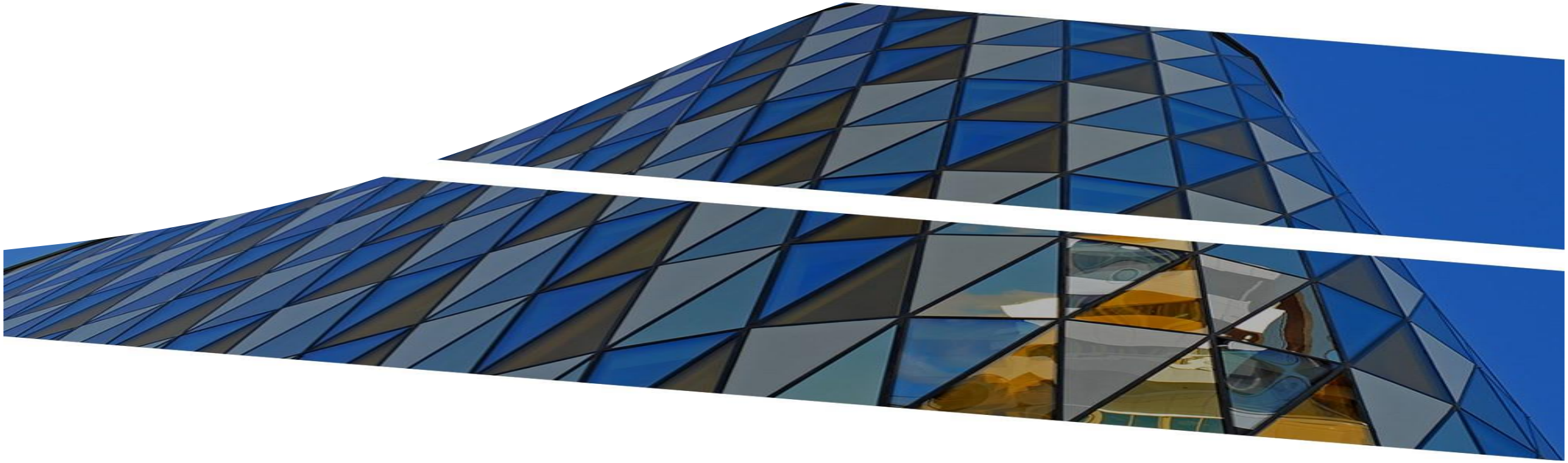


Golang Programming

Code Generation and Generics in Go

Where to Find The Code and Materials?

https://github.com/iproduct/coursego

Agenda for This Session

- The problem
- Code generation
- Generics and their purpose
- Type-specific wrappers with type-agnostic implementations
- Alternatives – using interfaces, assertions, reflection, code generation
- Generating code with go generate
- Generics in Go –Specification & Demo with Go 1.18.beta1
- Q&A. Projects mentoring.

The Problem

- Many algorithms and data structures are applicable to many data types. Examples: Stringer, Sorter, priority queue, sorted tree, concurrent hash map
- Container data types above could hold elements of string, int64, []int, map[string]string, or a struct type.
- We could implement a sorting algorithm using sorted tree for example. The requirement is that the elemets should be comparable to each other.
- But what if we want to reuse the same sorted tree implementation with different element types?
- If there are N methods and M element types we should write N x M function implementations …

Solutions from Other Languages – e.g. Java

```
public class SortedTree<E extends Comparable<E>> {
    public void insert(E element) {
        //...
    }
}
```

```
SortedTree<String> stringSortedTree = new SortedTree<>();
sortedTreeOfStrings.insert("xyz");
sortedTreeOfStrings.insert("abc");
sortedTreeOfStrings.insert("klm");
```

The Ways to Implement Generic Code in Go

- "If C++ and Java are about type hierarchies and the taxonomy of types, Go is about composition." (Rob Pike)
- Use multiple functions (copy & paste ☺)
- Interfaces
- Type assertions
- Reflection
- Code generation

Interfaces (1)

- Example: sort.Interface

```
type Interface interface {
      Len() int
      Less(i, j int) bool
      Swap(i, j int)
}
```

- Example: `io.Reader` interface:
  - many functions take an io.Reader as input
  - many data types, including files, network connections, ciphers, implement it
- Or even: `interface {}`. E.g.:

```
func Slice(slice interface{}, less func(i, j int) bool)
```

Interfaces (2)

```
import "sort"

type Person struct {
        Name string
        Age  int
}

// ByAge implements sort.Interface for []Person based on the Age field.
type ByAge []Person

func (a ByAge) Len() int           { return len(a) }
func (a ByAge) Swap(i, j int)      { a[i], a[j] = a[j], a[i] }
func (a ByAge) Less(i, j int) bool { return a[i].Age < a[j].Age }

func SortPeople(people []Person) {
        sort.Sort(ByAge(people))
}
```

Interfaces (3)

```
package main
import ("fmt"; "sort")
func main() {
	people := []struct {
		Name string
		Age  int
	}{
		{"Gopher", 7},
		{"Alice", 55},
		{"Vera", 24},
		{"Bob", 75},
	}
	sort.Slice(people, func(i, j int) bool { return people[i].Name < people[j].Name })
	fmt.Println("By name:", people)

	sort.Slice(people, func(i, j int) bool { return people[i].Age < people[j].Age })
	fmt.Println("By age:", people)
}
```

Type Assertions (1)

```
type MyContainer []interface{}

func (c *MyContainer) Put(elem interface{}) {
      *c = append(*c, elem)
}

func (c *MyContainer) Get() interface{} {
      elem := (*c)[0]
      *c = (*c)[1:]
      return elem
}
```

Type Assertions (2)

```
func main() {
	myIntContainer := &MyContainer{}
	myIntContainer.Put(12)
	myIntContainer.Put(70)
	elem, ok := myIntContainer.Get().(int)
	if !ok {
		fmt.Println("Error getting int from myIntContainer")
	}
	fmt.Printf("Got: %d (%T)\n", elem, elem)
}
```

Reflection (1)

```
package main

import (
	"fmt"
	"reflect"
)

type MyStack struct {
	t reflect.Type
	value reflect.Value
}

func New(tp reflect.Type) *MyStack {
	return &MyStack{
		t: tp,
		value: reflect.MakeSlice(reflect.SliceOf(tp), 0, 100),
	}
}
```

Reflection (2)

```
func (m *MyStack) Push(v interface{}) {
        if reflect.ValueOf(v).Type() != m.value.Type().Elem() {
                panic(fmt.Sprintf("Error putting %T into %s", v, m.value.Type().Elem()))
        }
        m.value = reflect.Append(m.value, reflect.ValueOf(v))
}

func (m *MyStack) Pop() interface{} {
        v := m.value.Index(0)
        m.value = m.value.Slice(1, m.value.Len())
        return v.Interface()
}

func main() {
        val := 2.88
        stack := New(reflect.TypeOf(val))
        stack.Push(val)
        fmt.Println(stack.value.Index(0))
        result := stack.Pop()
        fmt.Printf("Result: %[1]f (%[1]T)\n", result)
}
```

Problem: Reflection Performance – Getting Map Keys

https://github.com/iproduct/coursego/blob/master/13-generation/reflection-performance/invoc_test.go

```
func keysPrealloc(m map[uint64]string) {
        k := make([]uint64, len(m))
        var i uint64
        for key := range m {
                k[i] = key
                i++
        }
}

func keysAppend(m map[uint64]string) {
        keys := make([]uint64, 0)
        for key := range m {
                keys = append(keys, key)
        }
}

func keysReflect(m map[uint64]string) {
        reflect.ValueOf(m).MapKeys()
}
```

```
populating
filling 100000000 slots
done in 25.6922994s
running prealloc
took: 1.5210013s
running append
took: 2.908973s
running reflect
took: 6.4179969s
```

Problem: Reflection Performance

https://github.com/iproduct/coursego/blob/master/13-generation/reflection-performance/reflection.performance.go

```
func BenchmarkReflectMethodCall(b *testing.B) {
        i := new(myint)
        incnReflectCall(i.inc, b.N)
}

func incnReflectCall(v interface{}, n int) {
        for k := 0; k < n; k++ {
                reflect.ValueOf(v).Call(nil)
        }
}

func incnReflectOnceCall(v interface{}, n int) {
        fn := reflect.ValueOf(v)
        for k := 0; k < n; k++ {
                fn.Call(nil)
        }
}
```

```
goos: windows
goarch: amd64
pkg: github.com/iproduct/coursego/generation/reflection-performance
BenchmarkReflectMethodCall
BenchmarkReflectMethodCall-12              11213013        95.7 ns/op
BenchmarkReflectOnceMethodCall
BenchmarkReflectOnceMethodCall-12          12766160        94.8 ns/op
BenchmarkStructMethodCall
BenchmarkStructMethodCall-12               944913882       1.26 ns/op
BenchmarkInterfaceMethodCall
BenchmarkInterfaceMethodCall-12            666554833       1.80 ns/op
BenchmarkTypeSwitchMethodCall
BenchmarkTypeSwitchMethodCall-12           1000000000      0.957 ns/op
BenchmarkTypeAssertionMethodCall
BenchmarkTypeAssertionMethodCall-12        1000000000      1.18 ns/op
PASS
```

Code Generation - Rob Pike

[https://blog.golang.org/generate]

- A property of universal computation—Turing completeness—is that a computer program can write a computer program. This is a powerful idea that is not appreciated as often as it might be, even though it happens frequently.

- It's a big part of the definition of a compiler, for instance. It's also how the go test command works: it scans the packages to be tested, writes out a Go program containing a test harness customized for the package, and then compiles and runs it.

- Modern computers are so fast this expensive-sounding sequence can complete in a fraction of a second.

- Examples: Yacc, Protocol Buffers

Code Generation Example - Rob Pike
[https://blog.golang.org/generate]

- Get Go Yacc tool:

```
go get golang.org/x/tools/cmd/goyacc
```

- You can run it directly:

```
goyacc -o gopher.go -p parser gopher.y
```

- Go generate - add this comment anywhere in the non-generated go file:

```
//go:generate goyacc -o gopher.go -p parser gopher.y
```

```
$ cd $GOPATH/myrepo/gopher
$ go generate
$ go build
$ go test
```

Code Generation - Rob Pike

[https://blog.golang.org/generate]

- A property of universal computation—Turing completeness—is that a computer program can write a computer program. This is a powerful idea that is not appreciated as often as it might be, even though it happens frequently.

- It's a big part of the definition of a compiler, for instance. It's also how the go test command works: it scans the packages to be tested, writes out a Go program containing a test harness customized for the package, and then compiles and runs it.

- Modern computers are so fast this expensive-sounding sequence can complete in a fraction of a second.

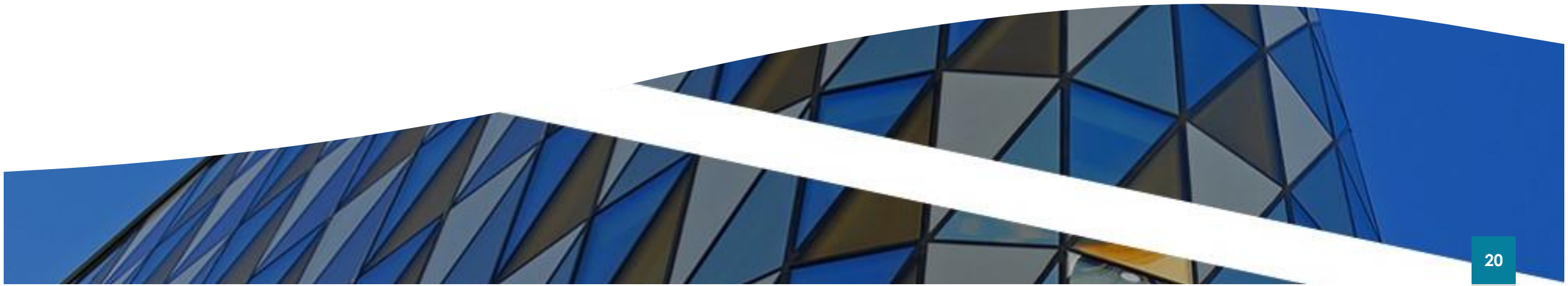
- Examples: Yacc, Protocol Buffers

Code Generation Examples

https://github.com/iproduct/coursego/tree/master/13-generation
https://github.com/iproduct/coursego/tree/master/generationlab

Generics in Go 1.18

experiments with generics



Type Parameters - Draft Design - I

Ian Lance Taylor, Robert Griesemer, January 11, 2021:
https://go.googlesource.com/proposal/+/refs/heads/master/design/go2draft-type-parameters.md

- Functions can have an additional type parameter list that uses square brackets but otherwise looks like an ordinary parameter list:
  func F[T any](p T) { ... }

- These type parameters can be used by the regular parameters and in the function body.

- Types can also have a type parameter list: **type M[T any] []T**

- Each type parameter has a type constraint, just as each ordinary parameter has a type: **func F[T Constraint](p T) { ... }**

- Type constraints are interface types.

Type Parameters - Draft Design - II

Ian Lance Taylor, Robert Griesemer, January 11, 2021:
https://go.googlesource.com/proposal/+/refs/heads/master/design/go2draft-type-parameters.md

- The new predeclared name **any** is a type constraint that permits any type.
- Interface types used as type constraints can have a list of predeclared types; only type arguments that match one of those types satisfy the constraint.
- Generic functions may only use operations permitted by the type constraint.
- Using a generic function or type requires passing type arguments.
- Type inference permits omitting the type arguments of a function call in common cases.

Simple Generics Demo

```
package main

import "fmt"

func PrintSlice [T any] (s []T) {
        for _,v := range s{
                fmt.Print(v)
        }
}

func main() {
        PrintSlice([]int {1,2,3,4,5,6,7,8,9})
        fmt.Println()
        PrintSlice([]string {"a","b","c","d"})
        fmt.Println()
}
```

- Enable experimental support in Goland
- Rename to .go2 => Ctrl+Alt+Shift+S to run code in The go2go Playground

Map-Filter-Reduce Demo - I

```
func Map [T1, T2 any] (s []T1, f func(T1) T2) []T2 {
        r := make([]T2, len(s))
        for i, v := range s {
            r[i] = f(v)
        }
        return r
}

func Reduce [T1, T2 any] (s []T1, initializer T2, f func(T2, T1) T2) T2 {
        r := initializer
        for _, v := range s { r = f(r, v) }
        return r
}

func Filter [T any] (s []T, f func(T) bool) []T {
        var r []T
        for _, v := range s {
            if f(v) { r = append(r, v) }
        }
        return r
}
```

Map-Filter-Reduce Demo - II

```
func main() {
	s := []int{1, 2, 3}

	floats := Map(s, func(i int) float64 { return float64(i) })
	fmt.Println(floats) // Now floats is []float64{1.0, 2.0, 3.0}.


	sum := Reduce(s, 0, func(i, j int) int { return i + j })
	fmt.Println(sum) // Now sum is 6.

	evens := Filter(s, func(i int) bool { return i%2 == 0 })
	fmt.Println(evens) // Now evens is []int{2}.
}
```

Generic Sorting - OrderedSlice Demo

```
type Ordered interface {
   ~int | ~int8 | ~int16 | ~int32 | ~int64 |
   ~uint | ~uint8 | ~uint16 | ~uint32 | ~uint64 | ~uintptr |
   ~float32 | ~float64 |
   ~string
}
type orderedSlice[T Ordered] []T
func (s orderedSlice[T]) Len() int           { return len(s) }
func (s orderedSlice[T]) Less(i, j int) bool { return s[i] < s[j] }
func (s orderedSlice[T]) Swap(i, j int)      { s[i], s[j] = s[j], s[i] }
func OrderedSlice[T Ordered](s []T) {
        sort.Sort(orderedSlice[T](s))
}

func main() {
        s1 := []int32{3, 5, 2}
        OrderedSlice(s1)
        fmt.Println(s1) // Now s1 is []int32{2, 3, 5}
        s2 := []string{"a", "c", "b"}
        OrderedSlice(s2)
        fmt.Println(s2) // Now s2 is []string{"a", "b", "c"}
}
```

Q&A. Projects mentoring

Recommended Literature

- Go Type Parameters Proposal - https://go.googlesource.com/proposal/+/refs/heads/master/design/43651-type-parameters.md
- Why Generics? - https://go.dev/blog/why-generics
- Tutorial: Getting started with generics - https://go.dev/doc/tutorial/generics
- Exploring Go v1.18's Generics - https://bignerdranch.com/blog/exploring-go-v1-18s-generics/
- The Go Documentation - https://golang.org/doc/
- The Go Bible: Effective Go - https://golang.org/doc/effective_go.html

Thank's for Your Attention!

Trayan Iliev

IPT – Intellectual Products & Technologies

http://iproduct.org/

http://robolearn.org/

https://github.com/iproduct

https://twitter.com/trayaniliev

https://www.facebook.com/IPT.EACAD