ILLINOIS INSTITUTE OF TECHNOLOGY

Final Review

CS-585

Natural Language Processing

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Exam info

- Exam location and time
  - Final exam: Tuesday, December 7, 7:30-9:30 PM
  - Regular classroom: IT Tower 1F6-1
- Final details
  - Timed: 120 minutes
  - 300 points total
  - Multiple-choice
  - Open-book, open-notes
  - Written or printed materials OK, but no electronics
  - Bring pencils with erasers

Content overview

- Review
- **Syntax and Parsing**
- Evaluation
- Sequence Modeling
- Modeling Frameworks
- Other NLP Tasks

CONCEPTS AND DEFINITIONS

Syntax

- Phrasal categories: NP, VP, PP, S
- Parts of speech
- Subcategorization
- Complements and adjuncts
- Tests for constituency
- Agreement
- Heads and dependents
- Grammar types:
  - Regular
  - context-free
  - transformational
- Chomsky Normal Form
- Compositionality
- Structural Ambiguity
- Treebank

Modeling

- Exploding/vanishing gradients
- Maximum entropy
- Label bias
- Local vs. global normalization
- Expectation-maximization
- Locality
- Dynamic programming
- Viterbi algorithm
- Forward algorithm
- Backward algorithm
- Inside algorithm
- Noisy channel model
- Alignment

MODEL TYPES

RNNs and CNNs

Convolutional network (CNN)

- Applies convolution function to a local receptive field -- a sliding
  seque
  - "Fe
- Typica
  are int
  layers
- Limite
  difficu
  distance dependencies

Long short-term memory (LSTM)

- A type of recurrent network
- Passes information forward
  rough
  step
- ate
  ugh the
  avoid
  gradients
- context,
  but associated issues with
  optimization

Which is BERT?

Generative vs. Discriminative Models

Generative models

- Estimate the joint distribution $P(Y, X)$
- Can use in a supervised way using labeled data OR in an unsupervised way using EM, etc.
- Based on a "generative story" about how observed Xs are derived from latent Ys

Discriminative models

- Estimate the conditional distribution $P(Y|X)$
- Can ONLY be trained using supervised methods
- NO generative story

LDA

- Latent Dirichlet Allocation is an unsupervised model for text clustering
- It is based on a model assuming that there are k latent topics for our documents
  - For a given document, a distribution z over topics is chosen
  - Each word in the document is chosen independently according to that distribution
- Overall, the model expresses the joint likelihood $P(T, D)$ of documents D and their latent topics T

EVALUATION METRICS

Explanations and relationships to tasks

Metrics

- Accuracy
- Precision
- Recall
- F-measure
- Cohen's kappa
- BLEU
- Labeled/unlabeled P/R/F
- Attachment score
- Correct root
- Perplexity

Tasks

- Text categorization
- Language modeling
- Sequence modeling
- Parsing
- Machine translation

CYK PARSING

Cocke-Younger-Kasami (CYK)

Assume "Chomsky Normal Form" grammar

```
for n := 0 to Nw-1 do:
  chart[0, n] := {X | X → wordn }

for m := 1 to Nw-1 do:
   for n := 0 to Nw-m-1 do:
      chart[m, n] := {}
      for k := n+1 to n+m do
         for every rule A → B C do
            if B ∈ chart[k-n-1, n] and C ∈ chart[n+m-k, k] then
               chart[m, n] := chart[m, n] ∪ {A}

if S ∈ chart[Nw-1, 0] then accept else reject
```

CYK Example (in CNF)

S	$\longrightarrow$	NP VP
S	$\longrightarrow$	V NP
S	$\longrightarrow$	S PP
VP	$\longrightarrow$	V NP
VP	$\longrightarrow$	V PP
VP	$\longrightarrow$	VP PP
PP	$\longrightarrow$	P NP
NP	$\longrightarrow$	Det NP
NP	$\longrightarrow$	NP PP

NP	$\rightarrow$	love
NP	$\rightarrow$	wins
NP	$\rightarrow$	end
V	$\rightarrow$	wins
V	$\rightarrow$	love
P	$\rightarrow$	in
Det	$\rightarrow$	the

“Love wins in the end”

Example

Love$_0$ wins$_1$ in$_2$ the$_3$ end$_4$

n (constituent start index)

m (constituent length -1)

	0	1	2	3	4
0	V,NP	V,NP	P	Det	V,NP
1					
2					
3					
4					

$N_w = 5$

$m = 0$

Example

Love$_0$ wins$_1$ in$_2$ the$_3$ end$_4$

n (constituent start index)

m (constituent length -1)

	0	1	2	3	4
0	V,NP	V,NP	P	Det	V,NP
1	S,VP				
2					
3					
4					

$N_w = 5$
$m = 1$
$n = 0$
$k = n+1$

S	$\longrightarrow$	V NP
VP	$\longrightarrow$	V NP

Example

Love$_0$ wins$_1$ in$_2$ the$_3$ end$_4$

n (constituent start index)

m (constituent length -1)

	0	1	2	3	4
0	V,NP	V,NP	P	Det	V,NP
1	S,VP	{}			
2					
3					
4					

$N_w = 5$

$m = 1$

$n = 1$

$k = n+1$

$\boxed{\emptyset}$

Example

Love$_0$ wins$_1$ in$_2$ the$_3$ end$_4$

n (constituent start index)

m (constituent length -1)

	0	1	2	3	4
0	V,NP	V,NP	P	Det	V,NP
1	S,VP	{}	{}		
2					
3					
4					

$N_w = 5$
$m = 1$
$n = 2$
$k = n+1$

$\boxed{\emptyset}$

Example

Love$_0$ wins$_1$ in$_2$ the$_3$ end$_4$

n (constituent start index)

m (constituent length -1)

	0	1	2	3	4
0	V,NP	V,NP	P	Det	V,NP
1	S,VP	{}	{}	NP	
2					
3					
4					

$N_w = 5$
$m = 1$
$n = 3$
$k = n+1$

$$NP \longrightarrow Det\ NP$$

Example

Love$_0$ wins$_1$ in$_2$ the$_3$ end$_4$

n (constituent start index)

m (constituent length -1)

	0	1	2	3	4
0	V,NP	V,NP	P	Det	V,NP
1	S,VP	{}	{}	NP	
2	{}				
3					
4					

$N_w = 5$
$m = 2$
$n = 0$
$k = n+1$

$\boxed{\emptyset}$

Example

Love$_0$ wins$_1$ in$_2$ the$_3$ end$_4$

n (constituent start index)

m (constituent length -1)

	0	1	2	3	4
0	V,NP	V,NP	P	Det	V,NP
1	S,VP	{}	{}	NP	
2	{}				
3					
4					

$N_w = 5$
$m = 2$
$n = 0$
$k = n+2$

∅

Example

Love$_0$ wins$_1$ in$_2$ the$_3$ end$_4$

n (constituent start index)

m (constituent length -1)

	0	1	2	3	4
0	V,NP	V,NP	P	Det	V,NP
1	S,VP	{}	{}	NP	
2	{}	{}			
3					
4					

$N_w = 5$
$m = 2$
$n = 1$
$k = n+1$

$\boxed{\emptyset}$

Example

Love$_0$ wins$_1$ in$_2$ the$_3$ end$_4$

n (constituent start index)

m (constituent length -1)

	0	1	2	3	4
0	V,NP	V,NP	P	Det	V,NP
1	S,VP	{}	{}	NP	
2	{}	{}			
3					
4					

$N_w = 5$
$m = 2$
$n = 1$
$k = n+2$

$\boxed{\emptyset}$

Example

Love_0 wins_1 in_2 the_3 end_4

n (constituent start index)

m (constituent length - 1)

	0	1	2	3	4
0	V,NP	V,NP	P	Det	V,NP
1	S,VP	{}	{}	NP	
2	{}	{}	PP		
3					
4					

$N_w = 5$
$m = 2$
$n = 2$
$k = n+1$

$$PP \longrightarrow P\ NP$$

Example

Love_0 wins_1 in_2 the_3 end_4

n (constituent start index)

m (constituent length -1)

	0	1	2	3	4
0	V,NP	V,NP	P	Det	V,NP
1	S,VP	{}	{}	NP	
2	{}	{}	PP		
3					
4					

$N_w = 5$
$m = 2$
$n = 2$
$k = n+2$

$\boxed{\emptyset}$

Example

Love$_0$ wins$_1$ in$_2$ the$_3$ end$_4$

n (constituent start index)

m (constituent length -1)

	0	1	2	3	4
0	V,NP	V,NP	P	Det	V,NP
1	S,VP	{}	{}	NP	
2	{}	{}	PP		
3	{}				
4					

$N_w = 5$
m = 3
n = 0
k = n+1

$\boxed{\emptyset}$

Example

Love$_0$ wins$_1$ in$_2$ the$_3$ end$_4$

n (constituent start index)

m (constituent length -1)

	0	1	2	3	4
0	V,NP	V,NP	P	Det	V,NP
1	S,VP	{}	{}	NP	
2	{}	{}	PP		
3	{}				
4					

$N_w = 5$
$m = 3$
$n = 0$
$k = n+2$

$\boxed{\emptyset}$

Example

Love$_0$ wins$_1$ in$_2$ the$_3$ end$_4$

n (constituent start index)

m (constituent length -1)

	0	1	2	3	4
0	V,NP	V,NP	P	Det	V,NP
1	S,VP	{}	{}	NP	
2	{}	{}	PP		
3	{}				
4					

$N_w = 5$
$m = 3$
$n = 0$
$k = n+3$

$\boxed{\emptyset}$

Example

Love$_0$ wins$_1$ in$_2$ the$_3$ end$_4$

n (constituent start index)

m (constituent length - 1)

	0	1	2	3	4
0	V,NP	V,NP	P	Det	V,NP
1	S,VP	{}	{}	NP	
2	{}	{}	PP		
3	{}	NP,VP			
4					

$N_w = 5$
m = 3
n = 1
k = n+1

$$\begin{aligned} NP &\longrightarrow NP\ PP \\ VP &\longrightarrow V\ PP \end{aligned}$$

Example

Love$_0$ wins$_1$ in$_2$ the$_3$ end$_4$

n (constituent start index)

m (constituent length -1)

	0	1	2	3	4
0	V,NP	V,NP	P	Det	V,NP
1	S,VP	{}	{}	NP	
2	{}	{}	PP		
3	{}	NP,VP			
4					

N_w = 5
m = 3
n = 1
k = n+2

$\boxed{\emptyset}$

Example

Love$_0$ wins$_1$ in$_2$ the$_3$ end$_4$

n (constituent start index)

m (constituent length -1)

	0	1	2	3	4
0	V,NP	V,NP	P	Det	V,NP
1	S,VP	{}	{}	NP	
2	{}	{}	PP		
3	{}	NP,VP			
4					

$N_w = 5$
$m = 3$
$n = 1$
$k = n+3$

$\boxed{\emptyset}$

Example

Love_0 wins_1 in_2 the_3 end_4

n (constituent start index)

m (constituent length -1)

	0	1	2	3	4
0	V,NP	V,NP	P	Det	V,NP
1	S,VP	{}	{}	NP	
2	{}	{}	PP		
3	{}	NP,VP			
4	S,VP				

$N_w = 5$
$m = 4$
$n = 0$
$k = n+1$

$$S \longrightarrow V\ NP$$
$$S \longrightarrow NP\ VP$$
$$VP \longrightarrow V\ NP$$

Example

Love_0 wins_1 in_2 the_3 end_4

n (constituent start index)

m (constituent length -1)

	0	1	2	3	4
0	V,NP	V,NP	P	Det	V,NP
1	S,VP	{}	{}	NP	
2	{}	{}	PP		
3	{}	NP,VP			
4	S,VP				

$N_w = 5$

$m = 4$

$n = 0$

$k = n+2$

S	$\longrightarrow$	S PP
VP	$\longrightarrow$	VP PP

Example

Love$_0$ wins$_1$ in$_2$ the$_3$ end$_4$

n (constituent start index)

m (constituent length -1)

	0	1	2	3	4
0	V,NP	V,NP	P	Det	V,NP
1	S,VP	{}	{}	NP	
2	{}	{}	PP		
3	{}	NP,VP			
4	S,VP				

$N_w = 5$
$m = 4$
$n = 0$
$k = n+3$

$\boxed{\emptyset}$

Example

Love$_0$ wins$_1$ in$_2$ the$_3$ end$_4$

n (constituent start index)

m (constituent length -1)

	0	1	2	3	4
0	V,NP	V,NP	P	Det	V,NP
1	S,VP	{}	{}	NP	
2	{}	{}	PP		
3	{}	NP,VP			
4	S,VP				

N_w = 5
m = 4
n = 0
k = n+4

$\boxed{\emptyset}$

Example

Love$_0$ wins$_1$ in$_2$ the$_3$ end$_4$

n (constituent start index)

m (constituent length -1)

	0	1	2	3	4
0	V, NP	V, NP	P	Det	V, NP
1	S, VP	{}	{}	NP	
2	{}	{}	PP		
3	{}	NP, VP			
4	S, VP				

Ambiguous?

Second exercise

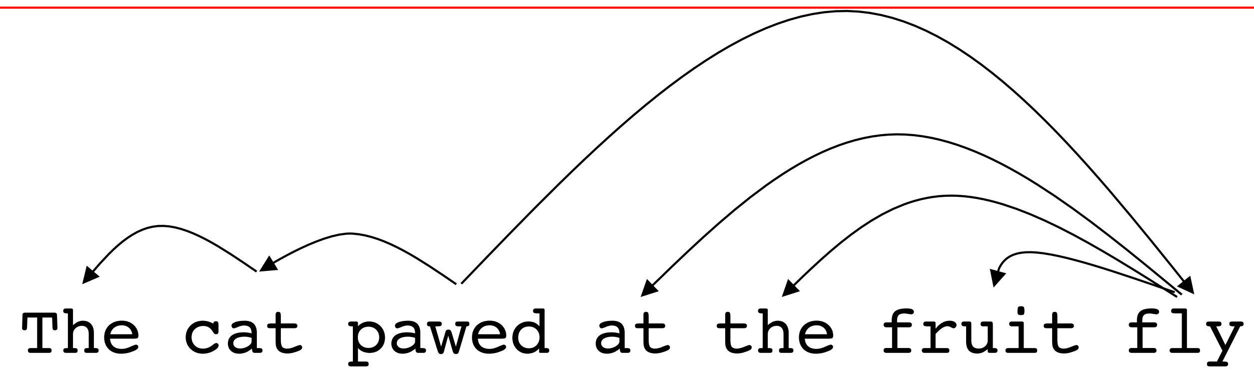
Love wins wins

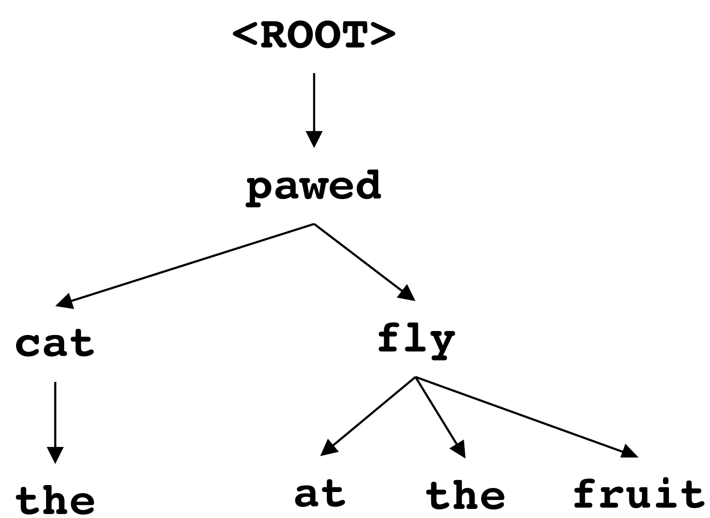
DEPENDENCY STRUCTURES

Spanning Trees

- A spanning tree for a sentence
  - Has a single root
  - Contains directed edges such that
    - every word can be reached from the root by following some sequence of edges
    - no word is the dependent of multiple elements (each word appears only once as the destination of an edge)
  - Contains no cycles
- If it is projective
  - Any element between a head and its direct dependent (in linear order) must be a (direct or indirect) dependent of one or the other

Spanning Trees





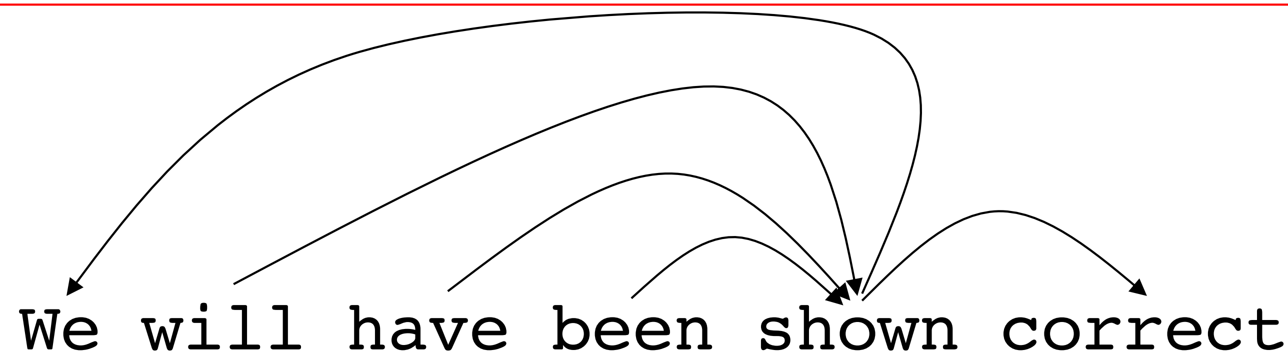
Spanning tree?

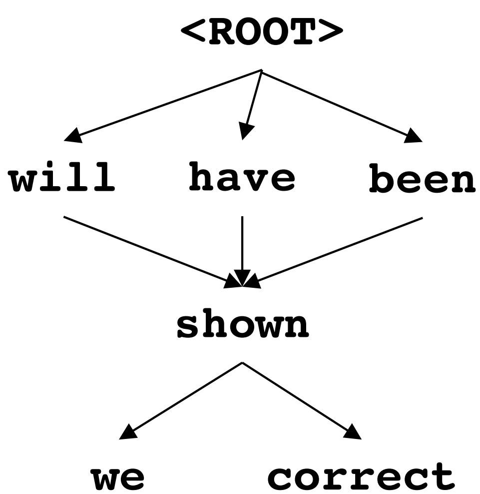
Yes

Projective?

Yes

Spanning Trees

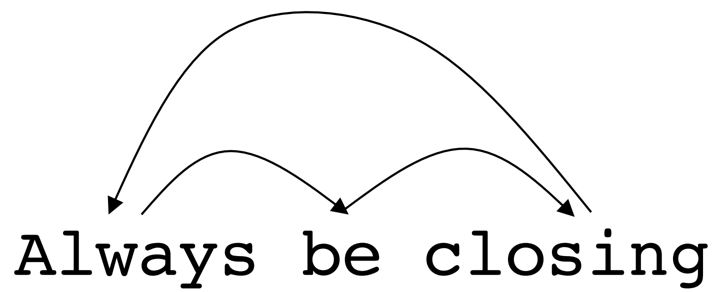


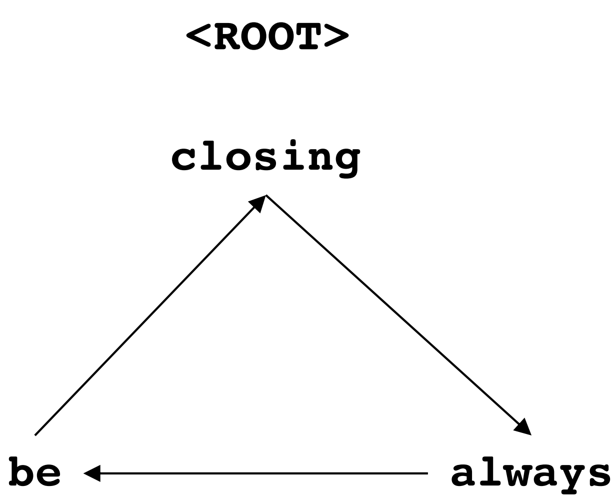


Spanning tree?

No

Spanning Trees

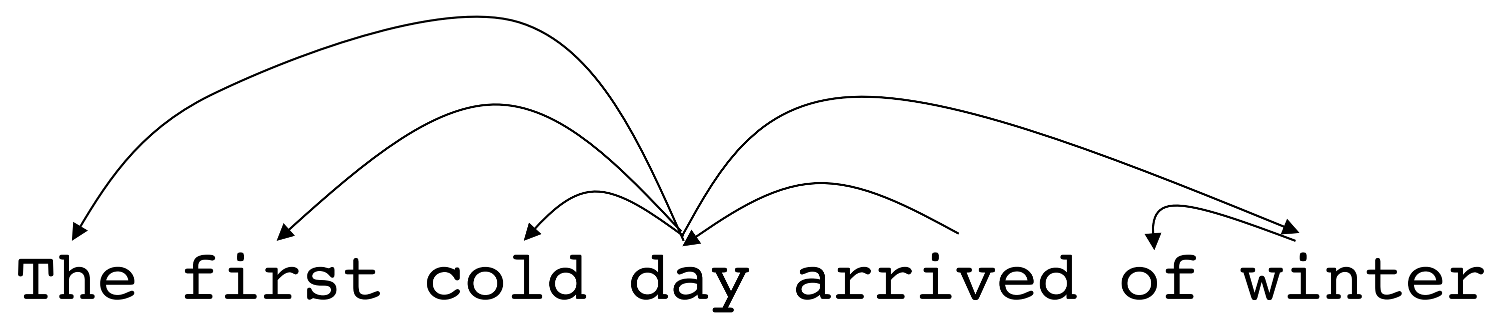


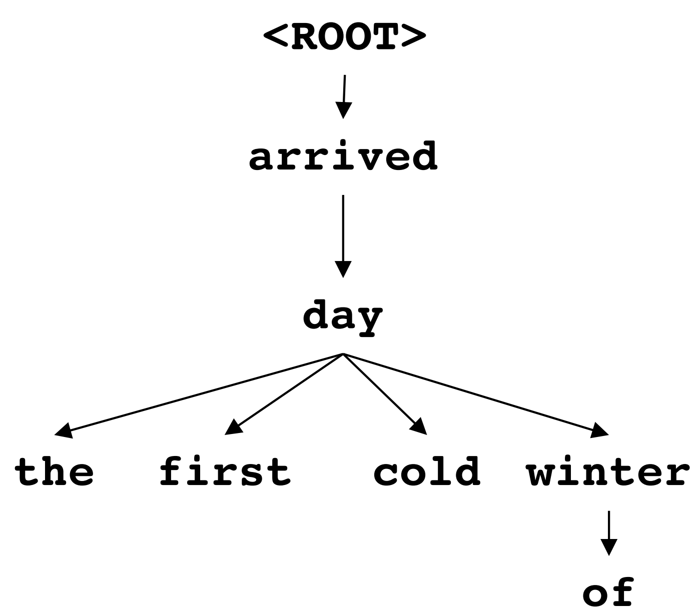


Spanning tree?

No

Spanning Trees





Spanning tree?

Yes

Projective?

No