CMSC 330: Organization of Programming Languages

Ruby Regular Expressions

Last Lecture

- Ruby language
  - Implicit variable declarations
  - Dynamic typing
  - Many control statements
  - Classes & objects
  - Strings
Introduction

- Ruby language
  - Regular expressions
    - Definition & examples
    - Back references
    - Scan
  - Code blocks
  - File
  - Exceptions

String processing in Ruby

- Earlier, we motivated scripting languages using a popular application of them: string processing
- The Ruby String class provides many useful methods for manipulating strings
  - Concatenating them, grabbing substrings, searching in them, etc.
- A key feature in Ruby is its native support for regular expressions
  - Very useful for parsing and searching
  - First gained popularity in Perl
String Operations in Ruby

- "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\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

Regular Expressions

- A way of describing patterns or sets of strings
  - Searching and matching
  - Formally describing strings
    - The symbols (lexemes or tokens) that make up a language
- Common to lots of languages and tools
  - awk, sed, perl, grep, Java, OCaml, C libraries, etc.
- Based on some really elegant theory
  - Future lecture
Example Regular Expressions in Ruby

- `/Ruby/`
  - Matches exactly the string "Ruby"
  - Regular expressions can be delimited by /’s
  - Use \ to escape /’s in regular expressions

- `/(Ruby|OCaml|Java)/`
  - Matches either "Ruby", "OCaml", or "Java"

- `/(Ruby|Regular)/ or /R(uby|egular)/`
  - Matches either "Ruby" or "Regular"
  - Use ( )’s for grouping; use \ to escape ( )’s

Using Regular Expressions

- Regular expressions are instances of Regexp
  - We’ll see use of a Regexp.new later

- Basic matching using =~ method of String

```ruby
line = gets # read line from standard input
if line =~ /Ruby/ then # returns nil if not found
    puts "Found Ruby"
end
```

- Can use regular expressions in index, search, etc.

```ruby
offset = line.index(/(MAX|MIN)/) # search starting from 0
line.sub(/(Perl|Python)/, "Ruby") # replace
line.split(/(\t|\n| )/) # split at tab, space, # newline
```
Using Regular Expressions (cont.)

- Invert matching using `!~` method of `String`
  - Matches strings that don't contain an instance of the regular expression

  - `s = "hello"`
  - `s !~ /hello/` => false
  - `s !~ /hel/` => false
  - `s !~ /hello!/` => true
  - `s !~ /bye/` => true

Repetition in Regular Expressions

- `/Ruby*/`
  - `{"", "Ruby", "RubyRuby", "RubyRubyRuby", ...}`
  - * means zero or more occurrences

- `/Ruby+/`
  - `{"Ruby", "Rubyy", "Rubyyy", ... }`
  - + means one or more occurrence
  - so `/e+/` is the same as `/ee*/`

- `/Ruby)?/`
  - `{"", "Ruby"}`
  - ? means optional, i.e., zero or one occurrence
Repetition in Regular Expressions

- `(Ruby){3}/`
  - `{“RubyRubyRuby”}
  - `{x}` means repeat the search for exactly `x` occurrences

- `(Ruby){3,}/`
  - `{“RubyRubyRuby”, “RubyRubyRubyRuby”, …}
  - `{x,}` means repeat the search for at least `x` occurrences

- `(Ruby){3, 5}/`
  - `{“RubyRubyRuby”, “RubyRubyRubyRuby”, “RubyRubyRubyRubyRuby”}
  - `{x, y}` means repeat the search for at least `x` occurrences and at most `y` occurrences

Watch Out for Precedence

- `(Ruby)*/` means `{“”, "Ruby", "RubyRuby", …}
  - But `/Ruby*/` matches {"Rub", "Ruby", "Rubyy", …}

- In general
  - `*` {`n`} and `+` bind most tightly
  - Then concatenation (adjacency of regular expressions)
  - Then `|`

- Best to use parentheses to disambiguate
Character Classes

- `/[abcd]/`
  - `{"a", "b", "c", "d"}` (Can you write this another way?)
- `/[a-zA-Z0-9]/`
  - Any upper or lower case letter or digit
- `/[^0-9]/`
  - Any character except 0-9 (the ^ is like not and must come first)
- `/[\t\n\ ]/`
  - Tab, newline or space
- `/[a-zA-Z_\$][a-zA-Z_\$0-9]*/`
  - Java identifiers ($ escaped...see next slide)

Special Characters

- .  any character
- ^  beginning of line
- $  end of line
- \$ just a $
- \d digit, [0-9]
- \s whitespace, [\t\r\n\f\s]
- \w word character, [A-Za-z0-9_]`
- \D non-digit, [^0-9]
- \S non-space, [^\t\r\n\f\s]
- \W non-word, [^A-Za-z0-9_]`
Potential Character Class Confusions

- ^
  - Inside character classes: not
  - Outside character classes: beginning of line

- [
  - Inside regular expressions: character class
  - Outside regular expressions: array
    - Note: [a-z] does not make a valid array

- (
  - Inside character classes: literal characters ( )
    - Note /(0..2)/ does not mean 012
  - Outside character classes: used for grouping

- –
  - Inside character classes: range (e.g., a to z given [a-z])
  - Outside character classes: subtraction

Summary

- Let re represents an arbitrary pattern; then:
  - /re/ – matches regexp re
  - /(re|re_2)/ – match either re, or re_2
  - /(re)^/ – match 0 or more occurrences of re
  - /(re)+/ – match 1 or more occurrences of re
  - /(re)?/ – match 0 or 1 occurrences of re
  - /(re){2}/ – match exactly two occurrences of re
  - /[^a-z]/ – same as (a|b|c|...|z)
  - /[^0-9]/ – match any character that is not 0, 1, etc.
  - ^, $ – match start or end of string
Regular Expression Practice

- Make Ruby regular expressions representing
  - All lines beginning with a or b
    \(^{/(a|b)/}\)
  - All lines containing at least two (only alphabetic) words separated by white-space
    \(^{/[a-zA-Z]\s+[a-zA-Z]/}\)
  - All lines where a and b alternate and appear at least once
    \(^{/(ab)\ ?| (ba)\ ?/}\)
  - An expression which would match both of these lines (but not radically different ones)
    - CMSC330: Organization of Programming Languages: Fall 2007
    - CMSC351: Algorithms: Fall 2007

Regular Expression Coding Readability

```ruby
> ls -l
drwx------ 2 sorelle sorelle 4096 Feb 18 18:05 bin
-rw------- 1 sorelle sorelle 674 Jun  1 15:27 calendar
drwx------ 3 sorelle sorelle 4096 May 11 12:19 cmsg311
drwx------ 2 sorelle sorelle 4096 Jun  4 17:31 cmsg330
drwx------ 1 sorelle sorelle 4096 May 30 19:19 cmsg630
drwx------ 1 sorelle sorelle 4096 May 30 19:20 cmsg631
```

What if we want to specify the format of this line exactly?

```ruby
/^\([d-]\)\([r-]\)\([w-]\)\([x-]\)\([r-]\)\([w-]\)\([x-]\)\([r-]\)\([w-]\)\([x-]\)
\(\([s+]\)\([d+]\)\([s+]\)\([w+]\)\([s+]\)\([w+]\)\([s+]\)\([d+]\)\([s+]\)\(Jan|Feb
|Mar|Apr|May|Jun|Jul|Aug|Sep|Oct|Nov|Dec\)\([s+]\)\([d\d]\)
\(\([s+]\)\([d\d]:\d\d\d\d\)\([s+]\)\([S+]\)$/
```

This is unreadable!
Regular Expression Coding Readability

Instead, we can do each part of the expression separately and then combine them:

```ruby
oneperm_re = '((r|-)(w|-)(x|-))'
permissions_re = '(d|-)' + oneperm_re + '(?3)'
month_re = '(Jan|Feb|Mar|Apr|May|Jun|Jul|Aug|Sep|Oct|Nov|Dec)'
day_re = '\d(1,2)'; time_re = '(\d(2):\d(2))'
date_re = month_re + '\s+' + day_re + '\s+' + time_re
total_re = '\d+'; user_re = '\w+'; group_re = '\w+'
space_re = '\d+'; filename_re = '\S+'

line_re = Regexp.new('^' + permissions_re + '\s+' + total_re
                           + '\s+' + user_re + '\s+' + group_re + '\s+'
                           + space_re + '\s+' + date_re + '\s+' + filename_re + '\$')
if line =~ line_re
  puts "found it!"
end
```

Extracting Substrings based on R.E.’s
Method 1: Back References

Two options to extract substrings based on R.E.’s:

- Use back references
  - Ruby remembers which strings matched the parenthesized parts of r.e.’s
  - These parts can be referred to using special variables called back references (named $1, $2,...)
Back Reference Example

- Extract information from a report

```
gets =~ /^Min: \d+ Max: \d+$/
min, max = $1, $2
```

- Warning
  - Despite their names, $1 etc are local variables

```
def m(s)
s =~ /(Foo)/
  puts $1   # prints Foo
end
m("Foo")
puts $1   # prints nil
```

Another Back Reference Example

- Warning 2
  - If another search is performed, all back references are reset to nil

```
gets =~ /(h)e(ll)o/
puts $1
puts $2
gets =~ /h(e)llo/
puts $1
puts $2
gets =~ /hello/
puts $1
```

```
hello
h
ll
hello
e
nil
hello
nil
```
Method 2: String.scan

- Also extracts substrings based on regular expressions
- Can optionally use parentheses in regular expression to affect how the extraction is done
- Has two forms which differ in what Ruby does with the matched substrings
  - The first form returns an array
  - The second form uses a code block
    - We’ll see this later

First Form of the Scan Method

- `str.scan(regexp)`
  - If `regexp` doesn't contain any parenthesized subparts, returns an array of matches
    - An array of all the substrings of `str` which matched

```ruby
s = "CMSC 330 Fall 2007"
s.scan(/\S+ \S+/)
# returns array ["CMSC 330", "Fall 2007"]
```

- Note: these strings are chosen sequentially from as yet unmatched portions of the string, so while “330 Fall” does match the regular expression above, it is *not* returned since “330” has already been matched by a previous substring.
First Form of the Scan Method (cont.)

- If `regexp` contains parenthesized subparts, returns an array of arrays
  - Each sub-array contains the parts of the string which matched one occurrence of the search
  
  ```ruby
  s = "CMSC 330 Fall 2007"
  s.scan(/\S+ (\S+)/)  #=> ["CMSC", "330"],
  #       ["Fall", "2007"]
  ```
  
  - Each sub-array has the same number of entries as the number of parenthesized subparts
  - All strings that matched the first part of the search (or $1 in back-reference terms) are located in the first position of each sub-array

Practice with Scan and Back-references

```bash
> ls -l
drwx------ 2 sorelle sorelle 4096 Feb 18 18:05 bin
-rw------- 1 sorelle sorelle 674 Jun  1 15:27 calendar
drwx------ 3 sorelle sorelle 4096 May 11 2006 cmsc311
drwx------ 2 sorelle sorelle 4096 Jun  4 17:31 cmsc330
drwx------ 1 sorelle sorelle 4096 May 30 19:19 cmsc630
drwx------ 1 sorelle sorelle 4096 May 30 19:20 cmsc631
```

Extract just the file or directory name from a line using

- `scan`
  ```ruby
  name = line.scan(/\S+/)  #=> ["bin"]
  ```

- `back-references`
  ```ruby
  if line =~ /\S+$/
    name = $1  #=> "bin"
  end
  ```
Revisiting Code Blocks

- Recall our earlier code block example with arrays
  
  ```ruby
  a = [1, 2, 3, 4, 5]
a.each { |x| puts x }
  ```

- A code block is a piece of code that is invoked by another piece of code
  - In this case, the `{ |x| puts x }` code is called five times by the each method

- Code blocks are useful for encapsulating repetitive computations

More examples of code block usage

- Sum up the elements of an array
  
  ```ruby
  a = [1, 2, 3, 4, 5]
  sum = 0
  a.each { |x| sum = sum + x }
  printf("sum is %d\n", sum)
  ```

- Print out each segment of the string as divided up by commas (commas are printed trailing each segment)
  - Can use any delimiter
    
    ```ruby
    s = "Student,Sally,099112233,A"
s.each(',') { |x| puts x }
    ```

    ("delimiter" = symbol used to denote boundaries)
Yet More Examples of Code Blocks

- `n.times` runs code block `n` times
- `n.upto(m)` runs code block for integers `n..m`
- `a.find` returns first element `x` of array such that the block returns true for `x`
- `a.collect` applies block to each element of array and returns new array (`.collect!` modifies the original)

```ruby
3.times { puts "hello"; puts "goodbye" }
5.upto(10) { |x| puts(x + 1) }
[1,2,3,4,5].find { |y| y % 2 == 0 }
[5,4,3].collect { |x| -x }
```

Still Another Example of Code Blocks

- `open` method takes code block with file argument
  - File automatically closed after block executed
- `readlines` reads all lines from a file and returns an array of the lines read
  - Use `each` to iterate

```ruby
File.open("test.txt", "r") do |f|
  f.readlines.each { |line| puts line }
end
```
Using Yield To Call Code Blocks

- Any method can be called with a code block
  - Inside the method, the block is called with `yield`
- After the code block completes
  - Control returns to the caller after the `yield` instruction

```ruby
def countx(x)
  for i in (1..x)
    puts i
    yield
  end
end

countx(4) { puts "foo" }
```

So What Are Code Blocks?

- A code block is just a special kind of method
  - `{ |y| x = y + 1; puts x }` is almost the same as
  - `def m(y) x = y + 1; puts x end`
- The `each` method takes a code block as an argument
  - This is called higher-order programming
    - In other words, methods take other methods as arguments
    - We’ll see a lot more of this in OCaml
- We’ll see other library classes with `each` methods
  - And other methods that take code blocks as arguments
  - As we saw, your methods can use code blocks too!
Second Form of the Scan Method

- Remember the scan method?
  - Executing returns an array of matches
  - Can also take a code block as an argument

- `str.scan(regexp) { |match| block }`
  - Applies the code block to each match
  - Short for `str.scan(regexp).each { |match| block }`
  - The regular expression can also contain parenthesized subparts

Example of Second Form of Scan

```
12 34 23
19 77 87
11 98 3
2 45 0
```

```
sum_a = sum_b = sum_c = 0
while (line = gets)
  line.scan(/(\d+)\s+(\d+)\s+(\d+)/) { |a,b,c|
    sum_a += a.to_i
    sum_b += b.to_i
    sum_c += c.to_i
  }
end
printf("Total: %d %d %d\n", sum_a, sum_b, sum_c)
```

Sums up three columns of numbers
Standard Library: File

- Lots of convenient methods for IO
  - `File.new("file.txt", "rw")` # open for rw access
  - `f.readline` # reads the next line from a file
  - `f.readlines` # returns an array of all file lines
  - `f.eof` # return true if at end of file
  - `f.close` # close file
  - `f << object` # convert object to string and write to f
  - `$stdin, $stdout, $stderr` # global variables for standard UNIX IO
    - By default stdin reads from keyboard, and stdout and stderr both write to terminal
  - `File` inherits some of these methods from `IO`

Exceptions

- Use `begin...rescue...ensure...end`
  - Like try...catch...finally in Java

```ruby
begin
  f = File.open("test.txt", "r")
  while !f.eof
    line = f.readline
    puts line
  end
rescue Exception => e
  puts "Exception:" + e.to_s + " (class " + e.class.to_s + ")"
ensure
  f.close if f != nil
end
```

Class of exception to catch
Local name for exception
Always happens
Command Line Arguments

- Stored in predefined array variable $*
  - Can refer to as predefined global constant ARGV

- Example
  - If
    - Invoke test.rb as "ruby test.rb a b c"
  - Then
    - ARGV[0] = "a"
    - ARGV[1] = "b"
    - ARGV[2] = "c"

Practice: Amino Acid counting in DNA

Write a function that will take a filename and read through that file counting the number of times each group of three letters appears so these numbers can be accessed from a hash.
(assume: the number of chars per line is a multiple of 3)

gcggcattcagcaccctgtatatctgttaagcaatccagatattttgtgataacataacccggc
catactgaagcattcattttaggctagcgtgataacagtaacgctaatcaatggggaatgtgg
cattacacggttgctgattactaagagccgggaccacacacaccgccgtaaggatggaacgtgg
taacaataatactcccttcaacagcagtgggcaaggtggaagatgtccagtaagaatagtggg
gggcctactaccccatggtacataattaagagatcgtcaatcttgagacggtaatggtacgc
cgcggacactatatactcacttagccgcgtatgcgtttactgtgacctcgttgactgacgga
Practice: Amino Acid counting in DNA

def countaa(filename)
    file = File.new(filename, "r")
    lines = file.readlines
    hash = Hash.new
    lines.each{|line|
        acids = line.scan(/.../)
        acids.each{|aa|
            if hash[aa] == nil
                hash[aa] = 1
            else
                hash[aa] += 1
            end
        }
    }
end

Comparisons

- Sorting requires ability to compare two values
- Ruby comparison method «>=»
  - -1 = less
  - 0 = equals
  - +1 = greater
- Examples
  - 3 «>=» 4 returns -1
  - 4 «>=» 3 returns +1
  - 3 «>=» 3 returns 0
**Sorting**

- Two ways to sort an Array
  - Default sort (puts values in ascending order)
    - `[2,5,1,3,4].sort`  # returns [1,2,3,4,5]
  - Custom sort (based on value returned by code block)
    - `[2,5,1,3,4].sort { |x,y| y <=> x }`  # returns [5,4,3,2,1]
    - Where -1 = less, 0 = equals, +1 = greater
    - Code block return value used for comparisons

**Ruby Summary**

- Interpreted
- Implicit declarations
- Dynamically typed
- Built-in regular expressions
- Easy string manipulation
- Object-oriented
  - Everything (!) is an object
- Code blocks
  - Easy higher-order programming!
  - Get ready for a lot more of this...
Other Scripting Languages

- Perl and Python are also popular scripting languages
  - Also are interpreted, use implicit declarations and dynamic typing, have easy string manipulation
  - Both include optional “compilation” for speed of loading/execution
- Will look fairly familiar to you after Ruby
  - Lots of the same core ideas
  - All three have their proponents and detractors
  - Use whichever language you personally prefer

Example Perl Program

```perl
#!/usr/bin/perl
foreach (split(/,/,$ARGV[0])) {
  if ($G{$_}) {
    $RE .= "\" . $G{$_};
  } else {
    $RE .= $N ? "(?![" \"](\w)" : "(\w)";
    $G{$_} = ++$N;
  }
}
```
Example Python Program

```python
#!/usr/bin/python
import re
list = ("deep", "deer", "duck")
x = re.compile("^\S{3,5}.[aeiou]"")
for i in list:
    if re.match(x, i):
        print(i)
    else:
        print
```