Introduction to Parsing

Parsing
ISCL-BA-06

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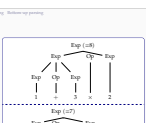
What is parsing?

- Parsing is the task of assigning a structure to a given sentence
- It is related to recognition: typically we follow the steps taken during derivation to obtain the structure
- From a different perspective, parsing is the inverse of the generation task
- Note: we focus on context-free parsing – the structures we build/recover are trees

Why do we need parsing?

- The formal approach to languages as sets emphasizes recognition
  - a string is whether in the language or not
- Parsing is in general a step for semantics
  - we cannot assign semantics without structure

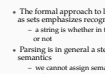


Overview

- Representation context-free analyses and parse trees
- Ambiguity
- Top-down parsing
- Bottom-up parsing
- General overview of the parsing methods
- Representing parsing methods: parse forests
- Parsing and semantics

Different ways to represent a context-free parse

A parse tree



A history of derivations

Sentential form	derivation
S	(start)
NP VP	S ⇒ NP VP
Prn VP	NP ⇒ Prn
I VP	Prn ⇒ I
I V NP	VP ⇒ V NP
I saw NP	V ⇒ saw
I saw Prn$_{\text{her}}$ N	NP ⇒ Prn$_{\text{her}}$ N
I saw her N	Prn$_{\text{her}}$ ⇒ her
I saw her duck	N ⇒ duck

(Labeled) brackets: $\left[_{\text{S}}\left[_{\text{NP}}\left[_{\text{Prn}}\ \text{I}\right]\right]\left[_{\text{VP}}\left[_{\text{V}}\ \text{saw}\right]\left[_{\text{NP}}\left[_{\text{Prn}_{\text{her}}}\ \text{her}\right]\left[_{\text{N}}\ \text{duck}\right]\right]\right]$

Relation between different representations

- The parse tree and the bracket representation is equivalent
  - parse trees are easier to read by humans
  - brackets are easier for computers
  - brackets are the typical representation for treebanks
- A parse tree (or bracket representation) can be obtained with a different order of production rules

Grammars and ambiguity

Exp → n
Exp → Exp + Exp
(terminal symbol 'n' stands for any number)

- If a grammar is ambiguous, some sentences produce multiple analyses
- If the resulting analysis lead to the same semantics, the ambiguity is *spurious*

Grammars and ambiguity

Exp → n
Exp → Exp − Exp

(terminal symbol 'n' stands for any number)

- Is this ambiguity spurious?
- If different structures yield different semantics, the ambiguity is *essential*

Languages and ambiguity

- A language is ambiguous if there is no unambiguous grammar that can produce it
- For example, the language $a^n b^n c^m \cup a^n b^k c^k$ is ambiguous
  - The strings of the form $a^n b^n c^k$ could be generated by either part of the language definition
- Note: do not confuse ambiguity with different derivations leading to same analysis
  - Ambiguity results in different structures
  - Multiple derivations with the same structure is related to the mechanism used for obtaining the derivations

Ambiguity can be removed from a grammar

if the language is not ambiguous

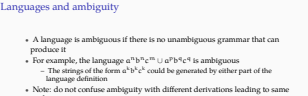
Exp → n
Exp → Exp + n
(terminal symbol 'n' stands for any number)

- This one does not have the ambiguity of

  Exp → n
  Exp → Exp + Exp

- Both grammars define the same language

Natural languages are ambiguous



- The grammars we define have to distinguish between two different structures

Top-down parsing

general idea

- Start from S, find a sequence of derivations that yield the sentence
- This is simply the same as the generation procedure we discussed earlier
- Attempt to generate all strings from the parse grammar, but allow productions that only leads to the input string

Top-down: demonstration

S	→	NP VP
NP	→	Det N
VP	→	V NP
VP	→	V
Det	→	a
Det	→	the
N	→	cat
N	→	dog
V	→	bites

From demonstration to parsing

- There may be multiple production applicable
- We need an automatic mechanism to select the correct productions
- We have two actions:
  - predict generate a hypothesis based on the grammar
  - match when a terminal is produced, check if it matches with the terminal in the expected position
    - if matched, continue
    - otherwise, backtrack
- if we eliminate all non terminals, and the complete input string is matched, then parsing successful

Top-down parsing: another demonstration

the grammar

S	→	NP VP
NP	→	Det N
VP	→	V NP
VP	→	V
Det	→	a
Det	→	the
N	→	cat
N	→	dog
V	→	bites

parse: *the cat bites a dog*

matched	goal	production
	S	S ⇒ NP VP
	NP VP	NP ⇒ Det VP
	Det N VP	Det ⇒ ✗
	Det N VP	Det ⇒ the ✓
the	N VP	N ⇒ dog ✗
the cat	N VP	N ⇒ cat ✓
the cat	V	VP ⇒ ✗
the cat bites	V	V ⇒ bites ✓
the cat bites		(end at the end) ✗
the cat	V NP	VP ⇒ V NP
the cat bites	NP	V ⇒ bites ✓
the cat bites	Det N	NP ⇒ Det N
the cat bites a	N	Det ⇒ a ✓
the cat bites a dog		Det ⇒ dog ✓

Note that the valid productions yield the parse tree.

Top-down parsing: problems and possible solutions

- Trial-and-error procedure leads to exponential time parsing
- But lots of repeated work: dynamic programming may help avoid it
- What happens if we had a rule like

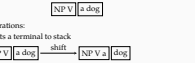
  NP → NP PP

  some rules may cause infinite loops
- Notice that if we knew which terminals are possible as the initial part of a non-terminal symbol, we can eliminate the unsuccessful matches earlier

Bottom-up parsing

general idea

- Start from from the input symbol, and try to *reduce* the input to start symbol
- We need to match parts of the sentential form (starting from the input) to the RHS of the grammar rules
- While top-down process relies on *productions* the bottom-up process relies on *reductions*



Bottom-up: demonstration

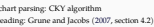
S	→	NP VP
NP	→	Det N
VP	→	V NP
VP	→	V
Det	→	a
Det	→	the
N	→	cat
N	→	dog
V	→	bites

A (first) introduction to shift-reduce parsing

- We keep two data structures:
  - a stack for the (partially) reduced sentential form
  - an input queue that contains only terminal symbols

- We use two operations:

  shift shifts a terminal to stack



  reduce when top symbols on stack mach a RHS, replace them with the LHS of the rule

Shift-reduce (bottom-up) parsing a demonstration

stack	input	rule
	the cat bites a dog	shift
the	cat bites a dog	Det → the
Det	cat bites a dog	shift
Det cat	bites a dog	N → cat
NP	bites a dog	NP → Det N
NP	bites a dog	shift
NP bites	a dog	V → bites
NP V	a dog	VP → V
NP VP	a dog	S → NP VP
S	a dog	shift
S a	dog	Det → A
S Det	dog	N → dog
S Det N		NP → Det N
S NP		(stuck)

stack	input	rule
NP V	a dog	shift
NP V a	dog	Det → a
NP V Det	dog	shift
NP V Det N		N → dog
NP V NP		NP → Det N
NP VP		VP → V NP
S		S → NP VP
		(done)

- All input reduced to S, accept
- Rules form the parse tree

Summary

- Parsing can be formulated as a top-down or bottom-up search (the search may also be depth-first or breadth first)
- Naive parsing algorithms are inefficient (exponential time complexity)
- There are some directions: dynamic programming, filtering
- Suggested reading for this part: Grune and Jacobs (2007, ch.3)

Next:

- Bottom-up chart parsing: CKY algorithm
- Suggested reading: Grune and Jacobs (2007, section 4.2), Jurafsky and Martin (2009, draft 3rd ed, section 13.2)

Acknowledgments, references, additional reading material

- Please read Grune and Jacobs (2007) chapter 3, a big part part of the lecture follows this chapter

Grune, D. and C.J.H. Jacobs (2007). *Parsing Techniques: A Practical Guide*. second. Monographs in Computer Science. The first edition is available at http://dickgrune.com/Books/PTAPG_1st_Edition/BookBody.pdf. Springer New York. isbn: 9780387202488.

Jurafsky, Daniel and James H. Martin (2009). *Speech and Language Processing: An Introduction to Natural Language Processing, Computational Linguistics, and Speech Recognition*. second. Prentice Hall. isbn: 978-0-13-504196-3. url: http://stp.stanford.edu/~jurafsky/slp3/.