

## CSE341: Programming Languages

### Lecture 19 *Introduction to Ruby and OOP*

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### *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

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2

### *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* (neither 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

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3

### *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

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4

### *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

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5

### *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

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6

## 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"`

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7

## 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

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8

## 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`

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9

## 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`

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10

## All code is methods

- All methods you define are part of a class
- Top-level methods (in file or REPL) just added to `Object` class
- 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

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11

## 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

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12

## 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()`
- Methods can take arguments, called like `e.m(e1, ..., en)`
  - Parentheses optional in some places, but recommended

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13

## 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

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14

## 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`

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15

## 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

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16

## Aliasing

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

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17

## 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

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18

## 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

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19

## 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

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20

## 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...

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21

## 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
```

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## 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

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23

## 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”

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24

## 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...

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25

## Method visibilities

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

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26

## 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

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27

## 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

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28

## 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”

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29

## 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

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30

## 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

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31

## 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

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32

## 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

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33

## 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=`"

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34

## 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
```

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35