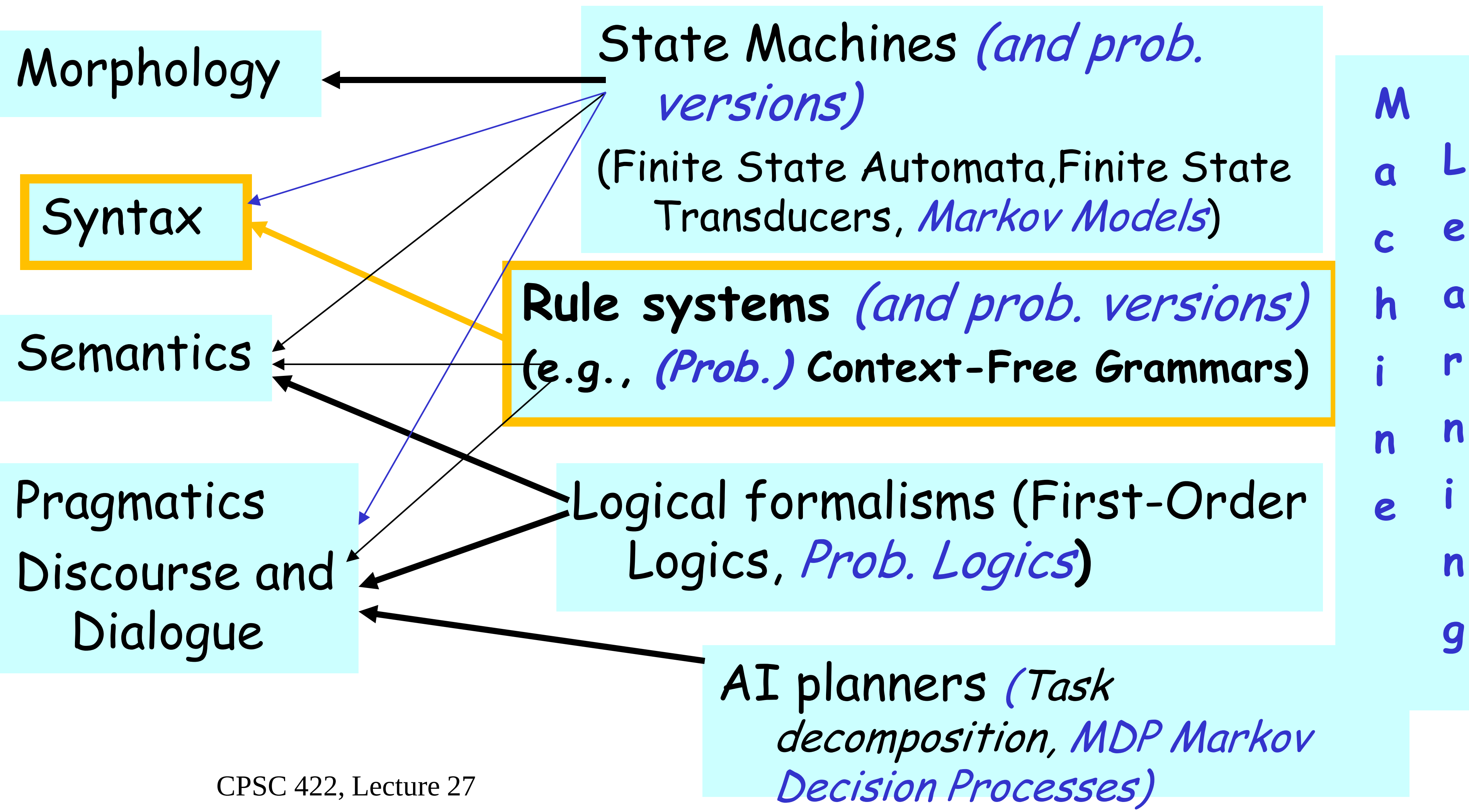
Intelligent Systems (AI-2)

Computer Science cpsc422, Lecture 27

Nov, 16, 2015

NLP: 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 $A \to \alpha$; $A \in \mathbf{N}$, $\alpha \in (\Sigma \cup N)^*$

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

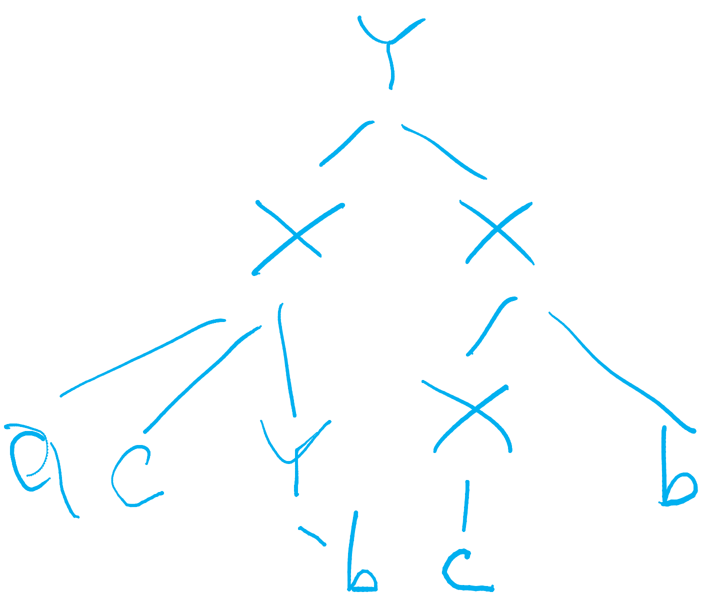
$X \to Xb$

$Y \to XX$

$X \to acY$

$X \to c$

$Y \to b$



CFG Example

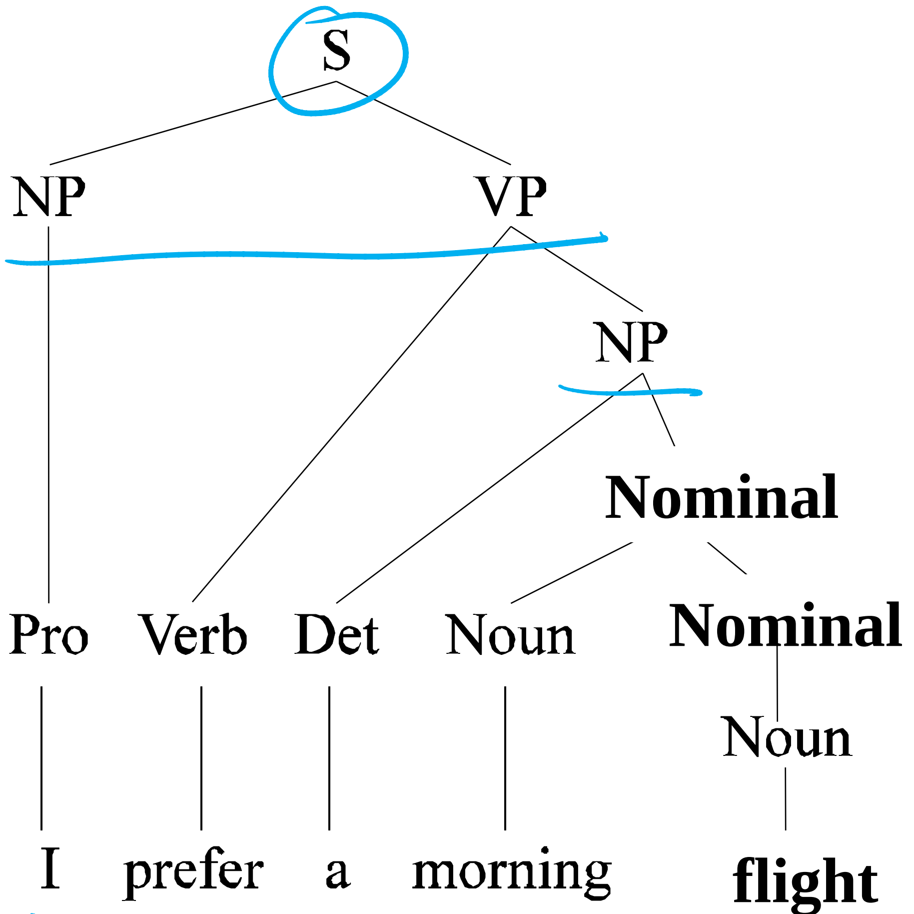
Grammar with example phrases			
S	$\rightarrow$	$NP\ VP$	I + want a morning flight
NP	$\rightarrow$	$Pronoun$	I
	$\vert$	$Proper\text{-}Noun$	Los Angeles
	$\vert$	$Det\ Nominal$	a + flight
Nominal	$\rightarrow$	$Noun\ Nominal$	morning + flight
	$\vert$	$Noun$	flights
VP	$\rightarrow$	$Verb$	do
	$\vert$	$Verb\ NP$	want + a flight
	$\vert$	$Verb\ NP\ PP$	leave + Boston + in the morning
	$\vert$	$Verb\ PP$	leaving + on Thursday
PP	$\rightarrow$	$Preposition\ NP$	from + Los Angeles

Lexicon

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

V NP

Derivations as Trees



S → *NP VP*

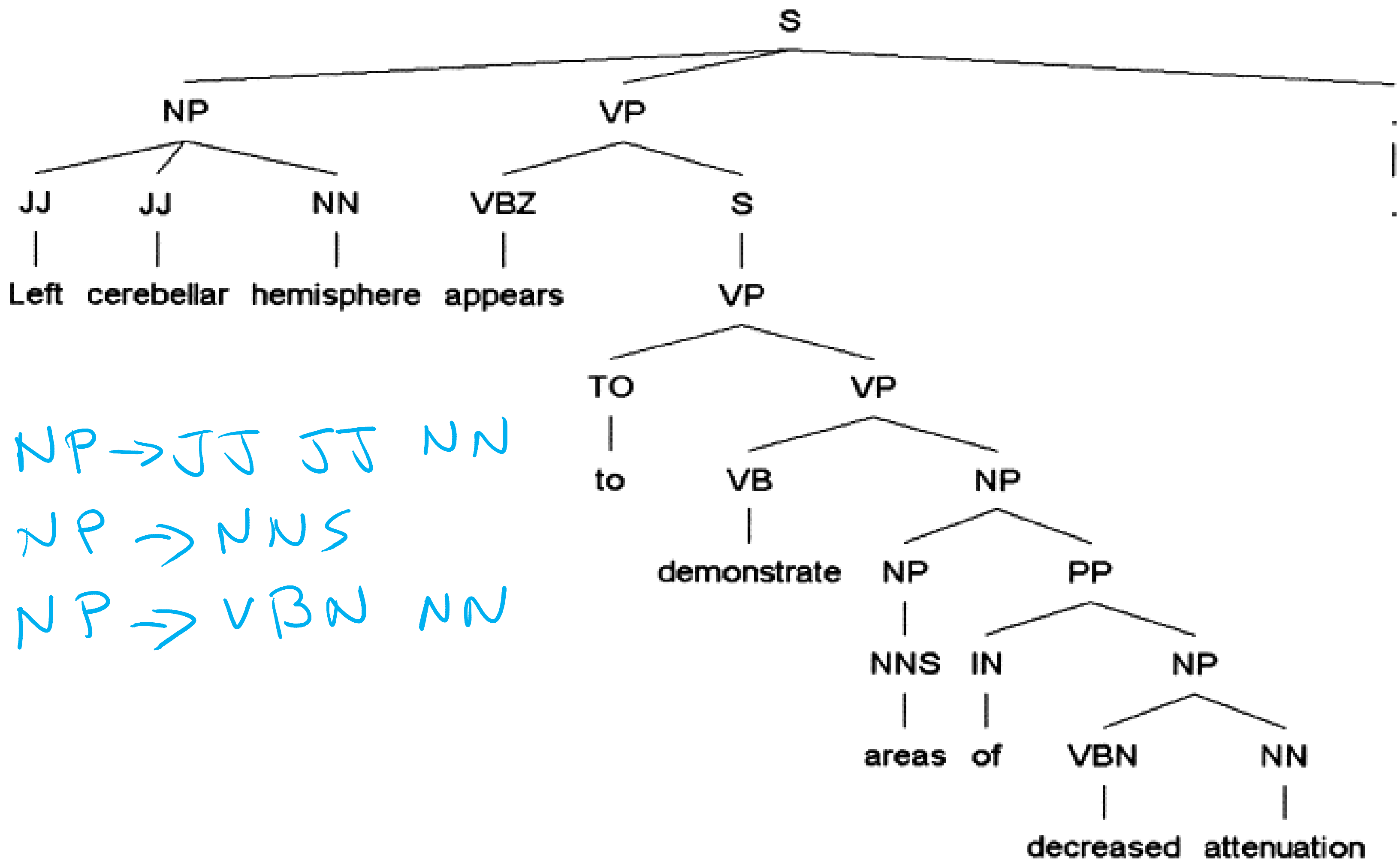
NP → *Pronoun*
| *Proper-Noun*
| *Det Nominal*

Nominal → *Noun Nominal*
| *Noun*

VP → *Verb*
| *Verb NP*
| *Verb NP PP*
| *Verb PP*

PP → *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

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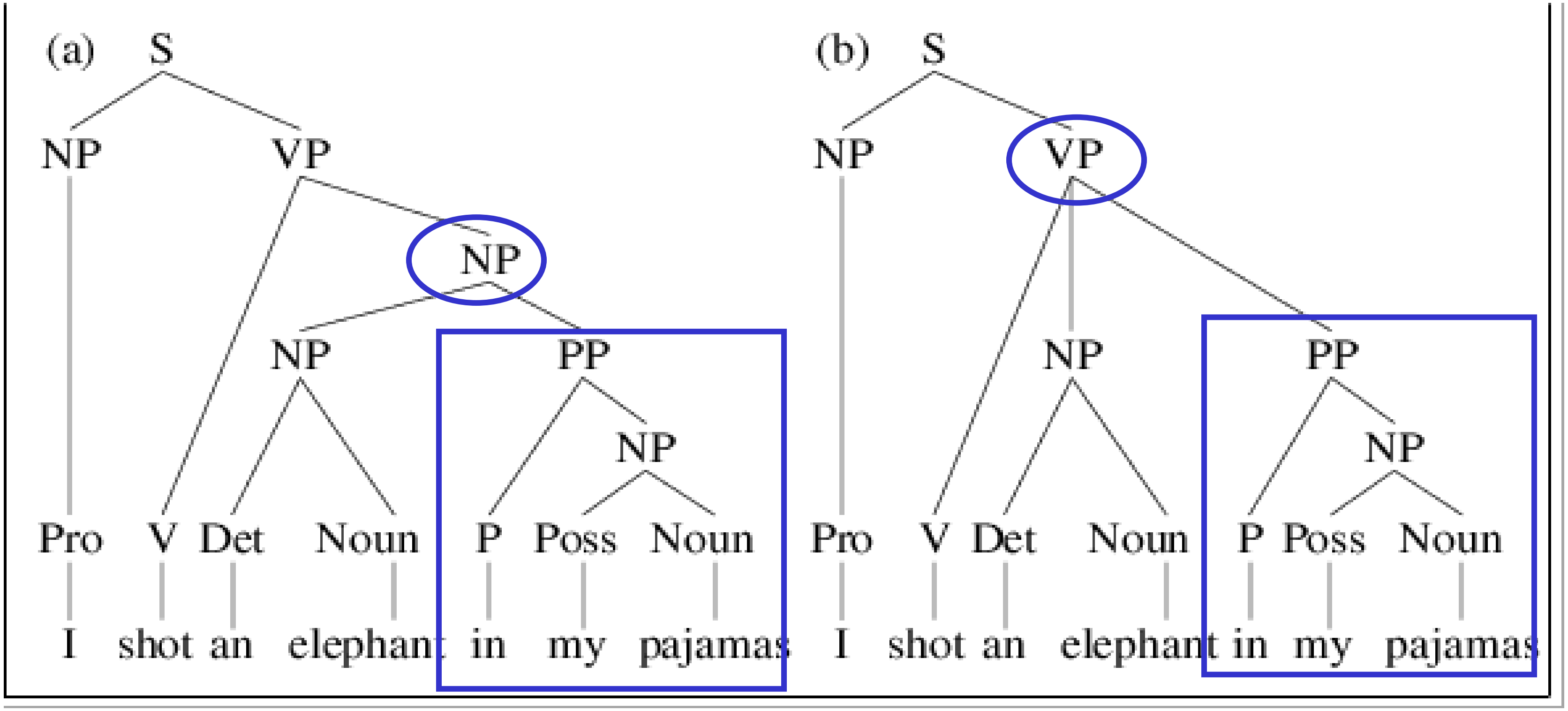
Structural Ambiguity (Ex. 1)

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)

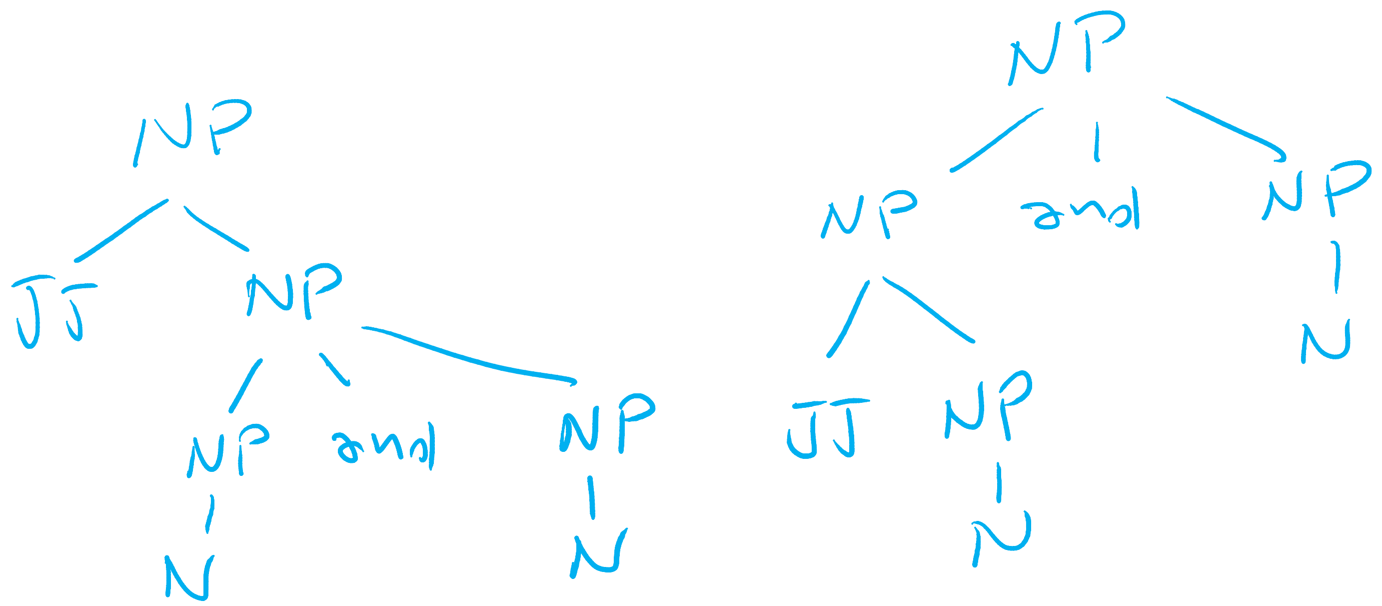
- **Coordination "new student and profs"**

JJ N N

NP → NP and NP

NP → JJ NP

NP → N



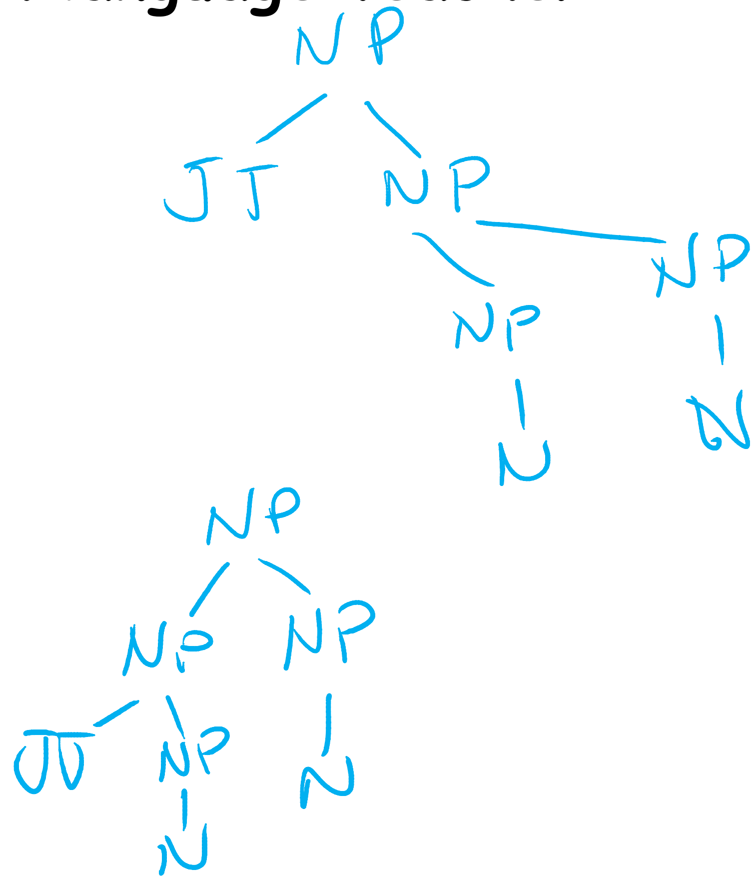
Structural Ambiguity (Ex. 4)

- **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->Verb | 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

iclicker.

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	P(VP->Verb | VP)
VP -> Verb NP	.40	P(VP->Verb NP | VP)
VP -> Verb NP NP	.05	P(VP->Verb NP NP | VP)

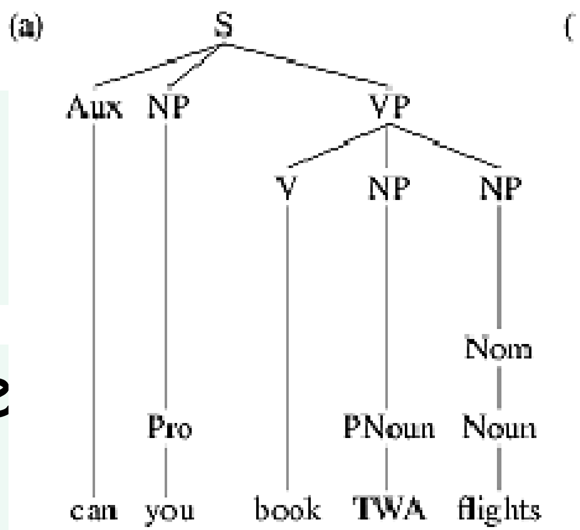
Formal Def: 5-tuple (N, ∑, P, S, D)

Sample PCFG

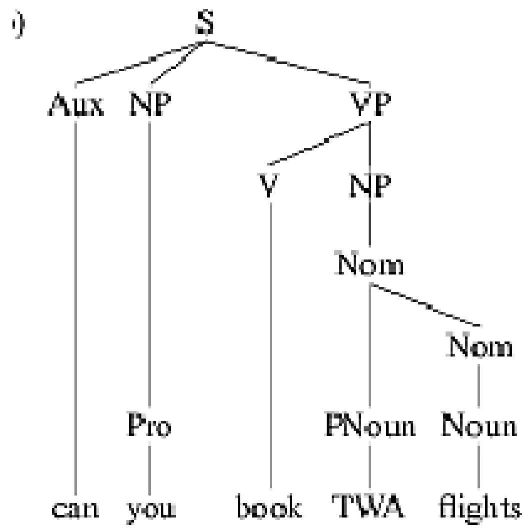
S → NP VP	[.80]	Det → that [.05] | the [.80] | a [.15]	
S → Aux NP VP	[.15]	Noun → book	[.10]
S → VP	[.05]	Noun → flights	[.50]
NP → Det Nom	[.20]	Noun → meal	[.40]
NP → Proper-Noun	[.35]	Verb → book	[.30]
NP → Nom	[.05]	Verb → include	[.30]
NP → Pronoun	[.40]	Verb → want	[.40]
Nom → Noun	[.75]	Aux → can	[.40]
Nom → Noun Nom	[.20]	Aux → does	[.30]
Nom → Proper-Noun Nom	[.05]	Aux → do	[.30]
VP → Verb	[.55]	Proper-Noun → TWA	[.40]
VP → Verb NP	[.40]	Proper-Noun → Denver	[.40]
VP → Verb NP NP	[.05]	Pronoun → 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**

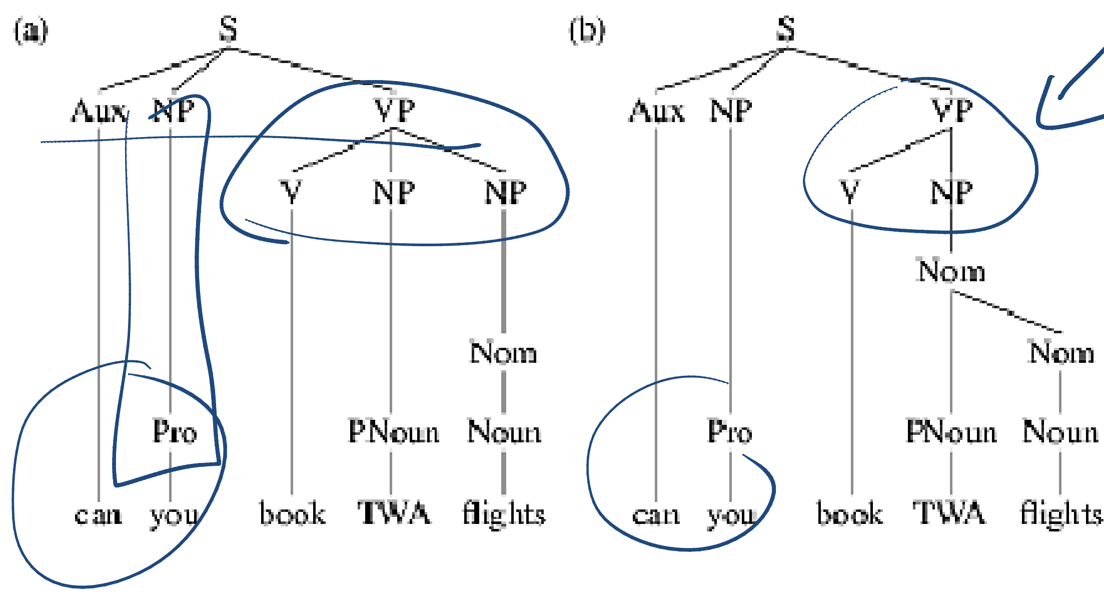
$$P(Tree) = \prod_{node \in Tree} P(\text{expansion for node})$$

- **Estimate Prob. to sentences**

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

Example

$P(Tree^a) = .15 * .4 * ... = 1.5\times10^{-6}$ $\quad$ $P(Tree^b) = .15 * .4 * ... = 1.7\times10^{-6}$



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

$1.7\times10^{-6} + 1.5\times10^{-6} =$

3.2×10^{-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

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- 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) ))
    (. .) ))
```

S → '' S '' NP VP .

S → NP VP

Treebank Grammars

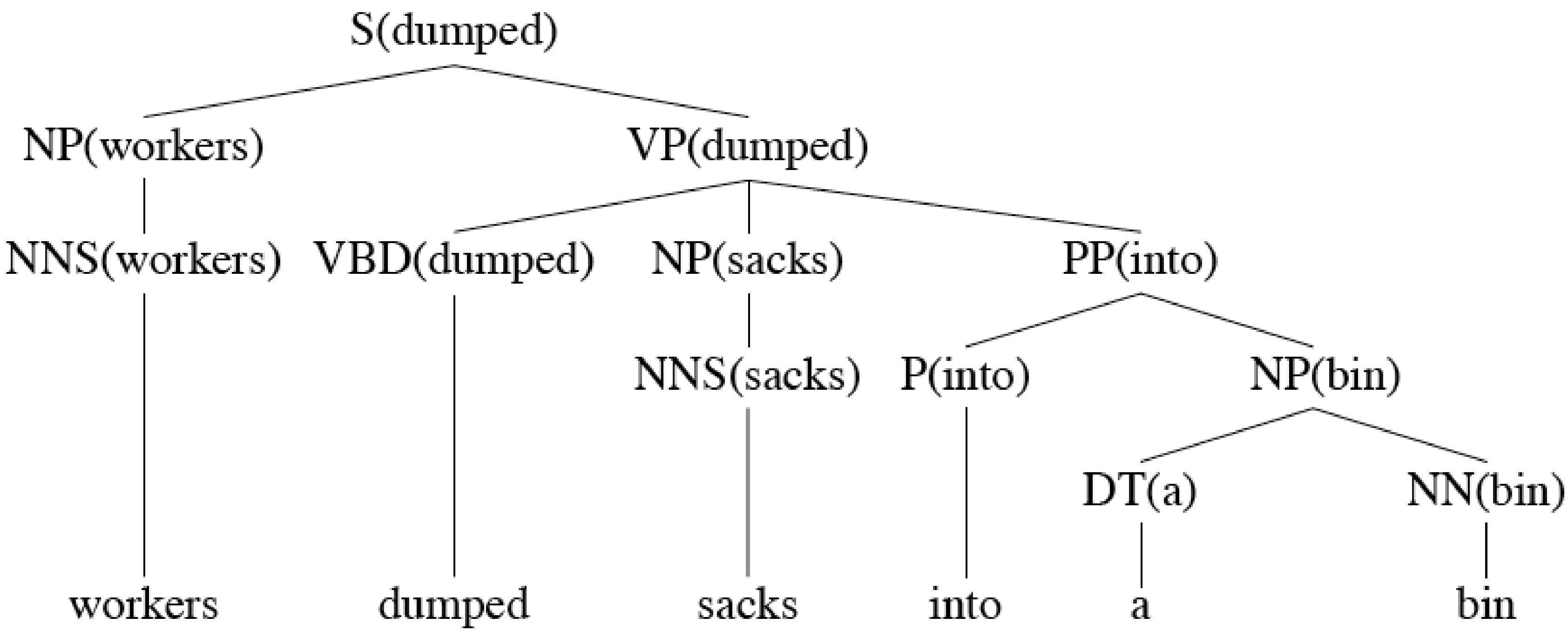
- Such grammars tend to contain lots of rules….
- For example, the Penn Treebank has 4500 different rules for VPs! Among them...

$$VP \rightarrow VBD\ PP$$
$$VP \rightarrow VBD\ PP\ PP$$
$$VP \rightarrow VBD\ PP\ PP\ PP$$
$$VP \rightarrow VBD\ PP\ PP\ PP\ PP$$

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

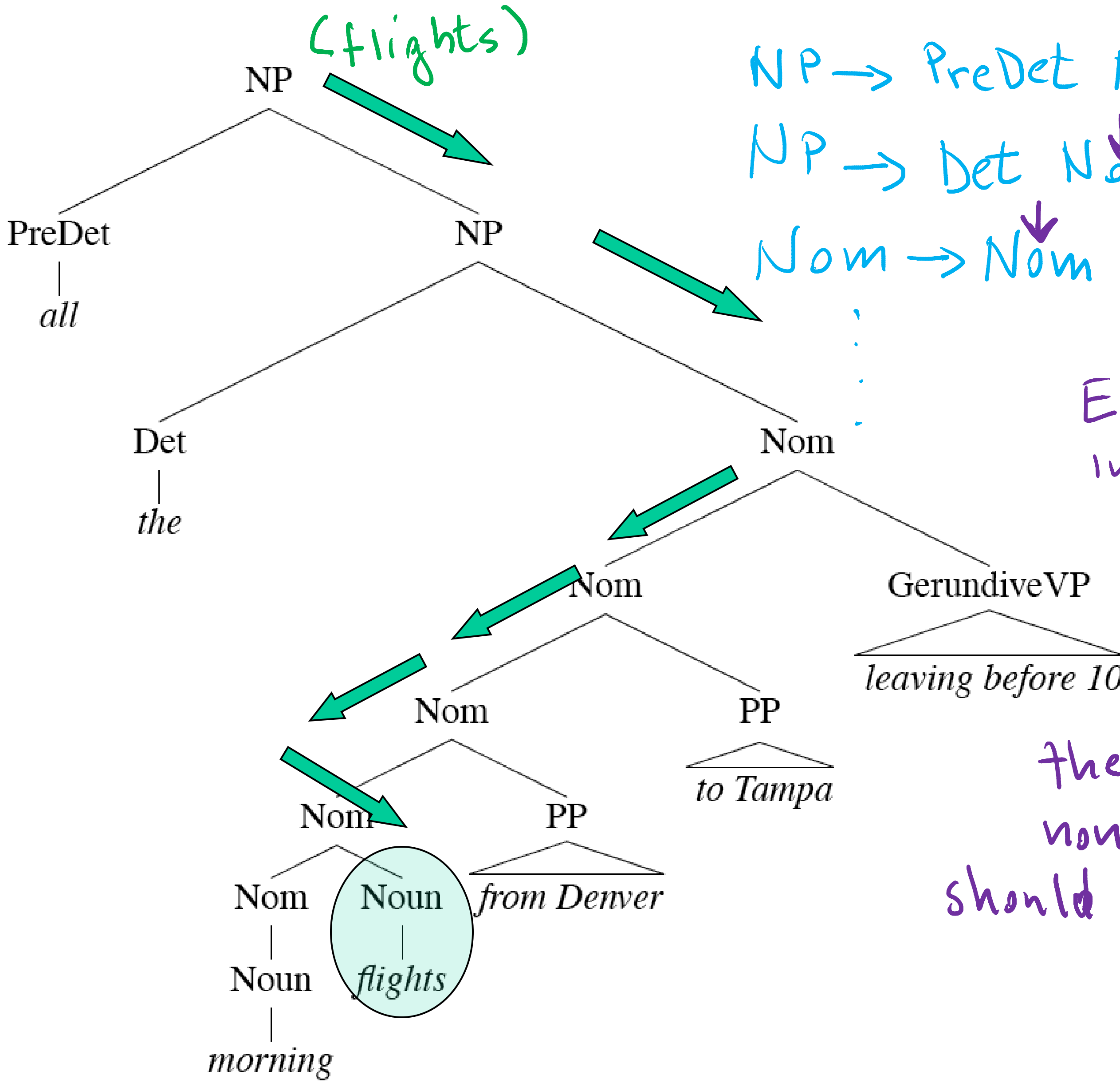


Head Finding

- 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*.

NP -> Pro

- **Probabilities:**

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

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

$P(① \mid NP) = 50/5000 = .01$

$P(② \mid NP) = 4000/5000 = .8$

$P(③ \mid NP) = 950/5000 = .19$

also = 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 on Fri
Assignment-4 out same day