The IO Programming Language

An Introduction

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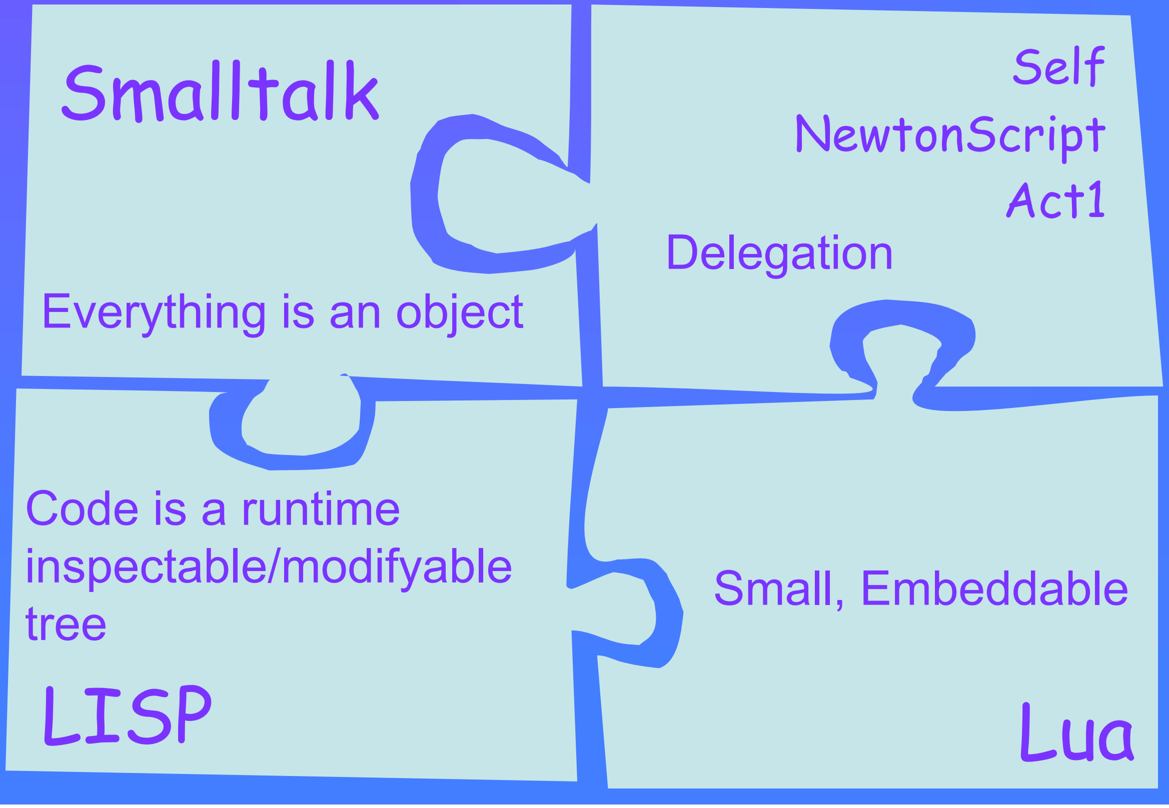
Io is…

- A small prototype-based language
- A server-side scripting language
- Inspired by:



Smalltalk

Everything is an object

Self

NewtonScript

Act1

Delegation

Code is a runtime inspectable/modifyable tree

LISP

Small, Embeddable

Lua

Io: Some Facts

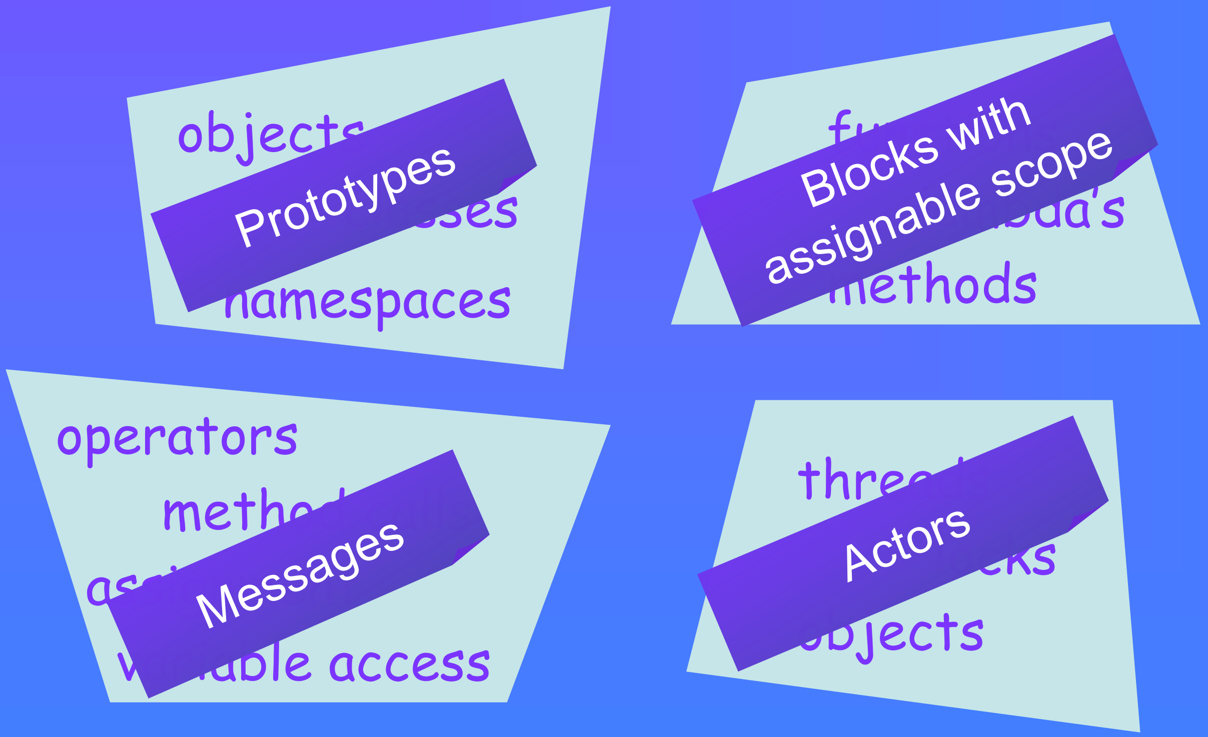
- Steve Dekorte, 2002 (www.iolanguage.com)
- Open Source, all platforms (even Symbian!)
- Intepreted, Virtual Machine is
  - ANSI C compatible (except for coroutines)
  - Very compact (~10K lines of code)
  - Incremental GC comparable to mark-and-sweep GC
  - Reasonably fast (cfr. Python, Perl, Ruby)
- Concurrency based on actors and implemented through coroutines

C bindings

- Easy embedding within a C program
- Multi-state embedding
- Bindings with C libraries easily incorporated:
  - Sockets
  - XML/HTML parsing
  - Regular expressions, encryption, compression
  - SQLite embedded transactional database
  - OpenGL bindings
  - Multimedia support
  - …

Simplicity!

- Tries to be the 🍎 of programming languages: things should “just work”



objects
ses
namespaces

Prototypes

fu
da's
methods

Blocks with assignable scope

operators
metho
as
v able access

Messages

threa
cks
objects

Actors

Sample Code: Basics

Hello World

```
“Hello World\n” print
```

Factorial

```
factorial := method(n,
   if (n == 1,
       return 1,
       return n * factorial(n - 1))
)
```

Control Flow v1

```
for(a,1,10,
  write(a))
```

Control Flow v3

```
block(a>0) whileTrue(
   a:=a-1 print)
```

Control Flow v2

```
10 repeatTimes(
  write(“hello”))
```

Sample Code: Data structures

- Built-in Maps, Lists and Linked lists

List Example

```
l := List clone
l add(2 sqrt)
l push(“foo”)
l foreach(k,v,writeln(k,“->”,v))
=>
0->1.414214
1->foo

l atPut(0, “Hello ” .. “World”)
```

In-line Lists

```
list(2 sqrt, “foo”)
```

Sample Code: Objects

Account

```
Account := Object clone
Account balance := 0
Account deposit  := method(v, balance := balance + v)
Account withdraw := method(v, balance := balance - v)
Account show := method(
  write("Account balance: ", balance, "\n")
)
myAccount := Account clone
myAccount deposit(10)
myAccount show
```

Extending primitives

```
Number double := method(self * 2)
1 double
=> 2
```

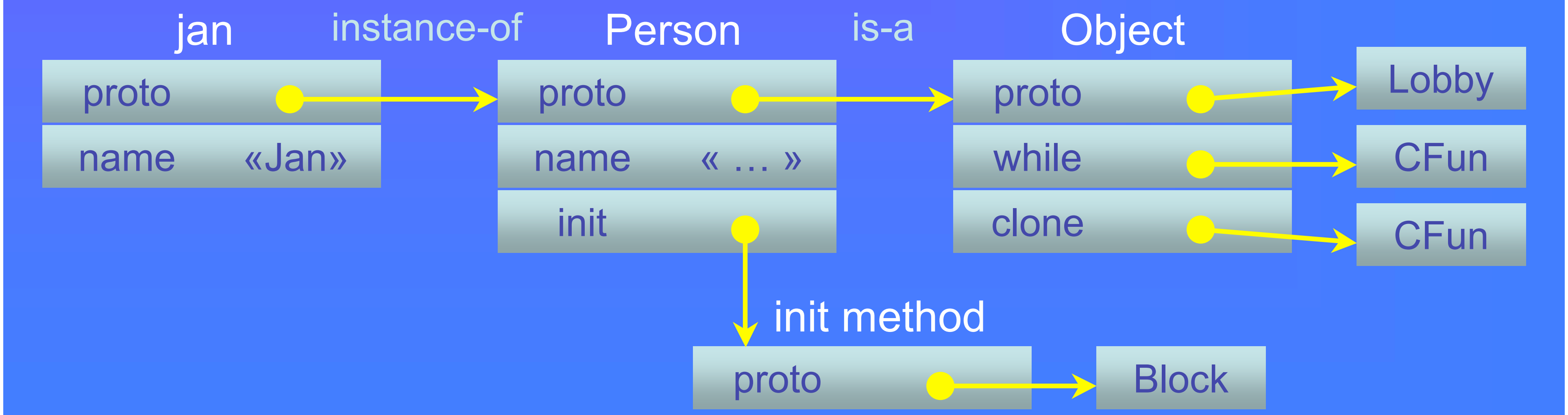
Singleton

```
MyObject := Object clone
MyObject clone := method(return self)
```

Delegation

Shallow copies

```
Person := Object clone
Person name := “John Doe”
Person init := method(write(“new person created”))

jan := Person clone
jan name := “Jan” // leaves Person’s name unchanged!
```



jan

instance-of

Person

is-a

Object

proto

name «Jan»

proto

name « … »

init

proto

while

clone

Lobby

CFun

CFun

init method

proto

Block

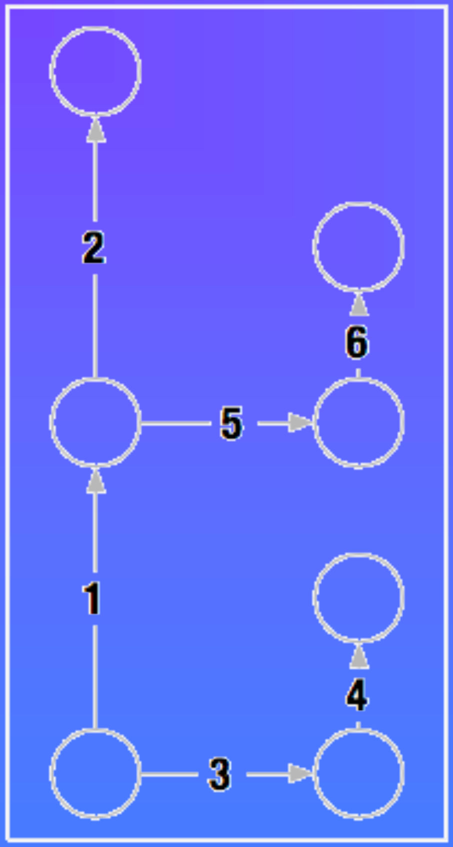
Super sends

Overriding

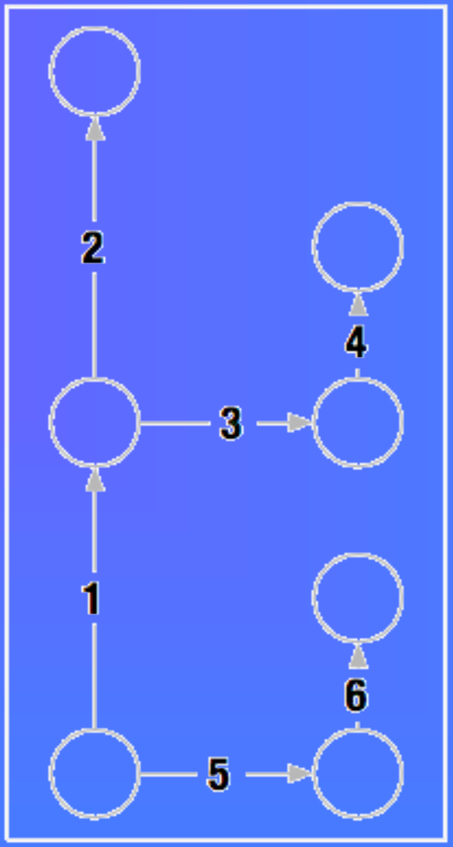
```
Person := Object clone
Person name := “Jane Doe”
Person title := method(write(name))

Doctor := Person clone
Doctor title := method(write(“Dr. ”); resend)
```

“Comb” Inheritance

Io’s multiple inheritance



Typical multiple inheritance



↑ : Proto slot links

→ : Parent slot links

Assignment

- Assignment is achieved through message passing
- `o x := v` is translated to `o setSlot("x",v)`
- `o x = v` is translated to `o updateSlot("x",v)`

First-class methods

- Selecting a method slot automatically activates it (cfr. Self)
- getSlot returns first-class reference to a method/block:

```
  dogSpeakMethod := Dog getSlot(“speak”)
```

- Methods do not encapsulate a scope: they can simply be introduced in other objects

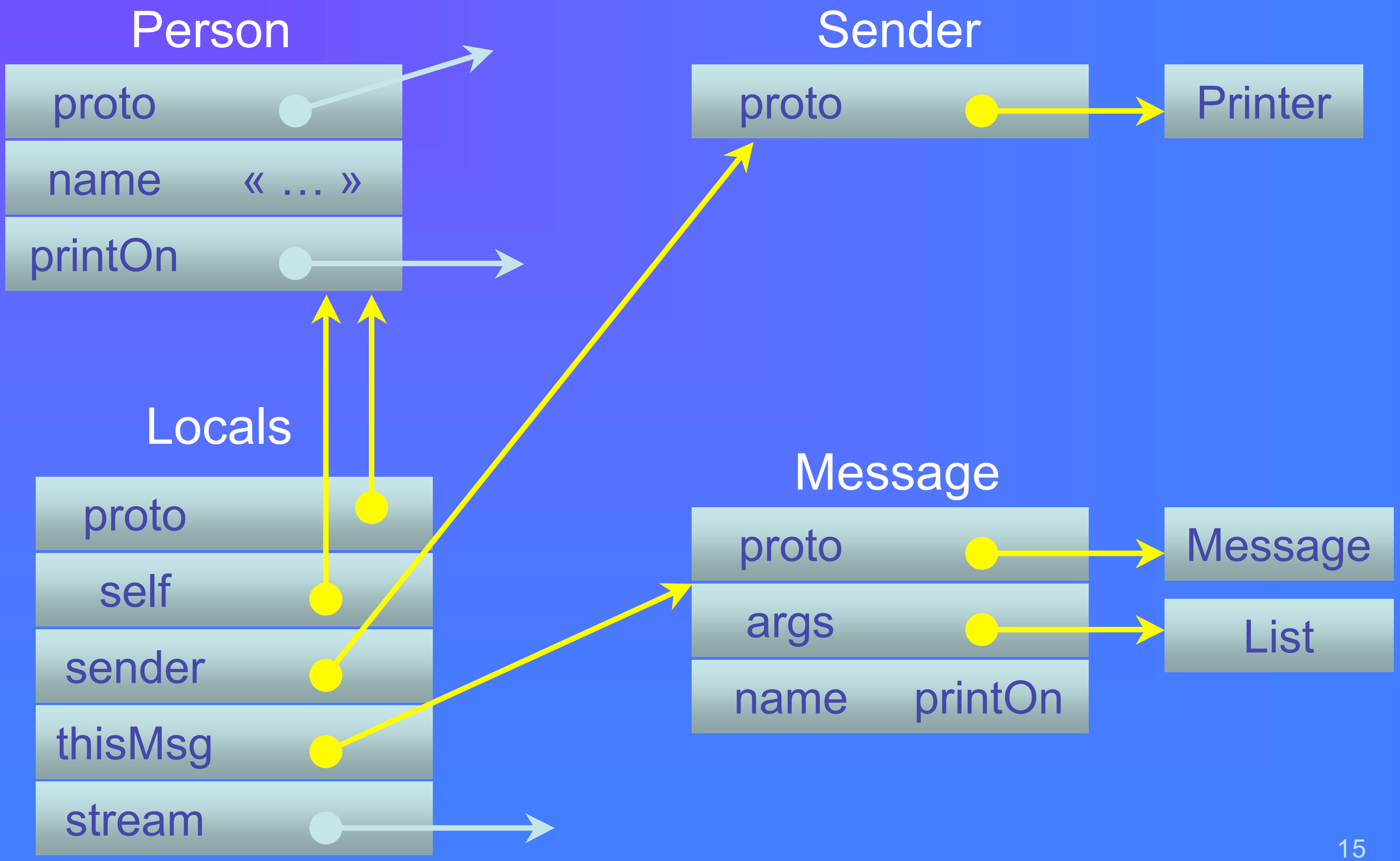
```
BarkingBird speak := getSlot(“dogSpeakMethod”)
```

OO Method Activation

- Similar to Self
- Upon method activation, a “locals” object is created with ao. the following slots:
  - proto: the message receiver
  - self: the message receiver
  - sender: locals object of the caller
  - thisMessage: reification of processed message
- Receiverless message sends are sent to the “locals” object (allows access to local variables)

OO Method Activation (2)

```
Person printOn(stream)
```



Blocks

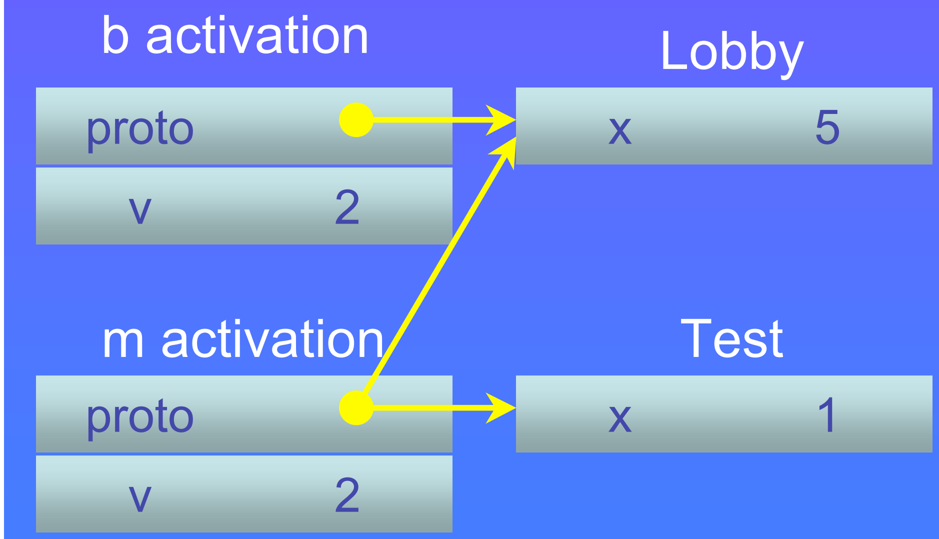
- Identical to methods, but lexically scoped

```
Pi := 3.14159
addPiTo := block(v, v+Pi)
list(1,2,3) translate(idx,val,addPiTo(val))
```

- The scope of a block always points to the “locals” object in which it was created
- Methods are just blocks whose scope is assignable: its scope is always re-set to the message receiver upon invocation

Blocks vs Methods

```
x := 5

b := block(v, v + x)

m := method(v, v + x)
```



```
Test := Object clone do (
   x := 1,
   accept := method(f, f(2))
)
b(2)
=> 7
Test accept(getSlot(“b”))
=> 7
m(2)
=> 7
Test accept(getSlot(“m”))
=> 3
```

OO Exception Mechanism

Catching exceptions

```
try(SomeObject someMessage)
  catch(FooError, e,
        fooLogger log(e))
     catch(BarError, e,
           barLogger log(e))
```

Nop

Nop

Nop

Catching exceptions

```
try(UserError raise(“Illegal action”))
  catch(SystemError, e,
        console print(e))
     catch(UserError, e,
           gui showDialog(e))
```

a UserError

a UserError

gui showDialog(a UserException); Nop

Concurrency: Coroutines

Coroutines

```
o1 := Object clone
o1 test := method(for(n, 1, 3, n print; yield))
o2 := o1 clone
o1 @test; o2 @test // @ = async message send
while(activeCoroCount > 1, yield)
=>
112233
```

Transparent Futures

```
result := o @msg  // returns a future
result := o @@msg // returns Nil
```

Metaprogramming

Quoted Expressions

```
firstClassMessage := message( putPixel(x,y,color) )
Screen doMessage(firstClassMessage)
firstClassMessage argAt(0) asString
=> “x”
```

Objects as dictionaries

```
Person := Object clone do(
 name := “Jan”;
 age := 18
)
Person foreach(slotNam, slotVal,
  writeln(slotNam, “ - ”, slotVal))
=>
age - 18
name - Jan
“proto” - Object(...)
```

Method Arity

- Actuals without corresponding formals are not evaluated
- Formals without corresponding actuals are set to `Nil`

Method Arity

```
test := method( “body” );
test( 1/0 )
=> “body”
identity := method(x, x);
identity
=> Nil
```

Reifying a message

- **thisMessage** denotes reification of message that triggered the current method

Variable argument lists

```
myAdd := method(
  args := thisMessage argsEvaluatedIn(sender);
  count := 0;
  args foreach(k,v, count += v);
  count)
```

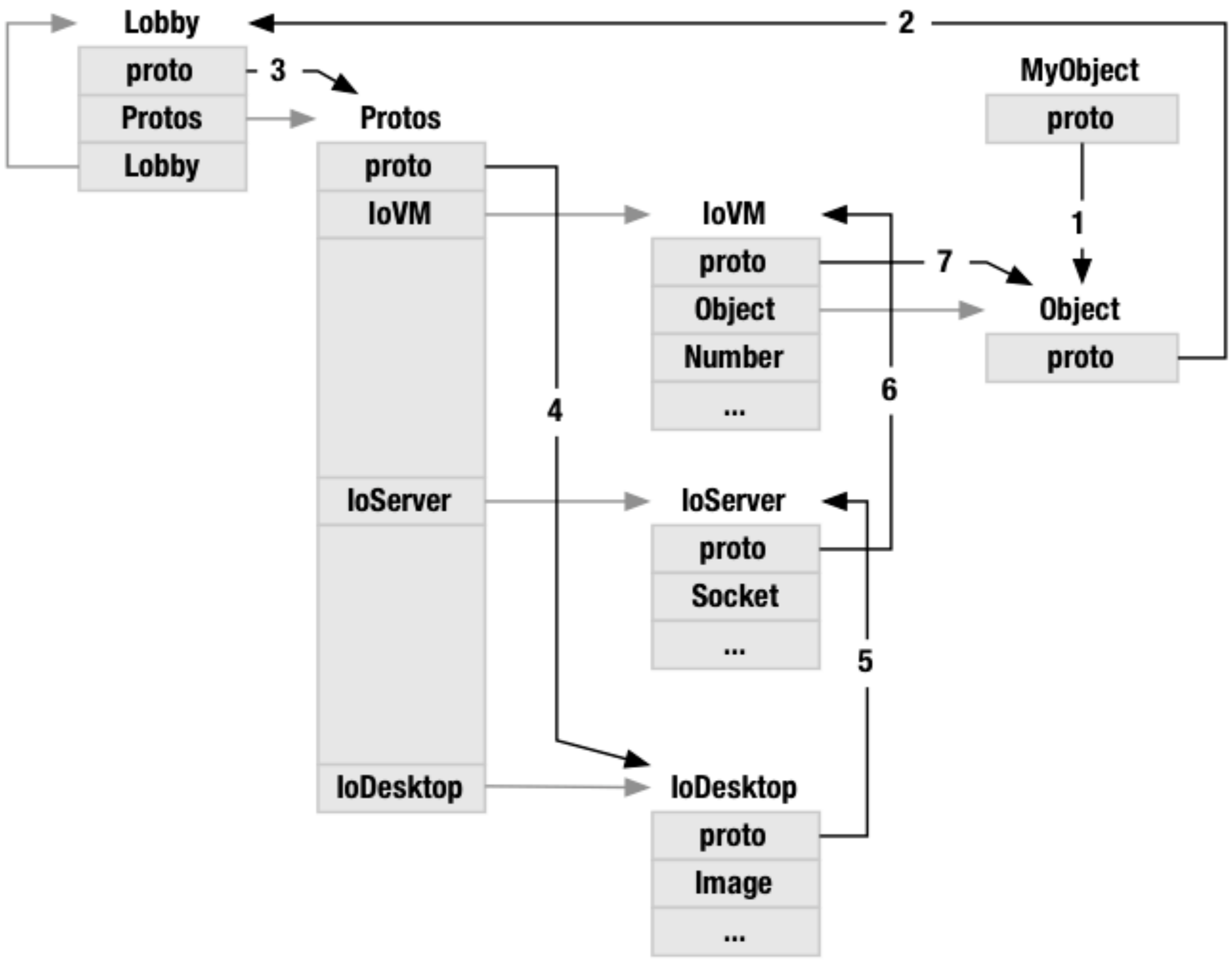
Lazy argument evaluation!

```
myif := method(
  if (sender doMessage(thisMessage argAt(0)),
      sender doMessage(thisMessage argAt(1)),
      sender doMessage(thisMessage argAt(2)))
)
myif(1 == 1, “ok”, 1/0)
```

Conclusions

- Simple pure prototype-based language
- Syntax: everything is a message, semantics: everything is an object
- Subclassing and object instantiation replaced by cloning
- Metaprogramming facilities allow for language extensions
- Lots of libraries thanks to simple C binding mechanism

Namespaces



- the Lobby is the root of the Io namespace
- The black arrows show the order of a slot lookup starting in an instance of the Object prototype
- lookups ignore already traversed paths