CS310 Natural Language Processing
自然语言处理
Lecture 00 - Python and Basic Text Processing

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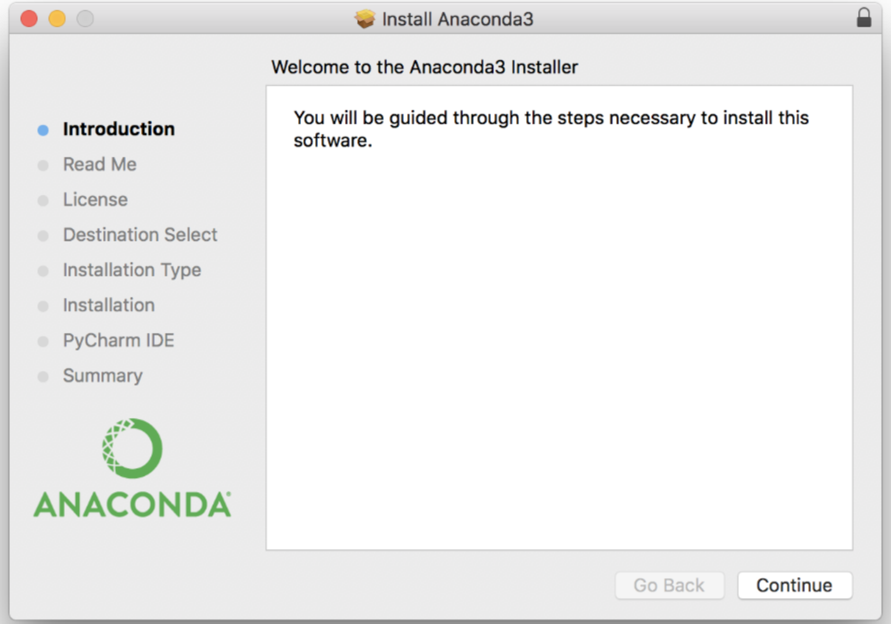
Some slides credit to Dan Jurafsky: https://web.stanford.edu/~jurafsky/slp3/

Content

- Python Basics
  - Install Python and Jupyter
  - String processing
  - Regular expression
- Basic Text Processing
  - Words and corpora
  - Tokenization

Python Installation

- Python installation via anaconda is recommended

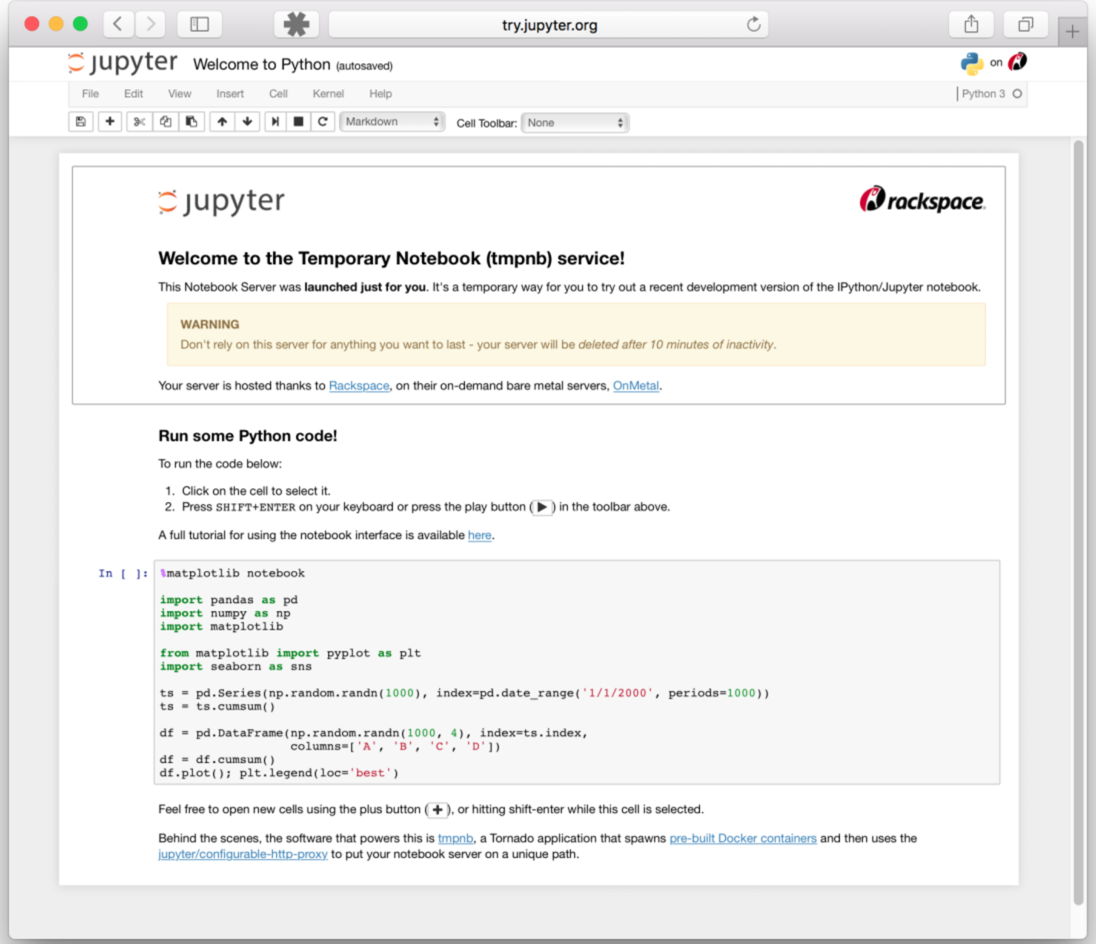


Link:
https://www.anaconda.com/distribution/
==> choose the distribution that suits you

Python 3.8 - 3.12 is recommended

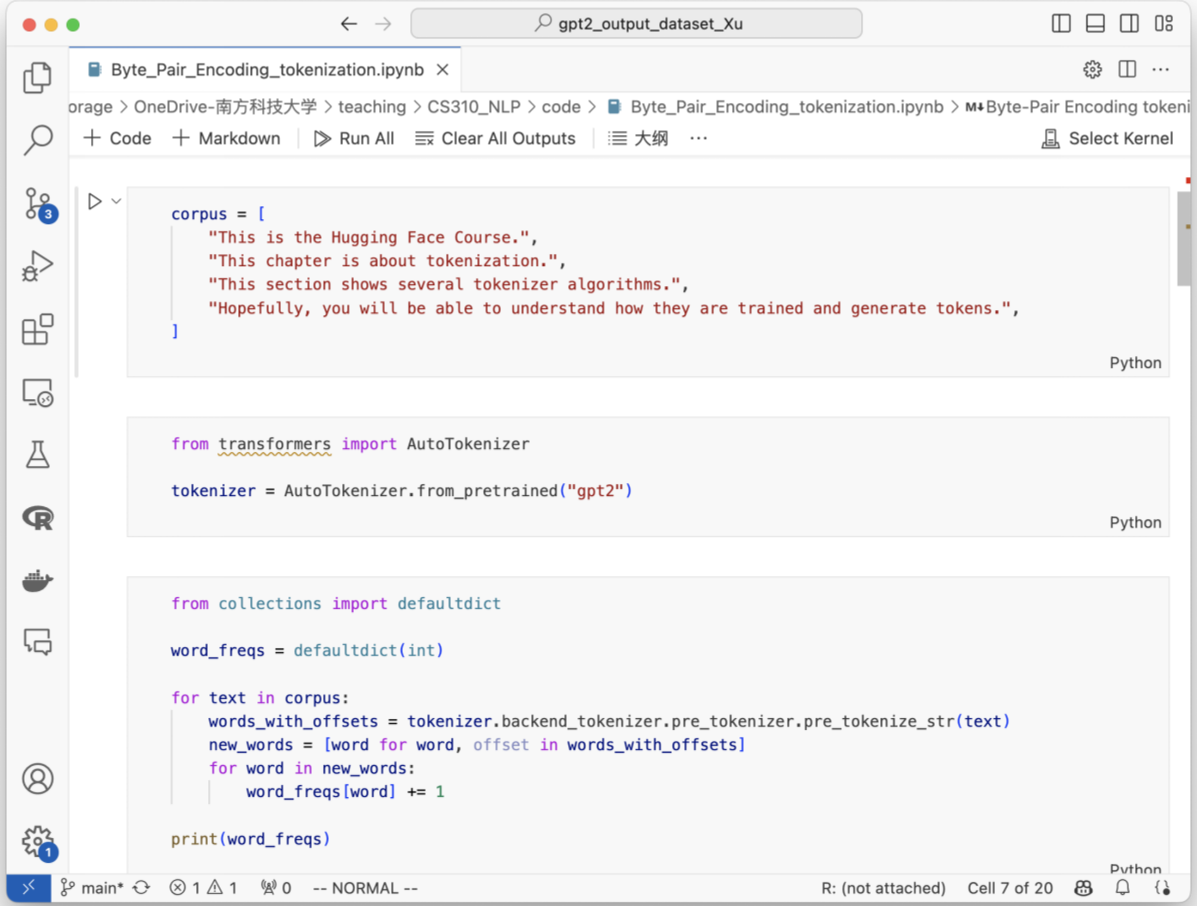
Jupyter Installation

- Official site: https://jupyter.org/install
- or via anaconda: https://anaconda.org/anaconda/jupyter
- Read the document: https://docs.jupyter.org/en/latest/start/index.html



IDEs recommendation

- Visual studio code
- Or JetBrains PyCharm



Python basics

- **str** is a built-in type for handling strings in Python
- Common sequence operations, on **str**, **list**, and **tuple**

- x **in** s True if an item of *s* is equal to *x*, else False
- x **not in** s False if an item of *s* is equal to *x*, else True

- s + t the concatenation of *s* and *t*
- len(s) the length of s
- **s[i]** the *i*th element of s, **start from 0**

```
s1 = [1, 2, 3]
s2 = [4, 5, 6]
print(s1 + s2)
```

```
[1, 2, 3, 4, 5, 6]
```

```
s = [1, 2, 3, 4]
print(s[0])
print(s[len(s)-1])
print(s[-1])
print(s[-2])
```

```
1
4
4
3
```

Common operations on string (str)

- **str.split(sep)** Return a list of substrings (e.g., words) in the string, resulted from using *sep* as the delimiter. The default separator is space ‘ ‘.
  E.g., ‘I love Python’.split() = ['I', 'love', 'Python']
  ‘I love Python’.split(‘ ‘) = ['I', 'love', 'Python']
  ‘144.182.67.1’.split(‘.’) = [‘144', ‘182', ‘67‘, ‘1’]

- **str.upper()** Return a copy of the string with all the cased characters converted to uppercase
- **str.lower()** Return a copy of the string with all the cased characters converted to lowercase

String is Immutable

- Operations on string do NOT change the value of the string.

S1= “hello world!”
S1.split(‘ ‘)
What does Python return?

What is the value of S1 now?
S2=S1.split(‘ ‘)

What is the value of S1 now?
What is the value of S2 now?

S1=S1.split(‘ ‘)
What is the value of S1 now?

Common operations on string (str)

- **str.strip()** Returns a copy of the string with the leading and trailing

  characters removed

  E.g., ‘ hello\n ’.strip() = ‘hello’

- **str.startswith(prefix)** Returns True if string starts with the *prefix*

  E.g., ‘Python’.startswith(‘P’) = True

- **str.endswith(suffix)**

Common operations on string

- **str.replace(*old*, *new*)** Return a copy of the string with all occurrences of substring *old* replaced by *new*

```
In [1]: 'This-is-a-long-string'.replace('-', ' ')
Out[1]: 'This is a long string'
```

```
In [2]: 'I do not want spaces'.replace(' ', '')
Out[2]: 'Idonotwantspaces'
```

Regular expressions

- A **formal language** for specifying text strings

- How can we search for any of these?
    - woodchuck
    - woodchucks
    - Woodchuck
    - Woodchucks

Stephen C Kleene

The concept of regular expressions began in the 1950s, when the American mathematician Stephen Cole Kleene formalized the concept of a regular language.

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Regular Expressions: Disjunctions

- Letters inside square brackets []

Pattern	Matches
[wW]oodchuck	Woodchuck, woodchuck
[1234567890]	Any digit

- Ranges [A-Z]

Pattern	Matches	
[A-Z]	An upper case letter	Drenched Blossoms
[a-z]	A lower case letter	my beans were impatient
[0-9]	A single digit	Chapter 1: Down the Rabbit Hole

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Regular Expressions: Negation in Disjunction

- Negations [^Ss]
  - Carat (^) means negation only when first in []

Pattern	Matches	
[^A-Z]	Not an upper case letter	Oyfn pripetchik
[^Ss]	Neither 'S' nor 's'	I have no exquisite reason"
[^e^]	Neither e nor ^	Look here
a^b	The pattern a carat b	Look up a^b now

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Regular Expressions: More Disjunction

- Woodchuck is another name for groundhog!
- The **pipe |** for disjunction

<table>
<tr><th>Pattern</th><th>Matches</th></tr>
<tr><td>groundhog|woodchuck</td><td>woodchuck</td></tr>
<tr><td>yours|mine</td><td>yours</td></tr>
<tr><td>a|b|c</td><td>= [abc]</td></tr>
<tr><td>[gG]roundhog|[Ww]oodchuck</td><td>Woodchuck</td></tr>
</table>

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Regular Expressions: ? * + .

? question mark
* asterisk
+ plus
. dot

Pattern	Matches	
colou?r	Optional previous char	color colour
oo*h!	0 or more of previous char	oh! ooh! oooh! ooooh!
o+h!	1 or more of previous char	oh! ooh! oooh! ooooh!
baa+		baa baaa baaaa baaaaa
beg.n		begin begun begun beg3n

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Regular Expressions: Anchors ^ $

Note that ^ is outside []

Pattern	Matches
^[A-Z]	Palo Alto
^[^A-Za-z]	1 "Hello"
\.$	The end.
.$	The end? The end!

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Example

- Find me all instances of the word “the” in a text.

    the

        Misses capitalized examples

    [tT]he

        Incorrectly returns other or theology

    [^a-zA-Z][tT]he[^a-zA-Z]

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Errors

- The previous examples show two kinds of errors:

1. Matching strings that we should not have matched (there, then, other)
   False positives (Type I errors)
2. Not matching things that we should have matched (The)
   False negatives (Type II errors)

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Errors (cont.)

- We are always dealing with these kinds of errors.
- Reducing the error rate for an application often involves two antagonistic efforts:
  - Increasing ***precision*** (minimizing false positives)
  - Increasing ***recall*** (minimizing false negatives).

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Summary

- Regular expressions play a surprisingly large role
  - Sophisticated sequences of regular expressions are often the "**first model**" for any text processing text
- For hard tasks, we use machine learning classifiers
  - But regular expressions are still used for pre-processing, or as features in the classifiers
  - Can be very useful in capturing generalizations

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Regular expression in Python

- Use re module
- Doc: https://docs.python.org/3/library/re.html
- Example: search() vs. match()
- re.match() checks for a match only at the beginning of the string
- re.search() checks for a match anywhere in the string (this is what Perl does by default)
- re.fullmatch() checks for entire string to be a match

```
>>> re.match("c", "abcdef")    # No match
>>> re.search("^c", "abcdef")  # No match
>>> re.search("^a", "abcdef")  # Match
<re.Match object; span=(0, 1), match='a'>
```

- re.findall() Return all non-overlapping matches of pattern in string, as a list of strings or tuples

```
>>> re.findall(r'\bf[a-z]*', 'which foot or hand fell fastest')
['foot', 'fell', 'fastest']
>>> re.findall(r'(\w+)=(\d+)', 'set width=20 and height=10')
[('width', '20'), ('height', '10')]
```

RegEx for Chinese characters

```python
raw = """
一些中文夹杂着English words以及数字1234
"""
```
✓ 0.0s

```python
re.findall(r'[\u4e00-\u9fa5]', raw)
```
✓ 0.0s

```
['一', '些', '中', '文', '夹', '杂', '着', '以', '及', '数', '字']
```

```python
re.findall(r'[一-龟]', raw)
```
✓ 0.0s

```
['一', '些', '中', '文', '夹', '杂', '着', '以', '及', '数', '字']
```

```python
re.findall(r'[\u4e00-\u9fa5]+[0-9]+', raw)
```
✓ 0.0s

```
['以及数字1234']
```

Table of Content

How many words in a sentence?

- "I do uh main- mainly business data processing"
  - Fragments, filled pauses
- "Seuss's cat in the hat is different from other cats!"
  - **Lemma**: same stem, part of speech, rough word sense
    - cat and cats = same lemma
  - **Wordform**: the full inflected surface form
    - cat and cats = different wordforms

Lemma: 词目

Word form: 词形

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How many words in a sentence?

they lay back on the San Francisco grass and looked at the stars and their

- **Type**: an element of the vocabulary.
- **Token**: an instance of that type in running text.
- How many?
  - 15 tokens (or 14)
  - 13 types (or 12) (or 11?)

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How many words in a corpus?

N = number of tokens

V = vocabulary = set of types, |***V***| is size of vocabulary

Heaps Law = Herdan's Law = $|V| = kN^{\beta}$ where often $.67 < \beta < .75$

i.e., vocabulary size grows with > square root of the number of word tokens

	Tokens = *N*	Types = |*V*|
Switchboard phone conversations	2.4 million	20 thousand
Shakespeare	884,000	31 thousand
COCA	440 million	2 million
Google N-grams	1 trillion	13+ million

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Corpora

Words don't appear out of nowhere!

A text is produced by

- a specific writer(s),
- at a specific time,
- in a specific variety,
- of a specific language,
- for a specific function.

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Corpora vary along dimension like

- **Language:** 7097 languages in the world
- **Variety,** like African American Language varieties.
  - Double Negatives: "I don't know nothing" to emphasize negation.
  - "I ain't got no time for that" (I don't have any time for that).
  - "He be running every morning" (He runs every morning).
- **Code switching**, e.g., Spanish/English, Hindi/English:
  - “Selina, double check 一下我的 case”
- **Genre:** news article, fiction, scientific articles, Wikipedia document
- **Author Demographics**: writer's age, gender, ethnicity, SES

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Corpus **datasheets**

Gebru et al (2020), Bender and Friedman (2018)

Motivation:

- Why was the corpus collected? By whom? Who funded it?

Situation: In what situation was the text written?

Collection process: If it is a subsample how was it sampled? Was there consent? Pre-processing?

- **+Annotation process, language variety, demographics, etc.**

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  - regular expression
- **Basic Text Processing**
  - **Words and corpora**
  - **Tokenization**

Text Normalization

- Every NLP task requires text normalization:
  1. **Tokenizing (segmenting) words**
  2. Normalizing word formats
  3. Segmenting sentences

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Space-based tokenization

- A very simple way to tokenize
  - For languages that use space characters between words
    - Arabic, Cyrillic, Greek, Latin, etc., based writing systems
  - Segment off a token between instances of spaces
- Unix tools for space-based tokenization
  - The "tr" command
  - Inspired by Ken Church's UNIX for Poets
  - Given a text file, output the word tokens and their frequencies

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Simple Tokenization in UNIX

- (Inspired by Ken Church's UNIX for Poets.)
- Given a text file, output the word tokens and their frequencies

```
tr -sc 'A-Za-z' '\n' < shakes.txt
     | sort
     | uniq -c
```

Change all non-alpha to newlines

Sort in alphabetical order

Merge and count each type

```
1945 A
  72 AARON
  19 ABBESS
   5 ABBOT
 ... ...
```

```
25 Aaron
 6 Abate
 1 Abates
 5 Abbess
 6 Abbey
 3 Abbot
....     …
```

Slides credit to Dan Jurafsky: https://web.stanford.edu/~jurafsky/slp3/

The first step: tokenizing

```
tr -sc 'A-Za-z' '\n' < shakes.txt | head
```

THE
SONNETS
by
William
Shakespeare
From
fairest
creatures
We
...

Slides credit to Dan Jurafsky: https://web.stanford.edu/~jurafsky/slp3/

The second step: sorting

```
tr -sc 'A-Za-z' '\n' < shakes.txt | sort | head
```

```
A
A
A
A
A
A
A
A
A
...
```

Slides credit to Dan Jurafsky: https://web.stanford.edu/~jurafsky/slp3/

More counting

- Merging upper and lower case

tr ‘A-Z’ ‘a-z’ < shakes.txt | tr –sc ‘A-Za-z’ ‘\n’ | sort | uniq –c

- Sorting the counts

tr ‘A-Z’ ‘a-z’ < shakes.txt | tr –sc ‘A-Za-z’ ‘\n’ | sort | uniq –c | sort –n –r

```
23243 the
22225 i
18618 and
16339 to
15687 of
12780 a
12163 you
10839 my
10005 in
8954  d
```

What happened here?

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Issues in Tokenization

- Can't just blindly remove punctuation:
  - m.p.h., Ph.D., AT&T, cap'n
  - prices ($45.55)
  - dates (01/02/06)
  - URLs (http://www.stanford.edu)
  - hashtags (#nlproc)
  - email addresses (someone@cs.colorado.edu)
- Clitic: a word that doesn't stand on its own
  - "are" in we're, French "je" in j'ai, "le" in l'honneur
- When should multiword expressions be words?
  - New York, rock 'n' roll

Slides credit to Dan Jurafsky: https://web.stanford.edu/~jurafsky/slp3/

Solution: Regular Expressions for Tokenizing Text

```
>>> raw = """'When I'M a Duchess,' she said to herself, (not in a very hopeful tone
... though), 'I won't have any pepper in my kitchen AT ALL. Soup does very
... well without--Maybe it's always pepper that makes people hot-tempered,'..."""
```

```
>>> re.split(r' ', raw) ❶
["'When", "I'M", 'a', "Duchess,'", 'she', 'said', 'to', 'herself,', '(not', 'in',
'a', 'very', 'hopeful', 'tone\nthough),', "'I", "won't", 'have', 'any', 'pepper',
'in', 'my', 'kitchen', 'AT', 'ALL.', 'Soup', 'does', 'very\nwell', 'without--Maybe',
"it's", 'always', 'pepper', 'that', 'makes', 'people', "hot-tempered,'..."]
>>> re.split(r'[ \t\n]+', raw) ❷
["'When", "I'M", 'a', "Duchess,'", 'she', 'said', 'to', 'herself,', '(not', 'in',
'a', 'very', 'hopeful', 'tone', 'though),', "'I", "won't", 'have', 'any', 'pepper',
'in', 'my', 'kitchen', 'AT', 'ALL.', 'Soup', 'does', 'very', 'well', 'without--Maybe',
"it's", 'always', 'pepper', 'that', 'makes', 'people', "hot-tempered,'..."]
```

```
>>> print(re.findall(r"\w+(?:[-']\w+)*|'|[-.(]+|\S\w*", raw))
["'", 'When', "I'M", 'a', 'Duchess', ',', "'", 'she', 'said', 'to', 'herself', ',',
'(', 'not', 'in', 'a', 'very', 'hopeful', 'tone', 'though', ')', ',', "'", 'I',
"won't", 'have', 'any', 'pepper', 'in', 'my', 'kitchen', 'AT', 'ALL', '.', 'Soup',
'does', 'very', 'well', 'without', '--', 'Maybe', "it's", 'always', 'pepper',
'that', 'makes', 'people', 'hot-tempered', ',', "'", '...']
```

Source: https://www.nltk.org/book/ch03.htm

Symbol	Function
\b	Word boundary (zero width)
\d	Any decimal digit (equivalent to [0-9])
\D	Any non-digit character (equivalent to [^0-9])
\s	Any whitespace character (equivalent to [\t\n\r\f\v])
\S	Any non-whitespace character (equivalent to [^ \t\n\r\f\v])
\w	Any alphanumeric character (equivalent to [a-zA-Z0-9_])
\W	Any non-alphanumeric character (equivalent to [^a-zA-Z0-9_])
\t	The tab character
\n	The newline character

Tokenization in languages without spaces

How about languages that don't use spaces to separate words (like Chinese, Japanese, Thai)?

How do we decide where the token boundaries should be?

Word tokenization in Chinese

- Chinese words are composed of characters called **"hanzi"** (or sometimes just **"zi"**)
- Each one represents a *meaning* unit called a **morpheme**. 词素
- Each word has on average 2.4 of them.
- But deciding what counts as a word is complex and not agreed upon.

Slides credit to Dan Jurafsky: https://web.stanford.edu/~jurafsky/slp3/

How to do word tokenization in Chinese?

- **姚明进入总决赛 “Yao Ming reaches the finals”**

Slides credit to Dan Jurafsky: https://web.stanford.edu/~jurafsky/slp3/

How to do word tokenization in Chinese?

- 姚明进入总决赛 “Yao Ming reaches the finals”

- 3 words?
- 姚明 进入 总决赛
- YaoMing reaches finals

Slides credit to Dan Jurafsky: https://web.stanford.edu/~jurafsky/slp3/

How to do word tokenization in Chinese?

- 姚明进入总决赛 “Yao Ming reaches the finals”

- 3 words?
- 姚明 进入 总决赛
- YaoMing reaches finals

- 5 words?
- 姚 明 进入 总 决赛
- Yao Ming reaches overall finals

Slides credit to Dan Jurafsky: https://web.stanford.edu/~jurafsky/slp3/

How to do word tokenization in Chinese?

- 姚明进入总决赛 "Yao Ming reaches the finals"

- 3 words?
- 姚明 进入 总决赛
- YaoMing reaches finals

- 5 words?
- 姚 明 进入 总 决赛
- Yao Ming reaches overall finals

- 7 characters? (don't use words at all):
- 姚 明 进 入 总 决 赛
- Yao Ming enter enter overall decision game

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Word tokenization / segmentation

In Chinese it's common to just treat each character (zi) as a token.

- So the **segmentation** step is very simple

In other languages (like Thai and Japanese), more complex word segmentation is required.

- The standard algorithms are neural sequence models trained by supervised machine learning.

Slides credit to Dan Jurafsky: https://web.stanford.edu/~jurafsky/slp3/

From a modern Chinese perspective

- 词 word ≠ 字 character
- Roughly, 词 = [字]+
- 中文分词 Chinese word segmentation: Segment a sequence of characters into a list of words

```
seg_list = jieba.cut("我来到北京清华大学", cut_all=False)
print("Default Mode: " + "/ ".join(seg_list))  # 精确模式

seg_list = jieba.cut("他来到了网易杭研大厦")  # 默认是精确模式
print(", ".join(seg_list))

seg_list = jieba.cut_for_search("小明硕士毕业于中国科学院计算所，后在日本京都大学深造")  # 搜索引擎模式
print(", ".join(seg_list))
```

Source: https://github.com/fxsjy/jieba

【精确模式】: 我/ 来到/ 北京/ 清华大学

【新词识别】: 他, 来到, 了, 网易, 杭研, 大厦 (此处，"杭研"并没有在词典中，但是也被Viterbi算法识别出来了)

【搜索引擎模式】: 小明, 硕士, 毕业, 于, 中国, 科学, 学院, 科学院, 中国科学院, 计算, 计算所, 后, 在, 日本, 京都, 大学, 日本京都大学, 深造