CMSC 330: Organization of Programming Languages

More Ruby:

Methods, Classes, Arrays, Hashes

In Ruby, everything is an Object

- Ruby is object-oriented

- All values are (references to) objects
  - Java/C/C++ distinguish *primitives* from *objects*

- Objects communicate via method calls

- Each object has its own (private) state

- Every object is an instance of a class
  - An object's class determines its behavior:
  - The class contains method and field definitions
    - Both instance fields and per-class ("static") fields

Everything is an Object

- ► Examples
  - (-4).abs ← No-argument instance method of Fixnum
    - ➤ integers are instances of class Fixnum
  - 3 + 4
    - ➤ infix notation for "invoke the + method of 3 on argument 4"
  - "programming".length
    - ➤ strings are instances of String
  - String.new
    - ➤ classes are objects with a new method
  - 4.13.class
    - ➤ use the class method to get the class for an object
    - ➤ floating point numbers are instances of Float

Ruby Classes

- Class names begin with an uppercase letter

- The new method creates an object

  - s = String.new creates a new String and makes s refer to it

- Every class inherits from Object

Objects and Classes

- Objects are data
- Classes are types (the kind of data which things are)
- Classes are *also* objects

Object	Class (aka *type*)
10	Integer
-3.30	Float
"CMSC 330"	String
String.new	String
['a', 'b', 'c']	Array
Integer	Class

- Integer, Float, and String are *objects* of type Class
  - So is Class itself!

Two Cool Things to Do with Classes

▶ Since classes are objects, you can manipulate them however you like

```
if p then
  x = String
else
  x = Time
End
y = x.new
```

- Here, the type of y depends on p
  ➢ Either a String or a Time object

▶ You can get names of all the methods of a class

- Object.methods
  ➢ => ["send", "name", "class_eval", "object_id", "new", "autoload?", "singleton_methods", ...]

Standard Library: String class

- Strings in Ruby have class String
  - "hello".class == String

- The String class has many useful methods
  - s.length   # length of string
  - s1 == s2   # structural equality (string contents)
  - s = "A line\n"; s.chomp   # returns "A line"
    - Return new string with s's contents minus any trailing newline
  - s = "A line\n"; s.chomp!
    - Destructively removes newline from s
    - *Convention:* methods ending in ! modify the object
    - *Another convention:* methods ending in ? observe the object

Creating Strings in Ruby

- Substitution in double-quoted strings with #{ }
  - course = "330"; msg = "Welcome to #{course}"
  - "It is now #{Time.new}"
  - The contents of #{ } may be an arbitrary expression
  - Can also use single-quote as delimiter
    - No expression substitution, fewer escaping characters
- Here-documents

s = <<END

This is a text message on multiple lines

and typing \\n is annoying

END

Creating Strings in Ruby (cont.)

- Ruby has printf and sprintf
  - printf("Hello, %s\n", name);
  - sprintf("%d: %s", count, Time.now)
    - Returns a String
- to_s returns a String representation of an object
  - Can be invoked implicitly – write puts(p) instead of puts(p.to_s)
    - Like Java's toString()
- inspect converts any object to a string

  irb(main):033:0> p.inspect
  => "#<Point:0x54574 @y=4, @x=7>"

Symbols

- Ruby *symbols* begin with a colon
  - :foo, :baz_42, :"Any string at all"
- Symbols are "interned" Strings
  - The same symbol is at the same physical address
  - Can be compared with physical equality

```
"foo" == "foo"        # true
"foo".equal? "foo"  # false
:foo == :foo          # true
:foo.equal :foo       # true
```

- Are symbols worth it? Probably not…

The nil Object

- Ruby uses nil (not null)
  - All uninitialized fields set to nil (@ prefix used for fields)

    irb(main):004:0> @x

    => nil

- nil is an object of class NilClass
  - Unlike null in Java, which is a non-object
  - nil is a *singleton object* – there is only one instance of it
    - NilClass does not have a **new** method
  - nil has methods like to_s, but not other methods

    irb(main):006:0> nil + 2

    NoMethodError: undefined method `+' for nil:NilClass

Quiz 1

► What is the type of variable x at the end of the following program?

```
p = nil
x = 3
if p then
   x = "hello"
else
   x = nil
end
```

A. Integer

B. NilClass

C. String

D. *Nothing* – there's a type error

Quiz 1

▶ What is the type of variable x at the end of the following program?

```
p = nil
x = 3
if p then
  x = "hello"
else
  x = nil
end
```

A. Integer

B. **NilClass**

C. String

D. *Nothing* – there's a type error

Arrays and Hashes

- Ruby data structures are typically constructed from Arrays and Hashes
  - Built-in syntax for both
  - Each has a rich set of standard library methods
  - They are integrated/used by methods of other classes

Array

- Arrays of objects are instances of class Array
  - Arrays may be heterogeneous

    a = [1, "foo", 2.14]

- C-like syntax for accessing elements
  - indexed from 0
  - return nil if no element at given index

    irb(main):001:0> b = []; b[0] = 0; b[0]
     => 0
    irb(main):002:0> b[1] # no element at this index
     => nil

Arrays Grow and Shrink

- **Arrays are** growable
  - Increase in size automatically as you access elements

    irb(main):001:0> b = []; b[0] = 0; b[5] = 0; b

    => [0, nil, nil, nil, nil, 0]

  - [ ] is the empty array, same as Array.new

- **Arrays can also** shrink
  - Contents shift left when you delete elements

    a = [1, 2, 3, 4, 5]

    a.delete_at(3)   # delete at position 3; a = [1,2,3,5]

    a.delete(2)   # delete element = 2; a = [1,3,5]

Iterating Through Arrays

- It's easy to iterate over an array with while
  - length method returns array's current length

```
a = [1,2,3,4,5]
i = 0
while i < a.length
  puts a[i]
  i = i + 1
end
```

- Looping through elements of an array is common
  - We'll see a better way soon, using code blocks

Arrays as Stacks and Queues

- Arrays can model stacks and queues

```
a = [1, 2, 3]
a.push("a")       # a = [1, 2, 3, "a"]
x = a.pop         # x = "a"
a.unshift("b")    # a = ["b", 1, 2, 3]
y = a.shift       # y = "b"
```

Note that `push`, `pop`, `shift`, and `unshift` all permanently modify the array

Hash

- A hash acts like an associative array
  - Elements can be indexed by *any kind* of value
  - Every Ruby object can be used as a hash key, because the Object class has a hash method

- Elements are referred to like array elements

```ruby
italy = Hash.new
italy["population"] = 58103033
italy["continent"] = "europe"
italy[1861] = "independence"
pop = italy["population"] # pop is 58103033
planet = italy["planet"]  # planet is nil
```

Hash methods

- **new(o)** returns hash whose default value is **o**
  - h = Hash.new("fish"); h["go"]   # returns "fish"
- **values** returns array of a hash's values
- **keys** returns an array of a hash's keys
- **delete(k)** deletes mapping with key **k**
- **has_key?(k)** is **true** if mapping with key **k** present
  - has_value?(v) is similar

Hash creation

Convenient syntax for creating literal hashes

- Use { key => value, ... } to create hash table

```
credits = {
  "cmsc131" => 4,
  "cmsc330" => 3,
}


x = credits["cmsc330"]   # x now 3
credits["cmsc311"] = 3
```

- Use { } for the empty hash

Quiz 2: What is the output?

```
a = {"foo" => "bar"}
a[0] = "baz"
print a[1]
print a["foo"]
```

A. Error
B. bar
C. bazbar
D. baznilbar

Quiz 2: What is the output?

```
a = {"foo" => "bar"}
a[0] = "baz"
print a[1]
print a["foo"]
```

A. Error

B. bar

C. bazbar

D. baznilbar

Quiz 3: What is the output?

```
a = { "Yellow" => [] }
a["Yellow"] = {}
a["Yellow"]["Red"] = ["Green", "Blue"]
print a["Yellow"]["Red"][1]
```

A. Green

B. *(nothing)*

C. Blue

D. *Error*

Quiz 3: What is the output?

```
a = { "Yellow" => [] }
a["Yellow"] = {}
a["Yellow"]["Red"] = ["Green", "Blue"]
print a["Yellow"]["Green"][1]
```

A. Green

B. *(nothing)*

C. Blue

D. *Error*

Quiz 4: What is the output?

```
a = [1,2,3]
a[1] = 0
a.shift
print a[1]
```

A. *Error*

B. 2

C. 3

D. 0

Quiz 4: What is the output?

```
a = [1,2,3]
a[1] = 0
a.shift
print a[1]
```

A. *Error*

B. 2

C. 3

D. 0

Defining Your Own Classes

```ruby
class Point                          ← class name is uppercase
  def initialize(x, y)               ← constructor definition
    @x = x
    @y = y
  end                                instance variables prefixed with "@"

  def add_x(x)
    @x += x
  end                                method with no arguments

  def to_s
    return "(" + @x.to_s + "," + @y.to_s + ")"
  end
end
                                     instantiation
p = Point.new(3, 4)
p.add_x(4)
puts(p.to_s)                         ← invoking no-arg method
```

Methods in Ruby

Methods are declared with def...end

List parameters at definition

```ruby
def sayN(message, n)
  i = 0
  while i < n
    puts message
    i = i + 1
  end
  return i
end

x = sayN("hello", 3)
puts(x)
```

May omit parens on call

Invoke method

Like print, but Adds newline

Methods should begin with lowercase letter and be defined before they are called
Variable names that begin with uppercase letter are *constants* (only assigned once)

Methods: Terminology

- **Formal** parameters
  - Variable parameters used in the method
  - def sayN(message, n) in our example

- **Actual** arguments
  - Values passed in to the method at a call
  - x = sayN("hello", 3) in our example

- **Top-level** methods are "global"
  - Not part of a class. sayN is a top-level method.

Method Return Values

- Value of the return is the value of the last executed statement in the method
  - These are the same:

```
def add_three(x)
   return x+3
end
```

```
def add_three(x)
   x+3
end
```

- Methods can return multiple results (as an Array)

```
def dup(x)
   return x,x
end
```

Method naming style

- Names of methods that return `true` or `false` should end in **?**

- Names of methods that modify an object's state should end in **!**

- Example: suppose `x = [3,1,2]` (this is an array)
  - `x.member?` 3 returns true since **3** is in the array `x`
  - `x.sort` returns a **new** array that is sorted
  - `x.sort!` modifies `x` in place

No Outside Access To Internal State

- An object's instance variables (with **@**) can be directly accessed only by instance methods

- Outside class, they require accessors:

<u>A typical getter</u>
```
def x
    @x
end
```

<u>A typical setter</u>
```
def x= (value)
    @x = value
end
```

- Very common, so Ruby provides a shortcut

```
class ClassWithXandY
    attr_accessor :x, :y
end
```

Says to generate the x= and x and y= and y methods

No Method Overloading in Ruby

- Thus there can only be one initialize method
  - A typical Java class might have two or more constructors

- No overloading of methods in general
  - You can code up your own overloading by using a variable number of arguments, and checking at run-time the number/types of arguments

- Ruby does issue an exception or warning if a class defines more than one initialize method
  - But last initialize method defined is the valid one

Quiz 5: What is the output?

```
class Dog
    def smell(thing)
      "I smelled #{thing}"
    end
    def smell(thing,dur)
      "#{smell(thing)} for #{dur} seconds"
    end
end
fido = Dog.new
puts fido.smell("Alice",3)
```

A. I smelled Alice for nil seconds

B. I smelled #{thing}

C. I smelled Alice

D. *Error*

Quiz 5: What is the output?

```
class Dog
    def smell(thing)
      "I smelled #{thing}"
    end
    def smell(thing,dur)
      "#{smell(thing)} for #{dur} seconds"
    end
end
fido = Dog.new
puts fido.smell("Alice",3)
```

A. I smelled Alice for nil seconds

B. I smelled #{thing}

C. I smelled Alice

D. *Error – call from Dog expected two args*

Quiz 6: What is the output?

```
class Dog
    def smell(thing)
      "I smelled #{thing}"
    end
    def smelltime(thing,dur)
      "#{smell(thing)} for #{dur} seconds"
    end
end
fido = Dog.new
puts fido.smelltime("Alice",3)
```

A. I smelled Alice for seconds

B. I smelled #{thing} for #{dur} seconds

C. I smelled Alice for 3 seconds

D. *Error*

Quiz 6: What is the output?

```
class Dog
    def smell(thing)
      "I smelled #{thing}"
    end
    def smelltime(thing,dur)
      "#{smell(thing)} for #{dur} seconds"
    end
end
fido = Dog.new
puts fido.smelltime("Alice",3)
```

A. I smelled Alice for seconds

B. I smelled #{thing} for #{dur} seconds

C. **I smelled Alice for 3 seconds**

D. *Error*

Inheritance

▶ Recall that every class inherits from Object

```
class A          ## < Object
  def add(x)
    return x + 1
  end
end


class B < A
  def add(y)
    return (super(y) + 1)
  end
end


b = B.new
puts(b.add(3))
```

extend superclass

invoke add method
of parent

```
b.is_a? A
true
b.instance_of? A
false
```

Quiz 7: What is the output?

```ruby
class Gunslinger
  def initialize(name)
    @name = name
  end
  def full_name
    "#{@name}"
  end
end
class Outlaw < Gunslinger
    def full_name
      "Dirty, no good #{super}"
    end
end
d = Outlaw.new("Billy the Kid")
puts d.full_name
```

A. Dirty, no good Billy the kid

B. Dirty, no good

C. Billy the Kid

D. *Error*

Quiz 7: What is the output?

```
class Gunslinger
  def initialize(name)
    @name = name
  end
  def full_name
    "#{@name}"
  end
end
class Outlaw < Gunslinger
   def full_name
      "Dirty, no good #{super}"
   end
end
d = Outlaw.new("Billy the Kid")
puts d.full_name
```

A. **Dirty, no good Billy the kid**

B. Dirty, no good

C. Billy the Kid

D. *Error*

Global Variables in Ruby

▶ Ruby has two kinds of global variables
- Class variables beginning with @@ (static in Java)
- Global variables across classes beginning with $

```ruby
class Global
  @@x = 0

  def Global.inc
    @@x = @@x + 1; $x = $x + 1
  end

  def Global.get
    return @@x
  end
end
```

```ruby
$x = 0
Global.inc
$x = $x + 1
Global.inc
puts(Global.get)
puts($x)
```

define a class
("singleton") method
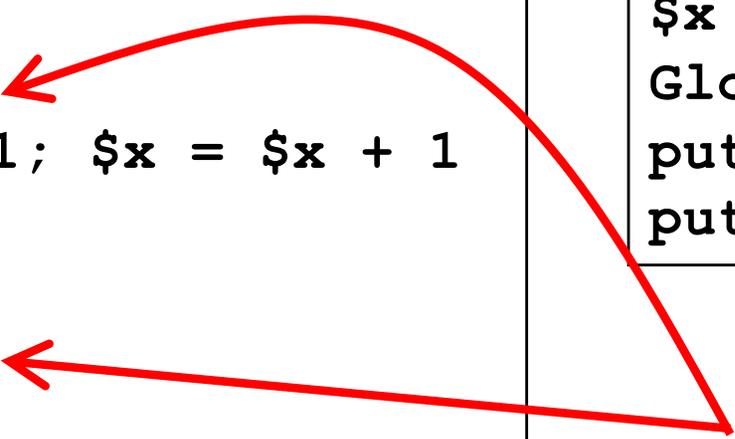
Quiz 8: What is the output?

```
class Rectangle
 def initialize(h, w)
    @@h = h
    @w = w
 end
 def measure()
   return @@h + @w
 end
End
r = Rectangle.new(1,2)
s = Rectangle.new(3,4)
puts r.measure()
```

A. 0

B. 5

C. 3

D. 7

Quiz 8: What is the output?

```
class Rectangle
 def initialize(h, w)
    @@h = h
    @w = w
 end
 def measure()
   return @@h + @w
 end
End
r = Rectangle.new(1,2)
s = Rectangle.new(3,4)
puts r.measure()
```

A. 0

B. **5**

C. 3

D. 7

What is a Program?

- **In C/C++, a program is...**
  - A collection of declarations and definitions
  - With a distinguished function definition
    - int main(int argc, char *argv[]) { ... }
  - When you run a C/C++ program, it's like the OS calls main(...)

- **In Java, a program is...**
  - A collection of class definitions
  - With some class (say, MyClass) containing a method
    - public static void main(String[] args)
  - When you run java MyClass, the main method of class MyClass is invoked

A Ruby Program is...

▶ ## The class Object

- When the class is loaded, any expressions not in method bodies are executed

defines a method of Object
(i.e., top-level methods belong to Object)

invokes self.sayN

invokes self.puts
(part of Object)

```ruby
def sayN(message, n)
  i = 0
  while i < n
    puts message
    i = i + 1
  end
  return i
end


x = sayN("hello", 3)
puts(x)
```