INTRODUCTION TO NATURAL LANGUAGE PROCESSING IN PYTHON

Introduction to regular expressions

Katharine Jarmul
Founder, kjamistan

What is Natural Language Processing?

- Field of study focused on making sense of language
  - Using statistics and computers
- You will learn the basics of NLP
  - Topic identification
  - Text classification
- NLP applications include:
  - Chatbots
  - Translation
  - Sentiment analysis
  - ... and many more!

What exactly are regular expressions?

- Strings with a special syntax
- Allow us to match patterns in other strings
- Applications of regular expressions:
  - Find all web links in a document
  - Parse email addresses, remove/replace unwanted characters

```
In [1]: import re

In [2]: re.match('abc', 'abcdef')
Out[2]: <_sre.SRE_Match object; span=(0, 3), match='abc'>

In [3]: word_regex = '\w+'

In [4]: re.match(word_regex, 'hi there!')
Out[4]: <_sre.SRE_Match object; span=(0, 2), match='hi'>
```

Common Regex Patterns

pattern	matches	example
\w+	word	'Magic'

Common Regex patterns (2)

pattern	matches	example
\w+	word	'Magic'
\d	digit	9

Common regex patterns (3)

pattern	matches	example
\w+	word	'Magic'
\d	digit	9
\s	space	' '

Common regex patterns (4)

pattern	matches	example
\w+	word	'Magic'
\d	digit	9
\s	space	' '
.*	wildcard	'username74'

Common regex patterns (5)

pattern	matches	example
\w+	word	'Magic'
\d	digit	9
\s	space	' '
.*	wildcard	'username74'
+ or *	greedy match	'aaaaaa'

Common regex patterns (6)

pattern	matches	example
\w+	word	'Magic'
\d	digit	9
\s	space	' '
.*	wildcard	'username74'
+ or *	greedy match	'aaaaaa'
\S	**not** space	'no_spaces'

Common regex patterns (7)

pattern	matches	example
\w+	word	'Magic'
\d	digit	9
\s	space	' '
.*	wildcard	'username74'
+ or *	greedy match	'aaaaaa'
\S	**not** space	'no_spaces'
[a-z]	lowercase group	'abcdefg'

Python's re Module

- `re` module
- `split`: split a string on regex
- `findall`: find all patterns in a string
- `search`: search for a pattern
- `match`: match an entire string or substring based on a pattern
- Pattern first, and the string second
- May return an iterator, string, or match object

```
In [5]: re.split('\s+', 'Split on spaces.')
Out[5]: ['Split', 'on', 'spaces.']
```

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Introduction to tokenization

Katharine Jarmul
Founder, kjamistan

What is tokenization?

- Turning a string or document into **tokens** (smaller chunks)
- One step in preparing a text for NLP
- Many different theories and rules
- You can create your own rules using regular expressions
- Some examples:
  - Breaking out words or sentences
  - Separating punctuation
  - Separating all hashtags in a tweet

nltk library

- `nltk`: natural language toolkit

```
In [1]: from nltk.tokenize import word_tokenize

In [2]: word_tokenize("Hi there!")
Out[2]: ['Hi', 'there', '!']
```

Why tokenize?

- Easier to map part of speech
- Matching common words
- Removing unwanted tokens
- "I don't like Sam's shoes."
- "I", "do", "n't", "like", "Sam", "'s", "shoes", "."

Other nltk tokenizers

- `sent_tokenize`: tokenize a document into sentences
- `regexp_tokenize`: tokenize a string or document based on a regular expression pattern
- `TweetTokenizer`: special class just for tweet tokenization, allowing you to separate hashtags, mentions and lots of exclamation points!!!

More regex practice

- Difference between `re.search()` and `re.match()`

```
In [1]: import re

In [2]: re.match('abc', 'abcde')
Out[2]: <_sre.SRE_Match object; span=(0, 3), match='abc'>

In [3]: re.search('abc', 'abcde')
Out[3]: <_sre.SRE_Match object; span=(0, 3), match='abc'>

In [4]: re.match('cd', 'abcde')

In [5]: re.search('cd', 'abcde')
Out[5]: <_sre.SRE_Match object; span=(2, 4), match='cd'>
```

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Advanced tokenization with regex

Katharine Jarmul
Founder, kjamistan

Regex groups using or "|"

- OR is represented using `|`
- You can define a group using `()`
- You can define explicit character ranges using `[]`

```
In [1]: import re

In [2]: match_digits_and_words = ('(\d+|\w+)')

In [3]: re.findall(match_digits_and_words, 'He has 11 cats.')
Out[3]: ['He', 'has', '11', 'cats']
```

Regex ranges and groups

pattern	matches	example
[A-Za-z]+	upper and lowercase English alphabet	'ABCDEFghijk'
[0-9]	numbers from 0 to 9	9
[A-Za-z\-\.]+	upper and lowercase English alphabet, - and .	'My-Website.com'
(a-z)	a, - and z	'a-z'
(\s+l,)	spaces or a comma	', '

Character range with re.match()

```
In [1]: import re

In [2]: my_str = 'match lowercase spaces nums like 12, but no commas'

In [3]: re.match('[a-z0-9 ]+', my_str)
Out[3]: <_sre.SRE_Match object;
          span=(0, 42), match='match lowercase spaces nums like 12'>
```

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Charting word length with nltk

Katharine Jarmul
Founder, kjamistan

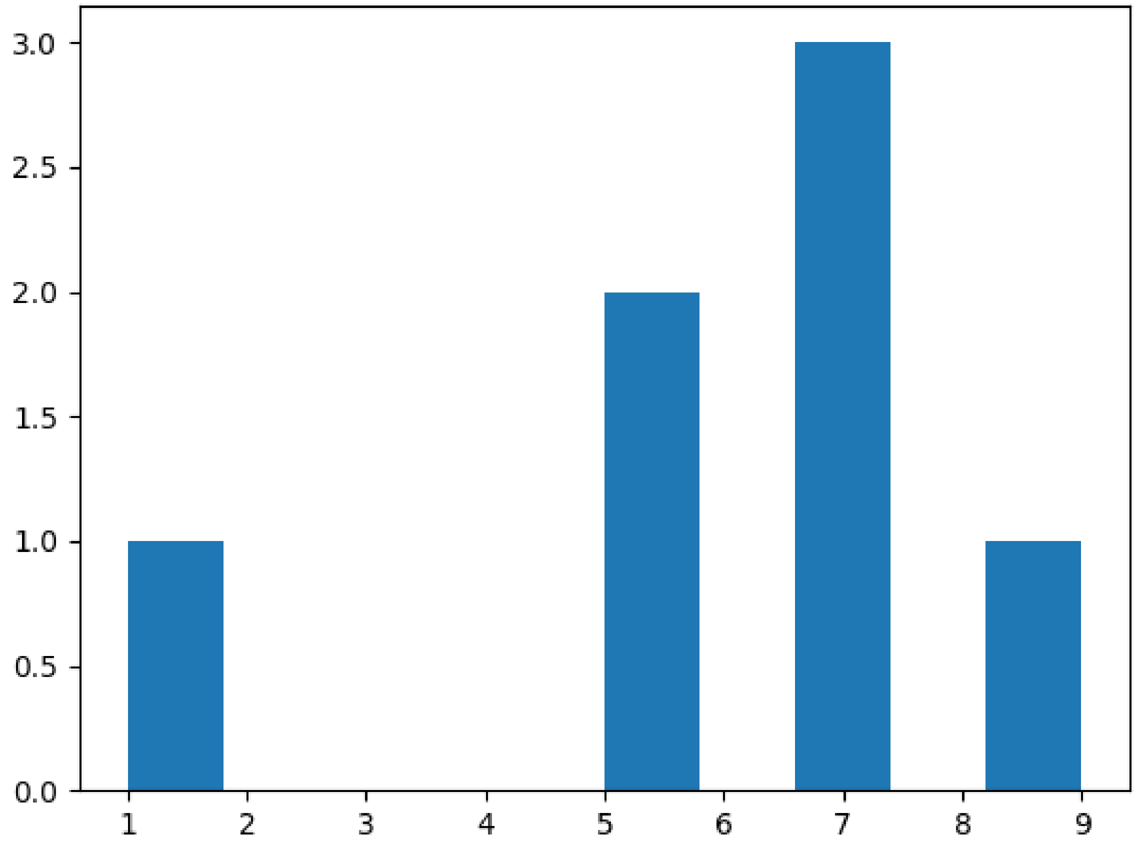
Getting started with matplotlib

- Charting library used by many open source Python projects
- Straightforward functionality with lots of options
  - Histograms
  - Bar charts
  - Line charts
  - Scatter plots
- ... and also advanced functionality like 3D graphs and animations!

Plotting a histogram with matplotlib

```
In [1]: from matplotlib import pyplot as plt

In [2]: plt.hist([1, 5, 5, 7, 7, 7, 9])
Out[2]: (array([ 1.,  0.,  0.,  0.,  0.,  2.,  0.,  3.,  0.,  1.]),
        array([ 1. ,  1.8,  2.6,  3.4,  4.2,  5. ,  5.8,  6.6,
                 7.4,  8.2,  9. ]),
        <a list of 10 Patch objects>)

In [3]: plt.show()
```

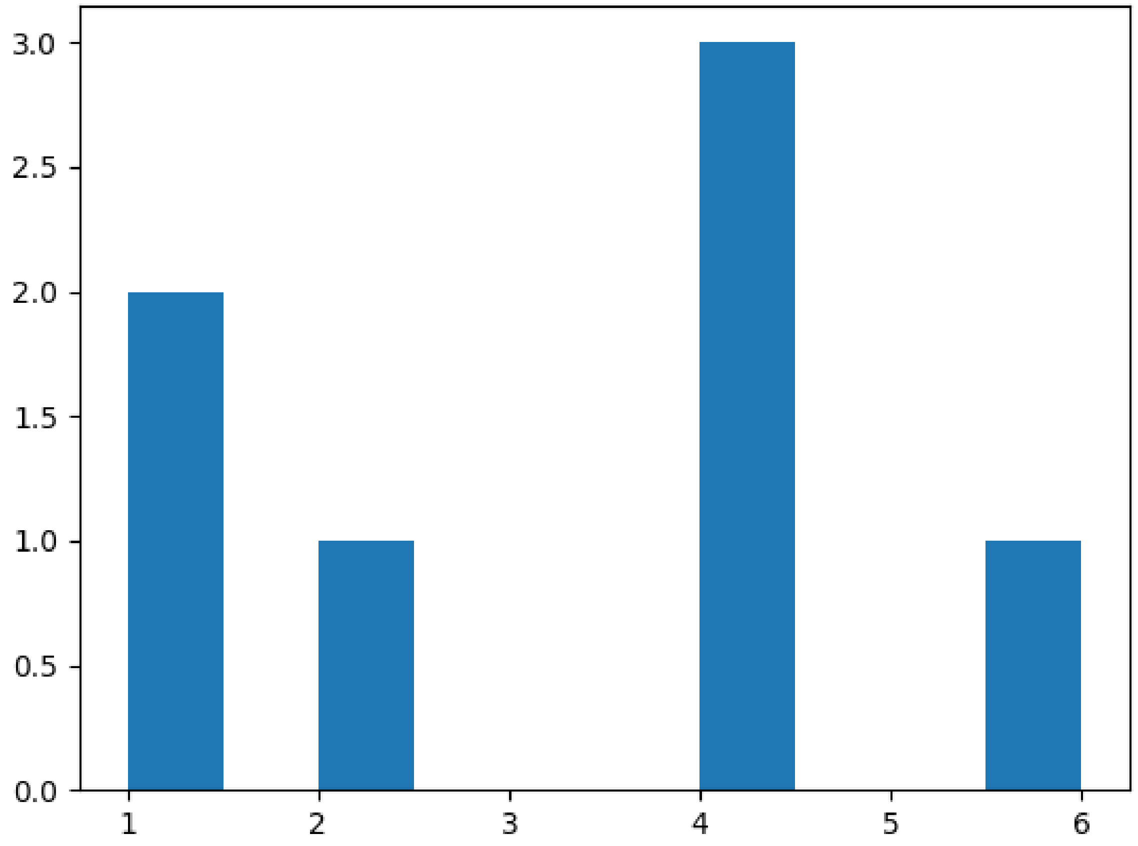
Generated Histogram



Combining NLP data extraction with plotting

```
In [1]: from matplotlib import pyplot as plt

In [2]: from nltk.tokenize import word_tokenize

In [3]: words = word_tokenize("This is a pretty cool tool!")

In [4]: word_lengths = [len(w) for w in words]

In [5]: plt.hist(word_lengths)
Out[5]: (array([ 2.,  0.,  1.,  0.,  0.,  0.,  3.,  0.,  0.,  1.]),
        array([ 1. ,  1.5,  2. ,  2.5,  3. ,  3.5,  4. ,  4.5,  5. ,  5.5,
                6. ]),
        <a list of 10 Patch objects>)

In [6]: plt.show()
```

Word length histogram



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Word counts with bag-of-words

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Bag-of-words

- Basic method for finding topics in a text
- Need to first create tokens using tokenization
- ... and then count up all the tokens
- The more frequent a word, the more important it might be
- Can be a great way to determine the significant words in a text

Bag-of-words example

- Text: "The cat is in the box. The cat likes the box. The box is over the cat."
- Bag of words (stripped punctuation):
  - "The": 3, "box": 3
  - "cat": 3, "the": 3
  - "is": 2
  - "in": 1, "likes": 1, "over": 1

Bag-of-words in Python

```
In [1]: from nltk.tokenize import word_tokenize

In [2]: from collections import Counter

In [3]: Counter(word_tokenize(
                """The cat is in the box. The cat likes the box.
                 The box is over the cat."""))
Out[3]:
Counter({'.': 3,
         'The': 3,
         'box': 3,
         'cat': 3,
         'in': 1,
         ...
         'the': 3})

In [4]: counter.most_common(2)
Out[4]: [('The', 3), ('box', 3)]
```

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Simple text preprocessing

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Founder, kjamistan

Why preprocess?

- Helps make for better input data
  - When performing machine learning or other statistical methods
- Examples:
  - Tokenization to create a bag of words
  - Lowercasing words
- Lemmatization/Stemming
  - Shorten words to their root stems
- Removing stop words, punctuation, or unwanted tokens
- Good to experiment with different approaches

Preprocessing example

- Input text: Cats, dogs and birds are common pets. So are fish.
- Output tokens: cat, dog, bird, common, pet, fish

Text preprocessing with Python

```
In [1]: from ntlk.corpus import stopwords

In [2]: text = """The cat is in the box. The cat likes the box.
                  The box is over the cat."""

In [3]: tokens = [w for w in word_tokenize(text.lower())
                  if w.isalpha()]

In [4]: no_stops = [t for t in tokens
                    if t not in stopwords.words('english')]

In [5]: Counter(no_stops).most_common(2)
Out[5]: [('cat', 3), ('box', 3)]
```

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Introduction to gensim

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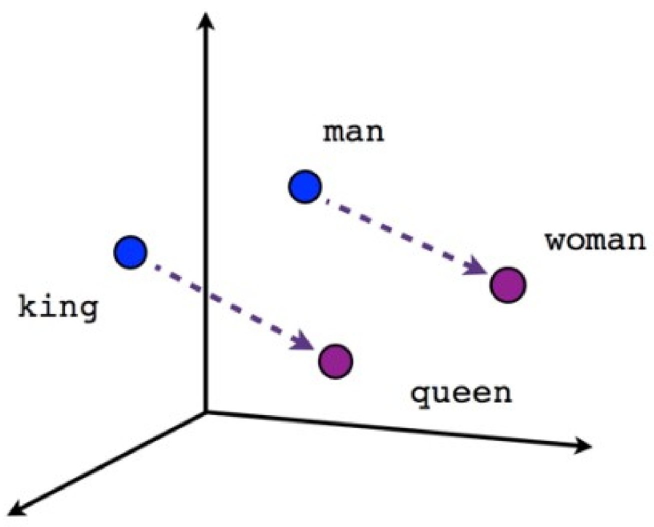
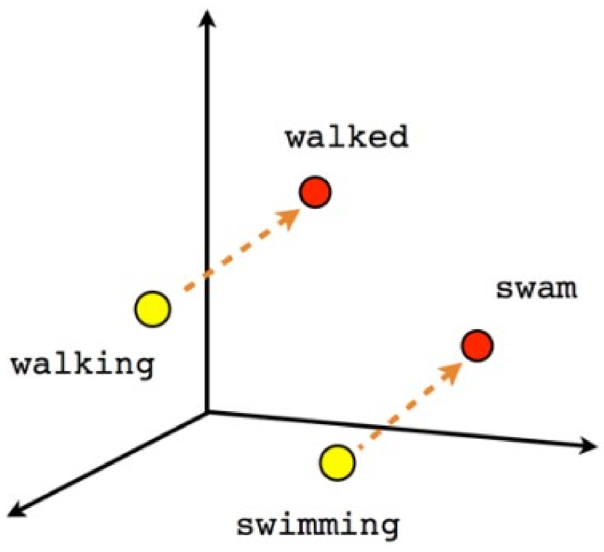
What is gensim?

- Popular open-source NLP library
- Uses top academic models to perform complex tasks
  - Building document or word vectors
  - Performing topic identification and document comparison

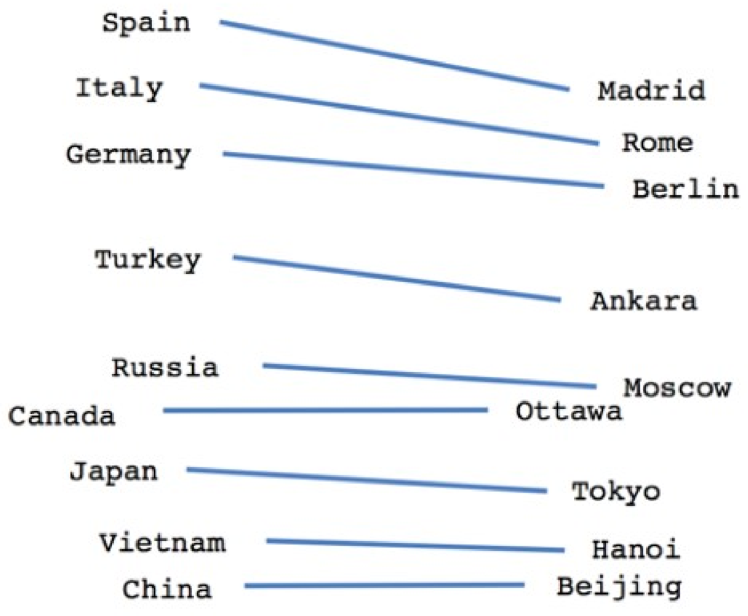
What is a word vector?



Male-Female

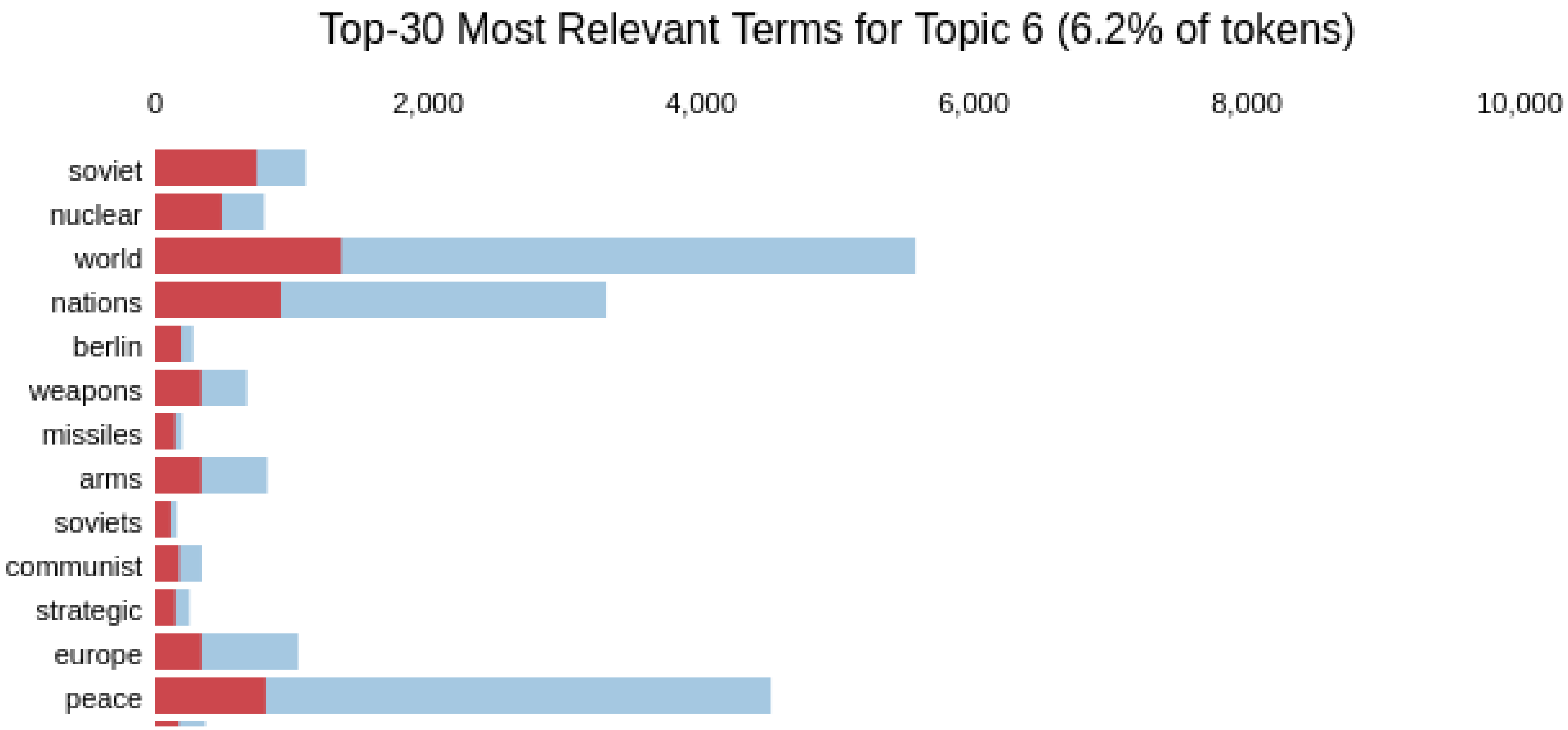


Verb tense



Country-Capital

Gensim Example



(Source: http://tlfvincent.github.io/2015/10/23/presidential-speech-topics)

Creating a gensim dictionary

```
In [1]: from gensim.corpora.dictionary import Dictionary

In [2]: from nltk.tokenize import word_tokenize

In [3]: my_documents = ['The movie was about a spaceship and aliens.',
   ...:                 'I really liked the movie!',
   ...:                 'Awesome action scenes, but boring characters.',
   ...:                 'The movie was awful! I hate alien films.',
   ...:                 'Space is cool! I liked the movie.',
   ...:                 'More space films, please!',]

In [4]: tokenized_docs = [word_tokenize(doc.lower())
   ...:                   for doc in my_documents]

In [5]: dictionary = Dictionary(tokenized_docs)

In [6]: dictionary.token2id
Out[6]:
{'!': 11,
 ',': 17,
 '.': 7,
 'a': 2,
 'about': 4,
...
}
```

Creating a gensim corpus

```
In [7]: corpus = [dictionary.doc2bow(doc) for doc in tokenized_docs]

In [8]: corpus
Out[8]:
[[(0, 1), (1, 1), (2, 1), (3, 1), (4, 1), (5, 1), (6, 1), (7, 1), (8, 1)],
 [(0, 1), (1, 1), (9, 1), (10, 1), (11, 1), (12, 1)],
...
]
```

- `gensim` models can be easily saved, updated, and reused
- Our dictionary can also be updated
- This more advanced and feature rich bag-of-words can be used in future exercises

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Tf-idf with gensim

Katharine Jarmul
Founder, kjamistan

What is tf-idf?

- Term frequency - inverse document frequency
- Allows you to determine the most important words in each document
- Each corpus may have shared words beyond just stopwords
- These words should be down-weighted in importance
- Example from astronomy: "Sky"
- Ensures most common words don't show up as key words
- Keeps document specific frequent words weighted high

Tf-idf formula

$$w_{i,j} = tf_{i,j} * \log(\frac{N}{df_i})$$

$$w_{i,j} = \text{tf-idf weight for token } i \text{ in document } j$$

$$tf_{i,j} = \text{number of occurences of token } i \text{ in document } j$$

$$df_i = \text{number of documents that contain token } i$$

$$N = \text{total number of documents}$$

Tf-idf with gensim

```
In [10]: from gensim.models.tfidfmodel import TfidfModel

In [11]: tfidf = TfidfModel(corpus)

In [12]: tfidf[corpus[1]]
Out[12]:
[(0, 0.1746298276735174),
 (1, 0.1746298276735174),
 (9, 0.29853166221463673),
 (10, 0.7716931521027908),
...
]
```

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Named Entity Recognition

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What is Named Entity Recognition?

- NLP task to identify important named entities in the text
  - People, places, organizations
  - Dates, states, works of art
  - ... and other categories!
- Can be used alongside topic identification
  - ... or on its own!
- Who? What? When? Where?

Example of NER

In 1917, Einstein applied the general theory of relativity to model the large-scale structure of the universe. He was visiting the United States when Adolf Hitler came to power in 1933 and did not go back to Germany, where he had been a professor at the Berlin Academy of Sciences. He settled in the U.S., becoming an American citizen in 1940. On the eve of World War II, he endorsed a letter to President Franklin D. Roosevelt alerting him to the potential development of "extremely powerful bombs of a new type" and recommending that the U.S. begin similar research. This eventually led to what would become the Manhattan Project. Einstein supported defending the Allied forces, but largely denounced using the new discovery of nuclear fission as a weapon. Later, with the British philosopher Bertrand Russell, Einstein signed the Russell-Einstein Manifesto, which highlighted the danger of nuclear weapons. Einstein was affiliated with the Institute for Advanced Study in Princeton, New Jersey, until his death in 1955.

Tag colours:

LOCATION TIME PERSON ORGANIZATION MONEY PERCENT DATE

(Source: Europeana Newspapers (http://www.europeana-newspapers.eu))

nltk and the Stanford CoreNLP Library

- The Stanford CoreNLP library:
  - Integrated into Python via `nltk`
  - Java based
  - Support for NER as well as coreference and dependency trees

Using nltk for Named Entity Recognition

```
In [1]: import nltk

In [2]: sentence = '''In New York, I like to ride the Metro to visit MOMA
                     and some restaurants rated well by Ruth Reichl.'''

In [3]: tokenized_sent = nltk.word_tokenize(sentence)

In [4]: tagged_sent = nltk.pos_tag(tokenized_sent)

In [5]: tagged_sent[:3]
Out[5]: [('In', 'IN'), ('New', 'NNP'), ('York', 'NNP')]
```

nltk's ne_chunk()

```
In [6]: print(nltk.ne_chunk(tagged_sent))
(S
  In/IN
  (GPE New/NNP York/NNP)
  ,/,
  I/PRP
  like/VBP
  to/TO
  ride/VB
  the/DT
  (ORGANIZATION Metro/NNP)
  to/TO
  visit/VB
  (ORGANIZATION MOMA/NNP)
  and/CC
  some/DT
  restaurants/NNS
  rated/VBN
  well/RB
  by/IN
  (PERSON Ruth/NNP Reichl/NNP)
  ./.)
```

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Introduction to SpaCy

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Founder, kjamistan

What is SpaCy?

- NLP library similar to `gensim`, with different implementations
- Focus on creating NLP pipelines to generate models and corpora
- Open-source, with extra libraries and tools
  - Displacy

Displacy entity recognition visualizer

In New York GPE , I like to ride the Metro to visit MOMA ORG and some restaurants rated well by Ruth Reichl PERSON .

(source: https://demos.explosion.ai/displacy-ent/)

SpaCy NER

```
In [1]: import spacy

In [2]: nlp = spacy.load('en')

In [3]: nlp.entity
Out[3]: <spacy.pipeline.EntityRecognizer at 0x7f76b75e68b8>

In [4]: doc = nlp("""Berlin is the capital of Germany;
                  and the residence of Chancellor Angela Merkel.""")

In [5]: doc.ents
Out[5]: (Berlin, Germany, Angela Merkel)

In [6]: print(doc.ents[0], doc.ents[0].label_)
Berlin GPE
```

Why use SpaCy for NER?

- Easy pipeline creation
- Different entity types compared to `nltk`
- Informal language corpora
    - Easily find entities in Tweets and chat messages
- Quickly growing!

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Multilingual NER with polyglot

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What is polyglot?

- NLP library which uses word vectors
- Why `polyglot`?
  - Vectors for many different languages
  - More than 130!

```
which      ويكه
India      يند يا
beat       بيت
Bermuda    بيرمودا
in         ين
Port       بورت
of         وف
Spain      سبا ين
in         ين
2007
,
which      ويكه
was        واس
equalled   يكالليد
five       فيفي
days       دايس
ago        اغو
by         بي
South      سووث
Africa     افريكا
in         ين
their      ثير
victory    فيكتوري
over       وفير
West       ويست
Indies     يندييس
in         ين
Sydney     سيدني
.
```

Spanish NER with polyglot

```
In [1]: from polyglot.text import Text

In [2]: text = """El presidente de la Generalitat de Cataluña,
                  Carles Puigdemont, ha afirmado hoy a la alcaldesa
                  de Madrid, Manuela Carmena, que en su etapa de
                  alcalde de Girona (de julio de 2011 a enero de 2016)
                  hizo una gran promoción de Madrid."""

In [3]: ptext = Text(text)

In [4]: ptext.entities
Out[4]:
[I-ORG(['Generalitat', 'de']),
 I-LOC(['Generalitat', 'de', 'Cataluña']),
 I-PER(['Carles', 'Puigdemont']),
 I-LOC(['Madrid']),
 I-PER(['Manuela', 'Carmena']),
 I-LOC(['Girona']),
 I-LOC(['Madrid'])]
```

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Classifying fake news using supervised learning with NLP

Katharine Jarmul
Founder, kjamistan

What is supervised learning?

- Form of machine learning
  - Problem has predefined training data
  - This data has a label (or outcome) you want the model to learn
  - Classification problem
  - Goal: Make good hypotheses about the species based on geometric features

Sepal Length	Sepal Width	Petal Length	Petal Width	Species
5.1	3.5	1.4	0.2	I. setosa
7.0	3.2	4.77	1.4	I.versicolor
6.3	3.3	6.0	2.5	I.virginica

Supervised learning with NLP

- Need to use language instead of geometric features
- `scikit-learn`: Powerful open-source library
- How to create supervised learning data from text?
  - Use bag-of-words models or tf-idf as features

IMDB Movie Dataset

Plot	Sci-Fi	Action
In a post-apocalyptic world in human decay, a ...	1	0
Mohei is a wandering swordsman. He arrives in ...	0	1
#137 is a SCI/FI thriller about a girl, Marla,...	1	0

- Goal: Predict movie genre based on plot summary
- Categorical features generated using preprocessing

Supervised learning steps

- Collect and preprocess our data
- Determine a label (Example: Movie genre)
- Split data into training and test sets
- Extract features from the text to help predict the label
  - Bag-of-words vector built into `scikit-learn`
- Evaluate trained model using the test set

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Building word count vectors with scikit-learn

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Predicting movie genre

- Dataset consisting of movie plots and corresponding genre
- Goal: Create bag-of-word vectors for the movie plots
    - Can we predict genre based on the words used in the plot summary?

Count Vectorizer with Python

```
In [1]: import pandas as pd

In [2]: from sklearn.model_selection import train_test_split

In [3}: from sklearn.feature_extraction.text import CountVectorizer

In [4]: df = ... # Load data into DataFrame

In [5]: y = df['Sci-Fi']

In [6]: X_train, X_test, y_train, y_test = train_test_split(
                                             df['plot'], y,
                                             test_size=0.33,
                                             random_state=53)

In [7]: count_vectorizer = CountVectorizer(stop_words='english')

In [8]: count_train = count_vectorizer.fit_transform(X_train.values)

In [9]: count_test = count_vectorizer.transform(X_test.values)
```

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Training and testing a classification model with scikit-learn

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Naive Bayes classifier

- Naive Bayes Model
  - Commonly used for testing NLP classification problems
  - Basis in probability
- Given a particular piece of data, how likely is a particular outcome?
- Examples:
  - If the plot has a spaceship, how likely is it to be sci-fi?
  - Given a spaceship **and** an alien, how likely **now** is it sci-fi?
- Each word from `CountVectorizer` acts as a feature
- Naive Bayes: Simple and effective

Naive Bayes with scikit-learn

```
In  [10]: from sklearn.naive_bayes import MultinomialNB

In  [11]: from sklearn import metrics

In  [12]: nb_classifier = MultinomialNB()

In  [13]: nb_classifier.fit(count_train, y_train)

In  [14]: pred = nb_classifier.predict(count_test)

In  [15]: metrics.accuracy_score(y_test, pred)
Out [15]: 0.85841849389820424
```

Confusion Matrix

```
In  [16]: metrics.confusion_matrix(y_test, pred, labels=[0,1])
Out [16]:
array([[6410,  563],
       [ 864, 2242]])
```

	Action	Sci-Fi
Action	6410	563
Sci-Fi	864	2242

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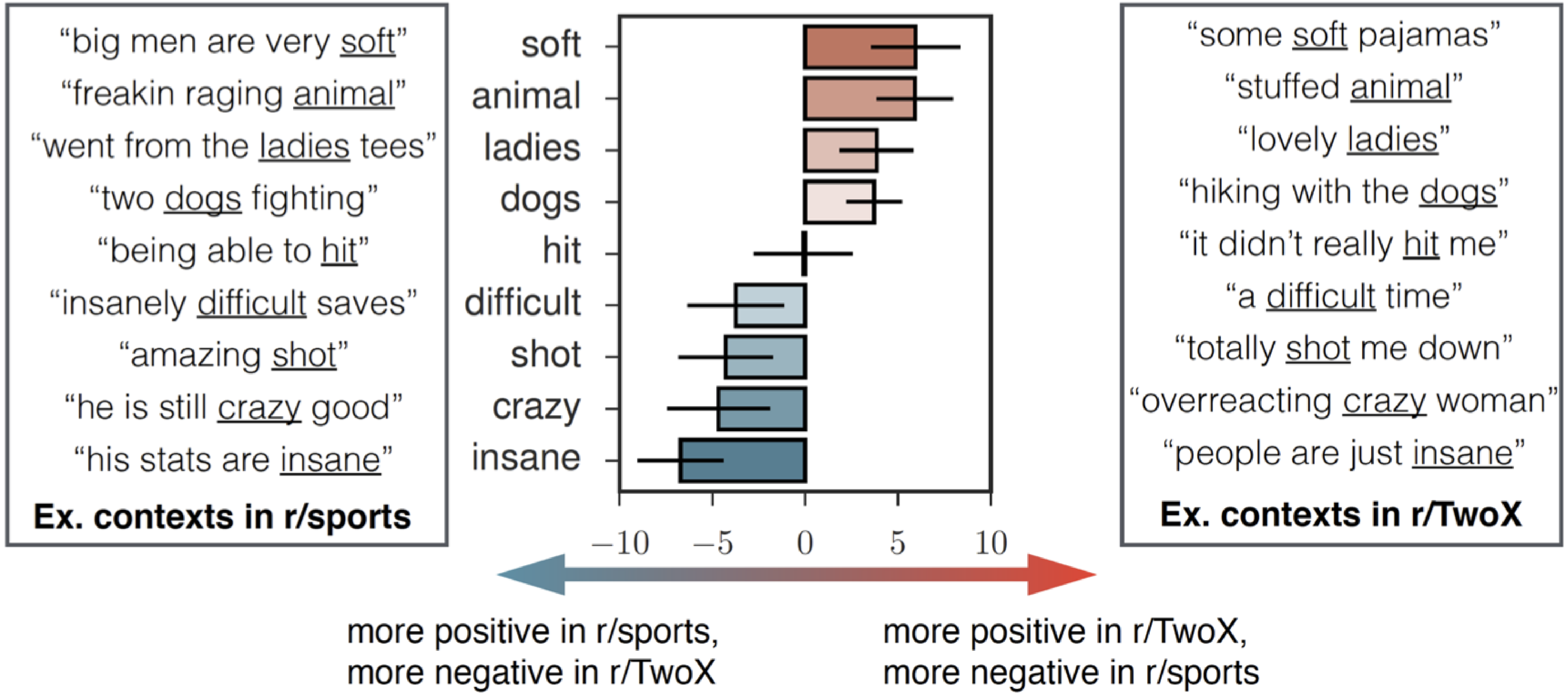
Simple NLP, Complex Problems

Katharine Jarmul
Founder, kjamistan

Translation

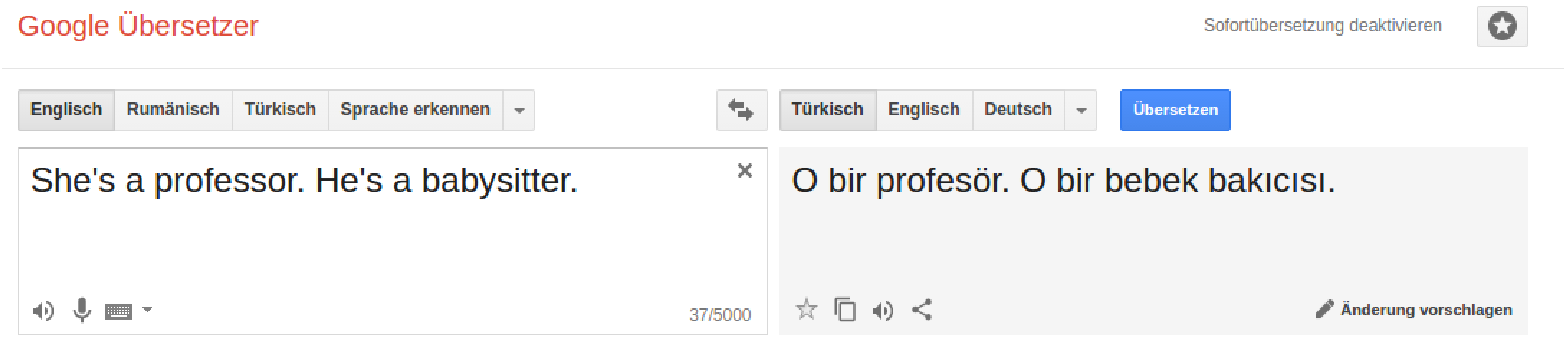
(source: https://twitter.com/Lupintweets/status/865533182455685121)

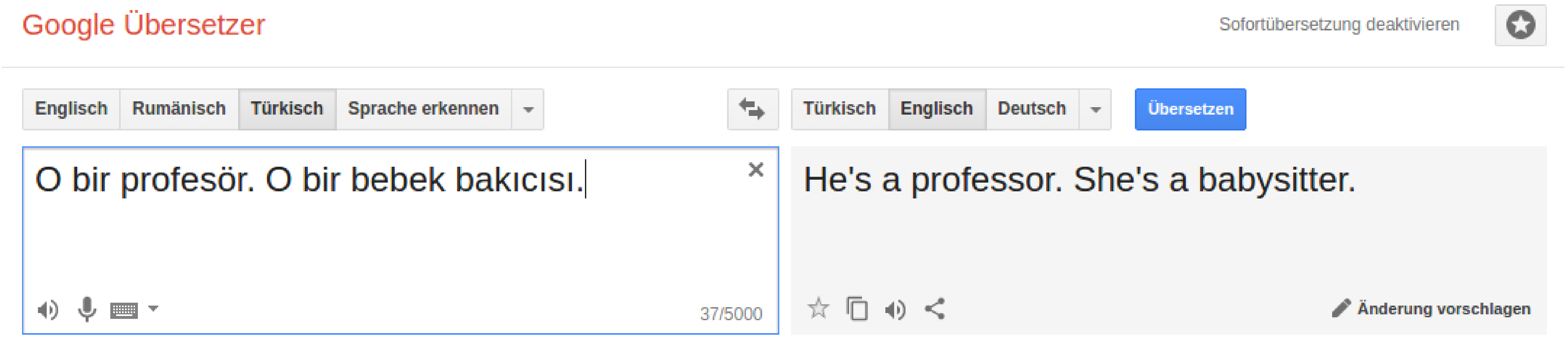
Sentiment Analysis



(source: https://nlp.stanford.edu/projects/socialsent/)

Language Biases





(related talk: https://www.youtube.com/watch?v=j7FwpZB1hWc)

INTRODUCTION TO NATURAL LANGUAGE PROCESSING IN PYTHON

Let's practice!