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Optimizing C/C++ programs using the GProf profiler

Profiling with GProf

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Abstract:

One of the most important things to keep in mind while optimizing an application is: optimize where it counts. It is no use to spend hours optimizing a piece of code that usually runs for only 0.04 seconds anyway.

GProf provides a surprisingly easy way to profile your C/C++ application and spot the interesting pieces right away. A small case study shows how GProf was used to reduce the running time of a real–world application from over 3 minutes to under 5 seconds, by identifying 2 data structures as important and optimizing those.

Historically, the program goes back as far as 1982, when it was introduced on the the SIGPLAN Symposium on Compiler Construction. It is now a standard tool available on virtually all flavors of UNIX.

Profiling in a nutshell

The concept of profiling is a very simple one: by recording at what times a program enters and leaves functions, it's possible to calculate in what parts of the program it spends most of its time. Now making this measurement sounds like something that requires a lot of effort – luckily, nothing is further from the truth! It's as simple as compiling with an extra gcc flag ('–pg'), running the program (to collect the profiling data), and running 'gprof' on the resulting statistics file to present it in a more convenient manner.

Case study: Pathalizer

I use a real–world application as an example here, part of pathalizer: The `event2dot` executable which translates a pathalizer 'events' file to a graphviz 'dot' file.

In short, it reads the events from a file, storing them as graphs (with pages as nodes, and transitions between pages as edges). This collection of graphs is then 'summarized' into one big graph, which is printed in the graphviz 'dot' format.

Timing the application

First, we run the program we want to optimize without profiling, and measure how long it takes. The example sources used, along with a sample input of considerable size (55000 lines), are provided.

On my machine, a run of `event2dot` took more than 3 minutes on this input:

```
real    3m36.316s
user    0m55.590s
sys     0m1.070s
```

The profiling

Enabling gprof profiling is done by adding the '−pg' flag at compile time. We recompile the application with this flag:

```
g++ −pg dotgen.cpp readfile.cpp main.cpp graph.cpp config.cpp −o event2dot
```

We can now run `event2dot` again on our test−eventsfile. During this run, profiling information on `event2dot` will be gathered, and a 'gmon.out' file will be generated. We view the result by running 'gprof `event2dot` | less'.

gprof now shows us the following functions are important:

```
 % cumulative  self              self     total
 time seconds  seconds  calls s/call s/call name
43.32   46.03  46.03 339952989   0.00  0.00 CompareNodes(Node *,Node *)
25.06   72.66  26.63     55000   0.00  0.00 getNode(char *,NodeListNode *&)
16.80   90.51  17.85 339433374   0.00  0.00 CompareEdges(Edge *,AnnotatedEdge *)
12.70  104.01  13.50     51987   0.00  0.00 addAnnotatedEdge(AnnotatedGraph *,Edge *)
 1.98  106.11   2.10     51987   0.00  0.00 addEdge(Graph *,Node *,Node *)
 0.07  106.18   0.07         1   0.07  0.07 FindTreshold(AnnotatedEdge *,int)
 0.06  106.24   0.06         1   0.06 28.79 getGraphFromFile(char *,NodeListNode *&,Config *)
 0.02  106.26   0.02         1   0.02 77.40 summarize(GraphListNode *,Config *)
 0.00  106.26   0.00     55000   0.00  0.00 FixName(char *)
```

The most interesting column is the first one: this is the percentage of the running time of the program that is spent in this function.

The optimization

This shows the program spends almost half its time in `CompareNodes`. A quick grep shows CompareNodes is called only by `CompareEdges`, which in turn is only called by `addAnnotatedEdge` – both of which are also in this list. This looks like an interesting point to do some optimizing.

We notice `addAnnotatedEdge` is traversing a linked list. Though easy to implement, a linked list is not the best of data types. We decide to replace g−>edges with a binary tree: this should make finding stuff in the structure much faster, while still being able to 'walk' through it.

Results

We see this indeed reduces the execution time:

```
real     2m19.314s
user     0m36.370s
sys      0m0.940s
```

A second pass

Running gprof again reveals:

```
%   cumulative self              self    total
 time    seconds seconds calls   s/call  s/call name
87.01      25.25  25.25  55000     0.00     0.00 getNode(char *,NodeListNode *&)
10.65      28.34   3.09  51987     0.00     0.00 addEdge(Graph *,Node *,Node *)
```

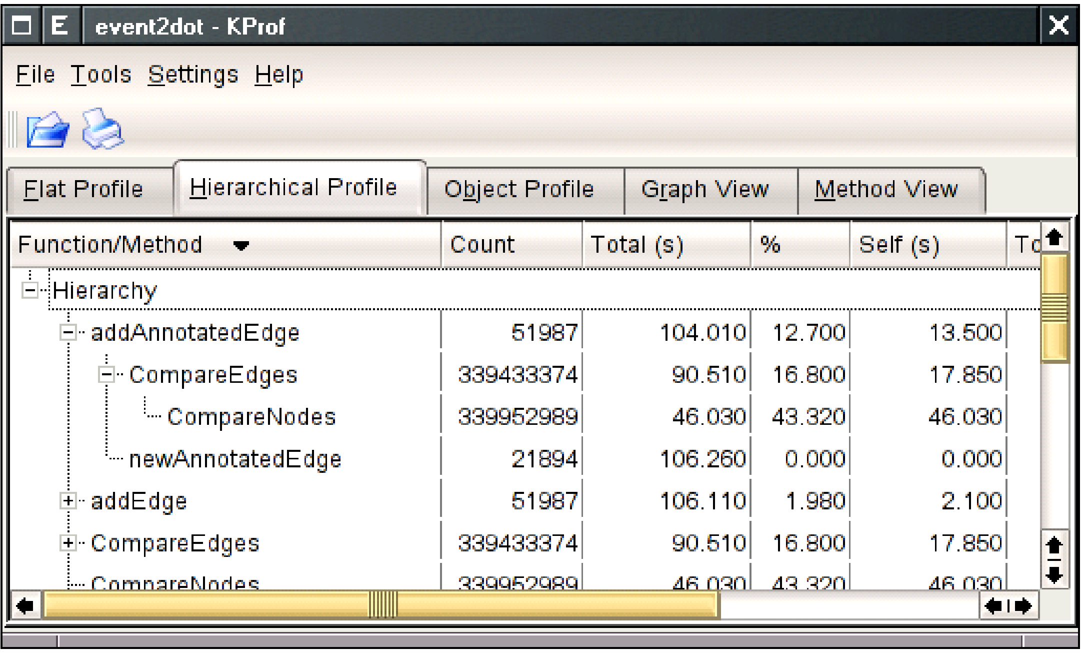
It looks like the functions that used to take up more than half of the time have now been reduced to irrelevant details! Let's try this again: we replace the NodeList by a NodeHashTable.

This is also clearly a big improvement:

```
real     0m3.269s
user     0m0.830s
sys      0m0.090s
```

Other C/C++ profilers

There are several profilers available that use the gprof data, for example KProf (screenshot) and cgprof. Though the graphical views are a nice touch, personally I think the commandline gprof is more convenient.



Function/Method	Count	Total (s)	%	Self (s)
Hierarchy				
addAnnotatedEdge	51987	104.010	12.700	13.500
CompareEdges	339433374	90.510	16.800	17.850
CompareNodes	339952989	46.030	43.320	46.030
newAnnotatedEdge	21894	106.260	0.000	0.000
addEdge	51987	106.110	1.980	2.100
CompareEdges	339433374	90.510	16.800	17.850
CompareNodes	339952989	46.030	43.320	46.030

Profiling other languages

We covered profiling C/C++ applications with gprof here, but similar things can be done for other languages: for Perl, you use the Devel::DProf module. Start your application with `perl -d:DProf mycode.pl` and view the results with `dprofpp`. If you can compile your Java program with gcj, you can just use gprof, however only single threaded Java code is currently supported.

Conclusion

We have seen that, using profiling, we can quickly find the portions of an application that would benefit from optimization. By optimizing where it counts, we have reduced the running time of the example application from 3m36 to less than 5 seconds.

References

- Pathalizer: http://pathalizer.sf.net
- KProf: http://kprof.sf.net
- cgprof: http://mvertes.free.fr
- Devel::DProf http://www.perldoc.com/perl5.8.0/lib/Devel/DProf.html
- gcj: http://gcc.gnu.org/java
- : pathalizer example files: download for article371

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