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 many useful, such as
  - Concatenate two strings
  - grabbing substrings
  - Searching and Replacing

String Operations in Ruby

- What if we want to find more complicated patterns?
  - Find Steve, Stephen, Steven, Stefan, Esteve
  - Count the number of words that have even number vowels

- We need Regular Expressions

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.
    - Popularized (and made fast) as a language feature in Perl
- Based on some really elegant theory
  - Future lecture

Regular Expressions

- Regular expressions consist of
  - Constants
    - empty set ∅:
    - empty string ε
    - literal character a in Σ,a finite alphabet
  - Operations over these sets
    - Concatenation: a • b
    - Union: a | b
    - Kleene star: a*
  - We can build complicated patterns by recursively applying the 3 operation on those 3 constants

Example Regular Expressions in Ruby

- /Ruby/
  - Matches exactly the string "Ruby"
  - Concatenation: /r • u • b • y/
- /Ruby | OCaml/
  - Matches either "Ruby" or "OCaml"
- /(ab)*/
  - 0 or more occurrences of "ab", matches "", "ab", "abab","ababab",…

Using Regular Expressions

- Regular expressions are instances of Regexp
- Basic matching using =~ method of String

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

Repetition in Regular Expressions

- *: zero or more
- +: one or more
  - so /e+/ is the same as /ee*/
- ?: zero or one occurrence
- {x} means repeat the search for exactly x occurrences
- {x,} means repeat the search for at least x occurrences
- {x, y} means repeat the search for at least x occurrences and at most y occurrences

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 ^ 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_]

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

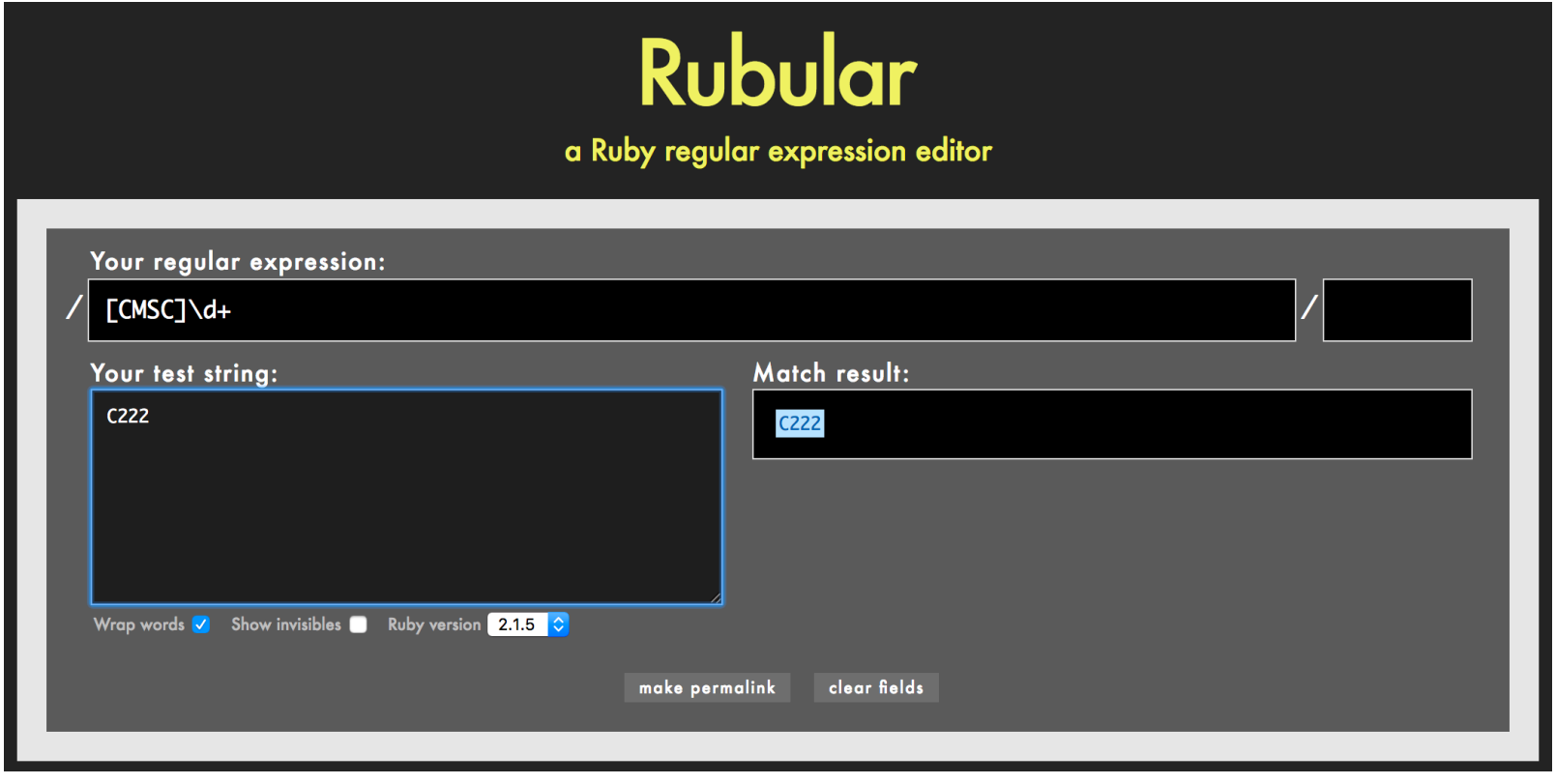
Potential Character Class Confusions

- ^
  - 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 by [a-z])
  - Outside character classes: subtraction

Summary

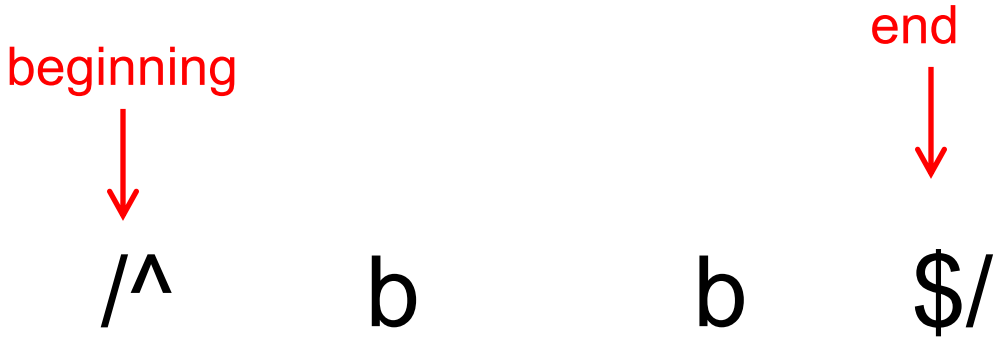
- Let *re* represents an arbitrary pattern; then:
  - /*re*/ – matches regexp *re*
  - /(*re*$_1$|*re*$_2$)/ – match either *re*$_1$ or *re*$_2$
  - /(*re*)*/ – match 0 or more occurrences of *re*
  - /(*re*)+/ – match 1 or more occurrences of *re*
  - /(*re*)?/ – match 0 or 1 occurrences of *re*
  - /(*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

Contains 2 b's, may not be consecutive.



Regular Expression Practice

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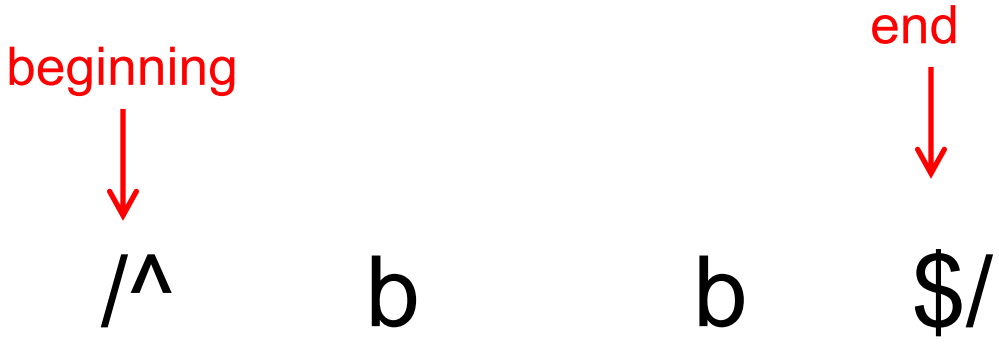

/^ [^b]* b [^b]* b [^b]* $/

Any number of not b

Regular Expression Practice

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

/^c $/

Regular Expression Practice

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

/^c $/

Regular Expression Practice

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

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

Regular Expression Practice

- All letters are in alphabetic order

Regular Expression Practice

- All letters are in alphabetic order

/^a*b*c*d*e*f*g*h*i*j*k*l*m*n*o*p*r*t*$/

Regular Expression Practice

Contains sss or ccc

Regular Expression Practice

Contains sss or ccc

/s{3}|c{3}/

Regular Expression Practice

- contains 2 ab

/(ab){2}/

- contains 2 b

/b{2}/

Regular Expression Practice

- Starts with a, 0 or 1 letter after that

Regular Expression Practice

- Starts with a, 0 or 1 letter after that

/^a[a-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

- steve, steven, or stephen

Regular Expression Practice

- steve, steven, or stephen

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

Regular Expression Practice

- Even length string

/^(..)*$/

Regular Expression Practice

- Even number of vowels

Regular Expression Practice

- Even number of vowels

/^([^aouei]*[aouei][^aouei]*[aouei][^aouei]*)*$/

Regular Expression Practice

- starts with not-b, followed by one or more a's

Regular Expression Practice

- starts with not-b, followed by one or more a's

/^[^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?

∈ or nothing

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

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

Quiz 2

Which regex is not equivalent to the others?

A. `^[crab]$`

B. `^c?r?a?b?$`

C. `^(c|r|a|b)$`

D. `^([cr]|[ab])$`

Quiz 2

Which regex is not equivalent to the others?

A. `^[crab]$`

B. `^c?r?a?b?$`

C. `^(c|r|a|b)$`

D. `^([cr]|[ab])$`

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?

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

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

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

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

```
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

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
```

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. help
B. I
C. I'm
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. help
B. I
C. I'm
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 $2
```

A. afraid
B. Why
C. 6
D. 7

Quiz 5

What is the output of the following code?

```
"Why was 6 afraid of 7?" =~ /\d\s(\w+).*(\d)/
puts $2
```

A. afraid
B. Why
C. 6
D. 7

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 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 doesn't contain any parenthesized subparts, returns an array of matches
    - An array of all the substrings of *str* which matched

```
s = "CMSC 330 Fall 2018"
s.scan(/\S+ \S+/)
# returns array ["CMSC 330", "Fall 2018"]
```

```
s.scan(/\S{2}/)
# => ["CM", "SC", "33", "Fa", "ll", "20", ”18"]
```

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

```
s = "CMSC 330 Fall 2018"
s.scan(/(\S+) (\S+)/)   # [["CMSC", "330"],
                        #  ["Fall", "2018"]]
```

  - 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

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

- back-references

```
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)

```
gcggcattcagcacccgtatactgttaagcaatccagattttgtgtataacataccggc
catactgaagcattcattgaggctagcgctgataacagtagcgctaacaatgggggaatg
tggcaatacggtgcgattactaagagccgggaccacacaccccgtaaggatggagcgtgg
taacataataatccgttcaagcagtgggcgaaggtggagatgttccagtaagaatagtgg
gggcctactacccatggtacataattaagagatcgtcaatcttgagacggtcaatggtac
cgagactatatcactcaactccggacgtatgcgcttactggtcacctcgttactgacgga
```

Practice: Amino Acid counting in DNA