Computational Linguistics 1

CMSC/LING 723, LBSC 744

Kristy Hollingshead Seitz
Institute for Advanced Computer Studies
University of Maryland

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Agenda

- Homework
  - HW3 – graded!
  - Comments
- Questions, comments, concerns?
- Context-Free Grammars
  - Trees
  - Chomsky hierarchy
  - Treebanks?
  - Next week: parsing algorithms
- Take-home midterm

Grammar and Syntax

- By grammar, or syntax, we mean implicit knowledge of a native speaker
  - Acquired by around three years old, without explicit instruction
  - It's already inside our heads, we're just trying to formally capture it
- **Not** the kind of stuff you were later taught in school:
  - Don't split infinitives
  - Don't end sentences with prepositions

Syntax

- Why should you care?
- Syntactic analysis is a key component in many applications
  - Grammar checkers
  - Conversational agents
  - Question answering
  - Information extraction
  - Machine translation
  - …

Constituency

- Basic idea: groups of words act as a single unit
- Constituents form coherent classes that behave similarly
  - With respect to their internal structure: e.g., at the core of a noun phrase is a noun
  - With respect to other constituents: e.g., noun phrases generally occur before verbs

Constituency: Example

- The following are all noun phrases in English...

Harry the Horse	a high-class spot such as Mindy's
the Broadway coppers	the reason he comes into the Hot Box
they	three parties from Brooklyn

- Why?
  - They can all precede verbs
  - They can all be preposed
  - …

Grammars and Constituency

- For a particular language:
  - What are the "right" set of constituents?
  - What rules govern how they combine?
- Answer: not obvious and difficult
  - That's why there are so many different theories of grammar and competing analyses of the same data!
- Approach here:
  - Very generic
  - Focus primarily on the "machinery"
  - Doesn't correspond to any modern linguistic theory of grammar

Context-Free Grammars

- Context-free grammars (CFGs)
  - Aka phrase structure grammars
  - Aka Backus-Naur form (BNF)
- Consist of
  - Rules
  - Terminals
  - Non-terminals

Context-Free Grammars

- Terminals
  - We'll take these to be words (for now)
- Non-Terminals
  - The constituents in a language (e.g., noun phrase)
- Rules
  - Consist of a single non-terminal on the left and any number of terminals and non-terminals on the right

Some NP Rules

- Here are some rules for our noun phrases

$$\begin{aligned} NP &\rightarrow Det\ Nominal \\ NP &\rightarrow ProperNoun \\ Nominal &\rightarrow Noun \mid Nominal\ Noun \end{aligned}$$

- Rules 1 & 2 describe two kinds of NPs:
  - One that consists of a determiner followed by a nominal
  - Another that consists of proper names
- Rule 3 illustrates two things:
  - An explicit disjunction
  - A recursive definition

L_0 Grammar

Grammar Rules			Examples
S	$\rightarrow$	*NP VP*	I + want a morning flight
NP	$\rightarrow$	*Pronoun*	I
	|	*Proper-Noun*	Los Angeles
	|	*Det Nominal*	a + flight
Nominal	$\rightarrow$	*Nominal Noun*	morning + flight
	|	*Noun*	flights
VP	$\rightarrow$	*Verb*	do
	|	*Verb NP*	want + a flight
	|	*Verb NP PP*	leave + Boston + in the morning
	|	*Verb PP*	leaving + on Thursday
PP	$\rightarrow$	*Preposition NP*	from + Los Angeles

CFG: Formal definition

N	a set of **non-terminal symbols** (or **variables**)
Σ	a set of **terminal symbols** (disjoint from N)
R	a set of **rules** or productions, each of the form $A \rightarrow \beta$, where A is a non-terminal, β is a string of symbols from the infinite set of strings $(\Sigma \cup N)*$
S	a designated **start symbol**

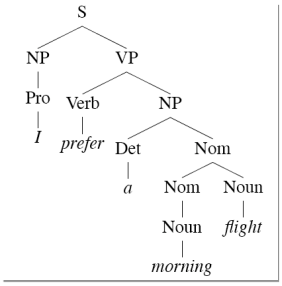
Three-fold View of CFGs

- Generator
- Acceptor
- Parser

Derivations and Parsing

- A derivation is a sequence of rules applications that
  - Covers all tokens in the input string
  - Covers only the tokens in the input string
- Parsing: given a string and a grammar, recover the derivation
  - Derivation can be represented as a parse tree
  - Multiple derivations?

Parse Tree: Example



Note: equivalence between parse trees and bracket notation

Parse Tree Example: Bracket Notation

(S (NP (Pro I))
(VP (Verb prefer)
(NP (Det a)
(Nom (Nom (Noun morning))
(Noun flight)))))

Natural vs. Programming Languages

- Wait, don't we do this for programming languages?
- What's similar?
- What's different?

An English Grammar Fragment

- Sentences
- Noun phrases
  - Issue: agreement
- Verb phrases
  - Issue: subcategorization

Sentence Types

- Declaratives: A plane left.
  S → NP VP
- Imperatives: Leave!
  S → VP
- Yes-No Questions: Did the plane leave?
  S → Aux NP VP
- WH Questions: When did the plane leave?
  S → WH-NP Aux NP VP

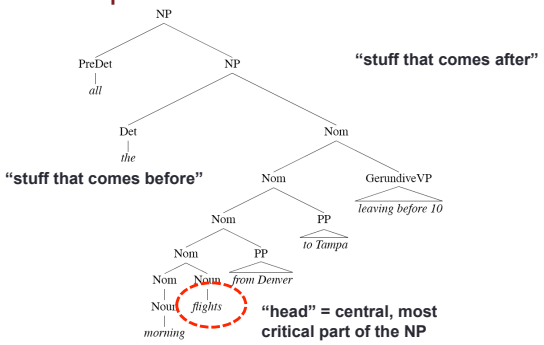
Noun Phrases

- Let's consider these rules in detail:

$$NP \rightarrow Det\ Nominal$$
$$NP \rightarrow ProperNoun$$
$$Nominal \rightarrow Noun \mid Nominal\ Noun$$

- NPs are a bit more complex than that!
  - Consider: "All the morning flights from Denver to Tampa leaving before 10"

A Complex Noun Phrase



"stuff that comes after"

"stuff that comes before"

"head" = central, most critical part of the NP

Determiners

- Noun phrases can start with determiners...
- Determiners can be
  - Simple lexical items: the, this, a, an, etc. (e.g., "a car")
  - Or simple possessives (e.g., "John's car")
  - Or complex recursive versions thereof (e.g., John's sister's husband's son's car)

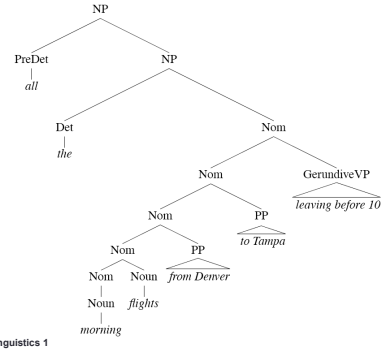
Premodifiers

- Come before the head
- Examples:
  - Cardinals, ordinals, etc. (e.g., "three cars")
  - Adjectives (e.g., "large car")
- Ordering constraints
  - "three large cars" vs. "?large three cars"

Postmodifiers

- Naturally, come after the head
- Three kinds
  - Prepositional phrases (e.g., "from Seattle")
  - Non-finite clauses (e.g., "arriving before noon")
  - Relative clauses (e.g., "that serve breakfast")
- Similar recursive rules to handle these
  - Nominal → Nominal PP
  - Nominal → Nominal GerundVP
  - Nominal → Nominal RelClause

A Complex Noun Phrase Revisited



Agreement

- Agreement: constraints that hold among various constituents
- Example, number agreement in English

This flight	***This flights**
Those flights	***Those flight**
One flight	***One flights**
Two flights	***Two flight**

Problem

- Our NP rules don't capture agreement constraints
  - Accepts grammatical examples (this flight)
  - Also accepts ungrammatical examples (*these flight)
- Such rules **overgenerate**
  - We'll come back to this later

Verb Phrases

- English verb phrases consists of
  - Head verb
  - Zero or more following constituents (called arguments)
- Sample rules:

$VP \rightarrow Verb$ disappear
$VP \rightarrow Verb\ NP$ prefer a morning flight
$VP \rightarrow Verb\ NP\ PP$ leave Boston in the morning
$VP \rightarrow Verb\ PP$ leaving on Thursday

Possible CFG Solution

- Encode agreement in non-terminals:
  - SgS → SgNP SgVP
  - PlS → PlNP PlVP
  - SgNP → SgDet SgNom
  - PlNP → PlDet PlNom
  - PlVP → PlV NP
  - SgVP → SgV Np
- Can use the same trick for verb subcategorization

Possible CFG Solution

- Critique?
  - It works…
  - But it's ugly…
  - And it doesn't scale (explosion of rules)
- Alternatives?
  - Multi-pass solutions

Three-fold View of CFGs

- Generator
- Acceptor
- Parser

The Point

- CFGs have about just the right amount of machinery to account for basic syntactic structure in English
  - Lots of issues though...
- Good enough for many applications!
  - But there are many alternatives out there…

Agenda:Summary

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  - Trees
  - Chomsky hierarchy
  - Treebanks?
  - Next week: parsing algorithms
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