

Natural Language Processing

Chapter 2

Regular Expressions, Text Normalization, Edit Distance



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Regular Expression (RE)



- A language for specifying text search strings.

Regular Expression (RE)



- A language for specifying text search strings.
- Formally,
 - an algebraic notation for characterizing a set of strings.

Basic RE Patterns: Simplest Kind



- The simplest kind of RE is
 - a sequence of simple characters.

Basic RE Patterns: Simplest Kind



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 - a sequence of simple characters.

RE	Example Patterns Matched
/woodchucks/	“interesting links to <u>woodchucks</u> and lemurs”
/a/	“ <u>M</u> ary Ann stopped by Mona’s”
/!/	“You’ve left the burglar behind again <u>!</u> ” said Nori

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- We’ll show REs delimited by slashes (/).

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- We’ll show REs delimited by slashes (/).
- But slashes (/) are not part of the REs.

Basic RE Patterns: Case Sensitivity



- Regular expressions are **case sensitive**.

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- Lower case `/s/` is distinct from uppercase `/S/`.

Basic RE Patterns: Case Sensitivity



- Regular expressions are **case sensitive**.
- Lower case `/s/` is distinct from uppercase `/S/`.
- The pattern `/woodchucks/` will not match the string *Woodchucks*.

Basic RE Patterns: Disjunction



- The string of characters inside the **square braces** [and] specifies
 - a **disjunction of characters** to match.

Basic RE Patterns: Disjunction



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RE	Match	Example Patterns
/[wW]oodchuck/	Woodchuck or woodchuck	“ <u>W</u> oodchuck”
/[abc]/	‘a’, ‘b’, <i>or</i> ‘c’	“In uomini, in soldat <u>i</u> ”
/[1234567890]/	any digit	“plenty of <u>7</u> to 5”

Basic RE Patterns: Range



- Where there is a well-defined sequence associated with a set of characters,
 - the **brackets** can be used **with the dash** (-) to specify any one character in a **range**.

Basic RE Patterns: Range



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 - the **brackets** can be used **with the dash (-)** to specify any one character in a **range**.

RE	Match	Example Patterns Matched
/[A-Z]/	an upper case letter	“we should call it ‘ <u>D</u> renched Blossoms’ ”
/[a-z]/	a lower case letter	“ <u>m</u> y beans were impatient to be hoed!”
/[0-9]/	a single digit	“Chapter <u>1</u> : Down the Rabbit Hole”

Basic RE Patterns: Negation



- If the **caret** \wedge is the **first symbol** after the open square brace **[**,
 - the resulting pattern is **negated**.

Basic RE Patterns: Negation



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- If the caret \wedge occurs **anywhere else**,
 - it usually stands for a **caret** \wedge .

Basic RE Patterns: Negation



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 - the resulting pattern is **negated**.
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 - it usually stands for a **caret** \wedge .

RE	Match (single characters)	Example Patterns Matched
<code>/[\wedgeA-Z]/</code>	not an upper case letter	"Oyfn pri <u>p</u> rietchik"
<code>/[\wedgeSs]/</code>	neither 'S' nor 's'	" <u>I</u> have no exquisite reason for't"
<code>/[\wedge.]/</code>	not a period	" <u>o</u> ur resident Djinn"
<code>/[\wedgee]/</code>	either 'e' or ' \wedge '	"look up \wedge now"
<code>/a\wedgeb/</code>	the pattern 'a \wedge b'	"look up <u>a</u> \wedge b now"

Basic RE Patterns: Optionality



- How can we talk about optional elements,
 - like an optional *s* in *woodchuck* and *woodchucks*?

Basic RE Patterns: Optionality



- Use the question mark `/?/`,
 - which means “zero or one instances of the previous character”.

Basic RE Patterns: Optionality



- Use the **question mark** `/?/`,
 - which means “zero or one instances of the previous character”.

RE	Match	Example Patterns Matched
<code>/woodchucks?/</code>	woodchuck or woodchucks	“ <u>woodchuck</u> ”
<code>/colou?r/</code>	color or colour	“ <u>color</u> ”

Basic RE Patterns: Problem



- Consider the language of certain sheep, which consists of strings that look like the following:

baa!

baaa!

baaaa!

baaaaa!

...

Basic RE Patterns: Problem



- Consider the language of certain sheep, which consists of strings that look like the following:
baa!
baaa!
baaaa!
baaaaa!
...
■ How can we represent the language using RE?

Basic RE Patterns: Kleene *



- Use the *

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- Use the *
- Pronounced “cleany star”.

Basic RE Patterns: Kleene *



- Use the *
- Pronounced “cleany star”.
- Means “zero or more occurrences of the immediately previous character or regular expression”.

Basic RE Patterns: Kleene *



- An **integer** (a string of digits) is thus `/[0-9][0-9]*/`.

Basic RE Patterns: Kleene *



- An **integer** (a string of digits) is thus `/[0-9][0-9]*/`.
- Why isn't it just `/[0-9]*/?`

Basic RE Patterns: Kleene +



- Have to write the regular expression for digits twice,
 - so there is a shorter way to specify “at least one” of some character.

Basic RE Patterns: Kleene +



- Have to write the regular expression for digits twice,
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- **Kleene +** means “one or more occurrences of the immediately preceding character or regular expression”.

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- Have to write the regular expression for digits twice,
 - so there is a shorter way to specify “at least one” of some character.
- **Kleene +** means “one or more occurrences of the immediately preceding character or regular expression”.
- An **integer** (a string of digits) is thus `/[0-9]+/`.
- Two ways to specify the sheep language: `/baa*!/` or `/baa+!/`.

Basic RE Patterns: Wildcard



- The period (`/./`),
 - a wildcard expression that matches any single character (except a carriage return).

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RE	Match	Example Matches
<code>/beg.n/</code>	any character between <i>beg</i> and <i>n</i>	<u>begin</u> , <u>beg'n</u> , <u>begun</u>

Basic RE Patterns: Wildcard



- The **wildcard** (.) is often used together with the **Kleene ***
 - to mean “any string of characters”.

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- Suppose we want to find any line in which a particular word, for example, **aardvark**, appears twice.

Basic RE Patterns: Wildcard



- The **wildcard** (.) is often used together with the **Kleene ***
 - to mean “any string of characters”.
- Suppose we want to find any line in which a particular word, for example, **aardvark**, appears twice.
- We can specify this with the regular expression **/aardvark.*aardvark/**.

Basic RE Patterns: Anchors



- Special characters that anchor regular expressions to particular places in a string.

Basic RE Patterns: Anchors



- Special characters that anchor regular expressions to particular places in a string.
- The most common **anchors** are
 - the **caret** `^` and the **dollar sign** `$`.

Basic RE Patterns: Anchor caret ^



- The caret ^
 - matches the start of a line.

Basic RE Patterns: Anchor caret ^



- The caret ^
 - matches the start of a line.
- The pattern /^The/ matches
 - the word *The* only at the start of a line.

Basic RE Patterns: The caret ^



- The caret ^ has three uses:

Basic RE Patterns: The caret ^



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 - To match the start of a line,
 - To indicate a negation inside of square brackets,

Basic RE Patterns: The caret ^



- The caret ^ has three uses:
 - To match the start of a line,
 - To indicate a negation inside of square brackets,
 - Just to mean a caret ^.

Basic RE Patterns: Anchor dollar sign \$



- The dollar sign \$ matches
 - the end of a line.

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- The dollar sign \$ matches
 - the end of a line.
- `\s$`
 - a useful pattern for matching a space at the end of a line.

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- `/^The dog\.$/`
 - matches a line that contains only the phrase *The dog.*

Basic RE Patterns: Anchor dollar sign \$



- The dollar sign \$ matches
 - the end of a line.
- `\s$`
 - a useful pattern for matching a space at the end of a line.
- `/^The dog\.$/`
 - matches a line that contains only the phrase *The dog.*
- We have to use the backslash (\\) here
 - since we want the . to mean “period” and not the wildcard.

Basic RE Patterns: Anchors more



- Two other **anchors**:
 - `\b` matches a word boundary
 - `\B` matches a non-boundary.

Basic RE Patterns: Anchors more



- Two other **anchors**:
 - `\b` matches a word boundary
 - `\B` matches a non-boundary.
- `/\bthe\b/`
 - matches the word *the* but *not the word other*.

Basic RE Patterns: “word” definition



- Based on the definition of “words” in programming languages.

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- `/\b99\b/`

Basic RE Patterns: “word” definition



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- Technically, a “word” for the purposes of a regular expression is defined as
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- `/\b99\b/`
 - will match the string 99 in *There are 99 bottles of beer on the wall* (because 99 follows a space)

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- `/\b99\b/`
 - will match the string 99 in *There are 99 bottles of beer on the wall* (because 99 follows a space)
 - but not 99 in *There are 299 bottles of beer on the wall* (since 99 follows a number).

Basic RE Patterns: “word” definition



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- Technically, a “word” for the purposes of a regular expression is defined as
 - any sequence of digits, underscores, or letters.
- `/\b99\b/`
 - will match the string 99 in *There are 99 bottles of beer on the wall* (because 99 follows a space)
 - but not 99 in *There are 299 bottles of beer on the wall* (since 99 follows a number).
 - But it will match 99 in *\$99* (since 99 follows a dollar sign (\$), which is not a digit, underscore, or letter).

Break

Basic RE Patterns: Disjunction operator



- Search for either the string *cat* or the string *dog*.

Basic RE Patterns: Disjunction operator



- Search for either the string *cat* or the string *dog*.
- Why can't we say `/[catdog]/?`

Basic RE Patterns: Disjunction operator



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- Use the **disjunction operator**, also called the **pipe symbol** `|`.

Basic RE Patterns: Disjunction operator



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- Why can't we say `/[catdog]/?`
- Use the **disjunction operator**, also called the **pipe symbol** `|`.
- The pattern `/cat|dog/` matches
 - either the string *cat* or the string *dog*.

Basic RE Patterns: Precedence



- How can I specify both *guppy* and *guppies*?

Basic RE Patterns: Precedence



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- We cannot simply say `/guppy|ies/`,
 - because that would match only the strings *guppy* and *ies*.

Basic RE Patterns: Precedence



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- We cannot simply say `/guppy|ies/`,
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- Use the **parenthesis operators** (and).

Basic RE Patterns: Precedence



- How can I specify both *guppy* and *guppies*?
- We cannot simply say `/guppy|ies/`,
 - because that would match only the strings *guppy* and *ies*.
- Use the **parenthesis operators** (and).
- The pattern `/gupp(y|ies)/` would specify that
 - we meant the disjunction only to apply to the suffixes *y* and *ies*.

Basic RE Patterns: Operator precedence hierarchy



Parenthesis	()
Counters	* + ? {}
Sequences and anchors	the ^my end\$
Disjunction	

- Counters have a higher precedence than sequences,
 - /the*/ matches *theeee* but not *thethe*.

Basic RE Patterns: Operator precedence hierarchy



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Counters	* + ? {}
Sequences and anchors	the ^my end\$
Disjunction	

- Counters have a higher precedence than sequences,
 - `/the*/` matches *theeee* but not *thethe*.
- Sequences have a higher precedence than disjunction,
 - `/the|any/` matches *the* or *any* but not *thany* or *theny*.

Basic RE Patterns: A Simple Example



- Write a RE to find cases of the English article *the*.

Basic RE Patterns: A Simple Example



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- Solution: `/the/`

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- Miss the word when it begins a sentence and hence is capitalized (i.e., *The*)

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- Still incorrectly return texts with the embedded in other words (e.g., *other* or *theology*)

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- Might want to find *the* in some context where it might also have underlines or numbers nearby (*the_* or *the25*)

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- Might want to find *the* in some context where it might also have underlines or numbers nearby (*the_* or *the25*)
- Solution: `/[^\a-zA-Z][tT]he[^\a-zA-Z]/`

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- Still incorrectly return texts with the embedded in other words (e.g., *other* or *theology*)
- Solution: `/\b[tT]he\b/`
- Might want to find *the* in some context where it might also have underlines or numbers nearby (*the_* or *the25*)
- Solution: `/[~a-zA-Z][tT]he[~a-zA-Z]/`
- Won't find the word *the* when it begins a line.

Basic RE Patterns: A Simple Example



- Write a RE to find cases of the English article *the*.
- Solution: `/the/`
- Miss the word when it begins a sentence and hence is capitalized (i.e., *The*)
- Solution: `/[tT]he/`
- Still incorrectly return texts with the embedded in other words (e.g., *other* or *theology*)
- Solution: `/\b[tT]he\b/`
- Might want to find *the* in some context where it might also have underlines or numbers nearby (*the_* or *the25*)
- Solution: `/[^a-zA-Z][tT]he[^a-zA-Z]/`
- Won't find the word *the* when it begins a line.
- Solution: `/(^|[^a-zA-Z])[tT]he([^a-zA-Z]|$)/`



Two kind of Errors:

- **false positives:**

- strings that we incorrectly matched like *other* or *there*



Two kind of Errors:

- **false positives:**

- strings that we incorrectly matched like *other* or *there*

- **false negatives:**

- strings that we incorrectly missed, like *The*.

NLP Errors: Two efforts



Two kind of Efforts:

- Increasing **precision** (minimizing false positives)

NLP Errors: Two efforts



Two kind of Efforts:

- Increasing **precision** (minimizing false positives)
- Increasing **recall** (minimizing false negatives)

A More Complex Example



- Write a RE for
 - any machine with at least 6 GHz and 500 GB of disk space for less than \$1000.

A More Complex Example



- Write a RE for
 - any machine with at least 6 GHz and 500 GB of disk space for less than \$1000.
- HOME WORK: Section 2.1.4

More RE Operators: Aliases



- **Aliases** for common sets of characters.

More RE Operators: Aliases



- **Aliases** for common sets of characters.

RE	Expansion	Match	First Matches
\d	[0-9]	any digit	Party_of_5
\D	[^0-9]	any non-digit	Blue_moon
\w	[a-zA-Z0-9_]	any alphanumeric/underscore	Daiyu
\W	[^\w]	a non-alphanumeric	!!!!
\s	[\r\t\n\f]	whitespace (space, tab)	
\S	[^\s]	Non-whitespace	in_Concord

More RE Operators: Counters



- RE operators for **counting**.

More RE Operators: Counters



- RE operators for **counting**.

RE	Match
*	zero or more occurrences of the previous char or expression
+	one or more occurrences of the previous char or expression
?	exactly zero or one occurrence of the previous char or expression
{n}	n occurrences of the previous char or expression
{n,m}	from n to m occurrences of the previous char or expression
{n,}	at least n occurrences of the previous char or expression
{,m}	up to m occurrences of the previous char or expression

More RE Operators: Backslashed



- Some characters that need to be **backslashed**.

More RE Operators: Backslashed



- Some characters that need to be **backslashed**.

RE	Match	First Patterns Matched
*	an asterisk “*”	“K_A*P*L*A*N”
\.	a period “.”	“Dr. Livingston, I presume”
\?	a question mark	“Why don’t they come and lend a hand?”
\n	a newline	
\t	a tab	

THANK YOU