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Trends in concurrent programming languages

Google's Go

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Go (golang)

- Created in 2007 internally at Google
- Announced in 2009
- Currently on Go 1.0.3 (Go 1.1RC2 released yesterday)

- Headlines
  - Intended for ‘systems programming’
  - Statically typed
  - Garbage collected
  - Designed for concurrency
  - Very high speed compilation
  - Syntax very familiar to C/C++/Java programmers
  - “A small language”

Small number of built in types

- int, float, string (mutable), boolean
- pointers
- map

```
m := make(map[string]int)
m[“Hello”] = 10
```

- slice (bounds checked)

```
a := make([]int, 10)

a[0] = 42
b := a[1,3]
```

- channel
- structure, function, interface

OO using interfaces

- Interface type
- Static ‘duck’ typing

```
type Sequence []int

func (s Sequence) Size() int {
    return len(s)
}

type Sizer interface {
    Size() int
}

func Foo (o Sizer) {
    ...
}
```

Statically typed

- Familiar type declarations

```
type currency struct {
    id string
    longName string
}

type transaction struct {
    cur currency
    amnt int
}

sterling := currency{“GBP”, “British Pounds Sterling”}

var credit = transaction{cur: sterling, amnt: 100}

lastCredit = &credit

lastCredit.amnt += 100
```

One type of loop, one iterator

```
for i := 0; i < 10; i++ {
    ...
}

for {
    ...
}

for some_boolean {
    ...
}

for i, v := range some_slice {
    ...
}

for k, v := range some_map {
    ...
}
```

Explicit error returns

- No (actually, very limited) exception mechanism
- The Go way is multiple returns with errors

```
conn, err := net.Dial("tcp", "example.com”)

if x, err := do(); err == nil {
    ...
} else {
    ...
}
```

- Can explicitly ignore errors if desired

```
conn, _ := net.Dial("tcp", "example.com”)
```

Garbage Collected

- Parallel mark-and-sweep garbage collector

Possible Concurrency Options

- Processes with IPC
  - Classic ‘Unix’ processes
  - Erlang processes and mailboxes
- coroutines
  - Lua uses coroutines with explicit yields
- Threads with shared memory
  - OS vs. user space
  - Go’s goroutines are close to ‘green threads’
- Event driven
  - node.js, JavaScript
  - Many GUI frameworks

Concurrency

- goroutines
  - Very lightweight processes/threads
  - All scheduling handled internally by the Go runtime
  - Unless you are CPU bound you do not have to think about scheduling
  - Multiplexed onto system threads, OS polling for I/O
- Channel-based communication
  - The right way for goroutines to talk to each other
- Synchronization Library (`sync`)
  - For when a channel is too heavyweight
  - Rarely used—not going to discuss

goroutines

- “Lightweight”
  - Starting 10,000 goroutines on my MacBook Pro took 22ms
  - Allocated memory increased by 3,014,000 bytes (301 bytes per goroutine)
  - https://gist.github.com/jgrahamc/5253020
- Not unusual at CloudFlare to have a single Go program running 10,000s of goroutines with 1,000,000s of goroutines created during life program.
- So, `go yourFunc()` as much as you like.

Channels

- `c := make(chan bool)` – Makes an unbuffered channel of `bools`

  `c <- x` – Sends a value on the channel

  `<- c` – Waits to receive a value on the channel

  `x = <- c` – Waits to receive a value and stores it in `x`

  `x, ok = <- c` – Waits to receive a value; `ok` will be false if channel is closed and empty.

Unbuffered channels are best

- They provide both communication and synchronization

```
func from(connection chan int) {
    connection <- rand.Intn(100)
}

func to(connection chan int) {
    i := <- connection
    fmt.Printf("Someone sent me %d\n", i)
}

func main() {
    cpus := runtime.NumCPU()
    runtime.GOMAXPROCS(cpus)

    connection := make(chan int)
    go from(connection)
    go to(connection)
    ...
}
```

Using channels for signaling (1)

- Sometimes just closing a channel is enough

```
c := make(chan bool)

go func() {
        // ... do some stuff
        close(c)
}()

// ... do some other stuff
<- c
```

Using channels for signaling (2)

- Close a channel to coordinate multiple goroutines

```
func worker(start chan bool) {
    <- start
    // ... do stuff
}

func main() {
    start := make(chan bool)

    for i := 0; i < 100; i++ {
        go worker(start)
    }

    close(start)

    // ... all workers running now
}
```

Select

- Select statement enables sending/receiving on multiple channels at once

```
select {
case x := <- somechan:
    // ... do stuff with x

case y, ok := <- someOtherchan:
    // ... do stuff with y
    // check ok to see if someOtherChan
    // is closed

case outputChan <- z:
    // ... ok z was sent

default:
    // ... no one wants to communicate
}
```

Common idiom: `for/select`

```
for {
    select {
    case x := <- somechan:
        // ... do stuff with x

    case y, ok := <- someOtherchan:
        // ... do stuff with y
        // check ok to see if someOtherChan
        // is closed

    case outputChan <- z:
        // ... ok z was sent

    default:
        // ... no one wants to communicate
    }
}
```

Using channels for signaling (4)

- Close a channel to terminate multiple goroutines

```
func worker(die chan bool) {
    for {
        select {
            // ... do stuff cases
        case <- die:
            return
        }
    }
}

func main() {
    die := make(chan bool)
    for i := 0; i < 100; i++ {
        go worker(die)
    }
    close(die)
}
```

Using channels for signaling (5)

- Terminate a goroutine and verify termination

```
func worker(die chan bool) {
    for {
        select {
            // ... do stuff cases
        case <- die:
            // ... do termination tasks
            die <- true
            return
        }
    }
}
func main() {
    die := make(chan bool)
    go worker(die)
    die <- true
    <- die
}
```

Example: unique ID service

- Just receive from `id` to get a unique ID
- Safe to share `id` channel across routines

```
id := make(chan string)

go func() {
    var counter int64 = 0
    for {
        id <- fmt.Sprintf("%x", counter)
        counter += 1
    }
}()

x := <- id // x will be 1
x = <- id  // x will be 2
```

Example: memory recycler

```
func recycler(give, get chan []byte) {
    q := new(list.List)

    for {
        if q.Len() == 0 {
            q.PushFront(make([]byte, 100))
        }

        e := q.Front()

        select {
        case s := <-give:
            q.PushFront(s[:0])

        case get <- e.Value.([]byte):
            q.Remove(e)
        }
    }
}
```

Timeout

```
func worker(start chan bool) {
    for {
       timeout := time.After(30 * time.Second)
       select {
            // ... do some stuff

        case <- timeout:
            return
        }
    }
}
```

```
func worker(start chan bool) {
    timeout := time.After(30 * time.Second)
    for {
       select {
            // ... do some stuff

        case <- timeout:
            return
        }
    }
}
```

Heartbeat

```
func worker(start chan bool) {
    heartbeat := time.Tick(30 * time.Second)
    for {
       select {
            // ... do some stuff

        case <- heartbeat:
            // ... do heartbeat stuff
        }
    }
}
```

Example: network multiplexor

- Multiple goroutines can send on the same channel

```
func worker(messages chan string) {
    for {
        var msg string // ... generate a message
        messages <- msg
    }
}
func main() {
    messages := make(chan string)
    conn, _ := net.Dial("tcp", "example.com")

    for i := 0; i < 100; i++ {
        go worker(messages)
    }
    for {
        msg := <- messages
        conn.Write([]byte(msg))
    }
}
```

Example: first of N

- Dispatch requests and get back the first one to complete

```
type response struct {
    resp *http.Response
    url string
}

func get(url string, r chan response ) {
    if resp, err := http.Get(url); err == nil {
        r <- response{resp, url}
    }
}

func main() {
    first := make(chan response)
    for _, url := range []string{"http://code.jquery.com/jquery-1.9.1.min.js",
        "http://cdnjs.cloudflare.com/ajax/libs/jquery/1.9.1/jquery.min.js",
        "http://ajax.googleapis.com/ajax/libs/jquery/1.9.1/jquery.min.js",
        "http://ajax.aspnetcdn.com/ajax/jQuery/jquery-1.9.1.min.js"} {
        go get(url, first)
    }

    r := <- first
    // ... do something
}
```

range

- Can be used to consume all values from a channel

```
func generator(strings chan string) {
    strings <- "Five hour's New York jet lag"
    strings <- "and Cayce Pollard wakes in Camden Town"
    strings <- "to the dire and ever-decreasing circles"
    strings <- "of disrupted circadian rhythm."
    close(strings)
}

func main() {
    strings := make(chan string)
    go generator(strings)

    for s := range strings {
        fmt.Printf("%s ", s)
    }
    fmt.Printf("\n");
}
```

Passing a ‘response’ channel

```
type work struct {
    url string
    resp chan *http.Response
}

func getter(w chan work) {
    for {
        do := <- w
        resp, _ := http.Get(do.url)
        do.resp <- resp
    }
}

func main() {
    w := make(chan work)

    go getter(w)

    resp := make(chan *http.Response)
    w <- work{"http://cdnjs.cloudflare.com/jquery/1.9.1/jquery.min.js",
        resp}

    r := <- resp
}
```

Buffered channels

- Can be useful to create queues
- But make reasoning about concurrency more difficult

```
c := make(chan bool, 100)
```

High Speed Compilation

- Go includes its own tool chain
- Go language enforces removal of unused dependencies
- Output is a single static binary

- Result is very large builds in seconds

Things not in Go

- Generics of any kind
- Assertions
- Type inheritance
- Operator overloading
- Pointer arithmetic
- Exceptions

THANKS

The Go Way: “small sequential pieces joined by channels”

APPENDIX

Example: an HTTP load balancer

- Limited number of HTTP clients can make requests for URLs
- Unlimited number of goroutines need to request URLs and get responses

- Solution: an HTTP request load balancer

A URL getter

```
type job struct {
    url string
    resp chan *http.Response
}

type worker struct {
    jobs chan *job
    count int
}

func (w *worker) getter(done chan *worker) {
    for {
        j := <- w.jobs
        resp, _ := http.Get(j.url)
        j.resp <- resp
        done <- w
    }
}
```

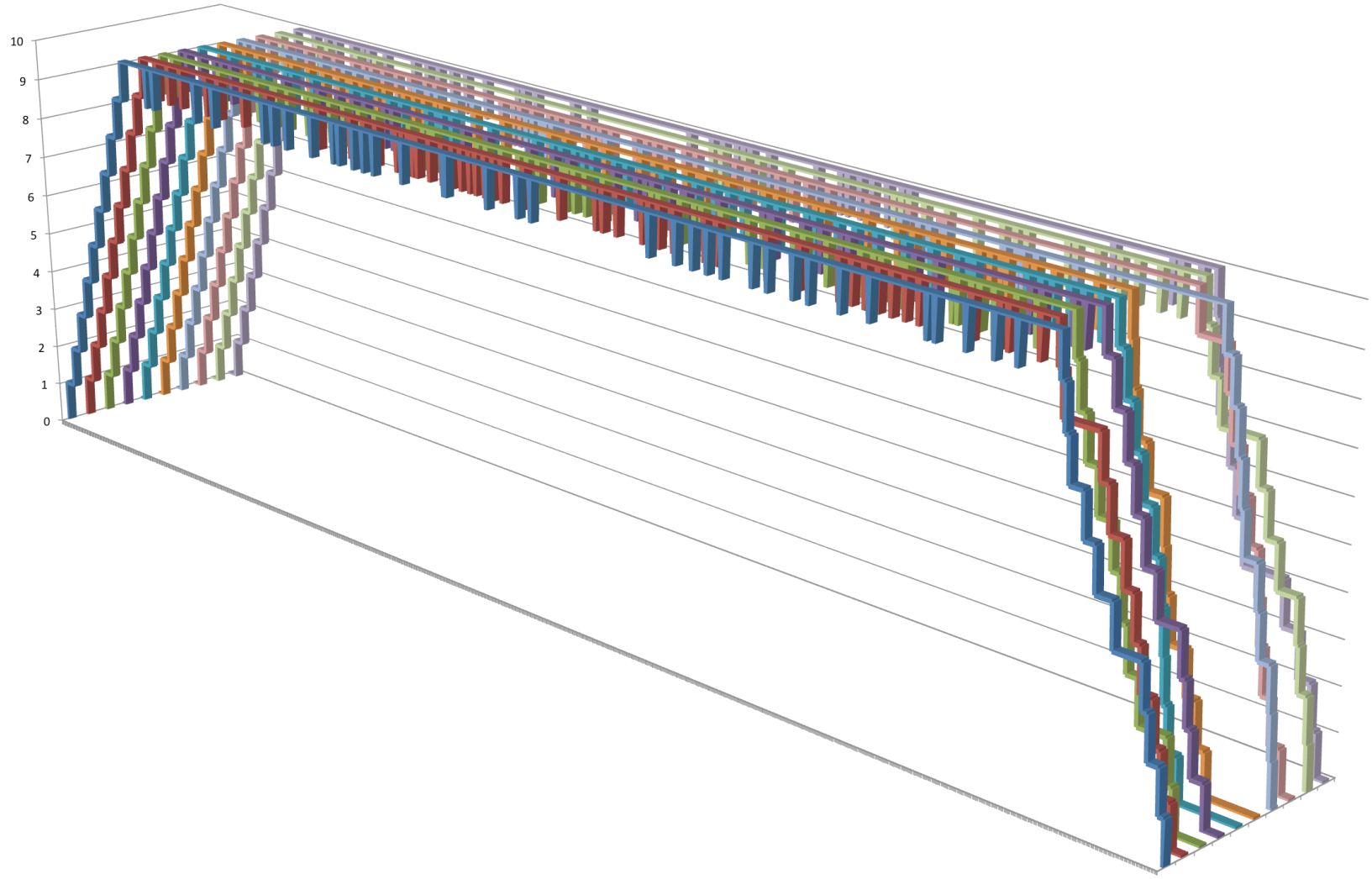
A way to get URLs

```
func get(jobs chan *job, url string, answer chan string) {
    resp := make(chan *http.Response)
    jobs <- &job{url, resp}
    r := <- resp
    answer <- r.Request.URL.String()
}

func main() {
    jobs := balancer(10, 10)
    answer := make(chan string)
    for {
        var url string
        if _, err := fmt.Scanln(&url); err != nil {
            break
        }
        go get(jobs, url, answer)
    }
    for u := range answer {
        fmt.Printf("%s\n", u)
    }
}
```

A load balancer

```
func balancer(count int, depth int) chan *job {
    jobs := make(chan *job)
    done := make(chan *worker)
    workers := make([]*worker, count)

    for i := 0; i < count; i++ {
        workers[i] = &worker{make(chan *job,
            depth), 0}
        go workers[i].getter(done)
    }

    go func() {
        for {
            var free *worker
            min := depth
            for _, w := range workers {
                if w.count < min {
                    free = w
                    min = w.count
                }
            }

            var jobsource chan *job
            if free != nil {
                jobsource = jobs
            }
            select {
            case j := <- jobsource:
                free.jobs <- j
                free.count++

            case w := <- done:
                w.count--
            }
        }
    }()

    return jobs
}
```

Top 500 web sites loaded



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