



PAUL G. ALLEN SCHOOL
OF COMPUTER SCIENCE & ENGINEERING

CSE341: Programming Languages

Lecture 20

Arrays and Such, Blocks and Procs, Inheritance and Overriding

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This lecture

Three mostly separate topics

- Flexible arrays, ranges, and hashes [actually covered in section]
- Ruby's approach to almost-closures (blocks) and closures (Procs)
 - [partially discussed in section as well]
 - Convenient to use; unusual approach
 - Used throughout large standard library
 - Explicit loops rare
 - Instead of a loop, go find a useful iterator
- Subclasses, inheritance, and overriding
 - The essence of OOP, now in a more dynamic language

Ruby Arrays

- Lots of special syntax and many provided methods for the `Array` class
- Can hold any number of other objects, *indexed* by number
 - Get via `a[i]`
 - Set via `a[i] = e`
- Compared to arrays in many other languages
 - More flexible and dynamic
 - Fewer operations are errors
 - Less efficient
- “The standard collection” (like lists were in ML and Racket)

Using Arrays

- See many examples, some demonstrated here
- Consult the documentation/tutorials
 - If seems sensible and general, probably a method for it
- Arrays make good tuples, lists, stacks, queues, sets, ...
- Iterating over arrays typically done with methods taking blocks
 - Next topic...

Blocks

Blocks are probably Ruby's strangest feature compared to other PLs

But *almost* just closures

- Normal: easy way to pass anonymous functions to methods for all the usual reasons
- Normal: Blocks can take 0 or more arguments
- Normal: Blocks use lexical scope: block body uses environment where block was defined

Examples:

```
3.times { puts "hi" }  
[4,6,8].each { puts "hi" }  
i = 7  
[4,6,8].each { |x| if i > x then puts (x+1) end }
```

Some strange things

- Can pass 0 or 1 block with *any* message
 - Callee might ignore it
 - Callee might give an error if you do not send one
 - Callee might do different things if you do/don't send one
 - Also number-of-block-arguments can matter
- Just put the block “next to” the “other” arguments (if any)
 - Syntax: `{e}`, `{|x| e}`, `{|x,y| e}`, etc. (plus variations)
 - Can also replace `{` and `}` with `do` and `end`
 - Often preferred for blocks > 1 line

Blocks everywhere

- Rampant use of great block-taking methods in standard library
- Ruby has loops but very rarely used
 - Can write `(0..i).each { |j| e }`, but often better options
- Examples (consult documentation for many more)

```
a = Array.new(5) { |i| 4*(i+1) }
a.each { puts "hi" }
a.each { |x| puts (x * 2) }
a.map { |x| x * 2 } #synonym: collect
a.any? { |x| x > 7 }
a.all? { |x| x > 7 }
a.inject(0) { |acc,elt| acc+elt }
a.select { |x| x > 7 } #non-synonym: filter
```

More strangeness

- Callee does not give a name to the (potential) block argument
- Instead, just calls it with `yield` or `yield(args)`

– Silly example:

```
def silly a
  (yield a) + (yield 42)
end
```

```
x.silly 5 { |b| b*2 }
```

- See code for slightly less silly example
- Can ask `block_given?` but often just assume a block is given or that a block's presence is implied by other arguments

Blocks are “second-class”

All a method can do with a block is `yield` to it

- Cannot return it, store it in an object (e.g., for a callback), ...
- But can also turn blocks into real closures
- Closures are instances of class `Proc`
 - Called with method `call`

This is Ruby, so there are several ways to make `Proc` objects 😊

- One way: method `lambda` of `Object` takes a block and returns the corresponding `Proc`

Example

```
a = [3,5,7,9]
```

- Blocks are fine for applying to array elements

```
b = a.map { |x| x+1 }  
i = b.count { |x| x>=6 }
```

- But for an array of closures, need Proc objects
 - More common use is callbacks

```
c = a.map { |x| lambda { |y| x>=y } }  
c[2].call 17  
j = c.count { |x| x.call(5) }
```

Moral

- First-class (“can be passed/stored anywhere”) makes closures more powerful than blocks
- But blocks are (a little) more convenient and cover most uses
- This helps us understand what first-class means
- Language design question: When is convenience worth making something less general and powerful?

More collections

- *Hashes* like arrays but:
 - *Keys* can be *anything*; strings and symbols common
 - No natural ordering like numeric indices
 - Different syntax to make themLike a dynamic record with anything for field names
 - Often pass a hash rather than many arguments
- *Ranges* like arrays of contiguous numbers but:
 - More efficiently represented, so large ranges fine

Good style to:

- Use ranges when you can
- Use hashes when non-numeric keys better represent data

Similar methods

- Arrays, hashes, and ranges all have some methods other don't
 - E.g., `keys` and `values`
- But also have many of the same methods, particularly iterators
 - Great for duck typing
 - Example

```
def foo a
  a.count { |x| x*x < 50 }
end

foo [3,5,7,9]
foo (3..9)
```

Once again separating “how to iterate” from “what to do”

Next major topic

- Subclasses, inheritance, and overriding
 - The essence of OOP
 - Not unlike you have seen in Java, but worth studying from PL perspective and in a more dynamic language

Subclassing

- A class definition has a *superclass* (Object if not specified)

```
class ColorPoint < Point ...
```

- The superclass affects the class definition:
 - Class *inherits* all method definitions from superclass
 - But class can *override* method definitions as desired
- Unlike Java/C#/C++:
 - No such thing as “inheriting fields” since all objects create instance variables by assigning to them
 - Subclassing has nothing to do with a (non-existent) type system: can still (try to) call any method on any object

Example (to be continued)

```
class Point
  attr_accessor :x, :y
  def initialize(x,y)
    @x = x
    @y = y
  end
  def distFromOrigin
    # direct field access
    Math.sqrt(@x*@x
              + @y*@y)
  end
  def distFromOrigin2
    # use getters
    Math.sqrt(x*x
              + y*y)
  end
end
```

```
class ColorPoint < Point
  attr_accessor :color
  def initialize(x,y,c)
    super(x,y)
    @color = c
  end
end
```


An object has a class

```
p = Point.new(0,0)
cp = ColorPoint.new(0,0,"red")
p.class                # Point
p.class.superclass    # Object
cp.class               # ColorPoint
cp.class.superclass   # Point
cp.class.superclass.superclass # Object
cp.is_a? Point        # true
cp.instance_of? Point # false
cp.is_a? ColorPoint   # true
cp.instance_of? ColorPoint # true
```

- Using these methods is usually non-OOP style
 - Disallows other things that “act like a duck”
 - Nonetheless semantics is that an instance of `ColorPoint` “is a” `Point` but is not an “instance of” `Point`
 - [Java note: `instanceof` is like Ruby's `is_a?`]

Example continued

- Consider alternatives to:

```
class ColorPoint < Point
  attr_accessor :color
  def initialize(x,y,c)
    super(x,y)
    @color = c
  end
end
```

- Here subclassing is a good choice, but programmers often overuse subclassing in OOP languages

Why subclass

- Instead of creating `ColorPoint`, could add methods to `Point`
 - That could mess up other users and subclassers of `Point`

```
class Point
  attr_accessor :color
  def initialize(x,y,c="clear")
    @x = x
    @y = y
    @color = c
  end
end
```

Why subclass

- Instead of subclassing `Point`, could copy/paste the methods
 - Means the same thing *if* you don't use methods like `is_a?` and `superclass`, but of course code reuse is nice

```
class ColorPoint
  attr_accessor :x, :y, :color
  def initialize(x,y,c="clear")
    ...
  end
  def distFromOrigin
    Math.sqrt(@x*@x + @y*@y)
  end
  def distFromOrigin2
    Math.sqrt(x*x + y*y)
  end
end
```

Why subclass

- Instead of subclassing `Point`, could use a `Point` instance variable
 - Define methods to send same message to the `Point`
 - Often OOP programmers overuse subclassing
 - But for `ColorPoint`, subclassing makes sense: less work and can use a `ColorPoint` wherever code expects a `Point`

```
class ColorPoint
  attr_accessor :color
  def initialize(x,y,c="clear")
    @pt = Point.new(x,y)
    @color = c
  end
  def x
    @pt.x
  end
  ... # similar "forwarding" methods
      # for y, x=, y=
end
```

Overriding

- `ThreeDPoint` is more interesting than `ColorPoint` because it overrides `distFromOrigin` and `distFromOrigin2`
 - Gets code reuse, but *highly disputable* if it is appropriate to say a `ThreeDPoint` “is a” `Point`
 - Still just avoiding copy/paste

```
class ThreeDPoint < Point
  ..
  def initialize(x,y,z)
    super(x,y)
    @z = z
  end
  def distFromOrigin # distFromOrigin2 similar
    d = super
    Math.sqrt(d*d + @z*@z)
  end
  ..
end
```

So far...

- With examples so far, objects are not so different from closures
 - Multiple methods rather than just “call me”
 - Explicit instance variables rather than environment where function is defined
 - Inheritance avoids helper functions or code copying
 - “Simple” overriding just replaces methods
- But there is one big difference:
 - Overriding can make a method defined in the superclass call a method in the subclass*
 - *The essential difference of OOP, studied carefully next lecture*

Example: Equivalent except constructor

```
class PolarPoint < Point
  def initialize(r, theta)
    @r = r
    @theta = theta
  end
  def x
    @r * Math.cos(@theta)
  end
  def y
    @r * Math.sin(@theta)
  end
  def distFromOrigin
    @r
  end
  ...
end
```

- Also need to define `x=` and `y=` (see code file)
- Key punchline: `distFromOrigin2`, defined in `Point`, “already works”

```
def distFromOrigin2
  Math.sqrt(x*x+y*y)
end
```

- Why: calls to `self` are resolved in terms of the object's class