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May 28, 2021 | 04:50 #Go | #profiling | #benchmarks

Go Performance Tools Cheat Sheet

Go has a lot of tools available for you to understand where your application might be spending CPU time or allocating memory. I don't use these tools daily so I always end up searching for the same thing every time. This post aims to be a reference document for everything that Go has to provide.

We'll be using https://gitlab.com/steveazz-blog/go-performance-tools-cheat-sheet as a demo project and there are 3 implementations of the same thing, one more performant than the other.

- default
- better
- best

Benchmarks

One of the most popular ways to see if you improved something is to use Benchmarks which is built into Go.

In our demo project, there is already benchmarks avaiable and we can run them with a single command.

```
go test -bench=. -test.benchmem  ./rand/

goos: darwin
```

```
goarch: amd64
pkg: gitlab.com/steveazz/blog/go-performance-tools-cheat-sheet/rand
cpu: Intel(R) Core(TM) i7-6820HQ CPU @ 2.70GHz
BenchmarkHitCount100-8              3020            367016 ns/op          269
BenchmarkHitCount1000-8              326           3737517 ns/op         2696
BenchmarkHitCount100000-8              3         370797178 ns/op        2694
BenchmarkHitCount1000000-8             1        3857843580 ns/op        2697
PASS
ok      gitlab.com/steveazz/blog/go-performance-tools-cheat-sheet/rand 8.828s
```

Note: `-test.benchmem` is an optional flag to show memory allocations

Taking a closer look at what each column means:

```
BenchmarkHitCount100-8              3020            367016 ns/op
^____________________^ ^              ^                    ^
         |             |              |                    |
       Name   Number of CPUs     Total runs    Nanoseconds per operation
```

Comparing Benchmarks

Go created perf which provides benchstat so that you can compare to benchmark outputs together and it will give you the delta between them.

For example, let's compare the `main` and `best` branches.

```
# Run benchmarks on `main`
git checkout main
go test -bench=. -test.benchmem -count=5 ./rand/ > old.txt

# Run benchmarks on `best
git checkout best
go test -bench=. -test.benchmem -count=5 ./rand/ > new.txt

# Compare the two benchmark results
benchstat old.txt new.txt
name               old time/op    new time/op    delta
```

```
HitCount100-8          366µs ± 0%     103µs ± 0%  -71.89%  (p=0.008 n=5+5)
HitCount1000-8        3.66ms ± 0%    1.06ms ± 5%  -71.13%  (p=0.008 n=5+5)
HitCount100000-8       367ms ± 0%     104ms ± 1%  -71.70%  (p=0.008 n=5+5)
HitCount1000000-8      3.66s ± 0%     1.03s ± 1%  -71.84%  (p=0.016 n=4+5)

name                old alloc/op   new alloc/op   delta
HitCount100-8          270kB ± 0%      53kB ± 0%  -80.36%  (p=0.008 n=5+5)
HitCount1000-8        2.70MB ± 0%    0.53MB ± 0%  -80.39%  (p=0.008 n=5+5)
HitCount100000-8       270MB ± 0%      53MB ± 0%  -80.38%  (p=0.008 n=5+5)
HitCount1000000-8     2.70GB ± 0%    0.53GB ± 0%  -80.39%  (p=0.016 n=4+5)

name                old allocs/op  new allocs/op  delta
HitCount100-8          3.60k ± 0%     1.50k ± 0%  -58.33%  (p=0.008 n=5+5)
HitCount1000-8         36.0k ± 0%     15.0k ± 0%  -58.34%  (p=0.008 n=5+5)
HitCount100000-8       3.60M ± 0%     1.50M ± 0%  -58.34%  (p=0.008 n=5+5)
HitCount1000000-8      36.0M ± 0%     15.0M ± 0%  -58.34%  (p=0.008 n=5+5)
```

Notice that we pass the `-count` flag to run the benchmarks multiple times so it can get the mean of the runs.

pprof

Go comes with its own profiler where it will give you a better understanding of where the CPU time is being spent on or where the application is allocatingthe memory. Go samples these over some time for example it will look at the CPU/Memory usage every X nanoseconds for X amount of seconds.

Generating Profiles

Benchmarks

You can generate profiles using benchmarks that we have in the demo project.

CPU:

```
go test -bench=. -cpuprofile cpu.prof ./rand/
```

Memory:

```
go test -bench=. -memprofile mem.prof ./rand/
```

net/http/pprof package

If you are writing a webserver you can import the `net/http/pprof` and it will expose the `/debug/pprof` HTTP endpoints on the DefaultServeMux as we are doing in the demo application.

Make sure that your application is not sitting idle and doing work or receiving requests so that the profiler can sample calls, or you might end up with an empty profile since the application is idle.

```
# CPU profile
curl http://127.0.0.1:8080/debug/pprof/profile > /tmp/cpu.prof
# Heap profile
curl http://127.0.0.1:8080/debug/pprof/heap > /tmp/heap.prof
# Allocations profile
curl http://127.0.0.1:8080/debug/pprof/allocs > /tmp/allocs.prof
```

If you visit `/debug/pprof` it will give a list of all the available endpoints and what they mean.

runtime/pprof package

This is similar to the `net/http/pprof` where add it to your application, but instead of adding for all of the project, you can specify a specific code path where you want to generate the profile. This can be useful when you are only interested in a certain part of your application and you want to sample only that part of the application. To read how to use it check the go reference.

You might also use this to label your application which can help you understand the profile better.

Reading profiles

Now that we know how to generate profiles, let's see how we can read them to know what our application is doing.

The command that we will be using is `go tool pprof`.

Callgraph

For example to use the `/debug/pprof` endpoints that we have registered in our demo application, we can pass in the HTTP endpoint directly.

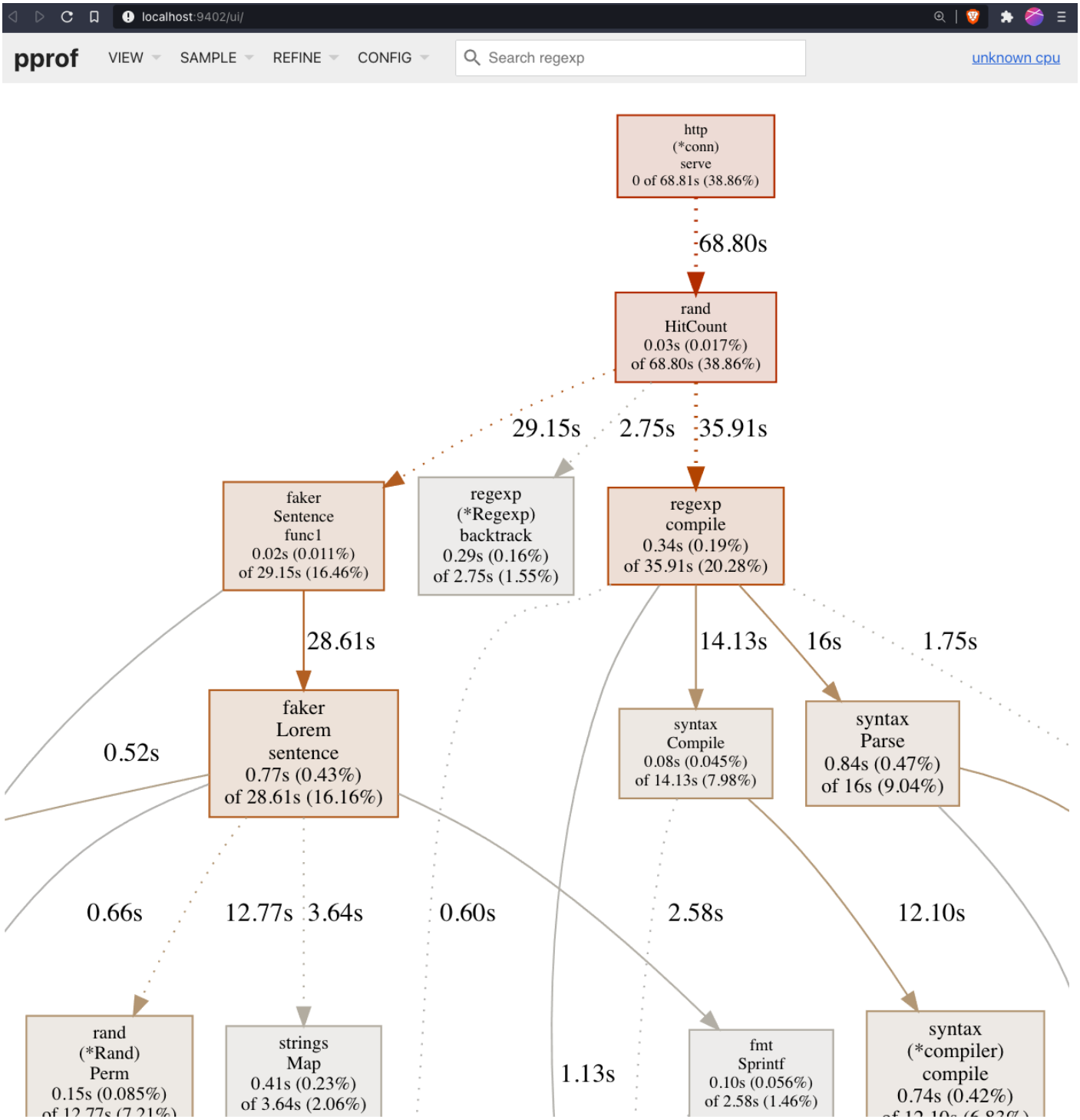
```
# Open new browser window with call graph after 30s profiling.
go tool pprof -http :9402 http://127.0.0.1:8080/debug/pprof/profile
```

Another option is to use `curl` to download the profile and then use `go tool` which might be useful to get profiles from production endpoints that aren't exposed to the public internet.

```
# Server.
curl http://127.0.0.1:8080/debug/pprof/profile > /tmp/cpu.prof
# Locally after you get it from the server.
go tool pprof -http :9402 /tmp/cpu.prof
```

Notice that in all the commands we are passing the `-http` flag, this is optional because by default this opens the CLI interface.

Below you can see our demo application call graph. To better understand what it means you should read Interpreting the Callgraph



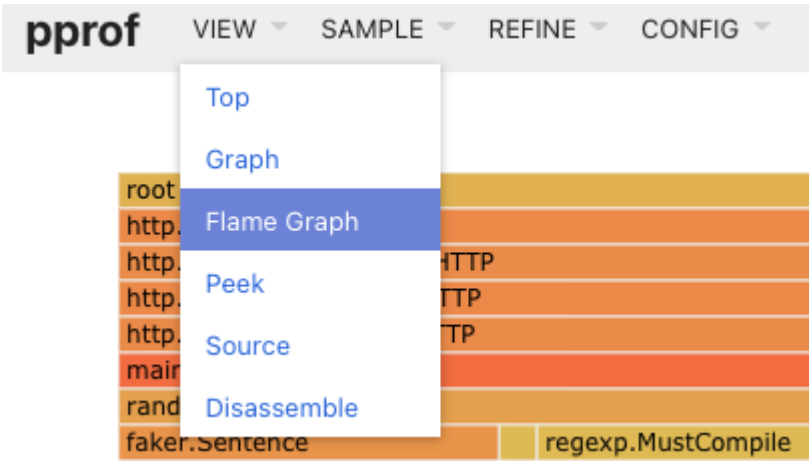
Flame graphs

The callgraph is useful to see what the program is calling and can also help you understand where the application is spending time. An alternative way of understanding where the CPU time or memory allocation is going is to use a Flame Graph.

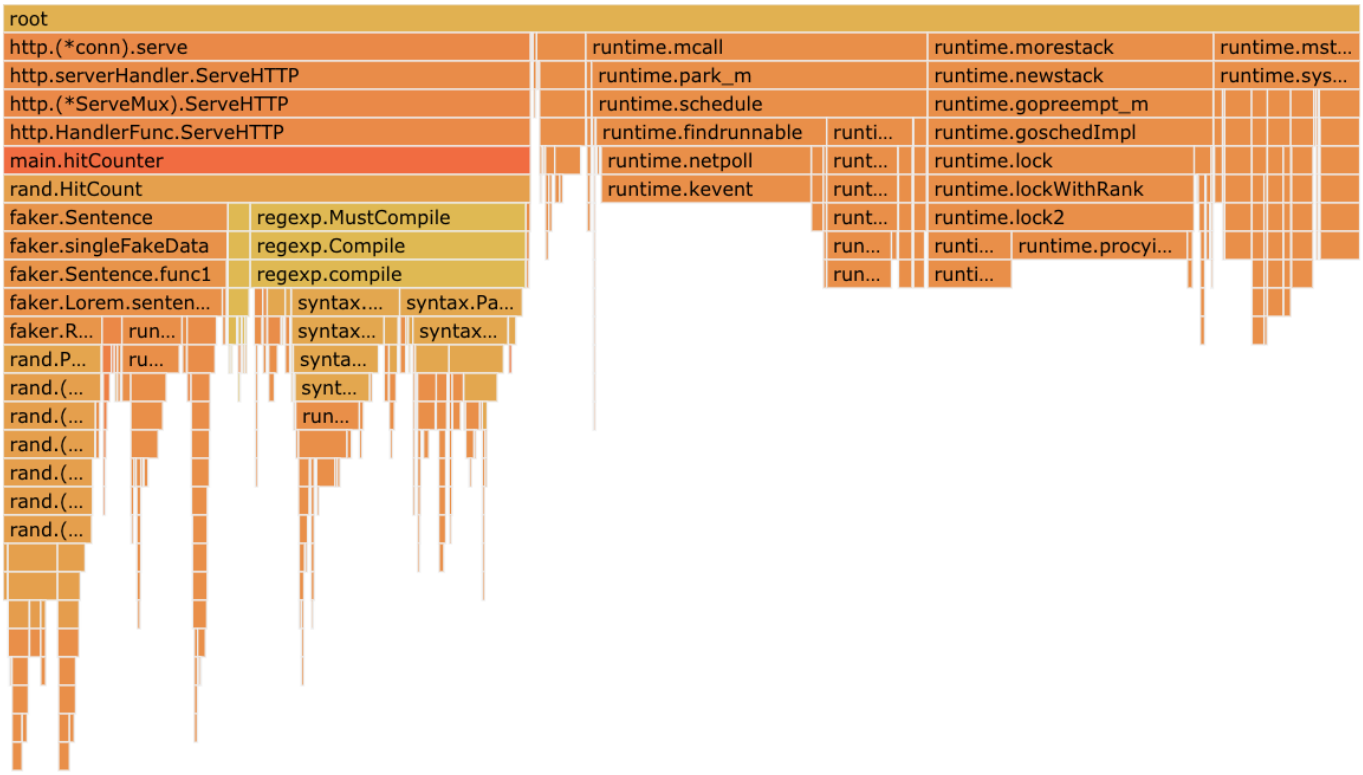
Using the same demo application let's run `go tool pprof` once more:

```
# From endpoint
go tool pprof -http :9402 http://127.0.0.1:8080/debug/pprof/profile
# From the local profile
go tool pprof -http :9402 /tmp/cpu.prof
```

However this time we will use the top navigation bar go to `View` > `Flame Graph`

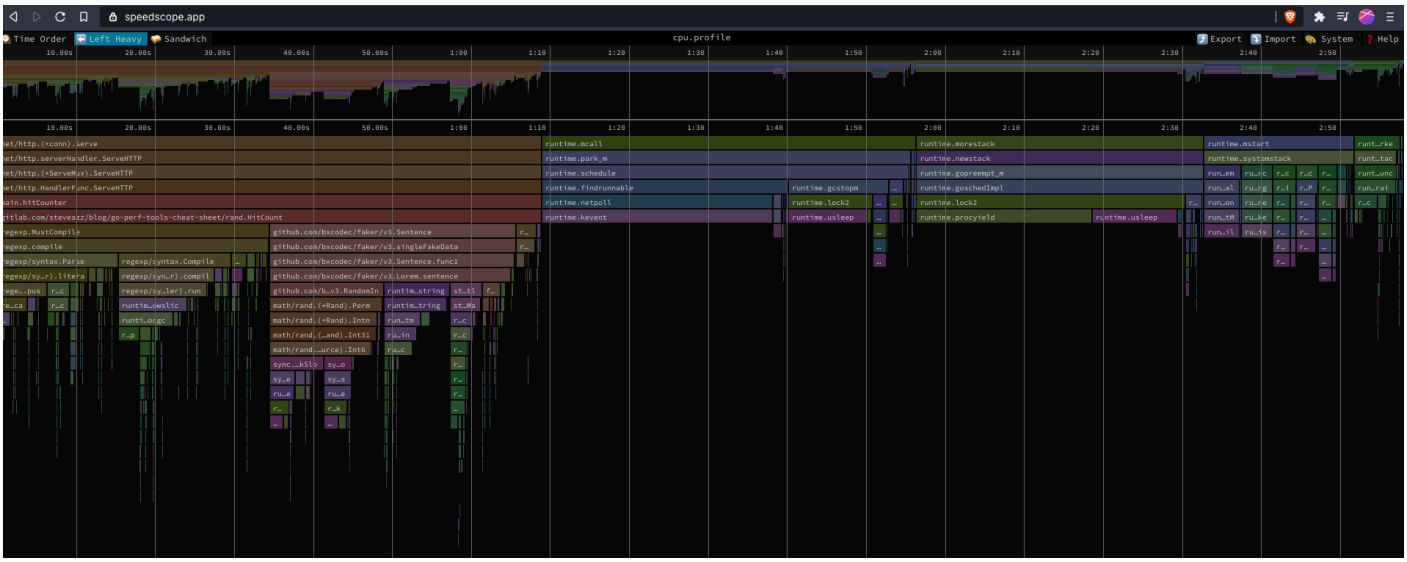


Then you should see something like below:



For you to better understand how to read flame graphs you can check out What Are Flame Graphs and How to Read Them, RubyConfBY 2017

You can also use speedscope which is a language-agnostic application to generate flame graphs from profiles and it's a bit more interactive than the one provided from Go.



Comparing profiles

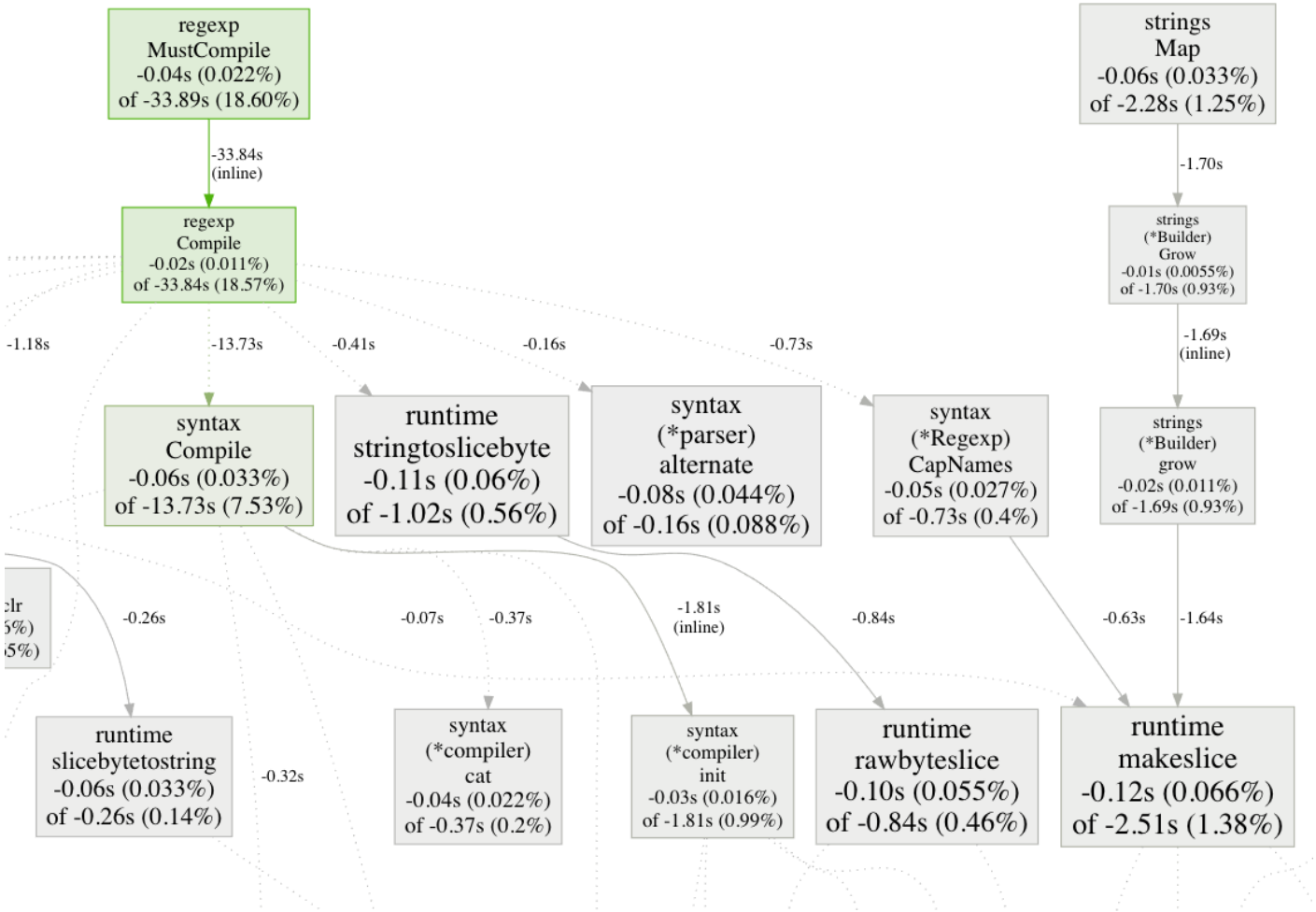
The `go tool pprof` also allows you to use to compare profiles to show you the difference between 1 profile and another.

Using our demo project once again we can generate profiles for the `main` and `best` branches.

```
# Run on `main`
curl http://127.0.0.1:8080/debug/pprof/profile > /tmp/main.prof

# Run on `best`
curl http://127.0.0.1:8080/debug/pprof/profile > /tmp/best.prof

# Compare profiles
go tool pprof -http :9402 --diff_base=/tmp/main.prof /tmp/best.prof
```



Traces

One last tool that we need to go through is the CPU tracer. This gives you an accurate representation of what was happening during the program execution. It can show you which cores are sitting idle and which ones are busy. This is great if you are debugging some concurrent code that isn't performing as expected.

Using our demo application again let's get the CPU trace using the `/debug/pprof/trace` endpoint that is added using the `net/http/pprof`.

```
curl http://127.0.0.1:8080/debug/pprof/trace > /tmp/best.trace

go tool trace /tmp/best.trace
```

A more detailed explanation of the tracer can be found over at Gopher Academy Blog

Resources

- High Performance Go Workshop
- go-perf book
- Go Tooling in Action
- pprof++
- Trace deisgn docs
- How to write benchmarks in Go