CMSC 330: Organization of Programming Languages

Ruby Regular Expressions

String Processing in Ruby

- Scripting languages provide many useful libraries for manipulating strings

- The Ruby String class provides useful methods that can
  - Concatenate two strings
  - Extract substrings
  - Search for a substring and Replace with something else

String Operations in Ruby

- What if we want to find more complicated patterns? E.g.,
  - Either Steve, Stephen, Steven, Stefan, or Esteve
  - All words that have even number vowels

We need Regular Expressions

Regular Expressions

- A regular expression is a pattern that describes a set of strings. It is useful for
  - Searching and matching
  - Formally describing strings
    - The symbols (lexemes or tokens) that make up a language
- Common to lots of languages and tools
  - Syntax for them in sed, grep, awk, Perl, Python, Ruby, …
    - Popularized (and made fast) as a language feature in Perl
- Based on some elegant theory
  - Future lecture

Ruby Regular Expressions

- Regular expressions are instances of Regexp
  - Surround regexp *e* with slashes: so /*e*/ has type Regexp

- Basic matching using =~ method of String

```
line = gets                    # read line from standard input
if line =~ /Ruby/ then         # =~ returns nil if regexp not matched
  puts "Read-in line contained Ruby"
end
```

  - x =~ y is sugar for x.=~(y)

Example Regular Expressions in Ruby

- /Ruby/
  - Strings are matched exactly; here, the string "Ruby"
- /Ruby|OCaml/
  - *e1*|*e2* means to match either *e1* or *e2*
  - Here, matches either "Ruby" or "OCaml"
- /(ab)*/
  - 0 or more occurrences of “ab”: matches “”, “ab”, “abab”,”abababab”,…

Repetition in Regular Expressions

The following are suffixes on a regular expression *e*

*e** *zero or more occurrences of e*

e+ *one or more occurrences of e*

so *e*+ is the same as *ee**

a* “”, “a”, “aa”, “aaa”, …

a+ “a”, “aa”, “aaa”, …

bc* “b”, “bc”, “bcc”, …

a+b* “a”, “ab”, “aa”, “aab”, “aabb”, “aabbb”, “aaa”, …

Repetition in Regular Expressions

The following are suffixes on a regular expression *e*

*e** *zero or more occurrences of e*

e+ *one or more occurrences of e*

so *e*+ is the same as *ee**

e? *exactly zero or one e*

e{*x*} *exactly x occurrences of e*

e{*x*,} *at least x occurrences of e*

e{*x*,*y*} *at least x and at most y occurrences of e*

Watch Out for Precedence

- /(Ruby)*/ means {"", "Ruby", "RubyRuby", ...}
- /Ruby*/ means {"Rub", "Ruby", "Rubyy", ...}
- Best to use parentheses to disambiguate
  - Note that parentheses have another use, to extract matches, as we'll see later

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 ^ means *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]
\w	word character, [A-Za-z0-9_]
\D	non-digit, [^0-9]
\S	non-space, [^\t\r\n\f]
\W	non-word, [^A-Za-z0-9_]

Using /^pattern$/ ensures entire string/line must match pattern

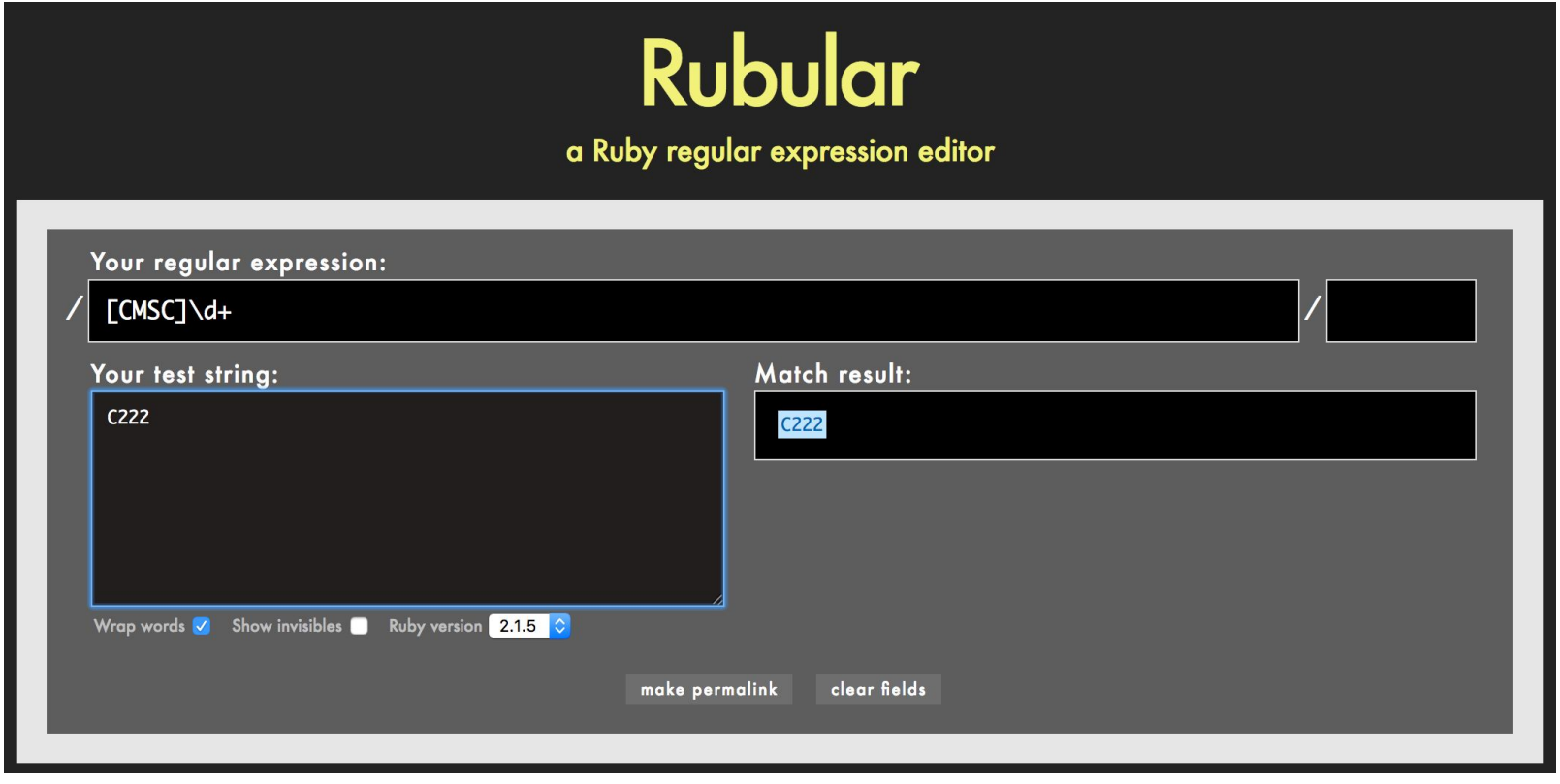
Potential Syntax Confusions

- [ ]
  - Inside regular expressions: character class
  - Outside regular expressions: array
    - Note: [a-z] does not make a valid array
- ^
  - Inside regex character class: *not*
  - Outside regex character class: beginning of line
- ( )
  - Inside character classes: literal characters ( )
    - Note /(0..2)/ does not mean 012
  - Outside character classes in regex: used for grouping
- –
  - Inside regex character classes: range (e.g., a to z given by [a-z])
  - Outside regular expressions: subtraction

Summary

- Let *re* represents an arbitrary pattern; then:
  - /*re*/ – matches regexp *re*
  - /(*re*$_1$|*re*$_2$)/ – match either *re*$_1$ 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

Try out regexps at rubular.com



Regular Expression Practice

- Any string containing two consecutive ab

- Any string containing a or two consecutive b

Regular Expression Practice

- Any string containing two consecutive ab

/(ab){2}/

- Any string containing a or two consecutive b

/a|bb/

Regular Expression Practice

Contains sss or ccc

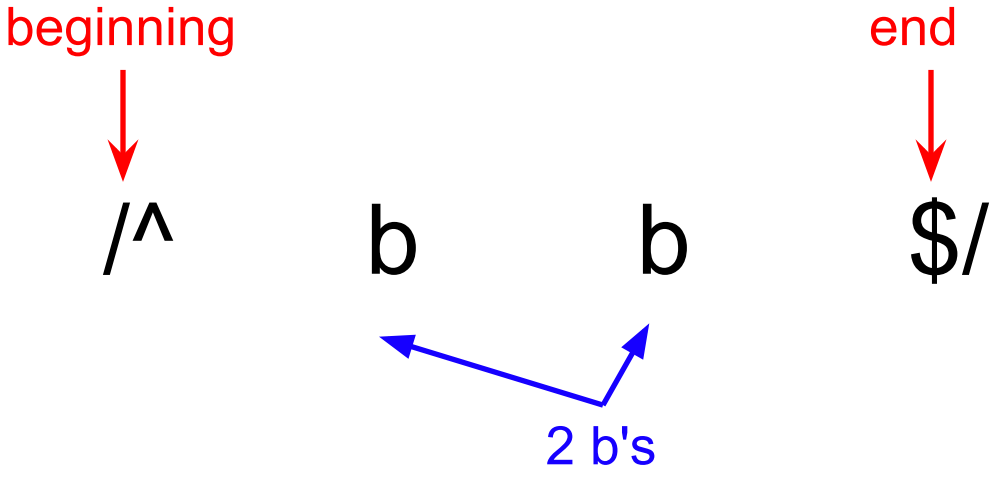
Regular Expression Practice

Contains sss or ccc

/s{3}|c{3}/

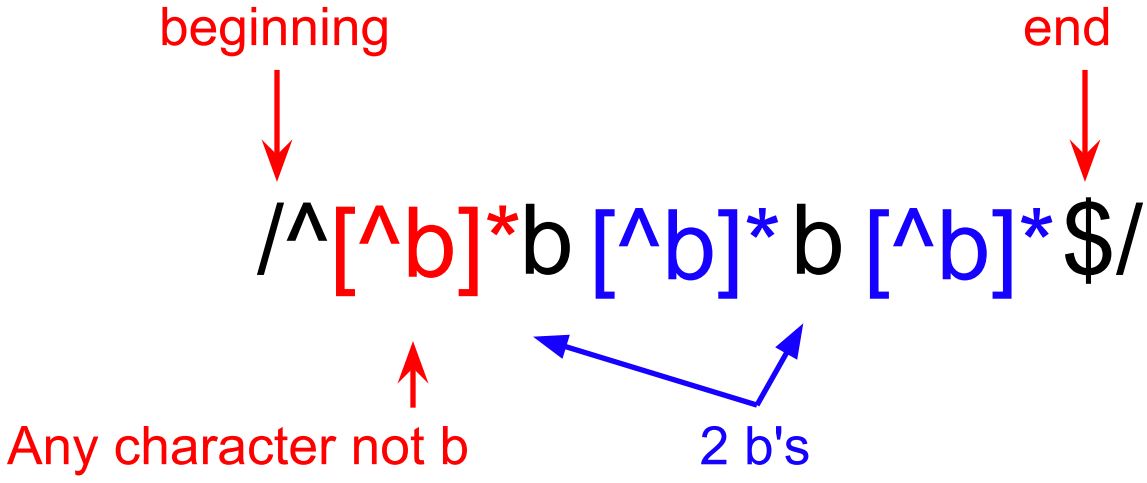
Regular Expression Practice

Contains exactly 2 b's, not necessarily consecutive.



Regular Expression Practice

Contains exactly 2 b's, not necessarily consecutive.



Regular Expression Practice

- Starts with c, followed by one lowercase vowel, and ends with any number of lowercase letters

/^c $/

Regular Expression Practice

- Starts with c, followed by one lowercase vowel, and ends with any number of lowercase letters

/^c [aouei] [a-z]* $/

one vowel

any number of letters

Regular Expression Practice

- Starts with a and has exactly 0 or 1 letter after that

Regular Expression Practice

- Starts with a and has exactly 0 or 1 letter after that

/^a[A-Za-z]?$/

Regular Expression Practice

- Only lowercase letters, in any amount, in alphabetic order

Regular Expression Practice

- Only lowercase letters, in any amount, in alphabetic order

```
/^a*b*c*d*e*f*g*h*i*j*k*l*m*n*o*p*r*t*u*v*w*x*y*z*$/
```

Regular Expression Practice

- Contains one or more ab or ba

Regular Expression Practice

- Contains one or more ab or ba

/(ab|ba)+/

Regular Expression Practice

- Precisely steve, steven, or stephen

Regular Expression Practice

- Precisely steve, steven, or stephen

/^ste(ve|phen|ven)$/

Regular Expression Practice

- Even length string

Regular Expression Practice

- Even length string

/^(..)*$/

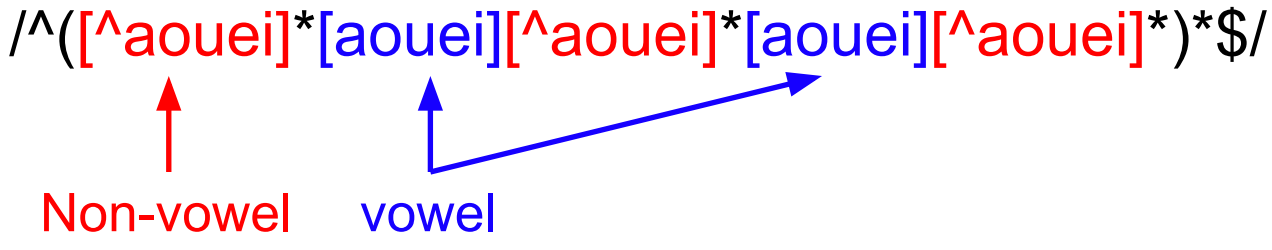
any two characters

Regular Expression Practice

- Even number of lowercase vowels

Regular Expression Practice

- Even number of lowercase vowels



Regular Expression Practice

- Starts with anything but b, followed by one or more a's and then no other characters

Regular Expression Practice

- Starts with anything but b, followed by one or more a's and then no other characters

/^[^b]+a+$/

Quiz 1

How many different strings could this regex match?

```
/^Hello, Anyone awake?$/
```

A. 1
B. 2
C. 4
D. More than 4

Quiz 1

How many different strings could this regex match?

```
/^Hello, Anyone awake?$/
```

ϵ or nothing

A. 1
B. 2
C. 4
D. More than 4

Quiz 2

Which regex is not equivalent to the others?

A. `^[cmsc]$`

B. `^c?m?s?c?$`

C. `^(c|m|s|c)$`

D. `^([cm]|[sc])$`

Quiz 2

Which regex is not equivalent to the others?

A. `^[cmsc]$`

B. `^c?m?s?c?$`

C. `^(c|m|s|c)$`

D. `^([cm]|[sc])$`

Quiz 3

Which string does not match the regex?

```
/[a-z]{4}\d{3}/
```

A. "cmsc\d\d\d"
B. "cmsc330"
C. "hellocmsc330"
D. "cmsc330world"

Quiz 3

Which string does not match the regex?

```
/[a-z]{4}\d{3}/
```

A. "cmsc\d\d\d"
B. "cmsc330"
C. "hellocmsc330"
D. "cmsc330world"

Recall that without ^ and $, a regex will match any **sub**string

Extracting Substrings based on Regexps Method 1: Back References

Two options to extract substrings based on Regexps:

- Use back references
  - Ruby remembers which strings matched the parenthesized parts of a Regexp
  - These parts can be referred to using special variables called back references (named $1, $2,…)

Back Reference Example

```
gets =~ /^Min:(\d+) Max:(\d+)$/
min, max = $1, $2
puts "mini=#{min} maxi=#{max}"
```

```
sets min = $1
 and max = $2
```

- Input

```
Min:1 Max:27
Min:10 Max:30
Min:  11 Max: 30
Min: a Max: 24
```

- Output

```
mini=1 maxi=27
mini=10 maxi=30
mini= maxi=
mini= maxi=
```

Extra space messes up match

Not a digit; messes up match

Quiz 4

What is the output of the following code?

```
s = "Help I'm stuck in a text editor"
s =~ /([A-Z]+)/
puts $1
```

A. H
B. Help
C. I
D. I'm stuck in a text editor

Quiz 4

What is the output of the following code?

```
s = "Help I'm stuck in a text editor"
s =~ /([A-Z]+)/
puts $1
```

A. H
B. Help
C. I
D. I'm stuck in a text editor

Quiz 5

What is the output of the following code?

```
"Why was 6 afraid of 7?" =~ /\d\s(\w+).*(\d)/
puts $1
```

A. afraid
B. Why
C. 6
D. *(empty string)*

Quiz 5

What is the output of the following code?

```
"Why was 6 afraid of 7?" =~ /\d\s(\w+).*(\d)/
puts $1
```

A. afraid
B. Why
C. 6
D. *(empty string)*

Back References are Local

- Warning
  - Despite their names, $1 etc are local variables
  - (Normally, variables starting with $ are global)

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

Back References are Reset

- 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 when matching a Regexp
  - Can optionally use parentheses in Regexp to affect how the extraction is done
- Has two forms that 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* does *not* contain any parenthesized subparts, returns an array of matches
    - An array of all the substrings of *str* which matched

```
s = "CMSC 330 Spring 2021"
s.scan(/\S+ \S+/)
# returns array ["CMSC 330", "Spring 2021"]
```

```
s.scan(/\S{2}/)
# => ["CM", "SC", "33", "Sp", "ri", "ng", "20", "21"]
```

First Form of the Scan Method (cont.)

- *str*.scan(*regexp*)
  - If *regexp* *does* contain parenthesized subparts, returns an array of arrays
    - Each sub-array contains the parts of the string which matched one occurrence of the search

```
s = "CMSC 330 Spring 2021"
s.scan(/(\S+) (\S+)/)   # [["CMSC", "330"],
                        #  ["Spring", "2021"]]
```

    - 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

```
> 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
- back-references

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

```
if line =~ /(\S+$)/
    name = $1  # "bin"
end
```

Quiz 6

What is the output of the following code?

```
s = "Hello World"
t = s.scan(/\w{2}/).length
puts t
```

A. 3
B. 4
C. 5
D. 6

Quiz 6

What is the output of the following code?

```
s = "Hello World"
t = s.scan(/\w{2}/).length
puts t
```

A. 3
B. 4
C. 5
D. 6

Quiz 7

What is the output of the following code?

```
s = "To be, or not to be!"
a = s.scan(/(\S+) (\S+)/)
puts a.inspect
```

A. `["To","be,","or","not","to","be!"]`
B. `[["To","be,"],["or","not"],["to","be!"]]`
C. `["To","be,"]`
D. `["to","be!"]`

Quiz 7

What is the output of the following code?

```
s = "To be, or not to be!"
a = s.scan(/(\S+) (\S+)/)
puts a.inspect
```

A. `["To","be,","or","not","to","be!"]`
B. `[["To","be,"],["or","not"],["to","be!"]]`
C. `["To","be,"]`
D. `["to","be!"]`

Second Form of the Scan Method

- Can take a code block as an optional 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
```

input file:
will be read line by line, but
column summation is desired

```
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)
```

converts the string
to an integer

Sums up three columns of numbers

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)

```
gcggcattcagcacccgtatactgttaagcaatccagatttttgtgtataacataccggc
catactgaagcattcattgaggctagcgctgataacagtagcgctaacaatgggggaatg
tggcaatacggtgcgattactaagagccgggaccacacaccccgtaaggatggagcgtgg
taacataataatccgttcaagcagtgggcgaaggtggagatgttccagtaagaatagtgg
gggcctactacccatggtacataattaagagatcgtcaatcttgagacggtcaatggtac
cgagactatatcactcaactccggacgtatgcgcttactggtcacctcgttactgacgga
```

Practice: Amino Acid counting in DNA