CSCI 5832
Natural Language Processing

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Lecture 11

Today 2/21

- Review HMMs
- EM Example
- Syntax
  - Context-Free Grammars

Review

- Parts of Speech
  - Basic syntactic/morphological categories that words belong to
- Part of Speech tagging
  - Assigning parts of speech to all the words in a sentence

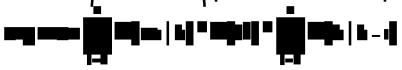
Probabilities

- We want the best set of tags for a sequence of words (a sentence)
- W is a sequence of words
- T is a sequence of tags

So…

- We start with

- And get

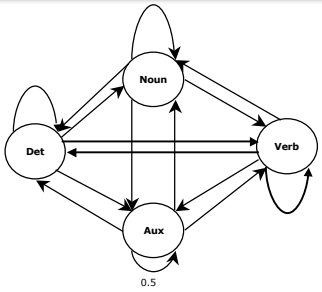


HMMs

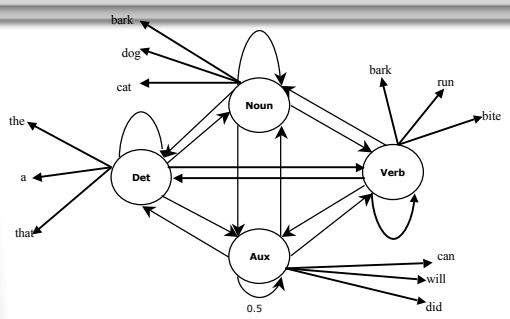
- This is an HMM

- The states in the model are the tags, and the observations are the words.
  - The state to state transitions are driven by the bigram statistics
  - The observed words are based solely on the state that you're currently in

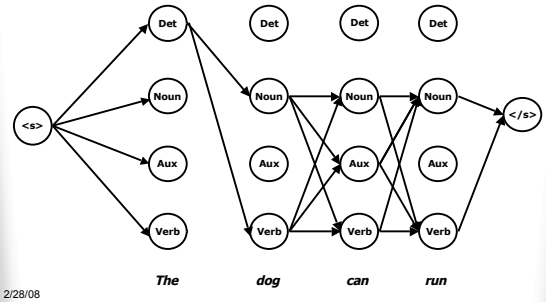
State Transitions



State Transitions and Observations



The State Space



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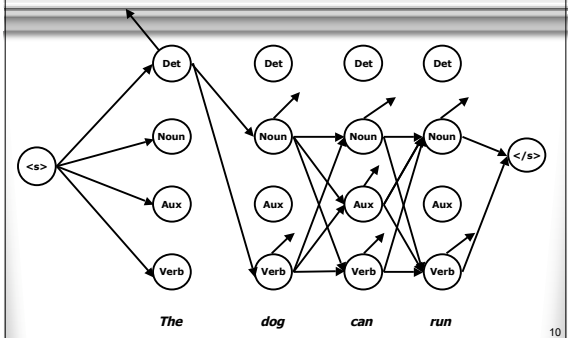
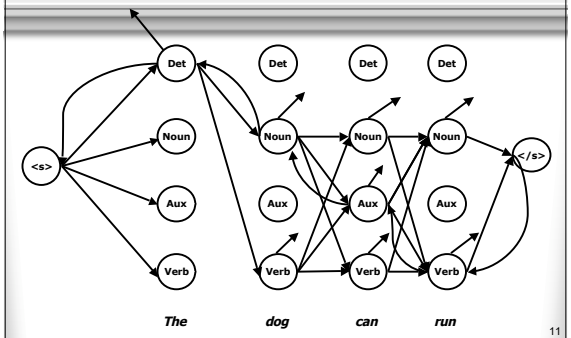


The State Space



Viterbi

- Efficiently return the most likely path
- Sweep through the columns multiplying the probabilities of one row, times the transition probabilities to the next row, times the appropriate observation probabilities
- And store the MAX

Forward

- Efficiently computes the probability of an observed sequence given a model
  - P(sequence|model)
- Nearly identical to Viterbi; replace the MAX with a SUM
  - There is one complication there if you think about the logs that we've been using

EM

- Forward/Backward
  - Efficiently arrive at the right model parameters given a model structure and an observed sequence
  - So for POS tagging
    - Given a tag set
    - And an observed sequence
    - Fill the A, B and PI tables with the right numbers
      - Numbers that give a model that Argmax P(model | data)

Urn Example

- A genie has two urns filled with red and blue balls. The genie selects an urn and then draws a ball from it (and replaces it). The genie then selects either the same urn or the other one and then selects another ball…
  - The urns are hidden
  - The balls are observed

Urn

- Based on the results of a long series of draws...
  - Figure out the distribution of colors of balls in each urn
  - Figure out the genie's preferences in going from one urn to the next

Urns and Balls

- Pi: Urn 1: 0.9; Urn 2: 0.1
- A

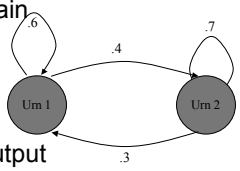
	Urn 1	Urn 2
Urn 1	0.6	0.4
Urn 2	0.3	0.7

- B

	Urn 1	Urn 2
Red	0.7	0.4
Blue	0.3	0.6

Urns and Balls

- Let's assume the input (observables) is Blue Blue Red (BBR)
- Since both urns contain red and blue balls any path through this machine could produce this output



Urns and Balls

Blue Blue Red

1 1 1	(0.9*0.3)*(0.6*0.3)*(0.6*0.7)=0.0204
1 1 2	(0.9*0.3)*(0.6*0.3)*(0.4*0.4)=0.0077
1 2 1	(0.9*0.3)*(0.4*0.6)*(0.3*0.7)=0.0136
1 2 2	(0.9*0.3)*(0.4*0.6)*(0.7*0.4)=0.0181
2 1 1	(0.1*0.6)*(0.3*0.7)*(0.6*0.7)=0.0052
2 1 2	(0.1*0.6)*(0.3*0.7)*(0.4*0.4)=0.0020
2 2 1	(0.1*0.6)*(0.7*0.6)*(0.3*0.7)=0.0052
2 2 2	(0.1*0.6)*(0.7*0.6)*(0.7*0.4)=0.0070

Urns and Balls

Viterbi: Says 111 is the most likely state sequence

1 1 1	(0.9*0.3)*(0.6*0.3)*(0.6*0.7)=0.0204
1 1 2	(0.9*0.3)*(0.6*0.3)*(0.4*0.4)=0.0077
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2 2 2	(0.1*0.6)*(0.7*0.6)*(0.7*0.4)=0.0070

Urns and Balls

Forward: P(BBR| model) = .0792 $\sum$

1 1 1	(0.9*0.3)*(0.6*0.3)*(0.6*0.7)=0.0204
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Urns and Balls

- EM
  - What if I told you I lied about the numbers in the model (Priors,A,B). I just made them up.
  - Can I get better numbers just from the input sequence?

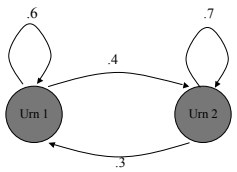
Urns and Balls

- Yup
  - Just count up and prorate the number of times a given transition is traversed while processing the observations inputs.
  - Then use that count to re-estimate the transition probability for that transition

Urns and Balls

- But… we just saw that don't know the actual path the input took, its hidden!
  - So prorate the counts from all the possible paths based on the path probabilities the model gives you
- But you said the numbers were wrong
  - Doesn't matter; use the original numbers then replace the old ones with the new ones.

Urn Example



Let's re-estimate the Urn1->Urn2 transition and the Urn1->Urn1 transition (using Blue Blue Red as training data).

Urns and Balls

Blue Blue Red

1 1 1	(0.9*0.3)*(0.6*0.3)*(0.6*0.7)=0.0204
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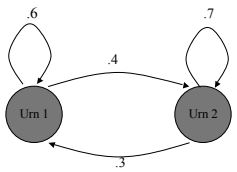
2 2 2	(0.1*0.6)*(0.7*0.6)*(0.7*0.4)=0.0070

Urns and Balls

- That's
  - (.0077*1)+(.0136*1)+(.0181*1)+(.0020*1)
  = .0414
- Of course, that's not a probability, it needs to be divided by the probability of leaving Urn 1 total.
- There's only one other way out of Urn 1 (going back to urn1)
  - So let's reestimate Urn1-> Urn1

Urn Example



Let's re-estimate the Urn1->Urn1 transition

Urns and Balls

Blue Blue Red

1 1 1	(0.9*0.3)*(0.6*0.3)*(0.6*0.7)=0.0204
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Urns and Balls

- That's just
  - (2*.0204)+(1*.0077)+(1*.0052) = .0537
- Again not what we need but we're closer… we just need to normalize using those two numbers.

Urns and Balls

- The 1->2 transition probability is
  .0414/(.0414+.0537) = 0.435
- The 1->1 transition probability is
  .0537/(.0414+.0537) = 0.565
- So in re-estimation the 1->2 transition went from .4 to .435 and the 1->1 transition went from .6 to .565

EM Re-estimation

- As with Problems 1 and 2, you wouldn't actually compute it this way. The Forward-Backward algorithm re-estimates these numbers in the same dynamic programming way that Viterbi and Forward do.

EM Re-estimation

- With a long enough training string, completely random initial model parameters will converge to the right parameters
- In real systems, you try to get the initial model parameters as close to correct as possible
  - Then you use a small amount of training material to home in on the right parameters

Break

- Next HW
  - I'll give you a training corpus
    - You build a bigram language model for that corpus
    - Use it to assign a log prob to withheld data
    - We'll use to implement the author identification task
    - To get started
      - Alter your code to count acquire unigram and bigram counts from a corpus.
  - Due 3/4

Syntax

- By syntax (or grammar) I mean the kind of implicit knowledge of your native language that you had mastered by the time you were 2 or 3 years old without explicit instruction
- Not the kind of stuff you were later taught in school.

Syntax

- Why should you care?
  - Grammar checkers
  - Question answering
  - Information extraction
  - Machine translation

Search?

On Friday, PARC is announcing a deal that underscores that strategy. It is licensing a broad portfolio of patents and technology to a well-financed start-up with an ambitious and potentially lucrative goal: to build a search engine that could some day rival Google.The start-up, Powerset, is licensing PARC's natural language technology - the art of making computers understand and process languages like English… Powerset hopes the technology will be the basis of a new search engine that allows users to type queries in plain English, rather than using keywords.

Search

For a lot of things, keyword search works well, said Barney Pell, chief executive of Powerset. But I think we are going to look back in 10 years and say, remember when we used to search using keywords.

Search

In a November interview, Marissa Mayer, Google's vice president for search and user experience, said: "Natural language is really hard. I don't think it will happen in the next five years."

Context-Free Grammars

- Capture constituency and ordering
  - Ordering is easy
    What are the rules that govern the ordering of words and bigger units in the language
  - What's constituency?
    How words group into units and how the various kinds of units behave wrt one another

CFG Examples

- S -> NP VP
- NP -> Det NOMINAL
- NOMINAL -> Noun
- VP -> Verb
- Det -> *a*
- Noun -> *flight*
- Verb -> *left*

CFGs

- S -> NP VP
  - This says that there are units called S, NP, and VP in this language
  - That an S consists of an NP followed immediately by a VP
  - Doesn't say that that's the only kind of S
  - Nor does it say that this is the only place that NPs and VPs occur

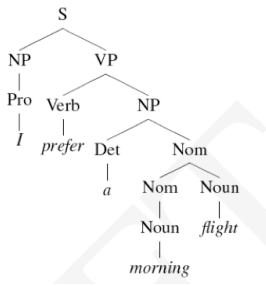
Generativity

- As with FSAs and FSTs you can view these rules as either analysis or synthesis machines
  - Generate strings in the language
  - Reject strings not in the language
  - Impose structures (trees) on strings in the language

Derivations

- A derivation is a sequence of rules applied to a string that accounts for that string
  - Covers all the elements in the string
  - Covers only the elements in the string

Derivations as Trees



Parsing

- Parsing is the process of taking a string and a grammar and returning a (many?) parse tree(s) for that string
- It is completely analogous to running a finite-state transducer with a tape
  - It's just more powerful
    - Remember this means that there are languages we can capture with CFGs that we can't capture with finite-state methods

Other Options

- Regular languages (expressions)
  - Too weak
- Context-sensitive or Turing equiv
  - Too powerful (maybe)

Context?

- The notion of context in CFGs has nothing to do with the ordinary meaning of the word context in language.
- All it really means is that the non-terminal on the left-hand side of a rule is out there all by itself (free of context)

  A -> B C

  Means that
  - I can rewrite an A as a B followed by a C regardless of the context in which A is found
  - Or when I see a B followed by a C I can infer an A regardless of the surrounding context

Key Constituents (English)

- Sentences
- Noun phrases
- Verb phrases
- Prepositional phrases

Sentence-Types

- Declaratives: A plane left
  S -> NP VP
- Imperatives: Leave!
  S -> VP
- Yes-No Questions: Did the plane leave?
  S -> Aux NP VP
- WH Questions: When did the plane leave?
  S -> WH Aux NP VP

Recursion

- We'll have to deal with rules such as the following where the non-terminal on the left also appears somewhere on the right (directly).

  Nominal -> Nominal PP [[flight] [to Boston]]

  VP -> VP PP [[departed Miami] [at noon]]

Recursion

- Of course, this is what makes syntax interesting
  - flights from Denver
  - Flights from Denver to Miami
  - Flights from Denver to Miami in February
  - Flights from Denver to Miami in February on a Friday
  - Flights from Denver to Miami in February on a Friday under $300
  - Flights from Denver to Miami in February on a Friday under $300 with lunch

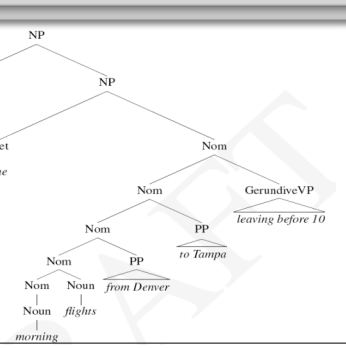
Recursion

- Of course, this is what makes syntax interesting
  - [[flights] [from Denver]]
  - [[[Flights] [from Denver]] [to Miami]]
  - [[[[Flights] [from Denver]] [to Miami]] [in February]]
  - [[[[[Flights] [from Denver]] [to Miami]] [in February]] [on a Friday]]
  - Etc.

The Point

- If you have a rule like
  - VP -> V NP
  - It only cares that the thing after the verb is an NP. It doesn't have to know about the internal affairs of that NP

The Point



Conjunctive Constructions

- S -> S and S
  - John went to NY and Mary followed him
- NP -> NP and NP
- VP -> VP and VP
- …
- In fact the right rule for English is
  X -> X and X

Problems

- Agreement
- Subcategorization
- Movement (for want of a better term)

Agreement

- This dog
- Those dogs
- *This dogs
- *Those dog

- This dog eats
- Those dogs eat
- *This dog eat
- *Those dogs eats

Subcategorization

- Sneeze: John sneezed
- Find: Please find [a flight to NY]$_{NP}$
- Give: Give [me]$_{NP}$[a cheaper fare]$_{NP}$
- Help: Can you help [me]$_{NP}$[with a flight]$_{PP}$
- Prefer: I prefer [to leave earlier]$_{TO\text{-}VP}$
- Told: I was told [United has a flight]$_{S}$
- …

Subcategorization

- *John sneezed the book
- *I prefer United has a flight
- *Give with a flight

- Subcat expresses the constraints that a predicate (verb for now) places on the number and syntactic types of arguments it wants to take (occur with).

So?

- So the various rules for VPs overgenerate.
  - They permit the presence of strings containing verbs and arguments that don't go together
  - For example
  - VP -> V NP therefore

    Sneezed the book is a VP since "sneeze" is a verb and "the book" is a valid NP

Next Time

- We're now into Chapters 12 and 13.
- Finish reading all of 12.
- Get through the CKY discussion in 13