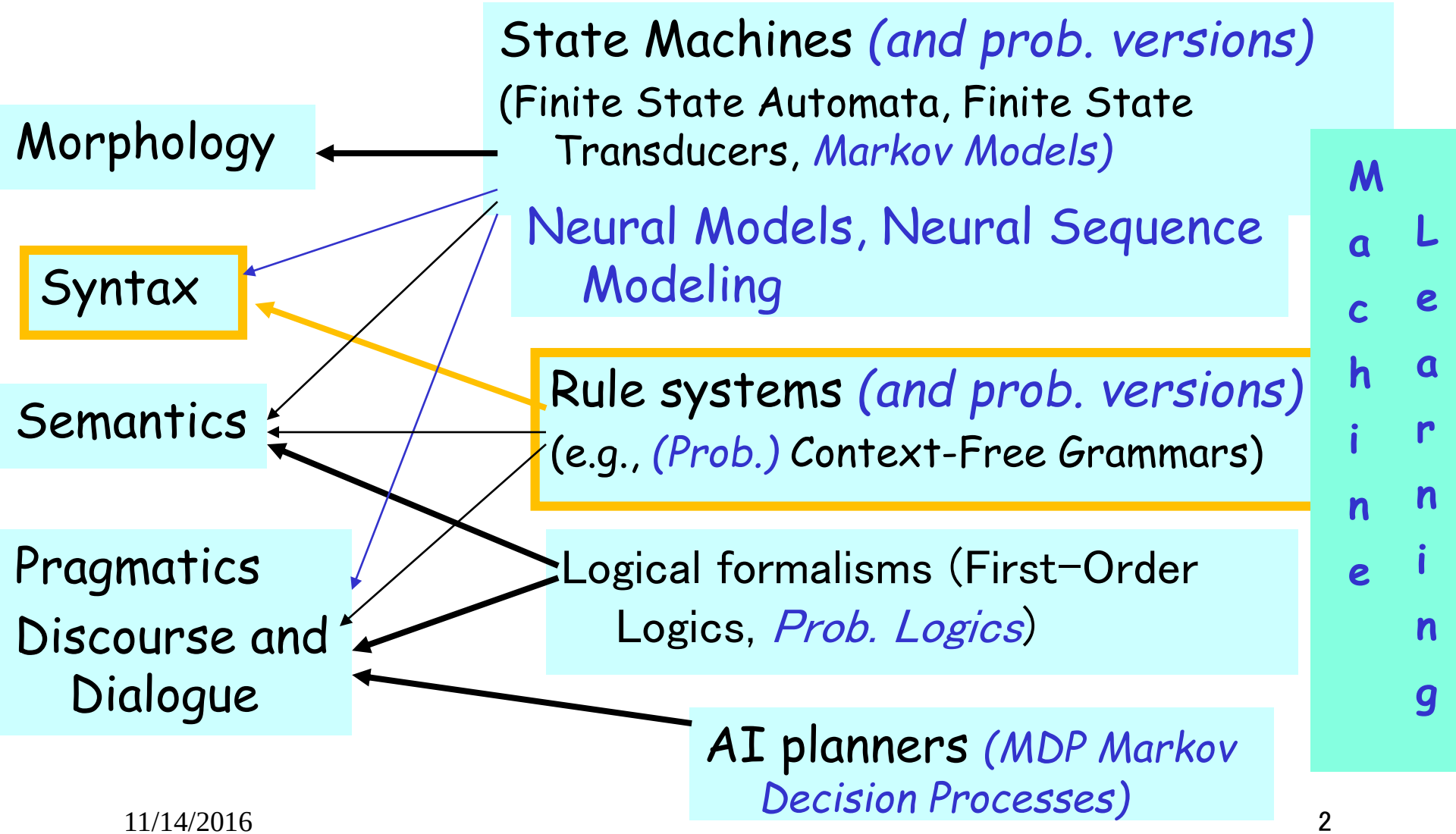
Intelligent Systems (AI-2)

Computer Science cpsc422, Lecture ~~27~~ 26

Nov, 14, 2016

Knowledge-Formalisms Map
(including probabilistic formalisms)



Lecture Overview

- Recap English Syntax and Parsing
- Key Problem with parsing: Ambiguity
- Probabilistic Context Free Grammars (PCFG)
- Treebanks and Grammar Learning

Key Constituents: Examples

Head

NP → N
NP → Det N

(Specifier) X (Complement)

• Noun phrases (NP)	• (Det)	N	(PP)
	the	cat	on the table
• Verb phrases (VP)	• (Qual)	V	(NP)
	never	eat	a cat
• Prepositional phrases (PP)	• (Deg)	P	(NP)
	almost	in	the net
• Adjective phrases(AP)	• (Deg)	A	(PP)
	very	happy	about it
• Sentences (S)	• (NP)	(-)	(VP)
	a mouse	--	ate it

Context Free Grammar (CFG)

- **4-tuple** (non-term., term., productions, start)
- (N, Σ, P, S)
- P is a set of rules $A \rightarrow \alpha$; $A \in \mathbf{N}$, $\alpha \in (\Sigma \cup N)^*$

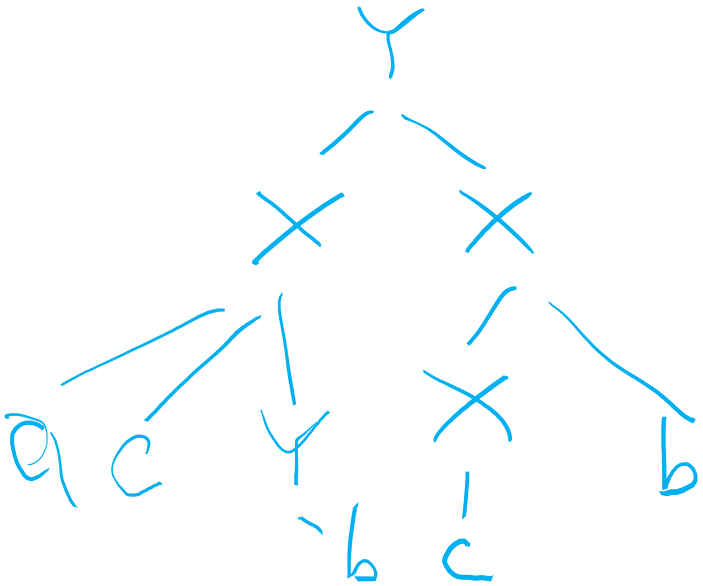
$N = \{X\ Y\}$ $\Sigma = \{a\ b\ c\}$ $P =$ $X \rightarrow Xb$

$Y \rightarrow XX$

$X \rightarrow aXc$

$X \rightarrow c$

$Y \rightarrow b$



CFG Example

Grammar with example phrases

	S	$\rightarrow$	$NP\ VP$
	NP	$\rightarrow$	$Pronoun$
		$\mid$	$Proper\text{-}Noun$
		$\mid$	$Det\ Nominal$
Nominal		$\rightarrow$	$Noun\ Nominal$
		$\mid$	$Noun$
	VP	$\rightarrow$	$Verb$
		$\mid$	$Verb\ NP$
		$\mid$	$Verb\ NP\ PP$
		$\mid$	$Verb\ PP$
	PP	$\rightarrow$	$Preposition\ NP$

I + want a morning flight

I

Los Angeles

a + flight

morning + flight

flights

do

want + a flight

leave + Boston + in the morning

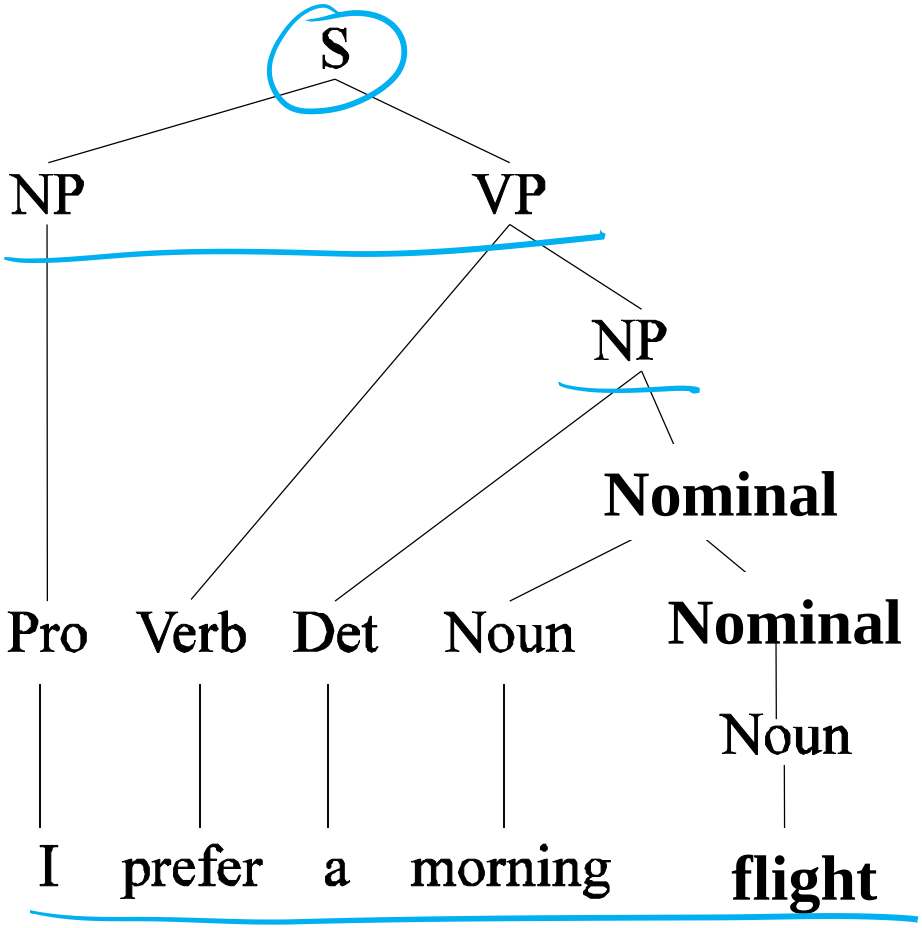
leaving + on Thursday

from + Los Angeles

Lexicon

$Noun$	$\rightarrow$	$flights \mid breeze \mid trip \mid morning \mid \ldots$
$Verb$	$\rightarrow$	$is \mid prefer \mid like \mid need \mid want \mid fly$
$Adjective$	$\rightarrow$	$cheapest \mid non-stop \mid first \mid latest$
		$\mid other \mid direct \mid \ldots$
$Pronoun$	$\rightarrow$	$me \mid I \mid you \mid it \mid \ldots$
$Proper\text{-}Noun$	$\rightarrow$	$Alaska \mid Baltimore \mid Los\ Angeles$
		$\mid Chicago \mid United \mid American \mid \ldots$
$Determiner$	$\rightarrow$	$the \mid a \mid an \mid this \mid these \mid that \mid \ldots$
$Preposition$	$\rightarrow$	$from \mid to \mid on \mid near \mid \ldots$
$Conjunction$	$\rightarrow$	$and \mid or \mid but \mid \ldots$

Derivations as Trees



$S \rightarrow NP\ VP$

$NP \rightarrow Pronoun$

$\quad\quad | \quad Proper\text{-}Noun$

$\quad\quad | \quad Det\ Nominal$

$Nominal \rightarrow Noun\ Nominal$

$\quad\quad | \quad Noun$

$VP \rightarrow Verb$

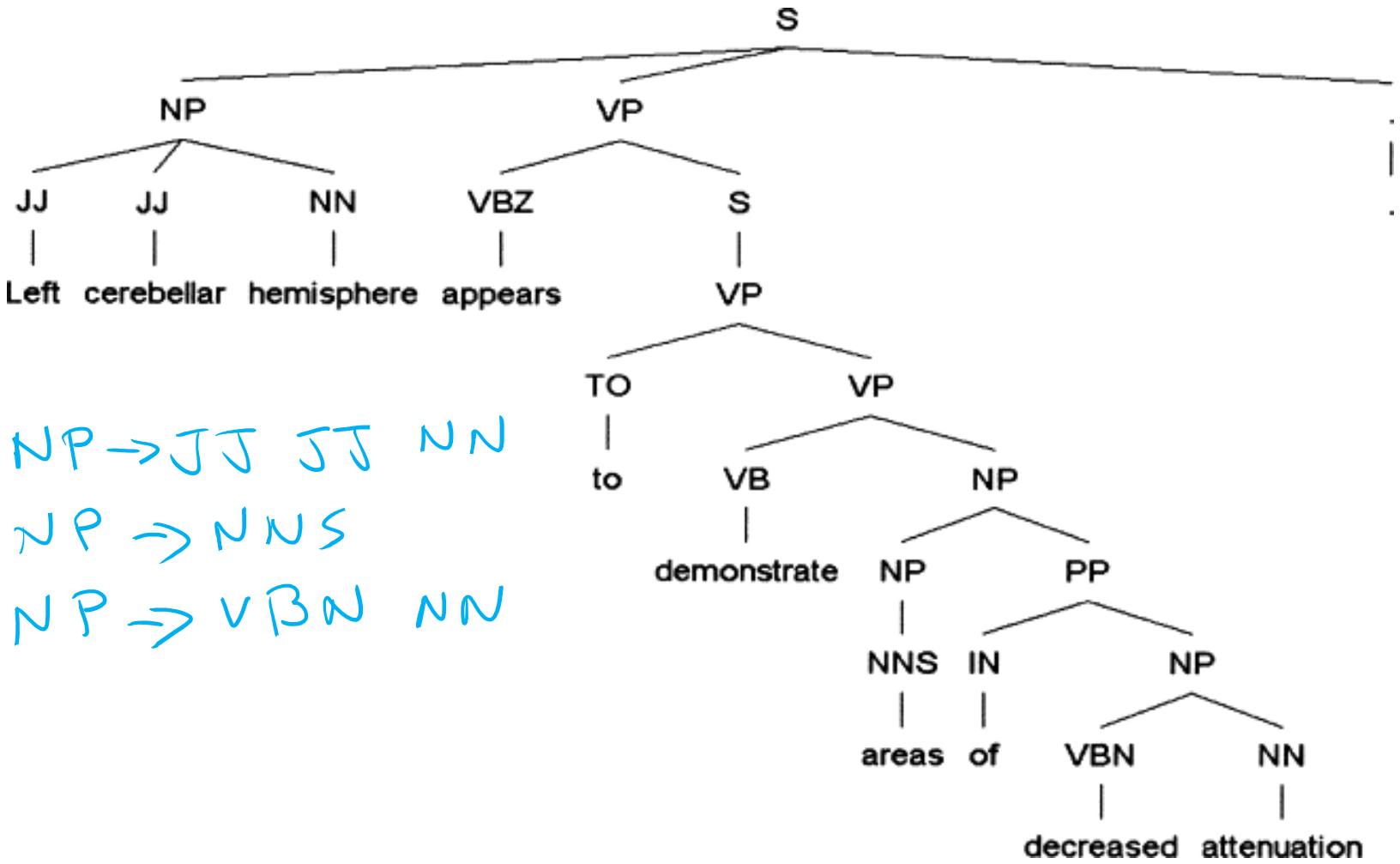
$\quad\quad | \quad Verb\ NP$

$\quad\quad | \quad Verb\ NP\ PP$

$\quad\quad | \quad Verb\ PP$

$PP \rightarrow Preposition\ NP$

Example of relatively complex parse tree



NP → JJ JJ NN

NP → NNS

NP → VBN NN

Journal of the American Medical Informatics Association, 2005, Improved Identification of Noun Phrases in Clinical Radiology Reports Using a High-Performance Statistical Natural Language Parser Augmented with the UMLS Specialist Lexicon

Lecture Overview

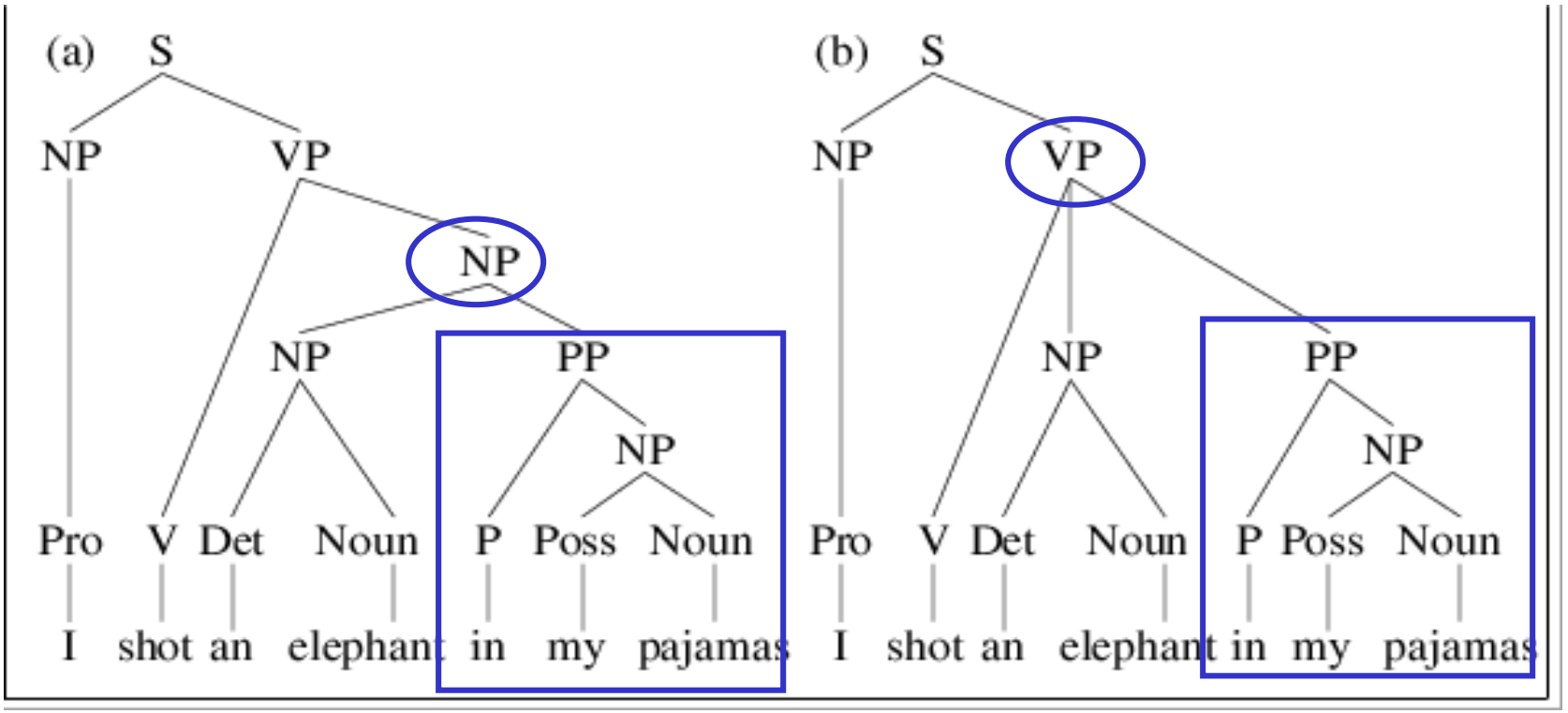
- Recap English Syntax and Parsing
- **Key Problem with parsing: Ambiguity**
- Probabilistic Context Free Grammars (PCFG)
- Treebanks and Grammar Learning

Structural Ambiguity (Ex. 1)

VP -> V NP ; NP -> NP PP

VP -> V NP PP

"***I shot an elephant in my pajamas***"



Structural Ambiguity (Ex.2)

"I saw Mary passing by cs2"

```
(ROOT
  (S
    (NP (PRP I))
    (VP (VBD saw)
      (S
        (NP (NNP Mary))
        (VP (VBG passing)
          (PP (IN by)
            (NP (NNP cs2))))))))
```

"I saw Mary passing by cs2"

```
(ROOT
  (S
    (NP (PRP I))
    (VP (VBD saw)
        (NP (NNP Mary))
        (S
          (VP (VBG passing)
            (PP (IN by)
              (NP (NNP cs2)))))))))
```

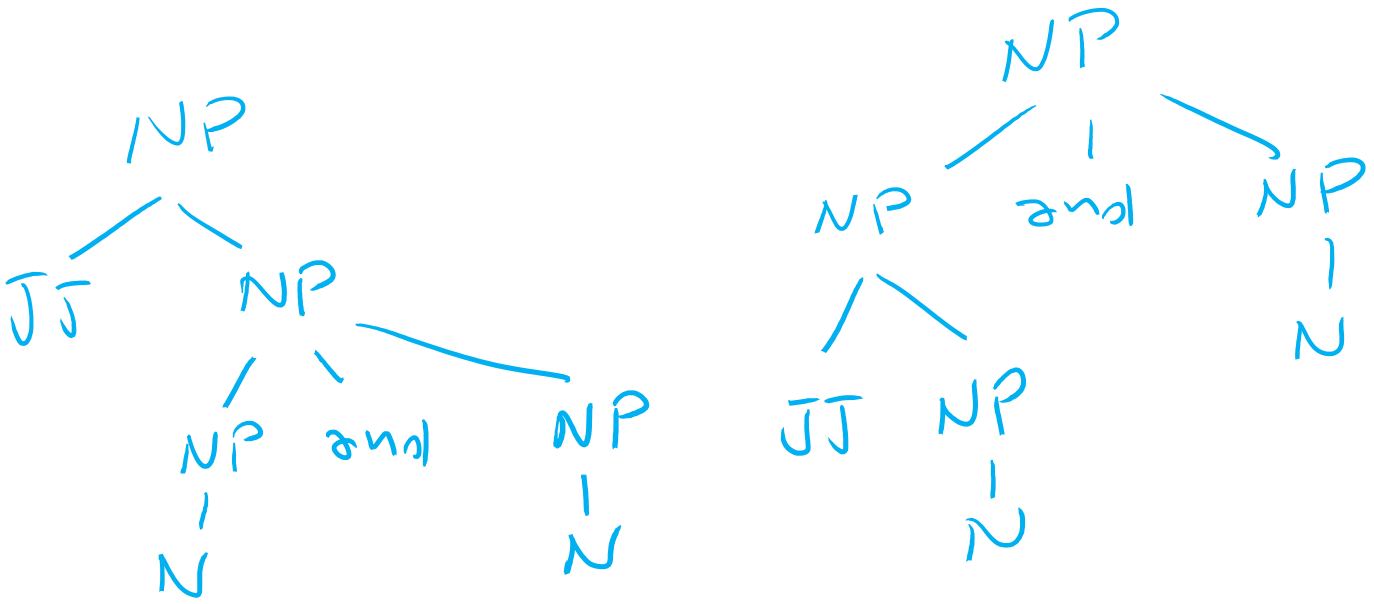
Structural Ambiguity (Ex. 3)

- **Coordination "new student and profs"**

NP -> NP and NP

NP -> JJ NP

NP -> N



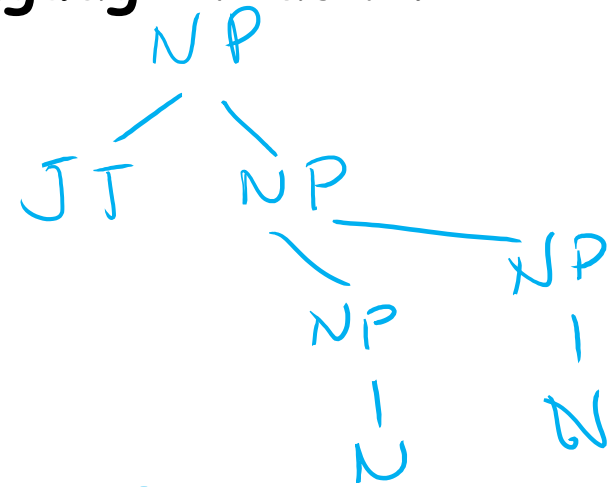
Structural Ambiguity (Ex. 4)

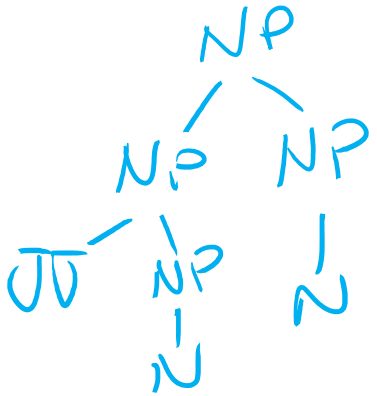
- **NP-bracketing "French language teacher"**

NP → JJ NP

NP → N

NP → NP NP





Lecture Overview

- Recap English Syntax and Parsing
- Key Problem with parsing: Ambiguity
- **Probabilistic Context Free Grammars (PCFG)**
- Treebanks and Grammar Learning (acquiring the probabilities)
- Intro to Parsing PCFG

Probabilistic CFGs (PCFGs)

- **GOAL: assign a probability to parse trees and to sentences**
- **Each grammar rule is augmented with a conditional probability**

- **If these are <u>all the rules for VP</u> and .55 is the** $P(VP \rightarrow Verb \mid VP)$

VP -> Verb	.55
VP -> Verb NP	.40
VP -> Verb NP NP	??

- **What ?? should be ?**

A. 1
B. 0
C. .05
D. None of the above

Probabilistic CFGs (PCFGs)

- **GOAL: assign a probability to parse trees and to sentences**
- **Each grammar rule is augmented with a conditional probability**
  - **The expansions for a given non-terminal sum to 1**

VP -> Verb	.55
VP -> Verb NP	.40
VP -> Verb NP NP	.05

$P(VP \rightarrow Verb \mid VP)$

$P(VP \rightarrow Verb\ NP \mid VP)$

$P(VP \rightarrow Verb\ NP\ NP \mid VP)$

Formal Def: 5-tuple (N, Σ, P, S, D)

Sample PCFG

$S \rightarrow NP\ VP$	[.80]	$Det \rightarrow that$ [.05] | the [.80] | a [.15]	
$S \rightarrow Aux\ NP\ VP$	[.15]	$Noun \rightarrow book$	[.10]
$S \rightarrow VP$	[.05]	$Noun \rightarrow flights$	[.50]
$NP \rightarrow Det\ Nom$	[.20]	$Noun \rightarrow meal$	[.40]
$NP \rightarrow Proper\text{-}Noun$	[.35]	$Verb \rightarrow book$	[.30]
$NP \rightarrow Nom$	[.05]	$Verb \rightarrow include$	[.30]
$NP \rightarrow Pronoun$	[.40]	$Verb \rightarrow want$	[.40]
$Nom \rightarrow Noun$	[.75]	$Aux \rightarrow can$	[.40]
$Nom \rightarrow Noun\ Nom$	[.20]	$Aux \rightarrow does$	[.30]
$Nom \rightarrow Proper\text{-}Noun\ Nom$	[.05]	$Aux \rightarrow do$	[.30]
$VP \rightarrow Verb$	[.55]	$Proper\text{-}Noun \rightarrow TWA$	[.40]
$VP \rightarrow Verb\ NP$	[.40]	$Proper\text{-}Noun \rightarrow Denver$	[.40]
$VP \rightarrow Verb\ NP\ NP$	[.05]	$Pronoun \rightarrow you$ [.40] | I [.60]	

PCFGs are used to….

- **Estimate Prob. of parse tree**

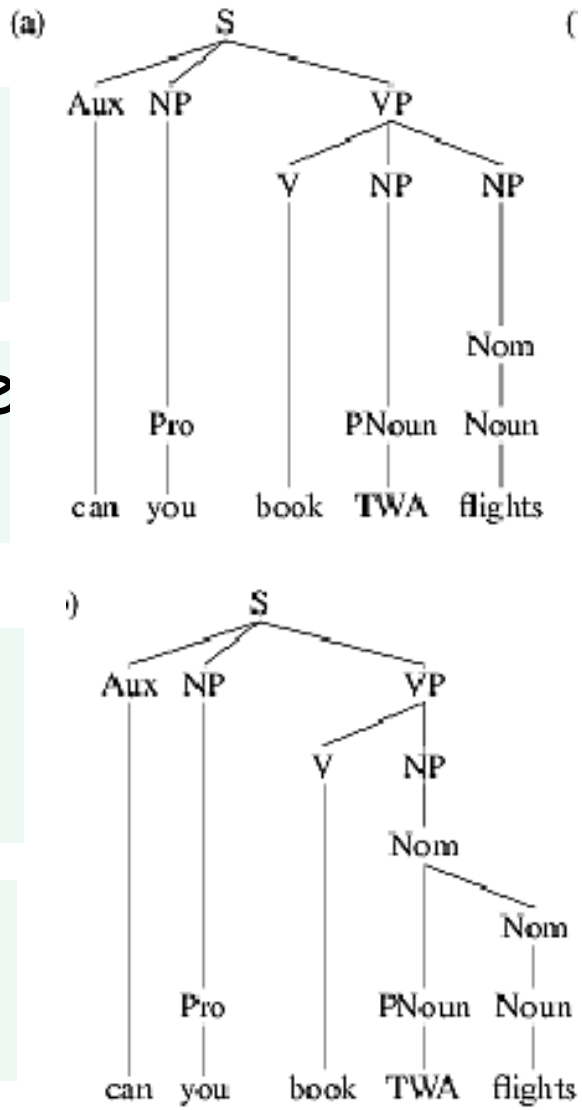
A. Sum of the probs of all the rules applied

B. Product of the probs of all the rules applied

- **Estimate Prob. of a sentence**

A. Sum of the probs of all the parse trees

B. Product of the probs of all the parse trees



PCFGs are used to….

- **Estimate Prob. of parse tree**

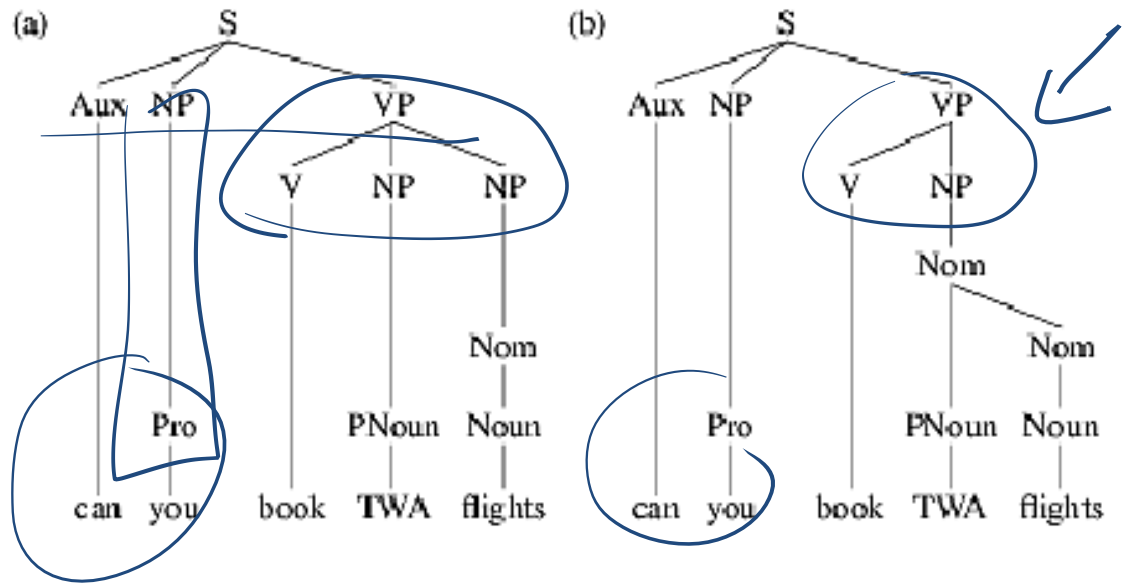
$$P(Tree) = \prod_{node \in Tree} P(\text{expansion for node})$$

- **Estimate Prob. to sentences**

$$P(Sentence) = \sum_{Tree \in Sentence\ parses} P(Tree)$$

Example

$P(Tree^a) = .15 * .4 * \ldots = 1.5 \times 10^{-6}$ $P(Tree^b) = .15 * .4 * \ldots = 1.7 \times 10^{-6}$



Rules			P
S	→	Aux NP VP	.15
NP	→	Pro	.40
VP	→	V NP NP	.05
NP	→	Nom	.05
NP	→	PNoun	.35
Nom	→	Noun	.75
Aux	→	Can	.40
~~NP~~	~~→~~	~~Pro~~	.40
Pro	→	you	.40
Verb	→	book	.30
PNoun	→	TWA	.40
Noun	→	flights	.50

Rules			P
S	→	Aux NP VP	.15
NP	→	Pro	.40
VP	→	V NP	.40
NP	→	Nom	.05
Nom	→	PNoun Nom	.05
Nom	→	Noun	.75
Aux	→	Can	.40
~~NP~~	~~→~~	~~Pro~~	.40
Pro	→	you	.40
Verb	→	book	.30
Pnoun	→	TWA	.40
Noun	→	flights	.50

(2) (5)

$P(\text{"Can you...."}) =$

$1.7 \times 10^{-6} + 1.5 \times 10^{-6} =$

3.2×10^{-6}

Lecture Overview

- Recap English Syntax and Parsing
- Key Problem with parsing: Ambiguity
- Probabilistic Context Free Grammars (PCFG)
- **Treebanks and Grammar Learning (acquiring the probabilities)**

Treebanks

- DEF. corpora in which each sentence has been paired with a parse tree
- These are generally created
  - Parse collection with parser
  - human annotators revise each parse
- Requires detailed annotation guidelines
  - POS tagset
  - Grammar
  - instructions for how to deal with particular grammatical constructions.

Penn Treebank

- **Penn TreeBank is a widely used treebank.**

- Most well known is the Wall Street Journal section of the Penn TreeBank.
  - 1 M words from the 1987-1989 Wall Street Journal.

```
( (S (`` ``)
   (S-TPC-2
     (NP-SBJ-1 (PRP We) )
     (VP (MD would)
       (VP (VB have)
         (S
           (NP-SBJ (-NONE- *-1) )
           (VP (TO to)
             (VP (VB wait)
               (SBAR-TMP (IN until)
                 (S
                   (NP-SBJ (PRP we) )
                   (VP (VBP have)
                     (VP (VBN collected)
                       (PP-CLR (IN on)
                         (NP (DT those)(NNS assets))))))))))))
   (, ,) (`` ``)
   (NP-SBJ (PRP he) )
   (VP (VBD said)
     (S (-NONE- *T*-2) ))
   (. .) ))
```

Treebank Grammars

- **Such grammars tend to contain lots of rules….**
- **For example, the Penn Treebank has 4500 different rules for VPs! Among them...**

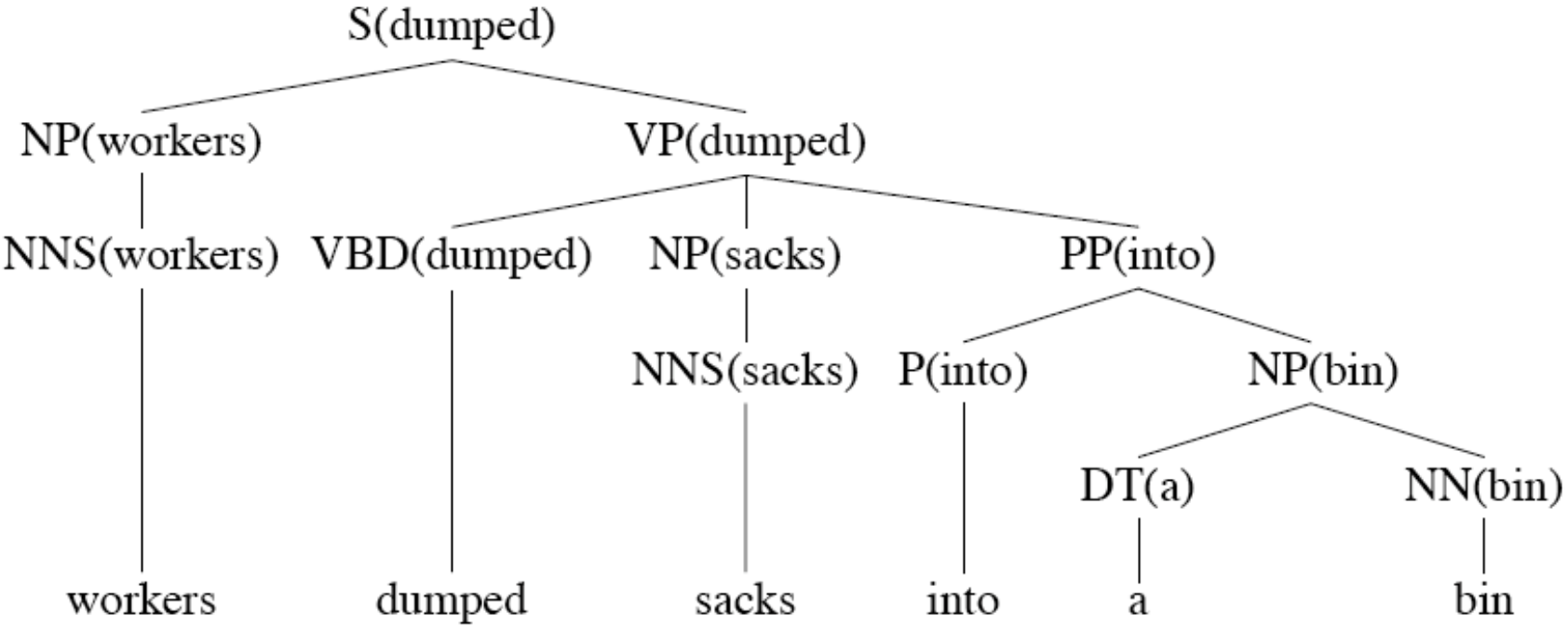
VP → VBD PP
VP → VBD PP PP
VP → VBD PP PP PP
VP → VBD PP PP PP PP

Heads in Trees

- Finding heads in treebank trees is a task that arises frequently in many applications.
  - Particularly important in statistical parsing

- We can visualize this task by annotating the nodes of a parse tree with the heads of each corresponding node.

Lexically Decorated Tree

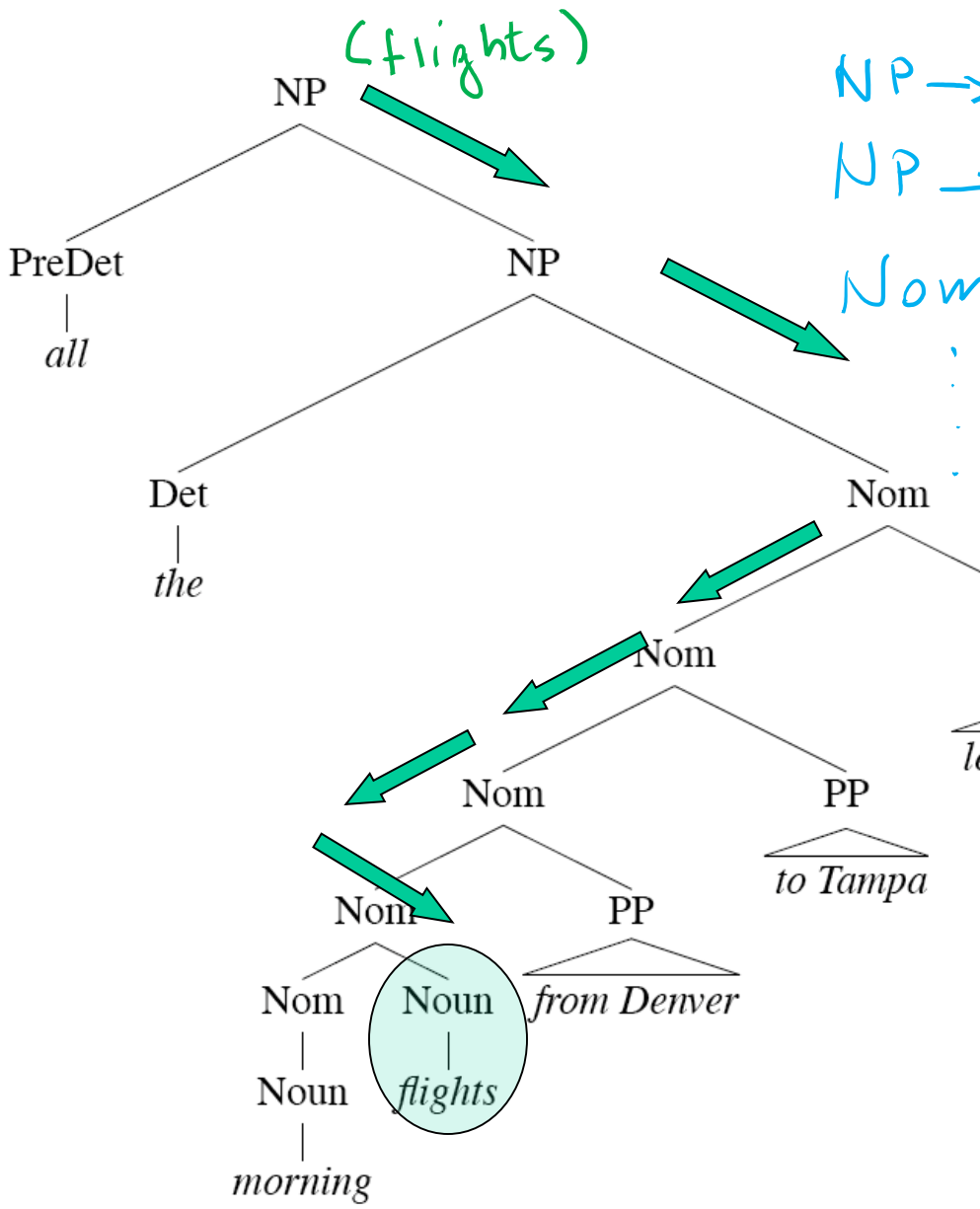


Head Finding

- **The standard way to do head finding is to use a simple set of tree traversal rules specific to each non-terminal in the grammar.**

- **Each rule in the PCFG specifies where the head of the expanded non-terminal should be found**

Noun Phrases



NP → PreDet NP

NP → Det Nom

Nom → Nom GerundiveVP

Each rule in the PCFG specifies where the head of the expanded non-terminal should be found

Acquiring Grammars and Probabilities

Manually parsed text corpora (e.g., PennTreebank)

- **Grammar**: read it off the parse trees

Ex: if an NP contains an ART, ADJ, and NOUN then we create the rule *NP -> ART ADJ NOUN*.

- **Probabilities**:

$$P(A \rightarrow \alpha \mid A) = \frac{count(A \rightarrow \alpha)}{\sum_{\gamma} count(A \rightarrow \gamma)} = \frac{count(A \rightarrow \alpha)}{count(A)}$$

NP -> Pro

Ex: if the *NP -> ART ADJ NOUN* rule is used 50 times and all NP rules are used 5000 times, then the rule's probability is … .01

Example

If you look at all the parse trees in the bank you find three rules for NP

	How many times
① NP → ART ADJ NOUN	50
② NP → NOUN	4000
③ NP → PRONOUN	950
	5000 total # of NP expansions

$P(① \mid NP) = 50/5000 = .01$

$P(② \mid NP) = 4000/5000 = .8$

$P(③ \mid NP) = 950/5000 = .19$

$.19 = 1 - (.01 + .8)$

Learning Goals for today's class

You can:

- Provide a formal definition of a PCFG
- Apply a PCFG to compute the probability of a parse tree of a sentence as well as the probability of a sentence
- Describe the content of a treebank
- Describe the process to identify a head of a syntactic constituent
- Compute the probability distribution of a PCFG from a treebank

Next class on Wed

- **Parsing Probabilistic CFG: CKY parsing**
- **PCFG in practice: Modeling Structural and Lexical Dependencies**

Assignment-3 due next Mon
Assignment-4 out same day