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3546 – Deep Learning

Module 6 - Natural Language Processing

Learning Outcomes for this Module

- Develop some familiarity with key concepts in NLP
- Understand NLP pipelines, word and document representation, and topic modeling
- Have a look at some of the features of the Natural Language Toolkit (NLTK), spaCy, gensim, coreNLP and keras

Topics for this Module

- **1.1** What is Natural Language Processing?
- **1.2** What Makes NLP Challenging?
- **1.3** NLP Pipelines
- **1.4** Information Categorization and Retrieval
- **1.5** Encoding Meaning
- **1.6** Resources and Wrap-up

Module 6 – Section 1

What is Natural Language Processing?

Natural Language Processing

- Natural Language Processing (NLP) is the study of computational treatment of natural (human) language
- Combines linguistics with AI
- Like other areas of AI, NLP evolved from *symbolic* to *statistical* to *neural*
  - 1950's: Symbolic programming languages and translation
  - 1960's: ELIZA
  - 1970's: Ontologies
  - 1980's: Racter
  - 1990's: ML using corpora
  - 2000's: Web corpora and larger models
  - 2010's: Neural
  - 2020's: Spoken word to…?

Interacting with Machines via Language

- *Formal* logic literally means logic enforced by language constructs (e.g. Lambda Calculus, First Order Logic)
- **The Sapir-Whorf Hypothesis**: A principle suggesting that the structure of a language affects its speakers' worldview or cognition, and thus people's perceptions are relative to their spoken language (Wikipedia: https://en.wikipedia.org/wiki/Linguistic_relativity)
- **LogLan**: *Logical Language* designed to test the Sapir-Whorf hypothesis

NLP Applications

- **Search**: Web, documents, autocomplete
- **Editing**: Spelling, grammar, style
- **Dialog**: Chatbots, assistants
- **Writing**: Index, concordance, table of contents
- **Email**: Spam filter, classification, prioritization
- **Text mining**: Summarization, knowledge extraction, medical diagnosis
- **Law**: Legal inference, precedent search, subpoena classification
- **News**: Event detection, fact checking, headline composition, short article generation

NLP Applications (cont'd)

- **Attribution**: Plagiarism detection, literary forensics, style coaching
- **Sentiment analysis**: Community morale monitoring, product review triage, customer care
- **Behavior prediction**: Finance, election forecasting, marketing
- **Mood evaluation**: Depression detection, guidance for call centre interactions
- **Creative writing**: Movie scripts, poetry, song lyrics
- **Automatic question answering**: Self-serve help
- **Picture and video generation**: Create a scene as described
- **Coding assistants**: GitHub Copilot, TabNine

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Module 6 – Section 2

What Makes NLP Challenging?

Ambiguity in Natural Language

- Stolen painting found by tree
- Local high school dropouts cut in half
- Doctor: “No heart, cognitive issues”
- Students cook & serve grandparents
- 1 million get shot to save on loans
- San Jose cops kill man with knife
- Queen Mother tries to help abuse girl
- Big rig carrying fruit crashes on 210 Freeway, creates jam
- Princess Diana dresses to be auctioned
- How to prepare pets for Thanksgiving

Other Issues

- **Synonyms**: A synonym is a word or phrase that means exactly or nearly the same as another lexeme in the same language
- **Homonyms**: Words which sound alike or are spelled alike but have different meanings
- **Misspellings**: Can be as a non-word or a different word
- **Sarcasm**: The use of irony to mock or convey contempt
- **Allegory**: A story, poem, or picture that can be interpreted to reveal a hidden meaning, typically a moral or political one
- **Dialects**: A particular form of a language which is peculiar to a specific region or social group
- **Language evolution**: Words, expressions and spelling change over time

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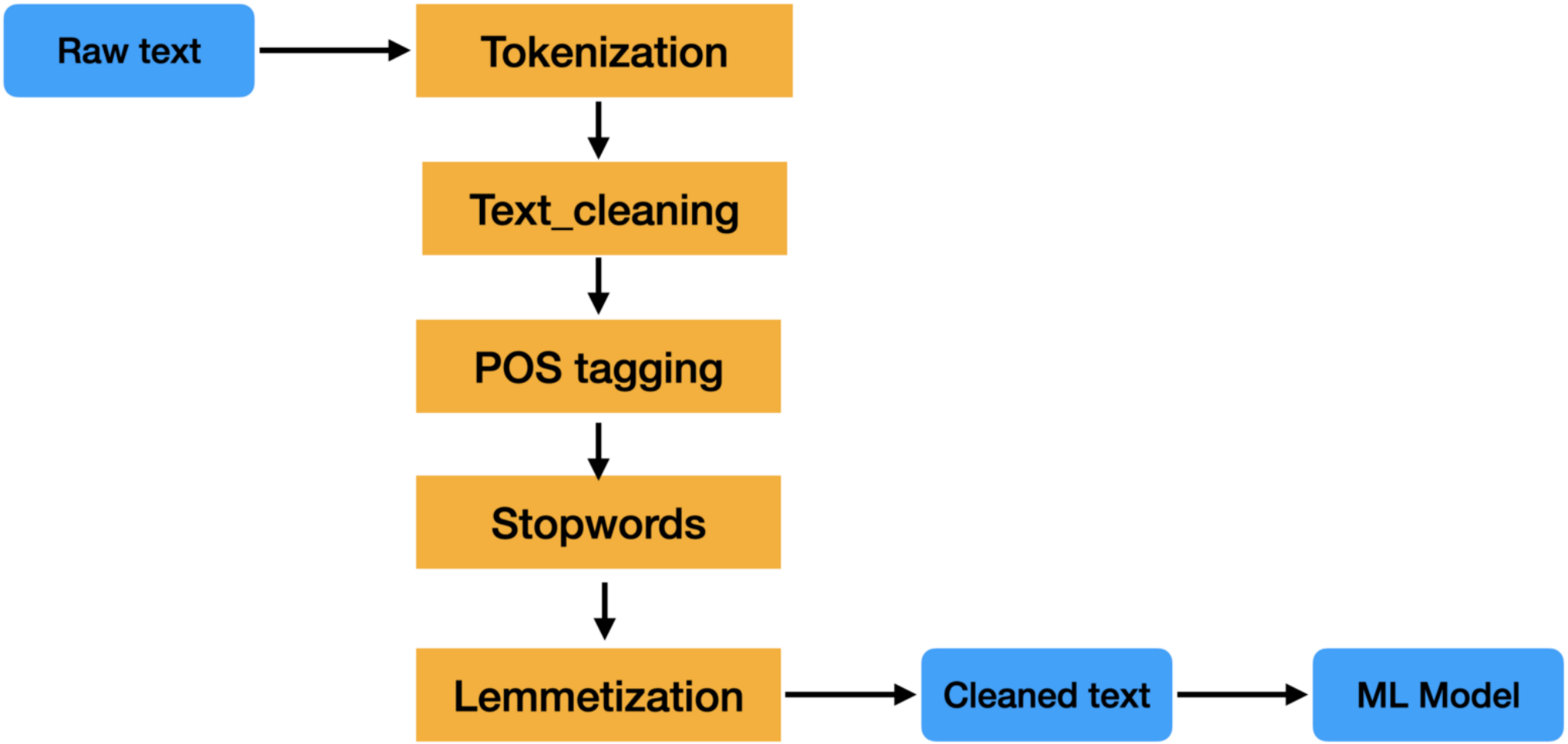
Module 6 – Section 3

NLP Pipelines

NLP Pipelines



Source: https://miro.medium.com/max/1838/1*CbzCcP3XFtYVJmWowZLugQ.png

Tokenization

- We could attempt to work with text as strings of characters: https://www.tensorflow.org/text/tutorials/text_generation
- Words (or pictograms) approximately represent a unit of meaning

Issues in Tokenization

- **Special cases**: Names (particularly multi-word), initials, hyphenated words, abbreviations, special forms (dates, phone numbers, URLs, etc.)
- **Punctuation**: Should ! be treated as a word?
- **Contractions**: How many words is "isn't"?
- **Named Entities**: e.g. Richard Feynman, CN Tower
- **Rare words**: Large vocabularies take a lot of CPU and/or memory
- **Very frequent words**: e.g. a, the

Issues in Tokenization (cont'd)

- **Issues specific to other languages**:
  - German and Welsh: Compounds words such as schadenfreude, Kraftfahrzeug-Haftpflichtversicherung and Llanfairpwllgwyngyllgogerychwyrndrob-wllllantysiliogogogoch https://youtu.be/fHxO0UdpoxM
  - Chinese: average of about 2 symbols/word
  - Japanese: kanji, hirigana, katakana, romanji

Stop Words

- Common words that convey little meaning
- Removed for some applications because vocabularies' size are usually limited
- Examples: the, a, is, at, which
- Removing them generally increases performance at tasks such as document comparison
- Removing them can cause problems with *named entity resolution* (e.g. "The Who") and translation
- There is no single agreed-on *stop words* list

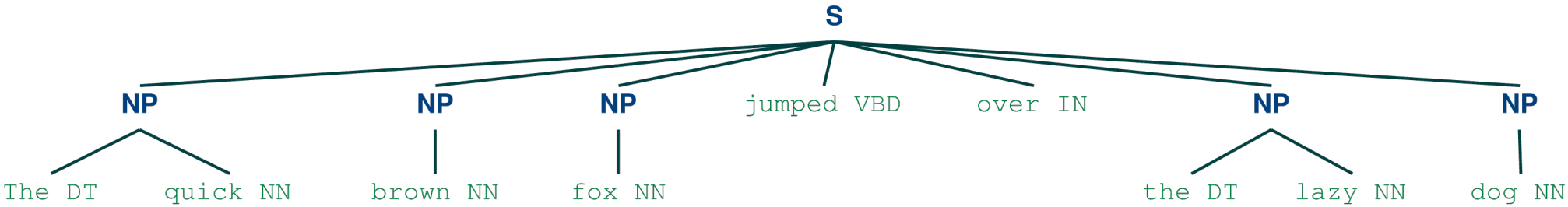
Sources of Text for Training

- A corpus (plural corpora) is a large and structured set of texts
- Examples:
  - Brown Corpus
  - Wikipedia
  - Common Crawl https://commoncrawl.org/
  - Gutenberg Corpus
  - The CMU Pronouncing Dictionary http://www.speech.cs.cmu.edu/cgi-bin/cmudict

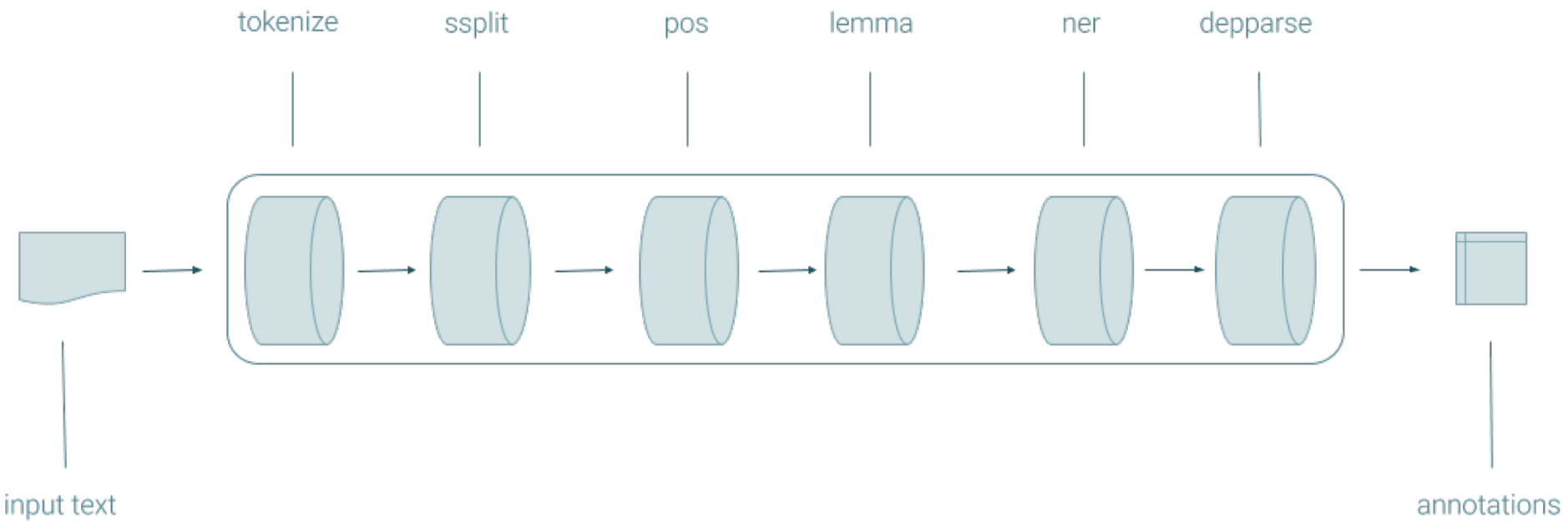
Normalization Techniques

- **Case folding**: Force all lower case
  - Can make named entity resolution more difficult
  - Becoming less common as a result
- **Stemming**: Crude chopping of affixes e.g. remove -s or -ing at end
  - Can cut vocabulary size in half (or more if aggressive)
  - Many algorithms: Porter's is most common English stemmer and has a lot of knowledge of English hardcoded in it
  - Useful for search where we are looking for similar, not exact matches (will improve recall but reduce precision)
- **Lemmatization**: Extraction of the base form e.g. "are", "am", "is" replaced with "be"
  - Better for most applications than stemmers which might take "better" and convert it to "bet"
- **Hashtag and emoji expansions**: e.g. #lol to laugh out loud

Parts Of Speech (POS) Taggers

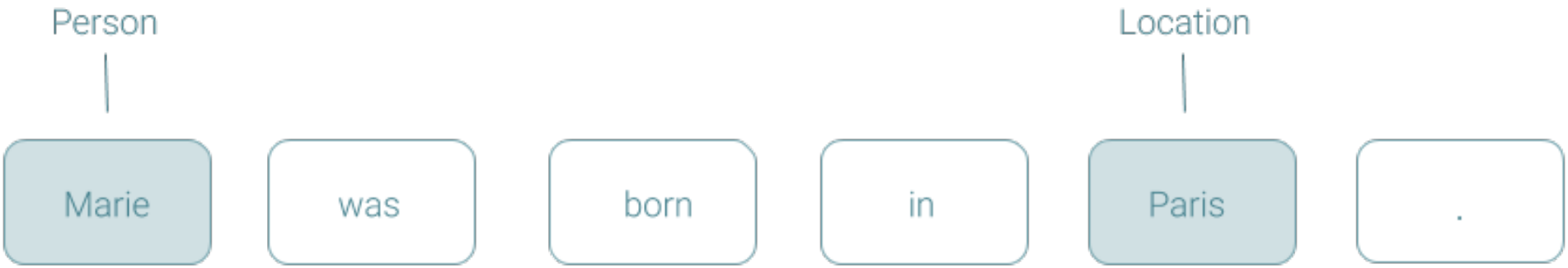


Annotators



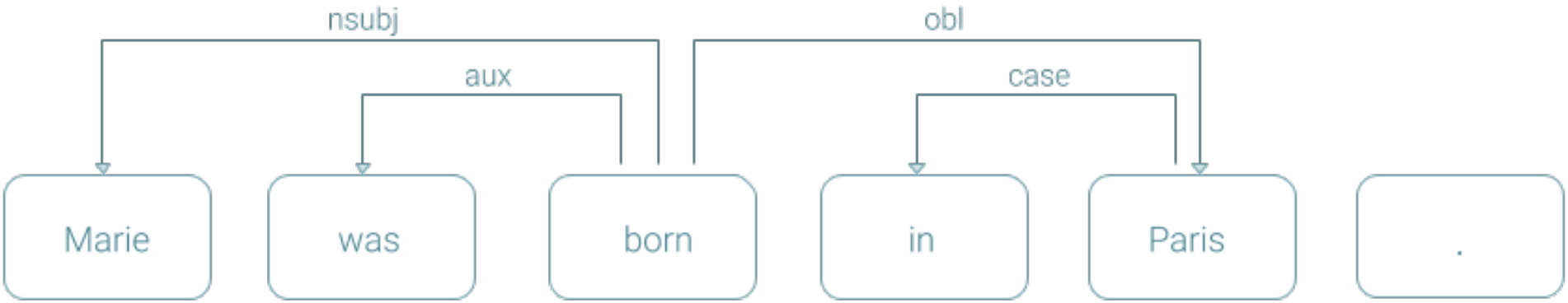
Source: https://stanfordnlp.github.io/CoreNLP/assets/images/pipeline.png

Named Entity Recognition



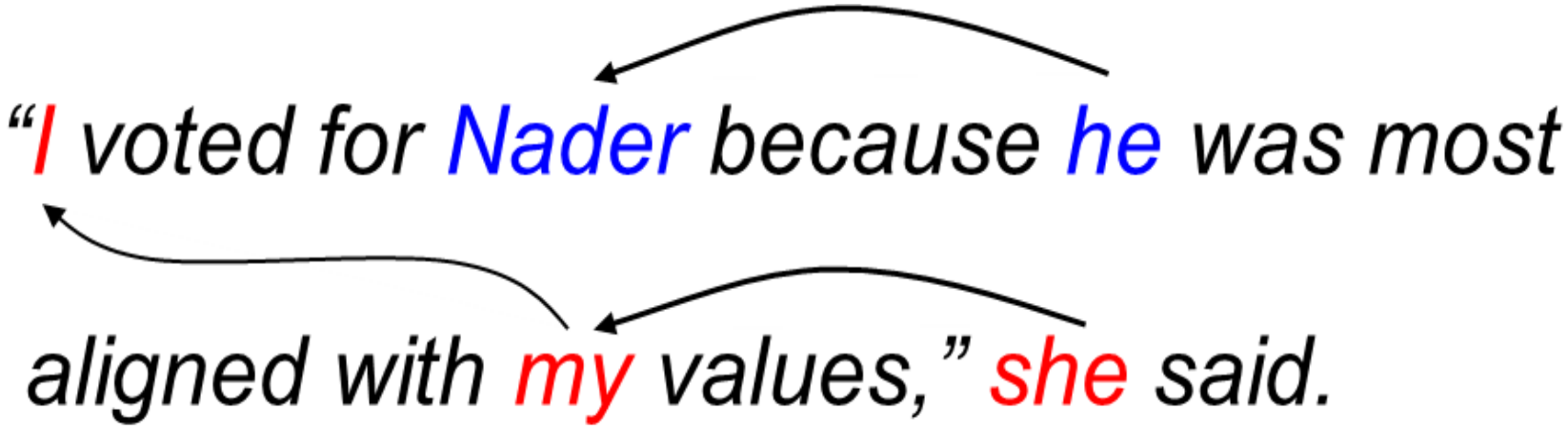
Source: https://stanfordnlp.github.io/CoreNLP/assets/images/ner.png

Constituent and Dependency Parsing



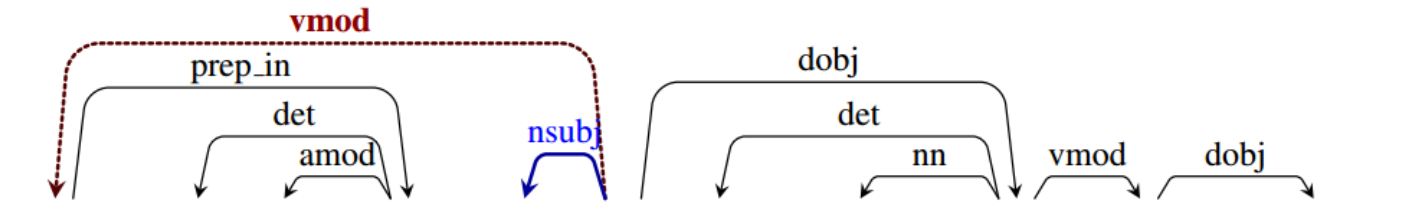
Source: https://stanfordnlp.github.io/CoreNLP/assets/images/depparse.png

Coreference Resolution



Source: https://nlp.stanford.edu/projects/corefexample.png

Stanford CoreNLP Open Information Extraction

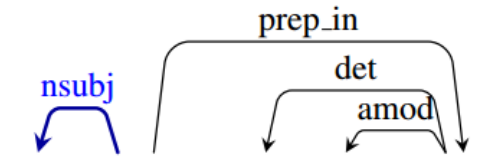


(input)

she took the midnight train going anywhere
Born in a small town, she took the midnight train
Born in a town, she took the midnight train

she took the midnight train
she took midnight train
. . .

(she; took; midnight train)



(extracted clause)

she Born in small town
she Born in a town
she Born in town

(she; born in; small town)
(she; born in; town)

Source: https://nlp.stanford.edu/software/openie.html

Python-friendly NLP Tools

- **NLTK**: The Natural Language Toolkit
- **SpaCy**: An alternative to NLTK
- **Spark NLP**: NLP tools for Apache Spark
- **Gensim**: Primarily topic modelling
- **TextBlob**: Extensions to NLTK
- **KerasNLP**: NLP tools for Keras
- **PyTorch NLP**: NLP tools for PyTorch
- **Hugging Face**: NLP tools and language models
- **MonkeyLearn**: Cloud-based simple NLP
- **Amazon Comprehend**: Amazon's NLP API
- **Google Cloud NLP API**: Google's NLP API

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Module 6 – Section 4

Information Categorization and Retrieval

Representing Documents

- Bag of words
- Bag of n-grams
- TF-IDF vectors

Bag of Words and One Hot Encoding

- Ignore word order
- Fix the vocabulary size
- One Hot encoding
- Enables arithmetic with vectors: union, intersection, addition, subtraction

Bag of N-Grams

- **n-gram**: A continuous sequence of n items from a given sample of text or speech
- Useful for translation, spelling correction, speech recognition, question answering
- We can add 2, 3, etc.-grams
- A vocabulary of about 20,000 words is sufficient to track 95% of words in a corpus of tweets, blog posts and news articles

TF-IDF Vectors

- Term Frequency, Inverse Document Frequency
- A measure of how important a word is to a document in a collection
- Let's say we want to divide up a corpus (collection) of documents into similar clusters
- How should we decide how similar two documents are?
  - How many words they have in common
  - How specialized those words are
- To capture these two aspects we need two measures for each word in our vocabulary:
  - Term Frequency: How frequently the word occurs in each document
  - Document Frequency: How often the word occurs in our corpus
- Document Frequency is usually measured on a log scale

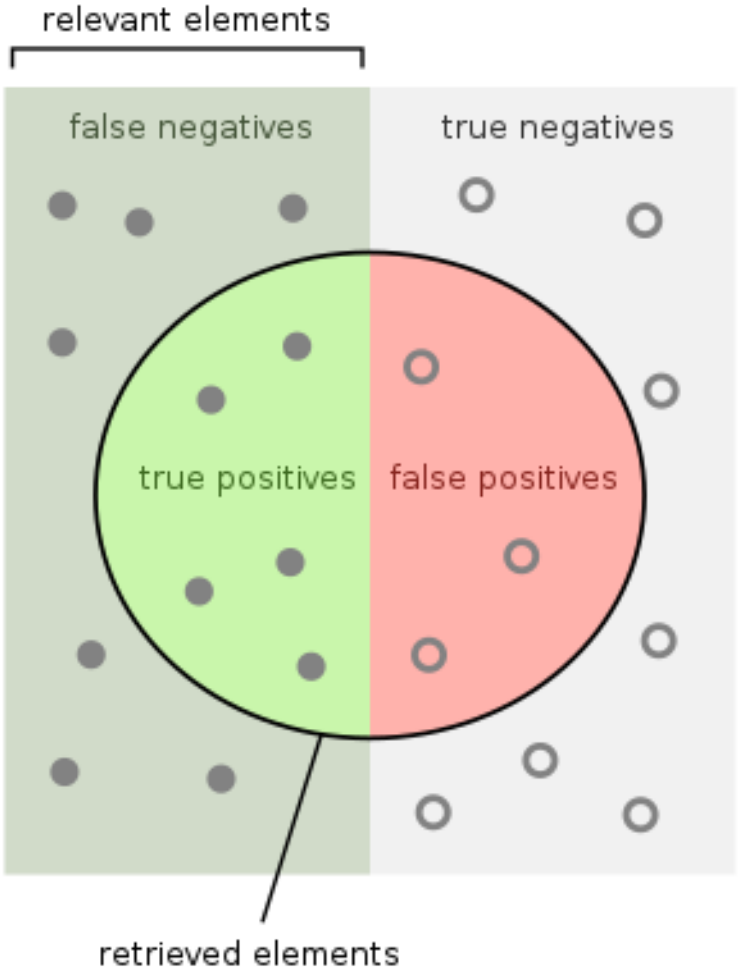
Cosine Similarity

- We can measure the similarity of vectors (such as TF-IDF vectors) using Cosine Similarity
- The more similar the vectors are, the smaller the angle there should be between them
- The cosine similarity of two vectors, x and y, is easily calculated using dot product:

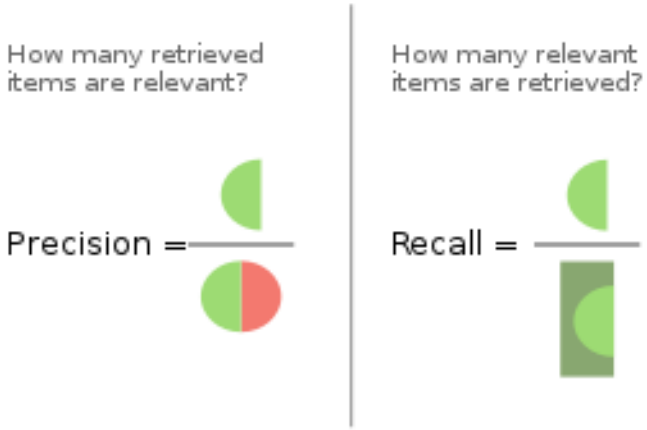
$$\cos(a, b) = \frac{a \cdot b}{\|a\|\|b\|}$$

- Cosine similarity is a number that runs between 0 (nothing in common) to 1 (identical) for TF-IDF vectors

Precision and Recall



Source:
https://en.wikipedia.org/wiki/Precision_and_recall



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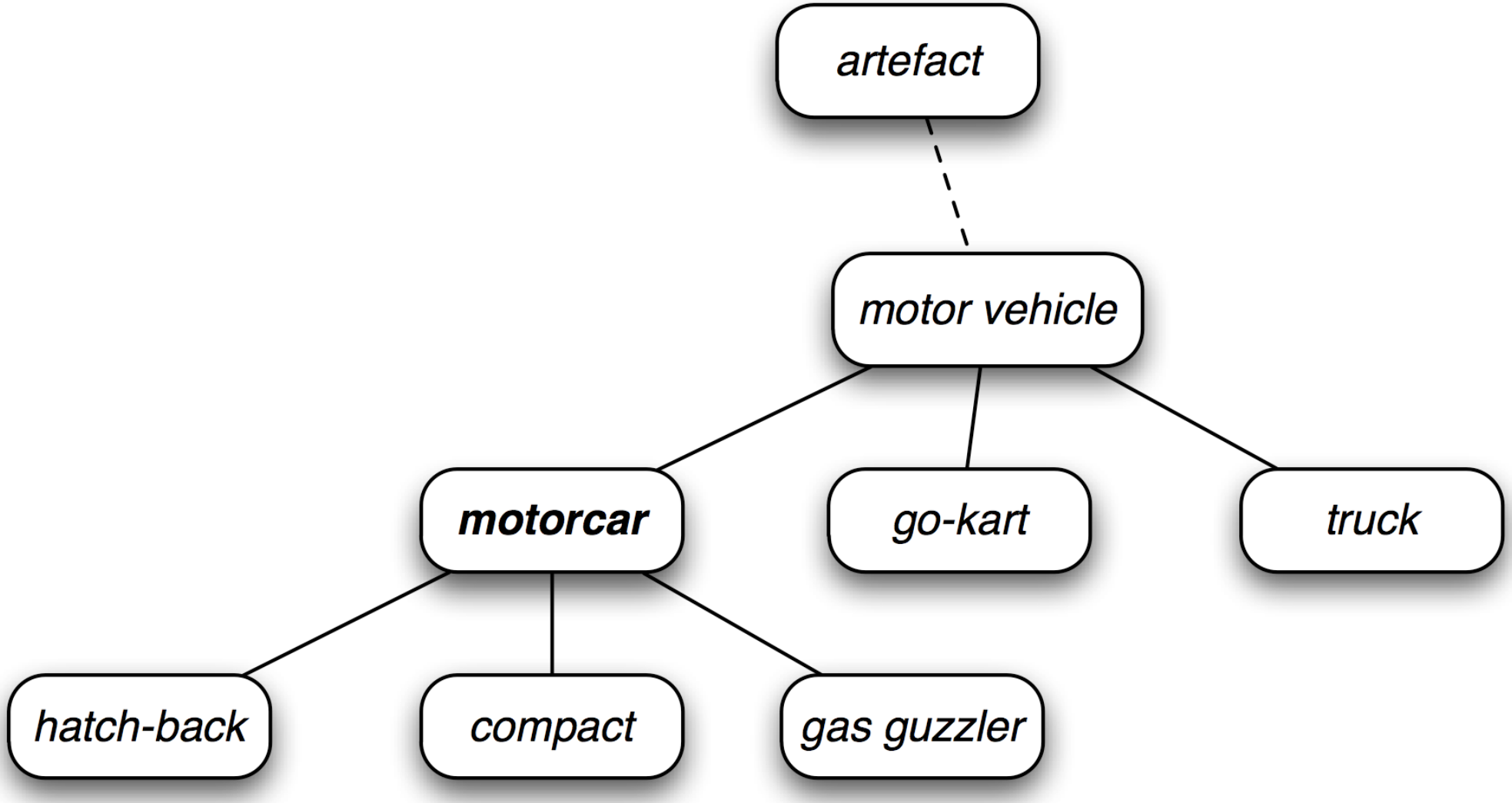
Module 6 – Section 5

Encoding Meaning

WordNet


artefact
motor vehicle
motorcar
go-kart
truck
hatch-back
compact
gas guzzler

The Meaning of Words

- **Wittgenstein (1949)**: “For a large class of cases–though not for all–in which we employ the word “meaning” it can be defined thus: *the meaning of a word is its use in the language*”.
- **Firth (1957**): ”You shall know a word by the company it keeps”.

Representing Meaning as Numerical Vectors

- WordToVec
- Glove
- TagLM
- ELMO
- GPT
- BERT

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Module 6 – Section 6

Resources and Wrap-up

Resources

- http://nlpprogress.com/english/dependency_parsing.html
- https://nlp.stanford.edu/IR-book/html/htmledition/tokenization-1.html
- https://wordnet.princeton.edu/
- https://www.nltk.org/
- https://github.com/mikhailklassen/Mining-the-Social-Web-3rd-Edition/tree/master/notebooks
- https://en.wikipedia.org/wiki/Regular_expression
- Lane, Howard & Hapke. Natural Language Processing in Action. Manning. 2019.
- Jurafsky & Martin. Speech and Language Processing, 3rd Ed. https://web.stanford.edu/~jurafsky/slp3/
- SpaCy: https://spacy.io/
- gensim: https://radimrehurek.com/gensim/
- Natural Language Processing with Python Steven Bird, Ewan Klein, and Edward Loper

Next Class

- Word Vectors
- Sequence-to-Sequence Models
- Attention and Transformers

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Any questions?

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Thank You

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