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/

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  - Install Python and Jupyter
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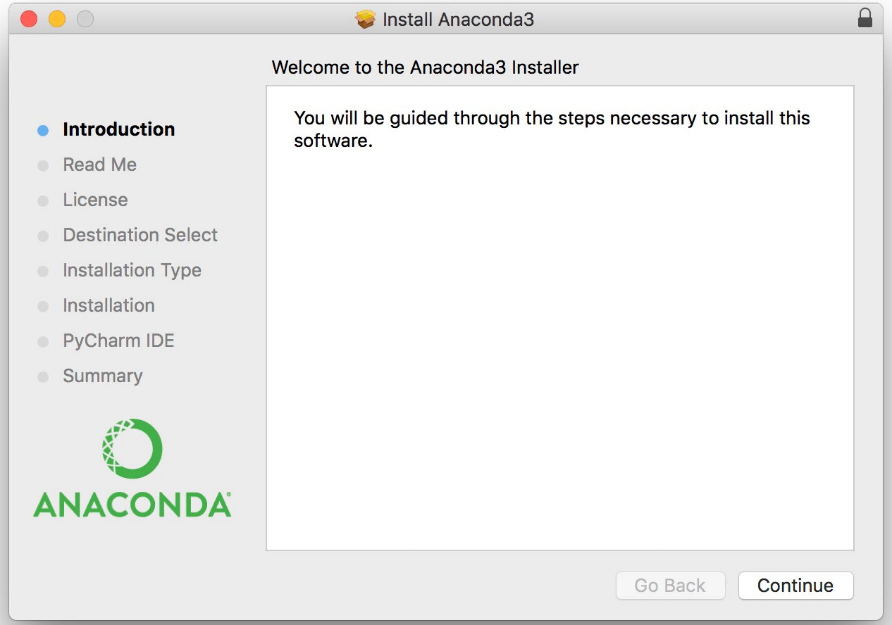
- Basic Text Processing

Python Installation

- Python installation via anaconda is recommended

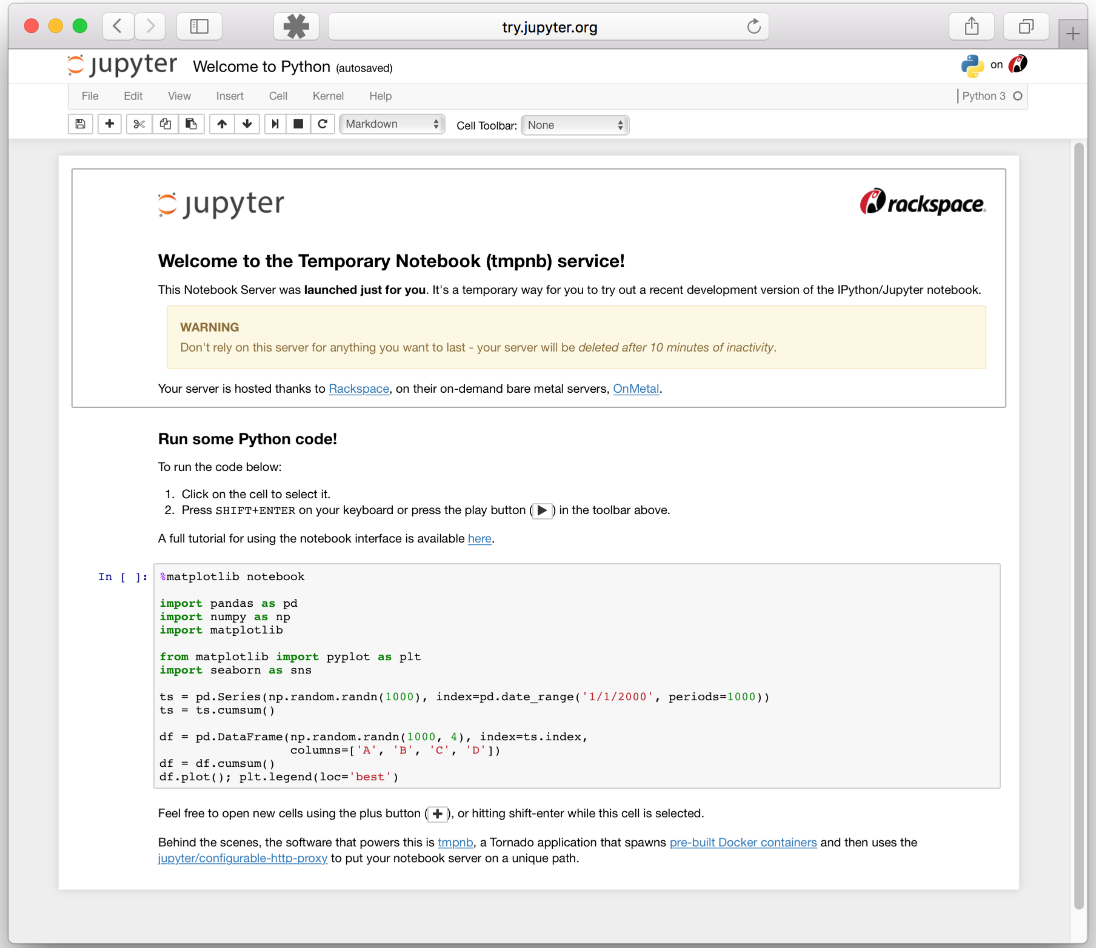


Link: https://www.anaconda.com/distribution/
==> choose the distribution that suits you

Python 3.8 - 3.11 is recommended

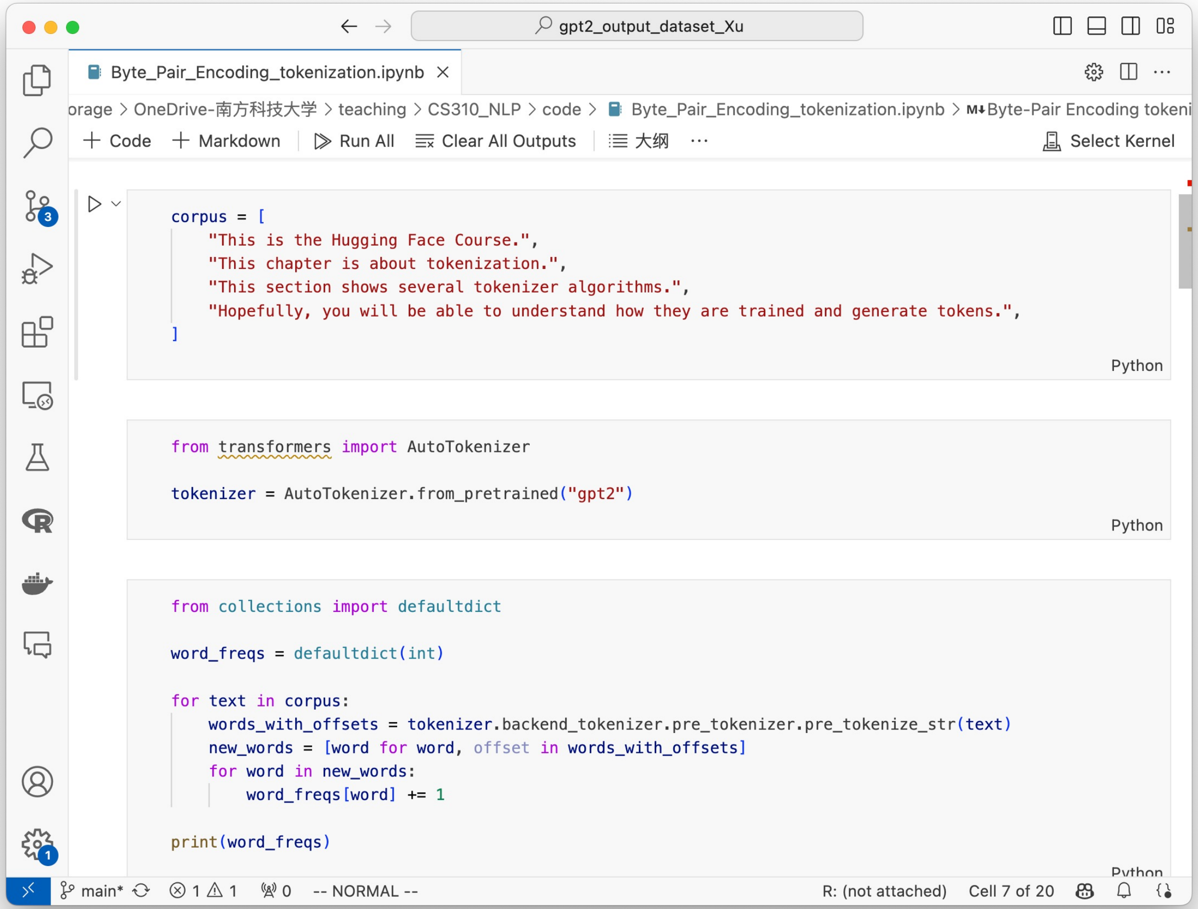
Jupyter Installation

- 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

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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

Pattern	Matches
groundhog|woodchuck	woodchuck
yours|mine	yours
a|b|c	= [abc]
[gG]roundhog|[Ww]oodchuck	Woodchuck

Regular Expressions: ? * + .

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

Stephen C Kleene

Kleene *, Kleene +

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 process we just went through was based on fixing 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.

- In NLP we are always dealing with these kinds of errors.
- Reducing the error rate for an application often involves two antagonistic efforts:
  - Increasing accuracy or precision (minimizing false positives)
  - Increasing coverage or 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')]
```

Regular expression for Chinese characters

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

✓ 0.0s

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

✓ 0.0s

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

```
re.findall(r'[一-龟]', raw)
```

✓ 0.0s

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

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

✓ 0.0s

```
['以及数字1234']
```

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

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

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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 < β < .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.
  - AAE Twitter posts might include forms like "*iont" (I don't)*
- **Code switching**, e.g., Spanish/English, Hindi/English:

  S/E: Por primera vez veo a @username actually being hateful! It was beautiful:)

  [For the first time I get to see @username actually being hateful! it was beautiful:)]

  H/E: dost tha or ra- hega ... dont wory ... but dherya rakhe

  ["he was and will remain a friend ... don't worry ... but have faith"]

- **Genre:** newswire, fiction, scientific articles, Wikipedia
- **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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  - **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

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

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?

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

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 (MWE) 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,'..."]
```

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

```
>>> 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', ',', "'", '...']
```

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

Many languages (like Chinese, Japanese, Thai) don't use spaces to separate words!

How do we decide where the token boundaries should be?

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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.

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

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

Word tokenization / segmentation

So 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