Last Class: Smoothing

Today: Parsing

1. Grammars and parsing
2. Top-down and bottom-up parsing
3. Chart parsers
4. Bottom-up chart parsing

Syntax

syntax: from the Greek *syntaxis*, meaning "setting out together or arrangement."
Refers to the way words are arranged together.

Why worry about syntax?

- The boy ate the frog.
- The frog was eaten by the boy.
- The frog that the boy ate died.
- The boy whom the frog was eaten by died.

Syntactic Analysis

Key ideas:

- **constituency**: groups of words may behave as a single unit or phrase
- **grammatical relations**: refer to the SUBJECT, OBJECT, INDIRECT OBJECT, etc.
- **subcategorization and dependencies**: refer to certain kinds of relations between words and phrases, e.g. *want* can be followed by an infinitive, but *find* and *work* cannot.

All can be modeled by various kinds of grammars that are based on context-free grammars.

Grammars and Parsing

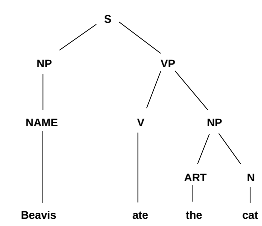
Need a **grammar:** a formal specification of the structures allowable in the language.

Need a **parser**: algorithm for assigning syntactic structure to an input sentence.

Sentence

Beavis ate the cat.

Parse Tree



CFG example

CFG's are also called phrase-structure grammars.
Equivalent to Backus-Naur Form (BNF).

1. S → NP VP
2. VP → V NP
3. NP → NAME
4. NP → ART N
5. NAME → Beavis
6. V → ate
7. ART → the
8. N → cat

- CFG's are *powerful* enough to describe most of the structure in natural languages.
- CFG's are *restricted* enough so that efficient parsers can be built.

CFG's

A context free grammar consists of:

1. a set of non-terminal symbols N
2. a set of terminal symbols Σ (disjoint from N)
3. a set of productions, P, each of the form $A \rightarrow \alpha$, where A is a non-terminal and α is a string of symbols from the infinite set of strings $(\Sigma \cup N)^*$
4. a designated start symbol S

Derivations

- If the rule $A \rightarrow \beta \in P$, and α and γ are strings in the set $(\Sigma \cup N)^*$, then we say that $\alpha A \gamma$ **directly derives** $\alpha\beta\gamma$, or $\alpha A \gamma \Rightarrow \alpha\beta\gamma$
- Let $\alpha_1, \alpha_2, \ldots, \alpha_m$ be strings in $(\Sigma \cup N)^*$, $m > 1$, such that

$$\alpha_1 \Rightarrow \alpha_2, \alpha_2 \Rightarrow \alpha_3, \ldots, \alpha_{m-1} \Rightarrow \alpha_m,$$

  then we say that α_1 **derives** α_m or $\alpha_1 \stackrel{*}{\Rightarrow} \alpha_m$

L_G

The language L_G generated by a grammar G is the set of strings composed of terminal symbols that can be derived from the designated start symbol S.

$L_G = \{w | w \in \Sigma^*, S \stackrel{*}{\Rightarrow} w\}$

Parsing: the problem of mapping from a string of words to its parse tree according to a grammar G.

General Parsing Strategies

Grammar	Top-Down	Bottom-Up
1. S → NP VP	S → NP VP	→ NAME ate the cat
2. VP → V NP	→ NAME VP	→ NAME V the cat
3. NP → NAME	→ Beav VP	→ NAME V ART cat
4. NP → ART N	→ Beav V NP	→ NAME V ART N
5. NAME → Beavis	→ Beav ate NP	→ NP V ART N
6. V → ate	→ Beav ate ART N	→ NP V NP
7. ART → the	→ Beav ate the N	→ NP VP
8. N → cat	→ Beav ate the cat	→ S

A Top-Down Parser

Input: CFG grammar, lexicon, sentence to parse
Output: yes/no

State of the parse: (*symbol list*, *position*)

$_1$ The $_2$ old $_3$ man $_4$ cried $_5$

start state: ((S) 1)

Grammar and Lexicon

Grammar:

1. S → NP VP
2. NP → art n
3. NP → art adj n
4. VP → v
5. VP → v NP

Lexicon:
the: art
old: adj, n
man: n, v
cried: v

$_1$ The $_2$ old $_3$ man $_4$ cried $_5$

Algorithm for a Top-Down Parser

$PSL \leftarrow$ (((S) 1))

1. *Check for failure.* If PSL is empty, return NO.
2. *Select the current state, C.* C ← pop (PSL).
3. *Check for success.* If C = (() <final-position>), YES.
4. *Otherwise, generate the next possible states.*
   (a) $s_1 \leftarrow$ first-symbol(C)
   (b) If s_1 is a *lexical symbol* and next word can be in that class, create new state by removing s_1, updating the word position, and adding it to PSL. (I'll add to front.)
   (c) If s_1 is a *non-terminal*, generate a new state for each rule in the grammar that can rewrite s_1. Add all to PSL. (Add to front.)

Example

Current state	Backup states	
1. ((S) 1)		
2. ((NP VP) 1)		
3. ((art n VP) 1)	((art adj n VP) 1)	
4. ((n VP) 2)	((art adj n VP) 1)	
5. ((VP) 3)	((art adj n VP) 1)	
6. ((v) 3)	((v NP) 3) ((art adj n VP) 1)	
7. (() 4)	((v NP) 3) ((art adj n VP) 1)	Backtrack

8. ((v NP) 3)	((art adj n VP) 1)	leads to backtracking
...		
9. ((art adj n VP) 1)		
10. ((adj n VP) 2)		
11. ((n VP) 3)		
12. ((VP) 4)		
13. ((v) 4)	((v NP) 4)	
14. (() 5)	((v NP) 4)	
YES		

DONE!

Problems with the Top-Down Parser

1. Only judges grammaticality.
2. Stops when it finds a single derivation.
3. No semantic knowledge employed.
4. No way to rank the derivations.
5. Problems with left-recursive rules.
6. Problems with ungrammatical sentences.

Efficient Parsing

The top-down parser is terribly inefficient.

Have the first year Phd students in the computer science department take the Q-exam.

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Chart Parsers

chart: data structure that stores partial results of the parsing process in such a way that they can be reused. The chart for an n-word sentence consists of:

- $n + 1$ **vertices**
- a number of **edges** that connect vertices

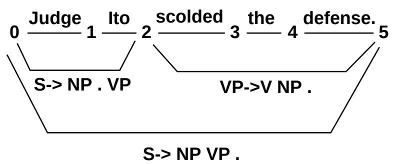

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Chart Parsing: The General Idea

The process of parsing an n-word sentence consists of forming a chart with $n + 1$ vertices and adding edges to the chart one at a time.

- Goal: To produce a complete edge that spans from vertex 0 to n and is of category S.
- There is no backtracking.
- Everything that is put in the chart stays there.
- Chart contains all information needed to create parse tree.

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