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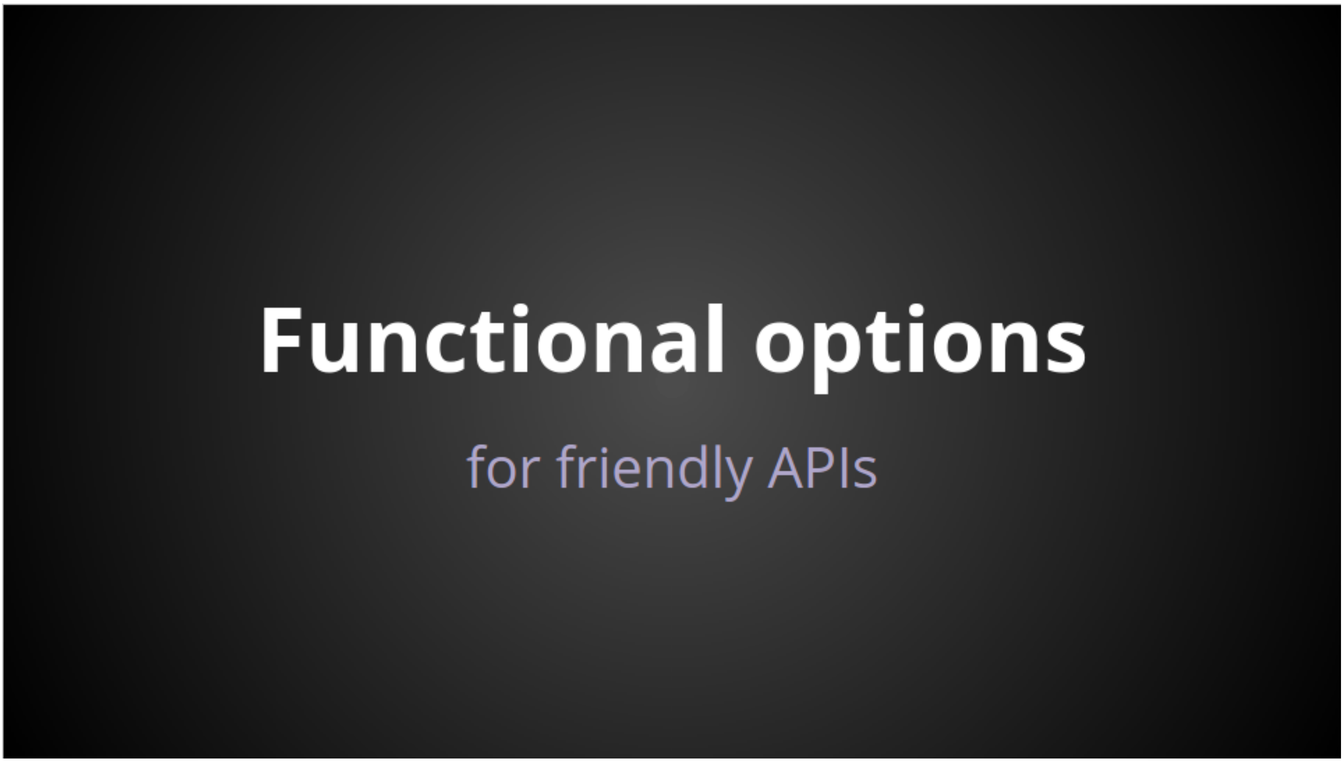
The acme of foolishness

Functional options for friendly APIs

What follows is the text of my presentation, Functional options for friendly APIs that I gave at dotGo this year. It has been edited slightly for readability.

I want to thank Kelsey Hightower, Bill Kennedy, Jeremy Saenz, and Brian Ketelsen, for their assistance in preparing this talk.



I want to begin my talk with a story.

It is late 2014, your company is launching a revolutionary new distributed social network. Wisely, your team has chosen Go as the language for this product.

You have been tasked with writing the crucial server component. Possibly it looks a little like this.

```go
package gplusplus

import "net"

type Server struct {
    listener net.Listener
}

func (s *Server) Addr() net.Addr
func (s *Server) Shutdown()

// NewServer returns a new Server listening on addr.
func NewServer(addr string) (*Server, error) {
    l, err := net.Listen("tcp", addr)
    if err != nil {
        return nil, err
    }
    srv := Server{listener: l}
    go srv.run()
    return &srv, nil
}
```

There are some unexported fields that need to be initialised, and a goroutine must be started to service incoming requests.

The package has a simple API, it is pretty easy to use.

But, there is a problem. Soon after you announce your first beta release, the feature requests start to roll in.

Features, features, features

"slow clients keep using up all my resources !!"

"does your server support TLS ?"

"can I limit the number of clients ?"

"someone is trying to DOS me, can I limit the number of connections from a single IP ?"

... and more ...

Mobile clients are often slow to respond, or stop responding altogether—you'll need to add support for disconnecting these slow clients.

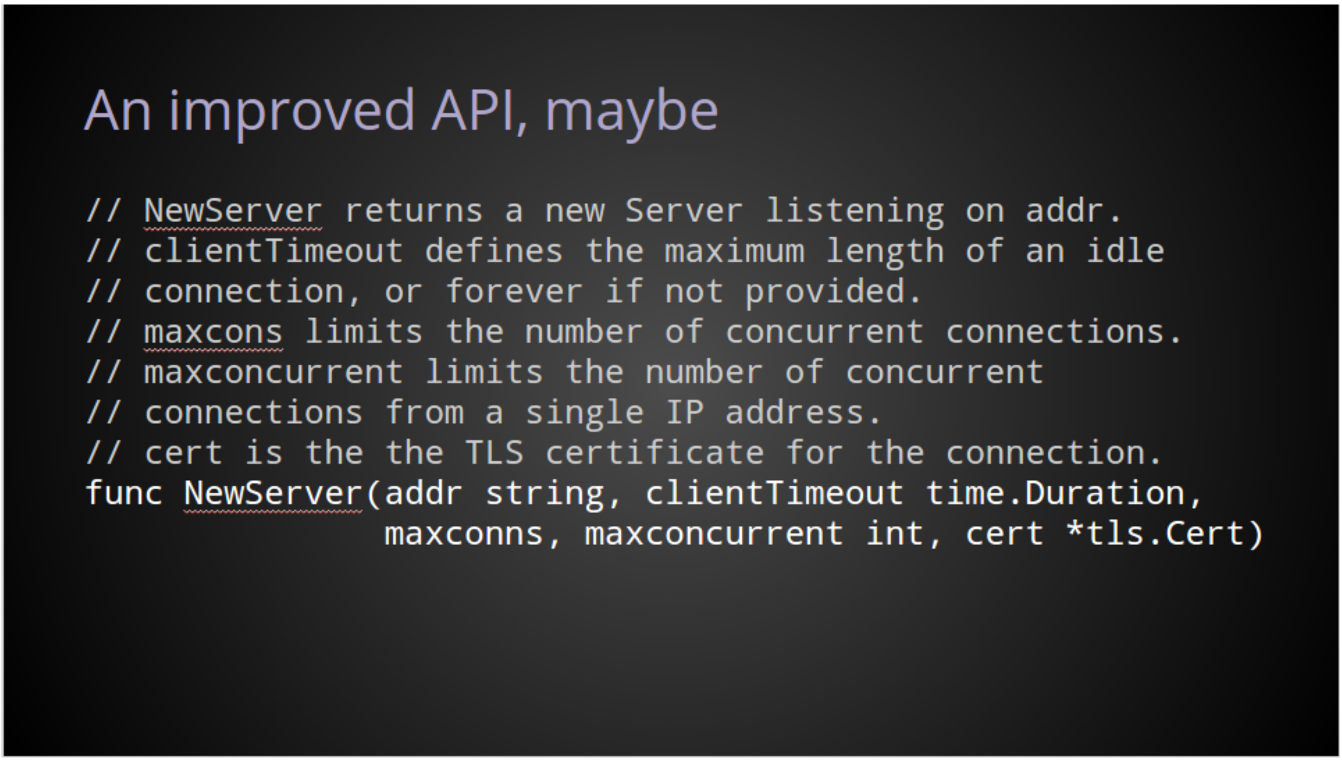
In this climate of heightened security awareness, your bug tracker starts to fill with demands to support secure connections.

Then, you get a report from a user who is running your server on a very small VPS. They need a way to limit the number of simultaneous clients.

Next is the request to rate limit concurrent connections from a group of users being targeted by a botnet.

... and on it goes.

Now, you need to change your API to incorporate all these feature requests.



It's kind of a sign that things are not going well when the function won't easily fit on a slide.

Show of hands, who has used an API like this ?

Who has written an API like this ?

Who has had their code break while depending on an API like this ?

Obviously this solution is cumbersome and brittle. It also isn't very discoverable.

Newcomers to your package have no idea which parameters are optional, and which are mandatory.

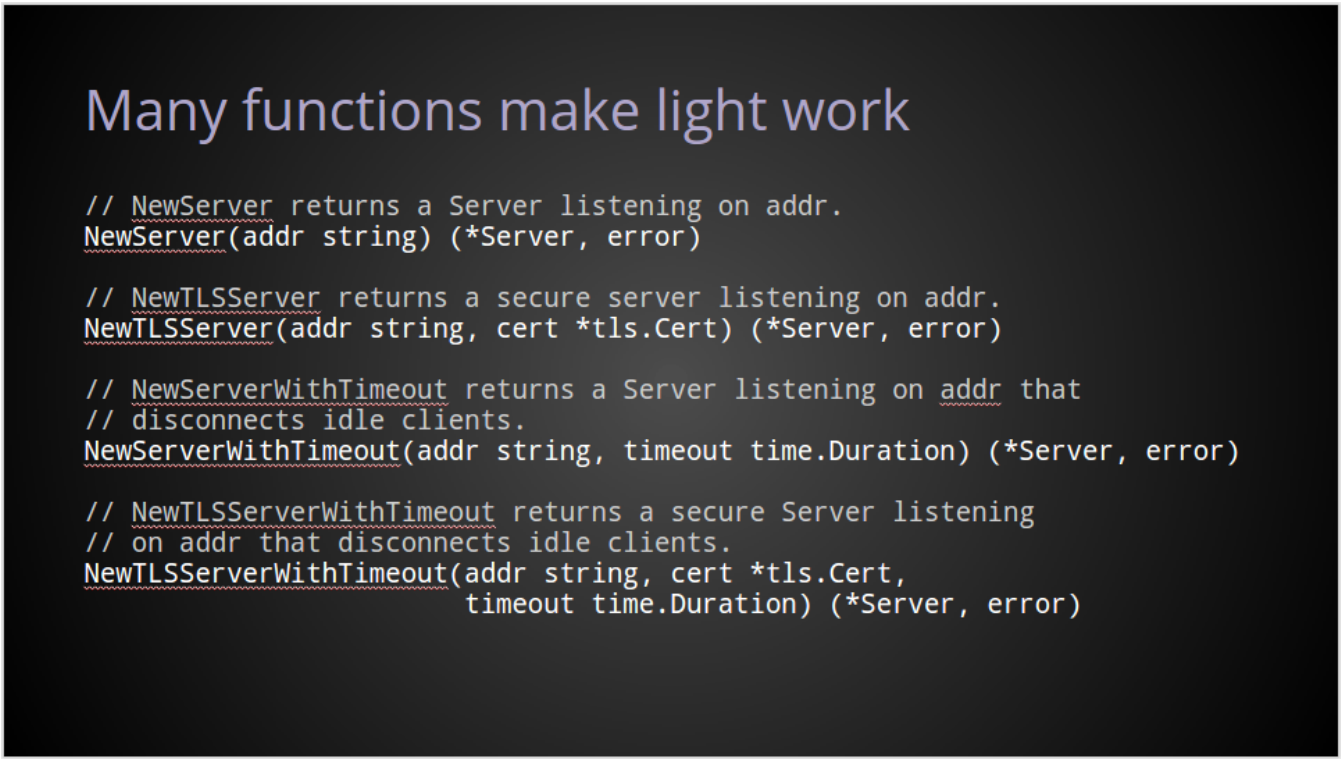
For example, if I want to create an instance of the Server for testing, do I need to provide a real TLS certificate ? If not, what do I provide instead ?

If I don't care about `maxconns`, or `maxconcurrent` what value should I use ? Do I use zero ? Zero sounds reasonable, but depending on how the feature was implemented, that might limit you to zero total concurrent connections.

It appears to me, that writing an API like this can be easy; as long as you make it the caller's responsibility to use it correctly.

While this example could be a considered an exaggeration, maliciously constructed and compounded by poor documentation, I believe that it demonstrates a real issue with ornate, brittle APIs such as this.

So now that I've defined the problem, lets look at some solutions.



Rather than trying to provide one single function which must cater for every permutation, a solution might be to create a set of functions.

With this approach, when callers need a secure server they can call the TLS variant.

When they need to establish a maximum duration for idle connections, they can use the variant that takes a timeout.

Unfortunately, as you can see, providing every possible permutation can quickly become overwhelming.

Let's move on to others way of making your API configurable.

Passing a configuration struct

```go
// A Config structure is used to configure the Server.
type Config struct {
	// Timeout sets the amount of time before closing
	// idle connections, or forever if not provided.
	Timeout time.Duration

	// The server will accept TLS connections is the
	// certificate provided.
	Cert *tls.Cert
}

func NewServer(addr string, config Config) (*Server, error)
```

A very common solution is to use a configuration struct.

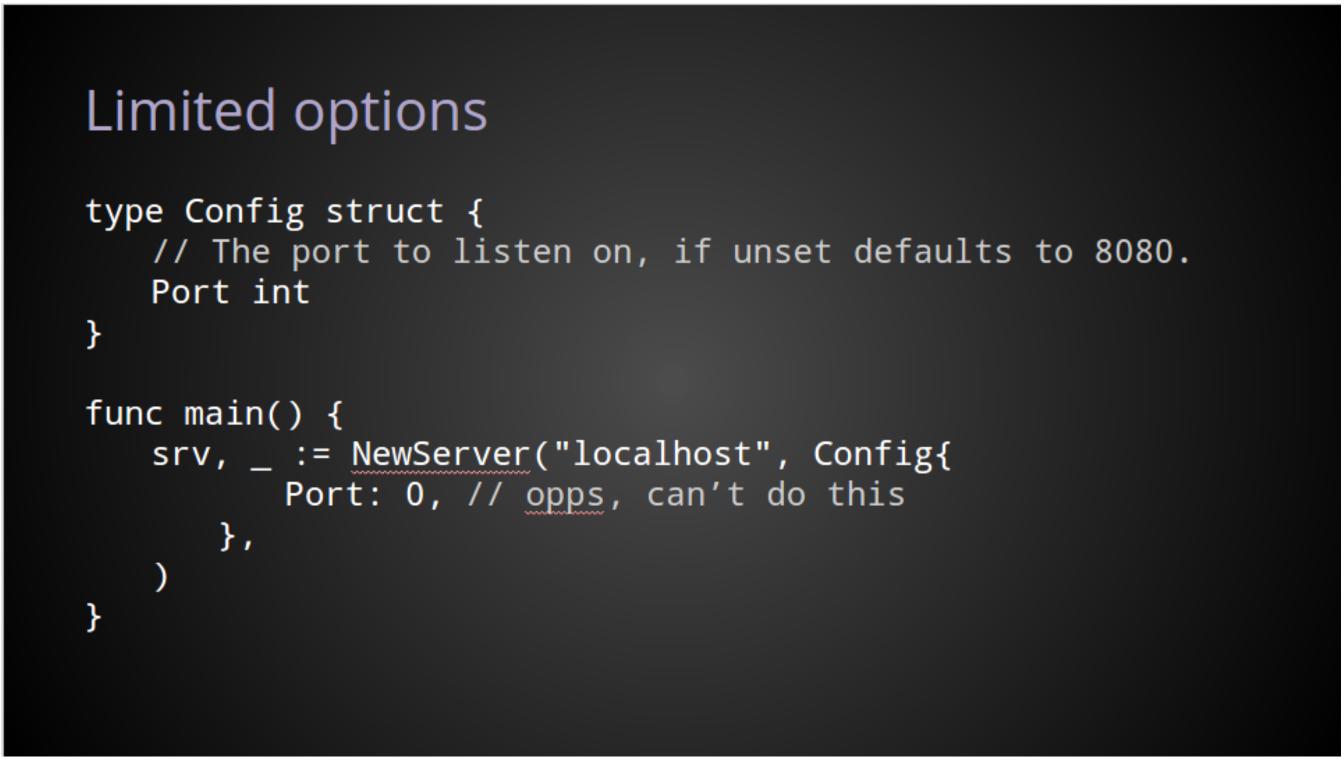
This has some advantages.

Using this approach, the configuration struct can grow over time as new options are added, while the public API for creating a server itself remains unchanged.

This method can lead to better documentation.

What was once a massive comment block on the `NewServer` function, becomes a nicely documented struct.

Potentially it also enables the callers to use the zero value to signify they they want the default behaviour for a particular configuration option.

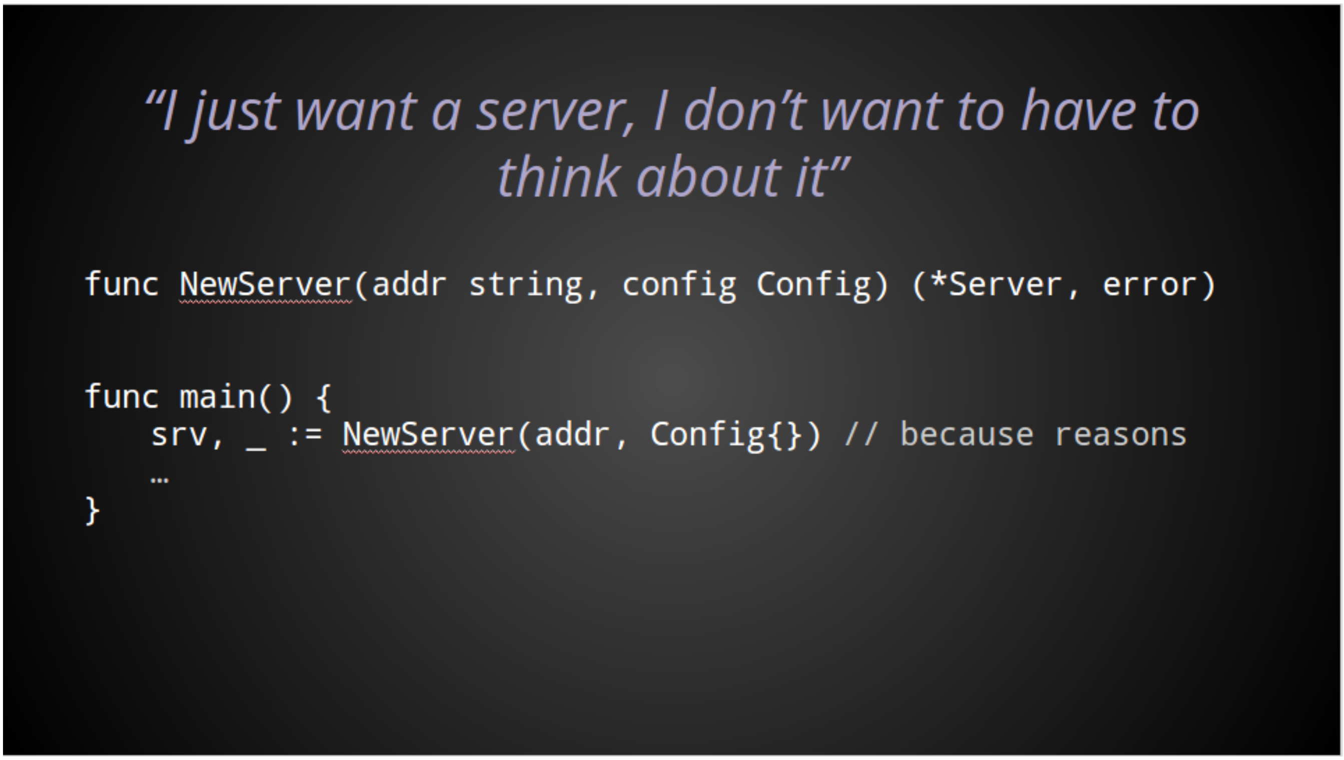


However, this pattern is not perfect.

It has trouble with defaults, especially if the zero value has a well understood meaning.

For example, in the config structure shown here, when `Port` is not provided, `NewServer` will return a `*Server` for listening on port 8080.

But this has the downside that you can no longer explicitly set `Port` to 0 and have the operating system automatically choose a free port, because that explicit 0 is indistinguishable from the fields’ zero value.



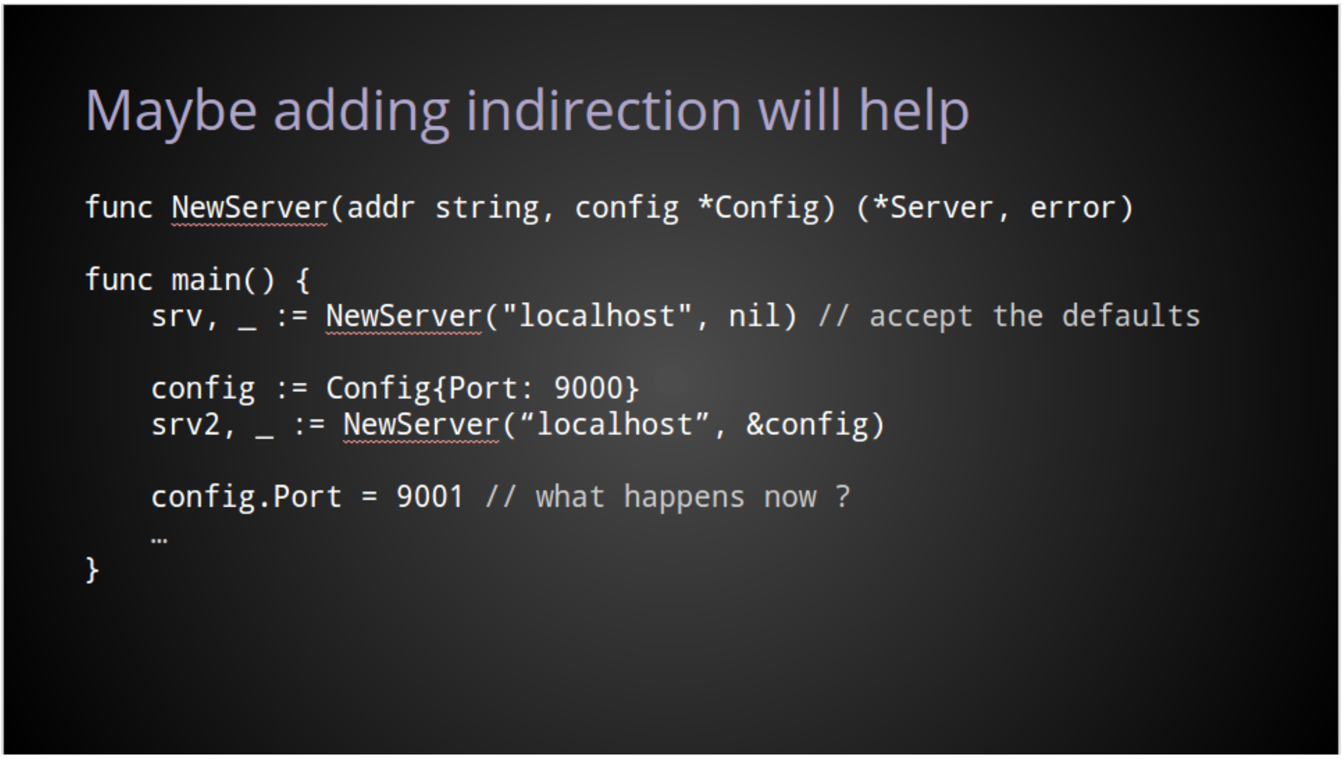
Most of the time, users of your API will be expecting to use its default behaviour.

Even though they do not intend to change any of the configuration parameters, those callers are still required to pass *something* for that second argument.

So, when people read your tests or your example code, trying to figure out how to use your package, they'll see this magic empty value, and it'll become enshrined in the collective unconsciousness.

[and] to me, this just feel wrong.

Why should users of your API be required to construct an empty value, simply to satisfy the signature of the function ?



A common solution to this empty value problem is to pass a pointer to the value instead, thereby enabling callers to use nil rather than constructing an empty value.

In my opinion this pattern has all the problems of the previous example, and it adds a few more.

We still have to pass *something* for this function's second argument, but now this value could be `nil`, and most of the time *will* be `nil` for those wanting the default behaviour.

It raises the question, is there a difference between passing `nil`, and passing a pointer to an empty value ?

More concerning to both the package's author, and its callers, is the Server and the caller can now share a reference to the same configuration value. Which gives rise to questions of what happens if this value is mutated after being passed to the `NewServer` function ?

I believe that well written APIs should not require callers to create dummy values to satisfy those rarer use cases.

I believe that we, as Go programmers, should work hard to ensure that nil is never a parameter that needs to be passed to any public function.

And when we do want to pass configuration information, it should be as self explanatory and as expressive as possible.

So now with these points in mind, I want to talk about what I believe are some better solutions.

Variadic configuration

```
func NewServer(addr string, config ...Config) (*Server, error)

func main() {
    srv, _ := NewServer("localhost") // defaults

    // timeout after 5 minutes, 10 clients max
    srv2, _ := NewServer("localhost", Config{
        Timeout:  300 * time.Second,
        MaxConns: 10,
    })
    …
}
```

To remove the problem of that mandatory, yet frequently unused, configuration value, we can change the `NewServer` function to accept a variable number of arguments.

Instead of passing `nil`, or some zero value, as a signal that you want the defaults, the variadic nature of the function means you don't need to pass *anything at all*.

And in my book this solves two big problems.

First, the invocation for the default behaviour becomes as concise as possible.

Secondly, `NewServer` now only accepts `Config` values, not pointers to config values, removing `nil` as a possible argument, and ensuring that the caller cannot retain a reference to the server's internal configuration.

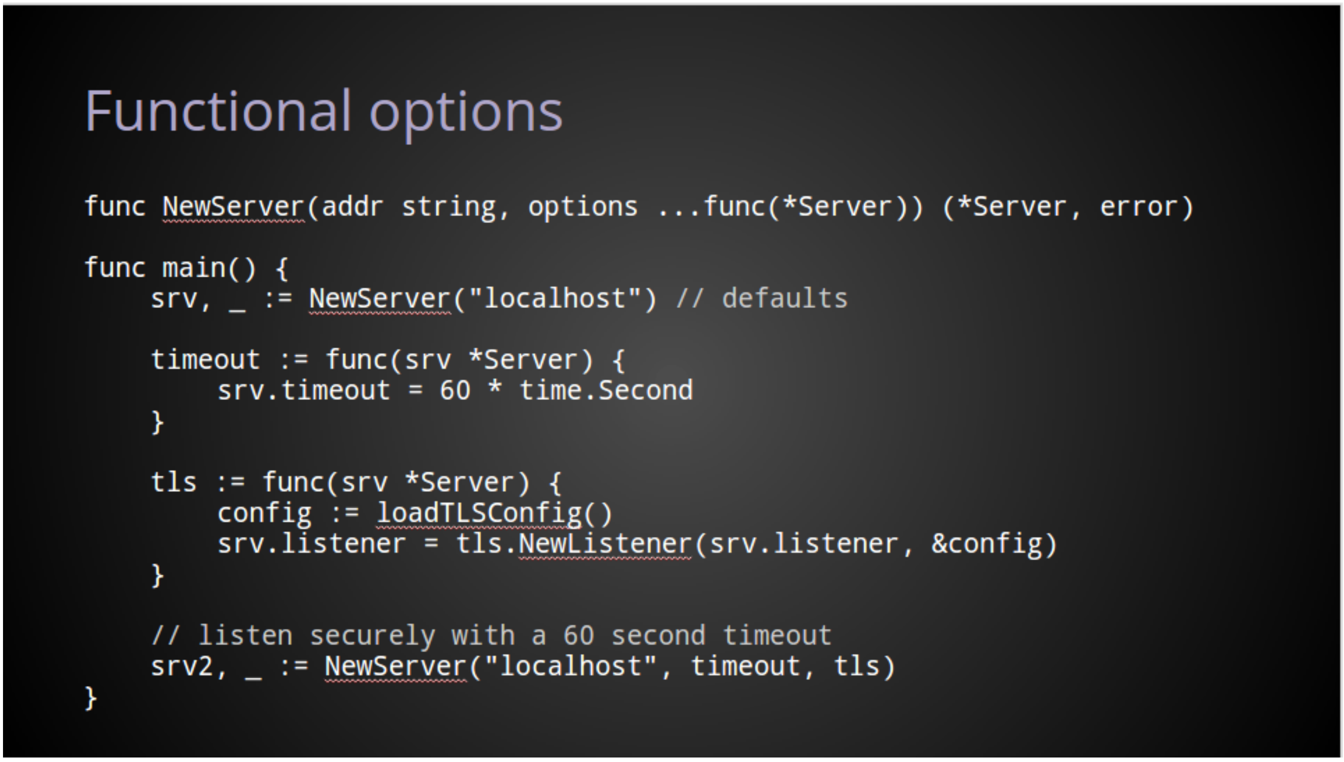
I think this is a big improvement.

But if we're being pedantic, it still has a few problems.

Obviously the expectation is for you to provide at most one `Config` value. But as the function signature is variadic, the implementation has to be written to cope with a caller passing multiple, possibly contradictory, configuration structs.

Is there a way to use a variadic function signature *and* improve the expressiveness of configuration parameters when needed ?

I think that there is.



At this point I want to make it clear that that the idea of functional options comes from a blog post titled. Self referential functions and design by Rob Pike, published in January this year. I encourage everyone here to read it.

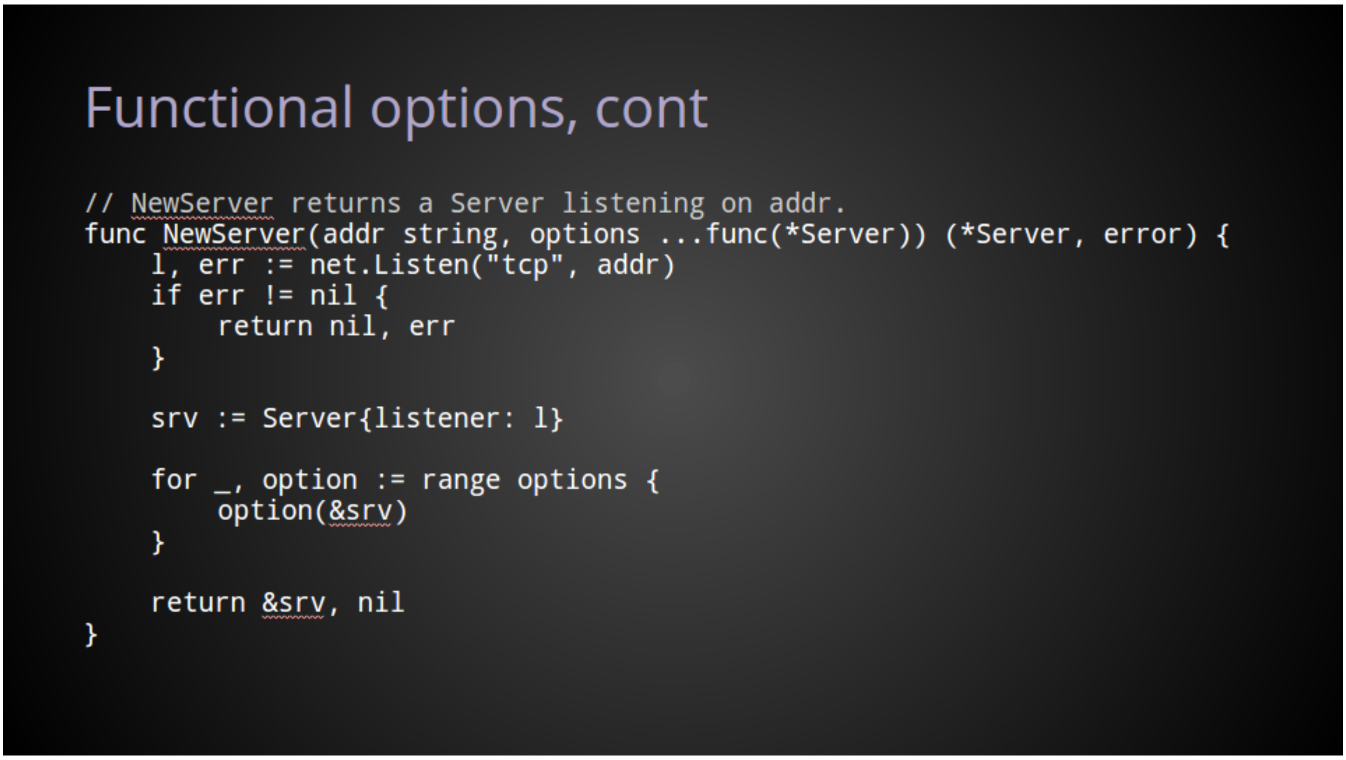
The key difference from the previous example, and in fact all the examples so far, is customisation of the Server is performed not with configuration parameters stored in a structure, but with *functions* which operate on the `Server` value itself.

As before, the variadic nature of the function's signature gives us the compact behaviour for the default case.

When configuration is required, I pass to `NewServer` functions which operate on the `Server` value as an argument.

The `timeout` function simply changes the `timeout` field of any `*Server` value passed to it.

The `tls` function is a little more complicated. It takes a `*Server` value and wraps the original `listener` value inside a `tls.Listener`, thereby transforming it into a secure listener.



Inside `NewServer`, applying these options is straightforward.

After opening a `net.Listener`, we declare a `Server` instance using that `listener`.

Then, for each option function provided to `NewServer`, we call that function, passing in a pointer to the `Server` value that was just declared.

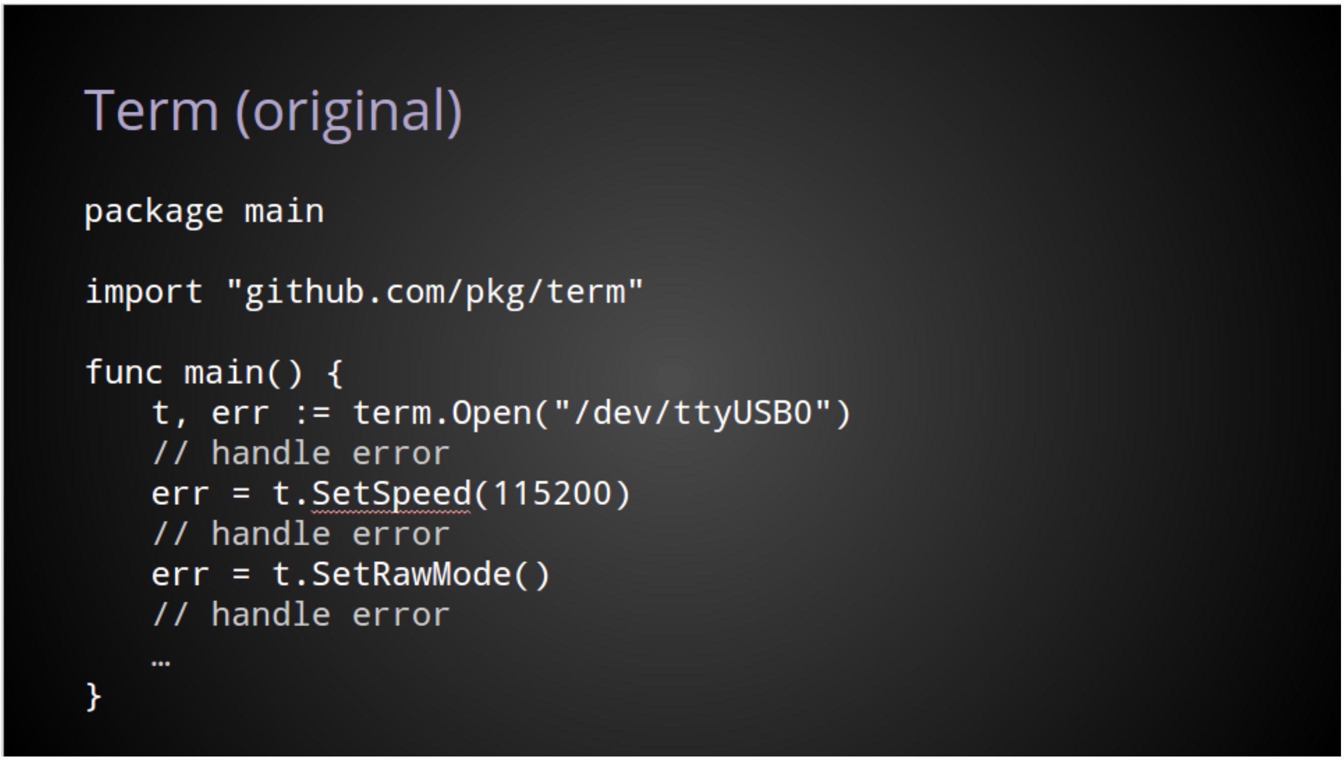
Obviously, if no option functions were provided, there is no work to do in this loop and so `srv` is unchanged.

And that’s all there is too it.

Using this pattern we can make an API that has

- sensible defaults
- is highly configurable
- can grow over time
- self documenting
- safe for newcomers
- and never requires nil or an empty value to keep the compiler happy

In the few minutes I have remaining I’d like to show you how I improved one of my own packages by converting it to use functional options.



I'm an amateur hardware hacker, and many of the devices I work with use a USB serial interface. A so a few months ago I wrote a terminal handling package.

In the prior version of this package, to open a serial device, change the speed and set the terminal to raw mode, you'd have to do each of these steps individually, checking the error at every stage.

Even though this package is trying to provide a friendlier interface on an even lower level interface, it still left too many procedural warts for the user.

Let's take a look at the package after applying the functional options pattern.

By converting the `Open` function to use a variadic parameter of function values, we get a much cleaner API.

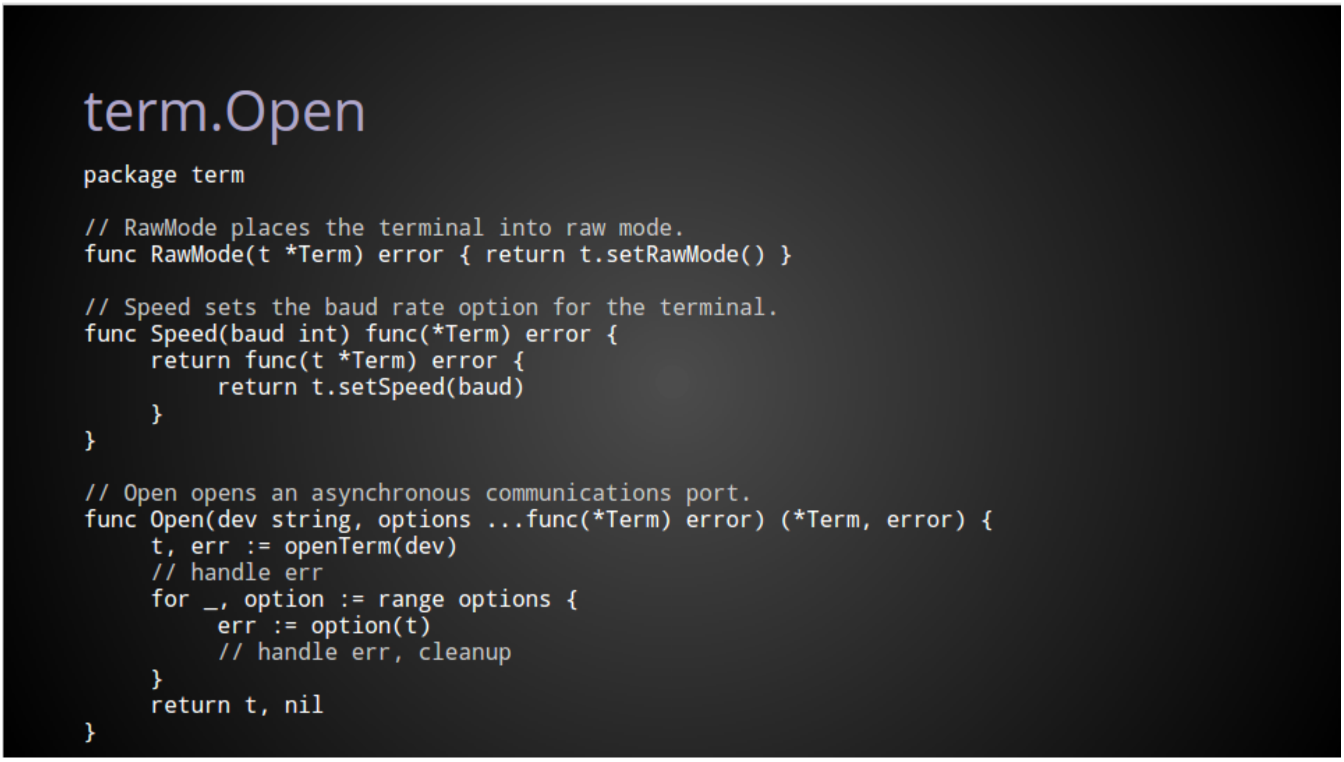
In fact, it’s not just the `Open` API that improves, the grind of setting an option, checking an error, setting the next option, checking the error, that is gone as well.

The default case, still just takes one argument, the name of the device.

For more complicated use cases, configuration functions, defined in the `term` package, are passed to the `Open` function and are applied in order before returning.

This is the same pattern we saw in the previous example, the only thing that is different is rather than being anonymous, these are public functions. In all other respects their operation is identical.

We’ll take a look at how `Speed`, `RawMode`, and `Open`, are implemented on the next slide.



`RawMode` is the easiest to explain. It just a function whose signature is compatible with Open.

Because `RawMode` is declared in the same package as `Term`, it can access the private fields and call private methods declared on the `Term` type, in this case calling the private `setRawMode` helper.

`Speed` is also just a regular function, however it does not match the signature `Open` requires. This is because `Speed` itself requires an argument; the baud rate.

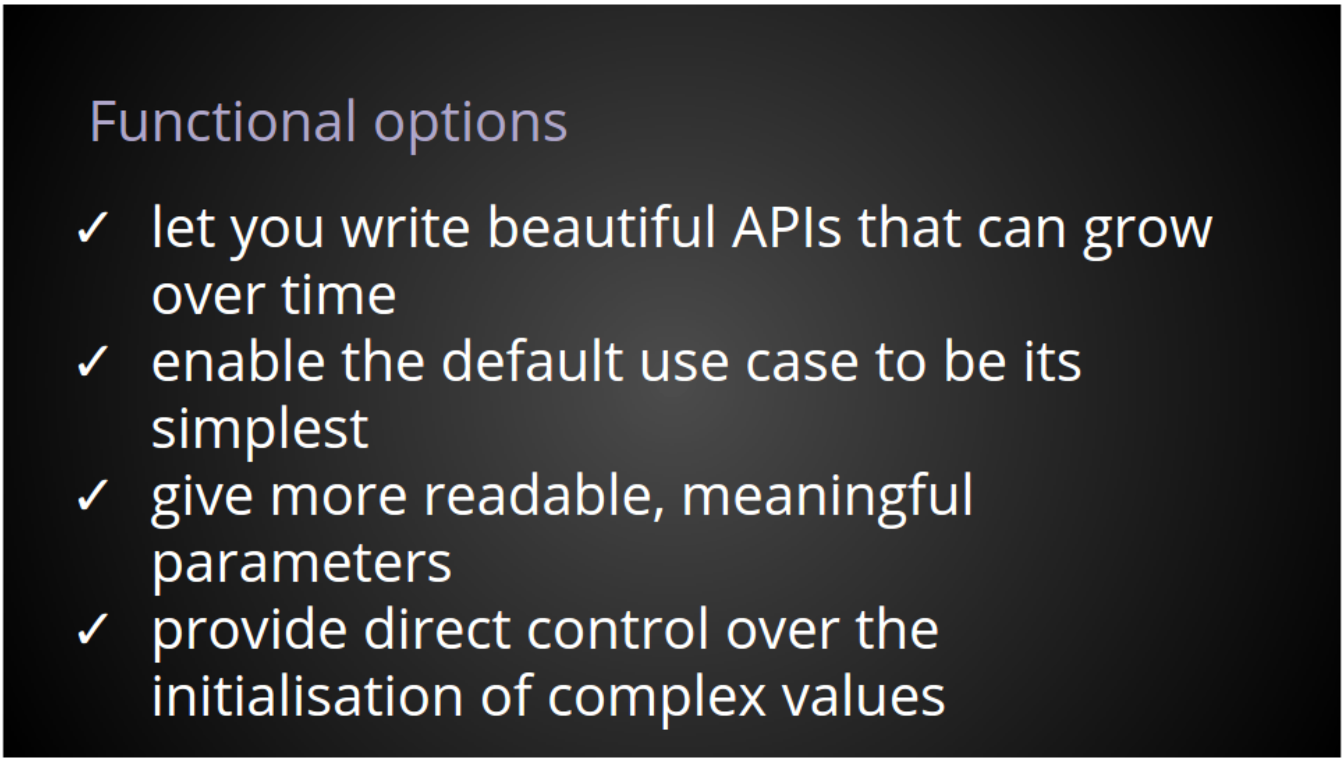
`Speed` returns an anonymous function which is compatible with the `Open` function’s signature, which closes over the baud rate parameter, capturing it for later when the function is applied.

Inside the call to `Open`, we first open the terminal device with the `openTerm` helper.

Next, just as before, we range over the slice of options functions, calling each one in turn passing in `t`, the pointer to our `term.Term` value.

If there is an error applying any function then we stop at that point, clean up and return the error to the caller.

Otherwise, returning from the function, we've now created and configured a Term value to the caller's specifications.



In summary

- Functional options let you write APIs that can grow over time.
- They enable the default use case to be the simplest.
- They provide meaningful configuration parameters.
- Finally they give you access to the entire power of the language to initialize complex values.

In this talk, I have presented many of the existing configuration patterns, those considered idiomatic and commonly in use today, and at every stage asked questions like:

- Can this be made simpler ?
- Is that parameter necessary ?
- Does the signature of this function make it easy for it to be used safely ?
- Does the API contain traps or confusing misdirection that will frustrate ?

I hope I have inspired you to do the same. To revisit code that you have written in the past and pose yourself these same questions and thereby improve it.

Thank you.

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