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 \texttt{a[i]}
  – Set via \texttt{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 \texttt{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)

```ruby
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
```
- 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

- Blocks are fine for applying to array elements
- But for an array of closures, need `Proc` objects
  - More common use is callbacks
```ruby
c = a.map { |x| lambda { |y| x>=y} }
c[2].call 17
```

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)

```
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

```
An object has a class
```n
- 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 (to be continued)**

**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

```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
  def distFromOrigin # distFromOrigin2 similar
    @pt.distFromOrigin
  end
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)
- 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
```