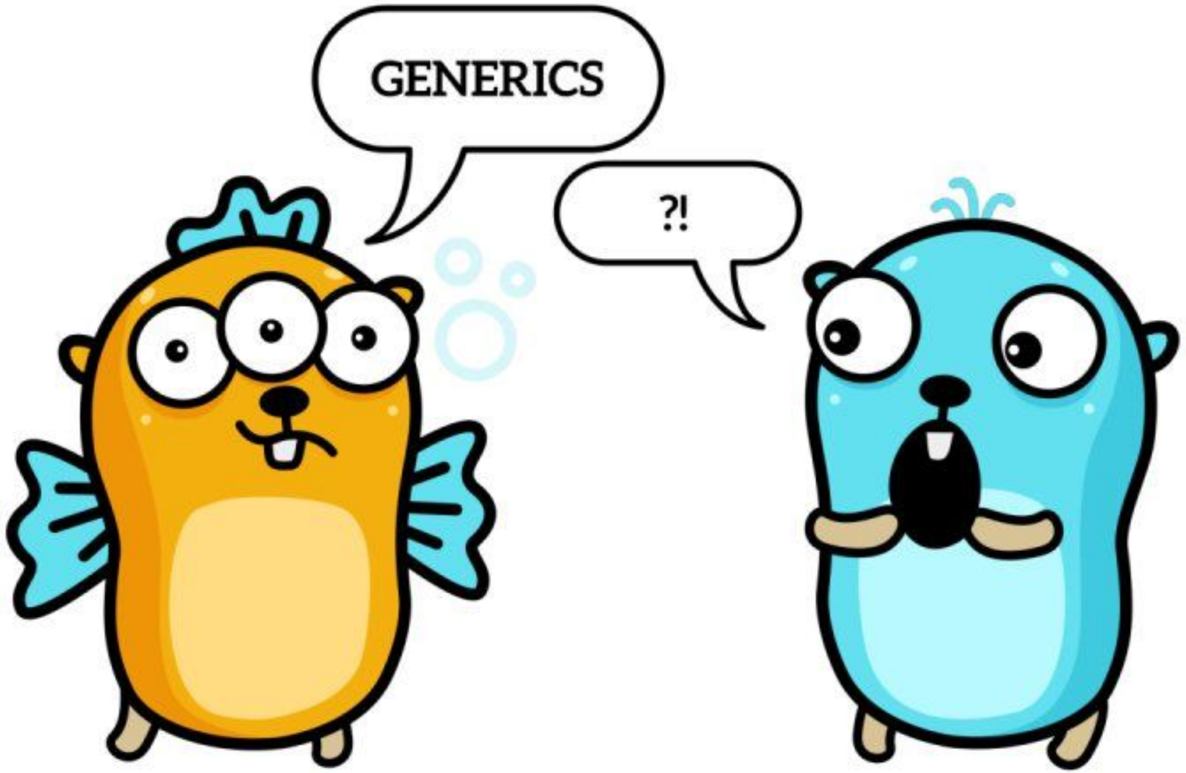
GENERICS
?!

We don’t need generics!

What generics alternatives do we have?

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➜ Manual monomorphization

What generics alternatives do we have?

➜ Copy => Paste

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✓ Copy => Paste

➜ Interfaces

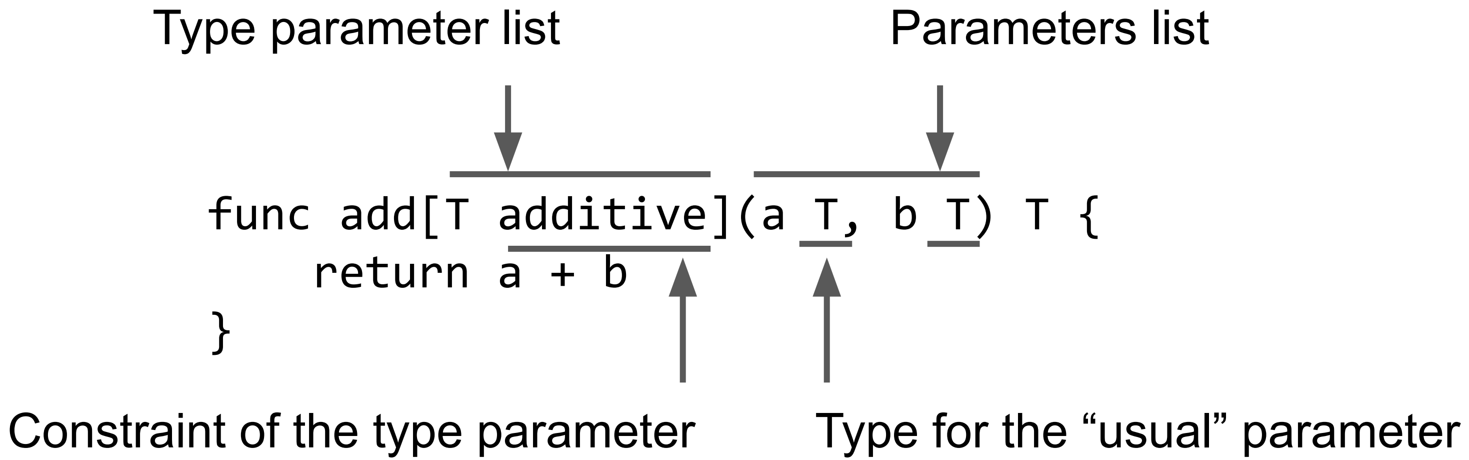
What generics alternatives do we have?

- ✓ Copy => Paste
- ✓ Interfaces
- ➜ Reflection

What generics alternatives do we have?

- ✓ Copy => Paste
- ✓ Interfaces
- ✓ Reflection
- ➜ Code generation

Syntax



Type parameter list
Parameters list
Constraint of the type parameter
Type for the “usual” parameter

```
func add[T additive](a T, b T) T {
    return a + b
}
```

Unconstrained generics

Unconstrained generics

```
func last[T any](a []T) T {
    return a[len(a)-1]
}
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Unconstrained generics

```
func last[T any](a []T) T {
    return a[len(a)-1]
}

// any is an alias for interface{}

func less[T any](a T, b T) bool {
    return a < b
}
```

Unconstrained generics

```
func last[T any](a []T) T {
    return a[len(a)-1]
}

// any is an alias for interface{}

func less[T any](a T, b T) bool {
    return a < b // Error
}

// you can not compare any type
```

Unconstrained generics

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func last[T any](a []T) T {
    return a[len(a)-1]
}

// any is an alias for interface{}

func less[T any](a T, b T) bool {
    return a < b // Error
}

// you can not compare any type
```

```
func less[T comparable](a T, b T) bool {
    return a < b
}

// comparable is a build in constraint
```

You can constraint generics by type

You can constraint generics by type

```
type additive interface {
    int|uint|~float64
}

func add[T additive](a T, b T) T {
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func add[T additive](a T, b T) T {
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// Constraint literal
func add[T int|~uint](a T, b T) T {
    return a + b
}
```

You can constraint generics by type

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    int|uint|~float64
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$\uparrow$

What’s this?

We have a new token! ~

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~T denotes the set of types whose underlying type is T

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```
type additive interface {
    int|uint|~uint64
}

type myUint uint64

func add[T additive](a T, b T) T {
    return a + b
}

x, y := myUint(0), myUint(1.18)
z := add(x, y)
```

You can constraint generics by interface

You can constraint generics by interface

```
type Stringer interface {
     String() string
}

func Tos[T Stringer](s []T) []string {
   var ret []string
   for _, v := range s {
      ret = append(ret, v.String())
   }

   return ret
}
```

Generics in structures

Generics in structures

```
// List is a doubly-linked list.
type List[V any] struct {
    Front, Back *Node[V]
}

// Node is a node in the linked list.
type Node[V any] struct {
    Value      V
    Prev, Next *Node[V]
}
```

Generics in structures

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func main() {
    myList := List[int]{}
}
```

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    myList := List[int]{}
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```

```go
func last[T any](a []T) T {
    return a[len(a)-1]
}

func main() {
    xx := []int{1,2,3}
    print(last[int](x))
}
```

Generics in structures

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    return a[len(a)-1]
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func main() {
    xx := []int{1,2,3}
    print(last(x))
}
```

Benchmarks

Benchmarks: general speed

Go 1.18 (generic)

```
func ContainsG[T comparable](s []T, e T)
bool {
     for _, a := range s {
          if a == e {
               return true
          }
     }
     return false
}
```

Benchmarks: general speed

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func ContainsG[T comparable](s []T, e T)
bool {
	for _, a := range s {
		if a == e {
			return true
		}
	}
	return false
}
```

Go 1.17 (reflect)

```go
func ContainsR(in interface{}, elem interface{}) bool{
	inValue := reflect.ValueOf(in)
	if inValue.Type().Kind() != reflect.Slice {
		panic("'in' is not a Slice")
	}
	for i := 0; i < inValue.Len(); i++ {
		if equal(elem, inValue.Index(i)) {
			return true
		}
	}
	return false
}

func equal(e interface{}, val reflect.Value) bool {
	if val.IsZero() {
		return val.Interface() == e
	}
	return reflect.DeepEqual(val.Interface(), e)
}
```

Benchmarks: general speed

```
const l = 1000

func Benchmark____(b *testing.B) {
	s := make([]int, l)
	for i := 0; i < l; i++ {
		s[i] = i
	}

	for n := 0; n < b.N; n++ {
		Contains___(s, l-1)
	}
}
```

Benchmarks: general speed

```
const l = 1000

func Benchmark____(b *testing.B) {
	s := make([]int, l)
	for i := 0; i < l; i++ {
		s[i] = i
	}

	for n := 0; n < b.N; n++ {
		Contains___(s, l-1)
	}
}
```

```
[0] $ go test -bench=.
goos: linux
goarch: amd64
cpu: Intel(R) Core(TM) i5-8365U CPU

Reflect     19527    64353   ns/op
Generic   3909652      292.7 ns/op
Native    3977557      307.3 ns/op
```

Benchmarks: general speed

```
func Benchmark__(b *testing.B) {
     for n := 0; n < b.N; n++ {
          Fib__(20)
     }
}

func Fib_(a T)T {
     if a <= 1 {
          return a
     }
     return Fib_(a-1) + Fib_(a-2)
}
```

Benchmarks: general speed

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func Benchmark__(b *testing.B) {
	for n := 0; n < b.N; n++ {
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```
[0] $ go test -bench=.
goos: linux
goarch: amd64
cpu: Intel(R) Core(TM) i5-8365U CPU

Interface    13354      88085 ns/op
Generic      39980      32544 ns/op
Native       37729      32275 ns/op
```

Benchmarks: compilation time

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Go 1.18 (generic)

```
type number interface {
     ~int | ~int32 | ~int64 | ~float32 |
     ~float64 | ~uint | ~uint64
}

func MaxGeneric**[T number](a, b T) T {
     if a > b {
          return a
     }

     return b
}
```

Benchmarks: compilation time

Go 1.18 (generic)

```
type number interface {
     ~int | ~int32 | ~int64 | ~float32 |
     ~float64 | ~uint | ~uint64
}

func MaxGeneric**[T number](a, b T) T {
     if a > b {
          return a
     }

     return b
}
```

Go 1.17 (native)

```
func MaxInt**(a, b int) int {
     if a > b {
          return a
     }

     return b
}
```

Benchmarks: compilation time

1. Without actual function calls

Benchmarks: compilation time

1. Without actual function calls

Static typing

```
[0] $ time go build -o ogo static.go dummy_main.go
real 0m1.347s
user 0m3.566s
sys  0m0.192s
```

Benchmarks: compilation time

1. Without actual function calls

Static typing

```
[0] $ time gotip build -o ogo static.go dummy_main.go
real 0m1.347s
user 0m3.566s
sys  0m0.192s
```

Generics

```
[0] $ time gotip build -o ogo generics.go dummy_main.go
real 0m0.499s
user 0m0.843s
sys  0m0.097s
```

Benchmarks: compilation time

2. With functions calls

Benchmarks: compilation time

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Static typing

```
[0] $ time go build -o ogogo static.go calls_main.go
real 0m5.614s
user 0m9.924s
sys  0m0.423s
```

Generics

```
[0] $ time build -o ogogo generics.go calls_main.go
real 0m5.419s
user 0m10.395s
sys  0m0.409s
```

What else we need to know about performance?

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Interfaces, pointers to interfaces and <u>pointers to structs</u>

- Function is generated per every "GCShape"
- We will have GCShape dictionary

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Generics are like monomorphization, but not completely.

Built in types and structs

- Function is generated per every type

Interfaces, pointers to interfaces and pointers to structs

- Function is generated per every "GCShape"
- We will have GCShape dictionary
- Every function call will look up for a function in the dictionary

What else we need to know about performance?

```
name                       time/op       allocs/op
Monomorphized-16           5.06µs ± 1%  2.00 ± 0%
Iface-16                   6.85µs ± 1%  3.00 ± 0%
GenericWithPtr-16          7.18µs ± 2%  3.00 ± 0%
GenericWithExactIface-16  9.68µs ± 2%  3.00 ± 0%
GenericWithSuperIface-16  17.6µs ± 3%  3.00 ± 0%
```

What else we need to know about performance?

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name                         time/op       allocs/op
Monomorphized-16             5.06µs ± 1%   2.00 ± 0%
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GenericWithPtr-16            7.18µs ± 2%   3.00 ± 0%
GenericWithExactIface-16     9.68µs ± 2%   3.00 ± 0%
GenericWithSuperIface-16     17.6µs ± 3%   3.00 ± 0%
```

Generics can make your Go code slower

Generics via Dictionaries and Gcshape Stenciling

When to use/not to use generics?

When to use/not to use generics?

Use generics to not repeat yourself.

When to use/not to use generics?

Use generics to not repeat yourself.

As a conclusion:

try not to use generics
until you start to repeat yourself.

Read more:

Generics Proposal

Repository with Go generics research and examples:

Go generics: the hard way

Talk from masters of Go:

GopherCon: R Griesemer & Ian Lance Taylor

Functional library with Filter, Map, Reduce, etc.:

github.com/samber/lo

Benchmarks code from these slides

That’s all!

Questions?