IN2110: Språkteknologiske metoder

Dependenssyntaks

Lilja Øvrelid

Språkteknologigruppen (LTG)

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From Linear Order to Hierarchical Structure

- NLP approaches we have considered this far:
  - Distributional representations of documents or words:

    Cisco acquired Tandberg $\equiv$ *Tandberg acquired Cisco*
  - Sequence labeling: HMMs.
    - One layer of abstraction: BIO-labels as hidden states.
    - Still only sequential in nature.

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- Syntax adds hierarchical structure:
  - Sentences are constructed from groups of words that themselves may be constructed from groups of words.
  - Graph-based approaches are (re-) emerging as an important way of looking at text.
  - Shift focus from bags or sequences to hierarchical structure.

Today's lecture

- Very brief repetition of basic principles of syntax:
  - form vs function
  - constituents and phrases
  - context-free grammars
- Dependency Grammar
  - basic concepts: head, dependent
  - comparison to constituent structure
  - formal properties
- Treebanks

Syntax

- Syntax: study of the structure of sentences
- "Who does what to whom?"
- Wealth of theories: some differences, a lot in common
  - Government and Binding (GB)
  - Minimalist Program (MP)
  - Head-driven phrase structure grammar (HPSG)
  - Lexical Functional Grammar (LFG)
  - Categorial Grammar
  - Dependency Grammar
  - ...

Why bother?

- Theoretical syntacticians concerned with **grammaticality**
  - *The President nominated a new Supreme Court justice*
  - **President the new Supreme justice Court nominated*
- Some attractive features for NLP applications:
  - (Fairly) Independent of word order
  - Fast parsing
  - Somewhat possible to use the same labels across languages

```
She is studying for her exam right now.
 Right now she is studying for her exam.
```

Why bother?

- Parsing provides "scaffolding" for semantic analysis
- Direct, down-stream usage of syntactic information
  - opinion mining
  - information extraction
  - text generation
  - grammar checking
  - syntax-informed statistical machine translation
  - question answering
  - sentence compression
  - etc.

Constituents

- The words in a sentence are organized into groupings
- function as a whole
- relate to other words as a unit
  - The dog ate my homework
- linguistic tests of constituency
  - The dog ate it

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  - The dog ate it
  - My homework the dog ate

Form and function

- **Syntactic form** - constituents are described using parts of speech and phrases
  - phrases - larger constituents above word level
  - phrases named after the **head** - central, obligatory member
  - e.g. NP, VP

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NP	VP	
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Subject	Predicate	Object
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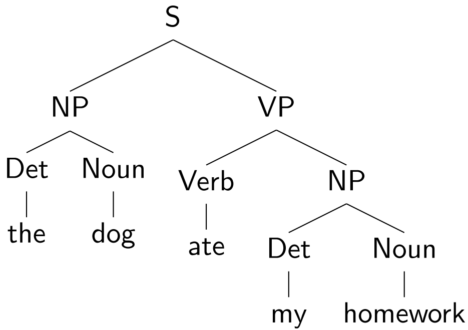
Phrase structure grammar (PSG)

- Capture constituent status and ordering
- Formal model: context-free grammar
  1. S $\rightarrow$ NP VP
  2. NP $\rightarrow$ D N
  3. VP $\rightarrow$ V NP
- Syntactic structure as phrase structure **trees**

Norwegian:
SVO
V2

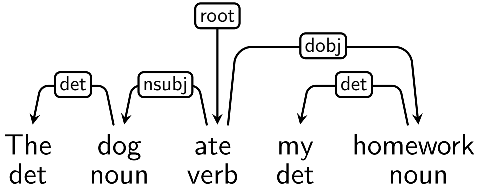
Syntactic categories

- Phrase Structure (PS) tree



Now: Dependency Grammar (DG)

- An alternative to phrase structure representations
- Syntactic functions are central
- Claimed to be closer to semantic analysis
- The basic idea:
  - Syntactic structure consists of lexical items, linked by binary asymmetric relations called dependencies.



Dependency Grammar

Dependency grammar is important for those interested in NLP:

- Increasing interest in dependency-based approaches to syntactic parsing in recent years (e.g., CoNLL shared tasks)
- Currently dominant approach
- Downstream applications: relation extraction, question answering, ontology learning, sentiment analysis, etc.

Constituency vs. Relations

- DG is based on relationships between words, i.e., **dependency relations**
  - A $\rightarrow$ B means *A governs B* or *B depends on A* ...
  - Dependency relations can refer to syntactic properties, semantic properties, or a combination of the two
  - These relations are generally things like subject, object/complement, (pre-/post-)adjunct, etc.
    - Subject/Agent: *John* fished.
    - Object/Patient: Mary hit *John*.
- PSG is based on groupings, or constituents
  - Grammatical relations are not usually seen as primitives, but as being derived from structure

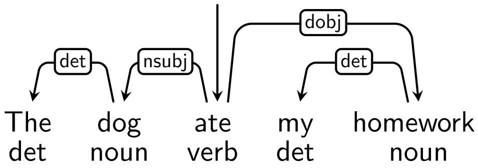
Simple relation example

For the sentence *The dog ate my homework*, we have the relations:

- ate $\rightarrow_{\text{subj}}$ The dog
- ate $\rightarrow_{\text{obj}}$ my homework

Both *The dog* and *my homework* depend on *ate*, which makes *ate* the head, or **root**, of the sentence (i.e., there is no word that governs *loves*)

- The structure of a sentence, then, consists of the set of pairwise relations among words.

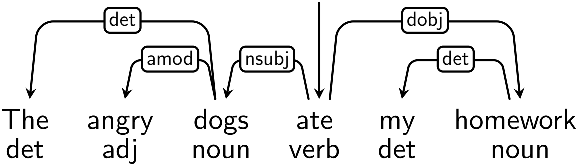


Comparison

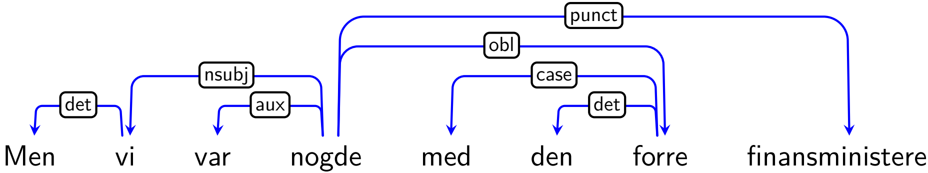
- Dependency structures explicitly represent
  - head-dependent relations (directed arcs),
  - functional categories (arc labels),
  - possibly some structural categories (parts-of-speech).
- Phrase structures explicitly represent
  - phrases (nonterminal nodes),
  - structural categories (nonterminal labels),
  - possibly some functional categories (grammatical functions).

Criteria for Heads and Dependents

- Criteria for a syntactic relation between a head H and a dependent D in a construction C:
  1. H determines the syntactic category of C; H can replace C.
  2. H determines the semantic category of C; D specifies H.
  3. H is obligatory; D may be optional.
  4. The form of D depends on H (agreement or government).
  5. The linear position of D is specified with reference to H.



Dependency Graphs



Dependency Graphs

- A dependency structure can be defined as a directed graph G, consisting of
  - a set V of nodes,
  - a set E of arcs (edges),
- Labeled graphs:
  - Nodes in V are labeled with word forms (and annotation).
  - Arcs in E are labeled with dependency types.

Formal Properties of Dependency Graphs

- **antisymmetric**: if A $\rightarrow$ B, then B $\nrightarrow$ A
  - If A governs B, B does not govern A
  - cf. *box lunch* (lunch $\rightarrow$ box) vs. *lunch box* (box $\rightarrow$ lunch)
- **antireflexive**: if A $\rightarrow$ B, then B $\neq$ A
  - No word can govern itself.
- **antitransitive**: if A $\rightarrow$ B and B $\rightarrow$ C, then A $\nrightarrow$ C
  - These are *direct* dependency relations
  - cf. *a usually reliable source*: source $\rightarrow$ reliable & reliable $\rightarrow$ usually, but source $\nrightarrow$ usually
- **labeled**: $\forall \rightarrow$, $\rightarrow$ has a label (r)

Formal Conditions on Dependency Graphs

- G is (weakly) connected:
  - For every node i there is a node j such that $i \rightarrow j$ or $j \rightarrow i$.
- G is acyclic:
  - If $i \rightarrow j$ then not $j \rightarrow^* i$.
- G obeys the single-head constraint:
  - If $i \rightarrow j$, then not $k \rightarrow j$, for any $k \neq i$.

Projectivity

- A head (A) and a dependent (B) must be adjacent: A is adjacent to B provided that every word between A and B is a subordinate of A.
- A projective graph: If $i \rightarrow j$ then $i \rightarrow^* k$, for any k such that $i < k < j$ or $j < k < i$

(1) with great difficulty

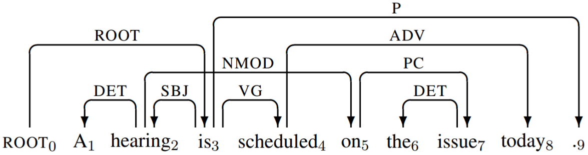
(2) *great with difficulty

- with $\rightarrow$ difficulty
- difficulty $\rightarrow$ great

**great with difficulty* is ruled out because branches would have to cross in that case

Projectivity

- Most theoretical frameworks do not assume projectivity.
- Non-projective structures are needed to account for
  - long-distance dependencies,
  - free word order.



Treebanks

- Collection of sentences manually annotated with syntactic analysis ⇒ a **treebank**
- Treebanks are used to train data-driven NLP tools (taggere, parsere)
- Treebanks for a number languages
  - Penn Treebank
  - Prague Dependency Treebank (czech)
  - Negra/Tuba-DZ (German)
  - Penn (Chinese)
  - Norwegian Dependency Treebank
  - Universal Dependencies

Dependency Treebanks

- Constituent tree with head information can be automatically converted.
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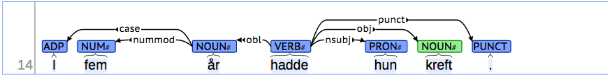
- Including, of course, the venerable Penn Treebank (PTB) for English.
- Recently, greatly increased interest in dependency syntax 'world-wide'.
- New annotation initiatives now more often 'natively' in dependencies.
- Ongoing cross-linguistic harmonization: Universal Dependencies (UD).
- 'Mainstream': treebanks for 70^{+} languages (including NOB & NNO).

Norwegian Dependency Treebank (NDT)

- NDT was completed in 2014 (Solberg et al, 2014) by Språkbanken, National Library
- Ca 600,000 tokens of manually annotated Bokmål and Nynorsk text (news, blogs, stortingsmeldinger)
- Enables training of taggers and parsers for Norwegian (Øvrelid & Hohle, 2016; Hohle et al, 2017; Velldal et al, 2017)
- Freely available so others can do the same (and better!)
- Converted to Universal Dependencies (Øvrelid & Hohle, 2016)



Universal Dependencies

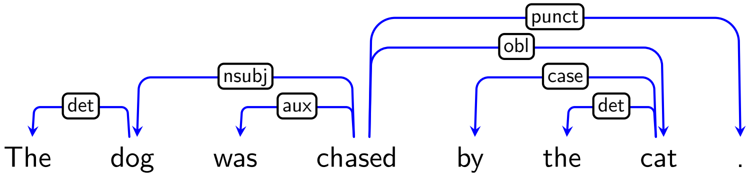
- Harmonized dependency treebanks for more than 100 languages (including Norwegian)
- Norwegian models in Google SyntaxNet and spaCy
- `http://universaldependencies.org/`

Latin-PROIEL	171K	✓
Latvian	54K	✓
Lithuanian	5K	✓
Maltese	2K	⧗
North Sami	55K	⧗
Norwegian-Bokmaal	310K	✓
Norwegian-Nynorsk	301K	✓
Old Church Slavonic	57K	✓
Persian	151K	✓
Polish	82K	✓
Portuguese	210K	✓
Portuguese-BR	297K	✓
Portuguese-PUD	21K	⧗
Romanian	218K	✓
Russian	99K	✓
Russian-PUD	19K	⧗
Russian-SynTagRus	1,107K	✓
Sanskrit	1K	✓
Serbian	86K	⧗
Slovak	106K	✓
Slovenian	140K	✓
Slovenian-SST	29K	✓
Spanish	423K	✓
Spanish-AnCora	547K	✓
Spanish-PUD	22K	⧗
Swedish	96K	✓
Swedish-LinES	79K	✓
Swedish-PUD	19K	⧗
Swedish Sign Language	<1K	✓
Tamil	8K	✓

Example 'Universal' Dependency Types

nsubj	nominal subject	She arrived.
csubj	clausal subject	That she arrived surprised me.
obj	(direct) object	My mother called me.
iobj	indirect object	She teaches my daughter maths.
ccomp	clausal complement	She knew that she arrived.
xcomp	open clausal complement	She promised to sing.
obl	oblique nominal	She arrived on Monday
obl	oblique nominal	She depends on me.
nmod	nominal modifier	the office of the chair is empty.
amod	adjectival modifier	the fierce dog barks.
acl	adjectival clause	the dog that barks arrived.
conj	conjunct	Kim and Sandy arrived.
cc	coordinating conjunction	Kim and Sandy arrived.

(Degrees of) Cross-Linguistic Consistency



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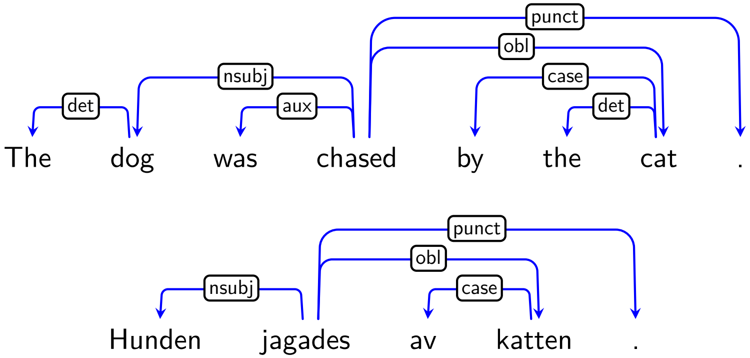

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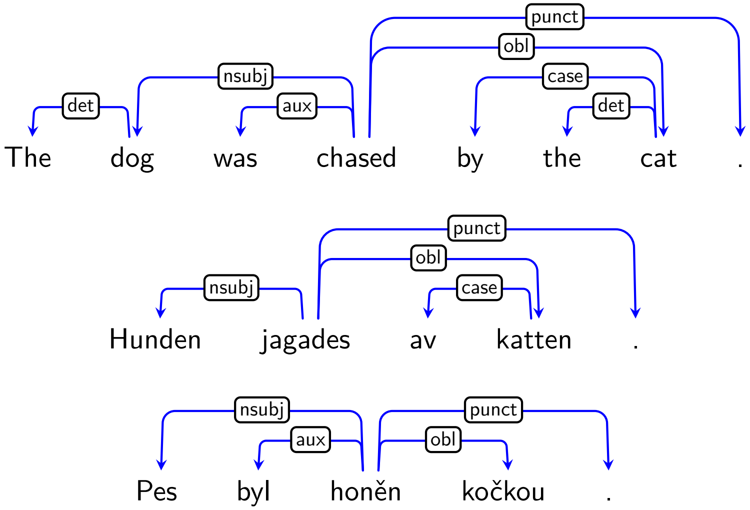

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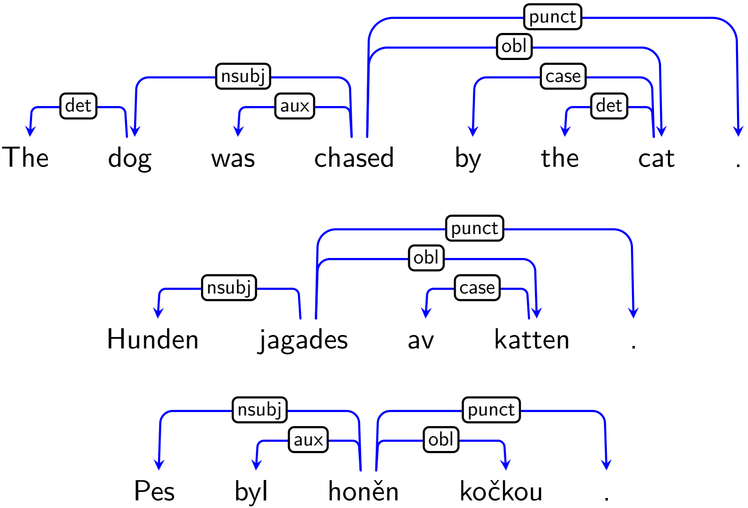

- Capitalize on content words, e.g. demote case-marking prepositions.

CoNLL-U format

1	Det	det	PRON	Gender=Neut|...	2	nsubj
2	foregikk	foregå	VERB	Mood=Ind|...	0	root
3	i	i	ADP	_	4	case
4	Norge	Norge	PROPN	_	2	obl
5	.	.	PUNCT	_	2	punct

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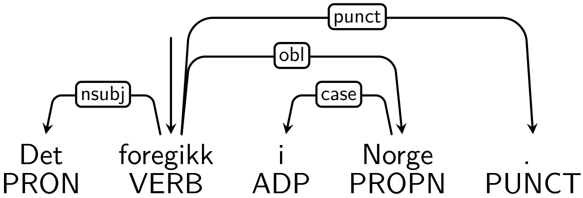

Next week

- Syntactic parsing
- Data-driven parsing
- Data-driven dependency parsing
- Evaluation