Introduction

Ruby is an object-oriented, imperative scripting language

- “I wanted a scripting language that was more powerful than Perl, and more object-oriented than Python. That’s why I decided to design my own language.”

- “I believe people want to express themselves when they program. They don’t want to fight with the language. Programming languages must feel natural to programmers. I tried to make people enjoy programming and concentrate on the fun and creative part of programming when they use Ruby.”

  – Yukihiro Matsumoto (“Matz”)

Books on Ruby

- Earlier version of Thomas book available on web
  - See course web page

Last Lecture

- Many types of programming languages
  - Imperative, functional, logical, OO, scripting

- Many programming language attributes
  - Clear, orthogonal, natural…

- Programming language implementation
  - Compiled, interpreted
Applications of Scripting Languages

- Scripting languages have many uses
  - Automating system administration
  - Automating user tasks
  - Quick-and-dirty development

- Major application
  - Text processing

Output from Command-Line Tool

```
% wc *
271  674  5323 AST.c
100  392  3219 AST.h
117  1459  23878 AST.o
1874 5428 47641 AST_defs.c
371  884  9483 AST_utils.c
810 2328 24589 AST_print.c
640 3070 33530 AST_types.h
285  846  7081 AST_utils.o
59  274  2154 AST_utils.h
50  400 28756 AST_utils.o
866 2757 25873 Makefile
270  725  5578 Makefile.am
866 2743 27320 Makefile.in
38 175 1154 alloca.c
2035 4516 47721 aloctypes.c
86  350 3286 aloctypes.h
104 1051 66848 aloctypes.o
```
A Simple Example

- Let’s start with a simple Ruby program

```ruby
# This is a ruby program
x = 37
y = x + 5
print(y)
print("\n")
```

`% ruby -w ruby1.rb
42
%

Language Basics

- comments begin with #, go to end of line
- variables need not be declared
- line break separates expressions (can also use ";" to be safe)

Run Ruby, Run

There are several ways to run a Ruby program
- `ruby -w filename` – execute script in `filename`
  - tip: the `-w` will cause Ruby to print a bit more if something bad happens
  - Ruby filenames should end with `.rb` extension
- `irb` – launch interactive Ruby shell
  - Can type in Ruby programs one line at a time, and watch as each line is executed
  - `irb(main):001> 3+4
  7`
  - Can load Ruby programs via `load` command
  - Form: `load string`
  - String must be name of file containing Ruby program
  - E.g.: `load ‘foo.rb’`

Ruby is installed on `linuxlab`, `Grace` clusters

Run Ruby, Run (cont.)

- `fxri` – launch standalone interactive Ruby shell

```ruby
#!/usr/local/bin/ruby -w
print("Hello, world!
")
```
Run Ruby, Run (cont.)

- Suppose you want to run a Ruby script as if it were an executable (e.g. “double-click”, or as a command)
  - Windows
    - Must associate .rb file extension with ruby command
    - If you installed Ruby using the Windows installer, this was done automatically
    - The Ruby web site has information on how to make this association

Run Ruby, Run (cont.)

- Suppose you want to run a Ruby script as if it were an executable (cont.)
  - *nix (Linux / Unix / etc.)
    - The first line ("shebang") tells the system where to find the program to interpret this text file
    - Must chmod u+x filename first, or chmod a+x filename so everyone has exec permission
    - Warning: Not very portable: Depends on location of Ruby interpreter
      - /usr/local/bin/ruby vs. /usr/bin/ruby vs. /opt/local/bin/ruby etc.

Creating Ruby Programs

- As with most programming languages, Ruby programs are text files.
  - Note: there are actually different versions of “plain text”! E.g. ASCII, Unicode, Utf-8, etc.
  - You won’t need to worry about this in this course.
- To create a Ruby program, you can use your favorite text editor, e.g.
  - notepad++ (free, much better than notepad)
  - emacs (free, infinitely configurable)
  - vim
  - Eclipse (see web page for plugin instructions)
  - Many others

Explicit vs. Implicit Declarations

- Java and C/C++ use explicit variable declarations
  - Variables are named and typed before they are used
    - int x, y; x = 37; y = x + 5;
- In Ruby, variables are implicitly declared
  - First use of a variable declares it and determines type
    - x = 37; y = x + 5;
    - x, y exist, will be integers
  - Ruby allows multi-assignment, too
    - x,y = 37, 5; y += x
    - x,y = 37,x+5 would have failed; x was not yet assigned
Tradeoffs?

Explicit Declarations
More text to type
Helps prevent typos
Forces programmer to document types

Implicit Declarations
Less text to type
Easy to mistype variable name
Variable not held to a fixed type (could imagine variable declarations without types)

Methods in Ruby

Methods are declared with def...end
List parameters at definition
Invoke method
Like print, but adds newline
May omit parens on call

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)

Method Return Values

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

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

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

• Methods can return multiple results (as a list)

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

Terminology

• Formal parameters
  • Parameters used in the body of the method
  • def sayN(message, n) in our example

• Actual parameters
  • Arguments passed in to the method at a call
  • x = sayN("hello", 3) in our example
Style

- Names of methods that return a boolean 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.

Control Statements in Ruby

- A control statement is one that affects which instruction is executed next.
  - We’ve seen two so far in Ruby:
    - `while` and method call.
  - Ruby also has conditionals:

```ruby
if grade >= 90 then
  puts "You got an A"
elsif grade >= 80 then
  puts "You got a B"
elsif grade >= 70 then
  puts "You got a C"
else
  puts "You're not doing so well"
end
```

Ruby Conditionals Must End!

- All Ruby conditional statements must be terminated with the `end` keyword.
- Examples:
  - `if grade >= 90 then
      puts "You got an A"
    end`
  - `if grade >= 90 then
      puts "You got an A"
    else
      puts "No A, sorry"
    end`

What is True?

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

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

- The true branch is taken if the guard evaluates to anything except:
  - `false`
  - `nil`

- Warning to C programmers: `0` is not `false`!
**Yet More Control Statements in Ruby**

- **unless cond then stmt-f else stmt-t end**
  - Same as “if not cond then stmt-t else stmt-f end”

```
unless grade < 90 then
  puts "You got an A"
else unless grade < 80 then
  puts "You got a B"
end
```

- **until cond body end**
  - Same as “while not cond body end”

```
until i >= n
  puts message
  i = i + 1
end
```

**Using If and Unless as Modifiers**

- Can write if and unless after an expression
  - puts "You got an A" if grade >= 90
  - puts "You got an A" unless grade < 90

**Why so many control statements?**

- **Good:** can make program more readable, expressing programs more directly. In natural language, many ways to say the same thing, which supports brevity and adds style.
- **Bad:** many ways to do the same thing may lead to confusion and hurt maintainability (if future programmers don’t understand all styles)

**Classes and Objects**

- 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

**Everything is an Object**

- In Ruby, everything is an object
  - (-4).abs
    - integers are instances of 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
Objects and Classes

- Objects are data
- Classes are types (the kind of data which things are)
- But in Ruby, classes themselves are objects!

<table>
<thead>
<tr>
<th>Object</th>
<th>Class (aka type)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Fixnum</td>
</tr>
<tr>
<td>-3.30</td>
<td>Float</td>
</tr>
<tr>
<td>&quot;CMSC 330&quot;</td>
<td>String</td>
</tr>
<tr>
<td>String.new</td>
<td>String</td>
</tr>
<tr>
<td>['a', 'b', 'c']</td>
<td>Array</td>
</tr>
<tr>
<td>Fixnum</td>
<td>Class</td>
</tr>
</tbody>
</table>

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

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

- You can get names of all the methods of a class
  - Object.methods
    - => ["send", "name", "class_eval", "object_id", "new", "autoload?", "singleton_methods", ... ]

The nil Object

- Ruby uses a special object nil
  - All uninitialized fields set to nil (@ prefix used for fields)
    ```ruby
    irb(main):004:0> @x => nil
    ```
  - Like NULL or 0 in C/C++ and null in Java
- nil is an object of class NilClass
  - It’s 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
    ```ruby
    irb(main):006:0> nil + 2
    NoMethodError: undefined method `+' for nil:NilClass
    ```

What is a Program?

- In C/++, a program is...
  - A collection of declarations and definitions
  - With a distinguished function definition
    ```ruby
    int main(int argc, char *argv[]) { ... }
    ```
  - When you run a 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
    ```ruby
    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

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

- Defines a method of **Object**
- Invokes `self.sayN`
- Invokes `self.puts` (part of **Object**)

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

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

Standard Library: Array

- Arrays of objects are instances of class **Array**
  - Arrays may be heterogeneous
    ```ruby
    a = [1, "foo", 2.14]
    ```
  - C-like syntax for accessing elements, indexed from 0
    ```ruby
    x = a[0]; a[1] = 37
    ```

- Arrays are **growable**
  - Increase in size automatically as you access elements
    ```ruby
    irb(main):001> b = []; b[0] = 0; b[5] = 0; puts b.inspect
    [0, nil, nil, nil, nil, 0]
    ```
  - `[]` is the empty array, same as `Array.new`

Standard Library: Arrays (cont.)

- Arrays can also shrink
  - Contents shift left when you delete elements
    ```ruby
    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]
    ```

- Can use arrays to model stacks and queues
  ```ruby
  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:** push, pop, shift, and unshift all permanently modify the array
Iterating Through Arrays

- It's easy to iterate over an array with `while`

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

- Looping through all elements of an array is very common
  - And there’s a better way to do it in Ruby:

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

Iteration and Code Blocks

- The `Array` class also has an `each` method
  - Takes a code block as an argument

```
a = [1,2,3,4,5]
a.each { |x| puts x }
```

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`
More Data-driven Control Statements

Ruby function to print all even numbers from 0 up to (but not including) some given number \( x \)

```ruby
def even(x)
  x.times { |i|
    if i % 2 == 0
      puts i
    end
  }
end
```

```ruby
def even(x)
  for i in (0...x)
    if i % 2 == 0
      puts i
    end
  end
end
```

```ruby
def even(x)
  0.upto(x-1) { |i|
    if i % 2 == 0
      puts i
    end
  }
end
```

Standard Library: Hash

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

- Elements are referred to using [] like array elements, but Hash.new is the Hash constructor

```
italy["population"] = 58103033
italy["continent"] = "europe"
italy[1861] = "independence"
```

Hash (cont.)

- Hash methods
  - `values` returns array of a hash’s values (in some order)
  - `keys` returns an array of a hash’s keys (in some order)

- Iterating over a hash

```
italy.keys.each { |k|
  print "key: ", k, " value: ", italy[k]
}

italy.each { |k,v|
  print "key: ", k, " value: ", v
}
```

Hash (cont.)

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
```
Defining Your Own Classes

```ruby
class Point
  def initialize(x, y)
    @x = x
    @y = y
  end
  def add_x(x)
    @x += x
  end
  def to_s
    return "(" + @x.to_s + "," + @y.to_s + ")"
  end
end
p = Point.new(3, 4)
p.add_x(4)
puts(p.to_s)
```

No Access To Internal State

- Instance variables (with @) can be directly accessed only by instance methods
- Outside class, they require accessors:
  ```ruby
  class												
  A typical getter	A typical setter
  def x									
def x= (value)
  @x										@x = value
  end									end
  ```

- Very common, so Ruby provides a shortcut
  ```ruby
  class ClassWithXandY
    attr_accessor "x", "y"
  end
  ```

No Method Overloading in Ruby

- Thus there can only be one `initialize` method
  - A typical Java class might have two or more constructors
  - You can code up your own overloading by using a variable number of arguments, and checking at runtime 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

Classes and Objects in Ruby (cont.)

- Recall classes begin with an uppercase letter
- `inspect` converts any instance to a string
  ```ruby
  irb(main):033:0> p.inspect
  => "<Point:0x54574 @y=4, @x=7>
  ```
- The `to_s` method can be invoked implicitly
  ```ruby
  
  ### CMSC 330
  ```
### Inheritance

- Recall that every class inherits from **Object**

```ruby
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))
```

### Mixins

- 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

```ruby
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
```

```ruby
p = OneDPoint.new
p.x = 1
q = OneDPoint.new
q.x = 2
x < y # true
puts [y,x].sort
# prints x, then y
```

### super() in Ruby

- Within the body of a method
  - Call to `super()` acts just like a call to that original method
  - Except that search for method body starts in the superclass of the object that was found to contain the original method

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

Creating Strings in Ruby

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

- Here-documents
  ```ruby
  s = <<END
  This is a text message on multiple lines
  and typing \n is annoying
  END
  ```

Creating Strings in Ruby (cont.)

- Ruby also has `printf` and `sprintf`
  ```ruby
  printf("Hello, %s\n", name);
  sprintf("%d: %s", count, Time.now)
  ```
  - Returns a string

- The `to_s` method returns a `String` representation of a class object

Standard Library: String

- The `String` class has many useful methods
  ```ruby
  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 except newline at end of line removed
  - 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

- "r1\nr2\nr3\nr4".each_line { |rec| puts rec }
  - Apply code block to each newline-separated substring
Standard Library: String (cont.)

- "hello".index("l", 0)
  - Return index of the first occurrence of string in s, starting at n
- "hello".sub("h", "j")
  - Replace first occurrence of "h" by "j" in string
  - Use gsub ("global" sub) to replace all occurrences
- "r1\tr2\t\tr3".split("\\t")
  - Return array of substrings delimited by tab

Consider these three examples again
- All involve searching in a string for a certain pattern
- What if we want to find more complicated patterns?
  - Find first occurrence of "a" or "b"
  - Split string at tabs, spaces, and newlines

Object Copy vs. Reference Copy

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

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

Which of these occur?

<table>
<thead>
<tr>
<th>x (reference)</th>
<th>&quot;groundhog&quot; (object)</th>
<th>y (reference)</th>
<th>&quot;groundhog&quot; (object)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Object copy</td>
<td>Reference copy</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Physical vs. Structural Equality

- Consider these cases again:

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

<table>
<thead>
<tr>
<th>x (reference)</th>
<th>&quot;groundhog&quot; (object)</th>
<th>y (reference)</th>
<th>&quot;groundhog&quot; (object)</th>
</tr>
</thead>
<tbody>
<tr>
<td>If we compare x and y, what is compared?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
  - 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 \texttt{equal?} method
    - Inherited from the \texttt{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>
<thead>
<tr>
<th>Language</th>
<th>Physical equality</th>
<th>Structural equality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Java</td>
<td>( a == b )</td>
<td>( a.equals(b) )</td>
</tr>
<tr>
<td>C</td>
<td>( a == b )</td>
<td>( *a == *b )</td>
</tr>
<tr>
<td>Ruby</td>
<td>( a.equal?(b) )</td>
<td>( a == b )</td>
</tr>
<tr>
<td>Ocaml</td>
<td>( a == b )</td>
<td>( a = b )</td>
</tr>
<tr>
<td>Python</td>
<td>( a is b )</td>
<td>( a == b )</td>
</tr>
<tr>
<td>Scheme</td>
<td>( (eq? a b) )</td>
<td>( (equal? a b) )</td>
</tr>
<tr>
<td>Visual Basic .NET</td>
<td>( a Is b )</td>
<td>( a = b )</td>
</tr>
</tbody>
</table>

Ruby is Dynamically Typed

- Recall we don’t declare types of variables
  - But Ruby does keep track of types at run time
    \[ x = 3; x.foo \]
    \texttt{NoMethodError: undefined method ‘foo’ for 3:Fixnum}
- We say that Ruby is dynamically typed
  - Types are determined and checked at run time
- Compare to C, which is statically typed

```ruby
x = 3
x = "foo" # gives x a # new type

/* C */
int x;
x = 3;
x = "foo"; /* not allowed */
```

Types in Java and C++

- Are Java and C++ statically or dynamically typed?
  - A little of both
  - Many things are checked statically
    \[ \text{Object } x = \text{new Object();} \]
    \[ x.println("hello"); // No such method error at compile time \]
  - But other things are checked dynamically
    \[ \text{Object o = new Object();} \]
    \[ \text{String s = (String) o; // No compiler warning, fails at run time} \]
    \[ // (Some Java compilers may be smart enough to warn about above cast) \]
### Tradeoffs?

<table>
<thead>
<tr>
<th>Static types</th>
<th>Dynamic types</th>
</tr>
</thead>
<tbody>
<tr>
<td>More work when coding</td>
<td>Less work when coding</td>
</tr>
<tr>
<td>Helps prevent some subtle errors</td>
<td>Can use objects incorrectly and not discover until run time</td>
</tr>
<tr>
<td>Fewer programs type check</td>
<td>More programs type check</td>
</tr>
</tbody>
</table>

### Summary

- **Scripting languages**
- **Ruby language**
  - Implicit variable declarations
  - Dynamic typing
  - Many control statements
  - Classes & objects
  - Strings