Part-of-speech Tagging

Topics

- Word classes
- Part of speech tagging
- Use HMMs for POS tagging

Word Classes: Parts of Speech

- traditional parts of speech
  - Noun, verb, adjective, preposition, adverb, article, interjection, pronoun, conjunction, etc
  - Called: parts-of-speech, lexical categories, word classes, morphological classes, lexical tags...

POS examples

- N noun *chair, bandwidth, pacing*
- V verb *study, debate, munch*
- ADJ adjective *purple, tall, ridiculous*
- ADV adverb *unfortunately, slowly*
- P preposition *of, by, to*
- PRO pronoun *I, me, mine*
- DET determiner *the, a, that, those*

POS Tagging

- The process of assigning a part-of-speech or lexical class marker to each word in a collection.

WORD	tag
the	**DET**
koala	**N**
put	**V**
the	**DET**
keys	**N**
on	**P**
the	**DET**
table	**N**

Why is POS Tagging Useful?

- First step of a vast number of practical tasks
- Information extraction
  - Finding names, e.g., people, organization --N.
- Machine Translation
- Parsing
  - Helpful to know parts of speech before you start parsing
- Many Others

POS Tagging: Choosing a Tagset

- To do POS tagging, we need to choose a standard set of tags to work with
  - Could pick very coarse tagsets
    - N, V, Adj, Adv.
  - More commonly used set is the finer grained, "Penn TreeBank tagset", 45 tags
  - Even more fine-grained tagsets exist

Penn TreeBank POS Tagset

Tag	Description	Example	Tag	Description	Example
CC	coordin. conjunction	*and, but, or*	SYM	symbol	+,%, &
CD	cardinal number	*one, two, three*	TO	"to"	*to*
DT	determiner	*a, the*	UH	interjection	*ah, oops*
EX	existential 'there'	*there*	VB	verb, base form	*eat*
FW	foreign word	*mea culpa*	VBD	verb, past tense	*ate*
IN	preposition/sub-conj	*of, in, by*	VBG	verb, gerund	*eating*
JJ	adjective	*yellow*	VBN	verb, past participle	*eaten*
JJR	adj., comparative	*bigger*	VBP	verb, non-3sg pres	*eat*
JJS	adj., superlative	*wildest*	VBZ	verb, 3sg pres	*eats*
LS	list item marker	*1, 2, One*	WDT	wh-determiner	*which, that*
MD	modal	*can, should*	WP	wh-pronoun	*what, who*
NN	noun, sing. or mass	*llama*	WP$	possessive wh-	*whose*
NNS	noun, plural	*llamas*	WRB	wh-adverb	*how, where*
NNP	proper noun, singular	*IBM*	$	dollar sign	*$*
NNPS	proper noun, plural	*Carolinas*	#	pound sign	#
PDT	predeterminer	*all, both*	"	left quote	' or "
POS	possessive ending	*'s*	"	right quote	' or "
PRP	personal pronoun	*I, you, he*	(	left parenthesis	[, (, {, <
PRP$	possessive pronoun	*your, one's*	)	right parenthesis	],), }, >
RB	adverb	*quickly, never*	,	comma	,
RBR	adverb, comparative	*faster*	.	sentence-final punc	. ! ?
RBS	adverb, superlative	*fastest*	:	mid-sentence punc	: ; ... – -
RP	particle	*up, off*			

Using the Penn Tagset

- The/DT grand/JJ jury/NN commmented/VBD on/IN a/DT number/NN of/IN other/JJ topics/NNS ./.
- Prepositions and subordinating conjunctions marked IN ("although/IN I/PRP..")
- Except the preposition "to" is just marked "TO".

POS Tagging

- Words often have more than one POS: *back*
  - The *back* door = JJ (adj)
  - On my *back* = NN
  - Win the voters *back* = RB (adv)
  - Promised to *back* the bill = VB (verb, base form)
- The POS tagging problem is to determine the POS tag for a particular instance of a word.

These examples from Dekang Lin

How Hard is POS Tagging? Measuring Ambiguity

		87-tag Original Brown		45-tag Treebank Brown	
Unambiguous (1 tag)		**44,019**		**38,857**	
Ambiguous (2–7 tags)		**5,490**		**8844**	
Details:	2 tags	4,967		6,731	
	3 tags	411		1621	
	4 tags	91		357	
	5 tags	17		90	
	6 tags	2	(*well*, *beat*)	32	
	7 tags	2	(*still*, *down*)	6	(*well*, *set*, *round*, *open*, *fit*, *down*)
	8 tags			4	(*'s*, *half*, *back*, *a*)
	9 tags			3	(*that*, *more*, *in*)

Two Methods for POS Tagging

1. Rule-based tagging
   - (ENGTWOL; Section 5.4)
2. Stochastic
   - Probabilistic sequence models
     - HMM (Hidden Markov Model) tagging
     - Using an HMM to do POS tagging is a special case of *Bayesian inference*

POS Tagging as Sequence Classification

- Input: We are given a sentence (an "observation" or "sequence of observations")
  - *Secretariat is expected to race tomorrow*
- Output: What is the best sequence of tags that corresponds to this sequence of observations?
- Probabilistic view:
  - Consider all possible sequences of tags
  - Out of this universe of sequences, choose the tag sequence which is most probable given the observation sequence of n words $w_1 \ldots w_n$.

Road to HMMs

- out of all sequences of n tags $t_1 \ldots t_n$ the single tag sequence such that $P(t_1 \ldots t_n | w_1 \ldots w_n)$ is highest.

$$\hat{t}_1^n = \underset{t_1^n}{\operatorname{argmax}} P(t_1^n | w_1^n)$$

- Hat ^ means "our estimate of the best one"
- $\operatorname{argmax}_x f(x)$ means "the x such that f(x) is maximized"

Road to HMMs

- This equation is guaranteed to give us the best tag sequence

$$\hat{t}_1^n = \underset{t_1^n}{\operatorname{argmax}} P(t_1^n | w_1^n)$$

- But how to compute this value?
- Intuition of Bayesian inference:
  - Use Bayes rule to transform this equation into a set of other probabilities that are easier to compute

Using Bayes Rule

$$P(x|y) = \frac{P(y|x)P(x)}{P(y)}$$

$$\hat{t}_1^n = \underset{t_1^n}{\operatorname{argmax}}\, P(t_1^n|w_1^n) \Rightarrow \hat{t}_1^n = \underset{t_1^n}{\operatorname{argmax}}\, \frac{P(w_1^n|t_1^n)P(t_1^n)}{P(w_1^n)}$$

$$\hat{t}_1^n = \underset{t_1^n}{\operatorname{argmax}}\, P(w_1^n|t_1^n)P(t_1^n)$$

Likelihood and Prior

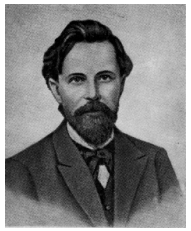
$$\hat{t}_1^n = \underset{t_1^n}{\operatorname{argmax}} \overbrace{P(w_1^n|t_1^n)}^{\text{likelihood}} \overbrace{P(t_1^n)}^{\text{prior}}$$

The/DT yellow/JJ hat/NN

$$P(w_1^n|t_1^n) \approx \prod_{i=1}^{n} P(w_i|t_i)$$

The probability of a word appearing depends only on its own POS tag

P (that | DT)



$$P(t_1^n) \approx \prod_{i=1}^{n} P(t_i|t_{i-1})$$

The probability of a tag appearing depends only on the previous tag

P(NN|JJ)

$$\hat{t}_1^n = \underset{t_1^n}{\operatorname{argmax}} P(t_1^n|w_1^n) \approx \underset{t_1^n}{\operatorname{argmax}} \prod_{i=1}^{n} P(w_i|t_i) P(t_i|t_{i-1})$$

Two Kinds of Probabilities

- Tag transition probabilities $p(t_i|t_{i-1})$
  - Determiners likely to precede adjs and nouns
    - That/DT flight/NN
    - The/DT yellow/JJ hat/NN
    - So we expect P(NN|DT) and P(JJ|DT) to be high
    - But P(DT|JJ) to be:
  - Compute P(NN|DT) by counting in a labeled corpus:

$$P(t_i|t_{i-1}) = \frac{C(t_{i-1}, t_i)}{C(t_{i-1})}$$

$$P(NN|DT) = \frac{C(DT, NN)}{C(DT)} = \frac{56,509}{116,454} = .49$$

Two Kinds of Probabilities

- Word likelihood probabilities $p(w_i|t_i)$
  - VBZ (3sg Pres verb) likely to be "is"
  - Compute P(is|VBZ) by counting in a labeled corpus:

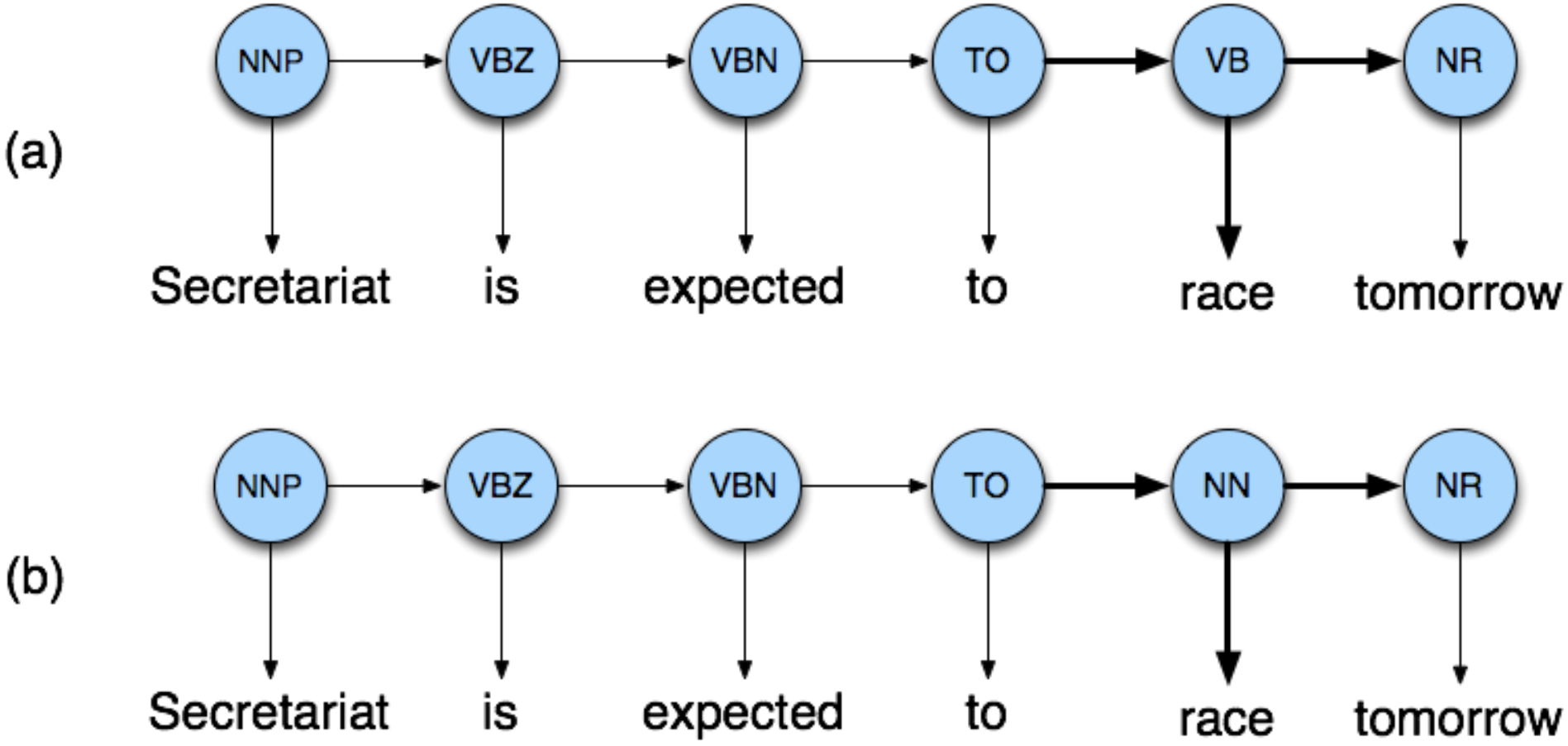
$$P(w_i|t_i) = \frac{C(t_i, w_i)}{C(t_i)}$$

$$P(is|VBZ) = \frac{C(VBZ, is)}{C(VBZ)} = \frac{10,073}{21,627} = .47$$

Example: The Verb “race”

- Secretariat/NNP is/VBZ expected/VBN to/TO **race**/VB tomorrow/NR
- People/NNS continue/VB to/TO inquire/VB the/DT reason/NN for/IN the/DT **race**/NN for/IN outer/JJ space/NN
- How do we pick the right tag?

Disambiguating "race"



Example

- From a training corpus, we know

  P(NN|TO) = .00047

  P(VB|TO) = .83

  P(race|NN) = .00057

  P(race|VB) = .00012

  P(NR|VB) = .0027

  P(NR|NN) = .0012

- How to use the above information to do POS tagging?

P(VB|TO)P(NR|VB)P(race|VB) = .00000027

P(NN|TO)P(NR|NN)P(race|NN)=.00000000032

- So we (correctly) choose the verb reading

$$\hat{t}_1^n = \underset{t_1^n}{\operatorname{argmax}} P(t_1^n|w_1^n) \approx \underset{t_1^n}{\operatorname{argmax}} \prod_{i=1}^{n} P(w_i|t_i)P(t_i|t_{i-1})$$

How to compute the kinds of probabilities?

- Also called: build the HMM model
- Training corpus:
  - People/NNS continue/VB the/DT race/NN
  - Secretariat/NNP inquire/VB reason/NN
- Compute transition probabilities

$$P(t_i|t_{i-1}) = \frac{C(t_{i-1}, t_i)}{C(t_{i-1})}$$

P(VB|NNS) = 1/1

P(DT|VB) = ½ P(NN|VB) = ½

P(NN|DT) = P(VB|NNP) =

- Compute Word likelihood probabilities

$$P(w_i|t_i) = \frac{C(t_i, w_i)}{C(t_i)}$$

P(people|NNS) = 1/1 P(continue|VB) = ½

P(inquire|VB) = ½ p(Secretariat|NNP) =

P(race|NN) = p(reason|NN) = P(the|DT) =

Summary

- Parts of speech
- Tagsets
- Part of speech tagging
- HMM Tagging
- Next:
  - Markov Chains
  - Hidden Markov Models
    - Viterbi decoding
- The next several slides are about linguistics and are for your references

Open and Closed Classes

- Closed class: a small(ish) fixed membership
  - Usually function words (short common words which play a role in grammar)
- Open class: new ones can be created all the time
  - English has 4: Nouns, Verbs, Adjectives, Adverbs
    - Many languages have these 4, but not all!
  - Nouns are typically where the bulk of the action is with respect to new items

Open Class Words

- Nouns
  - Proper nouns (Boulder, Granby, Beyoncé, Port-au-Prince)
    - English capitalizes these.
  - Common nouns (the rest)
  - Count nouns and mass nouns
    - Count: have plurals, get counted: goat/goats, one goat, two goats
    - Mass: don't get counted (snow, salt, communism) (*two snows)
- Adverbs: tend to modify things
  - Unfortunately, John walked home extremely slowly yesterday
  - Directional/locative adverbs (here,home, downhill)
  - Degree adverbs (extremely, very, somewhat)
  - Manner adverbs (slowly, slinkily, delicately)
- Verbs
  - In English, have morphological affixes (eat/eats/eaten)
    - With differing patterns of regularity

Closed Class Words

Examples:

- prepositions: *on, under, over, …*
- particles: *up, down, on, off, …*
- determiners: *a, an, the, …*
- pronouns: *she, who, I, ..*
- conjunctions: *and, but, or, …*
- auxiliary verbs: *can, may should, …*
- numerals: *one, two, three, third, …*