Speech and Language Processing

Chapter 12
Syntactic Parsing

Today

- Parsing with CFGs
  - Bottom-up, top-down
  - Ambiguity
  - CKY parsing
  - (Earley)
  - Shallow

Parsing

- Parsing with CFGs refers to the task of assigning proper trees to input strings
- Proper here means a tree that covers all and only the elements of the input and has an S at the top
- It doesn't actually mean that the system can select the correct tree from among all the possible trees

Parsing

- As with everything of interest, parsing involves a search which involves the making of choices
- We'll start with some basic (meaning bad) methods before moving on to the one that you need to know

For Now

- Assume…
  - You have all the words already in some buffer
  - The input isn't POS tagged
  - We won't worry about morphological analysis
  - All the words are known

  - These are all problematic in various ways, and would have to be addressed in real applications.

Top-Down Search

- Since we're trying to find trees rooted with an *S* (Sentences), why not start with the rules that give us an *S*.
- Then we can work our way down from there to the words.

- "Book that flight"

Bottom-Up Parsing

- Of course, we also want trees that cover the input words. So we might also start with trees that link up with the words in the right way.
- Then work your way up from there to larger and larger trees.

"The old dog the footsteps of the young."

S → NP VP	VP → V
S → Aux NP VP	*VP -> V PP*
S -> VP	*PP -> Prep NP*
NP → Det Nom	N → old | dog | footsteps | young
NP →PropN	V → dog | eat | sleep | bark | meow
Nom -> Adj N	Aux → does | can
Nom → N	Prep →from | to | on | of
Nom → N Nom	PropN → Fido | Felix
Nom → Nom PP	Det → that | this | a | the
VP → V NP	Adj -> old | happy| young

Top-Down and Bottom-Up

- Top-down
  - Only searches for trees that can be answers (i.e. S's)
  - But also suggests trees that are not consistent with any of the words
- Bottom-up
  - Only forms trees consistent with the words
  - But suggests trees that make no sense globally

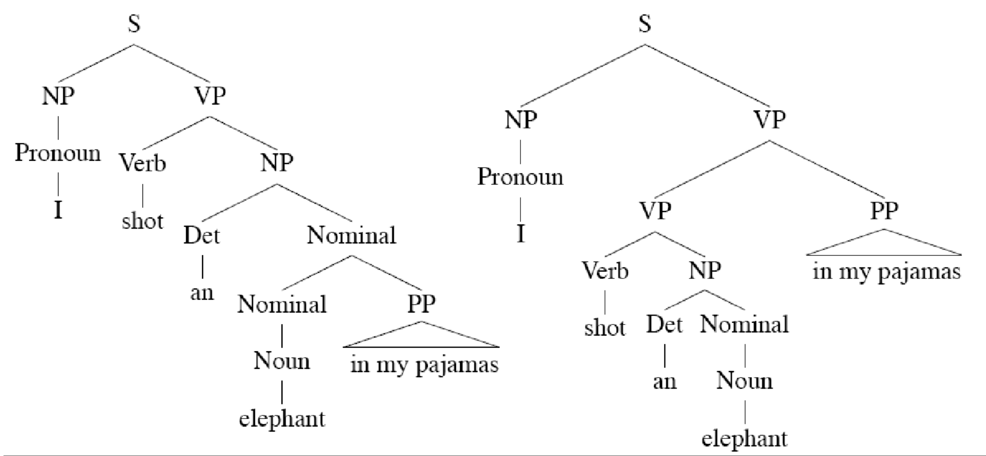
Control

- Of course, in both cases we left out how to keep track of the search space and how to make choices
  - Which node to try to expand next
  - Which grammar rule to use to expand a node
- One approach is called backtracking.
  - Make a choice, if it works out then fine
  - If not then back up and make a different choice

Problems

- Even with the best filtering, backtracking methods are doomed because of two inter-related problems
  - Ambiguity
  - Shared subproblems

Ambiguity



Example types of ambiguity

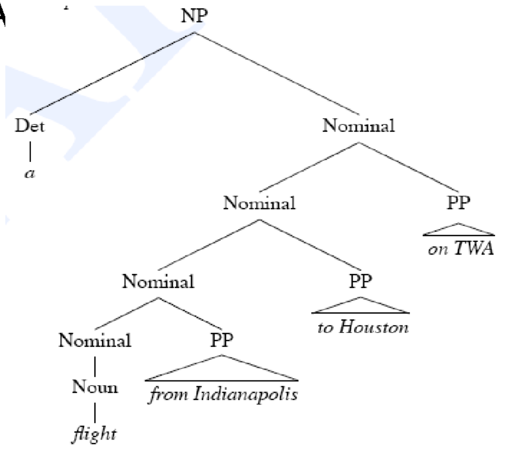
- POS
- Attachment
  - PP
  - Coordination (*old dogs and cats*)

Shared Sub-Problems

- No matter what kind of search (top-down or bottom-up or mixed) that we choose.
  - We don't want to redo work we've already done.
  - Unfortunately, naïve backtracking will lead to duplicated work.

Shared Sub-Problems

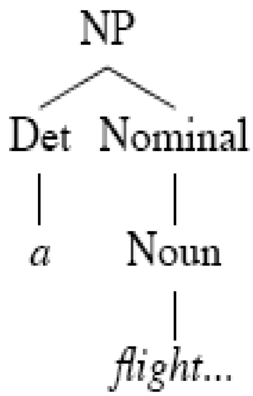
- Consider
  - A flight from Indianapolis to Houston on TWA



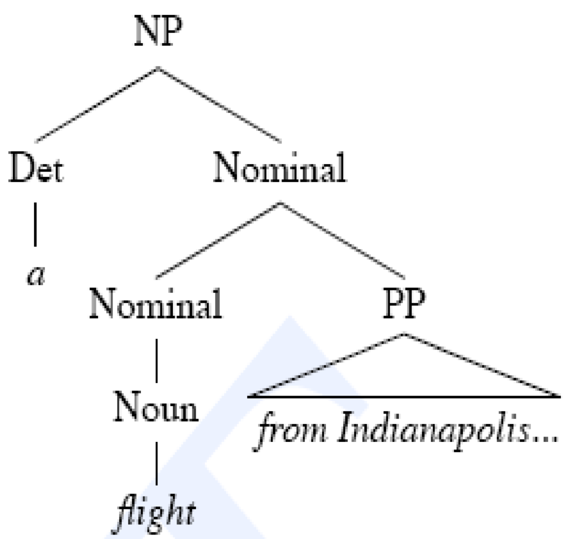
Shared Sub-Problems

- Assume a top-down parse making choices among the various Nominal rules.
- In particular, between these two
  - Nominal -> Noun
  - Nominal -> Nominal PP
- Statically choosing the rules in this order leads to the following bad results...

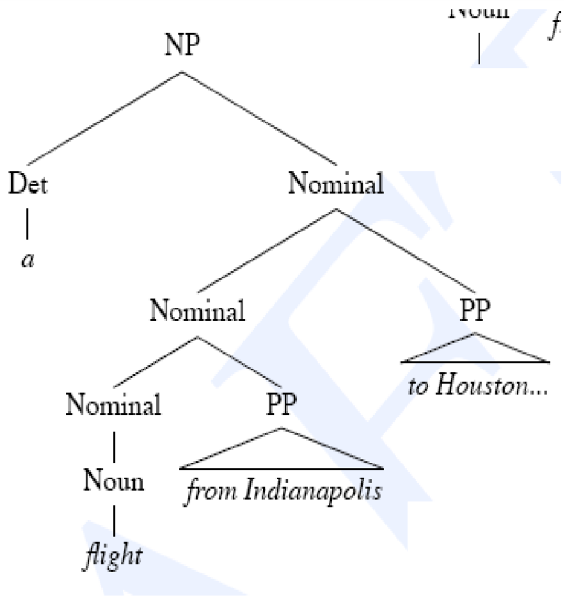
Shared Sub-Problems



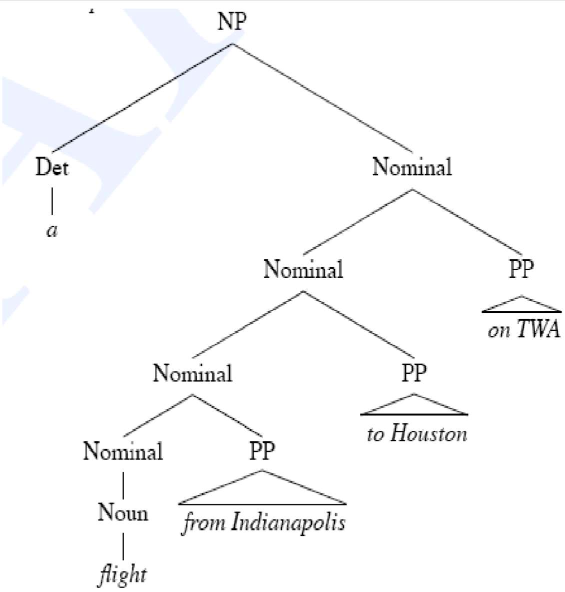
Shared Sub-Problems



Shared Sub-Problems



Shared Sub-Problems



Dynamic Programming

- DP search methods fill tables with partial results and thereby
  - Avoid doing avoidable repeated work
  - Solve exponential problems in polynomial time
  - Efficiently store ambiguous structures with shared sub-parts.
- Two approaches roughly correspond to bottom-up and top-down approaches.
  - CKY
  - Earley

CKY Parsing

- First we'll limit our grammar to epsilon-free, binary rules (more later)
- Consider the rule $A \rightarrow BC$
  - If there is an A somewhere in the input then there must be a B followed by a C in the input.
  - If the A spans from i to j in the input then there must be some k st. i<k<j
    - Ie. The B splits from the C someplace.

Problem

- What if your grammar isn't binary?
  - As in the case of the TreeBank grammar?
- Convert it to binary… any arbitrary CFG can be rewritten into Chomsky-Normal Form automatically.
- What does this mean?
  - The resulting grammar accepts (and rejects) the same set of strings as the original grammar.
  - But the resulting derivations (trees) are different.

Problem

- More specifically, we want our rules to be of the form

  A → B C

  Or

  A → *w*

  That is, rules can expand to either 2 non-terminals or to a single terminal.

Binarization Intuition

- Eliminate chains of unit productions.
- Introduce new intermediate non-terminals into the grammar that distribute rules with length > 2 over several rules.
  - So… *S → A B C turns into*

S → X C and

X → A B

Where X is a symbol that doesn't occur anywhere else in the the grammar.

Sample L1 Grammar

Grammar	Lexicon
$S \rightarrow NP\ VP$	$Det \rightarrow that \mid this \mid a$
$S \rightarrow Aux\ NP\ VP$	$Noun \rightarrow book \mid flight \mid meal \mid money$
$S \rightarrow VP$	$Verb \rightarrow book \mid include \mid prefer$
$NP \rightarrow Pronoun$	$Pronoun \rightarrow I \mid she \mid me$
$NP \rightarrow Proper\text{-}Noun$	$Proper\text{-}Noun \rightarrow Houston \mid NWA$
$NP \rightarrow Det\ Nominal$	$Aux \rightarrow does$
$Nominal \rightarrow Noun$	$Preposition \rightarrow from \mid to \mid on \mid near \mid through$
$Nominal \rightarrow Nominal\ Noun$	
$Nominal \rightarrow Nominal\ PP$	
$VP \rightarrow Verb$	
$VP \rightarrow Verb\ NP$	
$VP \rightarrow Verb\ NP\ PP$	
$VP \rightarrow Verb\ PP$	
$VP \rightarrow VP\ PP$	
$PP \rightarrow Preposition\ NP$	

CNF Conversion

$\mathscr{L}_1$ Grammar	$\mathscr{L}_1$ in CNF
$S \rightarrow NP\ VP$	$S \rightarrow NP\ VP$
$S \rightarrow Aux\ NP\ VP$	$S \rightarrow X1\ VP$
	$X1 \rightarrow Aux\ NP$
$S \rightarrow VP$	$S \rightarrow book \mid include \mid prefer$
	$S \rightarrow Verb\ NP$
	$S \rightarrow X2\ PP$
	$S \rightarrow Verb\ PP$
	$S \rightarrow VP\ PP$
$NP \rightarrow Pronoun$	$NP \rightarrow I \mid she \mid me$
$NP \rightarrow Proper\text{-}Noun$	$NP \rightarrow TWA \mid Houston$
$NP \rightarrow Det\ Nominal$	$NP \rightarrow Det\ Nominal$
$Nominal \rightarrow Noun$	$Nominal \rightarrow book \mid flight \mid meal \mid money$
$Nominal \rightarrow Nominal\ Noun$	$Nominal \rightarrow Nominal\ Noun$
$Nominal \rightarrow Nominal\ PP$	$Nominal \rightarrow Nominal\ PP$
$VP \rightarrow Verb$	$VP \rightarrow book \mid include \mid prefer$
$VP \rightarrow Verb\ NP$	$VP \rightarrow Verb\ NP$
$VP \rightarrow Verb\ NP\ PP$	$VP \rightarrow X2\ PP$
	$X2 \rightarrow Verb\ NP$
$VP \rightarrow Verb\ PP$	$VP \rightarrow Verb\ PP$
$VP \rightarrow VP\ PP$	$VP \rightarrow VP\ PP$
$PP \rightarrow Preposition\ NP$	$PP \rightarrow Preposition\ NP$

CKY

- So let's build a table so that an A spanning from i to j in the input is placed in cell [i,j] in the table.
- So a non-terminal spanning an entire string will sit in cell [0, n]
  - Hopefully an *S*
- If we build the table bottom-up, we'll know that the parts of the A must go from i to k and from k to j, for some k.