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/
    - 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 (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

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

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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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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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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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### Defining classes and methods

- 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

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

### 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

### 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

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

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

Class variables

• There is also state shared by the entire 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`):
    ```ruby
def self.method_name(args)
  ...
end
```
  - Use (of class method in class `C`):
    ```ruby
C.method_name(args)
```
  - Part of the class, not a particular instance of it

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

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...

Conventions and sugar

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

  ```ruby
def foo
  @foo
end
def foo= x
  @foo = x
end
e.foo= 42
```

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

- 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

```ruby
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…

```ruby
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

Some examples

• Numbers have methods like \(+\), \(\text{abs}\), \(\text{nonzero}\)?, etc.
  – Like \texttt{null} in Java/C#/C++ except it is an object
  – Every object has a \texttt{nil?} method, where \texttt{nil} returns \texttt{true} for it
  – Note: \texttt{nil} and \texttt{false} are “false”, everything else is “true”

• Strings also have a \texttt{+} method
  – String concatenation
  – Example: "\texttt{hello}" + \texttt{3.to_s}

Pure OOP

• Ruby is fully committed to OOP:
  
  \begin{center}
  \textit{Every value is a reference to an object}
  \end{center}

• Simpler, smaller semantics

• Can call methods on anything
  – May just get a dynamic "undefined method" error

• Almost everything is a method call
  – Example: \texttt{3 + 4}

All code is methods

• All methods you define are part of a class

• Top-level methods (in file or REPL) just added to \texttt{Object} class

• Subclassing discussion coming later, but:
  – Since all classes you define are \texttt{subclasses} of \texttt{Object}, all \texttt{inherit} the top-level methods
  – So you can call these methods anywhere in the program
  – Unless a class overrides (\texttt{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”

Examples

• Add a double method to our MyRational class

• Add a double method to the built-in FixNum class
  – Or replaces methods

• Replace the + method in the built-in FixNum class
  – Oops: watch irb crash

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

The moral

• Dynamic features cause interesting semantic questions

• Example:
  – First create an instance of class C, e.g., x = C.new
  – Now replace method 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 \texttt{Foo} argument” but really you need an object with enough methods similar to \texttt{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
- \texttt{x+x} versus \texttt{x*2} versus \texttt{2*x}
- Callers may assume a lot about how callees are implemented

**With our example**

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

- Plus: Maybe \texttt{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 \texttt{mirror_update}
  - For example, to \texttt{- pt.x}

- Better (?) example: Can pass this method a number, a string, or a \texttt{MyRational}

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

**Duck Typing Example**

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

- Natural thought: “Takes a \texttt{Point} object (definition not shown here), negates the \texttt{x} value”
  - Makes sense, though a \texttt{Point} instance method more OOP

- Closer: “Takes anything with getter and setter methods for \texttt{@x} instance variable and multiplies the \texttt{x} field by \texttt{-1}”

- Closer: “Takes anything with methods \texttt{x=} and \texttt{x} and calls \texttt{x=} with the result of multiplying result of \texttt{x} and \texttt{-1}”

- Duck typing: “Takes anything with method \texttt{x=} and \texttt{x} where result of \texttt{x} has a \texttt{*} method that can take \texttt{-1}. Sends result of calling \texttt{x} the \texttt{*} message with \texttt{-1} and sends that result to \texttt{x=}”

**With our example**

- Plus: Maybe \texttt{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 \texttt{mirror_update}
  - For example, to \texttt{- pt.x}

- Better (?) example: Can pass this method a number, a string, or a \texttt{MyRational}