

CS 241: Systems Programming

Lecture 24. Regular Expressions I

Fall 2019

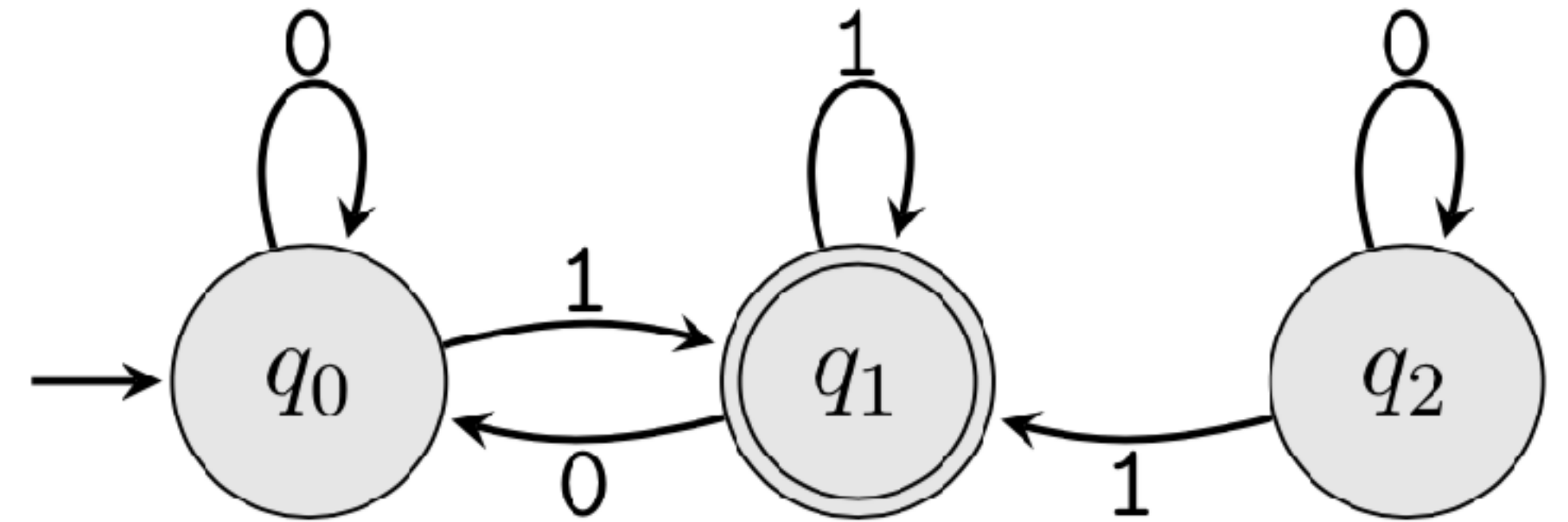
Prof. Stephen Checkoway

Theory of regular languages

Mathematical theory of sets of strings

- You'll see this in CS 383

Connection to finite state machines

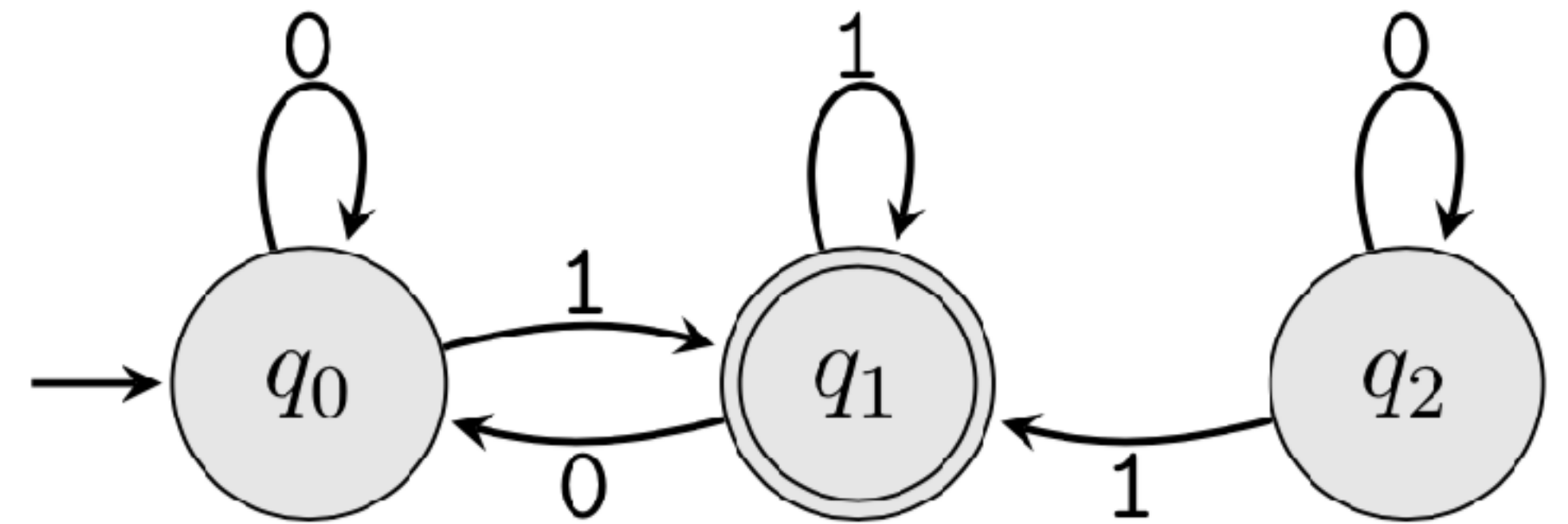


Theory of regular languages

Mathematical theory of sets of strings

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Connection to finite state machines



We're going to skip all of this for this course!

Problem we want to solve

Identify and/or extract text that matches a given pattern

Examples

- ▶ Find all lines of text in a file containing a given word
- ▶ Extract all phone numbers from a file
- ▶ Extract fields from structured text
- ▶ Classify types of text (e.g., compilers need to determine if some text is a number like 0x7D2 or symbols like == or keywords like double)
- ▶ Find all of the tags in an HTML file

grep(1)

grep matches lines of input against a given regular expression, printing each line that matches (or does not match)

```
$ grep 'Computer Science' file
```

- prints each line of `file` that contains the string "Computer Science"

More generally,

```
$ grep regex file
```

will print each line of `file` that matches the regular expression `regex`

What is a regular expression?

Text that describes a [search pattern](#)

Comes in a variety of "flavors"

- ▶ Basic Regular Expression (**BRE**)
- ▶ Extended Regular Expression (**ERE**)
- ▶ Perl-Compatible Regular Expressions (**PCRE**)

Be careful not to confuse with file globbing

Baseline regex characters

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 - ▶ [a-z] matches a range
 - ▶ [^] reverses the sense of match
 - ▶ put] or – at start to be a member of the list

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Every other character just matches itself; precede any of the above with \ to treat as normal

Basic regex (obsolete)

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`\{m,n\}` match previous item at least **m** times, but at most **n** times

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$\{m, n\}$ match previous item at least m times, but at most n times

$\{m\}$ match previous item exactly m times

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$(\)$ group and save enclosed pattern match

▶ $\1$ the first saved match

▶ $\5$ the fifth saved match

Basic regex (obsolete)

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$\{m\}$ match previous item exactly m times

$\{m, \}$ match previous item at least m times

$(\)$ group and save enclosed pattern match

- ▶ $\backslash 1$ the first saved match

- ▶ $\backslash 5$ the fifth saved match

- ▶ Using such "back references" makes it not a real regular expression and should be avoided

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- {m, n}** match previous item at least **m** times, but at most **n** times
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- {m, n}** match previous item at least **m** times, but at most **n** times
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- ?** match previous 0 or 1 time **{0, 1}**

Extended regex (modern)

- {m, n}** match previous item at least **m** times, but at most **n** times
- ()** group and save enclosed pattern match
- +** match 1 or more of the previous **{1, }**
- ?** match previous 0 or 1 time **{0, 1}**
- |** match RE either before or after
 - ▶ apple | banana

POSIX character classes

Within brackets `[]`, we can use character classes corresponding to those in `ctype.h` by surrounding the name with `[:` and `:]`

- ▶ `alnum`, `digit`, `punct`, `alpha`, `graph`, `space`, `blank`, `lower`, `upper`, `cntrl`, `print`, `xdigit`
- ▶ E.g., `[[:digit:][:blank:]]`

Shortcuts (needs "enhanced" regular expressions):

- ▶ `\d` is `[[:digit:]]` `\D` is `[^[:digit:]]`
- ▶ `\s` is `[[:space:]]` `\S` is `[^[:space:]]`
- ▶ `\w` is `[[:alnum:]_]` `\W` is `[^[:alnum:]_]`

Examples

Examples

a

Anything with the letter 'a'

Examples

a

Anything with the letter 'a'

abc

Anything with the string 'abc'

Examples

a

Anything with the letter 'a'

abc

Anything with the string 'abc'

a.c

'a' followed by any char then 'c'

Examples

a

Anything with the letter 'a'

abc

Anything with the string 'abc'

a.c

'a' followed by any char then 'c'

^a

Line starting with 'a'

Examples

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Anything with the letter 'a'

abc

Anything with the string 'abc'

a.c

'a' followed by any char then 'c'

^a

Line starting with 'a'

a\$

Line ending with 'a'

Examples

a

Anything with the letter 'a'

abc

Anything with the string 'abc'

a.c

'a' followed by any char then 'c'

^a

Line starting with 'a'

a\$

Line ending with 'a'

^a\$

Line with only a single 'a' on it

Examples

a	Anything with the letter 'a'
abc	Anything with the string 'abc'
a.c	'a' followed by any char then 'c'
^a	Line starting with 'a'
a\$	Line ending with 'a'
^a\$	Line with only a single 'a' on it
a.*b	'a' then anything else, then 'b' (includes 'ab')

Examples

<code>a</code>	Anything with the letter 'a'
<code>abc</code>	Anything with the string 'abc'
<code>a.c</code>	'a' followed by any char then 'c'
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<code>^a\$</code>	Line with only a single 'a' on it
<code>a.*b</code>	'a' then anything else, then 'b' (includes 'ab')
<code>[abc]</code>	One of 'a', 'b', or 'c'

Examples

a	Anything with the letter 'a'
abc	Anything with the string 'abc'
a.c	'a' followed by any char then 'c'
^a	Line starting with 'a'
a\$	Line ending with 'a'
^a\$	Line with only a single 'a' on it
a.*b	'a' then anything else, then 'b' (includes 'ab')
[abc]	One of 'a', 'b', or 'c'
(ab c){2}	'abab', 'abc', 'cab', 'cc' (ERE)

Which string does the ERE

`\(\d{3}\)\d{3}-\d{4}`
match?

- A. ddd ddd-dddd
- B. (ddd) ddd-dddd
- C. 123 456-7890
- D. (123) 456-7890
- E. \ (123\) 456-7890

Which of the following is an ERE for matching the syntax for an integer literal in C?

E.g., it should match all of 0, 5, 023, 0xFeeDFace, 0XA1f, but not 1x2 or 0789

A. `(0|0x|0X)[[:digit:]]+`

B. `(0[0-7]*)|[[1-9]][[:digit:]]*|0[xX][[:xdigit:]]+`

C. `([0-7]*)|[[[:digit:]]*|(0x|0X)[[:xdigit:]]*`

D. `\d`

E. This cannot be matched with a regular expression

grep(1)

Name comes from ed(1) program command `g/re/p`

<code>grep</code>	<code>-E</code>	<code>re</code>	<code>files</code>	use extended regex (or use <code>egrep</code>)
<code>egrep</code>	<code>-l</code>	<code>re</code>	<code>files</code>	just list file names
<code>egrep</code>	<code>-c</code>	<code>re</code>	<code>files</code>	just list count of matches
<code>egrep</code>	<code>-n</code>	<code>re</code>	<code>files</code>	just list line numbers
<code>egrep</code>	<code>-i</code>	<code>re</code>	<code>files</code>	ignore case
<code>egrep</code>	<code>-v</code>	<code>re</code>	<code>files</code>	show non-matching lines

awk(1)

Named after the developers

- ▶ A. Aho
- ▶ P. Weinberger
- ▶ B. Kernighan

Programming language for working on files

Consists of a sequence of pattern-action statements of the form

- ▶ `pattern { action }`
- ▶ Each line of the input is matched compared to each `pattern` in order; each matching pattern has its associated `action` run

Running AWK

Running

- ▶ `$ awk -f foo.awk files # foo.awk contains the program`
- ▶ `$ awk prog files # pattern-action separated by ;`

Understands whitespace separated fields (can change this via `-F` option)

- ▶ `$1, $2, $3`
- ▶ `$0` is the whole line

Other variables, just use their names

Patterns

- /re/** matches the regular expression **re**
- BEGIN** matches before any input is used (can be used to set variables)
- END** matches after all input is used (e.g., can print things)
- expr** matches if the expression is nonzero
- p1 , p2** matches all lines between the line matching p1 and the line matching p2 (including those lines)
- (empty pattern) matches every line

Actions

An action is a sequence of statements inside `{ }` separated by `;`

- ▶ assignment statements `var = value`
- ▶ conditionals/loops: `if`, `while`, `for`, `do-while`, `break`, `continue`,
- ▶ `for (var in array) stmt`
- ▶ `print expr-list`
- ▶ `printf format, expr-list`

A missing action means to print the line

Simple AWK program

Prints the lines of a file with START and END

```
BEGIN { print "START" }  
        { print }  
END   { print "END" }
```

Simple AWK program

Prints lines longer than 72 characters

```
length($0) > 72 { print }
```

Missing action block means print

```
length($0) > 72
```

Sum up a list of numbers

```
BEGIN { SUM = 0 }  
        { SUM += $1 }  
END   { print "Total is", SUM }
```


Print size and owner from ls -l

```
$ ls -l | awk '{ print $5, "\t", $3 }'
```

Given pop.txt with lines containing zip code, county, population, e.g.,

```
44001, Lorain, 20769
```

```
44011, Lorain, 21193
```

what is the awk command to print out the population of Oberlin (zip code 44074)?

A. `$ awk -F ' , ' ' /44074/ { print $3 } '`

B. `$ awk -F ' , ' ' $0 == 44074 { print $2 } '`

C. `$ awk -F ' , ' ' $1 == 44074 { print $3 } '`

D. `$ awk -F ' , ' ' 44074 { print $2 } '`

In-class exercise

<https://regex.sketchengine.co.uk> Do the four interactive exercises

Grab a laptop and a partner and try to get as much of that done as you can!