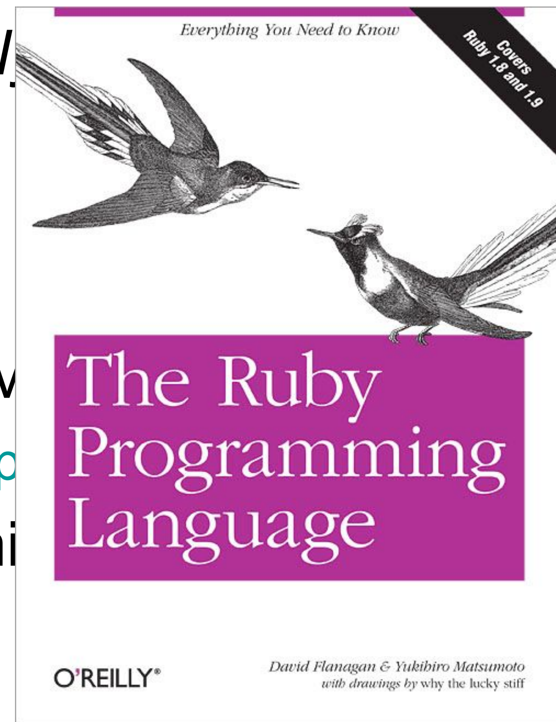
CMSC 330: Organization of Programming Languages

Introduction to Ruby

Ruby

- An *object-oriented, imperative, dynamicall*
  (scripting) language
  - Similar to Python, Perl
  - Fully object-oriented
- Created in 1993 by Yukihiro Matsumoto (M
  - "Ruby is designed to make programmers happ
- Adopted by Ruby on Rails web programmi
  2005
  - a key to Ruby's popularity



Static Type Checking (Static Typing)

- Before program is run
  - Types of all expressions are determined
  - Disallowed operations cause compile-time error
    - Cannot run the program

- Static types are often explicit (*aka* manifest)
  - Specified in text (at variable declaration)
    - C, C++, Java, C#
  - But may also be inferred – compiler determines type based on usage
    - OCaml, C#, Rust, and Go (limited)

Dynamic Type Checking

- During program execution
  - Can determine type from run-time value
  - Type is checked before use
  - Disallowed operations cause run-time exception
    - Type errors may be latent in code for a long time
- Dynamic types are *not* manifest
  - Variables are just introduced/used without types
  - Examples
    - **Ruby**, Python, Javascript, Lisp
    - **Note**: Ruby v3 adds support for static types, mixed with its native dynamic ones. We'll discuss this more, later in the course.

Static and Dynamic Typing

- Ruby is dynamically typed, C is statically typed

```
# Ruby
 x = 3
 x = "foo"   # gives x a
             # new type
 x.foo       # NoMethodError
             # at runtime
```

```
 /* C */
 int x;
 x = 3;
 x = "foo"; /* not allowed */
/* program doesn't compile */
```

Tradeoffs?

Static type checking	Dynamic type checking
More work for programmer (at first)	Less work for programmer (at first)
Catches more (and subtle) errors at compile time	Delays some errors to run time
Precludes some correct programs	Allows more programs (Including ones that will fail)
More efficient code (fewer run-time checks)	Less efficient code (more run-time checks)

Java: *Mostly* Static Typing

- In Java, types are mostly checked statically

```
Object x = new Object();
x.println("hello");   // No such method error at compile time
```

- But sometimes checks occur at run-time

```
Object o = new Object();
String s = (String) o;  // No compiler warning, fails at run time
// (Some Java compilers may be smart enough to warn about above cast)
```

Quiz 1

- True or false: This program has a type error

```
# Ruby
x = "hello"
y = 2.5
y = x
```

A. True
B. False

Quiz 1

- True or false: This program has a type error

```
# Ruby
x = "hello"
y = 2.5
y = x
```

A. True

B. **False**

Quiz 2

- True or false: This program has a type error

```
/* C */
void foo() {
  int a = 10;
  char *b = "hello";
  a = b;
}
```

A. True

B. False

Quiz 2

- True or false: This program has a type error

```
/* C */
void foo() {
  int a = 10;
  char *b = "hello";
  a = b;
}
```

A. **True**

B. False

Control Statements in Ruby

- A control statement is one that affects which instruction is executed next
  - While loops
  - Conditionals

```
i = 0
while i < n
  i = i + 1
end
```

```
if grade >= 90 then
  puts "You got an A"
elsif grade >= 80 then
  puts "You got a B"
else
  puts "You're not doing so well"
end
```

What is True?

- The guard of a conditional is the expression that determines which branch is taken

```
if grade >= 90 then
...
```

Guard

- True: anything except
  - false
  - nil
- Warning to C programmers: **0 is not false!**

Quiz 3: What is the output?

```
x = 0
if x then
  puts "true"
elsif x == 0 then
  puts "== 0"
else
  puts "false"
end
```

A. Nothing – there's an error
B. "false"
C. "== 0"
D. "true"

Quiz 3: What is the output?

```
x = 0
if x then
  puts "true"
elsif x == 0 then
  puts "== 0"
else
  puts "false"
end
```

A. Nothing – there's an error
B. "false"
C. "== 0"
D. "true"

`x` is neither **`false`** nor **`nil`** so the first guard is satisfied

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

```
> 1.class
Integer

> 1.methods
[:to_s, :to_i, :abs, …]
```

Object is the superclass of every class

```
> 1.class.ancestors
[Integer,Numeric,Comparable,Object,Kernel,BasicObject]
```

Objects Communicate via Method Calls

\+ is a method of the Integer class

```
1 + 2     => 3
1.+(2)    => 3
```

`1 + 2` is *syntactic sugar* for `1.+(2)`

```
1.add(2)     => 1.+(2) => 1 + 2
```

```
1.to_s       = "1"
1.to_s()     = "1"
```

no parens needed if no args

The nil Object

- Ruby uses nil (not null)
  - All uninitialized fields set to nil
  - 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

Classes are Objects too

```
> nil.class
NilClass

> 2.5.class
Float

> true.class
TrueClass

> Float.class
Class
```

First-class Classes

- Since classes are objects, you can manipulate them however you like
  - Here, the type of y depends on p
    - Either a String or a Time object

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

Quiz 4

- 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 4

- 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

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.)

- sprintf

```
count = 100
s = sprintf("%d: %s", count, Time.now)
=>"100: 2021-01-27 19:56:06 -0500"
```

- to_s returns a String representation of an object
  - 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,
- Symbols are more efficient than strings.
  - The same symbol is at the same physical address

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

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

- Create an empty Array

```
t = Array.new
x = [ ]
    b= Array.new(3)  #b = [nil,nil,nil]
    b =Array.new(5,"a")    # b = ["a", "a", "a", "a", "a"]
```

- Arrays may be heterogeneous

```
a = [1, "foo", 2.14]
```

Array Index

```
> s = ["a","b","c", 1, 1.5, true]
```

	"a"	"b"	"c"	1	1.5	true
Index	0	1	2	3	4	5
	-6	-5	-4	-3	-2	-1

```
> s[0]
"a"

> s[-6]
"a"
```

Arrays Grow and Shrink

- Arrays are growable

```
# b = [ ]; b[0] = 0; b[5] = 0; b
 => [0, nil, nil, nil, nil, 0]
```

- 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]
```

Two-Dimensional Array

```
> a = Array.new(3) { Array.new(3) }
> a[1][1]=100

> a
              [
               [nil, nil, nil],
               [nil, 100, nil],
               [nil, nil, nil]
              ]
```

Some Array Operations

```
a=[1,2,3,4]
b=[3,4,5,6]
```

Adding two arrays

a+b => [1, 2, 3, 4, 3, 4, 5, 6]

Union

a | b => [1, 2, 3, 4, 5, 6]

Intersection

a & b => [3, 4]

Subtract

a – b => [1, 2]

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

Quiz 5: What is the output?

A. *Error*
B. 2
C. 3
D. 0

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

Quiz 5: What is the output?

A. *Error*

B. 2

C. 3

D. 0

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

Hash

- A hash acts like an array, whose 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

```
italy = Hash.new     # or italy={}
italy["population"] = 58103033
italy[1861] = "independence”
p = italy[“population”] # pop is 58103033
planet = italy[“planet”]  # planet is nil
```

Hash methods

- new(v) returns hash whose default value is v
  - 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
```

Credits

Key	Value
cmsc131	4
cmsc330	3

Hashes of Hashes

```
h       = Hash.new(0)
h[1]    = Hash.new(0)
h[1][2] = 5
h[2]    = Hash.new(0)
h[2][1] = 1
h[3]    = Hash.new(0)
h[3][3] = 3
```

h is
```
{
  1=> {2=> 5},
  2=> {1=> 1},
  3=> {3=> 3}
}
```

Quiz 6: What is the output?

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

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

Quiz 6: What is the output?

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

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

Quiz 7: What is the output?

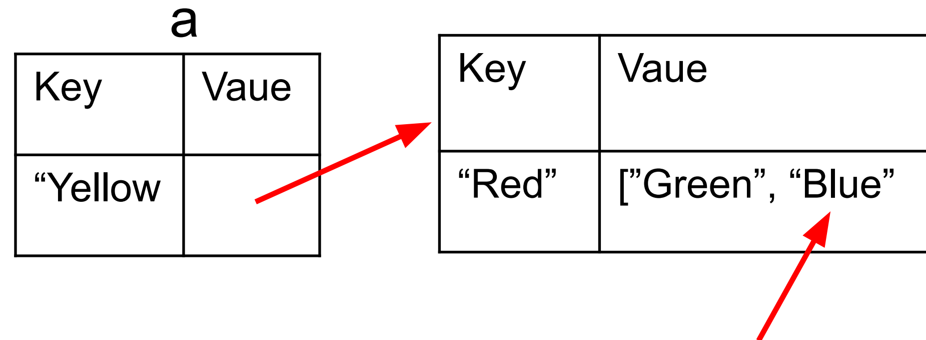
A. Green
B. *(nothing)*
C. Blue
D. *Error*

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

Quiz 7: What is the output?

A. Green
B. *(nothing)*
C. Blue
D. *Error*

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



Methods in Ruby

Note: Methods need not be part of a class

Methods are declared with def...end

List parameters at definition

May omit parens on call

Invoke method

Like print, but Adds newline

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

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

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
```

Defining Your Own Classes

```
class Point
  def initialize(x, y)
    @x = x
    @y = y
  end

  def add_x(x)
    @x += x
  end

  def to_s
    "(" + @x.to_s + "," + @y.to_s + ")"
  end
end

p = Point.new(3, 4)
p.add_x(4)
puts(p.to_s)
```

class name is uppercase

constructor definition

instance variables prefixed with "@"

method with no arguments

instantiation

invoking no-arg method

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:

A typical getter

```
def x
   @x
end
```

A typical setter

```
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

Defining Your Own Classes

```
class Point
  def initialize(x)
    @x = x
  end
  def x=(x)
     @x = x
  end
  def x
    @x
  end
 private
  def prt
      "#{@x}"
  end
 # Make the below methods public
 public
  def to_s
    prt
  end
end
```

```
> p = Point.new(10)
#<Point:0x00007f8 @x=10>

> p.x␣= 100
100

> p.prt
NoMethodError
(private method `prt' called)
```

Defining Your Own Classes: Sugared

```ruby
class Point
  def initialize(x)
    @x = x
  end
  def x=(x)
     @x = x
  end
  def x
    @x
  end
 private
  def prt
      "#{@x}"
  end
 # Make the below methods public
 public
  def to_s
    prt
  end
end
```

```ruby
class Point
  attr_accessor :x

  attr_reader :y
  attr_writer :z

  private
    def prt
      "#{@x}, #{@y}"
    end

  # Make the below methods public
  public
    def to_s
       prt
    end
end
```

Quiz 8: What is the output?

A. I smelled Alice for nil seconds
B. I smelled #{thing}
C. I smelled Alice
D. *Error*

```
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)
```

Quiz 8: What is the output?

A. I smelled Alice for nil seconds
B. I smelled #{thing}
C. I smelled Alice
D. *Error – call from Dog expected two args*

```
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)
```

Quiz 9: What is the output?

A. I smelled Alice for seconds
B. I smelled #{thing} for #{dur} seconds
C. I smelled Alice for 3 seconds
D. *Error*

```
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)
```

Quiz 9: What is the output?

A. I smelled Alice for seconds
B. I smelled #{thing} for #{dur} seconds
C. **I smelled Alice for 3 seconds**
D. *Error*

```
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)
```

Update Existing Classes (Including Builtins!)

```
10.double       => NoMethodError
             (undefined method `double' for 10:Integer)
```

Add a method to the Integer class

```
class Integer
  def double
     self + self
  end
end
```

```
10.double       => 20
```

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 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

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 10: What is the output?

A. Dirty, no good Billy the kid
B. Dirty, no good
C. Billy the Kid
D. *Error*

```
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
```

Quiz 10: What is the output?

A. Dirty, no good Billy the kid
B. Dirty, no good
C. Billy the Kid
D. *Error*

```
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
```

Global Variables in Ruby

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

```
class Global
  @@x = 0

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

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

```
$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?

A. 0
B. 5
C. 3
D. 7

```
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()
```

Quiz 8: What is the output?

A. 0

B. **5**

C. 3

D. 7

```
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()
```

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)

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

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