



PAUL G. ALLEN SCHOOL  
OF COMPUTER SCIENCE & ENGINEERING

# CSE341: Programming Languages

## Lecture 19

### Introduction to Ruby and OOP

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Autumn 2019

# *Ruby logistics*

- Next two sections use the Ruby language
  - <http://www.ruby-lang.org/>
  - Installation / basic usage instructions on course website
    - Version 2.X.Y required, but differences not so relevant
- Excellent documentation available, much of it free
  - So may not cover every language detail in course materials
  - <http://ruby-doc.org/>
  - <http://www.ruby-lang.org/en/documentation/>
  - Particularly recommend “Programming Ruby 1.9 & 2.0, The Pragmatic Programmers’ Guide”
    - Not free

# *Ruby: Our focus*

- *Pure object-oriented: all values are objects* (even numbers)
- *Class-based: Every object has a class that determines behavior*
  - Like Java, unlike Javascript
  - *Mixins* (not [old] Java interfaces nor C++ multiple inheritance)
- *Dynamically typed*
- Convenient *reflection*: Run-time inspection of objects
- *Very dynamic*: Can change classes during execution
- *Blocks* and libraries encourage lots of closure idioms
- Syntax, scoping rules, semantics of a “*scripting language*”
  - Variables “spring to life” on use
  - Very flexible arrays

# *Ruby: Not our focus*

- Lots of support for string manipulation and regular expressions
- Popular for server-side web applications
  - Ruby on Rails
- Often many ways to do the same thing
  - More of a “why not add that too?” approach

# Where Ruby fits

|                       | dynamically typed | statically typed |
|-----------------------|-------------------|------------------|
| functional            | Racket            | SML              |
| object-oriented (OOP) | Ruby              | Java             |

Note: Racket also has classes and objects when you want them

- In Ruby everything uses them (at least implicitly)

Historical note: *Smalltalk* also a dynamically typed, class-based, pure OOP language with blocks and convenient reflection

- Smaller just-as-powerful language
- Ruby less simple, more “modern and useful”

Dynamically typed OOP helps identify OOP's essence by not having to discuss types

# *A note on the homework*

Next homework is about understanding and extending an *existing* program in an *unfamiliar* language

- Good practice
- Quite different feel than previous homeworks
- *Read* code: determine what you do and do not (!) need to understand

Homework requires the Tk graphics library to be installed such that the provided Ruby code can use it

# *Getting started*

- See `lec19_silly.rb` file for our getting-started program
- Can run file `foo.rb` at the command-line with `ruby foo.rb`
- Or can use `irb`, which is a REPL
  - Run file `foo.rb` with `load "foo.rb"`

# *The rules of class-based OOP*

In Ruby:

1. All values are references to *objects*
2. Objects communicate via *method calls*, also known as *messages*
3. Each object has its own (private) *state*
4. Every object is an instance of a *class*
5. An object's class determines the object's *behavior*
  - How it handles method calls
  - Class contains method definitions

Java/C#/etc. similar but do not follow (1) (e.g., numbers, `null`) and allow objects to have non-private state

# Defining classes and methods

```
class Name
  def method_name1 method_args1
    expression1
  end
  def method_name2 method_args2
    expression2
  end
  ...
end
```

- Define a class with methods as defined
- Method returns its last expression
  - Ruby also has explicit **return** statement
- Syntax note: Line breaks often required (else need more syntax), but indentation always only style

# *Creating and using an object*

- **ClassName.new** creates a new object whose class is **ClassName**
- **e.m** evaluates **e** to an object and then calls its **m** method
  - Also known as “sends the **m** message”
  - Can also write **e.m()** with no space
- Methods can take arguments, called like **e.m(e1, ..., en)**
  - Parentheses optional in some places, but recommended

# *Variables*

- Methods can use local variables
  - Syntax: starts with letter
  - Scope is method body
- No declaring them, just assign to them anywhere in method body (!)
- Variables are mutable, **`x=e`**
- Variables also allowed at “top-level” or in REPL
- Contents of variables are always references to objects because all values are objects

# Self

- `self` is a special keyword/variable in Ruby
  - (Same as `this` in Java/C#/C++)
- Refers to “the current object”
  - The object whose method is executing
- So call another method on “same object” with `self.m(...)`
  - Syntactic sugar: can just write `m(...)`
- Also can pass/return/store “the whole object” with just `self`

# *Objects have state*

- An object's state persists
  - Can grow and change from time object is created
- State only directly accessible from object's methods
  - Can read, write, extend the state
  - Effects persist for next method call
- State consists of *instance variables* (also known as fields)
  - Syntax: starts with an @, e.g., @foo
  - “Spring into being” with assignment
    - So mis-spellings silently add new state (!)
  - Using one not in state not an error; produces `nil` object

# *Aliasing*

- Creating an object returns a reference to a new object
  - Different state from every other object
- Variable assignment (e.g.,  $\mathbf{x=y}$ ) creates an alias
  - Aliasing means same object means same state

# *Initialization*

- A method named **initialize** is special
  - Is called on a new object before **new** returns
  - Arguments to **new** are passed on to **initialize**
  - Excellent for creating object invariants
  - (Like constructors in Java/C#/etc.)
- Usually good *style* to create instance variables in **initialize**
  - Just a convention
  - Unlike OOP languages that make “what fields an object has” a (fixed) part of the class definition
    - In Ruby, different instances of same class can have different instance variables

# *Class variables*

- There is also state shared by the entire class
- Shared by (and only accessible to) all instances of the class
  - (Like Java static fields)
- Called *class variables*
  - Syntax: starts with an @@, e.g., @@foo
- Less common, but sometimes useful
  - And helps explain via contrast that each object has its own instance variables

# Class constants and methods

- *Class constants*
  - Syntax: start with capital letter, e.g., **Foo**
  - Should not be mutated
  - Visible outside class **C** as **C::Foo** (unlike class variables)
- *Class methods* (cf. Java/C# static methods)
  - Syntax (in some class **C**):

```
def self.method_name (args)
  ...
end
```

- Use (of class method in class **C**):

```
C.method_name (args)
```

- Part of the class, not a particular instance of it

# *Who can access what*

- We know “hiding things” is essential for modularity and abstraction
- OOP languages generally have various ways to hide (or not) instance variables, methods, classes, etc.
  - Ruby is no exception
- Some basic Ruby rules here as an example...

# Object state is private

- In Ruby, object state is always **private**
  - Only an object's methods can access its instance variables
  - Not even another instance of the same class
  - So can write `@foo`, but not `e.@foo`
- To make object-state publicly visible, define “getters” / “setters”
  - Better/shorter style coming next

```
def get_foo
  @foo
end
def set_foo x
  @foo = x
end
```

# Conventions and sugar

- Actually, for field `@foo` the convention is to name the methods

```
def foo
  @foo
end
```

```
def foo= x
  @foo = x
end
```

- Cute sugar: When *using* a method ending in `=`, can have space before the `=`

```
e.foo = 42
```

- Because defining getters/setters is so common, there is shorthand for it in class definitions
  - Define just getters: `attr_reader :foo, :bar, ...`
  - Define getters and setters: `attr_accessor :foo, :bar, ...`
- Despite sugar: getters/setters are just methods

# *Why private object state*

- This is “more OOP” than public instance variables
- Can later change class implementation without changing clients
  - Like we did with ML modules that hid representation
  - And like we will soon do with subclasses
- Can have methods that “seem like” setters even if they are not

```
def celsius_temp= x
  @kelvin_temp = x + 273.15
end
```

- Can have an unrelated class that implements the same methods and use it with same clients
  - See later discussion of “duck typing”

# *Method visibility*

- Three *visibilities* for methods in Ruby:
  - **private**: only available to object itself
  - **protected**: available only to code in the class or subclasses
  - **public**: available to all code
- Methods are **public** by default
  - Multiple ways to change a method's visibility
  - Here is one way...

# *Method visibilities*

```
class Foo =  
  # by default methods public  
  ...  
  protected  
  # now methods will be protected until  
  # next visibility keyword  
  ...  
  public  
  ...  
  private  
  ...  
end
```

## *One detail*

If `m` is private, then you can only call it via `m` or `m(args)`

- As usual, this is shorthand for `self.m ...`
- But for private methods, only the shorthand is allowed

## *Now (see the code)*

- Put together much of what we have learned to define and use a small class for rational numbers
  - Called **MyRational** because Ruby 1.9 has great built-in support for fractions using a class **Rational**
- Will also use several new and useful expression forms
  - Ruby is too big to show everything; see the documentation
- Way our class works: Keeps fractions in reduced form with a positive denominator
  - Like an ML-module example earlier in course

# Pure OOP

- Ruby is fully committed to OOP:
  - Every value is a reference to an object*
- Simpler, smaller semantics
- Can call methods on anything
  - May just get a dynamic “undefined method” error
- Almost everything is a method call
  - Example: **3 + 4**

# *Some examples*

- Numbers have methods like `+`, `abs`, `nonzero?`, etc.
- `nil` is an object used as a “nothing” object
  - Like `null` in Java/C#/C++ except it is an object
  - Every object has a `nil?` method, where `nil` returns `true` for it
  - Note: `nil` and `false` are “false”, everything else is “true”
- Strings also have a `+` method
  - String concatenation
  - Example: `"hello" + 3.to_s`

# *All code is methods*

- All methods you define are part of a class
- Top-level methods just added to `Object` class
  - Private in file, public in REPL, more or less (details are weird and not so important to us)
- Subclassing discussion coming later, but:
  - Since all classes you define are *subclasses* of `Object`, all *inherit* the top-level methods
  - So you can call these methods anywhere in the program
  - Unless a class overrides (*roughly-not-exactly*, shadows) it by defining a method with the same name

# *Reflection and exploratory programming*

- All objects also have methods like:
  - **methods**
  - **class**
- Can use at run-time to query “what an object can do” and respond accordingly
  - Called *reflection*
- Also useful in the REPL to explore what methods are available
  - May be quicker than consulting full documentation
- Another example of “just objects and method calls”

# *Changing classes*

- Ruby programs (or the REPL) can add/change/replace methods while a program is running
- Breaks abstractions and makes programs very difficult to analyze, but it does have plausible uses
  - Simple example: Add a useful helper method to a class you did not define
    - Controversial in large programs, but may be useful
- For us: Helps re-enforce “the rules of OOP”
  - Every object has a class
  - A class determines its instances’ behavior

# Examples

- Add a `double` method to our `MyRational` class
- Add a `double` method to the built-in `FixNum` class
- Defining top-level methods adds to the built-in `Object` class
  - Or replaces methods
- Replace the `+` method in the built-in `FixNum` class
  - Oops: watch `irb` crash

# *The moral*

- Dynamic features cause interesting semantic questions
- Example:
  - First create an instance of class **C**, e.g., **x = C.new**
  - Now replace method **m** in **C**
  - Now call **x.m**

Old method or new method? In Ruby, new method

The point is Java/C#/C++ do not have to ask the question

- May allow more optimized method-call implementations as a result

# *Duck Typing*

“If it walks like a duck and quacks like a duck, it's a duck”

- Or don't worry that it may not be a duck

When writing a method you might think, “I need a `Foo` argument” but really you need an object with enough methods similar to `Foo`'s methods that your method works

- Embracing duck typing is always making method calls rather than assuming/testing the class of arguments

Plus: More code reuse; very OOP approach

- What messages an object receive is “all that matters”

Minus: Almost nothing is equivalent

- `x+x` versus `x*2` versus `2*x`
- Callers may assume a lot about how callees are implemented

# Duck Typing Example

```
def mirror_update pt
  pt.x = pt.x * (-1)
end
```

- Natural thought: “Takes a `Point` object (definition not shown here), negates the `x` value”
  - Makes sense, though a `Point` instance method more OOP
- Closer: “Takes anything with getter and setter methods for `@x` instance variable and multiplies the `x` field by `-1`”
- Closer: “Takes anything with methods `x=` and `x` and calls `x=` with the result of multiplying result of `x` and `-1`”
- Duck typing: “Takes anything with method `x=` and `x` where result of `x` has a `*` method that can take `-1`. Sends result of calling `x` the `*` message with `-1` and sends that result to `x=`”

## *With our example*

```
def mirror_update pt
  pt.x = pt.x * (-1)
end
```

- Plus: Maybe `mirror_update` is useful for classes we did not anticipate
- Minus: If someone does use (abuse?) duck typing here, then we cannot change the implementation of `mirror_update`
  - For example, to `- pt.x`
- Better (?) example: Can pass this method a number, a string, or a `MyRational`

```
def double x
  x + x
end
```