Dependency grammars

Parsing

ISCL-BA-06

Çağrı Çöltekin

`ccoltekin@sfs.uni-tuebingen.de`

University of Tübingen

Seminar für Sprachwissenschaft

Winter Semester 2020/21

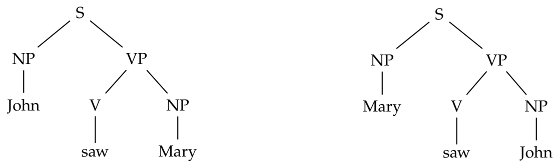
version: 78f2b15+ @2021-01-31

So far ...

a brief summary

- Preliminaries: (formal) languages, grammars and automata
  - Chomsky hierarchy of language classes
  - Expressivity and computational complexity
- Context-free grammars and parsing
  - Top-down, bottom-up, directional, non-directional
  - Chart parsing: Earley, CKY
  - Deterministic parsing: LL/LR grammars and parsers
  - Ambiguity resolution and PCFGs

Why do we need syntactic parsing?



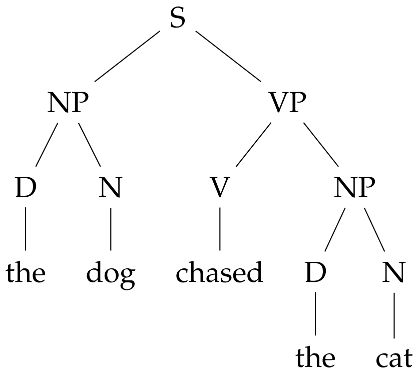
- Syntactic analysis is an intermediate step in (semantic) interpretation of sentences
- It is essential for understanding and generating natural language sentences (hence, also useful for applications like *question answering*, *information extraction*, ...)
- (Statistical) parsers are also used as *language models* for applications like *speech recognition* and *machine translation*
- It can be used for *grammar checking*, and can be a useful tool for linguistic research

Phrase structure (or constituency) grammars

The main idea is that a *span* of words form a natural unit, called a *constituent* or *phrase*.

- Constituency grammars are common in modern linguistics (also in computer science)
- Most are based on a context-free 'backbone', extensions or restricted forms are common

Syntactic representation using context-free grammars



```
(S (NP (D (the)) (N (dog))
   )
   (VP (V (chased))
       (NP (D (the))
           (N (cat))
       )
   )
)
```

An exercise

- Write down simple context-free analysis of the following sentence (draw a parse tree, send the bracketed form through chat)

```
I read a good book during the weekend
```

An exercise

- Write down simple context-free analysis of the following sentence (draw a parse tree, send the bracketed form through chat)

  `I read a good book during the weekend`

- Repeat the exercise for a (more-or-less direct) translation of the same sentence in another language

An exercise

- Write down simple context-free analysis of the following sentence (draw a parse tree, send the bracketed form through chat)

  `I read a good book during the weekend`

- Repeat the exercise for a (more-or-less direct) translation of the same sentence in another language
- How about the following sentence?

  `During the weekend I read a good book`

space for the exercise

Where do grammars come from?

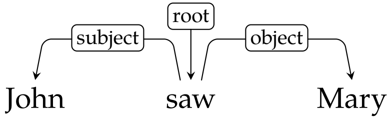
- Grammars for (constituency) parsing can be either
  - hand crafted (many years of expert effort)
  - extracted from *treebanks* (which also require lots of effort)
  - 'induced' from raw data (interesting, but not as successful)
- Current practice relies mostly on treebanks
- Hybrid approaches also exist
- Grammar induction is not common (for practical models), but exploiting unlabeled data for improving parsing is also a common trend

Treebanks

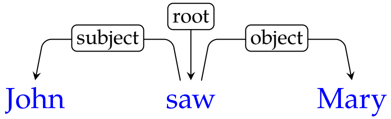
- Treebanks are an important tool for parsing (but also for many linguistic analysis tasks)
- Creating a treebank is a long-term, labor intensive task, with many phases/tasks, including
  - Planning, creating annotation guidelines
  - Annotation
  - Quality assurance
- Example, well-known constituency treebanks
  - Penn Treebank (English, Chinese, Arabic)
  - Tiger treebank (German)
  - TüBA-D/Z (German)
  - Tübingen spoken treebanks (German, English, Japanese)
  - Alpino (Dutch)
  - Talbanken (Swedish)
  - ...

Dependency grammars
introduction

- Dependency grammars gained popularity in linguistics (particularly in CL) rather recently
- They are old: roots can be traced back to Pāṇini (approx. 5th century BCE)
- Modern dependency grammars are often attributed to Tesnière 1959
- The main idea is capturing the relations between words, rather than grouping them into (abstract) constituents

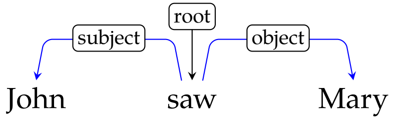


Dependency grammars



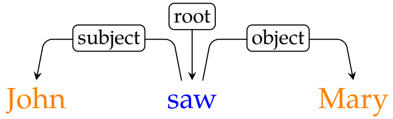
- No constituents, units of syntactic structure are words

Dependency grammars



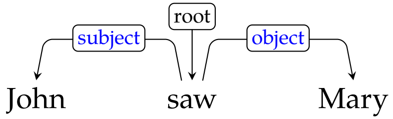
- No constituents, units of syntactic structure are words
- The structure of the sentence is represented by *asymmetric*, *binary* relations between syntactic units

Dependency grammars



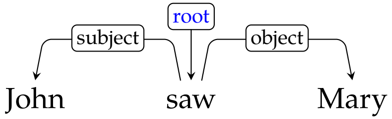
- No constituents, units of syntactic structure are words
- The structure of the sentence is represented by *asymmetric*, *binary* relations between syntactic units
- Each relation defines one of the words as the head and the other as dependent

Dependency grammars



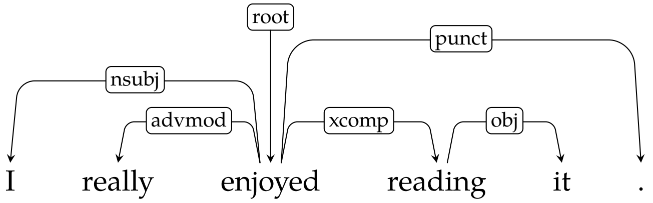
- No constituents, units of syntactic structure are words
- The structure of the sentence is represented by *asymmetric*, *binary* relations between syntactic units
- Each relation defines one of the words as the head and the other as dependent
- Typically, the links (relations) have labels (dependency types)

Dependency grammars

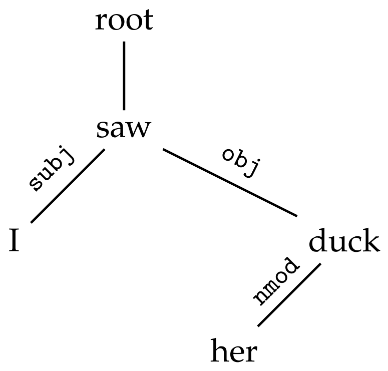


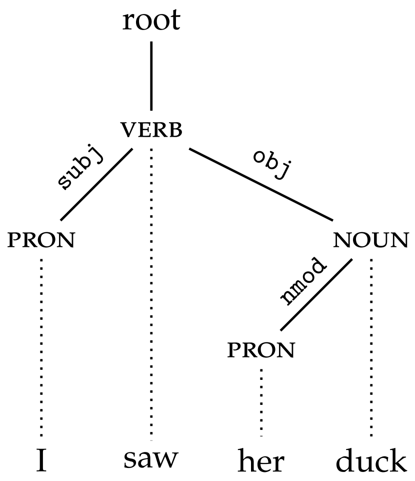
- No constituents, units of syntactic structure are words
- The structure of the sentence is represented by *asymmetric*, *binary* relations between syntactic units
- Each relation defines one of the words as the head and the other as dependent
- Typically, the links (relations) have labels (dependency types)
- Often an artificial *root* node is used for computational convenience

A more realistic example



Dependency grammars: alternative notation





Dependency analyses: definition

A dependency analyses/graph is a tuple (V, A)

- V is a set of nodes corresponding to the (syntactic) words (we implicitly assume that words have indexes)
- A is a set of arcs of the form (w_i, r, w_j) where
  - w_i $\in V$ is the head
  - r is the type of the relation (arc label)
  - w_j $\in V$ is the dependent

This defines a directed graph.

Dependency grammars: common assumptions

- Every word has a single head
- The dependency graphs are acyclic
- The graph is connected
- With these assumptions, the representation is a tree
- Note that these assumptions are not universal but common for dependency parsing

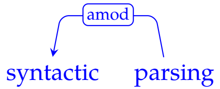
How to determine heads

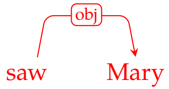
1. *Head* (H) determines the syntactic category of the *construction* (C) and can often replace C
2. H determines the semantic category of C; the *dependent* (D) gives semantic specification
3. H is obligatory, D may be optional
4. H selects D and determines whether D is obligatory or optional
5. The form and/or position of dependent is determined by the head
6. The form of D depends on H
7. The linear position of D is specified with reference to H

(from Kübler, McDonald, and Nivre 2009, p.3–4)

Issues with head assignment and dependency labels

- Determining heads are not always straightforward
- A construction is called *endocentric* if the head can replace the whole construction, *exocentric* otherwise

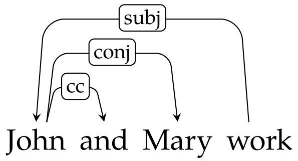


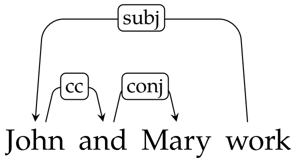


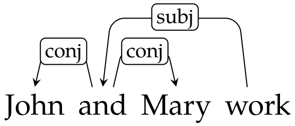
- It is often unclear whether dependency labels encode syntactic or semantic functions

Some tricky constructions

Coordination

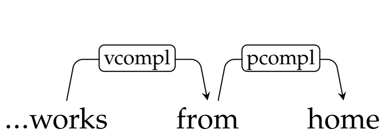


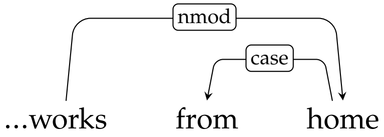




Some tricky constructions

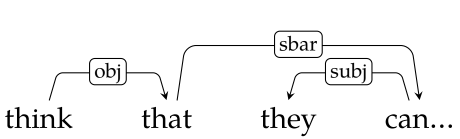
Adpositional phrases

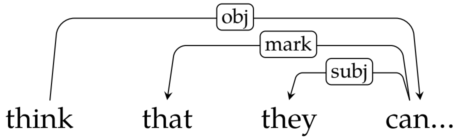




Some tricky constructions

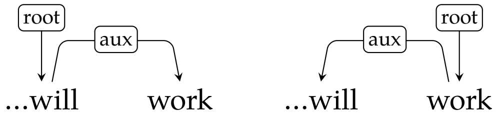
Subordinate clauses



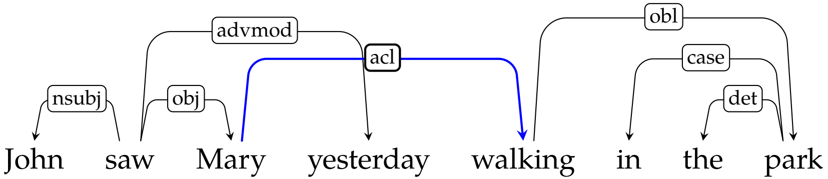


Some tricky constructions

Auxiliaries vs. main verbs



Dependency grammars: projectivity



- If a dependency graph has no crossing edges, it is said to be *projective*, otherwise *non-projective*
- Non-projectivity stems from long-distance dependencies and free word order
- Projective dependency trees can be represented with context-free grammars
- In general, projective dependencies are parseable more efficiently

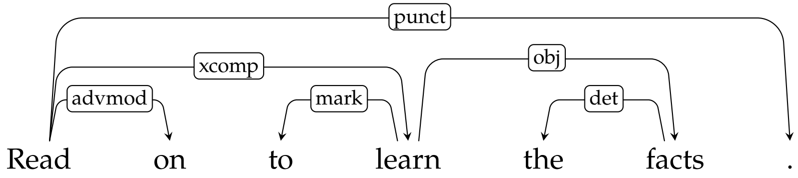
Universal Dependencies project

- Like constituency annotation efforts, most earlier dependency annotations were language- or even project-specific
- This has been a major hurdle for multi-lingual and cross-lingual work
- The Universal Dependencies (UD) project aims to unify dependency annotation efforts as much as possible
- The project releases treebanks (with mostly permissive licenses) for many languages
  - Currently (UD version 2.7) 183 treebanks covering 104 languages

CONLL-X/U format for dependency annotation

Single-head assumption allows flat representation of dependency trees

```
1    Read  read  VERB  VB  Mood=Imp|VerbForm=Fin 0 root
2    on    on    ADV   RB  _                     1 advmod
3    to    to    PART  TO  _                     4 mark
4    learn learn VERB  VB  VerbForm=Inf          1 xcomp
5    the   the   DET   DT  Definite=Def          6 det
6    facts fact  NOUN  NNS Number=Plur           4 obj
7    .     .     PUNCT .   _                     1 punct
```



example from English Universal Dependencies treebank

Back to the exercise

- Analyze of the following sentence with UD dependencies (draw a parse tree, send dependency triplets through chat)

```
I read a good book during the weekend
```

Back to the exercise

- Analyze of the following sentence with UD dependencies (draw a parse tree, send dependency triplets through chat)

```
I read a good book during the weekend
```

- Repeat, for the following version of the English sentence

```
During the weekend I read a good book
```

Back to the exercise

- Analyze of the following sentence with UD dependencies (draw a parse tree, send dependency triplets through chat)

```
I read a good book during the weekend
```

- Repeat, for the following version of the English sentence

```
During the weekend I read a good book
```

- Repeat the exercise for a another language (same translation as the constituency exercise) space for the exercise

Dependency parsing

- Dependency parsing has many similarities with context-free parsing (e.g., trees)
- It also has some differences (e.g., number of edges and depth of trees are limited)
- Dependency parsing can be
  - grammar-driven (hand crafted rules or constraints)
  - data-driven (rules/model is learned from a treebank)
- There are two main approaches:

  Graph-based similar to context-free parsing, search for the best tree structure

  Transition-based similar to shift-reduce parsing (used for programming language parsing), but using greedy search for the best transition sequence

Grammar-driven dependency parsing

- Grammar-driven dependency parsers typically based on
  - lexicalized CF parsing
  - constraint satisfaction problem
    - start from fully connected graph, eliminate trees that do not satisfy the constraints
    - exact solution is intractable, often employ heuristics, approximate methods
    - sometimes ‘soft’, or weighted, constraints are used
  - Practical implementations exist
- Our focus will be on data-driven methods

Dependency grammars

Advantages and disadvantages

+ Close relation to semantics
+ Easier for flexible/free word order
+ Lots, lots of (multi-lingual) computational work, resources
+ Often much useful in downstream tasks
+ More efficient parsing algorithms

– No distinction between modification of head or the whole ‘constituent’
– Some structures are difficult to annotate, e.g., coordination

Summary

- Dependency grammars are based on *asymmetric*, *binary* relations between syntactic units
- Focus is on *syntactic functions*, in comparison to *syntactic constituency*
- Dependencies are (typically) labeled
- Dependency analyses are used more in downstream tasks
- Suggested reading: Kübler, McDonald, and Nivre (2009, chapter 1))

Summary

- Dependency grammars are based on *asymmetric*, *binary* relations between syntactic units
- Focus is on *syntactic functions*, in comparison to *syntactic constituency*
- Dependencies are (typically) labeled
- Dependency analyses are used more in downstream tasks
- Suggested reading: Kübler, McDonald, and Nivre (2009, chapter 1))

Next:

- Dependency parsing
  - Transition based
  - Graph based
- Reading suggestion: Jurafsky and Martin (2009, draft chapter 14): `https://web.stanford.edu/~jurafsky/slp3/14.pdf`, Kübler, McDonald, and Nivre (2009)

Acknowledgments, references, additional reading material

Grune, Dick and Ceriel 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: 9780387689548.

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

Kübler, Sandra, Ryan McDonald, and Joakim Nivre (2009). *Dependency Parsing*. Synthesis lectures on human language technologies. Morgan & Claypool. ISBN: 9781598295962.

Tesnière, Lucien (1959). *Éléments de syntaxe structurale*. Paris: Éditions Klinksieck.

blank

blank

blank

blank

blank

blank