Syntax -CKY, PCFGs

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Week 5: Lecture 3

CKY Algorithm

- Let n be the number of words in the input. Think about $n+1$ lines separating them, numbered 0 to n.
- x_{ij} will denote the words between line i and j
- We build a table so that x_{ij} contains all the possible non-terminal spanning for words between line i and j.
- We build the Table bottom-up.

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Home Exercise

Use CKY algorithm to find the parse tree for “Book the flight through Houston” using the CNF form shown in the previous slide.

CKY for CFG

a	pilot	likes	flying	planes
1	2	3	4	5

S → *NP VP*
VP → *VBG NNS*
VP → *VBZ VP*
VP → *VBZ NP*
NP → *DT NN*
NP → *JJ NNS*
DT → *a*
NN → *pilot*
VBZ → *likes*
VBG → *flying*
JJ → *flying*
NNS → *planes*

CKY for CFG

a 1	pilot 2	likes 3	flying 4	planes 5
DT	NP	-	-	S S
	NN	-	-	-
		VBZ	-	VP VP
			JJ VBG	NP VP
				NNS

S → *NP VP*
VP → *VBG NNS*
VP → *VBZ VP*
VP → *VBZ NP*
NP → *DT NN*
NP → *JJ NNS*
DT → *a*
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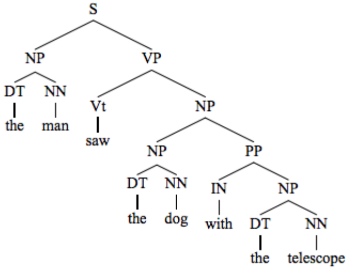
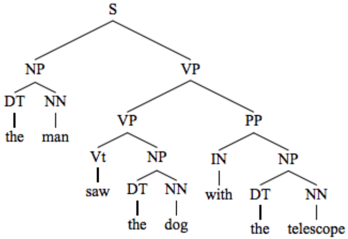
What about Ambiguities?





Probabilistic Context-free grammars (PCFGs)

PCFG: $G = (T, N, S, R, P)$

- T: set of terminals
- N: set of non-terminals
  - For NLP, we distinguish out a set $P \subset N$ of pre-terminals, which always rewrite as terminals
- S : start symbol
- R: Rules/productions of the form $X \rightarrow \gamma$, $X \in N$ and $\gamma \in (T \cup N)*$

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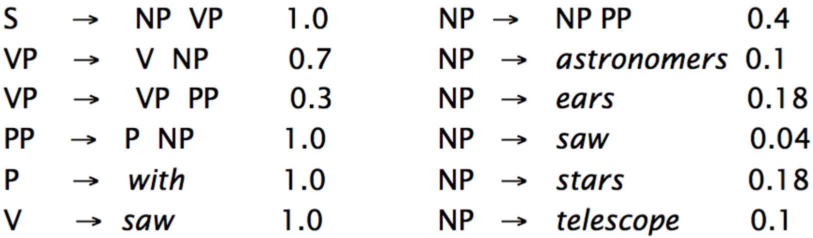
- R: Rules/productions of the form $X \rightarrow \gamma$, $X \in N$ and $\gamma \in (T \cup N)*$
- $P(R)$ gives the probability of each rule.

$$\forall X \in N, \sum_{X \rightarrow \gamma \in R} P(X \rightarrow \gamma) = 1$$

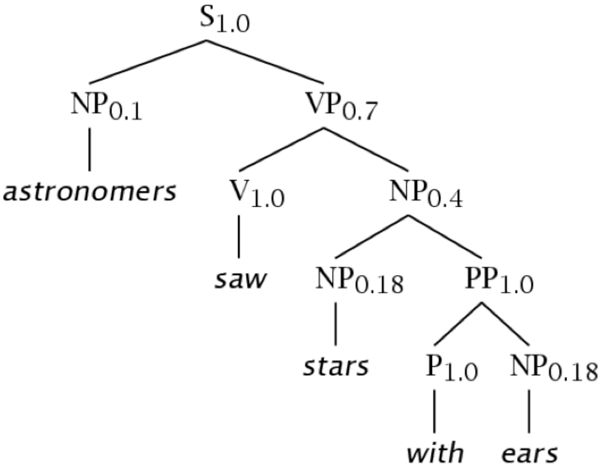
A Simple PCFG (in CNF)



S	→	NP VP	1.0	NP	→	NP PP	0.4
VP	→	V NP	0.7	NP	→	*astronomers*	0.1
VP	→	VP PP	0.3	NP	→	*ears*	0.18
PP	→	P NP	1.0	NP	→	*saw*	0.04
P	→	*with*	1.0	NP	→	*stars*	0.18
V	→	*saw*	1.0	NP	→	*telescope*	0.1

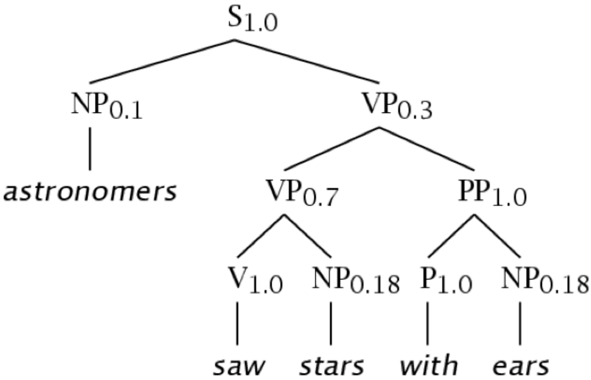
Example Trees

t_1:



Example Trees

t_2:



Probability of trees and strings

- $P(t)$: The probability of tree is the product of the probabilities of the rules used to generate it
- $P(w_{1n})$: The probability of the string is the sum of the probabilities of the trees which have that string as their yield

Tree and String probabilities

Tree and String probabilities

w_{15} = *astronomers saw stars with ears*

$$P(t_1) = 1.0 * 0.1 * 0.7 * 1.0 * 0.4 * 0.18 * 1.0 * 1.0 * 0.18 = 0.0009072$$

$$P(t_2) = 1.0 * 0.1 * 0.3 * 0.7 * 1.0 * 0.18 * 1.0 * 1.0 * 0.18 = 0.0006804$$

$$P(w_{15}) = P(t_1) + P(t_2) = 0.0009072 + 0.0006804 = 0.0015876$$

"Book the dinner flight"

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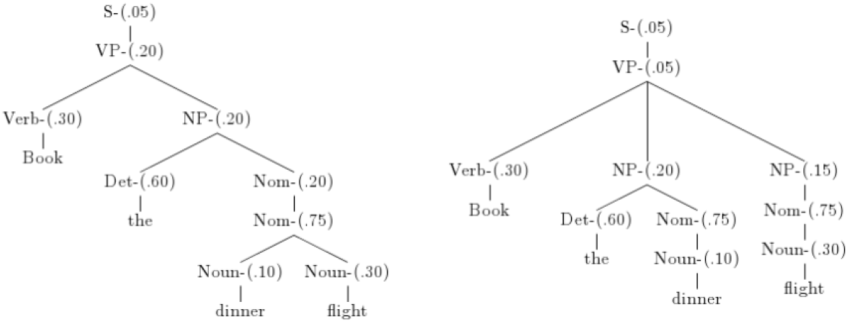
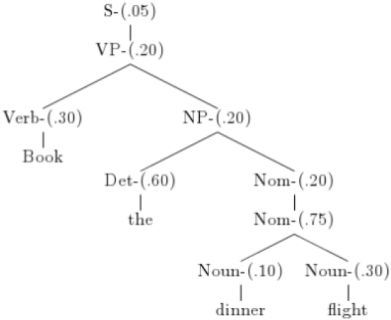
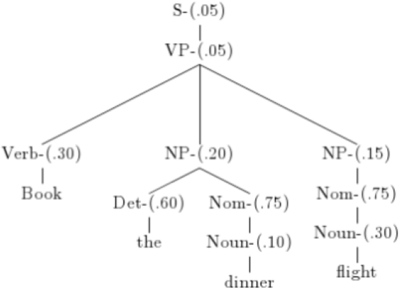


“Book the dinner flight”





Probabilities

- Parse tree 1: $.05 \times .20 \times .30 \times .20 \times .60 \times .20 \times .75 \times .10 \times .30 = 1.62 \times 10^{-6}$
- Parse tree 2: $.05 \times .05 \times .30 \times .20 \times .60 \times .75 \times .10 \times .15 \times .75 \times .30 = 2.28 \times 10^{-7}$

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- Real text tends to have grammatical mistakes. PCFG avoids this problem by ruling out nothing, but by giving implausible sentences a low probability
- In practice, a PCFG is a worse language model for English than an n-gram model
- All else being equal, the probability of a smaller tree is greater than a larger tree

Important Questions?

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- How to learn the rule probabilities in the grammar G?