Syntax -Parsing I

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CSE, IIT Kharagpur

Week 5: Lecture 2

Grammar Rewrite Rules

S → NP VP

S → Aux NP VP

S → VP

NP → Det NOM

NOM → Noun

NOM → Noun NOM

VP → Verb

VP → Verb NP

Det → *that* | *this* | *a* | *the*

Noun → *book* | *flight* | *meal* | *man*

Verb → *book* | *include* | *read*

Aux → *does*

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→ *The man* VP
→ *The man* Verb NP
→ *The man read* NP
→ *The man read* Det NOM
→ *The man read this* NOM
→ *The man read this* Noun
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Parse Tree

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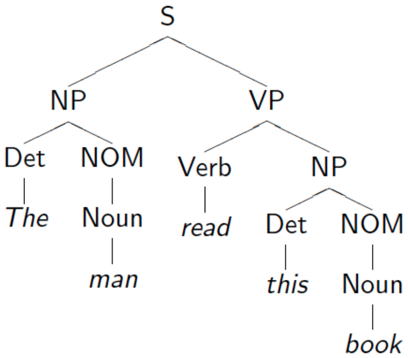

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What are the constraints? "book that flight"

- There must be three leaves, *book*, *that* and *flight*
- The tree must have one root, the start symbol S
- Give rise to two search strategies: *top-down* (goal-oriented) and *bottom-up* (data-directed)

Parsing

Grammar

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S → VP
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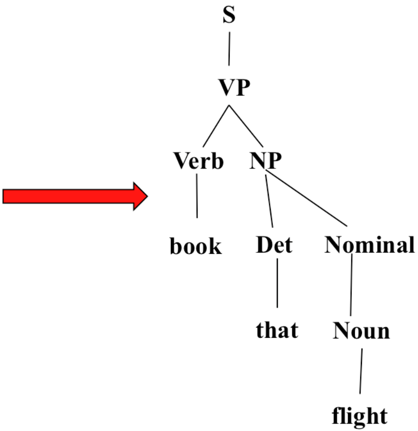
Lexicon

Det → the | a | that | this
Noun → book | flight | meal | money
Verb → book | include | prefer
Pronoun → I | he | she | me
Proper-Noun → Houston | NWA
Aux → does
Prep → from | to | on | near | through

Parsing

book that flight



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- Trees whose leaves fail to match the words in the input can be rejected

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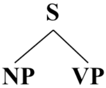

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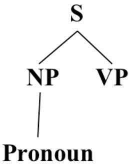

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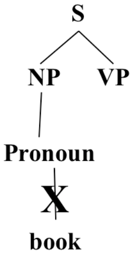

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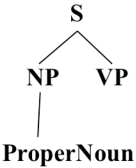

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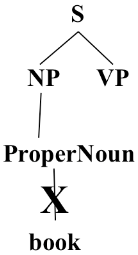

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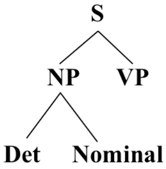

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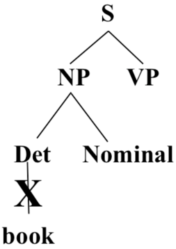

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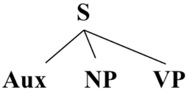

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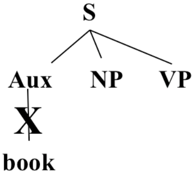

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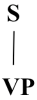

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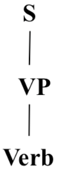

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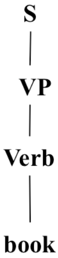

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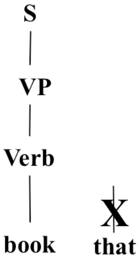

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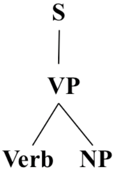

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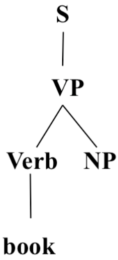

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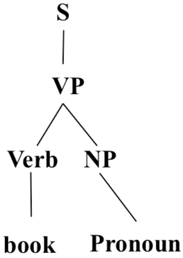

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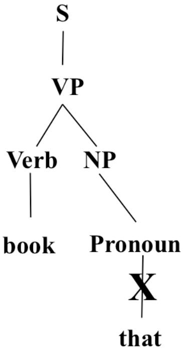

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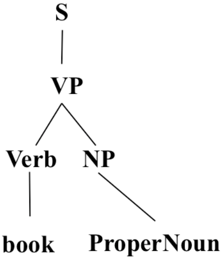

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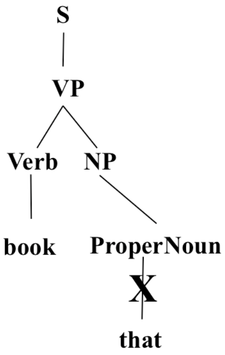

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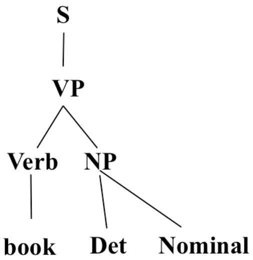

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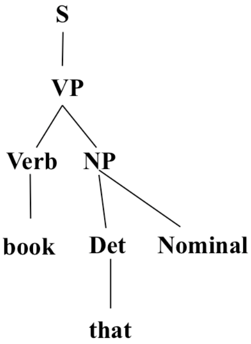

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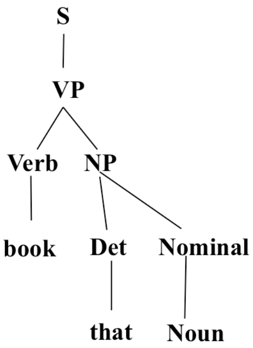

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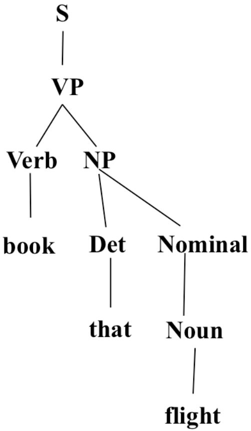

Bottom-Up Parsing

- The parser starts with the words of the input, and tries to build trees from the words up, by applying rules from the grammar one at a time
- Parser looks for the places in the parse-in-progress where the right-hand-side of some rule might fit.

Bottom-Up Parsing

book that flight

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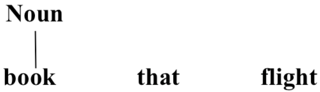

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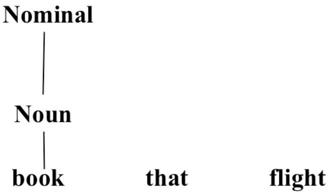

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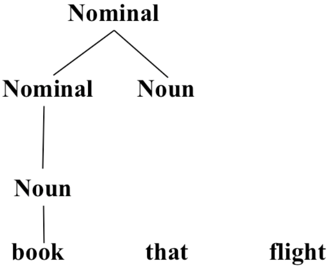

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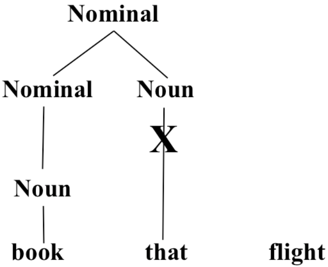

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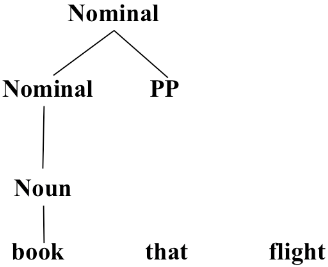

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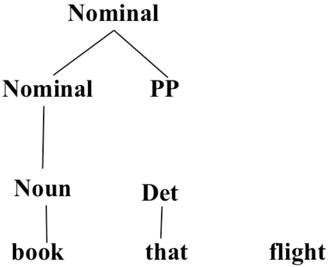

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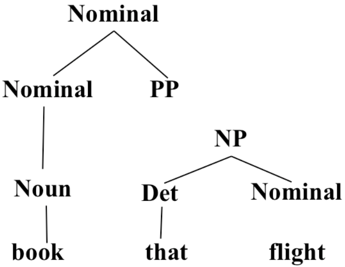

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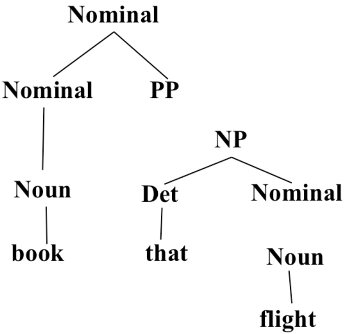

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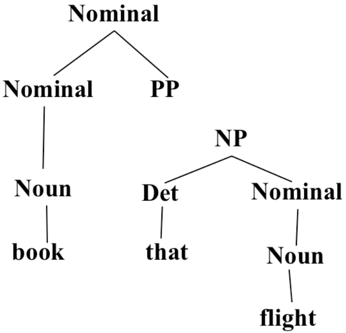

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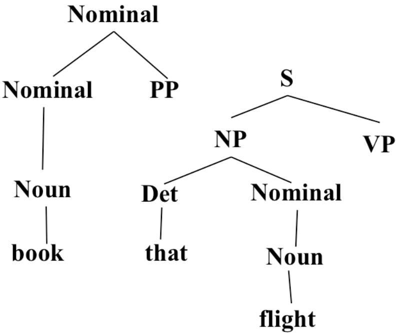

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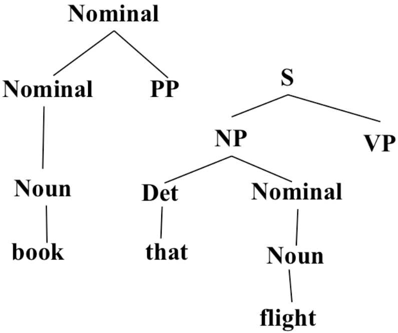

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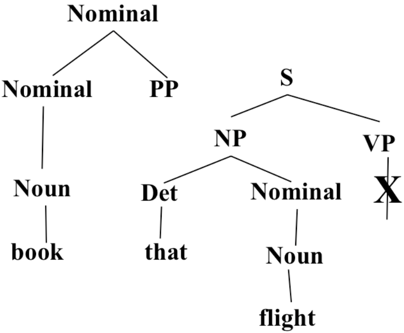

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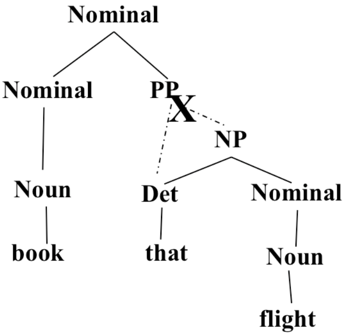

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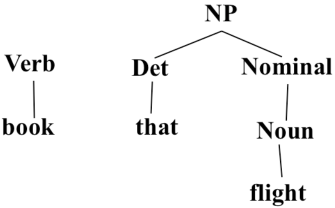

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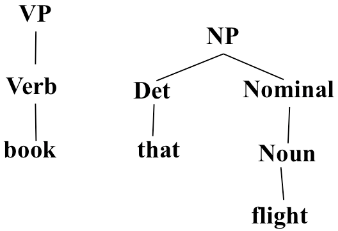

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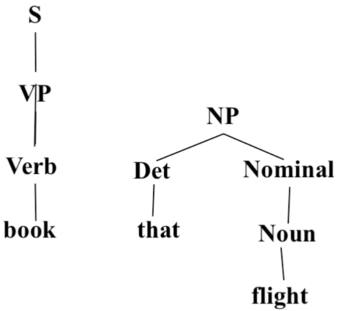

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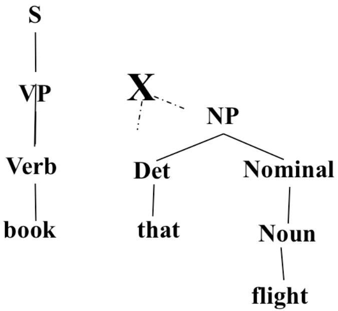

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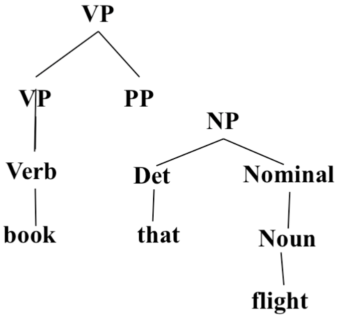

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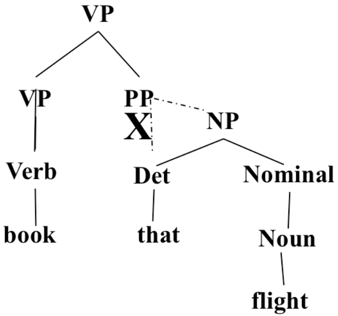

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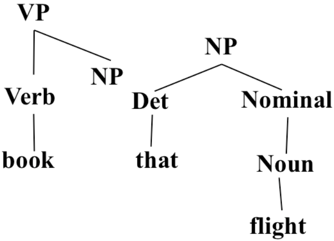

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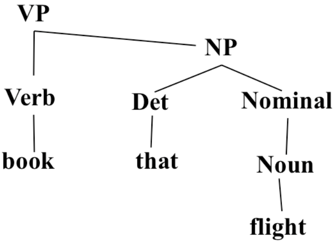

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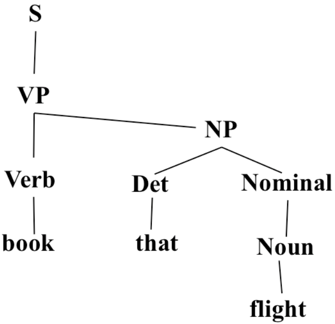

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Top-Down vs. Bottom-Up

- Top down never explores options that will not lead to a full parse, but can explore many options that never connect to the actual sentence.
- Bottom up never explores options that do not connect to the actual sentence but can explore options that can never lead to a full parse.
- Relative amounts of wasted search depend on how much the grammar branches in each direction.

Dynamic Programming Parsing

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- Caching (memoizing) critical to obtaining a polynomial time parsing (recognition) algorithm for CFGs.
- Dynamic programming algorithms based on both top-down and bottom-up search can achieve $O(n^3)$ recognition time where n is the length of the input string.

Dynamic Programming Parsing Methods

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- Earley Parser - top-down, does not require normalizing grammar, more complex
- More generally, *chart parsers* retain completed phrases in a chart and can combine top-down and bottom-up searches.

CKY Algorithm

- Grammar must be converted to Chomsky normal form (CNF) in which all productions must have
  - Either, exactly two non-terminals on the RHS
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  - Either, exactly two non-terminals on the RHS
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- Parse bottom-up storing phrases formed from all substrings in a triangular table (chart)

Converting to CNF

Original Grammar

S → NP VP
S → Aux NP VP
S → VP
NP → Pronoun
NP → Proper-Noun
NP → Det Nominal
Nominal → Noun
Nominal → Nominal Noun
Nominal → Nominal PP
VP → Verb
VP → Verb NP
VP → VP PP
PP → Prep NP
Pronoun → I | he | she | me
Noun → book | flight | meal | money
Verb → book | include | prefer
Proper-Noun → Houston | NWA

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Chomsky Normal Form

S → NP VP
S → X1 VP
X1 → Aux NP
S → book | include | prefer
S → Verb NP
S → VP PP
NP → I | he | she | me
NP → Houston | NWA
NP → Det Nominal
Nominal → book | flight | meal | money
Nominal → Nominal Noun
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