Regular Expressions

with a brief intro to FSM

15-123

Systems Skills in C and Unix

Case for regular expressions

- Many web applications require pattern matching
  - look for <a href> tag for links
  - Token search
- A regular expression
  - A pattern that defines a *class of strings*
  - Special syntax used to represent the class
    - Eg; *.c - any pattern that ends with .c

Formal Languages

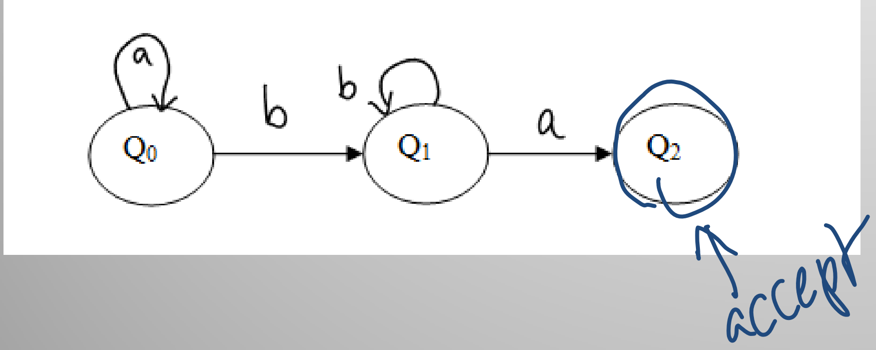
- Formal language consists of
  - An alphabet → {a, b, c, ..}
  - Formal grammar
- Formal grammar defines
  - Strings that belong to language
- Formal languages with **formal semantics** generates rules for semantic specifications of programming languages

Automaton

- An **automaton (**or **automata** in plural) is a machine that can recognize valid strings generated by a **formal language**.
- A **finite automata** is a mathematical model of a **finite state machine** (FSM), an abstract model under which all modern computers are built.

Automaton

- A FSM is a machine that consists of a set of finite states and a transition table.

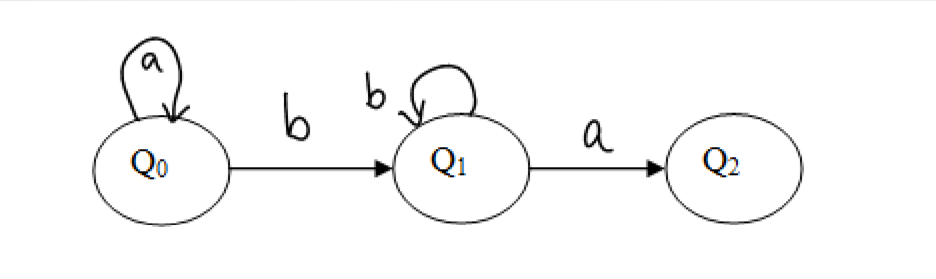


$\{a,b\}$	Q_0	Q_1	Q_2
a	Q_0	Q_2	
b	Q_1	Q_1	

- The FSM can be in any one of the states and can transit from one state to another based on a series of rules given by a transition function.

Example

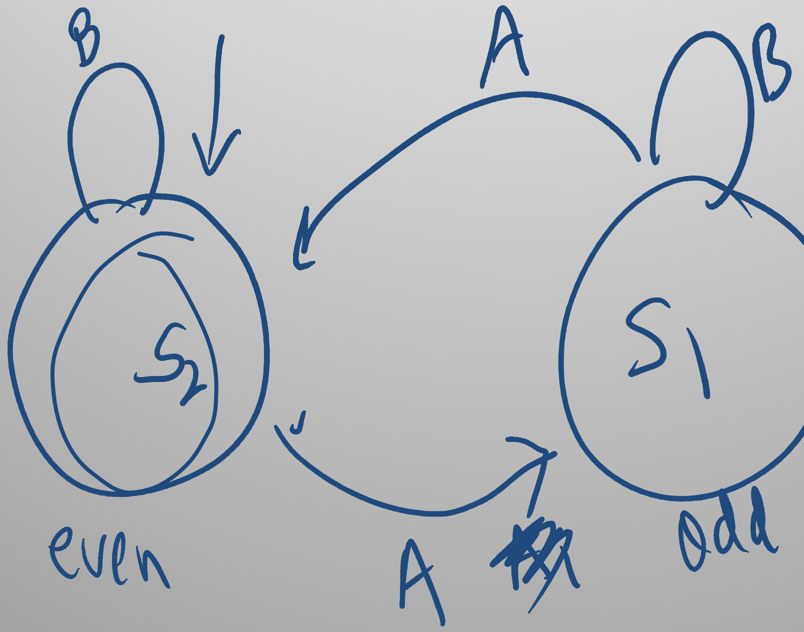
What does this machine represents? Describe the kind of strings it will accept.



$\{ a^n \, b \, b^m a \mid n, m \geq 0 \}$

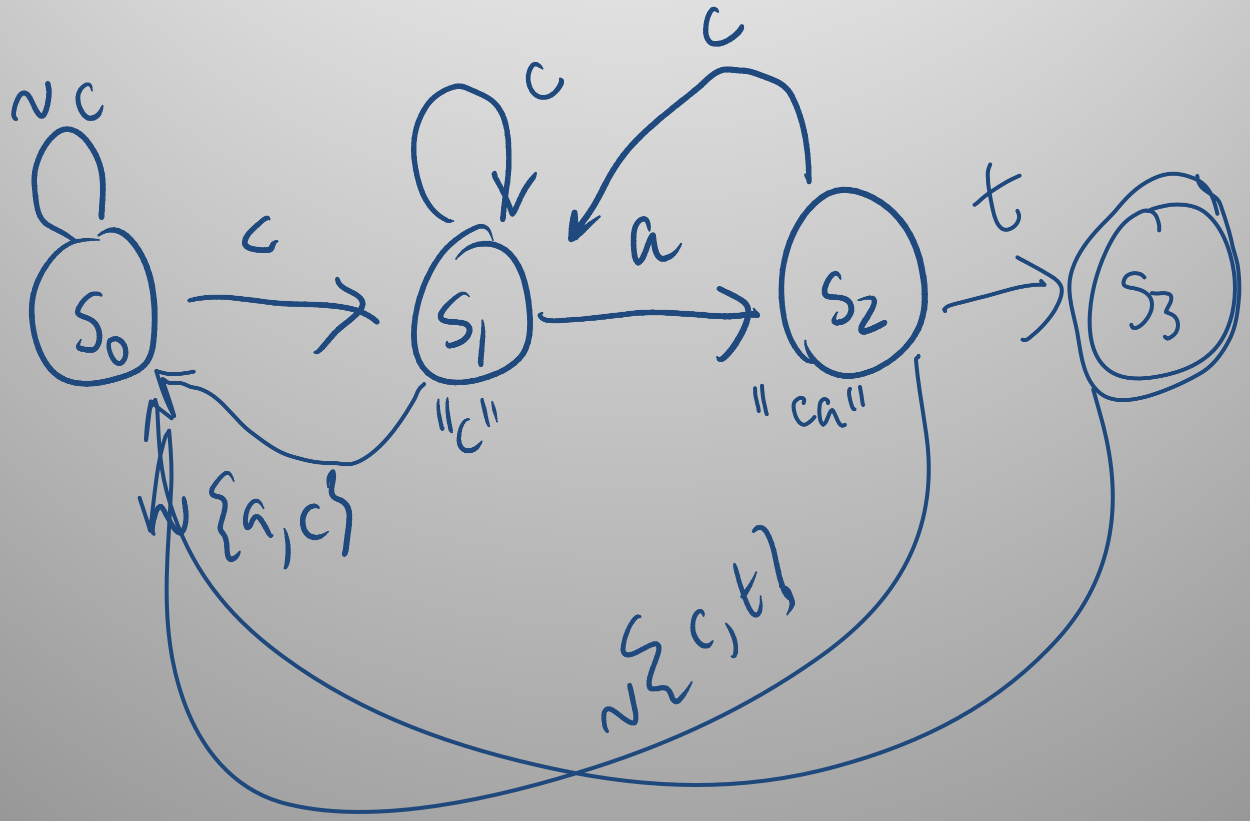
Exercise

- Draw a FSM that accepts any string with even number of A's. Assume the alphabet is {A,B}



Build a FSM

- Stream: “Ilovecatsandmorecatsandbigcats ”
- Pattern: “cat”



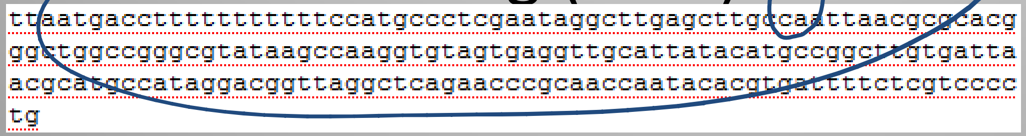
Regular Expressions

Regex versus FSM

- A regular expressions and FSM's are equivalent concepts.
- *Regular expression is a pattern that can be recognized by a FSM.*
- *Regex is an example of how good theory leads to good programs*

Regular Expression

- regex defines a class of patterns
  - Patterns that ends with a “*”
- Regex utilities in unix
  - grep, awk, sed
- Applications
  - Pattern matching (DNA)



```
ttaatgaccttttttttttttccatgccctcgaataggcttgagcttgccaattaacgcgcacg
ggctggccgggcgtataagccaaggtgtagtgaggttgcattatacatgccggcttgtgatta
acgcatgccataggacggttaggctcagaacccgcaaccaatacacgtgattttctcgtcccc
tg
```

  - Web searches

Regex Engine

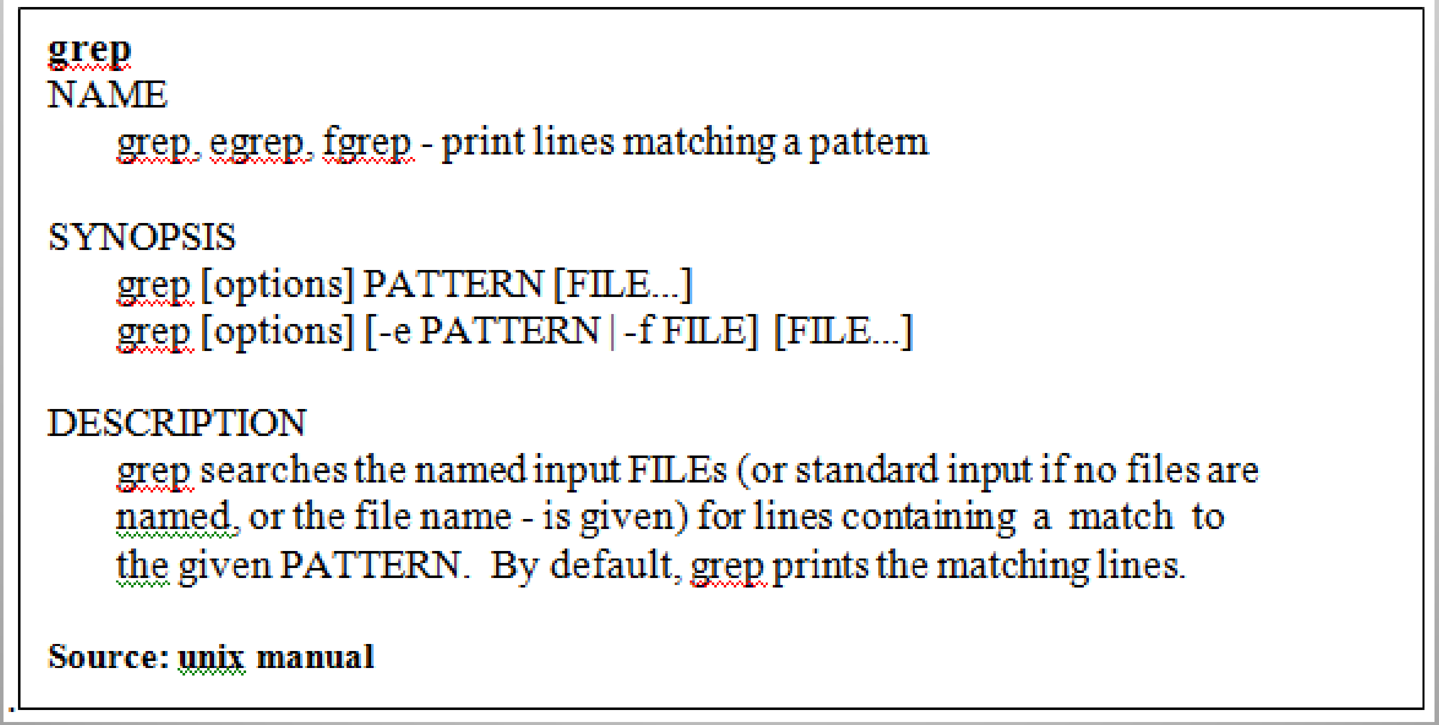
- A software that can process a string to find regex matches.
- Regex software are part of a larger piece of software
  - grep, awk, sed, php, python, perl, java etc..
- We can write our own regex engine that recognizes all "*caa*" in a strings
  - See democode folder
- Different regex engines may not be compatible with each other
  - Perl 5 is a popular one to learn

Regex machines

- Perl can do a “decent” job with simple regex’s
- But it can fail in cases where expressions can be of the form $\underline{(a?)^n a^n}$ where $a^n = a.a. \ldots a$
- One of the best regex machines was written in C by Ken Thompson in the 70’s
  - 400 lines of C code
  - Superior to perl, python and other implementations when working with real world applications

Unix grep utility

The grep command



grep

NAME

grep, egrep, fgrep - print lines matching a pattern

SYNOPSIS

grep [options] PATTERN [FILE...]
grep [options] [-e PATTERN | -f FILE] [FILE...]

DESCRIPTION

grep searches the named input FILEs (or standard input if no files are named, or the file name - is given) for lines containing a match to the given PATTERN. By default, grep prints the matching lines.

Source: unix manual

Simple grep examples

- grep “<a href” guna.html > output.txt
- ls | grep “guna”
- grep ‘regex’ filename
- man grep
  - For more info

regex grammer

Regular Expression Grammar

- Regex grammar defines a set of rules for finding patterns. Grammar categories
  - Alternation
  - Grouping
  - quantification

Regular Expression Grammar

- **Alternation**
- The vertical bar is used to describe alternating choices among two or more choices.
  - the notation **a | b | c** indicates that we can choose a or b or c as part of the string.
  - Another example is that **“(c|s)at”** describes the expressions “cat” or “sat”. **n**

Regular Expression Grammar

Grouping

Parenthesis can be used to describe the scope and precedence of operators.

In the example above **(c|s)** indicates that we can either begin with c or s but must immediately follow by “at”

Regular Expression Grammar

$a? = \phi , a$

- **Quantification**
  - Quantification is the notation used to define the number of symbols that could appear in the string.
- The most common quantifiers are

$a* = \phi$
$= a$
$= aaa$

  - **?, * and +**
  - The **? mark indicates that there is zero or one** of the previous expression.

$a+ = a$
aa

  - The **“*” indicates that zero or more** of the previous expression can be accepted.
  - The **“+” indicates that one or more** of the previous expression can be accepted.

Examples of *, ? , +

$$a\,?\;\underline{(ba)}\,\underline{+}\,c* \longrightarrow ba$$

$$\longrightarrow aba$$

$$\longrightarrow a\;ba\;baba\;c$$

Other facts

- . matches a single character

a+.*

- .* matches any string
- [a-zA-Z]* matches any string of alphabetic characters
- [ag].* matches any string that starts with a or g
- [a-d].* matches any string that starts with a,b,c or d
- ^(ab) matches any string that begins with ab. In general, to match all lines that begins with any string use ^string
- (ab)$ matches any string that ends with ab

h\([1-4])

Finding non-matches

- To exclude a pattern
  - [^class]
  - Eg: [^0-9]

^[^0-9]

does not start with

^[0-9]

starts with

Group Matches

- grep ‘<h\([1-4]\)>.*h\([1-3]\)>’ filename
  - What patterns match?
- grep ‘h\([1-4]\).*h\1’ filename
  - Back-reference

Character Classes

- \d digit [0-9]
- \D non-digit [^0-9]
- \w word character [0-9a-z_A-Z]
- \W non-word character [^0-9a-z_A-Z]
- \s a whitespace character [\t\n\r\f]
- \S a non-whitespace character [^ \t\n\r\f]

More regex notation

- *{n,m} at least n but not more than m times*

a{2,3}

- *{n,} – match at least n times*
- {n} – match exactly n times

More examples of regex

- Find all files that begins with “guna”
- Find all files that does not begins with “guna”
- Find all files that ends with guna
- Find all directories in current folder. Write them to an external file.

Exercise

- An email address must begin with an alpha character and can have any combination of alpha characters and characters from {0..9, %, _, +, -} followed by @ and a domain name {alpha-numeric} followed by {.} and any token from the set {edu, com, us, org, net}. Write a regex to describe this.

[a-z A-Z]~~+~~[a-z A-Z 0-9% _\+ -]* @ [0-9, a-z A-Z]

.(edu|com|net)

Summarized Facts about regex

- Two regular expressions may be concatenated; the resulting regular expression matches any string formed by concatenating two substrings that respectively match the concatenated sub expressions.
- Two regular expressions may be joined by the infix operator **| the resulting** regular expression matches any string matching either sub expression

Summarized Facts about regex

- Repetition takes precedence over concatenation, which in turn takes precedence over alternation. A whole sub expression may be enclosed in parentheses to override these precedence rules
- The backreference \n, where n is a single digit, matches the substring previously matched by the nth parenthesized sub expression of the regular expression.
- In basic regular expressions the metacharacters ?, +, {, |, (, and) lose their special meaning; instead use the backslashed versions \?, \+, \{, \|, \(, and \).

Text Processing Languages

- awk
  - Text processing language
  - awk ‘/pattern/’ somefile
  - awk '{if ($3 < 1980) print $3, " ",$5,$6,$7,$8}' somefile
- sed
  - A stream editor
  - sed s/moon/sun/ < moon.txt >sun.txt
- Perl
  - A powerful scripting language
  - We will discuss this next

Basics of sed

sed basics

- sed is a stream editor
- > sed ‘s/guna/foo/’ filename
  - Replaces guna by foo in the file
    - first occurrence on each line
  - output sent to stdout
- > sed ‘s/guna/foo/g’ filename
  - Globally replaces guna by foo in the file
- If you have special characters {.*[]^$\ }
  - Precede with \
  - eg: sed ‘s/guna\[me\.him\]/foobar/g’ filename

sed basics

- Replacing more than one token
  - sed -e ‘s/guna/foo/g’ -e ‘s/color/colour/g’ filename
- What if / is part of the string to replace?
  - Replace all *afs/andrew* with *afs/cs*
  - Solution: any character immediately following s is the delimiter
  - sed ‘s#afs/andrew#afs/cs’ filename

Basics of awk

S10, guna, —, —, SCS, CS, . . .

$1 $2

Basics of awk

- Uses
  - Use information from text files to create reports
  - Translating files from one format to another
  - Adding functionality to “vi”
  - Mathematical operations on numeric files
- awk also has a basic interpreted programming language
- Basic commands
  - General form:
    - awk ‘<search pattern> {<program actions>} ‘
  - awk ‘/guna/ file -- prints all lines with guna
  - awk ‘/guna/’ {print $1,$2,$3} ‘ file
  - awk -F',' '{if ($5=="MCS") print $2}' roster.txt

exercises

- Download an index.html file from your favorite website
  - use wget
- Change all URL's for example, www.cnn.com to www.foxnews.com
  - use sed

Coding Examples