CHAPTER 9

Essential Tools for Performance Tuning

To be able to improve the performance of your system you need a prior understanding of what can be improved, how it can be improved, how much it can be improved, and, most importantly, what impact the improvement will have on the overall performance of your system. You need to be able to identify those things that, after you have done your best to improve them, will yield substantial benefits for the overall system performance. Concentrate your efforts on them, and avoid wasting time on improvements that give little overall gain.

If you have a small application it may be possible to detect places that could be improved simply by inspecting the code. On the other hand, if you have a large application, or many applications, it's usually impossible to do the detective work with the naked eye. You need observation instruments and measurement tools. These belong to the benchmarking and code-profiling categories.

It's important to understand that in the majority of the benchmarking tests that we will execute, we will not be looking at absolute results. Few machines will have exactly the same hardware and software setup, so this kind of comparison would usually be misleading, and in most cases we will be trying to show which coding approach is preferable, so the hardware is almost irrelevant.

Rather than looking at absolute results, we will be looking at the differences between two or more result sets run on the same machine. This is what you should do; you shouldn't try to compare the absolute results collected here with the results of those same benchmarks on your own machines.

In this chapter we will present a few existing tools that are widely used; we will apply them to example code snippets to show you how performance can be measured, monitored, and improved; and we will give you an idea of how you can develop your own tools.

Server Benchmarking

As web service developers, the most important thing we should strive for is to offer the user a fast, trouble-free browsing experience. Measuring the response rates of our servers under a variety of load conditions and benchmark programs helps us to do this.

A benchmark program may consume significant resources, so you cannot find the real times that a typical user will wait for a response from your service by running the benchmark on the server itself. Ideally you should run it from a different machine. A benchmark program is unlike a typical user in the way it generates requests. It should be able to emulate multiple concurrent users connecting to the server by generating many concurrent requests. We want to be able to tell the benchmark program what load we want to emulate—for example, by specifying the number or rate of requests to be made, the number of concurrent users to emulate, lists of URLs to request, and other relevant arguments.

ApacheBench

ApacheBench (*ab*) is a tool for benchmarking your Apache HTTP server. It is designed to give you an idea of the performance that your current Apache installation can give. In particular, it shows you how many requests per second your Apache server is capable of serving. The *ab* tool comes bundled with the Apache source distribution, and like the Apache web server itself, it's free.

Let's try it. First we create a test script, as shown in Example 9-1.

Example 9-1. simple_test.pl

```
my $r = shift;
$r->send_http_header('text/plain');
print "Hello\n";
```

We will simulate 10 users concurrently requesting the file *simple_test.pl* through *http://localhost/perl/simple_test.pl*. Each simulated user makes 500 requests. We generate 5,000 requests in total:

```
panic% ./ab -n 5000 -c 10 http://localhost/perl/simple_test.pl

Server Software:        Apache/1.3.25-dev
Server Hostname:        localhost
Server Port:            8000

Document Path:          /perl/simple_test.pl
Document Length:        6 bytes

Concurrency Level:      10
Time taken for tests:   5.843 seconds
Complete requests:      5000
Failed requests:        0
```

```
    Broken pipe errors:     0
    Total transferred:      810162 bytes
    HTML transferred:       30006 bytes
    Requests per second:    855.72 [#/sec] (mean)
    Time per request:       11.69 [ms] (mean)
    Time per request:       1.17 [ms] (mean, across all concurrent requests)
    Transfer rate:          138.66 [Kbytes/sec] received

    Connnection Times (ms)
                  min  mean[+/-sd] median   max
    Connect:        0     1    1.4      0    17
    Processing:     1    10   12.9      7   208
    Waiting:        0     9   13.0      7   208
    Total:          1    11   13.1      8   208
```

Most of the report is not very interesting to us. What we really care about are the *Requests per second* and *Connection Times* results:

Requests per second
: The number of requests (to our test script) the server was able to serve in one second

Connect and Waiting times
: The amount of time it took to establish the connection and get the first bits of a response

Processing time
: The server response time—i.e., the time it took for the server to process the request and send a reply

Total time
: The sum of the Connect and Processing times

As you can see, the server was able to respond on average to 856 requests per second. On average, it took no time to establish a connection to the server both the client and the server are running on the same machine and 10 milliseconds to process each request. As the code becomes more complicated you will see that the processing time grows while the connection time remains constant. The latter isn't influenced by the code complexity, so when you are working on your code performance, you care only about the processing time. When you are benchmarking the overall service, you are interested in both.

Just for fun, let's benchmark a similar script, shown in Example 9-2, under mod_cgi.

Example 9-2. simple_test_mod_cgi.pl

```
#!/usr/bin/perl
print "Content-type: text/plain\n\n";
print "Hello\n";
```

The script is configured as:

```
ScriptAlias /cgi-bin/ /usr/local/apache/cgi-bin/

panic% /usr/local/apache/bin/ab -n 5000 -c 10 \
http://localhost/cgi-bin/simple_test_mod_cgi.pl
```

We will show only the results that interest us:

```
Requests per second:    156.40 [#/sec] (mean)
Time per request:       63.94 [ms] (mean)
```

Now, when essentially the same script is executed under mod_cgi instead of mod_perl, we get 156 requests per second responded to, not 856.

ApacheBench can generate KeepAlives, `GET` (default) and `POST` requests, use *Basic Authentication*, send cookies and custom HTTP headers. The version of *ApacheBench* released with Apache version 1.3.20 adds SSL support, generates *gnuplot* and CSV output for postprocessing, and reports median and standard deviation values.

`HTTPD::Bench::ApacheBench`, available from CPAN, provides a Perl interface for *ab*.

httperf

httperf is another tool for measuring web server performance. Its input and reports are different from the ones we saw while using *ApacheBench*. This tool's manpage includes an in-depth explanation of all the options it accepts and the results it generates. Here we will concentrate on the input and on the part of the output that is most interesting to us.

With *httperf* you cannot specify the concurrency level; instead, you have to specify the connection opening rate (*--rate*) and the number of calls (*--num-call*) to perform on each opened connection. To compare the results we received from *ApacheBench* we will use a connection rate slightly higher than the number of requests responded to per second reported by *ApacheBench*. That number was 856, so we will try a rate of 860 (*--rate 860*) with just one request per connection (*--num-call 1*). As in the previous test, we are going to make 5,000 requests (*--num-conn 5000*). We have set a timeout of 60 seconds and allowed *httperf* to use as many ports as it needs (*--hog*).

So let's execute the benchmark and analyze the results:

```
panic% httperf --server localhost --port 80 --uri /perl/simple_test.pl \
--hog --rate 860 --num-conn 5000 --num-call 1 --timeout 60

Maximum connect burst length: 11

Total: connections 5000 requests 5000 replies 5000 test-duration 5.854 s

Connection rate: 854.1 conn/s (1.2 ms/conn, <=50 concurrent connections)
Connection time [ms]: min 0.8 avg 23.5 max 226.9 median 20.5 stddev 13.7
Connection time [ms]: connect 4.0
Connection length [replies/conn]: 1.000
```

```
Request rate: 854.1 req/s (1.2 ms/req)
Request size [B]: 79.0

Reply rate [replies/s]: min 855.6 avg 855.6 max 855.6 stddev 0.0 (1 samples)
Reply time [ms]: response 19.5 transfer 0.0
Reply size [B]: header 184.0 content 6.0 footer 2.0 (total 192.0)
Reply status: 1xx=0 2xx=5000 3xx=0 4xx=0 5xx=0

CPU time [s]: user 0.33 system 1.53 (user 5.6% system 26.1% total 31.8%)
Net I/O: 224.4 KB/s (1.8*10^6 bps)

Errors: total 0 client-timo 0 socket-timo 0 connrefused 0 connreset 0
Errors: fd-unavail 0 addrunavail 0 ftab-full 0 other 0
```

As before, we are mostly interested in the average *Reply rate*—855, almost exactly the same result reported by *ab* in the previous section. Notice that when we tried *--rate 900* for this particular setup, the reported request rate went down drastically, since the server's performance gets worse when there are more requests than it can handle.

http_load

http_load is yet another utility that does web server load testing. It can simulate a 33.6 Kbps modem connection (*-throttle*) and allows you to provide a file with a list of URLs that will be fetched randomly. You can specify how many parallel connections to run (*-parallel N*) and the number of requests to generate per second (*-rate N*). Finally, you can tell the utility when to stop by specifying either the test time length (*-seconds N*) or the total number of fetches (*-fetches N*).

Again, we will try to verify the results reported by *ab* (claiming that the script under test can handle about 855 requests per second on our machine). Therefore we run *http_load* with a rate of 860 requests per second, for 5 seconds in total. We invoke is on the file *urls*, containing a single URL:

```
http://localhost/perl/simple_test.pl
```

Here is the generated output:

```
panic% http_load -rate 860 -seconds 5 urls
4278 fetches, 325 max parallel, 25668 bytes, in 5.00351 seconds
6 mean bytes/connection
855 fetches/sec, 5130 bytes/sec
msecs/connect: 20.0881 mean, 3006.54 max, 0.099 min
msecs/first-response: 51.3568 mean, 342.488 max, 1.423 min
HTTP response codes:
  code 200 -- 4278
```

This application also reports almost exactly the same response-rate capability: 855 requests per second. Of course, you may think that it's because we have specified a rate close to this number. But no, if we try the same test with a higher rate:

```
panic% http_load -rate 870 -seconds 5 urls
4045 fetches, 254 max parallel, 24270 bytes, in 5.00735 seconds
```

```
6 mean bytes/connection
807.813 fetches/sec, 4846.88 bytes/sec
msecs/connect: 78.4026 mean, 3005.08 max, 0.102 min
```

we can see that the performance goes down—it reports a response rate of only 808 requests per second.

The nice thing about this utility is that you can list a few URLs to test. The URLs that get fetched are chosen randomly from the specified file.

Note that when you provide a file with a list of URLs, you must make sure that you don't have empty lines in it. If you do, the utility will fail and complain:

```
./http_load: unknown protocol -
```

Other Web Server Benchmark Utilities

The following are also interesting benchmarking applications implemented in Perl:

`HTTP::WebTest`
: The `HTTP::WebTest` module (available from CPAN) runs tests on remote URLs or local web files containing Perl, JSP, HTML, JavaScript, etc. and generates a detailed test report.

`HTTP::Monkeywrench`
: `HTTP::Monkeywrench` is a test-harness application to test the integrity of a user's path through a web site.

`Apache::Recorder` *and* `HTTP::RecordedSession`
: `Apache::Recorder` (available from CPAN) is a mod_perl handler that records an HTTP session and stores it on the web server's filesystem. `HTTP::RecordedSession` reads the recorded session from the filesystem and formats it for playback using `HTTP::WebTest` or `HTTP::Monkeywrench`. This is useful when writing acceptance and regression tests.

Many other benchmark utilities are available both for free and for money. If you find that none of these suits your needs, it's quite easy to roll your own utility. The easiest way to do this is to write a Perl script that uses the `LWP::Parallel::UserAgent` and `Time::HiRes` modules. The former module allows you to open many parallel connections and the latter allows you to take time samples with microsecond resolution.

Perl Code Benchmarking

If you want to benchmark your Perl code, you can use the `Benchmark` module. For example, let's say that our code generates many long strings and finally prints them out. We wonder what is the most efficient way to handle this task—we can try to concatenate the strings into a single string, or we can store them (or references to them) in an array before generating the output. The easiest way to get an answer is to try each approach, so we wrote the benchmark shown in Example 9-3.

Example 9-3. strings_benchmark.pl

```
use Benchmark;
use Symbol;
my $fh = gensym;

open $fh, ">/dev/null" or die $!;

my($one, $two, $three) = map { $_ x 4096 } 'a'..'c';

timethese(100_000, {
    ref_array => sub {
        my @a;
        push @a, \($one, $two, $three);
        my_print(@a);
    },
    array => sub {
        my @a;
        push @a, $one, $two, $three;
        my_print(@a);
    },
    concat => sub {
        my $s;
        $s .= $one;
        $s .= $two;
        $s .= $three;
        my_print($s);
    },
});
sub my_print {
    for (@_) {
        print $fh ref($_) ? $$_ : $_;
    }
}
```

As you can see, we generate three big strings and then use three anonymous functions to print them out. The first one (`ref_array`) stores the references to the strings in an array. The second function (`array`) stores the strings themselves in an array. The third function (`concat`) concatenates the three strings into a single string. At the end of each function we print the stored data. If the data structure includes references, they are first dereferenced (relevant for the first function only). We execute each subtest 100,000 times to get more precise results. If your results are too close and are below 1 CPU clocks, you should try setting the number of iterations to a bigger number. Let's execute this benchmark and check the results:

```
panic% perl strings_benchmark.pl
Benchmark: timing 100000 iterations of array, concat, ref_array...
     array:  2 wallclock secs ( 2.64 usr +  0.23 sys =  2.87 CPU)
    concat:  2 wallclock secs ( 1.95 usr +  0.07 sys =  2.02 CPU)
 ref_array:  3 wallclock secs ( 2.02 usr +  0.22 sys =  2.24 CPU)
```

First, it's important to remember that the reported wallclock times can be misleading and thus should not be relied upon. If during one of the subtests your computer was more heavily loaded than during the others, it's possible that this particular subtest will take more wallclocks to complete, but this doesn't matter for our purposes. What matters is the CPU clocks, which tell us the exact amount of CPU time each test took to complete. You can also see the fraction of the CPU allocated to *usr* and *sys*, which stand for the user and kernel (system) modes, respectively. This tells us what proportions of the time the subtest has spent running code in user mode and in kernel mode.

Now that you know how to read the results, you can see that concatenation outperforms the two array functions, because concatenation only has to grow the size of the string, whereas array functions have to extend the array and, during the print, iterate over it. Moreover, the array method also creates a string copy before appending the new element to the array, which makes it the slowest method of the three.

Let's make the strings much smaller. Using our original code with a small correction:

```
my($one, $two, $three) = map { $_ x 8 } 'a'..'c';
```

we now make three strings of 8 characters, instead of 4,096. When we execute the modified version we get the following picture:

```
Benchmark: timing 100000 iterations of array, concat, ref_array...
     array:  1 wallclock secs ( 1.59 usr +  0.01 sys =  1.60 CPU)
    concat:  1 wallclock secs ( 1.16 usr +  0.04 sys =  1.20 CPU)
 ref_array:  2 wallclock secs ( 1.66 usr +  0.05 sys =  1.71 CPU)
```

Concatenation still wins, but this time the array method is a bit faster than ref_array, because the overhead of taking string references before pushing them into an array and dereferencing them afterward during `print()` is bigger than the overhead of making copies of the short strings.

As these examples show, you should benchmark your code by rewriting parts of the code and comparing the benchmarks of the modified and original versions.

Also note that benchmarks can give different results under different versions of the Perl interpreter, because each version might have built-in optimizations for some of the functions. Therefore, if you upgrade your Perl interpreter, it's best to benchmark your code again. You may see a completely different result.

Another Perl code benchmarking method is to use the `Time::HiRes` module, which allows you to get the runtime of your code with a fine-grained resolution of the order of microseconds. Let's compare a few methods to multiply two numbers (see Example 9-4).

Example 9-4. hires_benchmark_time.pl

```
use Time::HiRes qw(gettimeofday tv_interval);
my %subs = (
    obvious => sub {
        $_[0] * $_[1]
    },
    decrement => sub {
```

Example 9-4. hires_benchmark_time.pl (continued)

```
        my $a = shift;
        my $c = 0;
        $c += $_[0] while $a--;
        $c;
    },
);

for my $x (qw(10 100)) {
    for my $y (qw(10 100)) {
        for (sort keys %subs) {
            my $start_time = [ gettimeofday ];
            my $z = $subs{$_}->($x,$y);
            my $end_time = [ gettimeofday ];
            my $elapsed = tv_interval($start_time,$end_time);
            printf "%-9.9s: Doing %3.d * %3.d = %5.d took %f seconds\n",
                $_, $x, $y, $z, $elapsed;
        }
        print "\n";
    }
}
```

We have used two methods here. The first (`obvious`) is doing the normal multiplication, `$z=$x*$y`. The second method is using a trick of the systems where there is no built-in multiplication function available; it uses only the addition and subtraction operations. The trick is to add `$x` for `$y` times (as you did in school before you learned multiplication).

When we execute the code, we get:

```
panic% perl hires_benchmark_time.pl
decrement: Doing  10 *  10 =   100 took 0.000064 seconds
obvious  : Doing  10 *  10 =   100 took 0.000016 seconds

decrement: Doing  10 * 100 =  1000 took 0.000029 seconds
obvious  : Doing  10 * 100 =  1000 took 0.000013 seconds

decrement: Doing 100 *  10 =  1000 took 0.000098 seconds
obvious  : Doing 100 *  10 =  1000 took 0.000013 seconds

decrement: Doing 100 * 100 = 10000 took 0.000093 seconds
obvious  : Doing 100 * 100 = 10000 took 0.000012 seconds
```

Note that if the processor is very fast or the OS has a coarse time-resolution granularity (i.e., cannot count microseconds) you may get zeros as reported times. This of course shouldn't be the case with applications that do a lot more work.

If you run this benchmark again, you will notice that the numbers will be slightly different. This is because the code measures absolute time, not the real execution time (unlike the previous benchmark using the `Benchmark` module).

You can see that doing `10*100` as opposed to `100*10` results in quite different results for the decrement method. When the arguments are `10*100`, the code performs the *add 100* operation only 10 times, which is obviously faster than the second invocation, `100*10`, where the code performs the *add 10* operation 100 times. However, the normal multiplication takes a constant time.

Let's run the same code using the `Benchmark` module, as shown in Example 9-5.

Example 9-5. hires_benchmark.pl

```
use Benchmark;
my %subs = (
    obvious => sub {
        $_[0] * $_[1]
    },
    decrement => sub {
        my $a = shift;
        my $c = 0;
        $c += $_[0] while $a--;
        $c;
    },
);

for my $x (qw(10 100)) {
    for my $y (qw(10 100)) {
        print "\nTesting $x*$y\n";
        timethese(300_000, {
            obvious   => sub {$subs{obvious}->($x, $y)  },
            decrement => sub {$subs{decrement}->($x, $y)},
        });
    }
}
```

Now let's execute the code:

```
panic% perl hires_benchmark.pl
Testing 10*10
Benchmark: timing 300000 iterations of decrement, obvious...
 decrement:  4 wallclock secs ( 4.27 usr +  0.09 sys =  4.36 CPU)
   obvious:  1 wallclock secs ( 0.91 usr +  0.00 sys =  0.91 CPU)

Testing 10*100
Benchmark: timing 300000 iterations of decrement, obvious...
 decrement:  5 wallclock secs ( 3.74 usr +  0.00 sys =  3.74 CPU)
   obvious:  0 wallclock secs ( 0.87 usr +  0.00 sys =  0.87 CPU)

Testing 100*10
Benchmark: timing 300000 iterations of decrement, obvious...
 decrement: 24 wallclock secs (24.41 usr +  0.00 sys = 24.41 CPU)
   obvious:  2 wallclock secs ( 0.86 usr +  0.00 sys =  0.86 CPU)
```

```
Testing 100*100
Benchmark: timing 300000 iterations of decrement, obvious...
 decrement: 23 wallclock secs (23.64 usr +  0.07 sys = 23.71 CPU)
   obvious:  0 wallclock secs ( 0.80 usr +  0.00 sys =  0.80 CPU)
```

You can observe exactly the same behavior, but this time using the average CPU clocks collected over 300,000 tests and not the absolute time collected over a single sample. Obviously, you can use the `Time::HiRes` module in a benchmark that will execute the same code many times to report a more precise runtime, similar to the way the `Benchmark` module reports the CPU time.

However, there are situations where getting the average speed is not enough. For example, if you're testing some code with various inputs and calculate only the average processing times, you may not notice that for some particular inputs the code is very ineffective. Let's say that the average is 0.72 seconds. This doesn't reveal the possible fact that there were a few cases when it took 20 seconds to process the input. Therefore, getting the variance* in addition to the average may be important. Unfortunately `Benchmark.pm` cannot provide such results—system timers are rarely good enough to measure fast code that well, even on single-user systems, so you must run the code thousands of times to get any significant CPU time. If the code is slow enough that each single execution can be measured, most likely you can use the profiling tools.

Process Memory Measurements

A very important aspect of performance tuning is to make sure that your applications don't use too much memory. If they do, you cannot run many servers, and therefore in most cases, under a heavy load the overall performance will be degraded. The code also may leak memory, which is even worse, since if the same process serves many requests and more memory is used after each request, after a while all the RAM will be used and the machine will start swapping (i.e., using the swap partition). This is a very undesirable situation, because when the system starts to swap, the performance will suffer badly. If memory consumption grows without bound, it will eventually lead to a machine crash.

The simplest way to figure out how big the processes are and to see whether they are growing is to watch the output of the *top(1)* or *ps(1)* utilities.

For example, here is the output of *top(1)*:

```
8:51am  up 66 days,  1:44,  1 user,  load average: 1.09, 2.27, 2.61
  95 processes: 92 sleeping, 3 running, 0 zombie, 0 stopped
  CPU states: 54.0% user,  9.4% system,  1.7% nice, 34.7% idle
```

* See Chapter 15 in the book *Mastering Algorithms with Perl*, by Jon Orwant, Jarkko Hietaniemi, and John Macdonald (O'Reilly). Of course, there are gazillions of statistics-related books and resources on the Web; *http://mathforum.org/* and *http://mathworld.wolfram.com/* are two good starting points for anything that has to do with mathematics.

```
  Mem:  387664K av, 309692K used,  77972K free, 111092K shrd,  70944K buff
  Swap: 128484K av,  11176K used, 117308K free               170824K cached

 PID USER PRI NI SIZE  RSS SHARE STAT LIB %CPU %MEM   TIME COMMAND
  29225 nobody 0  0  9760 9760  7132 S      0 12.5  2.5   0:00 httpd_perl
  29220 nobody 0  0  9540 9540  7136 S      0  9.0  2.4   0:00 httpd_perl
  29215 nobody 1  0  9672 9672  6884 S      0  4.6  2.4   0:01 httpd_perl
  29255 root   7  0  1036 1036   824 R      0  3.2  0.2   0:01 top
376 squid  0  0 15920  14M   556 S      0  1.1  3.8 209:12 squid
  29227 mysql  5  5  1892 1892   956 S N    0  1.1  0.4   0:00 mysqld
  29223 mysql  5  5  1892 1892   956 S N    0  0.9  0.4   0:00 mysqld
  29234 mysql  5  5  1892 1892   956 S N    0  0.9  0.4   0:00 mysqld
```

This starts with overall information about the system and then displays the most active processes at the given moment. So, for example, if we look at the *httpd_perl* processes, we can see the size of the resident (RSS) and shared (SHARE) memory segments.* This sample was taken on a production server running Linux.

But of course we want to see all the apache/mod_perl processes, and that's where *ps(1)* comes in. The options of this utility vary from one Unix flavor to another, and some flavors provide their own tools. Let's check the information about mod_perl processes:

```
panic% ps -o pid,user,rss,vsize,%cpu,%mem,ucomm -C httpd_perl
  PID USER      RSS   VSZ %CPU %MEM COMMAND
29213 root     8584 10264  0.0  2.2 httpd_perl
29215 nobody   9740 11316  1.0  2.5 httpd_perl
29216 nobody   9668 11252  0.7  2.4 httpd_perl
29217 nobody   9824 11408  0.6  2.5 httpd_perl
29218 nobody   9712 11292  0.6  2.5 httpd_perl
29219 nobody   8860 10528  0.0  2.2 httpd_perl
29220 nobody   9616 11200  0.5  2.4 httpd_perl
29221 nobody   8860 10528  0.0  2.2 httpd_perl
29222 nobody   8860 10528  0.0  2.2 httpd_perl
29224 nobody   8860 10528  0.0  2.2 httpd_perl
29225 nobody   9760 11340  0.7  2.5 httpd_perl
29235 nobody   9524 11104  0.4  2.4 httpd_perl
```

Now you can see the resident (RSS) and virtual (VSZ) memory segments (and the shared memory segment if you ask for it) of all mod_perl processes. Please refer to the *top(1)* and *ps(1)* manpages for more information.

You probably agree that using *top(1)* and *ps(1)* is cumbersome if you want to use memory-size sampling during the benchmark test. We want to have a way to print memory sizes during program execution at the desired places. The GTop module, which is a Perl glue to the libgtop library, is exactly what we need for that task.

You are fortunate if you run Linux or any of the BSD flavors, as the libgtop C library from the GNOME project is supported on those platforms. This library provides an

* You can tell *top* to sort the entries by memory usage by pressing *M* while viewing the *top* screen.

API to access various system-wide and process-specific information. (Some other operating systems also support `libgtop`.)

With `GTop`, if we want to print the memory size of the current process we'd just execute:

```
use GTop ();
print GTop->new->proc_mem($$)->size;
```

`$$` is the Perl special variable that gives the process ID (PID) of the currently running process.

If you want to look at some other process and you have the necessary permission, just replace `$$` with the other process's PID and you can peek inside it. For example, to check the shared size, you'd do:

```
print GTop->new->proc_mem($$)->share;
```

Let's try to run some tests:

```
panic% perl -MGTop -e 'my $g = GTop->new->proc_mem($$); \
  printf "%5.5s => %d\n",$_,$g->$_( ) for qw(size share vsize rss)'

 size => 1519616
share => 1073152
vsize => 2637824
  rss => 1515520
```

We have just printed the memory sizes of the process: the real, the shared, the virtual, and the resident (not swapped out).

There are many other things `GTop` can do for you—please refer to its manpage for more information. We are going to use this module in our performance tuning tips later in this chapter, so you will be able to exercise it a lot.

If you are running a true BSD system, you may use `BSD::Resource::getrusage` instead of `GTop`. For example:

```
print "used memory = ".(BSD::Resource::getrusage)[2]."\n"
```

For more information, refer to the `BSD::Resource` manpage.

The `Apache::VMonitor` module, with the help of the `GTop` module, allows you to watch all your system information using your favorite browser, from anywhere in the world, without the need to *telnet* to your machine. If you are wondering what information you can retrieve with `GTop`, you should look at `Apache::VMonitor`, as it utilizes a large part of the API `GTop` provides.

Apache::Status and Measuring Code Memory Usage

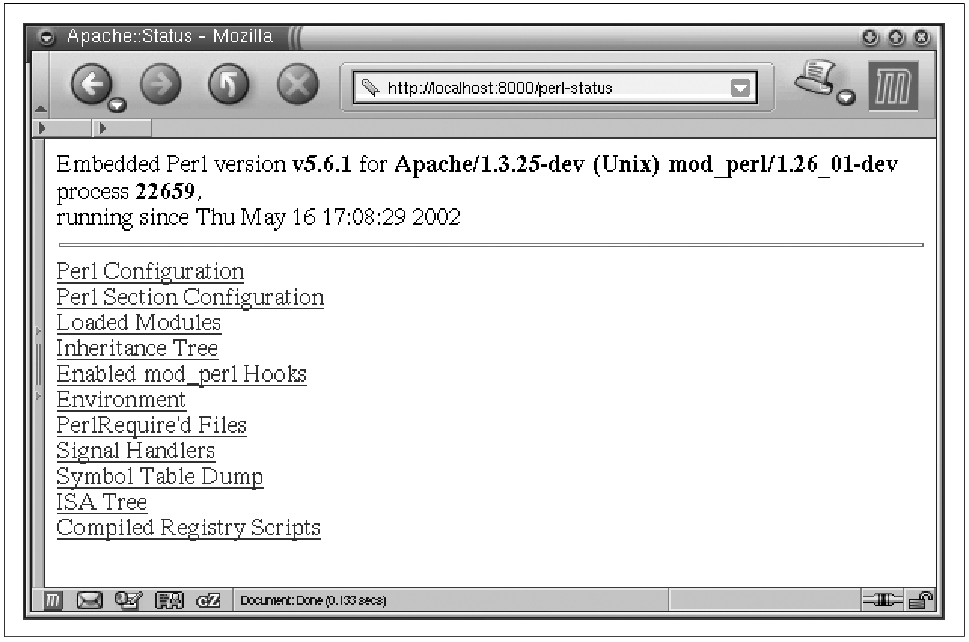
The `Apache::Status` module allows you to peek inside the Perl interpreter in the Apache web server. You can watch the status of the Perl interpreter: what modules and Registry scripts are compiled in, the content of variables, the sizes of the subroutines, and more.

To configure this module you should add the following section to your *httpd.conf* file:

```
<Location /perl-status>
    SetHandler perl-script
    PerlHandler +Apache::Status
</Location>
```

and restart Apache.

Now when you access the location *http://localhost:8000/perl-status* you will see a menu (shown in Figure 9-1) that leads you into various sections that will allow you to explore the innards of the Perl interpreter.


Apache::Status - Mozilla
http://localhost:8000/perl-status

Embedded Perl version **v5.6.1** for **Apache/1.3.25-dev (Unix) mod_perl/1.26_01-dev** process **22659**,
running since Thu May 16 17:08:29 2002

Perl Configuration
Perl Section Configuration
Loaded Modules
Inheritance Tree
Enabled mod_perl Hooks
Environment
PerlRequire'd Files
Signal Handlers
Symbol Table Dump
ISA Tree
Compiled Registry Scripts

Document: Done (0.133 secs)

Figure 9-1. Main menu for Apache::Status

When you use this module for debugging, it's best to run the web server in single-server mode (*httpd -X*). If you don't you can get confused, because various child processes might show different information. It's simpler to work with a single process.

To enable the `Apache::Status` modules to present more exotic information, make sure that the following modules are installed: `Data::Dumper`, `Apache::Peek`, `Devel::Peek`, `B::LexInfo`, `B::Deparse`, `B::Terse`, and `B::TerseSize`. Some of these modules are bundled with Perl; others should be installed by hand.

When you have the aforementioned modules installed, add these directives to your *httpd.conf* file:

```
PerlSetVar StatusOptionsAll On
PerlSetVar StatusDumper On
PerlSetVar StatusPeek On
PerlSetVar StatusLexInfo On
PerlSetVar StatusDeparse On
PerlSetVar StatusDeparseOptions "-p -sC"
PerlSetVar StatusTerse On
PerlSetVar StatusTerseSize On
PerlSetVar StatusTerseSizeMainSummary On
```

and restart Apache. Alternatively, if you enable all the options, you can use the option `StatusOptionsAll` to replace all the options that can be `On` or `Off`, so you end up with just these two lines:

```
PerlSetVar StatusOptionsAll On
PerlSetVar StatusDeparseOptions "-p -sC"
```

When you explore the contents of the compiled Perl module or Registry script, at the bottom of the screen you will see a Memory Usage link. When you click on it, you will be presented with a list of funtions in the package. For each function, the size and the number of OP codes will be shown.

For example, let's create a module that prints the contents of the `%ENV` hash. This module is shown in Example 9-6.

Example 9-6. Book/DumpEnv.pm

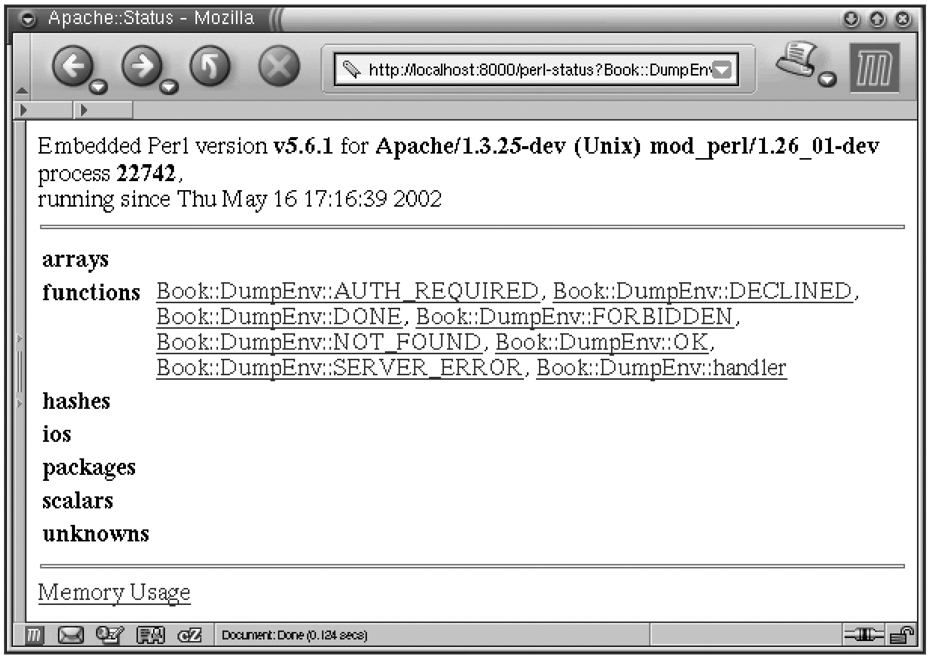
```
package Book::DumpEnv;
use strict;
use Apache::Constants qw(:common);
sub handler {
    shift->send_http_header('text/plain');
    print map {"$_ => $ENV{$_}\n"} keys %ENV;
    return OK;
}
1;
```

Now add the following to *httpd.conf*:

```
<Location /dumpenv>
    SetHandler perl-script
    PerlHandler +Book::DumpEnv
</Location>
```

Restart the server in single-server mode (*httpd -X*), request the URL *http://localhost:8000/dumpenv*, and you will see that the contents of `%ENV` are displayed.

Now it's time to peek inside the `Book::DumpEnv` package inside the Perl interpreter. Issue the request to *http://localhost:8000/perl-status*, click on the "Loaded Modules" menu item, and locate `Book::DumpEnv` on the displayed page. Click on it to request a page at the URI *http://localhost:8000/perl-status?Book::DumpEnv*. You will see the screen shown in Figure 9-2.


Apache::Status - Mozilla
http://localhost:8000/perl-status?Book::DumpEnv
Document: Done (0.124 secs)

Embedded Perl version **v5.6.1** for **Apache/1.3.25-dev (Unix) mod_perl/1.26_01-dev**
process **22742**,
running since Thu May 16 17:16:39 2002

arrays
functions Book::DumpEnv::AUTH_REQUIRED, Book::DumpEnv::DECLINED, Book::DumpEnv::DONE, Book::DumpEnv::FORBIDDEN, Book::DumpEnv::NOT_FOUND, Book::DumpEnv::OK, Book::DumpEnv::SERVER_ERROR, Book::DumpEnv::handler
hashes
ios
packages
scalars
unknowns

Memory Usage

Figure 9-2. Data structures compiled in the module

You can see seven functions that were imported with:

```
use Apache::Constants qw(:common);
```

and a single function that we have created, called `handler`. No other Perl variable types were created in the package `Book::DumpEnv`.

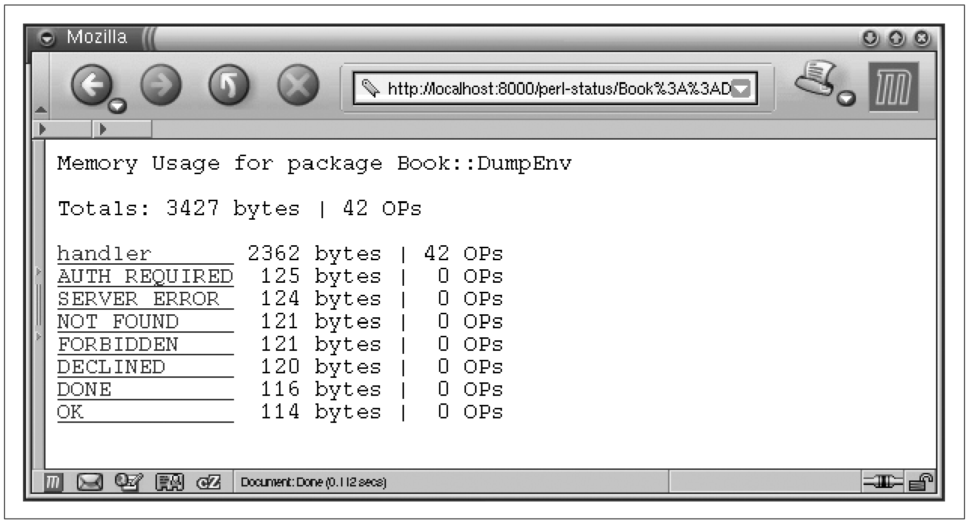
Now click on the "Memory Usage" link at the bottom of the page. The screen shown in Figure 9-3 will be rendered.

So you can see that `Book::DumpEnv` takes 3,427 bytes in memory, whereas the `handler` function takes 2,362 bytes.

Is this all? No, we can go even further inside the code and learn the syntax tree size (i.e., what opcodes construct each line of the source code and how many bytes each source-code line consumes). If we click on `handler` we will see the syntax tree of this function, and how much memory each Perl OPcode and line of code take. For example, in Figure 9-4 we can see that line 7, which corresponds to this source-code line in *Book/DumpEnv.pm*:

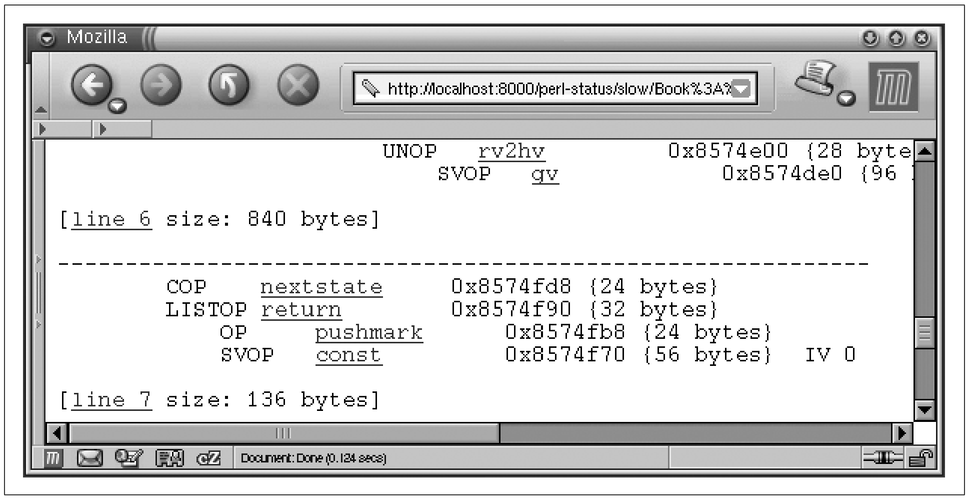
```
7:   return OK;
```

takes up 136 bytes of memory.


Mozilla
http://localhost:8000/perl-status/Book%3A%3AD
Document: Done (0.112 secs)

```
Memory Usage for package Book::DumpEnv

Totals: 3427 bytes | 42 OPs

handler        2362 bytes | 42 OPs
AUTH_REQUIRED   125 bytes |  0 OPs
SERVER_ERROR    124 bytes |  0 OPs
NOT_FOUND       121 bytes |  0 OPs
FORBIDDEN       121 bytes |  0 OPs
DECLINED        120 bytes |  0 OPs
DONE            116 bytes |  0 OPs
OK              114 bytes |  0 OPs
```

Figure 9-3. Book::DumpEnv memory usage

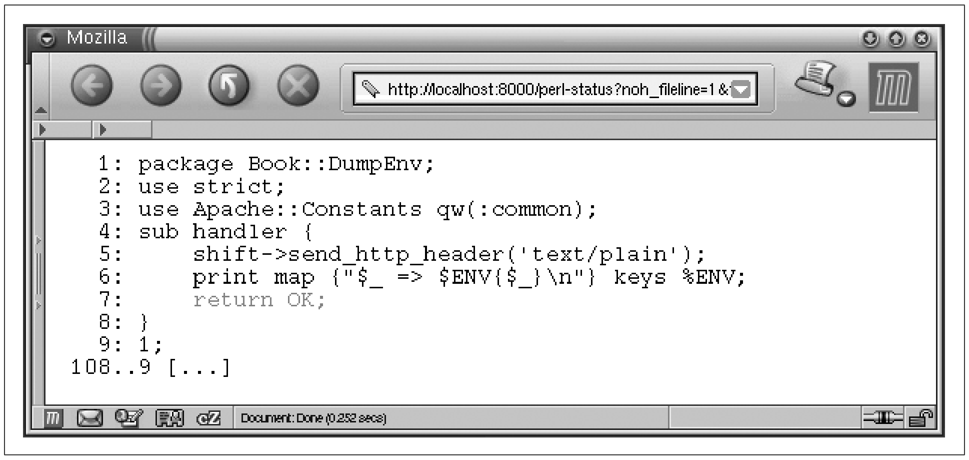

Mozilla
http://localhost:8000/perl-status/slow/Book%3A%
Document: Done (0.124 secs)

```
                         UNOP   rv2hv        0x8574e00 {28 byte
                             SVOP   gv           0x8574de0 {96 

[line 6 size: 840 bytes]

------------------------------------------------------------
        COP    nextstate     0x8574fd8 {24 bytes}
        LISTOP return        0x8574f90 {32 bytes}
            OP     pushmark      0x8574fb8 {24 bytes}
            SVOP   const         0x8574f70 {56 bytes}  IV 0

[line 7 size: 136 bytes]
```

Figure 9-4. Per line and Perl OPcode memory usage

We found the corresponding source-code line by clicking the "line 7" hyperlink shown in Figure 9-4, which displays the source code of the module with the relevant line highlighted (see Figure 9-5).

Now you should be able to to find out how much memory each subroutine or even each individual source line of Perl code consumes. This will allow you to optimize memory usage by comparing several implemenations of the same algorithm and choosing the one that consumes the smallest amount of memory.


Mozilla
http://localhost:8000/perl-status?noh_fileline=1&
Document: Done (0.252 secs)

```
  1: package Book::DumpEnv;
  2: use strict;
  3: use Apache::Constants qw(:common);
  4: sub handler {
  5:     shift->send_http_header('text/plain');
  6:     print map {"$_ => $ENV{$_}\n"} keys %ENV;
  7:     return OK;
  8: }
  9: 1;
108..9 [...]
```

Figure 9-5. Source code corresponding to the OPcodes

Code Profiling Techniques

The profiling process helps you to determine which subroutines (or just snippets of code) take longest to execute and which subroutines are called most often. You will probably want to optimize these.

When do you need to profile your code? You do that when you suspect that some part of your code is called very often and maybe there is a need to optimize it, which could significantly improve the overall performance.

Profiling with Devel::DProf

`Devel::DProf` collects information on the execution time of a Perl script and of the subroutines in that script.

Let's take for example the `diagnostics` pragma and measure the impact of its usage on the program compilation and execution speed. This pragma extends the terse diagnostics normally emitted by both the Perl compiler and the Perl interpreter, augmenting them with the more verbose and endearing descriptions found in the *perldiag* manpage. We have claimed that this pragma should not be used on a production server. We are going to use `Devel::DProf` to explain our claim.

We will run a benchmark, once with diagnostics enabled and once disabled, on a subroutine called `test_code( )`.

The code inside the subroutine does either a lexical or a numeric comparison of two strings. It assigns one string to another if the condition tests true, but the condition is always false. To demonstrate the `diagnostics` pragma overhead, the comparison operator that we use in Example 9-7 is intentionally wrong. It should be a string comparison (`eq`), and we use a numeric one (`= =`).

Example 9-7. bench_diagnostics.pl

```
use Benchmark;
use diagnostics;
use strict;

my $count = 50000;

disable diagnostics;
my $t1 = timeit($count,\&test_code);

enable  diagnostics;
my $t2 = timeit($count,\&test_code);

print "Off: ",timestr($t1),"\n";
print "On : ",timestr($t2),"\n";

sub test_code {
    my ($a, $b) = qw(foo bar);
    my $c;
    if ($a == $b) {
        $c = $a;
    }
}
```

For only a few lines of code we get:

```
Off:  1 wallclock secs ( 0.81 usr +  0.00 sys =  0.81 CPU)
On : 13 wallclock secs (12.54 usr +  0.01 sys = 12.55 CPU)
```

With diagnostics enabled, the subroutine `test_code( )` is 16 times slower (12.55/0.81: remember that we're talking in CPU time, not wallclock seconds) than with diagnostics disabled!

Now let's fix the comparison the way it should be, by replacing `==` with `eq`, so we get:

```
my ($a, $b) = qw(foo bar);
my $c;
if ($a eq $b) {
    $c = $a;
}
```

and run the same benchmark again:

```
Off:  1 wallclock secs ( 0.57 usr +  0.00 sys =  0.57 CPU)
On :  1 wallclock secs ( 0.56 usr +  0.00 sys =  0.56 CPU)
```

Now there is no overhead at all. The `diagnostics` pragma slows things down only when warnings are generated.

After we have verified that using the `diagnostics` pragma might add a big overhead to execution runtime, let's use code profiling to understand why this happens. We use `Devel::DProf` to profile the code shown in Example 9-8.

Example 9-8. diagnostics.pl

```
use diagnostics;

test_code();
sub test_code {
    my($a, $b) = qw(foo bar);
    my $c;
    if ($a == $b) {
        $c = $a;
    }
}
```

Run it with the profiler enabled, and then create the profiling statistics with the help of *dprofpp*:

```
panic% perl -d:DProf diagnostics.pl
panic% dprofpp

Total Elapsed Time = 0.342236 Seconds
  User+System Time = 0.335420 Seconds
Exclusive Times
%Time ExclSec CumulS #Calls sec/call Csec/c  Name
 92.1   0.309  0.358      1   0.3089 0.3578  main::BEGIN
 14.9   0.050  0.039   3161   0.0000 0.0000  diagnostics::unescape
 2.98   0.010  0.010      2   0.0050 0.0050  diagnostics::BEGIN
 0.00   0.000 -0.000      2   0.0000      -  Exporter::import
 0.00   0.000 -0.000      2   0.0000      -  Exporter::export
 0.00   0.000 -0.000      1   0.0000      -  Config::BEGIN
 0.00   0.000 -0.000      1   0.0000      -  Config::TIEHASH
 0.00   0.000 -0.000      2   0.0000      -  Config::FETCH
 0.00   0.000 -0.000      1   0.0000      -  diagnostics::import
 0.00   0.000 -0.000      1   0.0000      -  main::test_code
 0.00   0.000 -0.000      2   0.0000      -  diagnostics::warn_trap
 0.00   0.000 -0.000      2   0.0000      -  diagnostics::splainthis
 0.00   0.000 -0.000      2   0.0000      -  diagnostics::transmo
 0.00   0.000 -0.000      2   0.0000      -  diagnostics::shorten
 0.00   0.000 -0.000      2   0.0000      -  diagnostics::autodescribe
```

It's not easy to see what is responsible for this enormous overhead, even if `main::BEGIN` seems to be running most of the time. To get the full picture we must see the OPs tree, which shows us who calls whom, so we run:

```
panic% dprofpp -T
```

The output is:

```
main::BEGIN
  diagnostics::BEGIN
     Exporter::import
        Exporter::export
  diagnostics::BEGIN
     Config::BEGIN
     Config::TIEHASH
     Exporter::import
```

```
        Exporter::export
  Config::FETCH
  Config::FETCH
  diagnostics::unescape
  .....................
  3159 times [diagnostics::unescape] snipped
  .....................
  diagnostics::unescape
  diagnostics::import
diagnostics::warn_trap
  diagnostics::splainthis
     diagnostics::transmo
     diagnostics::shorten
     diagnostics::autodescribe
main::test_code
  diagnostics::warn_trap
     diagnostics::splainthis
        diagnostics::transmo
        diagnostics::shorten
        diagnostics::autodescribe
  diagnostics::warn_trap
     diagnostics::splainthis
        diagnostics::transmo
        diagnostics::shorten
       diagnostics::autodescribe
```

So we see that 2 executions of `diagnostics::BEGIN` and 3,161 of `diagnostics::unescape` are responsible for most of the running overhead.

If we comment out the `diagnostics` module, we get:

```
Total Elapsed Time = 0.079974 Seconds
  User+System Time = 0.059974 Seconds
Exclusive Times
%Time ExclSec CumulS #Calls sec/call Csec/c  Name
 0.00   0.000 -0.000      1   0.0000      -  main::test_code
```

It is possible to profile code running under mod_perl with the `Devel::DProf` module, available on CPAN. However, you must have `PerlChildExitHandler` enabled during the mod_perl build process. When the server is started, `Devel::DProf` installs an `END` block to write the *tmon.out* file. This block will be called at server shutdown. Here is how to start and stop a server with the profiler enabled:

```
panic% setenv PERL5OPT -d:DProf
panic% httpd -X -d `pwd` &
... make some requests to the server here ...
panic% kill `cat logs/httpd.pid`
panic% unsetenv PERL5OPT
panic% dprofpp
```

The `Devel::DProf` package is a Perl code profiler. It will collect information on the execution time of a Perl script and of the subroutines in that script (remember that `print()` and `map()` are just like any other subroutines you write, but they come bundled with Perl!).

Another approach is to use Apache::DProf, which hooks Devel::DProf into mod_perl. The Apache::DProf module will run a Devel::DProf profiler inside the process and write the *tmon.out* file in the directory *$ServerRoot/logs/dprof/$$* (make sure that it's writable by the server!) when the process is shut down (where *$$* is the PID of the process). All it takes to activate this module is to modify *httpd.conf*.

You can test for a command-line switch in *httpd.conf*. For example, to test if the server was started with *-DPERLDPROF*, use:

```
<Location /perl>
    SetHandler perl-script
    PerlHandler Apache::Registry
    <IfDefine PERLDPROF>
        PerlModule Apache::DProf
    </IfDefine>
</Location>
```

And to activate profiling, use:

```
panic% httpd -X -DPERLDPROF &
```

Remember that any PerlHandler that was pulled in before Apache::DProf in the *httpd.conf* or *startup.pl* file will not have code-debugging information inserted. To run *dprofpp*, *chdir* to *$ServerRoot/logs/dprof/$$*[*] and run:

```
panic% dprofpp
```

Use the command-line options for *dropfpp(1)* if a nondefault output is desired, as explained in the *dropfpp* manpage. You might especially want to look at the *-r* switch to display wallclock times (more relevant in a web-serving environment) and the *-l* switch to sort by number of subroutine calls.

If you are running Perl 5.6.0 or higher, take a look at the new module Devel::Profiler (Version 0.04 as of this writing), which is supposed to be a drop-in replacement for Apache::DProf, with improved functionality and stability.

Profiling with Devel::SmallProf

The Devel::SmallProf profiler is focused on the time taken for a program run on a line-by-line basis. It is called "small" because it's supposed to impose very little extra load on the machine (speed- and memory-wise) while profiling the code.

Let's take a look at the simple example shown in Example 9-9.

Example 9-9. table_gen.pl

```
for (1..1000) {
    my @rows = ();
    push @rows, Tr(  map { td($_) } 'a'..'d' );
```

[*] Look up the ServerRoot directive's value in *httpd.conf* to figure out what your $ServerRoot is.

Example 9-9. table_gen.pl (continued)

```
    push @rows, Tr(  map { td($_) } 'e'..'h' );
    my $var = table(@rows);
}
sub table { my @rows  = @_;    return "<table>\n@rows</table>\n";}
sub Tr    { my @cells = @_;    return "<tr>@cells</tr>\n";       }
sub td    { my $cell  = shift; return "<td>$cell</td>";          }
```

It creates the same HTML table in `$var`, with the cells of the table filled with single letters. The functions `table()`, `Tr()`, and `td()` insert the data into appropriate HTML tags. Notice that we have used `Tr()` and not `tr()`, since the latter is a built-in Perl function, and we have used the same function name as in `CGI.pm` that does the same thing. If we print `$var` we will see something like this:

```
<table>
 <tr><td>a</td> <td>b</td> <td>c</td> <td>d</td></tr>
 <tr><td>e</td> <td>f</td> <td>g</td> <td>h</td></tr>
</table>
```

We have looped a thousand times through the same code in order to get a more precise speed measurement. If the code runs very quickly we won't be able to get any meaningful results from just one loop.

If we run this code with `Devel::SmallProf`:

```
panic% perl -d:SmallProf table_gen.pl
```

we get the following output in the autogenerated *smallprof.out* file:

```
count wall tm  cpu time line
  1001 0.003855 0.030000     1:  for (1..1000) {
  1000 0.004823 0.040000     2:      my @rows = ();
  5000 0.272651 0.410000     3:      push @rows, Tr(  map { td($_) }
  5000 0.267107 0.360000     4:      push @rows, Tr(  map { td($_) }
  1000 0.067115 0.120000     5:      my $var = table(@rows);
     0 0.000000 0.000000     6:  }
  3000 0.033798 0.080000     7:  sub table { my @rows  = @_;    return
  6000 0.078491 0.120000     8:  sub Tr    { my @cells = @_;    return
 24000 0.267353 0.490000     9:  sub td    { my $cell  = shift; return
     0 0.000000 0.000000    10:
```

We can see in the *CPU time* column that Perl spends most of its time in the `td()` function; it's also the code that's visited by Perl the most times. In this example we could find this out ourselves without much effort, but if the code is longer it will be harder to find the lines of code where Perl spends most of its time. So we sort the output by the third column as a numerical value, in descending order:

```
panic% sort -k 3nr,3 smallprof.out | less
  24000 0.267353 0.490000     9:  sub td    { my $cell  = shift; return
   5000 0.272651 0.410000     3:      push @rows, Tr(  map { td($_) }
   5000 0.267107 0.360000     4:      push @rows, Tr(  map { td($_) }
   1000 0.067115 0.120000     5:      my $var = table(@rows);
   6000 0.078491 0.120000     8:  sub Tr    { my @cells = @_;    return
   3000 0.033798 0.080000     7:  sub table { my @rows  = @_;    return
```

```
    1000 0.004823 0.040000     2:      my @rows = ();
    1001 0.003855 0.030000     1:  for (1..1000) {
```

According to the Devel::SmallProf manpage, the wallclock's measurements are fairly accurate (we suppose that they're correct on an unloaded machine), but CPU clock time is always more accurate. That's because if it takes more than one CPU time slice for a directive to complete, the time that some other process uses CPU is counted in the wallclock counts. Since the load on the same machine may vary greatly from moment to moment, it's possible that if we rerun the same test a few times we will get inconsistent results.

Let's try to improve the td( ) function and at the same time the Tr( ) and table( ) functions. We will not copy the passed arguments, but we will use them directly in all three functions. Example 9-10 shows the new version of our script.

Example 9-10. table_gen2.pl

```
for (1..1000) {
    my @rows = ();
    push @rows, Tr(  map { td($_) } 'a'..'d' );
    push @rows, Tr(  map { td($_) } 'e'..'h' );
    my $var = table(@rows);
}
sub table { return "<table>\n@_</table>\n";}
sub Tr    { return "<tr>@_</tr>\n";      }
sub td    { return "<td>@_</td>";        }
```

Now let's rerun the code with the profiler:

```
panic% perl -d:SmallProf table_gen2.pl
```

The results are much better now—only 0.34 CPU clocks are spent in td( ), versus 0.49 in the earlier run:

```
panic% sort -k 3nr,3 smallprof.out | less
   5000 0.279138 0.400000  4:      push @rows, Tr(  map { td($_) }
  16000 0.241350 0.340000  9:  sub td    { return "<td>@_</td>";        }
   5000 0.269940 0.320000  3:      push @rows, Tr(  map { td($_) }
   4000 0.050050 0.130000  8:  sub Tr    { return "<tr>@_</tr>\n";      }
   1000 0.065324 0.080000  5:      my $var = table(@rows);
   1000 0.006650 0.010000  2:      my @rows = ();
   2000 0.020314 0.030000  7:  sub table{ return "<table>\n@_</table>\n";}
   1001 0.006165 0.030000  1:  for (1..1000) {
```

You will also notice that Devel::SmallProf reports that the functions were executed different numbers of times in the two runs. That's because in our original example all three functions had two statements on each line, but in the improved version they each had only one. Devel::SmallProf looks at the code after it's been parsed and optimized by Perl—thus, if some optimizations took place, it might not be exactly the same as the code that you wrote.

In most cases you will probably find `Devel::DProf` more useful than `Devel::SmallProf`, as it allows you to analyze the code by subroutine and not by line.

Just as there is the `Apache::DProf` equivalent for `Devel::DProf`, there is the `Apache::SmallProf` equivalent for `Devel::SmallProf`. It uses a configuration similar to `Apache::DProf`—i.e., it is registered as a `PerlFixupHandler`—but it also requires `Apache::DB`. Therefore, to use it you should add the following configuration to *httpd.conf*:

```
<Perl>
    if (Apache->define('PERLSMALLPROF')) {
        require Apache::DB;
        Apache::DB->init;
    }
</Perl>

<Location /perl>
    SetHandler perl-script
    PerlHandler Apache::Registry
    <IfDefine PERLSMALLPROF>
        PerlFixupHandler Apache::SmallProf
    </IfDefine>
</Location>
```

Now start the server:

```
panic% httpd -X -DPERLSMALLPROF &
```

This will activate `Apache::SmallProf::handler` during the request. As a result, the profile files will be written to the *$ServerRoot/logs/smallprof/* directory. Unlike with `Devel::SmallProf`, the profile is split into several files based on package name. For example, if `CGI.pm` was used, one of the generated profile files will be called *CGI.pm.prof*.

References

- The `diagnostics` pragma is a part of the Perl distribution. See *perldoc diagnostics* for more information about the program, and *perldoc perldiag* for Perl diagnostics; this is the source of this pragma's information.
- *ab(1)* (ApacheBench) comes bundled with the Apache web server and is available from *http://httpd.apache.org/*.
- *httperf(1)* is available from *http://www.hpl.hp.com/personal/David_Mosberger./httperf.html*.
- *http_load(1)* is available from *http://www.acme.com/software/http_load/*.
- BenchWeb (*http://www.netlib.org/benchweb/*) is a good starting point for finding information about computer system performance benchmarks, benchmark results, and benchmark code.

- The `libgtop` library (*ftp://ftp.gnome.org/pub/GNOME/stable/sources/gtop/*) is a part of the GNOME project (*http://www.gnome.org/*). Also try *http://fr.rpmfind.net/linux/rpm2html/search.php?query=libgtop*.
- Chapter 3 of *Web Performance Tuning*, by Patrick Killelea (O'Reilly).
- Chapter 9 of *mod_perl Developer's Cookbook*, by Geoffrey Young, Paul Lindner, and Randy Kobes (Sams).