current version of the BeOS. If a package expects to find this function, comment out the code and make sure that during the debugging process you test the effects of removing this section of code.

The sd argument specifies the socket descriptor to set the options on. The prot argument specifies the level at which the option should be set. To set the option at the socket level, specify the macro SOL_SOCKET. To set at a different level, you need to specify the protocol number. Levels other than socket level are not currently supported by the BeOS.

The opt argument is used to specify the option you want to set. The BeOS supports three options, as listed in Table 22.1. Other options not supported by the BeOS are shown in Table 22.2.

Table 22.1

Valid BeOS Options to getsockopt opt

Option	Action
SO_DEBUG	Toggle recording of debugging information
SO_REUSEADDR	Toggle address reuse
SO_NONBLOCK	Toggle non-blocking I/O

Table 22.2

Other Options to getsockopt opt

Option	Action
SO_KEEPALIVE	Toggle keeping connections alive
SO_DONTROUTE	Toggle routing bypass
SO_LINGER	Linger on close if data is present
SO_BROADCAST	Toggle permission to transmit broadcast messages
SO_OOBINLINE	Toggle reception of out-of-band data in band
SO_SNDBUF	Set buffer size for output
SO_RCVBUF	Set buffer size for input

The last two arguments in Table 22.2 are used to supply additional information to the option, depending on the option selected. The function returns zero on success and -1 on failure.

The main use for the setsockopt function is to set non-blocking I/O. We'll take a closer look at using sockets and non-blocking I/O later in this chapter.

send and recv

You can use a number of different functions to send data to and from a socket. The functions you use depend on the data you are sending and the socket type you have opened. Under UNIX if the socket is of type SOCK_STREAM, then you can use the read and write function calls just as you would use them on standard UNIX file descriptors.

However, under the BeOS the sockets are not created in the same way as UNIX file descriptors. Instead of read and write we need to use specially designed functions send and sendto for writing information to the socket, and recv and recvfrom for reading data from the socket. These functions are supported by other OS for using sockets, but, because the BeOS does not support them you may have to change the code to use these functions in place of the UNIX file descriptor versions. This is troublesome and time consuming, although once completed the code should still be cross platform compatible. If a socket is of type SOCK_DGRAM then you can only use the sendto and recvfrom functions.

All four functions are defined in socket.h as follows:

```
#include <socket.h>
ssize_t recvfrom(int fd, void *buf, size_t size, int flags,
                         struct sockaddr *from, int *fromlen);
ssize_t sendto(int fd, const void *buf, size_t size, int flags,
                   const struct sockaddr *to, int tolen);
ssize_t send(int fd, const void *buf, size_t size, int flags);
ssize_t recv(int fd, void *buf, size_t size, int flags);
```

The send function writes a block of data specified by the argument buf and of length size to the socket specified by the argument fd. The final argument is used to specify the options for sending the data. The BeOS only supports the macro MSG_OOB, which sends out-of-band data on sockets that support this option (see setsockopt, above). Otherwise the flags argument can be set to zero.For example, to send a string of information over the socket rem_socket you would use the following code fragment:

```
strcpy(buf,"Hellow World");
send(rem_socket, (void *)buf, sizeof(buf), 0);
```

The recv function is the equivalent function but reads information from the specified socket instead of writing it. The information received is stored in the variable pointed to by the buf argument.

Out-of-Band Data

The stream socket supports the notion of out-of-band data. *Out-of-band data* is an independent transmission channel separate from the main transmission channels used by the sockets for transferring information. The socket implementation specifies that the out-of-band functions should support the reliable delivery of at least one out-of-band message at any one time. The message must contain at least one byte of data.

Usually, out-of-band data is used to control the flow of information between machines without affecting the flow of information on the main transmission channel.

The recvfrom and sendto functions are identical to the recv and send functions but are designed to be used with datagram sockets. The only difference is that you must also specify the datagram address information in the sockaddr structure format specified by the from and to arguments. You also need to specify the size of the structure you are supplying to the function in the fromlen or tolen arguments, respectively. In all cases, the functions return the number of bytes read from or written to the socket, or -1 if an error occurred. The error is returned in the global variable errno.

The recvmsg and sendmsg functions, which are used to transfer fixed-format messages over a socket, are not currently supported by the BeOS.

Utility Functions

Different functions expect, and return, Internet addresses in different formats. Most people are familiar with net addresses as a collection of numbers or a collection of strings, for example, 127.0.0.1 or www.be.com. While we understand and can interpret these numbers easily, computers are naturally more specific about the format an address is in.

The number format x.x.x.x is known as the Internet-standard "." notation. Each number is represented by a single byte containing a value between 0 and 255. An Internet address is unique to an individual machine or network interface inside a machine, and with 256x256x256x256 numbers we can specify just under 4.3 billion Internet addresses. Because an address is made up of four individual bytes, it can be represented by a single four-byte variable. The type used for this is an unsigned long, which as we already know from Chapter 18 is four bytes long.

The inet_addr function converts a standard "." notation address into an unsigned long:

```
#include <sys/types.h>
#include <sys/socket.h>
#include <netdb.h>
unsigned long inet_addr(char *cp);
```

If you need to convert an unsigned long back to an Internet address, you can use the inet_ntoa function. This works in reverse, but the information passed to the function must be enclosed in an in_addr structure. This is, in fact, just a structure containing an unsigned long, and on the BeOS it is supplied in the socket.h header file as follows:

```
struct in_addr {
     unsigned int s_addr;
};
char *inet_ntoa(struct in_addr in);
```

Note. Under the BeOS int and long are of identical size.

Some packages, particularly the older ones or those targeted at SunOS users, define a much more complicated format for the in_addr structure:

```
struct in_addr {
     union {
          struct { u_char s_b1, s_b2, s_b3, s_b4; } S_un_b;
```

```
          struct { u_short s_w1, s_w2; } S_un_w;
          u_long S_addr;
     } S_un;
#define s_addr  S_un.S_addr
#define s_host  S_un.S_un_b.s_b2
#define s_net   S_un.S_un_b.s_b1
#define s_imp   S_un.S_un_w.s_w2
#define s_impno S_un.S_un_b.s_b4
#define s_lh    S_un.S_un_b.s_b3
};
```

Most packages should use (and should continue to use) only the s_addr member of the structure (specified here using a macro).

gethostbyname

The gethostbyname function obtains the Internet address attached to a specific hostname. The information is returned in a hostent structure:

```
#include <net/netdb.h>
struct hostent {
     char *h_name;
     char **h_aliases;
     int h_addrtype;
     int h_length;
     char **h_addr_list;
};
struct hostent gethostbyname(char *name);
```

Queries are sent to the Internet name service. The queries are first checked against the domain-name service records (using the default domain name) or against the hosts file if a name server isn't specified. Under UNIX this file was /etc/hosts (the BeOS file is located at /boot/beos/etc/hosts and will be found via a symlink between /etc and /boot/beos/etc). A NULL is returned if no matching host can be found in any of the databases. The members of the structure are shown in Table 22.3.

Table 22.3

The Members of the hostent Structure

Member	Meaning
h_name	The full host name, including domain if applicable
h_aliases	A NULL-terminated array of alternative names for the specified host
h_addrtype	The address type, currently AF_INET
h_length	The address length, in bytes
h_addr_list	A list of valid network addresses for this host

The example source code below takes the first argument to the application and looks for a matching host. Providing it can find a matching host, it then returns all the known addresses and names of the host back to the user.

```
#include <stdio.h>
#include <stdlib.h>
```

```
#include <sys/types.h>
#include <sys/socket.h>
#include <netdb.h>

int main (int argc, char **argv)
{
     int i;
     struct hostent *mine;

     if ((mine=gethostbyname(argv[1]))!=NULL)
          /* providing we find it... */
     {

          printf("Offical Name: %s\n",mine.h_name); /* Real name */

          for(i=0;mine.h_aliases[i]!='\0';i++) /* Print aliases */
               printf("Known alias: %s\n",mine.h_aliases[i]);

          for(i=0;mine.h_addr_list[i]!='\0';i++) /* Known addresses */
               printf("Known address: %u.%u.%u.%u\n",
               (unsigned char)mine.h_addr_list[i][0],
               (unsigned char)mine.h_addr_list[i][1],
               (unsigned char)mine.h_addr_list[i][2],
               (unsigned char)mine.h_addr_list[i][3]);
          return(0);
     }
     else
     {
          printf("Host not found\n”);
          return(1);
     }

}
```

gethostbyaddr

The gethostbyaddr function is the opposite of the gethostbyname function; it looks up an Internet address (for example, 193.122.10.110) and returns the host name and other information in the hostent structure:

```
#include <net/netdb.h>
struct hostent gethostbyaddr(char *addr, int len, int type);
```

The addr must be a pointer to a valid Internet address. In the example below I used the inet_addr() function to convert the string into a unsigned long variable type, which is then passed to the gethostbyaddr function as a character pointer.

```
#include <stdio.h>
#include <stdlib.h>
#include <sys/types.h>
#include <sys/socket.h>
#include <netdb.h>

int main (int argc, char **argv)
{
  int i;
  struct hostent *mine;
  unsigned long addr;

  addr = inet_addr(argv[1]);

  mine=gethostbyaddr((char *)&addr,sizeof(argv[1]),AF_INET);
```

```
  if (mine)
  {
     printf("Offical Name: %s\n",mine.h_name);

    for(i=0;mine.h_aliases[i]!='\0';i++)
      printf("Known alias: %s\n",mine.h_aliases[i]);

    for(i=0;mine.h_addr_list[i]!='\0';i++)
                 printf("Known address: %u.%u.%u.%u\n",
                 (unsigned char)mine.h_addr_list[i][0],
                 (unsigned char)mine.h_addr_list[i][1],
                 (unsigned char)mine.h_addr_list[i][2],
                 (unsigned char)mine.h_addr_list[i][3]);

    return(0);
  }
  else
  {
  printf("Host not found\n");
  return(1);
  }
}
```

Aside from the use of gethostbyaddr this program is identical to the previous example and it demonstrates how simple it is to obtain information about Internet addresses and machines.

getservbyname

The getservbyname function returns information about a specified service. A service is a port name and number combination as used by sockets. For example, SMTP, which transfers e-mail between different machines on the Internet, uses port 25.

```
#include <sys/types.h>
#include <sys/socket.h>
#include <netdb.h>
struct servent *getservbyname(const char *name, const char *proto);
```

The name argument specifies the required name, and the proto argument specifies the protocol. This second argument will be ignored if the user specifies NULL. Information is returned in a servent structure, which is defined in netdb.h as

```
struct servent {
     char *s_name;
     char **s_aliases;
     int s_port;
     char *s_proto;
};
```

A NULL is returned if the specified service name cannot be found. The members of the structure are listed in Table 22.4.

Table 22.4

Members of the servent Structure

Member **Meaning**

s_name	The official name of the service (for example, FTP)
s_aliases	A zero-terminated array of alternative names for the service
s_port	The port number of the service
s_proto	The name of the protocol to use when contacting the service

Like the previous examples, the source code below shows information about a specified port name:

```
#include <stdio.h>
#include <stdlib.h>
#include <sys/types.h>
#include <sys/socket.h>
#include <netdb.h>

int main (int argc, char **argv)
{
     int i;
     struct servent mine;

     mine=*getservbyname(argv[1],"tcp");

     if (mine)
     {
       printf("Offical Name: %s\n",mine.s_name);
       printf("Official Port: %ld\n",mine.s_port);

       for(i=0;mine.s_aliases[i]!='\0';i++)
            printf("Known alias: %s\n",mine.s_aliases[i]);

       return(0);
     }
     else
     {
        printf("Service not found\n");
        return(1);
     }

}
```

Note: The BeOS doesn't currently support /etc/services and will only recognize "ftp", "tcp" and "telnet", "tcp".

Using select

By default, all data transfers are blocking. That is, a call to read on a socket when no data is available or a write to a socket that isn't ready to accept data will cause execution of the process to sleep until some data is received. Blocking I/O is restrictive in situations where you want process execution to continue whether any data is available or not. You can get around this problem by using non-blocking I/O.

With non-blocking I/O, the call to the read or write function allows the remainder of the process to continue executing without waiting for the data or for the receiving end of the socket to accept the information. However, one problem with non-blocking I/O is that while execution continues, you don't automatically know when the request to read or write has completed. More significantly, if you are waiting for many requests to complete you may want to know that one of them has finished, but not necessarily which one.

To get around this problem, a number of different systems exist to notify you that a request has been completed. The solution under the original BSD was to use the select function, while under SVR4 the solution was to use the poll function. The BeOS supports select but not poll. The select function returns the status information of currently pending requests and can optionally block execution until a request completes.

The select function and the related structures and datatypes are defined as follows:

```
#include <socket.h>
#include <sys/time.h>
#define FDSETSIZE 256
#define NFDBITS 32

typedef struct fd_set {
        unsigned mask[FDSETSIZE / NFDBITS];
} fd_set;

struct timeval {
        long tv_sec;
        long tv_usec;
};

int select(int nbits,
           struct fd_set *rbits,
           struct fd_set *wbits,
           struct fd_set *ebits,
           struct timeval *timeout);
```

The fd_set structures are used to specify the file descriptors in use. The variable is a bitset, one bit per possible file descriptor. The size of the overall bitset is governed by the number of file descriptors you want to use, which is itself specified by the FDSETSIZE macro. The FDSETSIZE macro is set by default to 256. The macro is only defined (within socket.h) if you haven't already specified a different value. Since the figure of 256 open file descriptors is not a particularly large number (especially if you are creating some form of network server), you can specify a different figure *before* you include the socket.h header. For example, to set the bitmask to handle 512 file descriptors you would use this code fragment:

```
#define FDSETSIZE 512
#include <socket.h>
```

The rbits, wbits, and ebits arguments are the bitsets of the selected file descriptors. Since setting up these bitmask variables is complex, a number of macros are supplied to make the process easier:

```
#define FD_ZERO(setp) /* clear all bits in setp */
#define FD_SET(fd, setp) /* set bit fd in setp */
#define FD_CLR(fd, setp) /* clear bit fd in setp */
#define FD_ISSET(fd, setp) /* return value of bit fd in setp */
```

The select function checks the files specified in rbits for read completion, wbits for write completion, and ebits for exception conditions. You can set these arguments to NULL if you are not interested in the event. The action of select is dependent on the setting of the timeout argument:

- If timeout is NULL, select blocks until a completion occurs on one of the files specified by the bitsets.
- If the value of timeout is zero (both timeout->tv_sec and timeout->tv_usec are set to zero), then select checks the completion status and returns immediately.
- Otherwise, if timeout is nonzero, select waits for the specified time until a completion occurs.

The nbits argument specifies the highest number of file descriptors to check for completion. Since select checks all file descriptors for their status before checking them against the bitsets, we can save ourselves a significant amount of time by telling it the highest possible number to check.

The select function returns -1 on error conditions, placing the actual error detail in the errno global variable. Otherwise, assuming there are no errors, select returns the number of ready descriptors.

The usual way of using select is to start a number of I/O transfers and then wait for something to happen. A good example here is an Internet Web server, where the server will start and open the necessary sockets waiting for a request and some incoming data. When some data is received on one of the sockets, the correct function is called to read the data and act upon it. Therefore, a typical loop would contain something along the lines of the code fragment below:

```
if (select(nofds, &reads, &writes, NULL, NULL) >0)
/* were only interested in reads and writes,
 * and the current status */
{
     int checkfd;
     for (checkfd=3; checkfd<nofds; checkfd++)
/* Check all descriptors after stdin, stdout
 * and stderr */
     {
          if (FD_ISSET(checkfd, reads))
          /* descriptor has read completion */
               process_incoming(checkfd); /* so read the data */
          if (FD_ISSET(checkfd, writes))
          /* descriptor has write completion */
               prepare_outgoing(checkfd); /* so prepare the info */
     }
}
```

Although at first the operation of select looks complicated, using the function and implementing the results is relatively easy.

Remote Procedure Calls (RPCs)

When communicating between machines it is sometimes useful to call a function on a remote machine. Although many systems now do this using sockets to make a call to a remote machine, the tried and trusted method is to use remote procedure calls (RPC).

At the time of this writing, the BeOS doesn't support RPCs. If you plan on porting a package that uses RPCs you will have to make a choice: Either reimplement the communication method or port the RPC package. The RPC system relies on three units: the header files, the libraries (which support the data conversion functions and communication functions), and the rpcgen program itself, which converts the RPC specification into the required source code. Implementations of RPC are available in the Linux, FreeBSD, and NetBSD packages.

A *remote procedure call* is just like any other call to a function, except that the call is made to a function implemented on a remote machine, and the returned information (if any) is copied back over the network to the machine which called the function.

From the programmer's point of view this presents two problems: The first is data interpretation and the second is implementing a function call that is network-aware. The first problem, data interpretation, is related to the ways in which different machines handle different pieces of information. For example, we already know that some machines store strings with the first character of the string in the lowest byte (big-endian) while others store strings with the first character in the highest byte (little-endian). If we didn't take account of this, a little-endian machine communicating using RPCs to a big-endian machine would produce garbage.

In order to get around this, the RPC implementation includes a special set of functions which convert different datatypes, including strings and C structures, into a format for transferring over the network. The new data format is called External Data Representation (XDR) and has to be implemented differently on each machine. In my example, the data on a little-endian machine would be converted to XDR and be converted from XDR to big-endian when it reached the other machine. This conversion is handled semi-automatically by the build process.

A special program called rpcgen uses a special input file to specify XDR versions of structures, and also to define the functions that will be used during the functional implementation. Thus the programmer needs only to know how to use rpcgen to produce RPC function calls. This solves our second problem (implementing a function call that is network-aware), because the function itself can be written as a local function; it is the rpcgen program which handles the interface between the function that has been written and the network, producing a networkable version suitable for use as a remote procedure call.

RPCs are used extensively under UNIX to implement a number of different network functions. In particular, the monitor functions, such as rusers (which returns the number of users), rwho (which returns the list of users), and rstat (which provides status information) all use RPCs as their transport mechanism.

RPCs provide a simple way of getting specific information from one machine to another. The ability to call a function on a remote machine allows you to very easily transfer information between two machines. In particular, the ability to call a function and have Standard C structure returned allows very complicated data to be exchanged between machines.

But the remote procedure call does have its limitations. Although it is quite possible to transfer large quantities of information between computers using RPCs, they were not really designed for anything more than small pieces of information. With the advancement of the Internet, technology has shifted to use the streaming abilities of sockets. Both FTP and HTTP use the sockets method described above to transfer information. Sockets are easy to implement and work much better as a mass transfer mechanism than RPC. However, many software packages still use the RPC system. Many commercial and public-domain packages use the RPC system for passing semaphore information to other machines.

Networking has become an important part of modern computing life. The principles of networking are easy to understand, and with sockets the implementation is almost as easy as opening and closing file descriptors to read and write local files.

The difference is how the descriptor is created and how the information about the descriptor is defined. Beyond this setup, we also need to obtain information about the host we are talking to, and in all cases we need to convert the familiar Internet names that we are all used to into the structures and datatypes required by the networking functions.

Chapter 23 - Summary

As we seen throughout this book porting is complex, but largely procedural process. Like this book, the process can be conveniently split into three parts:

- Knowledge of the platform you are porting to
- Knowledge of the functions and libraries supported by the target platform
- Knowledge of the tools, techniques and processes used to write application software

Knowing about the platform you are porting to is critical. You need to identify the abilities of the platform, what tools are available that could make your life easier, and the layout of the new operating system for when you configure the application. On the BeOS, it is largely UNIX, or more correctly Posix in nature, and that makes porting most application software easier. Many packages have already been ported to UNIX/Posix platforms and so the layout is very familiar and many of the tools available will be familiar to you

The most important things to remember on the BeOS are that the layout, whilst similar, is very different to most UNIX variants, especially when it comes to the installation directories. It is also worth taking the time to find the tools, especially editors, that you are used to using. Although the BeOS comes with most of the desired tools, some, such as your favorite editor will need to be sourced from the various archives.

The second part of the porting process is the most complex, and the most time consuming. The process follows a simple sequence:

Configure the application for the platform

Modify header files and source code

Build the application

You then repeat the three steps above until you have completed the configuration changes, and in some cases code changes, to build the final application. Then you test the application, hopefully against a predefined and supplied set of test values. If anything doesn't work, you repeat the steps again until the application does work.

Finally, once you have a working and tested application, you run the installation program. You may need to make more changes to the installation process until the application installers and works correctly. The final stage is probably the easiest, you need to package up the application and provide it on to other people.

It is possible, with some thought, to relate the process of porting an application to moving a house. If the application is the contents of the house and the operating system is the house itself, then moving the contents involves some simple actions, such as placing your furniture in the rooms, which is analogous to running a simple configuration script.

There are also some more complicated actions, such as putting your books and kitchenware into different cupboards, which is analogous to making changes to the source code or build process for the operating system. Then there are the additional pieces of work which require attention, like building new shelves to put your books on. This is similar to writing completely new sections of missing code and functionality in the operating system to fit the application.

The BeOS is a well built operating system with many good foundations. These include the kernel and server structure for the operating system itself, the graphical user interface, and the Posix compatible libraries with the UNIX style interface which opens up the operating system to a wide range of software, from GUI to UNIX tools.

However, like all operating systems it has it's own tricks and traps, and despite the plans for compatibility there are still things that likely to cause problems during the porting process.

The shell is bash, not a standard shell even in the UNIX community, although bash itself is based on the Korn shell and Bourne shell. At the time of writing, bash is still missing some features in the BeOS version compared to most other versions of the shell. This will cause you some problems, especially during the configuration process, but as I've shown in this book there are ways around most of the problems.

Beyond these difficulties, the next problem you encounter will be the differences in the supported functions and tools compared to other UNIX based operating systems. Hopefully, the first and third parts of this book should help to answer most the queries and questions that come up during the porting process.

Finally, if you haven't attempted a port before, the second part of this book should have showed you the sequences and steps involved in the process of porting from start to finish.

As I stated at the start of this book, there is no clear cut way to port an application to a new platform. Nor is it easy for me to give you an idea on how quick, or slow, the porting process will be. It should be obvious by now that it could easily take weeks, or even months to complete a port successfully.

Above all, I hope this book will be helpful in the processes of porting to the BeOS, and I expect to see profusion of ports suddenly appearing on the websites!

Appendix A - Resources

Your first point of reference for information about programming on the Be, and for sources to start porting to the new operating system, is the Internet. It contains the largest repository of applications and source code in general. Furthermore, the Be community lives exclusively on the Internet, using combinations of Web sites, mailing lists, and newsgroups to swap information and ideas.

All the information about the BeOS and the packages that have already been ported will also be reported on the Internet, and there are a number of key sites which retain this information.

In addition to the sources listed here, I have also included a number of useful utilities and applications that will help you to make the best use of your BeOS machine either by providing BeOS tools, or by providing Windows, Mac, or UNIX tools which will plug the missing gaps in BeOS functionality.

FTP

There are quite literally thousands of FTP sites around the world that store a range of applications and source code. Usually the best location for getting the latest piece of source is one of the SunSITE FTP Servers. These are sites that are supported by Sun with equipment and storage space. They are home to a variety of mirrored sites and Sun's own archives. One of the most popular mirrored sites is the GNU FTP server, which contains all the source for all the GNU software that is available.

You will also find a range of other software sources in the UNIX directories on these machines, and they are a good repository of compatibility and utility software to use with your other machines when developing on the BeOS.

Below in table A.1 is a full list of the SunSITES around the world, and also some other, select sites that I use regularly for locating sources.

Table A.1

FTP Sites for C source code

Title	Internet Address	Location
Digitals Gatekeeper	gatekeeper.dec.com	Digital Corporate Research, Digital Equipment Corporation, Palo Alto, California, USA
GNU/FSF	prep.ai.mit.edu	Massachusetts Institute of Technology, Cambridge, Masschusetts, USA
SunSITE AskERIC	ericir.sunsite.syr.edu	Syracuse University, Syracuse, USA
SunSITE Australia	sunsite.anu.edu.au	Australian National University, Canberra, Australia
SunSITE Austria	sunsite.univie.ac.at	University of Vienna, Austria
SunSITE Brazil	sunsite.unicamp.br	Insitute of Computing, University of Campinas, São Paulo, Brazil
SunSITE Canada	sunsite.queensu.ca	Queen's University, Kingston, Ontario, Canada
SunSITE Central Europe	sunsite.informatik.rwth-aachen.de	RWTH-AAchen, Germany
SunSITE Chile	sunsite.dcc.uchile.cl	Universidad de Chile, Santiago, Chile
SunSITE Colombia	sunsite.univalle.edu.co	Universidad del Vvalle, Cali, Colombia
SunSITE Croatia	sunsite.hr	University of Zagreb, Croatia
SunSITE Czech Republic	sunsite.mff.cuni.cz	Charles University, Prague, Czech Republic
SunSITE Denmark	sunsite.auc.dk	Aalborg University, Aalborg, Denmark
SunSITE Digital Library	sunsite.berkeley.edu	University of California, Berkeley, California, USA

SunSITE Egypt	sunsite.scu.eun.eg	Supreme Council of Universities, Cairo, Egypt
SunSITE Estonia	sunsite.ee	Estonian Educational & Rresearch Network, Tartu, Estonia
SunSITE France	sunsite.cnam.fr	Conservatoire National des Arts-et-Metiers, Paris, France
SunSITE Greece	sunsite.csi.forth.gr	ICS FORTH, Iraklion, Grete, Greece
SunSITE Hong Kong	sunsite.ust.hk	University of Science and Tech., Hong Kong
SunSITE Hungary	sunsite.math.klte.hu	Lajos Kossuth University, Debrecen, Hungary
SunSITE Indonesia	sunsite.ui.ac.id	University of Indonesia, Jakarta, Indonesia
SunSITE Italy	sunsite.dsi.unimi.it	University of Milan, Milan, Italy
SunSITE Japan	sunsite.sut.ac.jp	Science University, Tokyo, Japan
SunSITE Korea	sunsite.snu.ac.kr	Seoul National University, Seoul, Korea
SunSITE Latvia	sunsite.lanet.lv	University of Latvia, Riga, Latvia
SunSITE Lithuania	sunsite.ktu.lt	Kaunas University of Technology, Kaunus, Lithuania
SunSITE Malaysia	sunsite.upm.edu.my	Universiti Putra Malaysia, Serdang, Selangor, Malaysia
SunSITE Mexico	sunsite.unam.mx	Universidad Nacional Autonoma de Mexico, Mexico
SunSITE New Zealand	www.sunsite.net.nz	University of Waikato, Hamilton , New Zealand
SunSITE Nordic	sunsite.kth.se	Kungliga Tekniska Høgskolan, Stockholm, Sweden
SunSITE Northern Europe	sunsite.doc.ic.ac.uk	Imperial College, London, London, UK
SunSITE Norway	sunsite.uio.no	University of Oslo, Norway

SunSITE People′'s Republic of China	sunsite.net.edu.cn	Tsinghua University, Beijing, China
SunSITE Poland	sunsite.icm.edu.pl	Warsaw University, Warsaw, Poland
SunSITE Russia	sunsite.cs.msu.su	Moscow State University, Moscow, Russia
SunSITE Russia	sunsite.nstu.nsk.su	Novosibirsk State Technical University, Novosibirsk, Russia
SunSITE Singapore	sunsite.nus.sg	National University of Singapore, Singapore
SunSITE Slovakia	sunsite.uakom.sk	UAKOM, Matej Bel University, Banska Bystrica, Slovakia
SunSITE Slovenia	sunsite.fri.uni-lj.si	Uuniversity of Ljubljana, Ljubljana, Slovenia
SunSITE South Africa	sunsite.wits.ac.za	University of the Witwatersrand, Johannesburg, South Africa
SunSITE Spain	sunsite.rediris.es	Consejo Superior de Investigaciones Cientificas, RedIRIS, Madrid, Spain
SunSITE Stockholm	sunsite.sipri.se	International Peace Research Institutde, Stockholm, Stockholm, Sweden
SunSITE Switzerland	sunsite.cnlab-switch.ch	cnlab & SWITCH, - Rapperswil and Zurich, Switzerland
SunSITE Taiwan	sunsite.ccu.edu.tw	National Chung Cheng University, Taiwan
SunSITE Thailand	sunsite.au.ac.th	Assumption University, Bangkok, Thailand
SunSITE Uniandes	sunsite.uniandes.edu.co	Universidad de los Andes, Bogota, Colombia
SunSITE USA	sunsite.unc.edu	University of North Carolina, Chapel Hill, North Carolina, USA
SunSITE UTK	sunsite.utk.edu	University of Tennessee, Knoxville, USA
Walnut Creek CD-ROM	ftp.cdrom.com	Walnut Creek CD-ROM, Concord, California, USA

Warwick University	ftp.warwick.ac.uk	Warwick University, CoventryWarwick, UK
Washington University Archives	wuarchive.wustl.edu	Washington University, St Louis, Missouri, USA

If you can't find a specific package, then the best thing is to use one of the Archie sites (all of the SunSITEs listed above have some form of searching mechanism). Archie enables you to search for a specific string within a product across hundreds of different FTP servers. The only danger with Archie is that you end up with hundreds of results that are actually dead links, so you may end up still not finding the package you were looking for. If this happens, try a different Archie server in a different country and search again; you might come up with a lot of duplicates, but you might also end up finding what you were looking for.

Web Sites

The main point of reference for all developers of Be software is www.be.com, Be Inc.'s Web site. There you will find a wealth of information about developing Be applications using both the BeOS C++ API and the POSIX-style C interface.

Within the Be Web site is the BeWare page, www.be.com/beware/index.html. This is a list of all the software written for and/or ported to the BeOS and is a good place to check up on what packages and products other people are working on. You can also find links to utilities and tools that you may find useful when porting.

There are some other Web and FTP sites worth special mention:

Fred Fish and Nine Moons Software (ftp://ftp.ninemoons.com/pub/be) is well known to the Commodore Amiga community for porting a wide range of software. He's repeated the exercise with the BeOS and has ported many of the GNU tools that Be doesn't currently include in the standard release. This includes most recently gcc, the GNU C compiler, and also documentation tools such as TeX.

Chris Herborth (http://www.qnx.com/~chrish/Be/) maintains what is probably the most comprehensive list of other Be software developers on the Internet. He also ported jove (Jonathan's Own Version of Emacs) and the official versions of the zip and unzip compression utilities.

Jake Hamby (http://people.delphi.com/jehamby/) ported Ghostscript, the software PostScript interpreter, to the BeOS before most people had even blinked. He also maintains a comprehensive list of libraries and tools, and now works for Be.

The Sun User Group (http://www.sunug.org) has a number of useful links to sources and applications which you can download directly off the Internet.

Mailing Lists and Newsgroups

Be hosts three development-related mailing lists; two of them are available to the public and one is available only to registered Be developers.

The main list that anybody developing applications should be a member of is BeDevTalk. This is a discussion list where people can read and respond to the e-mails that come as part of the mailing list. The problem with the list is that you receive a large number of messages, and not all of them contain information of use to everybody. The BeDevTalk mailing list is very busy with about a hundred messages per day.

The BeInfo mailing list is read-only and covers general announcements and information about Be, including the Be Newsletter.

The BeDevNews mailing list is also read-only, and is only available to registered Be developers. It relays the Be Newsletter and other confidential announcements about Be and software development.

The BeCodeTalk discussion list is for BeOS developers who want to talk specifically about writing code on the BeOS, rather than just about the BeOS in general which is what BeDevTalk is all about.To join any of these lists, send an e-mail to listserv@be.com with the following in the subject line of your message:

```
subscribe list_name
```

For example, to subscribe to the BeDevTalk mailing list you would put the following string in your message subject:

```
subscribe bedevtalk
```

With BeDevTalk you also have the facility to receive digests (condensed collections of messages) instead of each individual message sent to the mailing list. To receive a digest mailing, you add the word “digest” to your string:

```
subscribe bedevtalk digest
```

In addition to the mailing list, there are five main newsgroups available that discuss the BeOS directly:

Table A.2

Usenet newsgroups for discussing BeOS programming

Newsgroup	Description

comp.sys.be.advocacy	For flame wars (heated discussions) about how much better the BeOS is than UNIX, Windows, the MacOS, and any other OS you care to mention.
comp.sys.be.announce	Announcements to the BeOS user and developer community.
comp.sys.be.help	For help on using the BeOS and BeOS software.
comp.sys.be.misc	Discussions about anything which doesn't fit into the other newsgroups.
comp.sys.be.programmer	Discussions about developing and how to develop software for the BeOS.

To read any of these newsgroups you will need to speak to the person or company that supplies you with an Internet connection; they should be able to tell you how to receive newsgroups on your machine.

CD-ROMs

Since the explosion of the CD-ROM as a safe medium for delivering software, a number of companies have sprung up that redistribute software and source code from the Shareware and PD libraries and Internet sites on CD.

These are an excellent source of code, and the best thing about them is that no matter how hard you try, you can't accidentally delete the original!

The best type of CD-ROMs to go for are those targeted specifically at providing source code, rather than those aimed at specific applications or application groups. For example, you can get the FreeBSD, NetBSD, and BSDLite distributions on CD, along with the entire GNU source code, including glibc.

In the U.S., try using one of the following suppliers:

The Free Software Foundation

675 Massachusetts Avenue

Cambridge, MA 02139

Phone: (617) 876-3296

E-mail: gnu@prep.ai.mit.edu

WWW: www.gnu.ai.mit.edu

The FSFs sell CD-ROMS containing the full GNU source set. This includes all of the standard GNU utilities such as emacs and perl, and also a variety of sources and part-finished projects which you may like to work on.

Walnut Creek CD-ROM

4041 Pike Lane, Suite E

Concord, CA 94520

Phone: (510) 674-0783

E-mail: info@cdrom.com

WWW: www.cdrom.com

Walnut Creek distributes the GNU tools, a number of additional UNIX source code CDs, and most usefully the FreeBSD CD-ROM, which contains the full source and a working version of the FreeBSD version of UNIX. This is one the best sources of missing functions and abilities for the BeOS.

Outside of the U.S., try your local software distributor, who may be able to supply you with the CDs, or try one of the many Sun user groups, which will be happy to supply the GNU CD-ROM. You can find details of Sun user groups at www.sunug.org or check Yahoo, www.yahoo.com, which also keeps a fairly accurate list.

Compatibility and Utility Software

You can make working with the BeOS and another platform a lot easier by using some simple tools. If your other machine is UNIX, then most of the tools you need access to are already available. Setting up an FTP server or using the ftp command to communicate with the BeOS machine should be relatively painless. If it is a piece of nonstandard software, such as the TeX application, then you will need to find a source on the Internet or from one of the CD-ROM companies I've already mentioned and build it before you can make any reasonable use of it.

For the Mac, I suggest you get hold of at least two applications. The first is a version of telnet; I use NCSA Telnet, a product which was developed by the National Center for Supercomputing Applications (NCSA). They no longer support or develop the product, and in fact I'm still using v2.7b2, originally released in April 1995. I don't actually use NCSA Telnet for its remote access capabilities, but it does support a very simple and easy-to-use FTP server.

The second item is Anarchie, the excellent FTP client from Peter N. Lewis. Using Anarchie makes life very simple when you transfer files between the Mac and the BeOS. Probably its best feature is the ability to copy an entire folder hierarchy from one machine to another. Both tools can be obtained from your local Info-Mac archive; details of some of these sites are given below.

If you find you need to work with the TeX documentation supplied with most tools and packages, you can obtain OzTeX, a freeware application that processes TeX files so that they can be printed or displayed on screen. The URL for downloading the OzTeX software can be found below.

For Windows users, try NCSA again for a Telnet application and WinFTP for FTP transfers. The chances are that if you're a hardened netizen, you'll already have access to your favorite tools anyway.

Table A.3 contains some of the best sites to get these, and other useful utilities from.

Table A.3

Internet sites for MacOS and Windows utilities

URL	Site
ftp://sunsite.anu.edu.au/pub/mac/info-mac/	Info-Mac Australia
ftp://ftp.agt.net/pub/info-mac/	Info-Mac Canada
ftp://ftp.funet.fi/pub/mac/info-mac/	Info-Mac Finland
ftp://ftp.calvacom.fr/pub/mac/info-mac/	Info-Mac France
ftp://ftp.cs.tu-berlin.de/pub/mac/info-mac/	Info-Mac Germany
ftp://ftp.hk.super.net/pub/mirror/info-mac/	Info-Mac Hong Kong
ftp://src.doc.ic.ac.uk/packages/info-mac/	Info-Mac UK
ftp://ftp.amug.org/pub/info-mac/	Info-Mac USA, AMUG
ftp://mirror.apple.com/mirrors/Info-Mac.Archive/	Info-Mac USA, Apple
ftp://wuarchive.wustl.edu/systems/mac/info-mac/	Info-Mac USA, WU Archive
http://www.kagi.com/authors/akt/oztex.html	OzTeX
ftp://ftp.ncsa.uiuc.edu/telnet	Telnet (Mac/Windows)
ftp://ftp.stairways.com	Anarchie
ftp://ftp.cyberspace.com/pub/ppp/windows/ftp	WinFTP

Appendix B - Releasing the Software

We've made it!

Once you have finally built the software and got it working, it's time to let the rest of the world know about it.Before you start announcing your software, you need to prepare the package you're going to supply to people.

Checking the Compilation

There is nothing more frustrating than spending hours downloading a package, unpacking it, typing make, and finding out it doesn't work after all because the developer/porter forgot to supply some vital component.

You need to not only test the software once you've compiled it, but also test the package you are going to supply, from the point of unpacking all the way up to installation. This is not as easy as it sounds—your machine will undoubtedly be different from everybody else's—but you can minimize the effects of these differences.

First, make a complete copy of the working directory. Try to keep the file permissions and directory layout. You can use the cp command for this:

```
$ cp -pr gawk-3.0.2 begawk-3.0.2
```

but I prefer to use tar, which tends to work better with multiple directories:

```
$ mkdir begawk-3.0.2
$ cd begawk-3.0.2
$ (cd ../gawk-3.0.2;tar cf -)|tar xvf -
```

Within the new directory run a make clean, or the equivalent command to return the distribution to a base level. If you don't have access to a clean operation, make sure you remove any temporary editor files, object files, and applications.

Run make on the package again to ensure that it compiles correctly. If you come across any problems, you need to return to the earlier chapters of this book. If everything runs, then you need run make clean again, but this time you also need to delete any configuration files, settings, or scripts that would otherwise be used by the recipient during the process of installation. All of these files will be created as part of the build process, and we need to esnure that they get made correctly.

Now recreate the configuration files using the scripts, Makefiles, or whatever configuration tool is in use and build the package again. It shouldn't fail, providing there is nothing wrong with the configuration or build process.

You now need to clean the package directory up again, as last time, in preparation for packaging the files up for distribution. Removing these extra files helps keep the size of the package to as small a size as possible, and also ensures that you dont end up supplying files that you have created that affect the build process. For example, GNU configuration scripts create a number of files during the configuration process which are used to set defaults if you run the configuration script again. You dont want these files supplied to the end user, they need to tailor make their configuration for their system.

You can usually achieve a clean package directory by specifying realclean or distclean to make. This should delete everything but the base files for a package.

Packaging

How you package your ported software depends on the people you are supplying it to and the contents of the package. At the very least,you should include the following with your package:

- All the sources and associated files (Makefiles, scripts), plus any documentation
- Details on how to configure, build, and install the software
- How to get in contact with you, the author of this release, to report bugs, problems, and hopefully praise
- A license of some form to protect you, and legalize the release of the software. See the section below on Licenses.
- If the license from the original software states that you should include the entire contents of the package when you redistribute it (the GNU license specifies this), make sure you have all the files. Use the MANIFEST document, which lists the contents, to double-check.

There are also some things you *shouldn't* include in the package:

- Any work files you created during the build process that aren't required
- Any temporary editor files
- Executables, libraries, or object files, which take up unnecessary space in the archive;

Again, it is advisable to use a test directory to remove the sample files before packaging up the directory.

Once you are sure the package is complete, that it compiles correctly, and that it contains everything you need, you need to create a suitable archive for distribution.

In most cases, the most suitable file for a POSIX based application is a gzipped tar file; this is supported as standard on the BeOS and so makes an ideal format for exchanging packages. Use the examples in Chapter 6 to help you create the file. A simple example would be:

```
$ tar cf - ./gawk-3.0.2 |gzip -9 >gawk-3.02.tar.gz
```

Most BeOS software however should be supplied to BeWare, the Be software repository, as a ZIP archive.

You may decide to use an installation tool which uncompresses and extracts the files/directories automatically into their correct locations. This is more complicated and not really designed for supplying source-file-based packages. Generally a package installer should only be used for ready-to-run installations of the software. If you are targeting users, though, rather than programmers and network administrators, this might be the easier-to-use and tidier solution.

Once you've created the package, make a backup of the file you supply to the outside world, along with backups of your working versions. This helps to recreate the package when it comes to generating diff files for patching to later versions, and is also useful for reference purposes if someone reports a bug in a specific version.

Adding a License

Most packages come with some form of license having to do with the use of the package. This license is used to make the copying and distribution of a package legal, while simultaneously removing any responsibility from you regarding the suitability of the package for its task and any damages that might be incurred by the use of the software you supply.

In general, there are three basic levels of software supply, although over the years these have been subdivided and expanded on to suit the latest style. The three types are:

- **Commercial.** The software must be paid for in full; the license provides the user with the "right to use" for the compiled software, but not ownership of the software. It is unusual to find the source of a commercial piece included in the package.
- **Shareware.** Shareware packages are supplied by various means for free, but the user is expected to pay for the software after an initial "investigation" period. This is largely unenforceable without crippling the software in some way with anything from removed facilities to limited-time use.
- **Freeware.** The software is supplied completely free, with or without the source code. You can charge for the distribution of the software, but not

for the software itself. This is how most UNIX packages (such as those from the Free Software Foundation) are supplied.

Extensions to these basic types include Postcard-ware (you send a postcard to the author), E-mail-ware (you send an e-mail to author), and Donation-ware (you are asked to make a donation to charity).

If you are porting a package, chances are it already has some sort of distribution license. You should accept the terms of this license when you start to port the software, and, because you are redistributing someone else's code, you should also include and honor the license when you supply your version to other people. Most people use the GNU General Public License; this is a standard document outlining the legal aspects of software supply.

Check the package you have ported—the General Public License is probably in the file called COPYING, LICENCE, or LICENSE. You should also check for files with these names in other combinations of upper– and lowercase I have included it here in its entirety for reference purposes. This is only a sample, and you should make sure that you use the license supplied in the original package.

```
                 GNU GENERAL PUBLIC LICENSE
                    Version 2, June 1991

 Copyright (C) 1989, 1991 Free Software Foundation, Inc.
 59 Temple Place - Suite 330, Boston, MA 02111-1307, USA
 Everyone is permitted to copy and distribute verbatim copies
 of this license document, but changing it is not allowed.

                         Preamble

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```

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PROGRAMS), EVEN IF SUCH HOLDER OR OTHER PARTY HAS BEEN ADVISED OF THE
POSSIBILITY OF SUCH DAMAGES.

END OF TERMS AND CONDITIONS

Appendix: How to Apply These Terms to Your New Programs

If you develop a new program, and you want it to be of the greatest possible use to the public, the best way to achieve this is to make it free software which everyone can redistribute and change under these terms.

To do so, attach the following notices to the program. It is safest to attach them to the start of each source file to most effectively convey the exclusion of warranty; and each file should have at least the "copyright" line and a pointer to where the full notice is found.

<one line to give the program's name and a brief idea of what it does.>
Copyright (C) 19yy <name of author>

This program is free software; you can redistribute it and/or modify
it under the terms of the GNU General Public License as published by
the Free Software Foundation; either version 2 of the License, or
(at your option) any later version.

This program is distributed in the hope that it will be useful,
but WITHOUT ANY WARRANTY; without even the implied warranty of
MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the
GNU General Public License for more details.

You should have received a copy of the GNU General Public License
along with this program; if not, write to the Free Software
Foundation, Inc., 59 Temple Place - Suite 330, Boston,
MA 02111-1307, USA

Also add information on how to contact you by electronic and paper mail.

If the program is interactive, make it output a short notice like this when it starts in an interactive mode:

Gnomovision version 69, Copyright (C) 19yy name of author
Gnomovision comes with ABSOLUTELY NO WARRANTY; for details
type `show w'.
This is free software, and you are welcome to redistribute it
under certain conditions; type `show c' for details.

The hypothetical commands `show w' and `show c' should show the appropriate parts of the General Public License. Of course, the commands you use may be called something other than `show w' and `show c'; they could even be mouse-clicks or menu items--whatever suits your program.

You should also get your employer (if you work as a programmer) or your school, if any, to sign a "copyright disclaimer" for the program, if necessary. Here is a sample; alter the names:

Yoyodyne, Inc., hereby disclaims all copyright interest in the program
`Gnomovision' (which makes passes at compilers) written by James Hacker.

<signature of Ty Coon>, 1 April 1989
Ty Coon, President of Vice

This General Public License does not permit incorporating your program into

```
proprietary programs.  If your program is a subroutine library, you
may
consider it more useful to permit linking proprietary applications
with the
library.  If this is what you want to do, use the GNU Library General
Public License instead of this License.
```

An alternative to the GNU public licence is the BSD licence. This is simpler and far less restrictive on the use or re-use of the code. The Apache web server is a good example of a package which makes use of this licence, and I've included it below for reference purposes.

```
/*
====================================================================
 * Copyright (c) 1995-1997 The Apache Group.  All rights reserved.
 *
 * Redistribution and use in source and binary forms, with or without
 * modification, are permitted provided that the following conditions
 * are met:
 *
 * 1. Redistributions of source code must retain the above copyright
 *    notice, this list of conditions and the following disclaimer.
 *
 * 2. Redistributions in binary form must reproduce the above
copyright
 *    notice, this list of conditions and the following disclaimer in
 *    the documentation and/or other materials provided with the
 *    distribution.
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 * 3. All advertising materials mentioning features or use of this
 *    software must display the following acknowledgment:
 *    "This product includes software developed by the Apache Group
 *    for use in the Apache HTTP server project (http://
www.apache.org/)."
 *
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 *    prior written permission.
 *
 * 5. Redistributions of any form whatsoever must retain the following
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 *    for use in the Apache HTTP server project (http://
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 * STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE)
 * ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED
 * OF THE POSSIBILITY OF SUCH DAMAGE.
 *
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 *
 * This software consists of voluntary contributions made by many
 * individuals on behalf of the Apache Group and was originally based
 * on public domain software written at the National Center for
 * Supercomputing Applications, University of Illinois, Urbana-
Champaign.
 * For more information on the Apache Group and the Apache HTTP server
 * project, please see <http://www.apache.org/>.
 *
```

*/

Distribution

The best form of publicity is word of mouth. In the world of computers, word of mouth means making your package known to as many people as possible. The more people who know the package exists, the more people who will want to download it, and therefore the more people you can distribute the package to.

Luckily, with Be, this is very easy. The company has been built on e-mail, mailing lists, and Web sites, so there are numerous avenues available for you to peddle your wares.

To succeed, you need to give your package as much publicity as possible and make sure it's easily available. For example, announcing the latest port of a piece of software, but not actually providing the software on a Web site or FTP server, will only cause people to ignore the announcement.

As with the package itself, you need to ensure that your information is correct, and that the user has access to all the details he or she needs. Ideally, you should include:

- The package name
- A short description
- The reason for the port
- The version number of the package
- The version number of the OS under which it runs
- Your e-mail address
- Details of where to download the package from
- The package's formats (gzipped tar, self-installer, and so on)

Be have guidelines and information for supplying them with copies of your package. Go to http://www.be.com/developers/ftp/uploading.html. Refer to Appendix Afor more information on the Be website.

Once you have your message prepared, you need to advertise and supply the package. The best places to advertise are Web sites and mailing lists, and the best form of distribution is an FTP server. If you are a registered Be developer, you might also want to use BeWare, Be's software distribution Web site.

Web Sites

A Web site has the advantage that the information is up and available for as long as the page and the Web site are. There are a number of well-recognized Web sites on which you can advertise, including:

- http://www.be.com (Be's own Web site)
- http://www.qnx.com/~chrish (Chris Herborth, a Be evangelist)
- http:// www.ai-lab.fh-furtwangen.de/~DeBUG (The German Be User Group website)
- http://www.bemall.com (BeMall, a repository for BeOS software)

There are further sites you might like to try listed in the Appendix A. Remember, if you can, to include a link to the FTP server that stores your files.

FTP Servers

At the time of writing, there is not a great number of FTP sites devoted to Be software. However, any site that allows you to upload files can be used to store a Be package.

Be provides an FTP site (ftp.be.com) which is linked to their BeWare page and should be the first place you upload your file. Guidelines on using the Be FTP server can be found at http://www.be.com/developers/ftp/uploading.html.

Mailing Lists

Be hosts a number of mailing lists which can be used to announce the availability of software.

The main list that anybody developing applications should be a member of is BeDevTalk. This is the best list to post details about your latest release as it reaches the bulk of the programming, rather than the user community.

The BeInfo mailing list is read only and covers general announcements and information about Be, including the Be Newsletter.

The BeDevNews mailing list is also read only, and is only available to registered Be Developers. It relays the Be Newsletter and other confidential announcements about Be and software development.Details on these and other lists can be found in the appendix.

BeWare

BeWare is Be's very own online software store. It was designed to provide Be developers with a single channel for releasing software to the public. As such, it probably explains the lack of Web and FTP sites devoted to the task.

You can find to the BeWare page at http://www.be.com/beware.

Contacting the Author

The purpose of porting software is to make it available on a new platform. This is almost certainly something that the author would like to know about. In informing the author, you can supply the changes you had to make to the package to make it work on the BeOS. He/she can then include the changes into the next release of the package, making your and everybody else's lives considerably easier next time around.

You should take care when contacting authors, though; the aim is to help them to incorporate the changes, and note any bugs to them. Don't alienate them, and certainly don't make them feel insubstantial in the process; after all, they provided you with the package to port, not the other way around. Porting is not a competitive sport, and pointing out someone else's apparent inadequacies will only make matters worse.

You need to supply the following details to the author:

- The problems you encountered during the build. These should include everything from problems in the configuration and Makefile to difficulties during the compilation itself.
- The solutions to the problems. In particular, any BeOS-specific changes you needed to make should be detailed. Don't underplay or underestimate any changes, be as specific and verbose as possible.
- Any bugs you found not related to the porting process, for example a typo or a mismatch in the name of a definition.

Here is a copy of the message I sent to Arnold Robbins, writer of gawk, after I had ported the GNU awk package to the BeOS:

```
Subject:     Gawk port to BeOS
Sent:        16/2/97 1:36 pm
To:          Arnold Robbins, arnold@gnu.ai.mit.edu

Hi,

I've just completed a port of Gawk to BeOS (DR8.2), and I have a few
comments regarding the code.

1) The biggest problem with the port is that compilation of awktab.c
failed because of a bad union/structure for 'token'.

It turns out that this is because of the dfa code, where a 'token'
union is created which is in direct conflict with the 'token' defined
in the bison output for awktab.c file.
```

```
I've replaced the 'token' reference in dfa.[ch] to be dfatoken
instead. Is there any reason why this hasn't come to light before?

2) Running make test only reports a few errors. At the moment for
example BeOS doesn't support /dev/stdout. Also the 'manyfiles' script
fails, dropping you into the debugger on an fdopen call. This is a
BeOS bug I'm trying to trace/fix.

3) An assumption is made that 'strncasecmp' has no prototype, I've
changed this so that a define will skirt round this.

4) The makefile goes on to to automatically make the library
utilities, I've disabled this because nearly all of them fail on BeOS.

I'll mail you the patches I've made for BeOS. Do you support MIME
attachments?
```

Remember that the purpose of contacting authors is to let them know of the changes. Porting is a cooperative process; you only need to check the documentation supplied with most packages to see examples of the number of people who can be involved in the process.

Once you have been in contact with authors, they will almost certainly ask for the changes in the form of a patch file. Make sure they can accept the format and mail encoding you are going to use before sending it to them, particularly if it's large. For details on how to make patch files, refer to Chapter 7.