The Go Programming Language

Part 2

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Today's Outline

Exercise
- any questions?

Composite types
- structures, arrays, slices, maps

Methods
- they're not just for structs any more

Interfaces

Exercise

Any questions?

One nugget:

```
n0, n1 = n0+n1, n0
```

or for a general binary operator

```
n0, n1 = op(n0, n1), n0
```

Arrays

Arrays

Arrays are quite different from C arrays; more like Pascal arrays. (Slices, the next topic, act a little more like C arrays.)

```
var ar [3]int
```

declares `ar` to be an array of 3 integers, initially all set to zero.

Size is part of the type.

Built-in function `len` reports size:

```
len(ar) == 3
```

Arrays are values

Arrays are values, not implicit pointers as in C. You can take an array's address, yielding a pointer to the array (for instance, to pass it efficiently to a function):

```
func f(a [3]int) { fmt.Println(a) }
func fp(a *[3]int) { fmt.Println(a) }

func main() {
    var ar [3] int
    f(ar)    // passes a copy of ar
    fp(&ar)  // passes a pointer to ar
}
```

Output (`Print` and friends know about arrays):

```
[0 0 0]
&[0 0 0]
```

Array literals

All the composite types have similar syntax for creating values. For arrays it look like this:

Array of 3 integers:

```
[3]int{1, 2, 3}
```

Array of 10 integers, first three not zero:

```
[10]int{ 1, 2, 3}
```

Don't want to count? Use ... for the length:

```
[...]int{1, 2, 3}
```

Don't want to initialize them all? Use key:value pairs:

```
[10]int{2:1, 3:1, 5:1, 7:1}
```

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Pointers to array literals

You can take the address of an array literal to get a pointer to a newly created instance:

```
func fp(a *[3]int) { fmt.Println(a) }

func main() {
    for i := 0; i < 3; i++ {
        fp(&[3]int{i, i*i, i*i*i})
    }
}
```

Output:

```
&[0 0 0]
&[1 1 1]
&[2 4 8]
```

Slices

Slices

A slice is a reference to a section of an array.
Slices are used much more often than plain arrays.

A slice is very cheap. (More about this soon.)

A slice type looks like an array type without a size:

```
var a []int
```

Built-in `len(a)` returns the number of elements.

Create a slice by "slicing" an array or slice:

```
a = ar[7:9]
```

Valid indexes of `a` will then be `0` and `1`; `len(a)==2`.

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Slice shorthands

When slicing, first index defaults to `0`:

`ar[:n]` means the same as `ar[0:n]`.

Second index defaults to `len(array/slice)`:

`ar[n:]` means the same as `ar[n:len(ar)]`.

Thus to create a slice from an array:

`ar[:]` means the same as `ar[0:len(ar)]`.

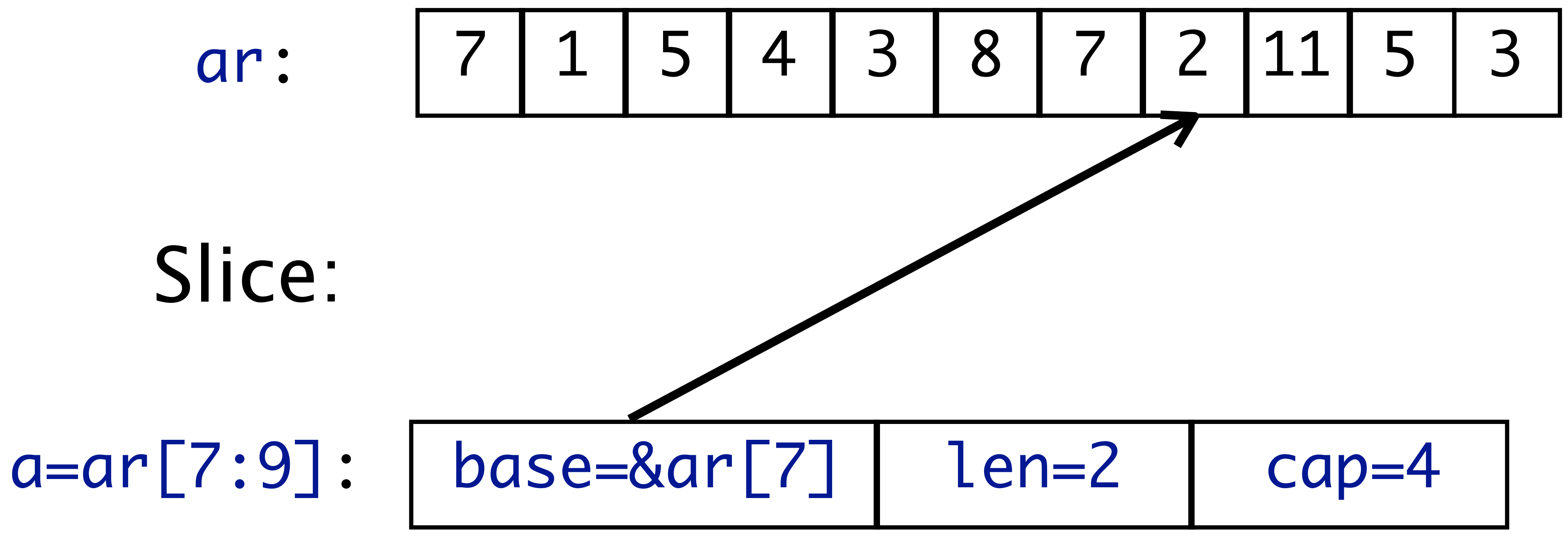
A slice references an array

Conceptually:

```
type Slice struct {
    base *elemType  // pointer to 0th element
    len int         // num. of elems in slice
    cap int         // num. of elems available
}
```

Array:

Slice:



Making slices

Slice literals look like array literals without a size:

```
var slice = []int{1,2,3,4,5}
```

What this does is create an array of length 5 and then create a slice to refer to it.

We can also allocate a slice (and underlying array) with the built-in function `make`:

```
var s100 = make([]int, 100) // slice: 100 ints
```

Why `make` not `new`? Because we need to make a slice, not just allocate the memory. Note `make([]int, 10)` returns `[]int` while `new([]int)` returns `*[]int`.

Use `make` to create slices, maps, and channels.

Slice capacity

A slice refers to an underlying array, so there may be elements off the end of the slice that are present in the array.

The built-in function `cap` (capacity) reports how long the slice could possibly grow. After

```
var ar = [10]int{0,1,2,3,4,5,6,7,8,9}
var a = ar[5:7]  // reference to subarray {5,6}
```

`len(a)` is 2 and `cap(a)` is 5. We can "reslice":

```
a = a[0:4]  // reference to subarray {5,6,7,8}
```

`len(a)` is now 4 but `cap(a)` is still 5.

Resizing a slice

Slices can be used like growable arrays. Allocate one using `make` with two numbers – length and capacity – and reslice as it grows:

```
var sl = make([]int, 0, 100)  // len 0, cap 100

func appendToSlice(i int, sl []int) []int {
    if len(sl) == cap(sl) { error(...) }
    n := len(sl)
    sl = sl[0:n+1]  // extend length by 1
    sl[n] = i
    return sl
}
```

Thus `sl`'s length is always the number of elements, but it grows as needed.
This style is cheap and idiomatic in Go.

Slices are cheap

Feel free to allocate and resize slices as required. They are cheap to pass around; no need to allocate. Remember they are references, so underlying storage can be modified.

For instance, I/O uses slices, not counts:

```
func Read(fd int, b []byte) int
var buffer [100]byte
for i := 0; i < 100; i++ {
    // Fill buffer one byte at a time.
    Read(fd, buffer[i:i+1])  // no allocation here
}
```

Split a buffer:

```
header, data := buf[:n], buf[n:]
```

Strings can be sliced too, with similar efficiency.

Maps

Maps

Maps are another reference type. They are declared like this:

```
var m map[string]float64
```

This declares a map indexed with key type `string` and value type `float64`. It is analogous to the C++ type `*map<string,float64>` (note the `*`).

Given a map `m`, `len(m)` returns the number of keys.

Map creation

As with a slice, a map variable refers to nothing; you must put something in it before it can be used.

Three ways:

1) Literal: list of colon-separated key:value pairs

```
m = map[string]float64{"1":1, "pi":3.1415}
```

2) Creation

```
m = make(map[string]float64)  // make not new
```

3) Assignment

```
var m1 map[string]float64
m1 = m // m1 and m now refer to same map
```

Indexing a map

(Next few examples all use

```
  m = map[string]float64{"1":1, "pi":3.1415}
```

)

Access an element as a value; if not present, get zero value for the map's value type:

```
one  := m["1"]
zero := m["not present"] // Sets zero to 0.0.
```

Set an element (setting twice updates value for key)

```
m["2"] = 2
m["2"] = 3  // mess with their heads
```

Testing existence

To test if a key is present in the map, we can use a multi-value assignment, the "comma ok" form:

```
m = map[string]float64{"1":1, "pi":3.1415}

var value float64
var present bool

value, present = m[x]
```

or idiomatically

```
value, ok := m[x]  // hence, the "comma ok" form
```

If `x` is present in the map, sets the boolean to `true` and the value to the entry for the key. If not, sets the boolean to `false` and the value to the zero for its type.

Deleting

Deleting an entry in the map is a multi-variate assignment to the map entry:

```
m = map[string]float64{"1":1.0, "pi":3.1415}

var keep bool
var value float64
var x string = f()

m[x] = v, keep
```

If keep is `true`, assigns `v` to the map; if keep is `false`, deletes the entry for key `x`. So to delete an entry,

```
m[x] = 0, false    // deletes entry for x
```

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For and range

The for loop has a special syntax for iterating over arrays, slices, maps (and more, as we'll see tomorrow).

```
m := map[string]float64{"1":1.0, "pi":3.1415}
for key, value := range m {
    fmt.Printf("key %s, value %g\n", key, value)
}
```

With only one variable in the range, get the key:

```
for key = range m {
    fmt.Printf("key %s\n", key)
}
```

Variables can be assigned or declared using := .

For arrays and slices, get index and value.

Range over string

A for using range on a string loops over Unicode code points, not bytes. (Use []byte for bytes, or use a standard for). The string is assumed to contain UTF-8.

The loop

```
s := "[\u00ff\u754c]"
for i, c := range s {
    fmt.Printf("%d:%q ", i, c) // %q for 'quoted'
}
```

Prints `0:'[' 1:'ÿ' 3:'界' 6:']'`

If erroneous UTF-8 is encountered, the character is set to U+FFFD and the index advances by one byte.

Structs

Structs

Structs should feel very familiar: simple declarations of data fields.

```
var p struct {
    x, y float64
}
```

More usual:

```
type Point struct {
    x, y float64
}
var p Point
```

Structs allow the programmer to define the layout of memory.

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Structs are values

Structs are values and new(StructType) returns a pointer to a zero value (memory all zeros).

```
type Point struct {
    x, y float64
}
var p Point
p.x = 7
p.y = 23.4
var pp *Point = new(Point)
*pp = p
pp.x = Pi  // sugar for (*pp).x
```

There is no -> notation for structure pointers. Go provides the indirection for you.

Making structs

Structs are values so you can make a zeroed one just by declaring it.

You can also allocate one with new.

```
var p Point          // zeroed value
pp := new(Point)     // idiomatic allocation
```

Struct literals have the expected syntax.

```
p = Point{7.2, 8.4}
p = Point{y:8.4, x:7.2}
pp = &Point{7.2, 8.4}   // idiomatic
pp = &Point{}     // also idiomatic; == new(Point)
```

As with arrays, taking the address of a struct literal gives the address of a newly created value.
These examples are constructors.

Exporting types and fields

The fields (and methods, coming up soon) of a `struct` must start with an Uppercase letter to be visible outside the package.

Private type and fields:

```
type point struct { x, y float64 }
```

Exported type and fields:

```
type Point struct { X, Y float64 }
```

Exported type with mix of fields:

```
type Point struct {
    X, Y float64  // exported
    name string   // not exported
}
```

You may even have a private type with exported fields. Exercise: when is that useful?

Anonymous fields

Inside a struct, you can declare fields, such as another struct, without giving a name for the field. These are called anonymous fields and they act as if the inner struct is simply inserted or "embedded" into the outer.

This simple mechanism provides a way to derive some or all of your implementation from another type or types.

An example follows.

An anonymous struct field

```go
type A struct {
    ax, ay int
}
type B struct {
    A
    bx, by float64
}
```

B acts as if it has four fields, ax, ay, bx, and by. It's almost as if B is {ax, ay int; bx, by float64}. However, literals for B must be filled out in detail:

```go
b := B{A{1, 2}, 3.0, 4.0}
fmt.Println(b.ax, b.ay, b.bx, b.by)
```

Prints `1 2 3 4`

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Anonymous fields have type as name

But it's richer than simple interpolation of the fields: B also has a field A. The anonymous field looks like a field whose name is its type.

```
b := B{A{ 1, 2}, 3.0, 4.0}
fmt.Println(b.A)
```

Prints {1 2}. If A came from another package, the field would still be called A:

```
import "pkg"
type C struct { pkg.A }
...
c := C {pkg.A{1, 2}}
fmt.Println(c.A)    // not c.pkg.A
```

Anonymous fields of any type

Any named type, or pointer to one, may be used in an anonymous field and it may appear at any location in the struct.

```
type C struct {
    x float64
    int
    string
}

c := C{3.5, 7, "hello"}
fmt.Println(c.x, c.int, c.string)
```

Prints `3.5 7 hello`

Conflicts and hiding

If there are two fields with the same name (possibly a type-derived name), these rules apply:

1) An outer name hides an inner name.

This provides a way to override a field/method.

2) If the same name appears twice at the same level, it is an error if the name is used by the program. (If it's not used, it doesn't matter.)

No rules to resolve the ambiguity; it must be fixed.

Conflict examples

```
type A struct { a int }
type B struct { a, b int }

type C struct { A; B }
var c C
```

Using `c.a` is an error: is it `c.A.a` or `c.B.a`?

```
type D struct { B; b float64 }
var d D
```

Using `d.b` is OK: it's the `float64`, not `d.B.b`
Can get at the inner `b` by `D.B.b`.

Methods

Methods on structs

Go has no classes, but you can attach methods to any type. Yes, (almost) any type. The methods are declared, separate from the type declaration, as functions with an explicit receiver. The obvious struct case:

```
type Point struct { x, y float64 }

// A method on *Point
func (p *Point) Abs() float64 {
    return math.Sqrt(p.x*p.x + p.y*p.y)
}
```

Note: explicit receiver (no automatic `this`), in this case of type `*Point`, used within the method.

Methods on struct values

A method does not require a pointer as a receiver.

```
type Point3 struct { x, y, z float64 }

// A method on Point3
func (p Point3) Abs() float64 {
    return math.Sqrt(p.x*p.x + p.y*p.y + p.z*p.z)
}
```

This is a bit expensive, because the `Point3` will always be passed to the method by value, but it is valid Go.

Invoking a method

Just as you expect.

```
p := &Point{ 3, 4 }
fmt.Print(p.Abs())  // will print 5
```

A non-struct example:

```
type IntVector []int
func (v IntVector) Sum() (s int) {
  for _, x := range v { // blank identifier!
    s += x
  }
  return
}

fmt.Println(IntVector{1, 2, 3}.Sum())
```

Ground rules for methods

Methods are attached to a named type, say Foo, and are statically bound.

The type of a receiver in a method can be either *Foo or Foo. You can have some Foo methods and some *Foo methods.

Foo itself cannot be a pointer type, although the methods can have receiver type *Foo.

The type Foo must be defined in the same package as all its methods.

Pointers and values

Go automatically indirects/dereferences values for you when invoking methods.

For instance, even though a method has receiver type `*Point` you can invoke it on an addressable value of type `Point`.

```
p1 := Point{ 3, 4 }
fmt.Print(p1.Abs())  // sugar for (&p1).Abs()
```

Similarly, if methods are on `Point3` you can use a value of type `*Point3`:

```
p3 := &Point3{ 3, 4, 5 }
fmt.Print(p3.Abs())  // sugar for (*p3).Abs()
```

Methods on anonymous fields

Naturally, when an anonymous field is embedded in a struct, the methods of that type are embedded as well – in effect, it inherits the methods.

This mechanism offers a simple way to emulate some of the effects of subclassing and inheritance.

Anonymous field example

```
type Point struct { x, y float64 }
func (p *Point) Abs() float64 { ... }

type NamedPoint struct {
    Point
    name string
}

n := &NamedPoint{Point{3, 4}, "Pythagoras"}
fmt.Println(n.Abs())  // prints 5
```

Overriding a method

Overriding works just as with fields.

```
type NamedPoint struct {
    Point
    name string
}
func (n *NamedPoint) Abs() float64 {
    return n.Point.Abs() * 100.
}

n := &NamedPoint{Point{3, 4}, "Pythagoras"}
fmt.Println(n.Abs())  // prints 500
```

Of course you can have multiple anonymous fields with various types - a simple version of multiple inheritance. The conflict resolution rules keep things simple, though.

Another example

A more compelling use of an anonymous field.

```
type Mutex struct { ... }
func (m *Mutex) Lock() { ... }

type Buffer struct {
    data [100]byte
    Mutex  // need not be first in Buffer
}
var buf = new(Buffer)
buf.Lock()  // == buf.Mutex.Lock()
```

Note that `Lock`'s receiver is (the address of) the `Mutex` field, not the surrounding structure. (Contrast to subclassing or Lisp mix-ins.)

Other types

Methods are not just for structs. They can be defined for any (non-pointer) type.

The type must be defined in your package though. You can't write a method for `int` but you can declare a new `int` type and give it methods.

```
type Day int

var dayName = []string {
    "Monday", "Tuesday", "Wednesday", ...
}

func (day Day) String() string {
    return dayName[day]
}
```

Other types

Now we have an enumeration-like type that knows how to print itself.

```
const (
    Monday Day = iota
    Tuesday
    Wednesday
    // ...
)

var day = Tuesday
fmt.Printf("%q", day.String())  // prints "Tuesday"
```

Print understands String methods

By techniques to be divulged soon, `fmt.Print` and friends can identify values that implement the method `String` as we defined for type `Day`. Such values are automatically formatted by invoking the method. Thus:

```
  fmt.Println(0, Monday, 1, Tuesday)
```

prints `0 Monday 1 Tuesday`.

`Println` can tell a plain `0` from a `0` of type `Day`.

So define a `String` method for your types and they will print nicely with no more work.

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Visibility of fields and methods

Review:
Go is very different from C++ in the area of visibility.
Go's rules:

1) Go has package scope (C++ has file scope).

2) Spelling determines exported/local (pub/priv).

3) Structs in the same package have full access to one another's fields and methods.

4) Local type can export its fields and methods.

5) No true subclassing, so no notion of "protected".

These simple rules seem to work well in practice.

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Interfaces

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Watch closely

We are about to look at Go's most unusual aspect: the interface.

Please leave your preconceptions at the door.

Introduction

So far, all the types we have examined have been concrete: they implement something.

There is one more type to consider: the interface type. It is completely abstract; it implements nothing. Instead, it specifies a set of properties an implementation must provide.

Interface as a concept is very close to that of Java, and Java has an interface type, but the "interface value" concept of Go is novel.

Definition of an interface

The word "interface" is a bit overloaded in Go: there is the concept of an interface, and there is an interface type, and then there are values of that type. First, the concept.

Definition:

An interface is a set of methods.

To turn it around, the methods implemented by a concrete type such as a `struct` form the interface of that type.

Example

We saw this simple type before:

```
type Point struct { x, y float64 }
func (p *Point) Abs() float64 { ... }
```

The interface of type `Point` has the method:

```
Abs() float64
```

It's not

```
func (p *Point) Abs() float64
```

because the interface abstracts away the receiver.

We embedded `Point` in a new type, `NamedPoint`; `NamedPoint` has the same interface.

The interface type

An interface type is a specification of an interface, a set of methods implemented by some other types. Here's a simple one, with only one method:

```
type AbsInterface interface {
    Abs() float64  // receiver is implied
}
```

This is a definition of the interface implemented by `Point`, or in our terminology,

`Point` implements `AbsInterface`

Also,

`NamedPoint` and `Point3` implement `AbsInterface`

Methods are written inside the interface declaration.

An example

```
type MyFloat float64

func (f MyFloat) Abs() float64 {
  if f < 0 { return float64(-f) }
  return f
}
```

`MyFloat` implements `AbsInterface` even though `float64` does not.

(Aside: `MyFloat` is not a "boxing" of `float64`; its representation is identical to `float64`.)

Many to many

An interface may be implemented by an arbitrary number of types. `AbsInterface` is implemented by any type that has a method with signature `Abs() float64`, regardless of what other methods that type may have.

A type may implement an arbitrary number of interfaces. `Point` implements at least these two:

```
type AbsInterface interface { Abs() float64 }
type EmptyInterface interface { }
```

And perhaps more, depending on its methods.

Every type implements `EmptyInterface`. That will come in handy.

Interface value

Once a variable is declared with interface type, it may store any value that implements that interface.

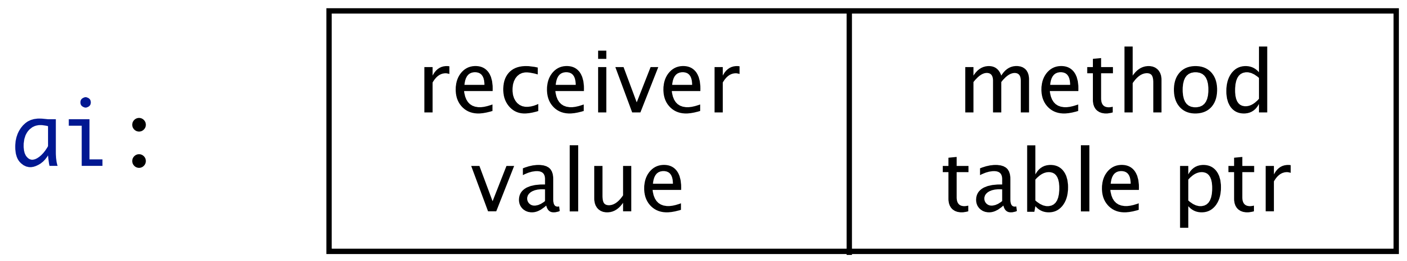
```
var ai AbsInterface

pp := new(Point)
ai = pp                 // OK: *Point has Abs()
ai = 7.                 // compile-time err:
                        // float64 has no Abs()
ai = MyFloat(-7.)       // OK: MyFloat has Abs()

ai = &Point{ 3, 4 }
fmt.Printf(ai.Abs())  // method call
```

Prints `5.`

Note: `ai` is not a pointer! It is an interface value.

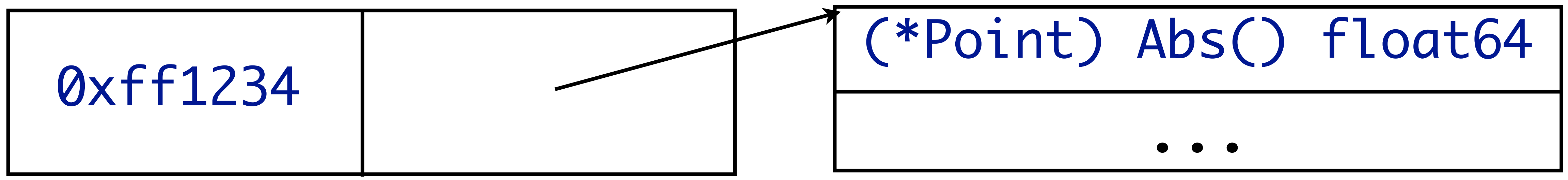
In memory

`ai` is not a pointer! It's a multiword data structure.

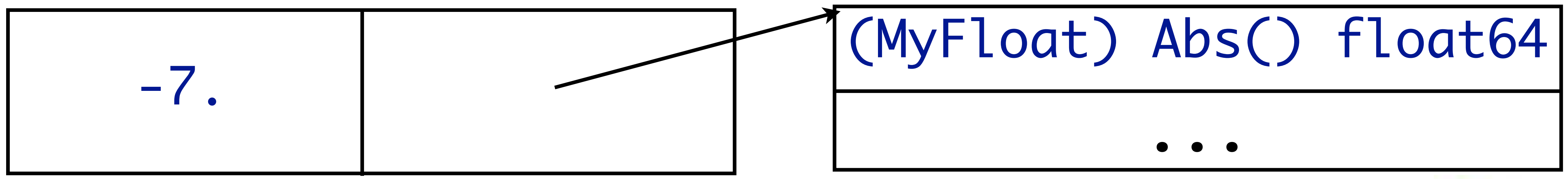


At different times it has different value and type:

```
ai = &Point{3,4} (a *Point at address 0xff1234):
```



```
ai = MyFloat(-7.):
```



Three important facts

1) Interfaces define sets of methods. They are pure and abstract: no implementation, no data fields. Go has a clear separation between interface and implementation.

2) Interface values are just that: values. They contain any concrete value that implements all the methods defined in the interface. That concrete value may or may not be a pointer.

3) Types implement interfaces just by having methods. They do not have to declare that they do so. For instance, every type implements the empty interface, `interface{}`.

Example: io.Writer

Here is the actual signature of `fmt.Fprintf`:

```
func Fprintf(w io.Writer, f string, a ... interface{})
            (n int, error os.Error)
```

It doesn't write to a file, it writes to something of type `io.Writer`, that is, `Writer` defined in the `io` package:

```
type Writer interface {
    Write(p []byte) (n int, err os.Error)
}
```

`Fprintf` can therefore be used to write to any type that has a canonical `Write` method, including files, pipes, network connections, and...

Buffered I/O

... a write buffer. This is from the `bufio` package:

```
type Writer struct { ... }
```

`bufio.Writer` implements the canonical `Write` method.

```
func (b *Writer) Write(p []byte) (n int, err os.Error)
```

It also has a factory: give it an `io.Writer`, it will return a buffered `io.Writer` in the form of a `bufio.Writer`:

```
func NewWriter(wr io.Writer) (b *Writer, err os.Error)
```

And of course, `os.File` implements `Writer` too.

Putting it together

```
import (
  "bufio"; "fmt"; "os"
)
func main() {
  // unbuffered
  fmt.Fprintf(os.Stdout, "%s, ", "hello")
  // buffered: os.Stdout implements io.Writer
  buf := bufio.NewWriter(os.Stdout)
  // and now so does buf.
  fmt.Fprintf(buf, "%s\n", "world!")
  buf.Flush()
}
```

Buffering works for anything that `Writes`.

Feels almost like Unix pipes, doesn't it? The composability is powerful; see `crypto` packages.

Other public interfaces in io

The `io` package has:

```
Reader
Writer
ReadWriter
ReadWriteCloser
```

These are stylized interfaces but obvious: they capture the functionality of anything implementing the functions listed in their names.

This is why we can have a buffered I/O package with an implementation separate from the I/O itself: it both accepts and provides interface values.

Comparison

In C++ terms, an interface type is like a pure abstract class, specifying the methods but implementing none of them.

In Java terms, an interface type is much like a Java interface.

However, in Go there is a major difference:

A type does not need to declare the interfaces it implements, nor does it need to inherit from an interface type. If it has the methods, it implements the interface.

Some other differences will become apparent.

Anonymous fields work too

```
type LockedBufferedWriter struct {
    Mutex  // has Lock and Unlock methods
    bufio.Writer  // has Write method
}

func (l *LockedBufferedWriter) Write(p []byte)
                                   (nn int, err os.Error) {
    l.Lock()
    defer l.Unlock()
    return l.Writer.Write(p)  // inner Write()
}
```

`LockedBufferedWriter` implements `io.Writer`, but also, through the anonymous `Mutex`,

```
type Locker interface { Lock(); Unlock() }
```

Example: HTTP service

```
type Handler interface {
    ServeHTTP(ResponseWriter, *Request)
}
```

This is the interface defined by the HTTP server package. To serve HTTP, define a type that implements this interface and connect it to the server (details omitted).

```
type Counter struct {
    n int  // or could just say type Counter int
}

func (ctr *Counter) ServeHTTP(w http.ResponseWriter,
                              req *http.Request) {
    fmt.Fprintf(w, "counter = %d\n", ctr.n)
    ctr.n++
}
```

A function (type) that serves HTTP

```
func notFound(w http.ResponseWriter, req *http.Request){
    w.SetHeader("Content-Type", "text/plain;" +
                                "charset=utf-8")
    w.WriteHeader(StatusNotFound)
    w.WriteString("404 page not found\n")
}
```

Now we define a type to implement `ServeHTTP`:

```
type HandlerFunc func(http.ResponseWriter, *http.Request)
func (f HandlerFunc) ServeHTTP(w http.ResponseWriter,
                               req *http.Request) {
    f(w, req)  // the receiver's a func; call it
}
```

Convert function to attach method, implement the interface:

```
var Handle404 = HandlerFunc(notFound)
```

Containers & the empty interface

Sketch of the implementation of vectors. (In practice, tend to use raw slices instead, but this is informative):

```
type Element interface {}

// Vector is the container itself.
type Vector []Element

// At() returns the i'th element.
func (p *Vector) At(i int) Element {
    return p[i]
}
```

Vectors can contain anything because any type implements the empty interface. (In fact every element could be of different type.)

Type assertions

Once you put something into a `Vector`, it's stored as an interface value. Need to "unbox" it to get the original back: use a "type assertion". Syntax:

```
  interfaceValue.(typeToExtract)
```

Will fail if type is wrong – but see next slide.

```
  var v vector.Vector
  v.Set(0, 1234.)        // stored as interface val
  i := v.At(0)           // retrieved as interface{}
  if i != 1234. {}       // compile-time err
  if i.(float64) != 1234. {}   // OK
  if i.(int) != 1234 {}        // run-time err
  if i.(MyFloat) != 1234. {}   // err: not MyFloat
```

Type assertions always execute at run time. Compiler rejects assertions guaranteed to fail.

Interface to interface conversion

So far we've only moved regular values into and out of interface values, but interface values that contain the appropriate methods can also be converted.

In effect, it's the same as unboxing the interface value to extract the underlying concrete value, then boxing it again for the new interface type.

The conversion's success depends on the underlying value, not the original interface type.

Interface to interface example

Given:

```
var ai AbsInterface
type SqrInterface interface { Sqr() float64 }
var si SqrInterface
pp := new(Point)  // say *Point has Abs, Sqr
var empty interface{}
```

These are all OK:

```
empty = pp      // everything satisfies empty
ai = empty.(AbsInterface) // underlying value
                // implements Abs()
                // (runtime failure otherwise)
si = ai.(SqrInterface)  // *Point has Sqr()
                // even though AbsInterface doesn't
empty = si      // *Point implements empty set
                // Note: statically checkable
                // so type assertion not necessary.
```

Testing with type assertions

Can use "comma ok" type assertions to test a value for type.

```
elem := vector.At(0)
if i, ok := elem.(int); ok {
    fmt.Printf("int: %d\n", i)
} else if f, ok := elem.(float64); ok {
    fmt.Printf("float64: %g\n", f)
} else {
    fmt.Print("unknown type\n")
}
```

Testing with a type switch

Special syntax:

```
switch v := elem.(type) { // literal keyword "type"
case int:
    fmt.Printf("is int: %d\n", v)
case float64:
    fmt.Printf("is float64: %g\n", v)
default:
    fmt.Print("unknown type\n")
}
```

Does v implement m()?

Going one step further, can test whether a value implements a method.

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

if sv, ok := v.(Stringer); ok {
    fmt.Printf("implements String(): %s\n",
               sv.String()) // note: sv not v
}
```

This is how `Print` etc. check if type can print itself.

Reflection and ...

There is a reflection package (`reflect`) that builds on these ideas to let you examine values to discover their type. Too intricate to describe here but `Printf` etc. use it to analyze the its arguments.

```
func Printf(format string, args ...interface{})
            (n int, err os.Error)
```

Inside `Printf`, the `args` variable becomes a slice of the specified type, i.e. `[]interface{}`, and `Printf` uses the reflection package to unpack each element to analyze its type.

More about variadic functions in the next section.

Reflection and Print

As a result, `Printf` and its friends know the actual types of their arguments.   Because they know if the argument is unsigned or long, there is no `%u` or `%ld`, only `%d`.

This is also how `Print` and `Println` can print the arguments nicely without a format string.

There is also a `%v` ("value") format that gives default nice output from `Printf` for values of any type.

```
fmt.Printf("%v %v %v %v", -1, "hello",
           []int{1,2,3}, uint64(456))
```

Prints `-1 hello [1 2 3] 456`.
In fact, `%v` is identical to the formatting done by `Print` and `Println`.

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Variadic functions

Variadic functions: ...

Variable-length parameter lists are declared with the syntax `...T`, where `T` is the type of the individual arguments. Such arguments must be the last in the argument list. Within the function the variadic argument implicitly has type `[]T`.

```
func Min(args ...int) int {
    min := int(^uint(0)>>1)   // largest possible int
    for _, x := range args {  // args has type []int
        if min > x { min = x }
    }
    return min
}

fmt.Println(Min(1,2,3), Min(-27), Min(), Min(7,8,2))
```

Prints `1 -27 2147483647 2`

Slices into variadics

The argument becomes a slice. What if you want to pass the slice as arguments directly? Use `...` at the call site. (Only works for variadics.)

Recall: `func Min(args ...int) int`

Both these invocations return `-2`:

```
  Min(1, -2, 3)
  slice := []int{1, -2, 3}
  Min(slice...) // ... turns slice into arguments
```

This, however, is a type error:

```
  Min(slice)
```

because `slice` is of type `[]int` while `Min`'s arguments must be individually `int`. The `...` is mandatory.

Printf into Error

We can use the `...` trick to wrap `Printf` or one of its variants to create our own custom error handler.

```
func Errorf(fmt string, args ...interface{}) {
    fmt.Fprintf(os.Stderr, "MyPkg: "+fmt+"\n", args...)
    os.Exit(1)
}
```

We can use it like this:

```
if err := os.Chmod(file, 0644); err != nil {
    Errorf("couldn't chmod %q: %s", file, err)
}
```

Output (which includes newline):

```
MyPkg: couldn't chmod "foo.bar": permission denied
```

Append

The built-in function append, which is used to grow slices, is variadic. It has (in effect) this signature:

```
append(s []T, x ...T) []T
```

where s is a slice and T is its element type. It returns a slice with the elements x appended to s.

```
slice := []int{1, 2, 3}
slice = append(slice, 4, 5, 6)
fmt.Println(slice)
```

prints `[1 2 3 4 5 6]`

When possible, append will grow the slice in place.

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Appending a slice

If we want to append a whole slice, rather than individual elements, we again use ... at the call site.

```
slice := []int{1, 2, 3}
slice2 := []int{4, 5, 6}
slice = append(slice, slice2...) // ... is necessary
fmt.Println(slice)
```

This example also prints `[1 2 3 4 5 6]`

Exercise

Exercise: Day 2

Look at the `http` package.

Write an HTTP server to present pages in the file system, but transformed somehow, perhaps rot13, perhaps something more imaginative. Can you make the transformation substitutable? Can you work in your Fibonacci program somehow?

Next lesson

Concurrency and communication

The Go Programming Language

Part 2

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