Script generated by TTT

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TECHNISCHE UNIVERSITÄT MÜNCHEN
FAKULTÄT FÜR INFORMATIK

Programming Languages

Prototypes

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Outline

Prototype based programming

1. Basic language features
2. Structured data
3. Code reusage
4. Imitating Object Orientation

"Why bother with modelling types for my quick hack?"

Motivation – Polemic

Bothersome features

- Specifying types for singletons
- Getting generic types right inspite of co- and contra-variance
- Massaging language imposed inheritance to by chance dodge redundancy

Prototype based programming

- Start by creating examples
- Only very basic concepts
- Introduce complexity only by need
- Shape language features yourself!

"Let's try to use only basic concepts – *Lua*"

Basic language features

- Chunks being sequences of statements.
- Global variables implicitely defined

```
s = 0;
i = 1          -- Single line comment
p = i+s p=42    --[[ Multiline
comment --]]
s = l
```


Basic types and values

- Dynamical types – no type definitions
- Each value carries its type
- `type` returns a string representation of a value's type

```
a = true
type(a)                 -- boolean
type("42"+0)            -- number
type("Simon "..1)       -- string
type(type)              -- function
type(nil)               -- nil
type([[<html><body>pretty long string</body>
</html>
]])                     -- string
a = 42
type(a)                 -- number
```

Functions for code

✓ First class citizens

```
function prettyprint(title, name, age)
  return title.." "..name.." ,born in " (2014-age)
end
a = prettyprint
a("Dr.","Simon",42)
```

prettyprint = 42

Introducing structure

- only one complex data type
- indexing via arbitrary values *except nil* (↝ Runtime Error)
- arbitrary large and dynamically growing/shrinking

```
a = {}                    -- create empty table/object
k = 42
a[k] = 3.14159            -- entry 3.14159 at key 42
a["honeydew"] = k         -- entry 42 at key "honeydew"
a[k] = nil                -- deleted entry at key 42
print(a.honeydew)         -- syntactic sugar for a["honeydew"]
```


Lifecycle

- creation from scratch
- modification persistent
- assignment with reference-semantics
- garbage collection

```
a = {}                    -- create empty table/object
a.k = 42
b = a                     -- b refers to same as a
b["k"] = "honeydew"       -- entry "honeydew" at key "k"
print(a.k)                -- yields honeydew
a = nil
print(b.k)                -- still honeydew
b = nil
print(b.k)                -- nill now
```


Lifecycle

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b = nil
print(b.k)                -- nill now
```

“So far nothing special – let’s compose types”

Table Behaviour

Metatables

- Change behaviour of tables
- Tables as collections of special functions
- Name conventions for special funtions
- Access to metatable via `getmetatable` and `setmetatable`

```
meta = {}
function meta.__tostring(person)
  return person.prefix .. " " .. person.name
end
a = { prefix="Dr.",name="Simon"} -- create Axel
setmetatable(a,meta)             -- install metatable for a
print(a)                         -- print "Dr. Simon"
```

- Overload operators like `__add`, `__mul`, `__sub`, `__div`, `__pow`, `__concat`, `__unm`
- Overload comparators like `__eq`, `__lt`, `__le`

Delegation

⚠ Forward name resolution to another table

```
meta = {}
function meta.__tostring(person)
  return person.prefix .. " " .. person.name
end
function meta.__index(table, key)
  return table.prototype[key]
end
job = { prefix="Dr." }
person = { name="Simon",prototype=job } -- create Axel
setmetatable(person,meta)               -- install metatable
print(person)                           -- print "Dr. Simon"
```

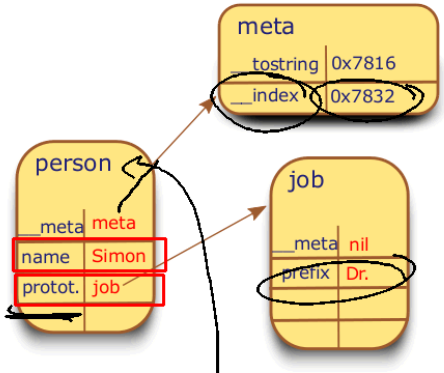

Delegation

⚠ Forward name resolution to another table

```
meta = {}
function meta.__tostring(person)
  return person.prefix .. " " .. person.name
end
function meta.__index(table, key)
  return table.prototype[key]
end
job = { prefix="Dr." }
person = { name="Simon",prototype=job } -- create Axel
setmetatable(person,meta)               -- install metatable
print(person)                           -- print "Dr. Simon"
```

Prototypes Delegation 13 / 28

Delegation



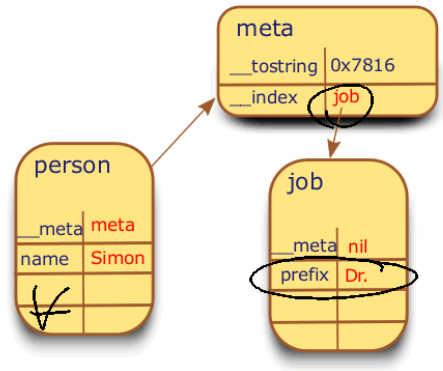

```lua
function meta.__tostring(person)   -- 0x7816
  return person.prefix .. " " .. person.name
end
function meta.__index(table,key)   -- 0x7832
  return table.prototype[key]
end
```


Delegation 2

- Conveniently, `__index` does not need to be a function

```lua
meta = {}
function meta.__tostring(person)
  return person.prefix .. " " .. person.name
end
job = { prefix="Dr." }
meta.__index = job                  -- delegate to job
person = { name="Simon" }           -- create Axel
setmetatable(person,meta)           -- install metatable
print(person)                       -- print "Dr. Simon"
```


Delegation 2




```lua
function meta.__tostring(person)   -- 0x7816
  return person.prefix .. " " .. person.name
end
```


Delegation 3

- `__newindex` handles unresolved updates
- frequently used to implement protection of objects

```lua
meta = {}
function meta.__newindex(table,key,val)
  if (key == "title" and table.name=="Guttenberg") then
    error("No title for You, sir!")
  else
    table.data[key]=val
  end
end
function meta.__tostring(table)
  return (table.title or "") .. table.name
end
person={ data={} }              -- create person's data
meta.__index = person.data
setmetatable(person,meta)
person.name = "Guttenberg"      -- name KT
person.title = "Dr."            -- try to give him Dr.
```

Object Oriented Programming

⚠ so far no concept for multiple objects

```
Account = { balance=0 }
function Account.withdraw (val)
 Account.balance=Account.balance-val
end
function Account.__tostring()
   return "Balance is "..Account.balance
end
setmetatable(Account,Account)
Account.withdraw(10)
print(Account)
```

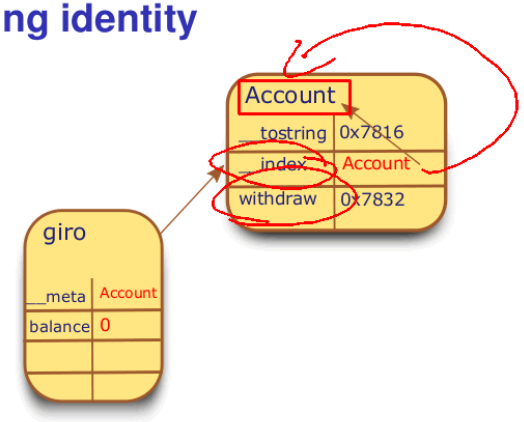

Introducing identity

- Concept of an object's *own identity* via parameter
- Programming aware of multiple instances
- Share code between instances

```
Account = { balance=0 }
function Account.withdraw (acc, val)
 acc.balance=acc.balance-val
end
function Account.tostring(acc)
   return "Balance is "..acc.balance
end
Account.__index=Account      -- share Account's functions

giro = { balance = 0 }
setmetatable(giro,Account)   -- delegate from giro to Account
Account.withdraw(giro,10)
giro.withdraw(giro,10)       -- withdraw independently
giro:withdraw(10)
print(Account:tostring())
print(giro:tostring())
```


Introducing identity



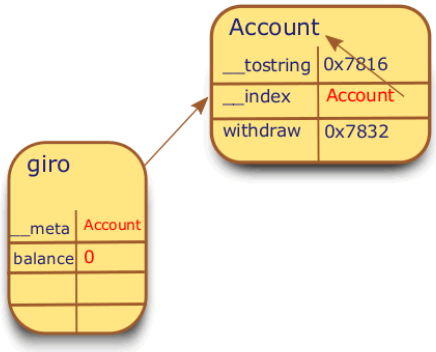

```
function Account.withdraw (acc, val)
 acc.balance=acc.balance-val
end
function Account.tostring(acc)
   return "Balance is "..acc.balance
end
```


Introducing "classes"

- Particular objects *used* as classes
- *self* for accessing own object

```
Account = {  }
function Account:withdraw (val)
 self.balance=self.balance-val
end
function Account:tostring()
   return "Balance is "..self.balance
end
function Account:new(template)
 template = template or {balance=0} -- initialize
 setmetatable(template,self)        -- Account is metatable
 self.__index=self                  -- delegate to Account
 self.__tostring = Account.tostring
 return template
end
giro = Account:new({balance=10})     -- create instance
giro:withdraw(10)
print(giro)
```

Introducing identity




```
function Account.withdraw (acc, val)
 acc.balance=acc.balance-val
end
function Account.tostring(acc)
   return "Balance is "..acc.balance
end
```


Introducing "classes"

- Particular objects *used* as classes
- *self* for accessing own object

```
Account = {  }
function Account:withdraw (val)
 self.balance=self.balance-val
end
function Account:tostring()
   return "Balance is "..self.balance
end
function Account:new(template)
 template = template or {balance=0} -- initialize
 setmetatable(template,self)        -- Account is metatable
 self.__index=self                  -- delegate to Account
 self.__tostring = Account.tostring
 return template
end
giro = Account:new({balance=10})     -- create instance
giro:withdraw(10)
print(giro)
```


Inheriting functionality

- Differential description possible in child class style
- Easily creating particular singletons

```
LimitedAccount = Account:new({balance=0,limit=100})
function LimitedAccount:withdraw(val)
  if (self.balance+self.limit < val) then
     error("Limit exceeded")
  end
  Account.withdraw(self,val)
end
specialgiro = LimitedAccount:new()
specialgiro:withdraw(90)
print(giro)
print(specialgiro)
```


Multiple Inheritance

⇝ Delegation leads to chain-like inheritance

```
function createClass (parent1,parent2)
  local c = {}                       -- new class
  setmetatable(c, {__index =
    function (t, k)                  -- search for each name
      local v = parent1[k]           -- in both parents
      if v then return v end
      return parent2[k]
    end}
  )
  c.__index = c                      -- c is metatable of instances
  function c:new (o)                 -- constructor for this class
    o = o or {}
    setmetatable(o, c)
    return o
  end
  return c                           -- finally return c
end
```

Multiple Inheritance

```
Doctor     = { postfix="Dr. "}
Researcher = { prefix=" ,Ph.D."}

ResearchingDoctor = createClass(Doctor,Researcher)
axel = ResearchingDoctor:new( { name="Axel Simon" } )
print(axel.prefix..axel.name..axel.postfix)
```

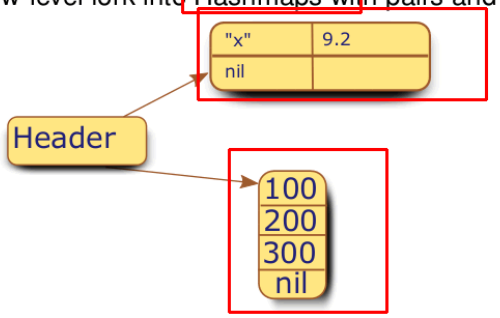
⇝ The special case of dual-inheritance can be extended to comprise multiple inheritance

Implementation of Lua

```
typedef struct {
  int type_id;
  Value v;
} TObject;
```

```
typedef union {
  void *p;
  int b;
  lua_number n;
  GCObject *gc;
} Value;
```

- Datatypes are simple values (Type+union of different flavours)
- Tables at low-level fork into Hashmaps with pairs and an integer-indexed array part



Further topics in Lua

- Coroutines
- Closures
- Bytecode & Lua-VM

Lessons Learned

Lessons Learned

1. Abandoning fixed inheritance yields ease/speed in development
2. Also leads to horrible runtime errors
3. Object-orientation and multiple-inheritance as special cases of delegation
4. Minimal featureset eases implementation of compiler/interpreter
5. Room for static analyses to find bugs ahead of time

Further reading...

- Roberto Ierusalimschy.
  Programming in Lua, Third Edition.
  Lua.Org, 2013.
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  Lua-an extensible extension language.
  Softw., Pract. Exper., 1996.
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  Journal of Universal Computer Science, 2005.