CSCI 544, Lecture 16: Grammars and statistical parsing

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2022-10-18

Administrative notes

Coding Assignment 3 will be graded soon

Coding Assignment 4 due October 25

- Submit early, submit often

Presentation:

Due Date	Task
October 18	**Article selection**
October 27	Presentation slides
November 1–10	Presentations

Project:

Due Date	Task
November 3	Project status report
Nov 29/Dec 1	Poster presentations (in class)
December 1	Final report
December 3	Self-evaluation and peer grading

Article presentations

7 minutes, 7 slides

- Practice to fit in time slot
- Invlove entire team

On Zoom
Sign-up sheet available

Use slides, but talk about research, not slides

The audience has not read the article

- Assume no prior knowledge of the topic
- Explain new methods or techniques

Concentrate on **main idea**

- Explain necessary details, but don't get bogged down
- Explain the linguistic aspects

Include **your own** critical evaluation

Syntax

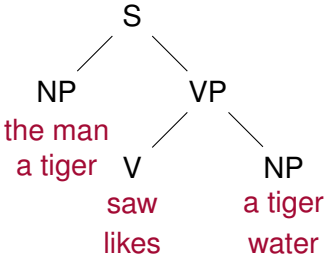
Structure of sentences

Context-Free Grammar (one grammatical formalism)

Context-free rules

$S \rightarrow NP\ VP$

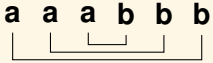
$VP \rightarrow V\ NP$



Other grammar formalisms

Regular grammars (not very expressive)

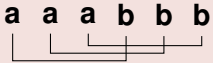
- Cannot capture center-embedding dependencies



☛ Captured by context-free grammars

Tree-Adjoining Grammars
Combinatory Categorial Grammars
} "mildly context sensitive"

- Can capture cross-serial dependencies



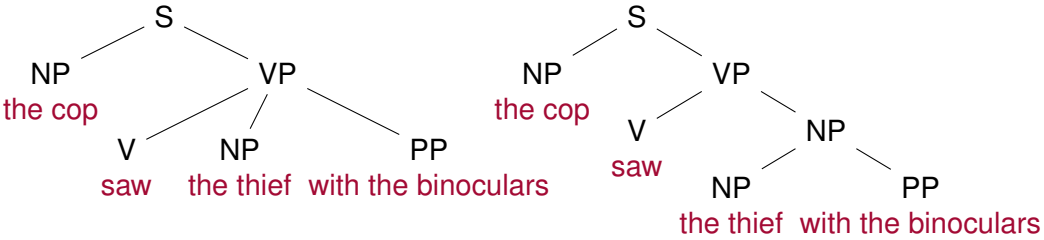
☛ Is human language context-free?

Dependency grammars

Ambiguity

A context-free grammar can produce ambiguous sentences:

The cop saw the thief with the binoculars **attachment ambiguity**



The parsing problem

1. Find possible structures according to the grammar
2. Find the most likely parse
- Charniak argues against **linguistic** grammaticality, not against formal grammaticality

Chart parsing (Earley, CYK, etc.): $O(n^3)$

CYK algorithm: bottom-up

- Chomsky Normal Form: all rules of form X $\rightarrow$ Y Z or X $\rightarrow$ word

CYK parsing example

S $\rightarrow$ NP VP	NP $\rightarrow$ United
VP $\rightarrow$ VP NP	NP $\rightarrow$ flights
VP $\rightarrow$ VP PP	NP $\rightarrow$ Houston
NP $\rightarrow$ NP PP	VP $\rightarrow$ diverted
PP $\rightarrow$ P NP	P $\rightarrow$ to

United diverted flights to Houston

CYK parsing example

S $\rightarrow$ NP VP	NP $\rightarrow$ United
VP $\rightarrow$ VP NP	NP $\rightarrow$ flights
VP $\rightarrow$ VP PP	NP $\rightarrow$ Houston
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NP	VP	NP	P	NP
United	diverted	flights	to	Houston

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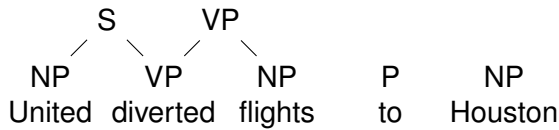

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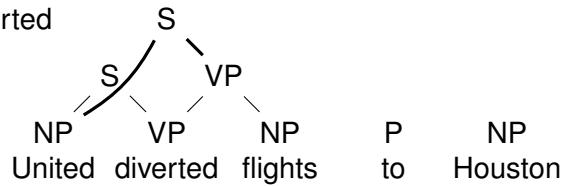

CYK parsing example

$S \rightarrow NP\ VP$
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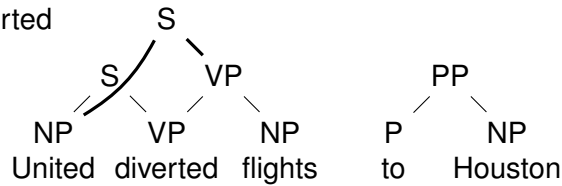

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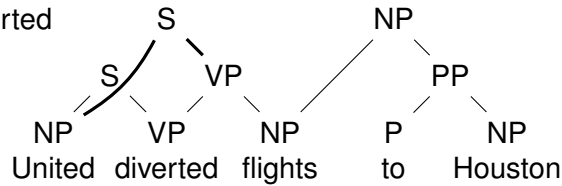

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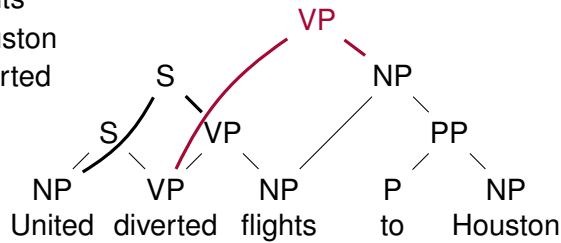
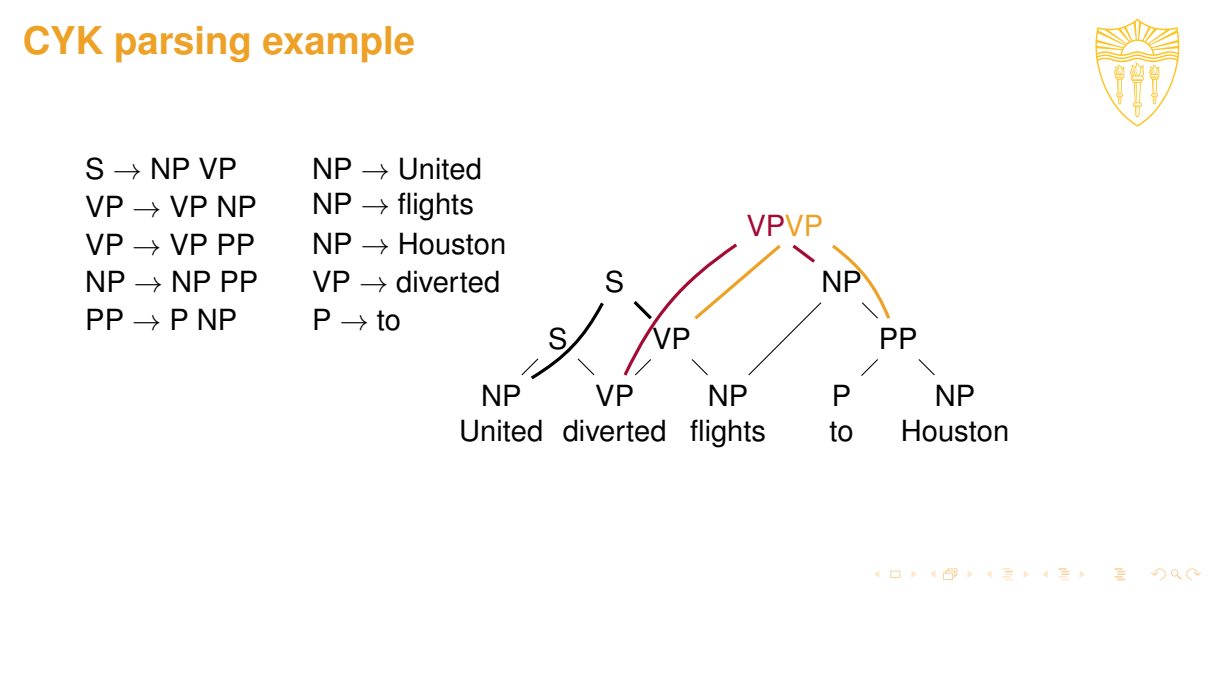


CYK parsing example



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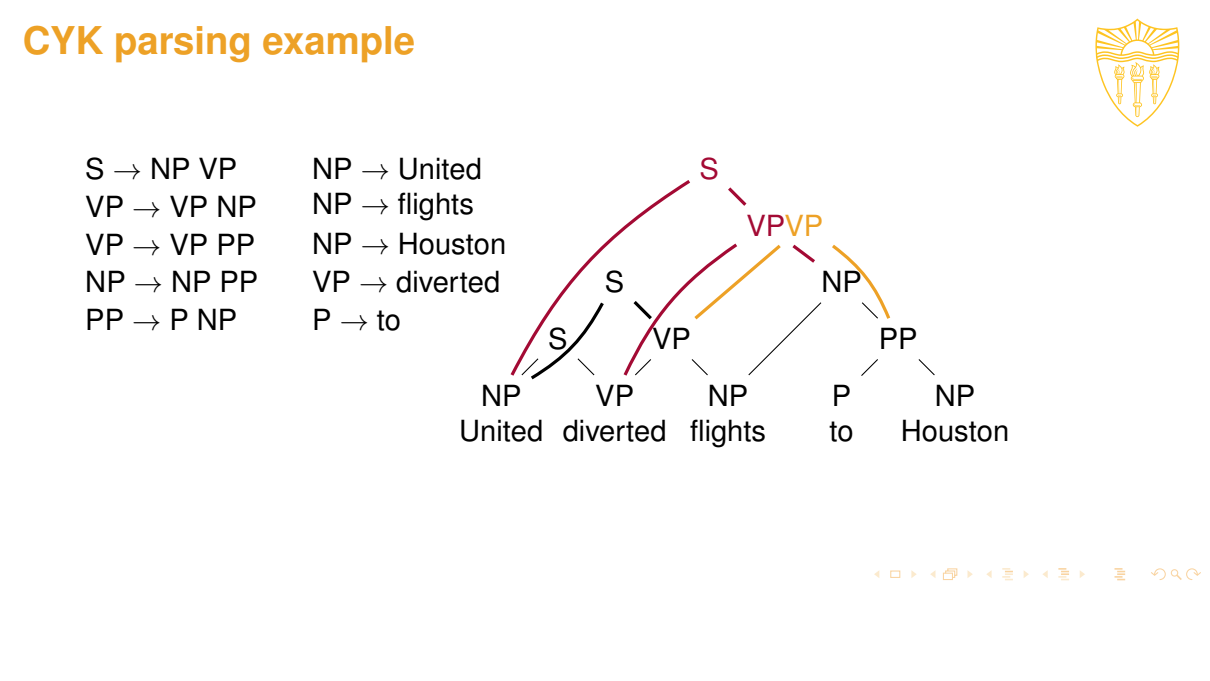

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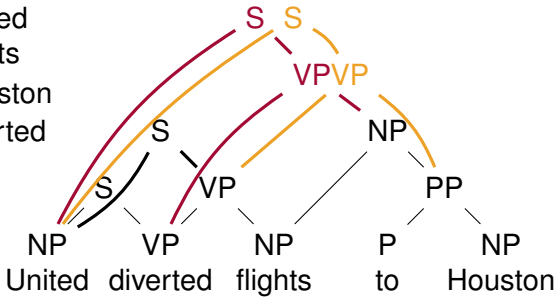


Bottom-up or top-down?

CYK is a **bottom-up algorithm**: it finds potential constituents that can never fit into the full parse of the sentence

A **top-down algorithm** only predicts constituents that fit. . .
. . . but it predicts constituents that don't match the data

At the end of class today (if we have time):
top-down agenda-based algorithm (bottom-up version also exists)

Statistical parsing

How do we find the most likely parse?

- United [$_{VP}$ [$_{VP}$ diverted flights] [$_{PP}$ to Houston]]
- United [$_{VP}$ diverted [$_{NP}$ flights [$_{PP}$ to Houston]]]

Probabilistic CFG: probabilities for rules

$P(S \rightarrow NP\ VP)$ $P(VP \rightarrow VP\ NP)$

$P(VP \rightarrow VP\ PP)$ $P(NP \rightarrow NP\ PP)$

Words matter too: I ate the animal crackers

I fed the animal crackers

More detailed symbols in the grammar: $V_{transitive} \rightarrow$ ate

$V_{ditransitive} \rightarrow$ fed

Or go fully lexical

Lexicalized PCFG

I ate the animal crackers **I fed the animal crackers**

P(rule | head) **A superscript $^{(h)}$ indicates the head constituent**

$P(\text{VP} \rightarrow \text{VP}^{(h)}\ \text{NP} \mid \text{VP}^{(h)} = \text{ate})$ $P(\text{VP} \rightarrow \text{VP}^{(h)}\ \text{NP} \mid \text{VP}^{(h)} = \text{fed})$

$P(\text{VP} \rightarrow \text{VP}^{(h)}\ \text{NP NP} \mid \text{VP}^{(h)} = \text{ate})$ $P(\text{VP} \rightarrow \text{VP}^{(h)}\ \text{NP NP} \mid \text{VP}^{(h)} = \text{fed})$

P(head | head of parent)

$P(\text{crackers} \mid \text{parent} = \text{ate})$ $P(\text{crackers} \mid \text{parent} = \text{fed})$

$P(\text{animal} \mid \text{parent} = \text{ate})$ $P(\text{animal} \mid \text{parent} = \text{fed})$

Dependency grammars

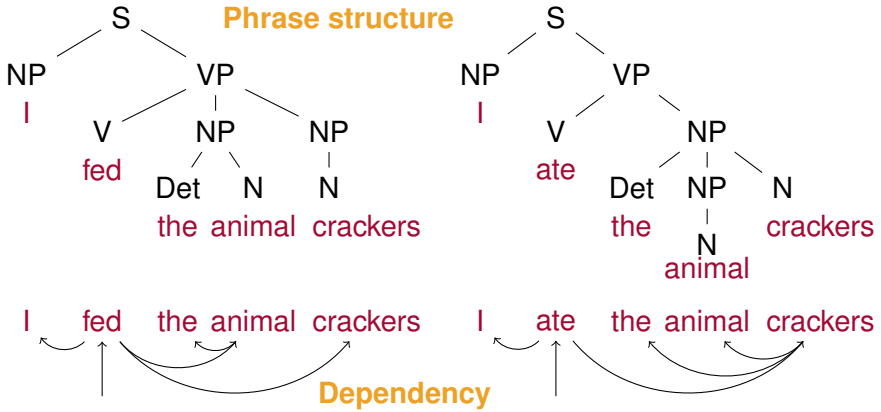
A different grammatical theory

- No phrases
- Dependencies = relations between words

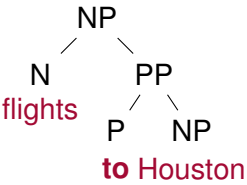
  head $\longrightarrow$ dependent

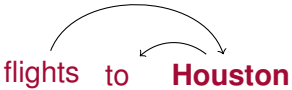
- “Head” notion different from phrase-structure grammars

Phrase structures and dependency structures



Heads in dependency structures





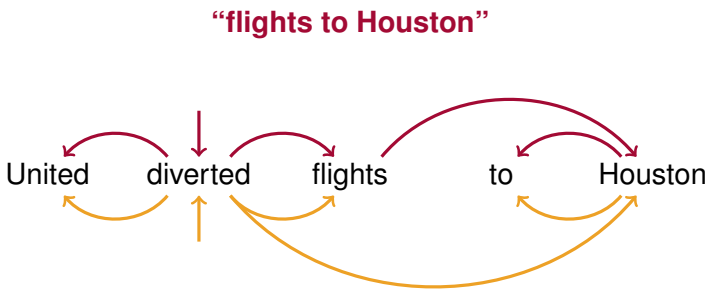
Dependency parsing

Arc-standard parsing (shift-reduce)

- Linear time
- Non-exhaustive search
- Use heuristics for finding the best path (trained oracle)
- Greedy

Other approaches (beam search, etc.)

Dependency parsing ambiguity



Dependency parsing derivation 1

“flights to Houston”

Stack	Word list	Action	Relations
root	United, diverted, flights, to, Houston		

Dependency parsing derivation 1

“flights to Houston”

Stack	Word list	Action	Relations
root	United, diverted, flights, to, Houston	Shift	
root, United	diverted, flights, to, Houston		

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root, diverted, flights	to, Houston	**Shift**	
root, diverted, flights, to	Houston		

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root, diverted, flights, to	Houston	Shift	
root, diverted, flights, to, Houston		LeftArc	to ← Houston
root, diverted, flights, Houston		RightArc	flights → Houston
root, diverted, flights			

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root, diverted			

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root, diverted, flights, to	Houston	Shift	
root, diverted, flights, to, Houston		LeftArc	to ← Houston
root, diverted, flights, Houston		RightArc	flights → Houston
root, diverted, flights		RightArc	diverted → flights
root, diverted		RightArc	root → diverted
root			

Dependency parsing derivation 2

“diverted to Houston”

Stack	Word list	Action	Relations
root	United, diverted, flights, to, Houston	Shift	
root, United	diverted, flights, to, Houston	Shift	
root, United, diverted	flights, to, Houston	LeftArc	United ← diverted
root, diverted	flights, to, Houston	Shift	
root, diverted, flights	to, Houston		

Dependency parsing derivation 2

“diverted to Houston”

Stack	Word list	Action	Relations
root	United, diverted, flights, to, Houston	Shift	
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root, diverted	flights, to, Houston	Shift	
root, diverted, flights	to, Houston	**RightArc**	diverted → flights
root, diverted	to, Houston		

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root, diverted	to, Houston	Shift	
root, diverted, to	Houston		

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root, diverted, flights	to, Houston	**RightArc**	diverted → flights
root, diverted	to, Houston	Shift	
root, diverted, to	Houston	Shift	
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root, diverted, to	Houston	Shift	
root, diverted, to, Houston		LeftArc	to ← Houston
root, diverted, Houston		RightArc	diverted → Houston
root, diverted			

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root, diverted, to	Houston	Shift	
root, diverted, to, Houston		LeftArc	to ← Houston
root, diverted, Houston		RightArc	diverted → Houston
root, diverted		RightArc	root → diverted
root			