CMSC 330: Organization of Programming Languages

Equality, Mixin Inheritance, Miscellany
Object Copy vs. Reference Copy

- Consider the following code
  - Assume an object-reference model like Java or Ruby
    - Or even two pointers pointing to the same structure

```plaintext
x = "groundhog" ; y = x
```

- Which of these occur?

**Object copy**
- `x` (reference) → "groundhog" (object)
- `y` → "groundhog"

**Reference copy**
- `x` (reference) → "groundhog" (object)
- `y` → "groundhog"
Object Copy vs. Reference Copy (cont.)

- For `x = "groundhog" ; y = x`
  - Ruby and Java would both do a reference copy

- But for
  
  `x = "groundhog"
y = String.new(x)`

  - Ruby would cause an object copy
  - Unnecessary in Java since Strings are immutable
Physical vs. Structural Equality

Consider these cases again:

- If we compare $x$ and $y$, what is compared?
  - The references, or the contents of the objects they point to?
- If references are compared (physical equality) the first would return false but the second true.
- If objects are compared both would return true.
String Equality

- In Java, `x == y` is **physical** equality, always
  - Compares references, not string contents
- In Ruby, `x == y` for strings uses **structural** equality
  - Compares contents, not references
  - `==` is a method that can be overridden in Ruby!
  - To check physical equality, use the `equal?` method
    - Inherited from the `Object` class
- It’s always important to know whether you’re doing a reference or object copy
  - And physical or structural comparison
## Comparing Equality

<table>
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<th>Language</th>
<th>Physical equality</th>
<th>Structural equality</th>
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<tr>
<td>Java</td>
<td><code>a == b</code></td>
<td><code>a.equals(b)</code></td>
</tr>
<tr>
<td>C</td>
<td><code>a == b</code></td>
<td><code>*a == *b</code></td>
</tr>
<tr>
<td>Ruby</td>
<td><code>a.equal?(b)</code></td>
<td><code>a == b</code></td>
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<td>Ocaml</td>
<td><code>a == b</code></td>
<td><code>a = b</code></td>
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<td>Python</td>
<td><code>a is b</code></td>
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<td><code>(eq? a b)</code></td>
<td><code>(equal? a b)</code></td>
</tr>
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<td>Visual Basic .NET</td>
<td><code>a Is b</code></td>
<td><code>a = b</code></td>
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</table>
Quiz 1: Which is true?

a) Structural equality implies physical equality
b) Physical equality implies structural equality
c) Physical equality does not work for cyclic data structures
d) == always means physical equality
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d) == always means physical equality
Comparisons

- Sorting requires ability to compare two values
- Ruby comparison method `<=>`
  - -1 = less
  - 0 = equals
  - +1 = greater

Examples
- 3 `<=>` 4 returns -1
- 4 `<=>` 3 returns +1
- 3 `<=>` 3 returns 0
Sorting

Two ways to sort an Array

• Default sort (puts values in ascending order)
  ➢ [2,5,1,3,4].sort  # returns [1,2,3,4,5]

• Custom sort (based on value returned by code block)
  ➢ [2,5,1,3,4].sort { |x,y| y <=> x }  # returns [5,4,3,2,1]
  ➢ Where -1 = less, 0 = equals, +1 = greater
  ➢ Code block return value used for comparisons
Quiz 2: What is the output?

print

[1,4,7,3,2].sort { |x,y| (x % 2) <=> (y % 2) }

• Recall that % is the modulus operator
• And <=> is the built in comparison operator

a) [1, 2, 3, 4, 7]
b) [4, 2, 1, 7, 3]
c) [1, 7, 3, 4, 2]
d) [7, 4, 3, 2, 1]
Quiz 2: What is the output?

print
[1,4,7,3,2].sort { |x,y| (x % 2) <=> (y % 2) }

- Recall that % is the modulus operator
- And <=> is the built in comparison operator

a) [1, 2, 3, 4, 7]
b) [4, 2, 1, 7, 3] – evens, then odds, in original order
c) [1, 7, 3, 4, 2]
d) [7, 4, 3, 2, 1]
Ranges

- 1..3 is an object of class `Range`
  - Integers between 1 and 3 inclusively
- 1…3 also has class `Range`
  - Integers between 1 and 3 but not including 3 itself.
- Not just for integers
  - ‘a’..’z’ represents the range of letters ‘a’ to ‘z’
  - 1.3…2.7 is the continuous range [1.3,2.7)
    - `(1.3…2.7).include? 2.0  #=> true`
- Discrete ranges offer the `each` method to iterate
  - And can convert to an array via `to_a`; e.g., `(1..2).to_a`
Special Global Variables

- Ruby has a special set of global variables that are implicitly set by methods
- The most insidious one: $_
  - Last line of input read by gets or readline
- Example program
  ```ruby
  gets    # implicitly reads input line into $
  print   # implicitly prints out $
  ```

- Using$_ leads to shorter programs
  - And confusion
  - We suggest you avoid using it
Mixins

- Inheritance is one form of code reuse
- Another form of code reuse is “mix-in” inclusion
  - include A “inlines” A’s methods at that point
    - Referred-to variables/methods captured from context
    - In effect: it adds those methods to the current class
- To define a mixin, use a module for A, not class
Ruby Modules

- A module is a collection of methods and constants
  - Module methods can be called directly
    - So module defines a namespace for those methods
  - Instance methods are “mixed in” to another class

```ruby
module Doubler
  def Doubler.base # module method
    2
  end
  def double       # instance method
    self + self
  end
end

Doubler.base => 2
Doubler.class => Module
Doubler.new
  #err, no method
Doubler.double
  #err, no method
Doubler.instance_methods
  => [:double]
```
Mixin Modules

module Doubler
  def double
    self + self
  end
end

class Integer # extends Integer
  include Doubler
  end
  10.double => 20

class String # extends String
  include Doubler
end

"hello".double => "hellohello"

Inserts instance methods from Doubler into the class Integer
Mixin Method Lookup

- When you call method \textit{m} of class \textit{C}, look for \textit{m}
  1. in \textit{class C} ... 
  2. in \textit{mixin} in class \textit{C} ... 
     - if multiple mixins included, start in \textit{latest mixin}, then try earlier (\textit{shadowed}) ones ...
  3. in \textit{C}'s superclass ...
  4. in \textit{C}'s superclass \textit{mixin} ...
  5. in \textit{C}'s superclass's superclass ...
  6. ...
Mixin Example 1

```ruby
module M1
  def hello
    "M1 hello"
  end
end

module M2
  def hello
    "M2 hello"
  end
end

class A
  include M1
  include M2
  def hello
    "A hello"
  end
end

a = A.new
a.hello
=> "A hello"
a.class.ancestors
=> [A, M2, M1, Object, Kernel, BasicObject]
```
Quiz 3: What is the output?

module M1
def hello
    "M1 hello"
end
end

module M2
def hello
    "M2 hello"
end
end

class A
    include M1
    include M2
end

• class A does not have a method hello.
• Both M1 and M2 have a method hello. M2's hello shadows M1's.

a = A.new
puts a.hello

a. "A hello"
b. "M1 hello"
c. "M2 hello"
d. (nothing)
Quiz 3: What is the output?

module M1
  def hello
    "M1 hello"
  end
end

module M2
  def hello
    "M2 hello"
  end
end

class A
  include M1
  include M2
end

a = A.new
puts a.hello

• class A does not have a method hello.
• Both M1 and M2 have a method hello. M2’s hello shadows M1’s.

a. “A hello”
b. “M1 hello”
c. “M2 hello”
d. (nothing)
Mixin Example 3

module M1
  def hello
    "m1 says hello, " + super
  end
  def what
    "Mary"
  end
end
class A
  def hello
    "A says hello, " + what
  end
  def what
    "Alice"
  end
end
class B < A
  include M1
  def hello
    "B says hello, " + super
  end
  def what
    "Bob"
  end
end
b = B.new
b.class.ancestors
=> [B, M1, A, Object, Kernel, BasicObject]
b.hello
=> B says hello, m1 says hello, A says hello, Bob

B's hello is called. super called B's superclass M1's hello. super in M1's hello called hello in superclass A. At the end, the "what" method of the current object "b" is called.
class OneDPoint  
    attr_accessor :x  
    include Comparable  

    def <=>(other)  
        # used by Comparable  
        if @x < other.x then return -1  
        elsif @x > other.x then return 1  
        else return 0  
        end  
    end  
end

p = OneDPoint.new  
p.x = 1  
q = OneDPoint.new  
qu.x = 2  
x < y  # true  
puts [y,x].sort  
# prints x, then y
class MyRange
  include Enumerable  #map, select, inject, collect, find

  def initialize(low,high)
    @low = low    #(2,8)
    @high = high
  end
  def each  #used by Enumerable
    i=@low
    while i <= @high
      yield i
    i=i+1
    end
  end
end
Ruby Summary

- Interpreted
- Implicit declarations
- Dynamically typed
- Built-in regular expressions
- Easy string manipulation
- Object-oriented
  - Everything (!) is an object
- Code blocks
  - Easy higher-order programming!
  - Get ready for a lot more of this...

Makes it quick to write small programs

Hallmark of scripting languages
Other Scripting Languages

- Perl and Python are also popular scripting languages
  - Also are interpreted, use implicit declarations and dynamic typing, have easy string manipulation
  - Both include optional “compilation” for speed of loading/execution
- Will look fairly familiar to you after Ruby
  - Lots of the same core ideas
  - All three have their proponents and detractors
  - Use whichever language you personally prefer