Introduction to Parsing: Top-Down vs. Bottom-Up Structural Ambiguities

Parsing algorithms defined:

- The process of finding a derivation (i. e. sequence of productions) leading from the START symbol to the TERMINAL symbols
  - Shows how a particular sentence ***could be*** generated by the rules of the grammar
- If sentence is structurally ambiguous, more than one possible derivation is produced
- Can solve both the recognition and analysis problems
  - Is this sentence derived from this grammar?
  - Give the derivation(s) that can derive this sentence.
- Parsing algorithms give a strategy for finding a derivation by making choices among the derivation rules and deciding when the derivation is complete or not.

Top-down Parser

- Goal-driven
- At each stage, the parser looks at goal of a non-terminal symbol (starting with S) and then sees which rules can be applied
  - Typically progresses from top-to-bottom, left-to-right
  - Non-deterministic (can be rewritten in more than one way)
- When rules derive lexical elements (words), check with the input to see if the right sentence is being derived
- An algorithm may include a backtracking mechanism
  - When it is determined that the wrong rule has been used, it backs up and tries another rule

Example Grammar

- The flight grammar from the text has multiple rules for S:

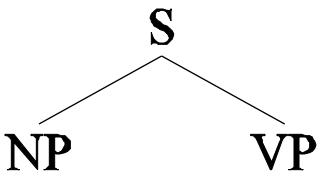
$S \rightarrow NP\ VP$
$S \rightarrow Aux\ NP\ VP$
$S \rightarrow VP$
$NP \rightarrow Pronoun$
$NP \rightarrow Proper\text{-}Noun$
$NP \rightarrow Det\ Nominal$
$Nominal \rightarrow Noun$
$Nominal \rightarrow Nominal\ Noun$
$Nominal \rightarrow Nominal\ PP$
$VP \rightarrow Verb$
$VP \rightarrow Verb\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

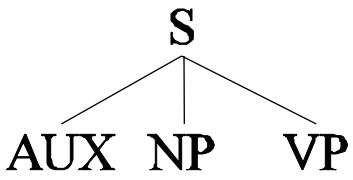
$Det \rightarrow that \mid this \mid a$
$Noun \rightarrow book \mid flight \mid meal \mid money$
$Verb \rightarrow book \mid include \mid prefer$
$Pronoun \rightarrow I \mid she \mid me$
$Proper\text{-}Noun \rightarrow Houston \mid TWA$
$Aux \rightarrow does$
$Preposition \rightarrow from \mid to \mid on \mid near \mid through$

Example Derivation

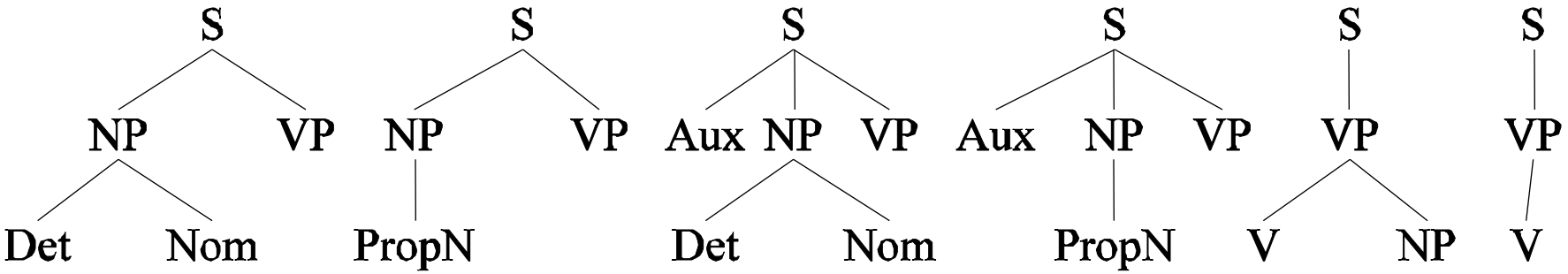
- Derivation for "Book that flight" (from the text)
  - The Start symbol

  - Can derive 3 rules as follows:





  - Each non-terminal can derive additional rules



  - Only the last two trees can derive the word "book" as first in the input

Top-down Parsing Demo

- NLTK parsing demos
  - Top-down parsing using a recursive descent algorithm
    - Top down parsing with back-tracking
    - Must not have left-recursion in the grammar rules

      nltk.app.rdparser()

- Described in NLTK book, Chapter 8, Analyzing Sentence Structure

Bottom-up Parser

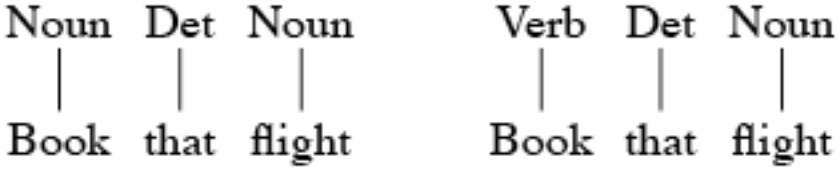
- Data-driven
- Looks at words in input string first, checks / assigns their category(ies), and tries to combine them into acceptable structures in the grammar
- Involves scanning the derivation so far for sub-strings which match the right-hand-side of grammar / production rules and using the rule that would show their derivation from the non-terminal symbol of that rule

Bottom-up Derivation

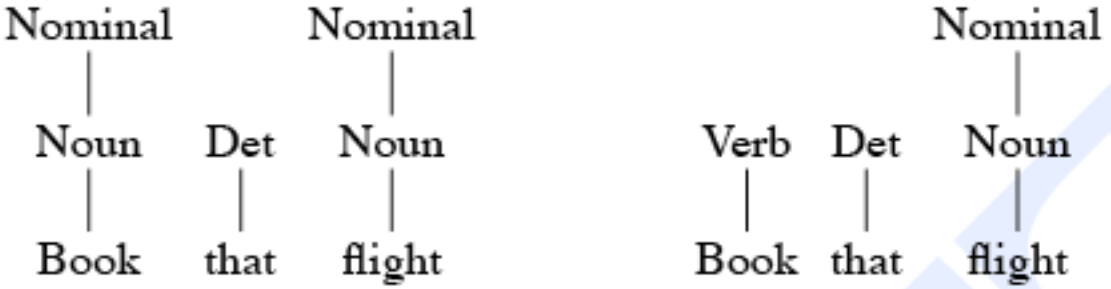
- Starts with input text

Book that flight

- derive the text from rules, in this case, two possible lexical rules

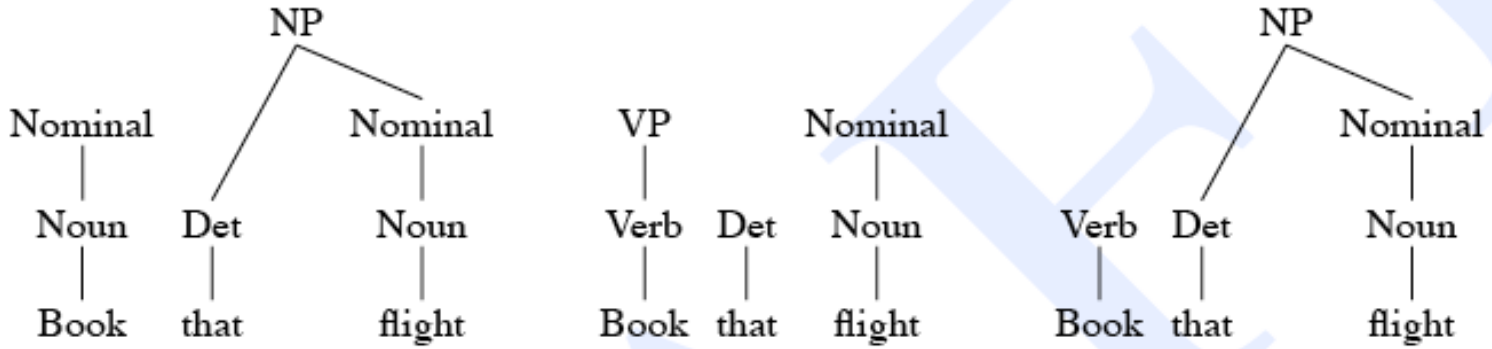


- Each of those can be derived from nonterminals

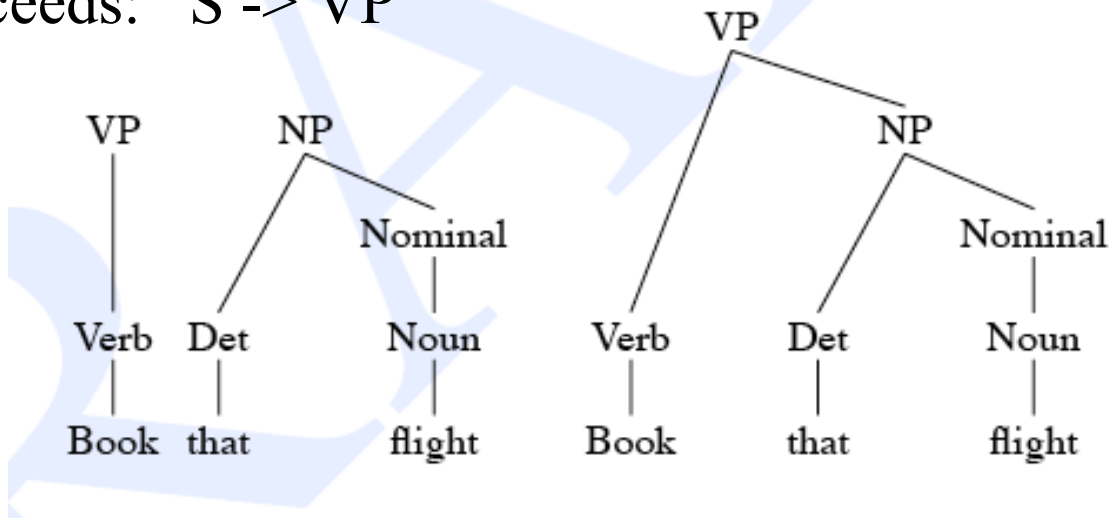


Bottom-Up Derivation

- Only the rightmost tree can continue the derivation here:



- And only one succeeds: S -> VP



Bottom-up Parsing

- Algorithm called shift/reduce parsing
  - Scans the input from left to right and keeps a "stack" of the partial parse tree so far
  - Chooses shift or reduce operations
    - The shift operation looks at the next input and shifts it onto the stack
    - The reduce operation looks at N symbols on the stack and if they match the RHS of a grammar rule, reduces the stack by replacing those symbols with the nonterminal
- Also must either incorporate back-tracking or must keep multiple possible parses

Bottom-up Parsing Demo

- NLTK parsing demos
  - Bottom-up parsing using a shift-reduce algorithm
    - Instead of back-tracking or multiple parses, this NLTK implementation requires outside intervention to apply the correct rule when there is a choice

      nltk.app.srparser()

- Described in NLTK book, Chapter 8, Analyzing Sentence Structure

Parsing issues

- 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 suggest trees that make no sense globally
- Ambiguity:
  - Note that in the "book that flight" example, there was local ambiguity between "book" being a verb or a noun that was resolved at the end of the parse
  - But examples with structural ambiguity will not be resolved, resulting in more than one possible derivation
- Performance of backtracking is exponential in time:
  - Backtracking may result in smaller sub-trees being parsed many times

Structural Ambiguity

- *One morning I shot an elephant in my pajamas. How he got into my pajamas I don't know.* Groucho Marx, *Animal Crackers,* 1930.