Natural Language Processing (CSE 490U): Dependency Structure

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Dependencies

Informally, you can think of **dependency** structures as a transformation of phrase-structures that

- maintains the word-to-word relationships induced by lexicalization,
- adds labels to them, and
- eliminates the phrase categories.

There are also linguistic theories built on dependencies (**??**), as well as treebanks corresponding to those.

- Free(r)-word order languages (e.g., Czech)

Dependency Tree: Definition

Let $\boldsymbol{x} = \langle x_1, \ldots, x_n \rangle$ be a sentence. Add a special $\textsc{root}$ symbol as "x_0."

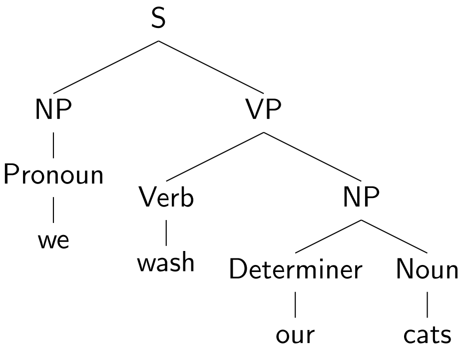
A dependency tree consists of a set of tuples $\langle p, c, \ell \rangle$, where

- $p \in \{0, \ldots, n\}$ is the index of a parent
- $c \in \{1, \ldots, n\}$ is the index of a child
- $\ell \in \mathcal{L}$ is a label

Different annotation schemes define different label sets $\mathcal{L}$, and different constraints on the set of tuples. Most commonly:

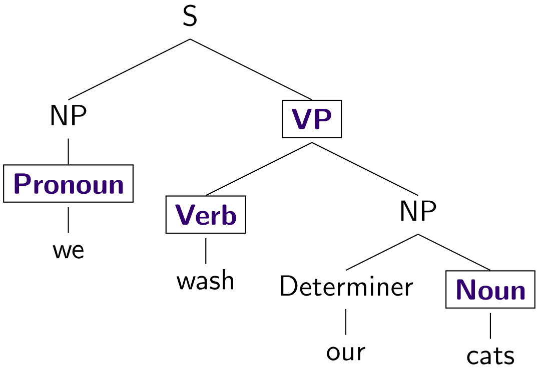
- The tuple is represented as a directed edge from x_p to x_c with label ℓ.
- The directed edges form an arborescence (directed tree) with x_0 as the root.

Example



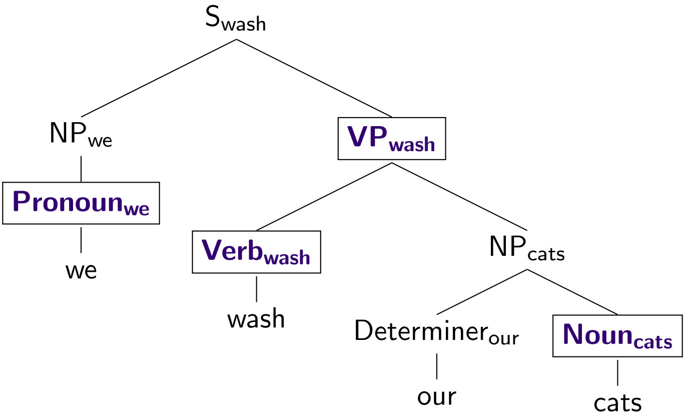
Phrase-structure tree.

Example



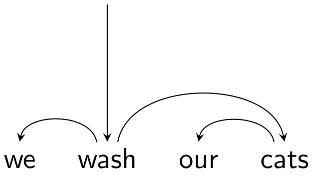
Phrase-structure tree with heads.

Example



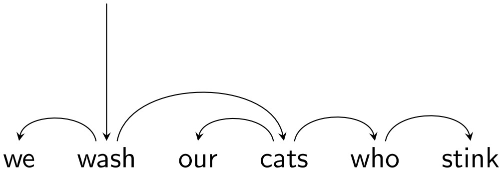
Phrase-structure tree with heads, lexicalized.

Example

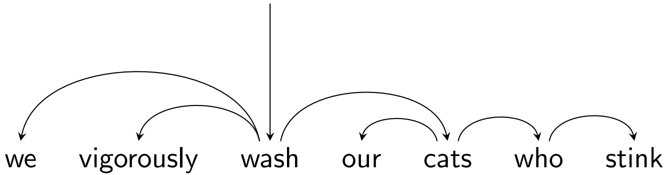


"Bare bones" dependency tree.

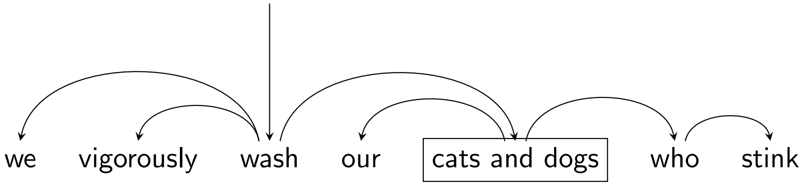
Example



Example

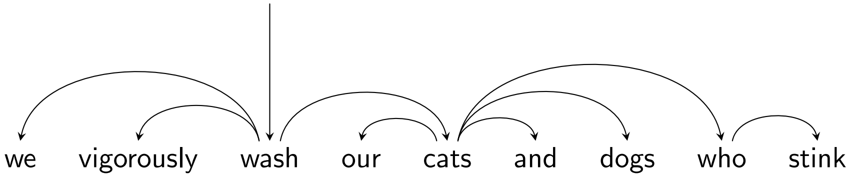


Example



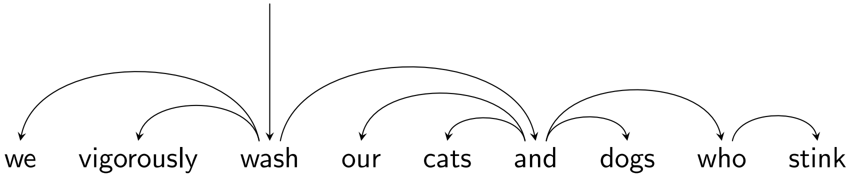
The bugbear of dependency syntax: coordination structures.

Example



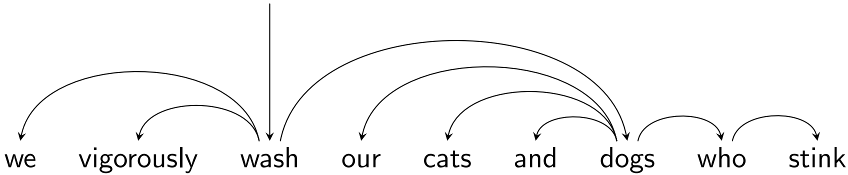
Make the first conjunct the head?

Example



Make the coordinating conjunction the head?

Example



Make the second conjunct the head?

Dependency Schemes

- Transform the treebank: define "head rules" that can select the head child of any node in a phrase-structure tree and label the dependencies.
- More powerful, less local rule sets, possibly collapsing some words into arc labels.
  - Stanford dependencies are a popular example (**?**).
- Direct annotation.

Dependencies and Grammar

Context-free grammars can be used to encode dependency structures.

For every head word and constellation of dependent children:

$$\mathrm{N}_{\text{head}} \quad \rightarrow \quad \mathrm{N}_{\text{leftmost-sibling}} \ldots \mathrm{N}_{\text{head}} \ldots \mathrm{N}_{\text{rightmost-sibling}}$$

And for every head word: $\mathrm{N}_{\text{head}} \rightarrow$ head

A **bilexical** dependency grammar binarizes the dependents, generating only one per rule, usually "outward" from the head.

Such a grammar can produce only **projective** trees, which are (informally) trees in which the arcs don't cross.

Nonprojective Example