Functional Ruby

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If you can read this, then we're ready to go!

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Functional Ruby

- Ruby is … “A dynamic, open source programming language with a focus on simplicity and productivity. It has an elegant syntax that is natural to read and easy to write.”

— From http://www.ruby-lang.org/en/

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Functional Ruby

- Ruby is … “A dynamic, open source programming language with a focus on simplicity and productivity. It has an elegant syntax that is natural to read and easy to write.”
  — From http://www.ruby-lang.org/en/
- Ruby is definitely an Object-Oriented language and *not* a Functional Language.

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Functional Ruby

- Ruby is … “A dynamic, open source programming language with a focus on simplicity and productivity. It has an elegant syntax that is natural to read and easy to write.”
  — From http://www.ruby-lang.org/en/
- Ruby is definitely an Object-Oriented language and *not* a Functional Language.
- *But …*

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Functional Ruby

- Ruby is a language of careful balance. Its creator, Yukihiro "matz" Matsumoto, blended parts of his favorite languages (Perl, Smalltalk, Eiffel, Ada, and Lisp) to form a new language that **balanced functional programming with imperative programming**. *(emphasis added)*
- He has often said that he is "trying to make Ruby natural, not simple," in a way that mirrors life.

Building on this, he adds:

—*Ruby is simple in appearance, but is very complex inside, just like our human body.*

- Matz, speaking on the Ruby-Talk mailing list, May 12th, 2000.

Functional Ruby

- The Haskell site begins with a definition: "What is functional programming?" which begins:
  - In functional programming, programs are executed by evaluating *expressions*, in contrast with imperative programming where programs are composed of *statements* which change global state when executed. Functional programming typically avoids using mutable state.
- It goes on, but if we stop there (for a moment), then Ruby starts looking a bit functional, too.

All statements are expressions

- All “statements” in Ruby are really just expressions that have a value.

```
irb1.9.2> foo = 42
#1.9.2 => 42
irb1.9.2> if foo > 20
            "too high"
          elsif foo > 10
            "need my toes"
          else
            "that's easy"
          end
#1.9.2 => "too high"
```

All statements are expressions

```
irb1.9.2> f = lambda {|foo|
                if foo > 20
                  "too high"
                elsif foo > 10
                  "need my toes"
                else
                  "that's easy"
                end
              }
#1.9.2 => #<Proc:0x136fa0@(irb):10 (lambda)>
irb1.9.2> f[9]
#1.9.2 => "that's easy"
irb1.9.2> f.call(15)
#1.9.2 => "need my toes"
irb1.9.2> foo
#1.9.2 => 42
```

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All statements are expressions

- For methods, the “value” is just the last expression that was evaluated unless there is a **`return`** statement.

```
def answer
  42
end
```

```
def answer
  return 42
end
```

- These have the same value when called, but Ruby is actually optimized such that the implicit value is *slightly* more performant.

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Functional Ruby

- "Higher-order functions (HOFs) are functions that take other functions as their arguments. A basic example of a HOF is **`map`** which takes a function and a list as its arguments, applies the function to all elements of the list, and returns the list of its results."
—Haskell site

Higher-order Functions

- Ruby has a construct called a **block** which acts as a closure and is “passed” to a method.

```
irb1.9.2> list = [ 8, 17, 29 ]
#1.9.2 => [8, 17, 29]
```

```
irb1.9.2> list.map {|element| element * 2 }
#1.9.2 => [16, 34, 58]
```

Higher-order Functions

- With a little bit of syntax, that could be any lambda (even our little *f* from before):

```
irb1.9.2> list
#1.9.2 => [8, 17, 29]
```

```
irb1.9.2> list.map &f
#1.9.2 => ["that's easy", "need my toes", "too high"]
```

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Higher-order Functions

- Like **`map`** (aka, **`collect`**) which applies a function to a list to obtain a new list, there is **`reduce`** (aka, **`inject`**) which applies a function across a list to obtain a single value.

```
irb1.9.2> list
#1.9.2 => [8, 17, 29]
irb1.9.2> list.reduce {|sum, element| sum + element}
#1.9.2 => 54

irb1.9.2> list.reduce(&:+)
#1.9.2 => 54
```

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Higher-order Functions

Higher-order Functions

- Oh, can we use our own favorite “function” *ƒ* ?

Higher-order Functions

- Oh, can we use our own favorite "function" *ƒ* ?
- Well, not quite:

Higher-order Functions

- Oh, can we use our own favorite “function” *f* ?
- Well, not quite:

```
irb1.9.2> list.reduce &f
ArgumentError: wrong number of arguments (2 for 1)
   from (irb):11:in `block in irb_binding'
   from (irb):31:in `each'
   from (irb):31:in `reduce'
   from (irb):31
   from /Users/rab/.rvm/rubies/ruby-1.9.2-p180/bin/
irb:16:in `<main>'
```

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Higher-order Functions

- But, we could do this:

```
irb1.9.2> list.map(&f).reduce(&:+)
#1.9.2 => "that's easyneed my toestoo high"
```

Higher-order Functions

- But, we could do this:

```
irb1.9.2> list.map(&f).reduce(&:+)
#1.9.2 => "that's easyneed my toestoo high"
```

- Did you catch that?

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Higher-order Functions

- But, we could do this:

```
irb1.9.2> list.map(&f).reduce(&:+)
#1.9.2 => "that's easyneed my toestoo high"
```

- Did you catch that?

`list.reduce(&:+)` used '**+**' to add numbers

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Higher-order Functions

- But, we could do this:

```
irb1.9.2> list.map(&f).reduce(&:+)
#1.9.2 => "that's easyneed my toestoo high"
```

- Did you catch that?

`list.reduce(&:+)` used '**+**' to add numbers

`list.map(&f).reduce(&:+)` used '**+**' to concatenate strings

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Iteration, Recursion, Tail-recursion

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Iteration, Recursion, Tail-recursion

- Most iteration is accomplished with an object's **`each`** method which is the key to all the features from the **`Enumerable`** module.
  - Since Ruby 1.9.2, most enumerations called without a block return an **`Enumerator`** instance.

Iteration, Recursion, Tail-recursion

- Most iteration is accomplished with an object's **`each`** method which is the key to all the features from the **`Enumerable`** module.
  - Since Ruby 1.9.2, most enumerations called without a block return an **`Enumerator`** instance.
- What better to illustrate these techniques than…

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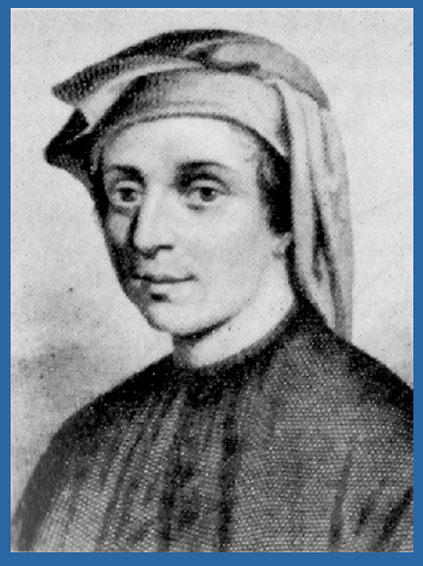
Iteration, Recursion, Tail-recursion

- Most iteration is accomplished with an object's **`each`** method which is the key to all the features from the **`Enumerable`** module.
  - Since Ruby 1.9.2, most enumerations called without a block return an **`Enumerator`** instance.
- What better to illustrate these techniques than…
- **The Fibonacci Sequence**



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Iteration, Recursion, Tail-recursion

```
irb1.9.2> class Integer
            def fib_i
              a, b = 0, 1
              self.times do
                a, b = b, a+b
              end
              a
            end
          end
```

```
irb1.9.2> (0..10).map {|number| number.fib_i }
#1.9.2 => [0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55]
```

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Iteration, Recursion, Tail-recursion

```
irb1.9.2> class Integer
            def fib_r
              if self < 2
                self
              else
                (self - 2).fib_r + (self - 1).fib_r
              end
            end
          end
```

```
irb1.9.2> (0..10).map {|number| number.fib_r }
#1.9.2 => [0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55]
```

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Iteration, Recursion, Tail-recursion

```
irb1.9.2> class Integer
            def fib_t
              fib_t_helper(self, 0, 1)
            end

            def fib_t_helper(n, a, b)
              if n.zero?
                a
              else
                fib_t_helper(n-1, b, a+b)
              end
            end
          end
irb1.9.2> (0..10).map {|number| number.fib_t }
#1.9.2 => [0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55]
```

Iteration, Recursion, Tail-recursion

Why does it matter?

```
require 'benchmark'
include Benchmark

bm(14) do |x|
  class Integer
    …
  end
  x.report("iteration 1000") {1000.times {|i| i.fib_i } }
  x.report("recursion 30  ") {  30.times {|i| i.fib_r } }
  x.report("recursion 40  ") {  40.times {|i| i.fib_r } }
  x.report("tail-rec. 1000") {1000.times {|i| i.fib_t } }
end
```

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Iteration, Recursion, Tail-recursion

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Iteration, Recursion, Tail-recursion

```
irb1.9.2> load 'fib_benchmark.rb'
                      user     system      total        real
iteration 1000  0.900000   0.010000   0.910000 (  0.907310)
```

Iteration, Recursion, Tail-recursion

```
irb1.9.2> load 'fib_benchmark.rb'
                      user     system      total        real
iteration 1000   0.900000   0.010000   0.910000 (  0.907310)
recursion 30     1.360000   0.010000   1.370000 (  1.371345)
```

Iteration, Recursion, Tail-recursion

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irb1.9.2> load 'fib_benchmark.rb'
                      user     system      total        real
iteration 1000   0.900000   0.010000   0.910000 (  0.907310)
recursion 30     1.360000   0.010000   1.370000 (  1.371345)
recursion 40   167.110000   0.840000 167.950000 (168.156662)
```

Iteration, Recursion, Tail-recursion

```
irb1.9.2> load 'fib_benchmark.rb'
                      user     system      total        real
iteration 1000   0.900000   0.010000   0.910000 (  0.907310)
recursion 30     1.360000   0.010000   1.370000 (  1.371345)
recursion 40   167.110000   0.840000 167.950000 (168.156662)
tail-rec. 1000   0.740000   0.000000   0.740000 (  0.746140)
```

Iteration, Recursion, Tail-recursion Memoization!

- In computing, **memoization** is an optimization technique used primarily to speed up computer programs by having function calls avoid repeating the calculation of results for previously-processed inputs.

  —Wikipedia

- Since pure functional programming means that an expression (or function) with the same input(s) **always** produces the same value.

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Iteration, Recursion, Tail-recursion

Memoization!

```
irb1.9.2> class Integer
            @@fibs = [0,1]
            def fib_m
              @@fibs[self] ||= ((self - 2).fib_m +
                                (self - 1).fib_m)
            end
          end
```

```
irb1.9.2> (0..10).map {|number| number.fib_m }
#1.9.2 => [0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55]
```

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Iteration, Recursion, Tail-recursion

Why does it matter?

```
require 'benchmark'
include Benchmark

bm(14) do |x|
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  end
  x.report("iteration 1000") {1000.times {|i| i.fib_i } }
  x.report("recursion 30  ") {  30.times {|i| i.fib_r } }
  x.report("recursion 40  ") {  40.times {|i| i.fib_r } }
  x.report("tail-rec. 1000") {1000.times {|i| i.fib_t } }
  x.report("memoized  40  ") {  40.times {|i| i.fib_m } }
  x.report("memoized  1000") {1000.times {|i| i.fib_m } }
end
```

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Iteration, Recursion, Tail-recursion

```
irb1.9.2> load 'fib_benchmark.rb'
                      user     system      total        real
iteration 1000   0.900000   0.010000   0.910000 (  0.907310)
recursion 30     1.360000   0.010000   1.370000 (  1.371345)
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tail-rec. 1000   0.740000   0.000000   0.740000 (  0.746140)
```

Iteration, Recursion, Tail-recursion Memoization!

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irb1.9.2> load 'fib_benchmark.rb'
                      user     system      total        real
iteration 1000   0.900000   0.010000   0.910000 (  0.907310)
recursion 30     1.360000   0.010000   1.370000 (  1.371345)
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tail-rec. 1000   0.740000   0.000000   0.740000 (  0.746140)
```

Iteration, Recursion, Tail-recursion Memoization!

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irb1.9.2> load 'fib_benchmark.rb'
                      user     system      total        real
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recursion 40   167.110000   0.840000 167.950000 (168.156662)
tail-rec. 1000   0.740000   0.000000   0.740000 (  0.746140)
memoized  40     0.000000   0.000000   0.000000 (  0.000153)
```

Iteration, Recursion, Tail-recursion Memoization!

```
irb1.9.2> load 'fib_benchmark.rb'
                      user     system      total        real
iteration 1000   0.900000   0.010000   0.910000 (  0.907310)
recursion 30     1.360000   0.010000   1.370000 (  1.371345)
recursion 40   167.110000   0.840000 167.950000 (168.156662)
tail-rec. 1000   0.740000   0.000000   0.740000 (  0.746140)
memoized  40     0.000000   0.000000   0.000000 (  0.000153)
memoized  1000   0.010000   0.000000   0.010000 (  0.003212)
```

Functional Ruby

- “Infinite Streams”
  —JEG2 site

Infinite Streams

- Like in the Scala example last month, we can define a stream that is lazily evaluated by knowing the next value and having a way to get the rest when it is needed.

```
module LazyStream
  class Node
    def initialize( head, &promise )
      @head, @tail = head, promise
    end
  end
end
```

Infinite Streams

- Then we can define the parts:

```
attr_reader  :head

def tail
  if @tail.is_a? Proc
    if @tail.arity == 1
      @tail.call(head)
    else
      @tail.call
    end
  else
    @tail
  end
end
```

Infinite Streams

- And a way to take an item from the stream:

```
def drop
  result, next_stream = head, tail
  @head, @tail = case next_stream
                 when self.class
                   next_stream.instance_eval {
                     [@head, @tail]
                   }
                 else
                   [next_stream, @tail]
                 end
  result
end
alias_method :tail!, :drop
```

Infinite Streams

- And a way to iterate over the stream, partially.

```
def each!(limit=nil)
  loop do
    break unless limit.nil? || (limit -= 1) > -1
    yield drop
    break if end?
  end
  self
end

def each(limit=nil, &block)
  clone.each!(limit, &block)
  self
end
include Enumerable
```

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Infinite Streams

- However, if you wanted to process more than one stream simultaneously, things get a bit messier.
- Fortunately, Ruby 1.9 introduced the **`Fiber`** class:
  - At their most basic, let you create simple generators (much as you could do previously with blocks).
    - Dave Thomas, http://pragdave.blogs.pragprog.com/pragdave/2007/12/pipelines-using.html

Infinite Streams

- Well, the Fibonacci Sequence is like that!

```
irb1.9.2> fib = Fiber.new do
            f1, f2 = 0, 1
            loop do
              Fiber.yield f1
              f1, f2 = f2, f1 + f2
            end

irb1.9.2> 11.times { print "#{fib.resume} " }; puts
0 1 1 2 3 5 8 13 21 34 55
```

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Infinite Streams

- We can define a **`Fiber`** that generates even numbers:

```
irb1.9.2> evens = Fiber.new do
            value = 0
            loop do
              Fiber.yield value
              value += 2
            end
          end
```

Infinite Streams

- And a consumer that accepts values from the generator and prints them:

```
irb1.9.2> consumer = Fiber.new do
            10.times do
              next_value = evens.resume
              puts next_value
            end
          end
```

- Technically, the consumer doesn't have to be a Fiber, but it will give us some flexibility.

Infinite Streams

- So, we need to kick off the **`consumer`** with resume:

```
irb1.9.2> consumer.resume
0
2
4
6
8
10
12
14
16
18
#1.9.2 => 10
```

Infinite Streams

- But we have hard-coded the name of the generator **`evens`** inside the **`consumer`**. ;-(
  - Lets's fix that!

```
irb1.9.2> def consumer(source)
            Fiber.new do
              10.times do
                next_value = source.resume
                puts next_value
              end
            end
          end
```

- And assume that we changed **`evens`** to a method, too.

Infinite Streams

- Let's also add another Fiber that is a filter that consumes values from a generator, but only yields values that are a multiple of 3.

```
irb1.9.2> def multiples_of_three(source)
        Fiber.new do
          loop do
            next_value = source.resume
            Fiber.yield next_value if next_value % 3 == 0
          end
        end
      end
```

Infinite Streams

- Of course, Fibers get better in Dave's next post: http://pragdave.blogs.pragprog.com/pragdave/2008/01/pipelines-using.html

  —*Yes, these are from 3½ years ago!*

Any Questions?

- About something I covered too quickly?
- About something I didn't cover at all?
- …

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- http://GaslightSoftware.com/

References

- **Functional Programming**
  Wikipedia (long list of citations)
  http://en.wikipedia.org/wiki/**Functional_programming**
- **Functional programming**
  From the Haskell site
  http://www.haskell.org/haskellwiki/**Functional_programming**

- **From the C2 Wiki:**
  http://c2.com/cgi/wiki?**RubyLanguage**
  http://c2.com/cgi/wiki?**FunctionalProgramming**
  http://c2.com/cgi/wiki?**FunctionalProgrammingLanguage**

References

- **Higher Order Ruby**
  A series of articles by James Edward Gray II
  http://blog.grayproductions.net/categories/higherorder_ruby
  (Note that the list is most-recent-first so start at the bottom.)
- **Pearls of Functional Algorithm Design**
  by Richard Bird
  ISBN-13: 9780521513388
  http://search.barnesandnoble.com/Pearls-of-Functional-Algorithm-Design/Richard-Bird/e/9780521513388#
- **Functional techniques in Ruby**
  Slides by @erockenjew *(no longer a Twitter name)*
  http://www.slideshare.net/erockendude/functional-techniques-in-ruby

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References

- **Thinking Functionally In Ruby**
  @tomstuart / tom@experthuman.com
  http://www.slideshare.net/RossC0/thinking-functionally-in-ruby
- **Memoization**
  Examples of memoization in various programming languages
  http://en.wikipedia.org/wiki/**Memoization**

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References

- **Structure and Interpretation of Computer Programs**
  - Video Lectures by Hal Abelson and Gerald Jay Sussman

    These twenty video lectures by Hal Abelson and Gerald Jay Sussman are a complete presentation of the course, given in July 1986 for Hewlett-Packard employees, and professionally produced by Hewlett-Packard Television. Note: These lectures follow the first edition (1985) of *Structure and Interpretation of Computer Programs*.
    http://groups.csail.mit.edu/mac/classes/6.001/abelson-sussman-lectures/

  - Companion site to the text and the video lectures.
    http://mitpress.mit.edu/sicp/

- **Higher-Order Procedures (in Ruby)**

  Slides from 13-Dec-2006 based on SICP
  http://www.slideshare.net/jashmenn/higher-order-procedures-in-ruby-15799

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Images

- http://en.wikipedia.org/wiki/File:Fibonacci.jpg
  Public Domain