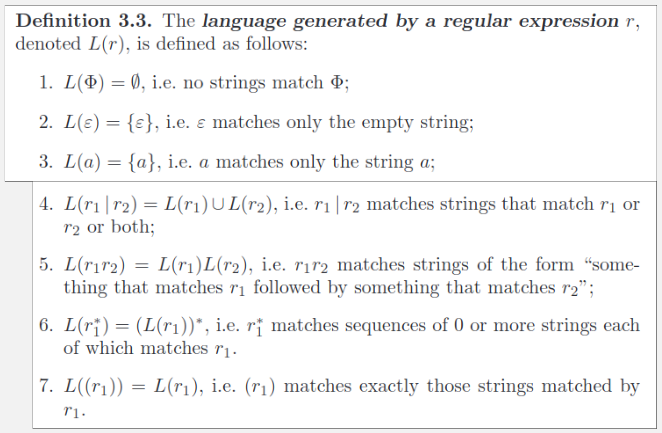
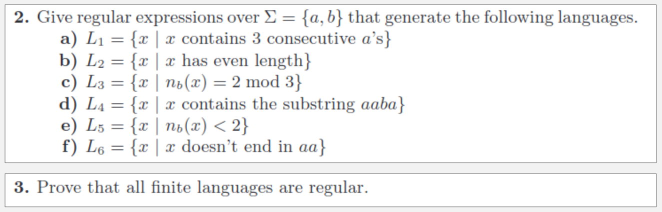
Regular Expressions


Definition 3.3. The ***language generated by a regular expression*** r, denoted $L(r)$, is defined as follows:

1. $L(\Phi) = \emptyset$, i.e. no strings match Φ;
2. $L(\varepsilon) = \{\varepsilon\}$, i.e. ε matches only the empty string;
3. $L(a) = \{a\}$, i.e. a matches only the string a;
4. $L(r_1 \mid r_2) = L(r_1) \cup L(r_2)$, i.e. $r_1 \mid r_2$ matches strings that match r_1 or r_2 or both;
5. $L(r_1 r_2) = L(r_1)L(r_2)$, i.e. $r_1 r_2$ matches strings of the form "something that matches r_1 followed by something that matches r_2";
6. $L(r_1^*) = (L(r_1))^*$, i.e. r_1^* matches sequences of 0 or more strings each of which matches r_1.
7. $L((r_1)) = L(r_1)$, i.e. (r_1) matches exactly those strings matched by r_1.

- this defines what a given regular expression means


2. Give regular expressions over $\Sigma = \{a, b\}$ that generate the following languages.

a) $L_1 = \{x \mid x \text{ contains 3 consecutive } a\text{'s}\}$
b) $L_2 = \{x \mid x \text{ has even length}\}$
c) $L_3 = \{x \mid n_b(x) = 2 \bmod 3\}$
d) $L_4 = \{x \mid x \text{ contains the substring } aaba\}$
e) $L_5 = \{x \mid n_b(x) < 2\}$
f) $L_6 = \{x \mid x \text{ doesn't end in } aa\}$

3. Prove that all finite languages are regular.

Regular Expressions in Practice

- used for *pattern matching*
- the alphabet is typically the characters on the keyboard
- use an *escape character* to distinguish *meta-characters* from alphabet characters
  - typically \

`|` `\*` `\( \)`	the characters |, *, (,)
`\n`	newline
`\t`	tab

Regular Expressions in Practice

$r_1 \mid r_2$	or (union)
`r*`	Kleene star (0 or more)
`(r)`	grouping
`r+`	1 or more times
`r?`	0 or 1 times
$[a_1a_2a_3]$	match any one of a_1, a_2, or a_3
$[a_1\text{-}a_n]$	match any one character between a_1 and a_n
$[\hat{}a_1a_2a_3]$	match any one character *not* a_1, a_2, or a_3
$[\hat{}a_1\text{-}a_n]$	match any one character *not* between a_1 and a_n
`.`	match any single character
`^`	match the beginning of the line
`$`	match the end of the line
`\b`	match word boundary
`\s`	match any whitespace

there are variations in implementation from one application to the next, especially beyond the basic core

1. The backslash is itself a meta-character. Suppose that you want to match a string that contains a backslash character. How do you suppose you would represent the backslash in the regular expression?

2. Using the notation introduced in this section, write a regular expression that could be used to match each of the following:

- **a)** Any sequence of letters (upper- or lowercase) that includes the letter Z (in uppercase).
- **b)** Any eleven-digit telephone number written in the form `(xxx)xxx-xxxx`.
- **c)** Any eleven-digit telephone number *either* in the form `(xxx)xxx-xxxx` or `xxx-xxx-xxxx`.
- **d)** A non-negative real number with an optional decimal part. The expression should match numbers such as 17, 183.9999, 182., 0, 0.001, and 21333.2.
- **e)** A complete line of text that contains only letters.
- **f)** A C++ style one-line comment consisting of `//` and all the following characters up to the end-of-line.

Substitution

`$0`	entire substring matching the pattern
`$1`	substring matched by the part of the pattern beginning with the first (and ending with the matching)
…	…
`$9`	

there are variations in implementation from one application to the next, especially beyond the basic core

3. Give a search pattern and a replace pattern that could be used to perform the following conversions:

- **a)** Convert a string that is enclosed in a pair of double quotes to the same string with the double quotes replaced by single quotes.
- **b)** Convert seven-digit telephone numbers in the format `xxx-xxx-xxxx` to the format `(xxx)xxx-xxxx`.
- **c)** Convert C++ one-line comments, consisting of characters between `//` and end-of-line, to C style comments enclosed between `/*` and `*/`.
- **d)** Convert any number of consecutive spaces and tabs to a single space.

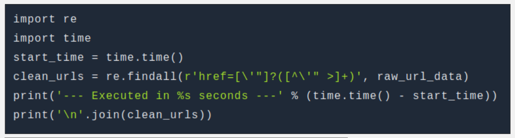
Back References

`\0`	entire substring matching the pattern
`\1`	substring matched by the part of the pattern beginning with the first (and ending with the matching)
…	…
`\9`	

there are variations in implementation from one application to the next, especially beyond the basic core

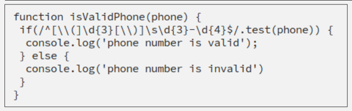
4. In some implementations of "regular expressions," the notations `\1`, `\2`, and so on can occur in a search pattern. For example, consider the search pattern `^([a-zA-Z]).*\1$`. Here, `\1` represents a recurrence of the same substring that matched `[a-zA-Z]`, the part of the pattern between the first pair of parentheses. The entire pattern, therefore, will match a line of text that begins and ends with the same letter. Using this notation, write a pattern that matches all strings in the language $L = \{a^n ba^n \mid n \geq 0\}$. (Later in this chapter, we will see that L is *not* a regular language, so allowing the use of `\1` in a "regular expression" means that it's not really a regular expression at all! This notation can add a real increase in expressive power to the patterns that contain it.)

Some Applications



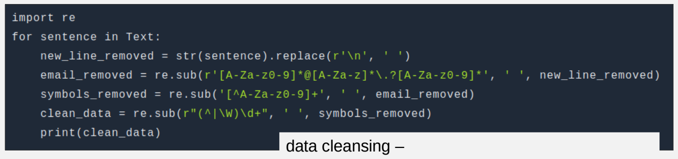
```
import re
import time
start_time = time.time()
clean_urls = re.findall(r'href=[\'"]?([^\'" >]+)', raw_url_data)
print('--- Executed in %s seconds ---' % (time.time() - start_time))
print('\n'.join(clean_urls))
```

parsing –
extract links in an
HTML document



```
function isValidPhone(phone) {
 if(/^[\\(]\d{3}[\\)]\s\d{3}-\d{4}$/.test(phone)) {
  console.log('phone number is valid');
 } else {
  console.log('phone number is invalid')
 }
}
```

input validation –
phone number



```
import re
for sentence in Text:
    new_line_removed = str(sentence).replace(r'\n', ' ')
    email_removed = re.sub(r'[A-Za-z0-9]*@[A-Za-z]*\.?[A-Za-z0-9]*', ' ', new_line_removed)
    symbols_removed = re.sub('[^A-Za-z0-9]+', ' ', email_removed)
    clean_data = re.sub(r"(^|\W)\d+", ' ', symbols_removed)
    print(clean_data)
```

data cleansing –
preprocess text by replacing newlines with spaces,
removing email addresses, symbols, digits

https://www.enjoyalgorithms.com/blog/regex-applications-in-data-science
https://levelup.gitconnected.com/extremely-useful-regular-expression-examples-for-real-world-applications-567e844a0822

WHENEVER I LEARN A NEW SKILL I CONCOCT ELABORATE FANTASY SCENARIOS WHERE IT LETS ME SAVE THE DAY.
OH NO! THE KILLER MUST HAVE FOLLOWED HER ON VACATION!
BUT TO FIND THEM WE'D HAVE TO SEARCH THROUGH 200 MB OF EMAILS LOOKING FOR SOMETHING FORMATTED LIKE AN ADDRESS!
IT'S HOPELESS!
EVERYBODY STAND BACK.
I KNOW REGULAR EXPRESSIONS.
PERL!
TAP TAP

https://xkcd.com/208/