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 }
```
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:
      ```ruby
      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`

```
    def silly a
      (yield a) + (yield 42)
    end
    x.silly 5 { |b| b*2 }
```

Example

```
a = [3,5,7,9]
b = a.map {|x| x+1 }
i = b.count {|x| x>=6 }
```

- Blocks are fine for applying to array elements
- 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 them
  - Like 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)
  ```ruby
class ColorPoint < Point  ...
end
```
- 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
end
```

```
class ColorPoint < Point
  attr_accessor  :color
  def initialize(x,y,c)
    super(x,y)
    @color = c
  end
  def distFromOrigin
    # use getters
    Math.sqrt(x*x + y*y)
  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:
  ```ruby
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

```ruby
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

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

```ruby
class ColorPoint
  attr_accessor :color
  def initialize(x,y,c="clear")
    @pt = Point.new(x,y)
    @color = c
  end
  def x
    @pt.x
  end
  def y
    @pt.y
  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

```ruby
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

```ruby
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
```

Example: Equivalent except constructor

• Also need to define x= and y= (see code file)

```ruby
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
```

• Key punchline: distFromOrigin2, defined in Point, “already works”

```ruby
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
```

– Why: calls to self are resolved in terms of the object’s class