NYC DATA SCIENCE ACADEMY

Introduction to Natural Language Processing

Data Science Bootcamp

Background

What is NLP?

Natural Language Processing

Computational Linguistics

Speech Recognition

Computational Psycholinguistics

Foundation of Linguistics

Phonetics and Phonology	The study of sounds
Morphology	The study of the meaningful components of words
Syntax	The study of the structural relationship between words
Semantics	The study of meaning
Pragmatics	The study of how language is used to accomplish goals
Discourse	The study of linguistic units larger than a single utterance

What is the big problem with language?

Ambiguity

All of the models and algorithms in NLP are aiming at reducing ambiguity.

Examples:

- POS tagging
- Probabilistic Parsing

How do we reduce ambiguity?

- Text Normalization
  - We will talk more about how to do this today, but first...

Regular Expressions

What is regular expression?

The standard notation for characterizing text sequences.

Regular Expressions: Basics

[Pp]erson		Person, person
[0123456789]		Any digit
[A-Z]		Any uppercase letter
[a-z]		Any lowercase letter
[0-9]		Any single digit
[^1]		Negation: Not a one
/a/	matches any “a” but not “A”	My name is Andrew.
/name␣is/		My name is Andrew.

Regular Expressions: ? * + .

colou?r	Optional previous character	color, colour
oo*h!	0 or more of previous character	oh!, ooh!, oooh!, ooooh!, etc…
o+h!	1 or more of previous character	oh!, ooh!, oooh!, ooooh!, etc…
baa+		baa, baaa, baaaa, etc...
beg.n		begin, begun, beg3n, beg'n, etc...

Regular Expressions: Anchors

\.$	The end.
^[A-Z]	New York

Example

Find all instances of “an” in a text.

'an '	Misses caps
' \b[Aa]n\b '	What we want
'[Aa]n'	Also returns words like “canal” and “anova”

What types of error are we trying to fix?

What types of error are we trying to fix?

Type I Error (False Positive)

Matching strings we don't want : "canal" and "anova"

Type II Error (False Negative)

Not matching the ones we want : when we miss caps

Working with words

How many words?

So, uh, yeah. I think we coul-, no, should do this.

- Fragments, pauses, fillers

That boy is not like the other boys.

- lemma - same stem
  - boy and boys
- Wordform - inflections
  - boy and boys

NOTE: The term tokenization can be used as a synonym for **text segmentation**.

However, in **lexical analysis**, tokenization refers to breaking up a stream of text into meaningful units (usually words or **clitics**). In this case, it is a specific type of text segmentation.

How many words?

their first time in the city and their last time as they were before they had

Type: element

Token: instance of type

How many types?

How many tokens?

Common Tokenization Problems

- boy boys boy's
- Uppercase upper case upper-case
- I'm you're what're should've
- state-of-the-art
- New York City (one token or three)
- M.B.A.
- New York-based (where should we split?)

Normalization

- N.Y.C. and NYC and New York City and New York
- can’t and cannot

Powerful but not very efficient!

Common Normalization Methods

- Case Folding
- Lemmatization

Lemmatization

- am, are, is, was, been → be
- book, books, book's, books' → book

The books' bindings are beautiful. → *The book binding be beautiful.*

Very useful for translation algorithms!

Stemming

In morphology:

- Stems ⟶ Base meaning
- Affixes ⟶ Modifier

produc = produce, produces, production, productive, productively

Porter Stemmer

The Porter algorithm is one of the most common stemmers in English. There are other stemmers which can be used but they will vary depending on the end result desired. No stemming algorithm is perfect and all of them will present both Type I and Type II errors.

*For the purposes, of this class we will be using this algorithm.

To see more details about how this algorithm stems:

http://snowball.tartarus.org/algorithms/porter/stemmer.html

Alternative stemming algorithms include: Snowball, Lancaster, ISRI, Regexp, etc…

NLTK

Prepare Our Environment

```
from bs4 import BeautifulSoup
import urllib2
import re
import nltk
```

NLTK

```
In [36]: nltk.download('all')
[nltk_data] Downloading collection u'all'
[nltk_data]    |
[nltk_data]    | Downloading package abc to /Users/andrew/nltk_data...
[nltk_data]    |   Unzipping corpora/abc.zip.
[nltk_data]    | Downloading package alpino to
[nltk_data]    |     /Users/andrew/nltk_data...
[nltk_data]    |   Unzipping corpora/alpino.zip.
[nltk_data]    | Downloading package biocreative_ppi to
[nltk_data]    |     /Users/andrew/nltk_data...
[nltk_data]    |   Unzipping corpora/biocreative_ppi.zip.
[nltk_data]    | Downloading package brown to
[nltk_data]    |     /Users/andrew/nltk_data...
[nltk_data]    |   Unzipping corpora/brown.zip.
```

Example 1: Creating a Corpus

Project Gutenberg - The Great Gatsby

http://gutenberg.net.au/ebooks02/0200041.txt

Ï»¿

Project Gutenberg Australia

a treasure-trove of literature

treasure found hidden with no evidence of ownership

```
Title:      The Great Gatsby
Author:     F. Scott Fitzgerald
* A Project Gutenberg of Australia eBook *
eBook No.:  0200041.txt
Language:   English
Date first posted:          January 2002
Date most recently updated: July 2008

This eBook was produced by: Colin Choat

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Title:      The Great Gatsby
Author:     F. Scott Fitzgerald



Then wear the gold hat, if that will move her;
```

Creating a Corpus

Scrape the text for the novel, clean it up using regex, and put into a list.

```
url = "http://gutenberg.net.au/ebooks02/0200041.txt"   # URL of book
text = urllib2.urlopen(url).read()                     # Read in the HTML
soup = BeautifulSoup(text, 'html.parser')              # Parse HTML
cleantext = BeautifulSoup.get_text(soup)               # Remove HTML and JS
cleantext = re.sub( '\s+', ' ', cleantext ).strip()    # Remove all whitespace
cleantext = cleantext.lower()                          # All lowercase
cleantext = re.sub( '[.:\',\-!;"()?]', "", cleantext).strip()  # Remove punctuation
corpus = cleantext.split(" ")                          # Tokenize text
corpus
```

Creating a Corpus

```
Out[142]: [u'\xef\xbb\xbf',
           u'project',
           u'gutenberg',
           u'australia',
           u'a',
           u'treasuretrove',
           u'of',
           u'literature',
           u'treasure',
           u'found',
           u'hidden',
           u'with',
           u'no',
           u'evidence',
           u'of',
           u'ownership',
           u'title',
           u'the',
```

Creating a Corpus

Remove text at beginning and end of corpus that doesn't belong to the novel.

```
for x in range(0, len(corpus)):
    if corpus[x] == "chapter":
        break_number_1 = x
        break

for x in range((len(corpus)-1), 0, -1):
    if corpus[x] == "end":
        break_number_2 = x + 1
        break

corpus = corpus[break_number_1 : break_number_2]
corpus
```

Creating a Corpus

```
Out[143]: [u'chapter',
           u'1',
           u'in',
           u'my',
           u'younger',
           u'and',
           u'more',
           u'vulnerable',
           u'years',
           u'my',
           u'father',
           u'gave',
           u'me',
           u'some',
           u'advice',
           u'that',
           u'ive',
           u'been'
```

Creating a Corpus

```
stemmer = nltk.stem.PorterStemmer()                          # Create our stemmer
stemmed_corpus = [stemmer.stem(word) for word in corpus]     # Apply stemmer
```

```
Out[15]: [u'chapter',
          u'1',
          u'in',
          u'my',
          u'younger',
          u'and',
          u'more',
          u'vulner',
          u'year',
          u'my',
          u'father',
          u'gave',
          u'me',
          u'some',
          u'advic',
          u'that',
          u'ive',
          u'been',
          u'turn',
          u'over',
          u'in',
          u'my',
          u'mind',
          u'ever',
          u'sinc',
          u'whenev',
          u'you',
          u'feel',
          u'like',
```

Creating a Corpus

Remember that no stemming algorithm is perfect. What are some problems that you see below?

```
to_be_stemmed = ["monkeys","possesses", "possess", "dogs", "eating",
                 "constitutional", "worthy", "relatable", "had", "was", "ties",
                "ive"]
[stemmer.stem(word) for word in to_be_stemmed]
```

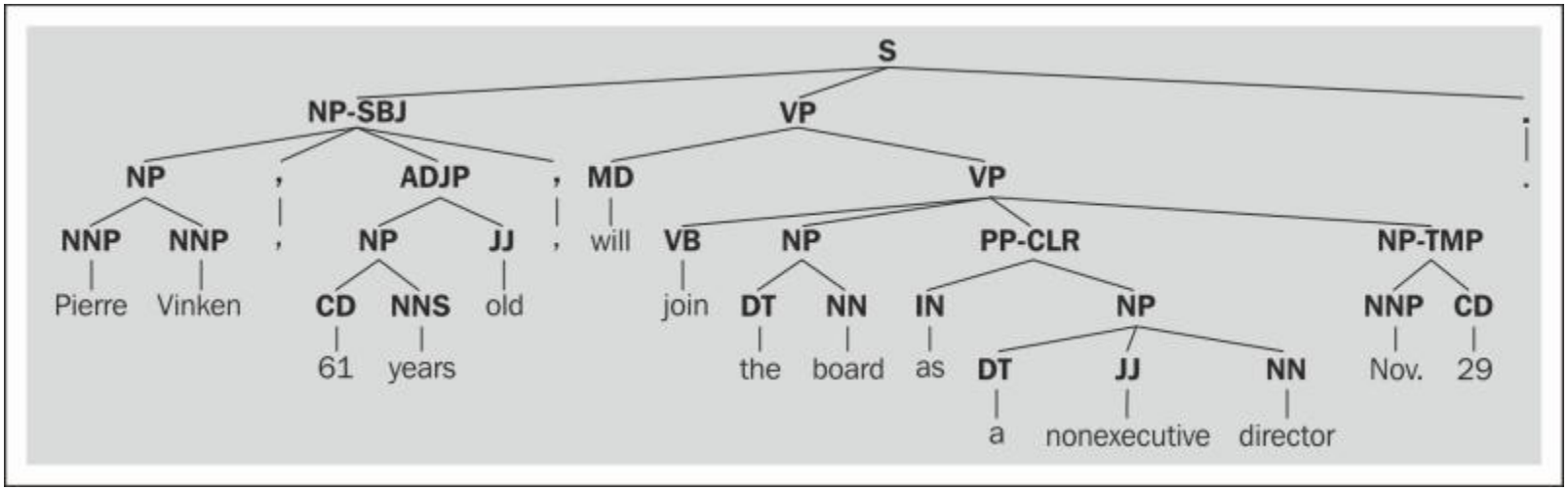
```
Out[6]: [u'monkey',
         u'possess',
         u'possess',
         u'dog',
         u'eat',
         u'constitut',
         u'worthi',
         u'relat',
         u'had',
         u'wa',
         u'tie',
         u'ive']
```

Part-of-Speech Tagging

What is a POS tagger?

The syntactic structure of language lends words to perform a specific structural element in a sentence or longer discourse.

In the field of syntax, this inherent structure is broken down using syntax trees.



Source: https://www.safaribooksonline.com/library/view/python-3-text/9781782167853/ch06s10.html

What problems are inherent when analyzing syntax?

- A word can present itself as various POS in the tree
- Different languages allow for different possibilities in their trees due to differences of information encoded in the lexicon
- Manipulation of syntax by native speakers
- Garden path sentences

POS

In order to look up definitions for all of the parts of speech, you can run this command.

```
nltk.help.upenn_tagset()
```

Note: There is linguistic vocabulary that is beyond the scope of this class in this help lookup. You can use a book like *Speech and Language Processing* or wikipedia as a good resource for learning more.

Just so you can get an idea…

1.	CC	Coordinating conjunction
2.	CD	Cardinal number
3.	DT	Determiner
4.	EX	Existential *there*
5.	FW	Foreign word
6.	IN	Preposition or subordinating conjunction
7.	JJ	Adjective
8.	JJR	Adjective, comparative
9.	JJS	Adjective, superlative
10.	LS	List item marker
11.	MD	Modal
12.	NN	Noun, singular or mass
13.	NNS	Noun, plural
14.	NNP	Proper noun, singular
15.	NNPS	Proper noun, plural
16.	PDT	Predeterminer
17.	POS	Possessive ending
18.	PRP	Personal pronoun
19.	PRP$	Possessive pronoun
20.	RB	Adverb
21.	RBR	Adverb, comparative
22.	RBS	Adverb, superlative
23.	RP	Particle
24.	SYM	Symbol
25.	TO	*to*
26.	UH	Interjection
27.	VB	Verb, base form
28.	VBD	Verb, past tense
29.	VBG	Verb, gerund or present participle
30.	VBN	Verb, past participle
31.	VBP	Verb, non-3rd person singular present
32.	VBZ	Verb, 3rd person singular present
33.	WDT	Wh-determiner
34.	WP	Wh-pronoun
35.	WP$	Possessive wh-pronoun
36.	WRB	Wh-adverb

POS

First tokenize the text.

```
sentence = """At eight o'clock on Thursday morning Arthur didn't feel very good."""
tokens = nltk.word_tokenize(sentence)
tokens
```

```
Out[38]: ['At',
          'eight',
          "o'clock",
          'on',
          'Thursday',
          'morning',
          'Arthur',
          'did',
          "n't",
          'feel',
          'very',
          'good',
          '.']
```

POS

Now we can tag the tokens.

```
tagged = nltk.pos_tag(tokens)

tagged[0:6]
```

```
Out[39]: [('At', 'IN'),
          ('eight', 'CD'),
          ("o'clock", 'JJ'),
          ('on', 'IN'),
          ('Thursday', 'NNP'),
          ('morning', 'NN')]
```

POS

One more example.

```
text = nltk.word_tokenize("And now I present to you the best professor on earth",
                                    language="english")
tagged = nltk.pos_tag(text)
tagged
```

```
Out[43]: [('And', 'CC'),
          ('now', 'RB'),
          ('I', 'PRP'),
          ('present', 'VBP'),
          ('to', 'TO'),
          ('you', 'PRP'),
          ('the', 'DT'),
          ('best', 'JJS'),
          ('professor', 'NN'),
          ('on', 'IN'),
          ('earth', 'JJ')]
```

Chunking

Chunking

Defining patterns in POS helps, for example, to find phrases in a corpus -- especially noun phrases.

Chunking

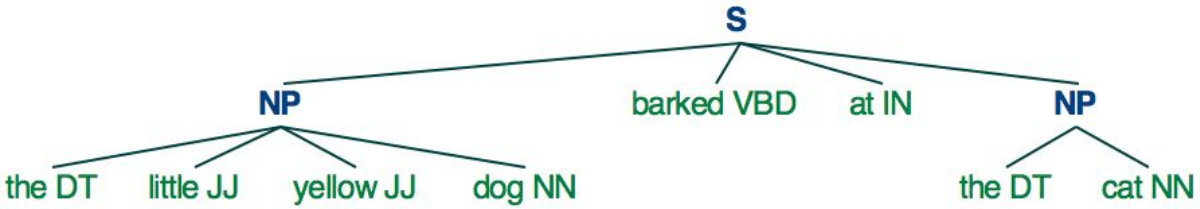
```
# a simple sentence with POS tags
sentence = [("the", "DT"), ("little", "JJ"), ("yellow", "JJ"), ("dog", "NN"), ("barked",
          "VBD"), ("at", "IN"), ("the", "DT"), ("cat", "NN")]
pattern = "NP: {<DT>?<JJ>*<NN>}"          # define a tag pattern of an NP chunk
NPChunker = nltk.RegexpParser(pattern)     # create a chunk parser
result = NPChunker . parse(sentence)        # parse the example sentence
print result                                # or draw graphically using result.draw()
```

```
(S
  (NP the/DT little/JJ yellow/JJ dog/NN)
  barked/VBD
  at/IN
  (NP the/DT cat/NN))
```

The example is from: http://www.nltk.org/book/ch07.html

Chunking

```
result.draw()
```



More Regex Patterns

- determiner/possessive, adjectives and noun: {<DT|PP\$>?<JJ>*<NN>}
- sequences of proper nouns: {<NNP>+}
- consecutive nouns: {<NN>+}

Regex Chunking

Pros:

- More control over patterns matched

Cons:

- Difficult to hard code in every rule

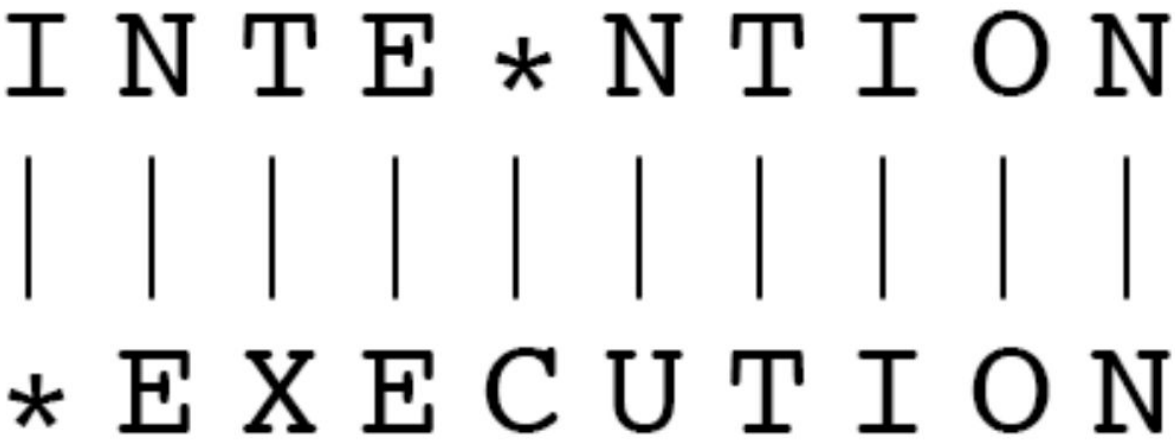
Minimum Edit Distance

Minimum Edit Distance

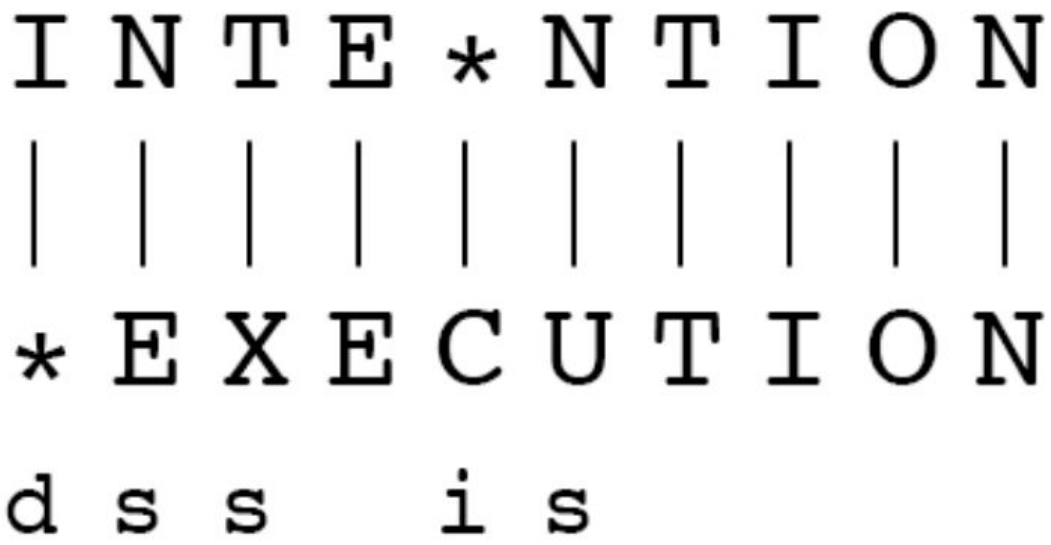
The Minimum Edit Distance between two string is the minimum number of insertions, deletions, and substitutions needed to transform the string.

1. **k**itten → **s**itten (substitution of "s" for "k")
2. sitt**e**n → sitt**i**n (substitution of "i" for "e")
3. sittin → sittin**g** (insertion of "g" at the end).

Minimum Edit Distance



Minimum Edit Distance



What is the minimum edit distance?

Text Classification

Text Classification

- Assigning a subject
- Spam Detection
- Age/Gender of author
- Who is the author?
- Sentiment Analysis

Example: Sentiment Analysis of Tweets

Sentiment Analysis

Let's say we have some tweets.

```
pos_tweets = [('I love this book', 'positive'),
              ('This food is amazing', 'positive'),
              ('I feel great this morning', 'positive'),
              ('I am so excited about the party', 'positive'),
              ('He is my best friend', 'positive')]

neg_tweets = [('I do not like this book', 'negative'),
              ('This food is horrible', 'negative'),
              ('I feel tired this morning', 'negative'),
              ('I am not looking forward to the party', 'negative'),
              ('He is my enemy', 'negative')]
```

Sentiment Analysis

Let's clean up our tweets.

```
tweets = []
for (words, sentiment) in pos_tweets + neg_tweets:
    words_filtered = [e.lower() for e in words.split() if len(e) >= 3]
    tweets.append((words_filtered, sentiment))
tweets
```

```
Out[33]: [(['love', 'this', 'book'], 'positive'),
          (['this', 'food', 'amazing'], 'positive'),
          (['feel', 'great', 'this', 'morning'], 'positive'),
          (['excited', 'about', 'the', 'party'], 'positive'),
          (['best', 'friend'], 'positive'),
          (['not', 'like', 'this', 'book'], 'negative'),
          (['this', 'food', 'horrible'], 'negative'),
          (['feel', 'tired', 'this', 'morning'], 'negative'),
          (['not', 'looking', 'forward', 'the', 'party'], 'negative'),
          (['enemy'], 'negative')]
```

Sentiment Analysis

And make some test tweets.

```
test_tweets = [
    (['feel', 'happy', 'this', 'morning'], 'positive'),
    (['larry', 'friend'], 'positive'),
    (['not', 'like', 'that', 'man'], 'negative'),
    (['house', 'not', 'great'], 'negative'),
    (['your', 'song', 'annoying'], 'negative')]
```

Sentiment Analysis

Now let's extract the features we'll use in this algorithm.

```
def get_words_in_tweets(tweets):
    all_words = []
    for (words, sentiment) in tweets:
      all_words.extend(words)
    return all_words

def get_word_features(wordlist):
    wordlist = nltk.FreqDist(wordlist)
    word_features = wordlist.keys()
    return word_features

word_features = get_word_features(get_words_in_tweets(tweets))
```

Sentiment Analysis

Finalize the extraction.

```
def extract_features(document):
    document_words = set(document)
    features = {}
    for word in word_features:
        features['contains(%s)' % word] = (word in document_words)
    return features
```

Sentiment Analysis

Create our training set and train our classifier.

```
training_set = nltk.classify.apply_features(extract_features, tweets)

classifier = nltk.NaiveBayesClassifier.train(training_set)
```

Sentiment Analysis

Now let's check how it does. *Keep in mind that this is a very simple classifier.*

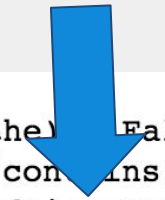
```
tweet = 'Larry is my friend'
print classifier.classify(extract_features(tweet.split()))
```

```
positive
```

Sentiment Analysis

Internally we can check how the classifier is working.

```
print extract_features(tweet.split())
```



```
{'contains(looking)': False, 'contains(feel)': False, 'contains(the)': False, 'contains(part
y)': False, 'contains(about)': False, 'contains(great)': False, 'contains(horrible)': False,
'contains(this)': False, 'contains(best)': False, 'contains(friend)': True, 'contains(enem
y)': False, 'contains(forward)': False, 'contains(excited)': False, 'contains(tired)': False,
'contains(like)': False, 'contains(love)': False, 'contains(book)': False, 'contains(amazin
g)': False, 'contains(food)': False, 'contains(not)': False, 'contains(morning)': False}
```

Recap

Recap

- What is NLP?
- What are the foundations of linguistics?
- What is the big problem with language?
- Regex
- Tokenization
- Normalization
- Lemmatization
- Stemming
- POS Tagger
- Chunking
- Minimum Edit Distance
- Text Classification