

Iteration in Go

Abram Hindle

abram.hindle@ualberta.ca

Department of Computing Science

University of Alberta

<http://softwareprocess.es/>

Warning

- This talk is not idiomatic
- Also it is written by a GO Impostor ;-)
- Wish I saw Nathan's talk before I did some of these examples :(

Iteration

- Programming is useful because we can repeat tasks
- Iteration is one of the fundamental building blocks of most programming languages
- Iteration usually refers to repetition
 - In mathematics iterating a functions means applying it repeatedly
 - In programming iteration can refer to any method of repetition.

Concepts

- Block
 - A chunk of code
 - Usually the part that gets repeated
 - Usually follows scope rules
- Condition
 - An expression that evaluates to true or false
 - Commonly used to determine if a loop continues

Concepts

- In Order – Execute in Sequence
- Out of Order – Execute in any order
- Dependency – One value depends on another

~~While~~ For Loops

- Repeats a block until a condition is met.
- Loop invariant executes first

```
condition := false
for condition {
    // ...
    condition = !condition
}
reader := bufio.NewReader(os.Stdin)
reads := 0
for {
    reads++
    _, err := reader.ReadString('\n');
    if err != nil {
        break;
    }
}
fmt.Printf("Reads: %d\n", reads)
```

```
x := 10
for x > 0 {
    x = x - 1
}
// x is 0
fmt.Printf("x is %d\n", x)

// maybe you're not sure how
// many iterations you need
y := 100.0
for y > 1 {
    y = y / 3;
}
fmt.Printf("y is %f\n", y)
// y is 0.4115226337448560
```

For Loop

- Iterate with a condition or over a collection of elements.

```
sum := 0;
for i := 0 ; i < 10; i++ {
    sum += i;
}
fmt.Printf("Sum is %d\n", sum)
```

```
s := ""
s2 := ""
v := []string{"a", "b", "c"}
u := map[string]string{"A": "a", "B": "b", "C": "c"}
```

```
for i, val := range v {
    for j := 0; j <= i; j++ {
        s += val;
    }
}
```

```
fmt.Printf("s is [%s]\n", s)
```

```
for key, val := range u {
    s += key;
    s += val;
}
fmt.Printf("s is [%s]\n", s)
for i, val := range s2 {
    // i is the byte location
    for j := 0; j <= i; j++ {
        s += string(val);
    }
}
fmt.Printf("s is (note that the
unique was base-4) [%s]\n", s)
```

Recursion

- Arbitrary flow control
- Good for iterating datastructures like trees
- Watch out for stackoverflows!

```
stump := map[string]Tree{}

tree := Tree{0,
  map[string]Tree{
    "a":Tree{1,stump},
    "b":Tree{2, map[string]Tree{
      "h":Tree{8,stump},
      "i":Tree{9,stump},
      "j":Tree{10,stump},
    },
  },
  "c":Tree{3,stump},
  "d":Tree{4, map[string]Tree{
    "e":Tree{5,stump},
    "f":Tree{6,stump},
    "g":Tree{7,stump},
  },
},
},
},
}
```


Recursion

- Arbitrary flow control
- Good for iterating datastructures like trees
- Watch out for stackoverflows!

```
fmt.Printf("Treesum %d\n", TreeSum( tree ))
```

```
for i := range iInt(6).Iter() {  
    fmt.Printf("Wow! %v\n", i)  
}
```

```
// Call Back walker
```

```
TreeWalker(tree, func(t Tree) {  
    fmt.Printf("Node value %d\n", t.Value) }  
}
```

Recursion

```
type Tree struct {  
    Value int  
    Branches map[string]Tree  
}
```

```
func TreeSum( tree Tree ) int {  
    sum := tree.Value;  
    for _, val := range tree.Banches {  
        sum += TreeSum(val)  
    }  
    return sum;  
}
```

```
func TreeWalker( tree Tree,  
                 f func(Tree) ) {  
    f(tree)  
    for _, val := range  
        tree.Banches {  
        TreeWalker(val,f)  
    }  
}
```

Channel Iterators

```
type iInt int
```

```
func (max iInt) Iter () <-chan iInt {  
    ch := make(chan iInt);  
    go func () {  
        m := int(max)  
        for i := 0; i <= m; i++ {  
            ch <- iInt(i)  
        }  
        close(ch)  
    } ();  
    return ch  
}
```

Channel Iterators

```
func TreeIter( tree Tree ) <-chan Tree {  
    ch := make(chan Tree);  
    go func () {  
        TreeWalker( tree, func(t Tree) {  
            ch <- t  
        })  
        close(ch)  
    } ();  
    return ch  
}
```

```
func (tree Tree) Iter() <-chan Tree {  
    return TreeIter( tree )  
}
```

Channel Iterators

```
for i := range iInt(6).Iter() {  
    fmt.Printf("Wow! %v\n", i)  
}
```

// Call Back walker

```
TreeWalker(tree, func(t Tree) { fmt.Printf("Node  
value %d\n",t.Value) } )
```

```
for tree := range tree.Iter() {  
    fmt.Printf("Now via Iter Node value  
%d\n",tree.Value)  
}
```

OO Iteration (Iterators)

- Object with a Next() method and Value()

```
type StringIterator struct {  
    current int  
    s []rune  
}  
  
// http://ewencp.org/blog/golang-iterators/  
func (si *StringIterator) Next() bool {  
    si.current++  
    return (si.current < len(si.s))  
}  
func (si *StringIterator) Value() string {  
    return string(si.s[si.current])  
}
```

OO Iteration (Iterators)

- Object with a Next() method and Value()

```
type EvenStringIterator struct {  
    current int  
    s []rune  
}  
func (si *EvenStringIterator) Next() bool {  
    si.current += 2;  
    return (si.current < len(si.s))  
}  
  
func (si *EvenStringIterator) Value() string {  
    return string(si.s[si.current])  
}  
  
func EvenIterator(s string) *EvenStringIterator {  
    return &EvenStringIterator{current: -1, s:  
        []rune(s)}
```

OO Iteration (Iterators)

- Object with a Next() method and Value()

```
si := Iterator(s)
for si.Next() {
    fmt.Printf("String val! %s\n", si.Value())
}
```

```
si2 := EvenIterator(s)
for si2.Next() {
    fmt.Printf("Even String val! %s\n", si2.Value())
}
```


Order

- Did you notice something?
- Everything iterated in order.
- But what if order doesn't really matter?

Map

- In mathematics iterating a functions means applying it repeatedly
- A map function applies 1 function to all elements in a collection and produces a new collection of the results of that function
 - Usually this is in order
 - But you don't have to do it in order
- $\text{Map } f(a,b,c) \Rightarrow (f(a), f(b), f(c))$
- $\text{Map square } (1,2,3) \Rightarrow (1,4,9)$

Map Example

```
func intIntMap( iarr []int, cb (func(int) int)) []int {  
    out := make( []int, len(iarr))  
    for i,v := range iarr {  
        out[i] = cb( v )  
    }  
    return out  
}
```

```
// MACROS??? GENERICS???
```

```
func strStrMap( iarr []string, cb (func(string) string)) []string {  
    out := make( []string, len(iarr))  
    for i,v := range iarr {  
        out[i] = cb( v )  
    }  
    return out  
}
```

Map Example

```
v2 := []int{1,2,3,4,5,6,7,8}
inc := func(x int) int { return 1 + x }
sqr := func(x int) int { return x * x }
// lack of generics
v3 := intIntMap(v2, inc)
fmt.Printf("inc v2: [%v] v3: [%v]\n",v2,v3)
// lack of generics
v3 = intIntMap(v2, sqr)
fmt.Printf("sqr v2: [%v] v3: [%v]\n",v2,v3)

basename := func(path string) string {
    sp := strings.Split(path, "/")
    return(sp[len(sp) - 1])
}
vs := []string{"/home", "/file", "/usr/local"}
vs2 := strStrMap( vs, basename )
fmt.Printf("basename vs: [%v] vs2: [%v]\n",vs,vs2)
```

Map Example

```
urls := []string{"http://cbc.ca", "http://gc.ca", "http://alberta.ca"}
status := func( uri string ) string {
    resp, _ := http.Get(uri)
    return(resp.Status)
}

statuses := strStrMap(urls, status);
fmt.Printf("statuses: %v\n", statuses)
```

Parallelism with Map

- Think in “map” -- Think Parallel
- Limit dependencies of a block in order to parallelize the computation!

```
mySum := func(l []int) int {  
    sum := 0  
    for _, v := range l {  
        sum += v  
    }  
    return sum  
}  
sumres := mySum( intIntMap(series(1,1000),sqr))  
fmt.Printf("sumres: %v\n", sumres)  
psumres := mySum(parallelIntIntMap( series(1,1000), sqr, 4))  
fmt.Printf("psumres: %v\n", psumres)
```

Parallelism with Map (Continued)

- IO is slow and inherently parallelizable!

```
pgets := parallelStrStrMap( urls, status, 3)  
fmt.Printf("Stupid examples with URLs %v\n", pgets)
```

Parallelism with Map (Continued)

```
func parallelIntIntMap( l []int, f (func(int) int),  
workers int) []int {  
    chans := make( [](chan []int), workers )  
    for i := range chans {  
        chans[i] = make(chan []int)  
    }  
    unit := len(l)/workers  
    for i := 0 ; i < workers; i++ {  
        mychan := chans[i]  
        start := i * unit  
        end := (i + 1)*unit  
        if end >= len(l) {  
            end = len(l)  
        }  
        subl := l[start:end]
```


Parallelism with Map (Continued)

```
for i := 0 ; i < workers; i++ {  
    mychan := chans[i]  
    start := i * unit  
    end := (i + 1)*unit  
    if end >= len(l) {  
        end = len(l)  
    }  
    subl := l[start:end]  
    par := func(l []int) {  
        mychan <- intIntMap(l, f)  
        close(mychan)  
    }  
    go par(subl)  
}  
out := make([]int, len(l))  
for i := 0; i < workers; i++ {  
    arr := <- chans[i]
```

Parallelism with Map (Continued)

```
out := make([]int, len(l))
for i := 0; i < workers; i++ {
    arr := <- chans[i]
    start := i*unit
    end := start + len(arr)
    copy(out[start:end], arr)
}
return out
}
```

Reduce

- Linear, 1 at a time
- Collapse a collection in a single value via an operator or function of 2 args
 - $f(e1, f(e2, f(e4, \dots f(e99, e100))) \dots))$
 - $\text{add}(e1, \text{add}(e2, \text{add}(e4, \dots \text{add}(e99, e100))) \dots))$
- Sum is a reduce

```
vex := []int{1,2,3,4,5,6,7,8,9};  
iadd := func(x, y int) int { return(x + y) }  
vexr := intIntReduce(vex, iadd)  
fmt.Printf("Sum: %v\n", vexr)
```

Reduce

```
func intIntReduce( iarr []int, cb (func(int,int) int))
    int {
        o := iarr[0]
        m := len(iarr)
        for i := 1; i < m; i++ {
            o = cb( iarr[i], o)
        }
        return o
    }
```

Reduce Can Be Parallel (Sometimes)

```
preduced := parallelIntIntMapReduce( series(1,1000000000),  
                                     sqr, iadd, 4)  
fmt.Printf("Reduced %v\n", preduced)
```

Reduce Can Be Parallel (Sometimes)

```
func parallelIntIntMapReduce( l []int,  
    mapper (func(int) int),  
    reducer (func(int,int) int),workers int) int {  
    chans := make( [](chan int),  workers )  
    //var chans [workers]chan []int  
    for i := range chans {  
        chans[i] = make(chan int)  
    }  
  
    unit := len(l)/workers
```

Reduce Can Be Parallel (Sometimes)

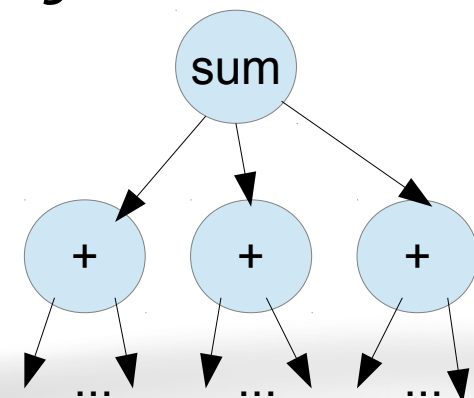
```
for i := 0 ; i < workers; i++ {  
    mychan := chans[i]  
    start := i * unit  
    end := (i + 1)*unit  
    if end >= len(l) {  
        end = len(l)  
    }  
    subl := l[start:end]  
    par := func(l []int) {  
        mychan <- intIntReduce(intIntMap(l, mapper), reducer)  
        close(mychan)  
    }  
    go par(subl)  
}
```

Reduce Can Be Parallel (Sometimes)

```
reductions := make( []int, workers)
for i := 0; i < workers; i++ {
    r := <- chans[i]
    reductions[i] = r
}
return intIntReduce(reductions, reducer)
}
```


Trees, Commutativity and Initialization

- Can your problem be modelled as a TREE?
- Problems with commutative or associative parts can often be modelled as a tree of computation.
- Different branches may be executed in Parallel.
- One can reduce dependencies by avoid initialization (e.g. $\text{sum} = 0$)



Conclusions

- Main forms of Go iteration:
 - For / Iterators / Range / Recursion / Map / Reduce
- Reducing dependencies in blocks allows iteration to be parallelized.
- Consider if order or strictness can be are actually needed?
- These concepts apply to other languages as well.

Resources

- Go Spec <http://golang.org/ref/spec>
- Eleanor McHugh - Going Loopy: Iteration in Go
<https://www.youtube.com/watch?v=RFIOSjkB-j8>
<http://www.slideshare.net/feyeleanor/presentation-28920130>
- <https://stackoverflow.com/questions/12363030/read-from-initial-stdin-in-go>
- Go Language Patterns
<https://sites.google.com/site/gopatterns/object-oriented/iterators>
- Iterators in Go <http://ewencp.org/blog/golang-iterators/>
- Map in Go <https://groups.google.com/forum/#!topic/golang-nuts/RKymTuSCHS0>

Labels and breaks

- Label1:
- `break Label1` // break the the loop at label1
- Label2:
- `continue Label2` //advance next loop with Label2 label

Goto

- `goto Label2 // goto Label2 if it isn't in a block`
`// must be same scope`

Go Channel Iterators

- See <https://sites.google.com/site/gopatterns/object-oriented/iterators>

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