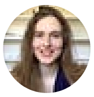
print(“lol”) doubled the speed of my Go function



Ludi Rehak · Follow

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Here is a Go function, `if_max()` . It finds the max value of an array of integers. Simple enough:

```
func if_max(values []int) int {
    maxV := values[0]
    for _, v := range values[1:] {
        if v > maxV {
            maxV = v
            continue
        }
    }
    return maxV
}
```

Next is another function, `if_max_lol()` , that is identical to `if_max()` , except that it adds a single `print("lol”)` statement:

```
func if_max_lol(values []int) int {
    maxV := values[0]
    for _, v := range values[1:] {
        if v > maxV {
            maxV = v
            continue
        }
        print("lol") // <---------- the new line
    }
    return maxV
}
```

I benchmark them on my M1 Apple Pro on an **increasing** array. Following standard practice, I use the `benchstat` tool to compare their speeds. Full code here.

```
goos: darwin
goarch: arm64
pkg: github.com/ludi317/max/blog
        │   if_max    │             if_max_lol             │
        │   sec/op    │   sec/op     vs base               │
Fn-10    63.51µ ± 2%   31.69µ ± 0%  -50.10% (p=0.002 n=6)
```

`if_max_lol()` runs in half the time of `if_max()`. What on Earth?!

Time to look at the disassembly. I generate a cpu profile by rerunning the benchmarks with an extra arg: `-test.cpuprofile cpu.out`. I feed the profile into `go tool pprof -http=”:” max.test cpu.out` and click on `View > Source` in my browser with great haste. Screenshots of the two functions of interest below:

/Users/lrehak/go/src/github.com/ludi317/max/blog/max_test.go

```
Total:       9.76s     10.09s (flat, cum) 54.36%
     2           .          .
     3           .          .           import (
     4           .          .                   "testing"
     5           .          .           )
     6           .          .
     7           .          .           func if_max(values []int) int {
     8           .          .                   maxV := values[0]
     9       9.34s      9.64s                   for _, v := range values[1:] {
    10       420ms      450ms                           if v > maxV {
             420ms      450ms 1000efc90:                      CMP R4, R3
```

/Users/lrehak/go/src/github.com/ludi317/max/blog/max_test.go

```
Total:       8.26s      8.38s (flat, cum) 45.15%
    17           .          .
    18           .          .           func if_max_lol(values []int) int {
    19           .          .                   maxV := values[0]
    20       8.06s      8.18s                   for _, v := range values[1:] {
    21       170ms      170ms                           if v > maxV {
             100ms      100ms 1000efd54:                      CMP R4, R3
              70ms       70ms 1000efd58:                      BLT -6(PC)
```

This view highlights that the comparison in `if_max_lol()` spends CPU time executing a branch instruction (**B**ranch if **L**ess **T**han): `BLT -6(PC)`.

So, the compiler saw the `print("lol")` statement in the source code, and generated an extra conditional branch instruction. This, in turn, invokes the branch predictor. What's that? Here is ChatGPT's explanation:

> *Branch prediction is a technique used in modern microprocessors to improve the throughput of their instruction pipelines by guessing the outcome of a conditional branch instruction before it's actually executed. Let's delve deeper into why it's needed and how it works.*
>
> *The Need for Branch Prediction:*
>
> *Microprocessors use pipelines to process multiple instructions simultaneously at different stages. Think of this like an assembly line in a factory, where different stages of a product are being worked on simultaneously. Each instruction goes through various stages like fetching, decoding, executing, and writing results.*
>
> *When a conditional branch instruction (like "if A is greater than B, jump to instruction X") comes into the pipeline, the CPU needs to know which instruction to fetch next: the one right after the branch or the one at the target of the jump (instruction X in the example). If the CPU waits until the branch instruction is fully executed to know the outcome, the entire pipeline would stall, leading to inefficiencies.*
>
> *How Branch Prediction Works:*
>
> *To avoid these stalls, the CPU makes an educated guess or "predicts" the outcome of the branch. This prediction allows the CPU to speculatively fetch and execute subsequent instructions.*
>
> *Challenges:*
>
> *The main challenge with branch prediction is ensuring accuracy. An incorrect prediction (a "misprediction") causes the pipeline to be flushed, leading to wasted cycles and reduced performance. As such, a significant amount of research and engineering effort is dedicated to improving branch predictor accuracy. Despite these efforts, no predictor is perfect, especially in the face of complex software behaviors.*

In this case, the array is increasing. As long as the predictor guesses "true" `if v > maxV`, it predicts with perfect accuracy. This allows it to keep its pipeline full and execute the next instruction without delay, maximizing its efficiency.

`cheat_max()` is a function that drops the `if v > maxV` comparison altogether. It takes a shortcut by explicitly avoiding the work of comparison.

```
func cheat_max(values []int) int {
    maxV := values[0]
    for _, v := range values[1:] {
        maxV = v
    }
    return maxV
}
```

```
goos: darwin
goarch: arm64
pkg: github.com/ludi317/max/blog
       │ if_max_lol  │           cheat_max             │
       │   sec/op    │   sec/op     vs base            │
Fn-10   31.70µ ± 3%   31.62µ ± 1%  ~ (p=0.145 n=6)
```

As the results show, `if_max_lol()` is about as fast as if it had no if-statement at all. Branch prediction effectively removes the if-statement.

Of course, this is just a toy example. If you wanted to know the max value of an increasing array, simply return the last element. These benchmarks serve to illustrate that very one-sided if-statements are where branching performance shines.

Even when the array contains **random** integers, branch prediction performs better than basic comparisons. There's no longer certainty about whether the kth element is a new max, but a different pattern emerges. The kth element has a `1/k` chance of being the new max. As long as the predictor predicts "false" for whether `v > maxV`, it has a `(k-1)/k` chance of being right, getting only more accurate as the array grows in size.

Instead of printing "lol", we can do something a little more useful to coax the compiler into generating a branch instruction, like finding the min value of the array.

```go
func if_max_min(values []int) (int, int) {
    minV := values[0]
    maxV := values[0]
    for _, v := range values[1:] {
         if v > maxV {
              maxV = v
              continue // generate branch instruction
         }
         if v < minV {
              minV = v
              continue // generate branch instruction
         }
    }
    return minV, maxV
}
```

How does `if_max_min()` compare against `if_max()` on a random array?

```
goos: darwin
goarch: arm64
pkg: github.com/ludi317/max
                  │ if_max_min  │              if_max            │
                  │   sec/op    │   sec/op     vs base           │
Fn/len=100000-10   64.98µ ± 1%   64.68µ ± 0%  ~ (p=0.132 n=6)
```

It's about as fast. But it gives you both the min and max of the array, whereas `if_max()` only gives the max. Branching allows it to deliver more information in the same amount of time.

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