Dependency Grammar

NASSLLI short course on Dependency Parsing
Summer 2010

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Where are we going?

Monday	Dependency Grammar
Tuesday	Transition-Based Parsing
Wednesday	Accounting for Non-Projectivity
Thursday	Graph-Based Parsing
Friday	Practical Issues (Treebanks, Software, Conversions, ...)

A good book to cover this topic is: Kübler, McDonald, & Nivre (2009), *Dependency Parsing*

Dependency Grammar

Dependency Grammar (DG) is based on word-word relations

- Not a coherent grammatical framework: wide range of different kinds of DG
    - just as there are wide ranges of ”generative syntax”
- Different core ideas than phrase structure grammar
- We will base a lot of our discussion on [Mel’čuk(1988)]

Dependency grammar is important for those interested in CL:

- Increasing interest in dependency-based approaches to syntactic parsing in recent years (e.g., CoNLL-X shared task, 2006)

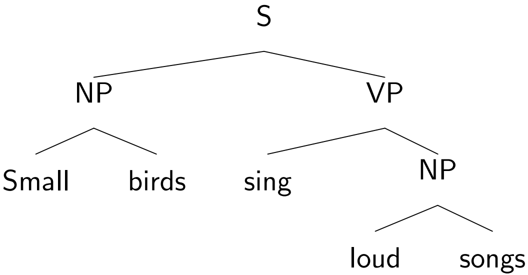
Dependency Syntax

- The basic idea:
  - Syntactic structure consists of lexical items, linked by binary asymmetric relations called dependencies.
- In the (translated) words of Lucien Tesnière [Tesnière(1959)]:
  - The sentence is an *organized whole*, the constituent elements of which are *words*. [1.2] Every word that belongs to a sentence ceases by itself to be isolated as in the dictionary. Between the word and its neighbors, the mind perceives *connections*, the totality of which forms the structure of the sentence. [1.3] The structural connections establish *dependency* relations between the words. Each connection in principle unites a *superior* term and an *inferior* term. [2.1] The superior term receives the name *governor*. The inferior term receives the name *subordinate*. Thus, in the sentence *Alfred parle* [. . .], *parle* is the governor and *Alfred* the subordinate. [2.2]

Overview: constituency

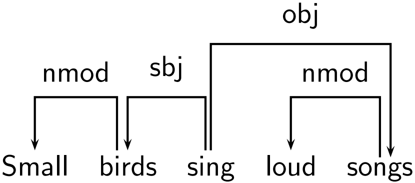
(1) Small birds sing loud songs

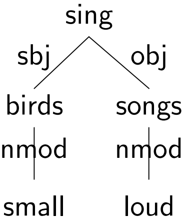
What you might be more used to seeing:



Overview: dependency

The corresponding dependency tree representations [Hudson(2000)]:





Constituency vs. Relations

- DG is based on relationships between words, i.e., **dependency relations**
  - A → 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
    - → Some variants of DG separate syntactic and semantic relations by representing different layers of dependency structures
  - 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

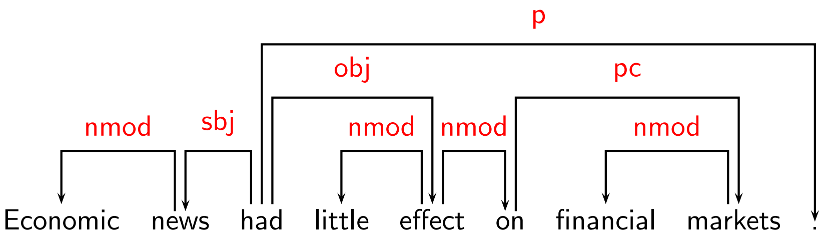
For the sentence *John loves Mary*, we have the relations:

- loves $\rightarrow_{\text{subj}}$ John
- loves $\rightarrow_{\text{obj}}$ Mary

Both *John* and *Mary* depend on *loves*, which makes *loves* 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.

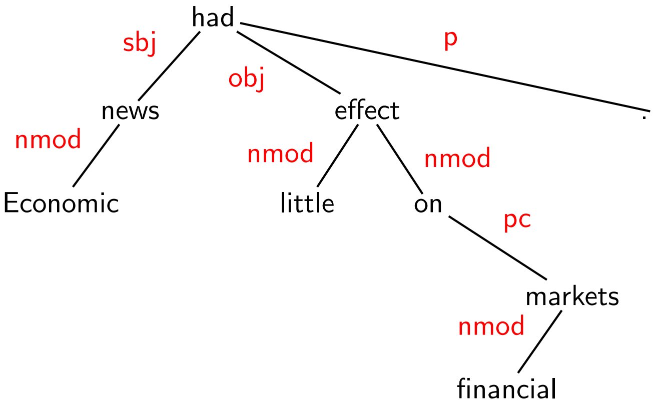
Dependency Structure



Terminology

Superior	**Inferior**
Head	Dependent
Governor	Modifier
Regent	Subordinate
⋮	⋮

Notational Variants



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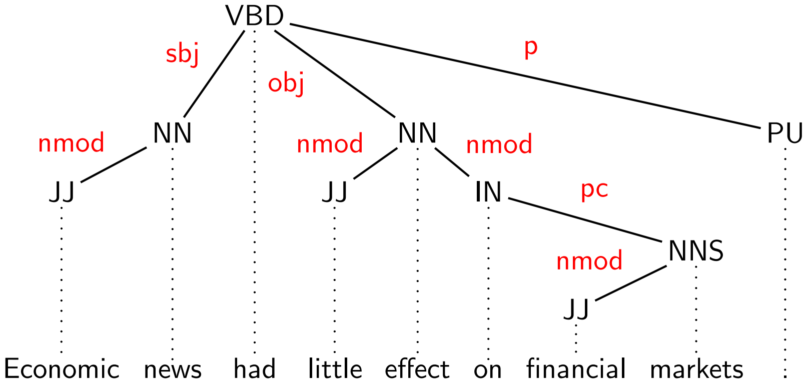

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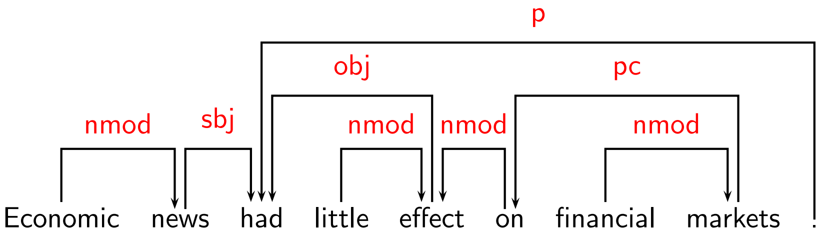

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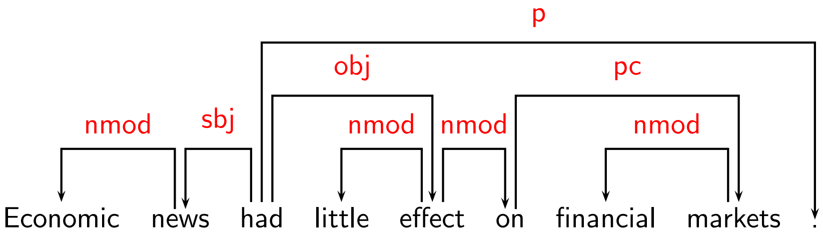
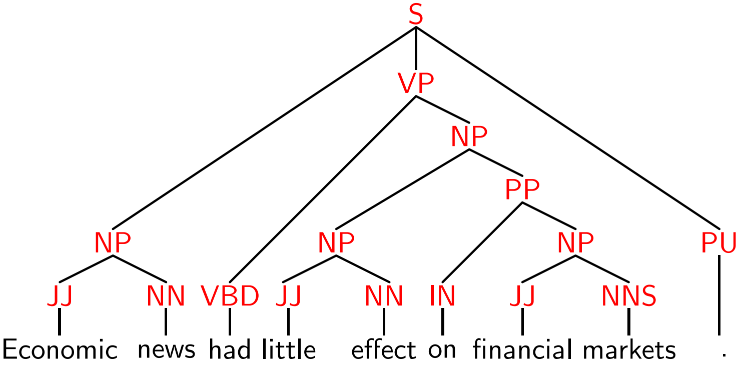


Phrase Structure



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).
- Hybrid representations may combine all elements.

Some Theoretical Frameworks

- Word Grammar (WG) [Hudson(1984), Hudson(1990)]
- Functional Generative Description (FGD) [Sgall et al.(1986)Sgall, Hajičová and Panevová]
- Dependency Unification Grammar (DUG) [Hellwig(1986), Hellwig(2003)]
- Meaning-Text Theory (MTT) [Mel'čuk(1988)]
- (Weighted) Constraint Dependency Grammar ([W]CDG) [Maruyama(1990), Harper and Helzerman(1995), Menzel and Schröder(1998), Schröder(2002)]
- Functional Dependency Grammar (FDG) [Tapanainen and Järvinen(1997), Järvinen and Tapanainen(1998)]
- Topological/Extensible Dependency Grammar ([T/X]DG) [Duchier and Debusmann(2001), Debusmann et al.(2004)Debusmann, Duchier and Kruijff]

Some Theoretical Issues

- Dependency structure sufficient as well as necessary?
- Mono-stratal or multi-stratal syntactic representations?
- What is the nature of lexical elements (nodes)?
  - Morphemes?
  - Word forms?
  - Multi-word units?
- What is the nature of dependency types (arc labels)?
  - Grammatical functions?
  - Semantic roles?
- What are the criteria for identifying heads and dependents?
- What are the formal properties of dependency structures?

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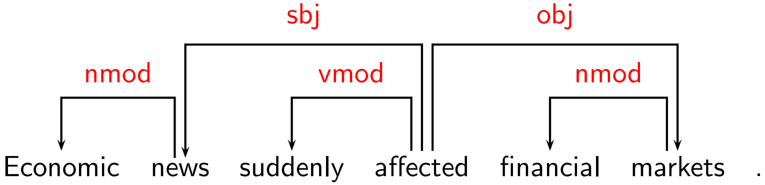
Criteria for Heads and Dependents

- Criteria for a syntactic relation between a head H and a dependent D in a construction C [Zwicky(1985), Hudson(1990)]:
  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. H selects D and determines whether D is obligatory.
  5. The form of D depends on H (agreement or government).
  6. The linear position of D is specified with reference to H.
- Issues:
  - Syntactic (and morphological) versus semantic criteria
  - Exocentric versus endocentric constructions

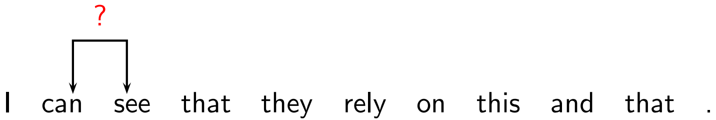
Some Clear Cases

Construction	Head	Dependent
Exocentric	Verb	Subject (sbj)
	Verb	Object (obj)
Endocentric	Verb	Adverbial (vmod)
	Noun	Attribute (nmod)



Some Tricky Cases

- Complex verb groups (auxiliary ↔ main verb)
- Subordinate clauses (complementizer ↔ verb)
- Coordination (coordinator ↔ conjuncts)
- Prepositional phrases (preposition ↔ nominal)
- Punctuation



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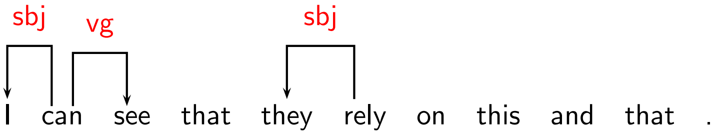

I can see that they rely on this and that .

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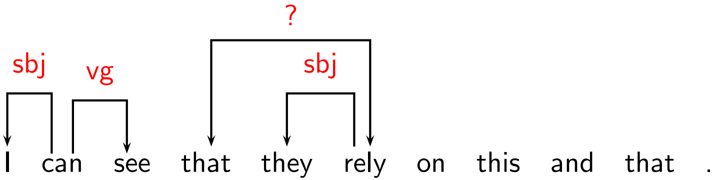

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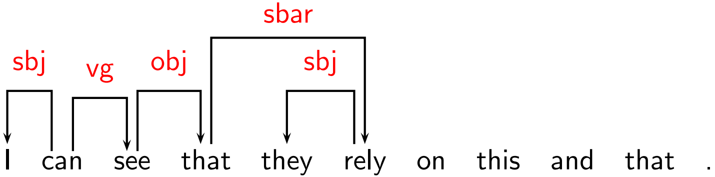

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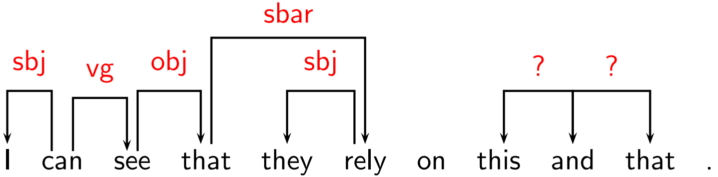

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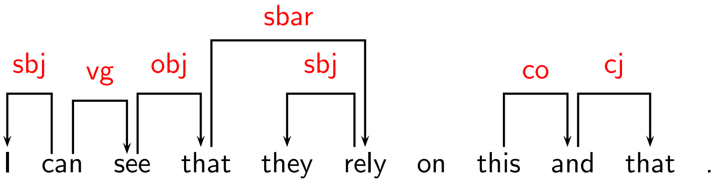

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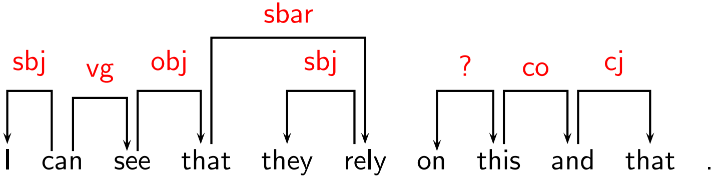

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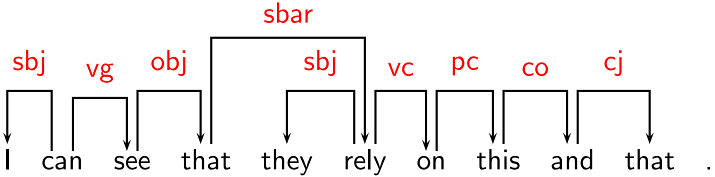

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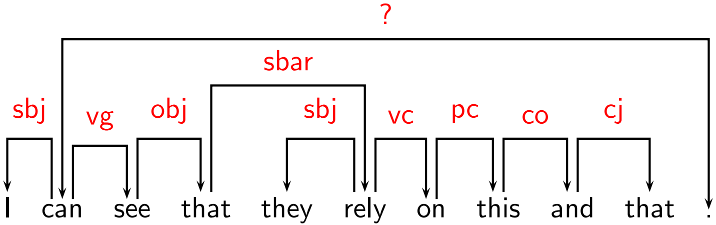

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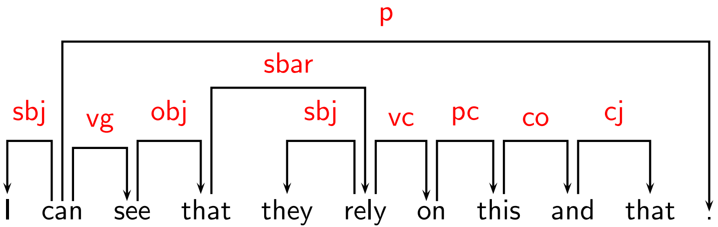
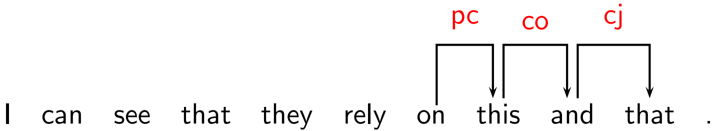
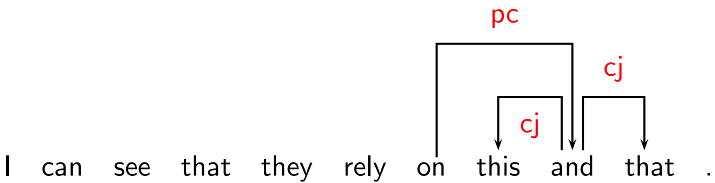


Coordination

Many different ways to capture coordination ...





... including allowing some degree of constituency

Valency and Grammaticality

An important concept in many variants of DG is that of **valency** = the ability of a word to take arguments

A lexicon might look like the following [Hajič et al.(2003)Hajič, Panevová, Urešová, Bémová, Kolářová and Pajas]:

	Slot$_1$	Slot$_2$	Slot$_3$
sink$_1$	ACT(nom)	PAT(acc)	
sink$_2$	PAT(nom)		
give	ACT(nom)	PAT(acc)	ADDR(dat)

To determine grammaticality (roughly) ...

1. Words have valency requirements that must be satisfied
2. Apply general rules to the valencies to see if a sentence is valid

Capturing Adjuncts and Complements

There are two main kinds of dependencies for A → B:

- Head-Complement: if A (the head) has a slot for B, then B is a complement
- Head-Adjunct: if B has a slot for A (the head), then B is an adjunct

B is dependent on A in either case, but the selector is different

- The adjunct/complement distinction is captured in the type of dependency relation and/or in the lexicon

Dependency Graphs

- A dependency structure can be defined as a directed graph G, consisting of
  - a set V of nodes ($V \subseteq \{w_0, w_1, ..., w_n\}$),
  - a set A of arcs (edges),
  - a linear precedence order $<$ on V (not in every theory)
- Labeled graphs:
  - Nodes in V are labeled with word forms (and annotation)
  - Arcs in A are labeled with dependency types from a label set R
    - $A \subseteq V \times R \times V$
    - Also: if $(w_i, r, w_j) \in A$, then $(w_i, r', w_j) \notin A$ for all $r' \neq r$
- Notational conventions ($i, j \in V$):
  - $i \rightarrow j \;\; \equiv \;\; (i, j) \in A$
  - $i \rightarrow^* j \;\; \equiv \;\; i = j \vee \exists k : i \rightarrow k, \; k \rightarrow^* j$

Dependency Graphs

A *well-formed dependency graph* $G = (V, A)$ ...

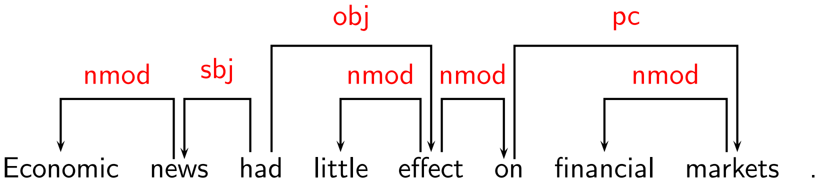
- is a dependency graph that is a directed tree originating out of node w_0
- has the spanning node set $V = V_S$ (i.e., covers all words in the sentence S)

e.g., *Economic news had little effect on financial markets .*

1. $G = (V, A)$
2. $V = V_S = \{$root, Economic, news, had, little, effect, on, financial, markets, .$\}$
3. $A = \{$(root, PRED, had), (had, SBJ, news), (had, OBJ, effect), (had, PU, .), (news, ATT, Economic), (effect, ATT, little), (effect, ATT, on), (on, PC, markets), (markets, ATT, financial)$\}$

Formal Conditions on Dependency Graphs

- Intuitions:
  - Syntactic structure is complete (Connectedness).
  - Syntactic structure is hierarchical (Acyclicity).
  - Every word has at most one syntactic head (Single-Head).
- Connectedness can be enforced by adding a special root node.



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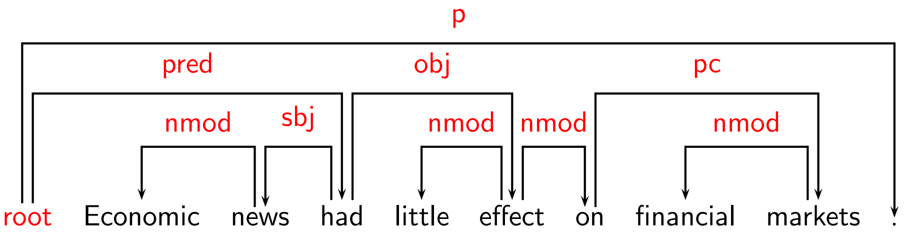


Formal Conditions on Dependency Graphs

- 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 $k \neq i$.
- G is projective:
  - If $i \rightarrow j$ then $i \rightarrow^* k$, for any k such that $i < k < j$ or $j < k < i$.

Projectivity

Projectivity (or, less commonly, **adjacency** [Hudson(1990)])

- An arc $(w_i, r, w_j) \in A$ is *projective* iff $w_i \longrightarrow^* w_k$ for all:
  - $i < k < j$ when $i < j$
  - $j < k < i$ when $j < i$

(2) with great difficulty

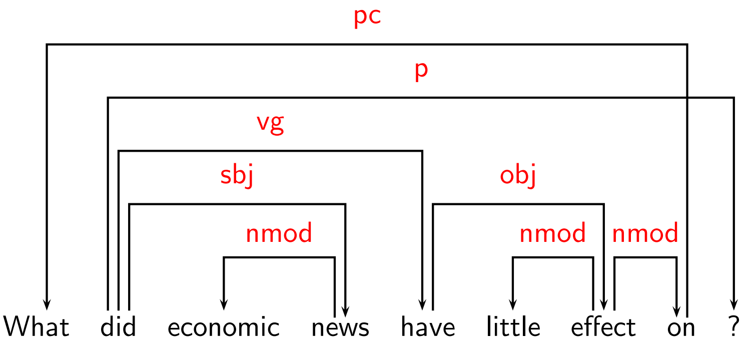
(3) *great with difficulty

- with → difficulty
- difficulty → great

**great with difficulty* may be 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.



Properties of Projective Trees

- *Planarity*: it is possible to graphically configure all the arcs of the tree in the space above the sentence without any arcs crossing
  e.g., drawing the tree for *A hearing is scheduled on the issue today* will result in non-planarity
- *Nestedness*: for all the nodes $w_i \in V$, the set of words $\{w_j | w_i \rightarrow^* w_j\}$ is a contiguous subsequence of the sentence S

Layers of dependencies

Before we move on to parsing, consider the fact that dependencies may capture different layers of information

- [Mel’čuk(1988)] allows for different dependency layers

It looks like a subject depends on the verb, but the form of the verb depends on the subject (mutual dependence):

(4) a. The child is playing.

b. The children are playing.

One solution:

- Dependence of *child*/*children* on the verb is syntactic
- Dependence of the verb(form) on the subject is morphological

Double dependencies

Likewise, here it seems that *clean* depends both on the verb *wash* and on the noun *dish*

(5) Wash the dish *clean*.

One solution:

- Dependence of *clean* on *wash* is syntactic (cf. case)
- Dependence of *clean* on *dish* is semantic (cf. gender)

(6) My našli zal pust-ym
We found the hall$_{masc}$ empty$_{masc.sg.inst}$

Double dependencies (2)

Hudson's Word Grammar [Hudson(2004)] explicitly allows for **structure-sharing**, explicitly violating the single-head constraint:

- wash → clean
- dish → clean

NB: Hudson also uses this to account for non-projectivity

Other approaches (e.g., annotation efforts for learner language) use multiple layers of dependencies for different types of information [Dickinson and Ragheb(2009)]

Relation to phrase structure

What is the relation between DG and PSG?

- If a PS tree has heads marked, then you can derive the dependencies
- Likewise, a DG tree can be converted into a PS tree by grouping a word with its dependents
    - To determine the constituents (binary-branching, flat) and phrase categorization, one needs features and arc labels [Rambow(2010)]

See [Rambow(2010)] for more discussion

Advantages and Disadvantages of DG

Advantages:

- Close connection to semantic representation
- Easier to capture some typological regularities
- Vast & expanding body of computational work on dependency parsing

Disadvantages:

- No constituents makes analyzing coordination difficult
- No distinction between modifying a constituent vs. an individual word
- May be harder to capture things like, e.g., subject-object asymmetries

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