Assignment 2

Quiz #1
- Thursday any time
- I’ll be available from 12:30-1:15pm on our class zoom session if you’d like to ask questions
- “Normal” class will start at 1:15pm
- Open book and open notes

Sakai or PDF??

Quiz #1 material
- T/F, short answer, pencil and paper work (no coding)
- Zipf’s law
- Regular expressions
- Probability basics
- Language modeling
  - MLE estimation estimating from a corpus
  - Development set
  - Perplexity
  - Determining vocabulary
  - Smoothing techniques
    - Add 1
    - Add Lambda
  - Interpolation
  - Backoff
  - Absolute discounting

Simplified View of Linguistics

Phonology/
Phonetics
-waddyasai-

Morphology
-waddyasai/what did you say

Syntax
- what did you say
- say subj obj
- you what
- \( P(\text{say(you, x)}) \)

Semantics

Discourse

say subj obj
- you what
- \( P(\text{say(you, x)}) \)
Morphology

What is morphology?
- study of the internal structure of words
  - morphology word-s jump-ing

Why might this be useful for NLP?
- generalization (runs, running, runner are related)
- additional information (it’s plural, past tense, etc)
- allows us to handle words we’ve never seen before
  - smoothing?

New words

AP newswire stories from Feb 1988 – Dec 30, 1988
- 300K unique words

New words seen on Dec 31
- compounds: prenatal-care, publicly-funded, channel-switching, …
- New words:
  - dumbbells, groveled, fuzzier, oxidized, ex-presidency, puppetry, boulderlike, over-emphasized, antiprejudice

Morphology basics

Words are built up from morphemes
- stems (base/main part of the word)
- affixes
  - prefixes
    - precedes the stem
  - suffixes
    - follows the stem
  - infixes
    - inserted inside the stem
  - circumfixes
    - surrounds the stem
- Examples?

Morpheme examples

prefix
- circum- (circumnavigate)
- dis- (dislike)
- mis- (misunderstood)
- com-, de-, dis-, in-, re-, post-, trans-, …

suffix
- -able (movable)
- -ance (resistance)
- -ly (quickly)
- -tion, -ness, -ate, -ful, …
Morpheme examples

infix
- fucking- (cinder-fucking-rella)
more common in other languages

circumfix
- doesn’t really happen in English
- a - ing
  - a-running
  - a-jumping

Agglutinative: Finnish

talo ‘the-house’
talo-ni ‘my house’
talo-ssa ‘in the-house’
talo-ssa-ni ‘in my house’
talo-i-ssa ‘in the-houses’
talo-i-ssa-ni ‘in my houses’

kaup-pa ‘the-shop’
kaup-pa-ni ‘my shop’
kaup-a-ssa ‘in the-shop’
kaup-a-ssa-ni ‘in my shop’
kaup-o-i-ssa ‘in the-shops’
kaup-o-i-ssa-ni ‘in my shops’

Stemming (baby lemmatization)

Reduce a word to the main stem/morpheme

automate
automates
automatic
automation

run
runs
running

automat
run

Stemming example

This is a poorly constructed example using the Porter stemmer.

This is a poorli construct example us the Porter stemmer.

https://text-processing.com/demo/stem/
(or you can download versions online)
Porter's algorithm (1980)

Most common algorithm for stemming English

- Results suggest it is at least as good as other stemming options

- Multiple sequential phases of reductions using rules, e.g.
  - sses → ss
  - les → i
  - onal → ate
  - tional → tion

http://tartarus.org/~martin/PorterStemmer/

What is Syntax?

- Study of the structure of language

- Examine the rules of how words interact and go together

- Rules governing grammaticality

- I will give you one perspective
  - no single correct theory of syntax
  - still an active field of research in linguistics
  - we will often use it as a tool/stepping stone for other applications

Structure in language

The man _____ all the way home.

- what are some examples of words that can/can’t go here?

- why can’t some words go here?
Structure in language

The man flew all the way home.

Language is bound by a set of rules

It’s not clear exactly the form of these rules, however, people can generally recognize them

This is syntax!

Syntax != Semantics

Colorless green ideas sleep furiously.

Syntax is only concerned with how words interact from a grammatical standpoint, not semantically (i.e. meaning)

Parts of speech

What are parts of speech (think 3rd grade)?

Parts of speech

Parts of speech are constructed by grouping words that function similarly:
- with respect to the words that can occur nearby
- and by their morphological properties

The man _____ all the way home.

ran, forgave, ate, drove, drank, hid, learned, hurt
integrated, programmed, shouted, sat, slept, understood, voted
washed, warned, walked, spoke, succeeded, survived, read, recorded
Parts of speech

What are the English parts of speech?

- 8 parts of speech
  - Noun (person, place or thing)
  - Verb (actions and processes)
  - Adjective (modify nouns)
  - Adverb (modify verbs)
  - Preposition (on, in, by, to, with)
  - Determiners (a, an, the, what, which, that)
  - Conjunctions (and, but, or)
  - Particle (off, up)

English parts of speech

Brown corpus: 87 POS tags

Penn Treebank: ~45 POS tags
- Derived from the Brown tagset
- Most common in NLP
- Many of the examples we’ll show use this one

British National Corpus (C5 tagset): 61 tags
- C6 tagset: 148
- C7 tagset: 146
- C8 tagset: 171

Tagsets

Brown tagset:

C8 tagset:
http://ucrel.lancs.ac.uk/claws8tags.pdf

English Parts of Speech

Noun (person, place or thing)
- Singular (NN): dog, fork
- Plural (NNS): dogs, forks
- Proper (NNP, NNPS): John, Springfields
- Personal pronoun (PRP): I, you, he, she, they, it
- Wh-pronoun (WP): who, what

Verb (actions and processes)
- Base, infinitive (VB): eat
- Past tense (VBD): ate
- Gerund (VBG): eating
- Past participle (VBN): eaten
- Non 3rd person singular present tense (VBP): eat
- 3rd person singular present tense: (VBZ): eats
- Modal (MD): should, can
- To (TO): to (to eat)
English Parts of Speech (cont.)

Adjective (modify nouns)
- Basic (JJ): red, tall
  - Comparative (JJR): redder, taller
  - Superlative (JJS): reddest, tallest

Adverb (modify verbs)
- Basic (RB): quickly
  - Comparative (RBR): quicker
  - Superlative (RBS): quickest

Preposition (IN): on, in, by, to, with

Determiner:
- Basic (DT): a, an, the
  - WH-determiner (WDT): which, that

Coordinating Conjunction (CC): and, but, or,

Particle (RP): off (took off), up (put up)

Closed vs. Open Class

Closed class categories are composed of a small, fixed set of grammatical function words for a given language.

- Pronouns, Prepositions, Modals, Determiners, Particles, Conjunctions

Open class categories have large number of words and new ones are easily invented.

- Nouns (Google, futon, iPad), Verbs (Google, futoning), Adjectives (geeky), Adverbs (chomply)

Part of speech tagging

Annotate each word in a sentence with a part-of-speech marker

Lowest level of syntactic analysis

John saw the saw and decided to take it to the table.

NNP VBD DT NN CC VBD TO VB PRP IN DT NN

https://xkcd.com/1443/
Ambiguity in POS Tagging

I like candy.

\textit{VBP} \\
\text{\{verb, non-3\textsuperscript{rd} person, singular, present\}}

Time flies like an arrow.

\textit{IN} \\
\text{\{preposition\}}

Does “like” play the same role (POS) in these sentences?

Ambiguity in POS Tagging

I bought it at the shop around the corner.

\textit{IN} \\
\text{\{preposition\}}

I never got around to getting the car.

\textit{RP} \\
\text{\{particle… on, off\}}

\textit{RB} \\
\text{\{adverb\}}

The cost of a new Prius is around $25K.

Does “around” play the same role (POS) in these sentences?

Ambiguity in POS tagging

Like most language components, the challenge with POS tagging is ambiguity

Brown corpus analysis

- 11.5\% of word types are ambiguous (this sounds promising!), but...
- 40\% of word appearances are ambiguous
- Unfortunately, the ambiguous words tend to be the more frequently used words

How hard is it?

If I told you had a POS tagger that achieved 90\% accuracy would you be impressed?

- Shouldn’t be… just picking the most frequent POS for a word gets you this

What about a POS tagger that achieves 93.7\%?

- Still probably shouldn’t be… only need to add a basic module for handling unknown words

What about a POS tagger that achieves 100\%?

- Should be suspicious… humans only achieve ~97\%
- Probably overfitting (or cheating!)
POS Tagging Approaches

**Rule-Based:** Human crafted rules based on lexical and other linguistic knowledge

**Learning-Based:** Trained on human annotated corpora like the Penn Treebank
- **Statistical models:** Hidden Markov Model (HMM), Maximum Entropy Markov Model (MEMM), Conditional Random Field (CRF), log-linear models, support vector machines (SVMs), neural networks
- **Rule learning:** Transformation Based Learning (TBL)

The book discusses some of the more common approaches

Many publicly available:
- [http://nlp.stanford.edu/links/statnlp.html](http://nlp.stanford.edu/links/statnlp.html) (list 15 different ones mostly publicly available!)  
- [http://www.coli.uni-saarland.de/~thorsten/tnt/](http://www.coli.uni-saarland.de/~thorsten/tnt/)

Constituency

Parts of speech can be thought of as the lowest level of syntactic information

Groups words together into categories

What can/can’t go here?

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Constituency

- **likes to eat candy.**

  **nouns**
  - Dave
  - Professor Kauchak
  - Dr. Suess

  **pronouns**
  - He
  - She
  - They

  **determiner nouns**
  - The man
  - The boy
  - The cat

  **determiner nouns +**
  - The man that I saw
  - The boy with the blue pants
  - The cat in the hat

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Constituency

Words in languages tend to form into functional groups (parts of speech)

Groups of words (aka phrases) can also be grouped into functional groups
- often some relation to parts of speech
- though, more complex interactions

These phrase groups are called constituents
Common constituents

He likes to eat candy.

The man in the hat ran to the park.

Syntactic structure

Hierarchical: syntactic trees

The man in the hat ran to the park.
A number of related problems:
- Given a sentence, can we determine the syntactic structure?
- Can we determine if a sentence is grammatical?
- Can we determine how likely a sentence is to be grammatical? to be an English sentence?
- Can we generate candidate, grammatical sentences?

**Grammars**

What is a grammar (3rd grade again...)?
Grammars

Grammar is a set of structural rules that govern the composition of sentences, phrases and words.

Lots of different kinds of grammars:
- regular
- context-free
- context-sensitive
- recursively enumerable
- transformation grammars

States

What is the capital of this state?
Jefferson City (Missouri)

Context free grammar

How many people have heard of them?

Look like:

\[ S \rightarrow NP \ VP \]

left hand side right hand side
(single symbol) (one or more symbols)

Formally...

\[ G = (NT, T, P, S) \]

NT: finite set of nonterminal symbols
T: finite set of terminal symbols, NT and T are disjoint
P: finite set of productions of the form
\[ A \rightarrow \alpha, \ A \in NT \text{ and } \alpha \in (T \cup NT)^* \]
S \in NT: start symbol
Many possible CFGs for English, here is an example (fragment):

\[
\begin{align*}
S & \rightarrow NP \ VP \\
NP & \rightarrow V N P \\
NP & \rightarrow \text{DetP} \ N \mid \text{DetP} \ AdjP \ N \\
V & \rightarrow \text{sees} \mid \text{likes} \\
N & \rightarrow \text{boy} \mid \text{girl} \\
Adj & \rightarrow \text{big} \mid \text{small} \\
Adv & \rightarrow \text{very} \\
\text{DetP} & \rightarrow \text{a} \mid \text{the}
\end{align*}
\]

Grammar questions

- Can we determine if a sentence is grammatical?
- Given a sentence, can we determine the syntactic structure?
- Can we determine how likely a sentence is to be grammatical to be an English sentence?
- Can we generate candidate, grammatical sentences?

Which of these can we answer with a CFG? How?