UPPSALA
UNIVERSITET

Dependency grammar and dependency parsing

Syntactic analysis (5LN455)

2012-12-11

Joakim Nivre
Department of Linguistics and Philology

Based on slides by Marco Kuhlmann

UPPSALA
UNIVERSITET

Dependency grammar

UPPSALA
UNIVERSITET

Dependency grammar

- The term ‘dependency grammar’
  does not refer to a specific grammar formalism.
- Rather, it refers to a specific way
  to describe the syntactic structure of a sentence.

The notion of dependency

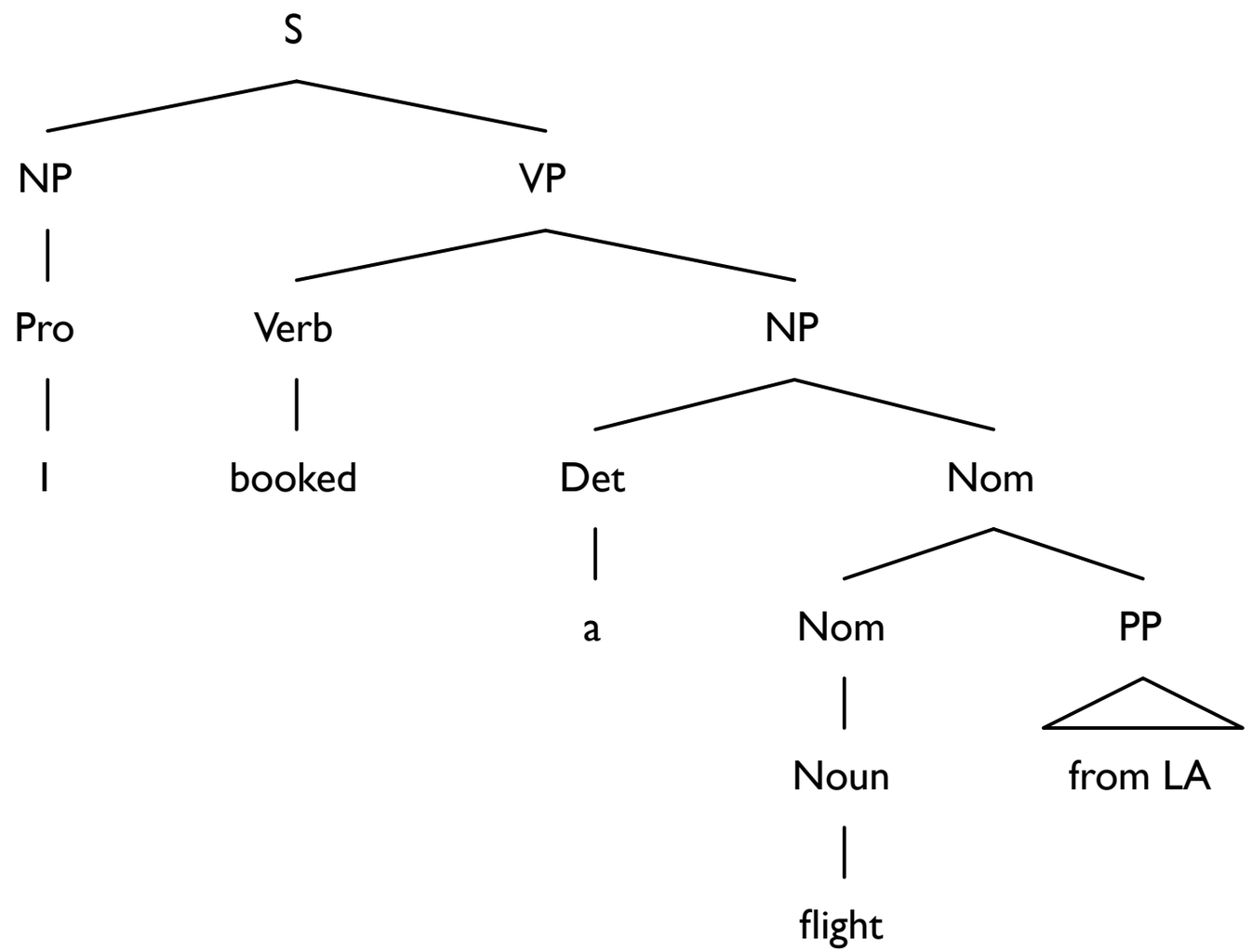
- The basic observation behind constituency is that groups of words may act as one unit.

  Example: noun phrase, prepositional phrase

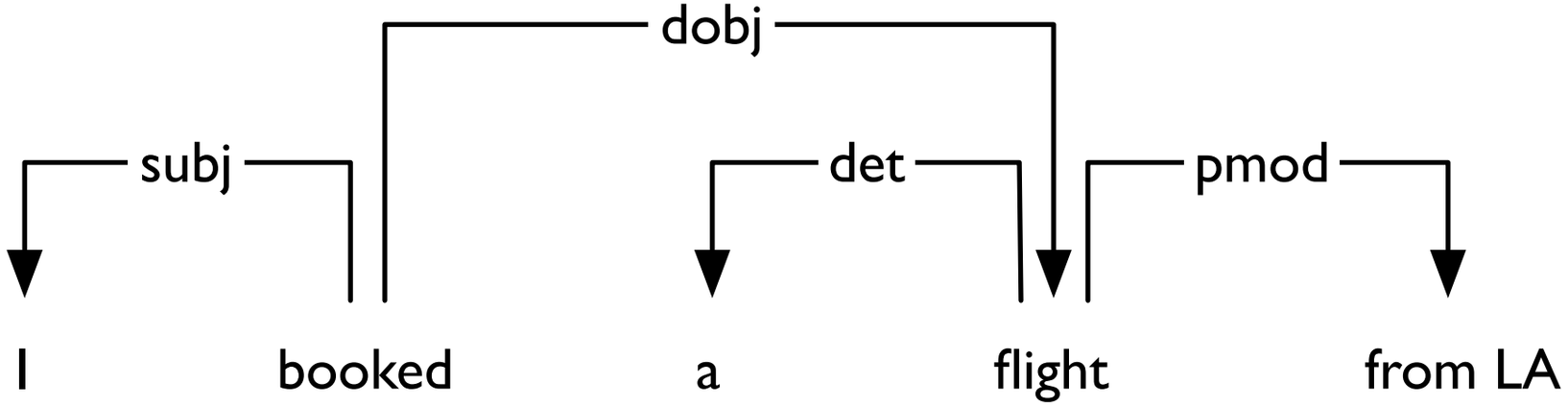
- The basic observation behind dependency is that words have grammatical functions with respect to other words in the sentence.

  Example: subject, modifier

Phrase structure trees



Dependency trees



- In an arc $h \rightarrow d$, the word *h* is called the head, and the word *d* is called the dependent.
- The arcs form a rooted tree.

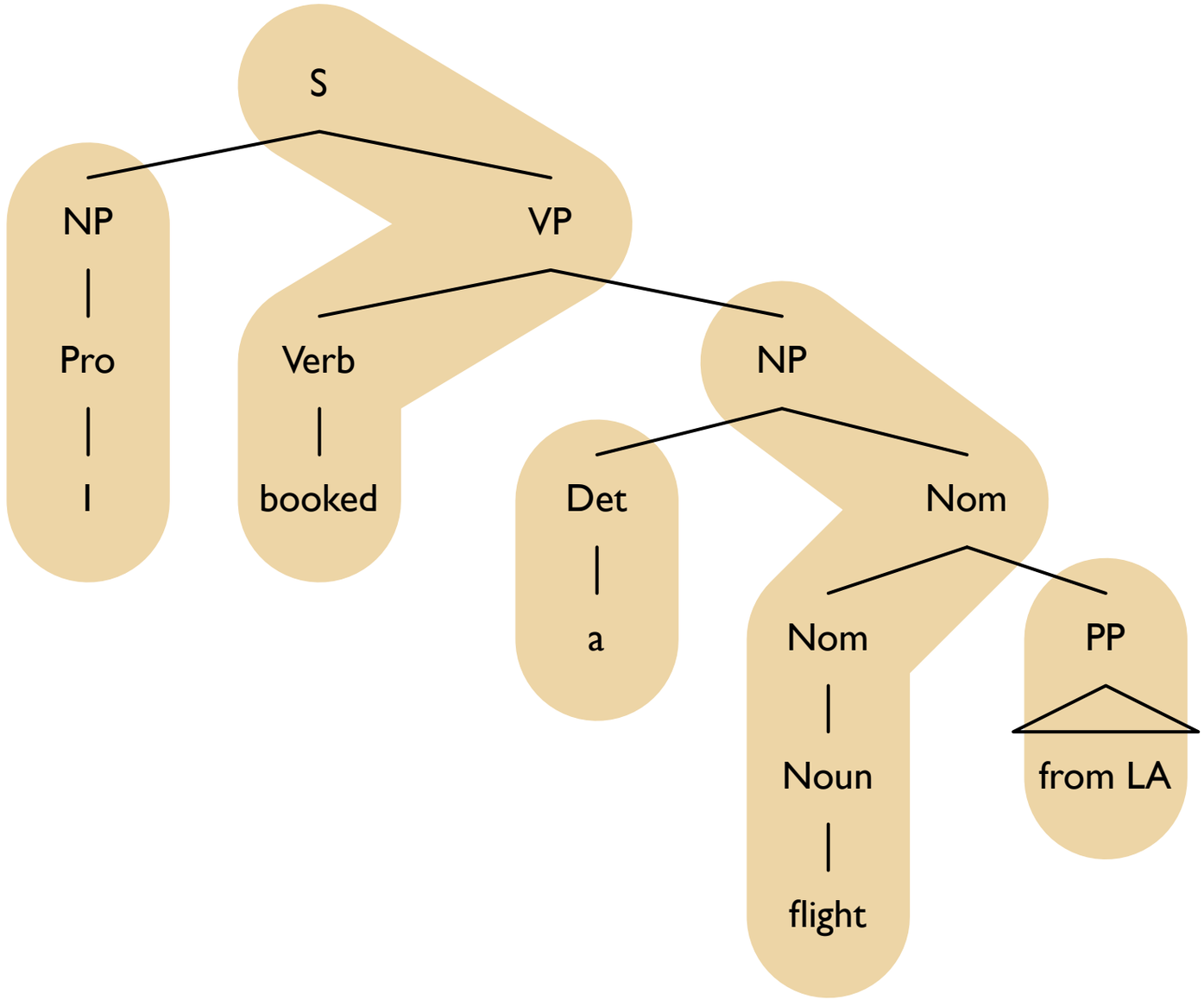
Heads in phrase structure grammar

- In phrase structure grammar,
  ideas from dependency grammar
  can be found in the notion of heads.

- **Roughly speaking, the head of a phrase**
  is the most important word of the phrase:
  the word that determines the phrase function.

  Examples: noun in a noun phrase,
  preposition in a prepositional phrase

Heads in phrase structure grammar



The history of dependency grammar

- The notion of dependency can be found in some of the earliest formal grammars.

- Modern dependency grammar is attributed to Lucien Tesnière (1893–1954).
- Recent years have seen a revived interest in dependency-based description of natural language syntax.

Head-dependency relations

- Verb + arguments
  - Subject: *Sandy writes poetry*
  - Object: *Sandy writes poetry*
- Noun + modifiers
  - Determiner: *the little black cat*
  - Adjectival modifier: *the little black cat*

Some tricky cases

- Coordination
  - *Sandy and Kim write poetry*
- Verb groups
  - *Sandy could have written poetry*
- Prepositional phrases
  - *Sandy went to London*

Examples

- What dependency relations do you find in the following sentences?

Her mother sent her a letter.

Economic news had little effect on financial markets.

Linguistic resources

- Descriptive dependency grammars exist for some natural languages.
- Dependency treebanks exist for a wide range of natural languages.
- These treebanks can be used to train accurate and efficient dependency parsers.

UPPSALA UNIVERSITET

Overview

- Arc-factored dependency parsing

  Collins' algorithm

  Eisner's algorithm

- Transition-based dependency parsing

  The arc-standard algorithm

- Evaluation of dependency parsers

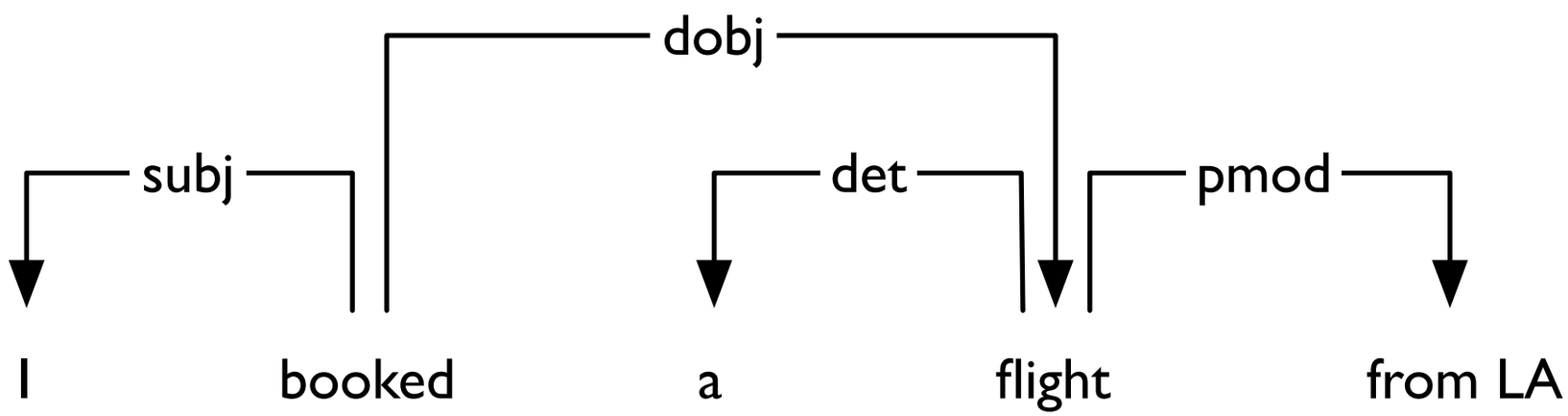
UPPSALA
UNIVERSITET

Arc-factored dependency parsing

UPPSALA
UNIVERSITET

Ambiguity

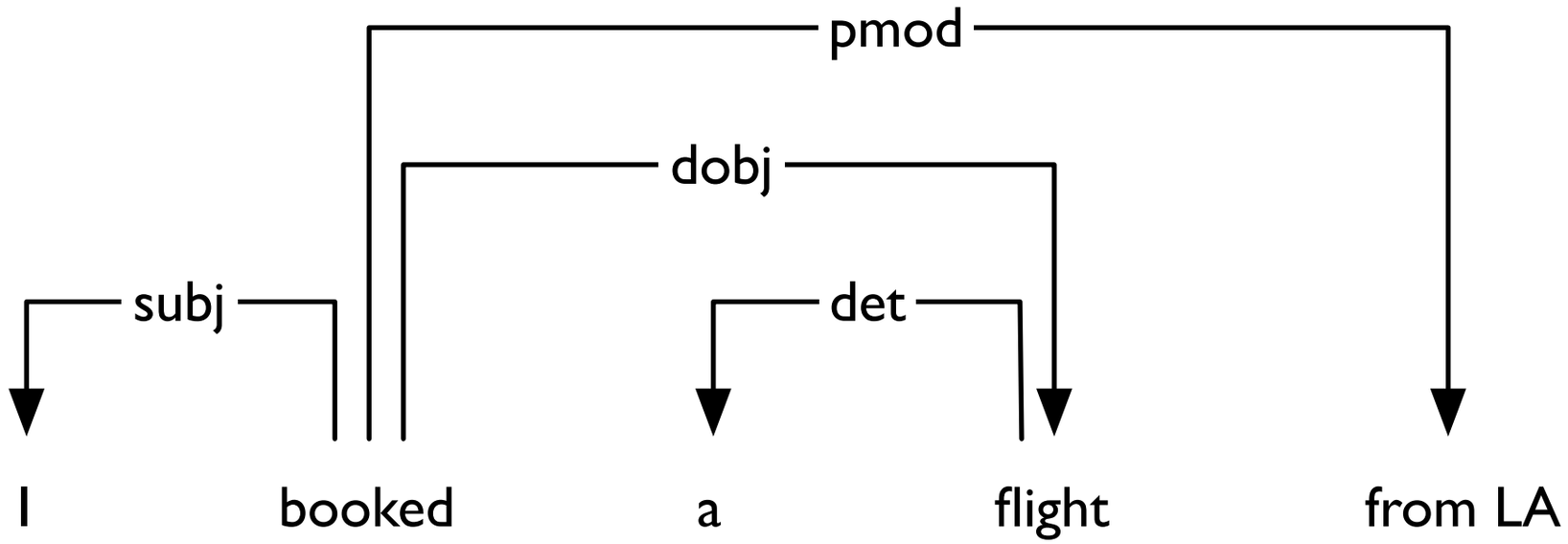
Just like phrase structure parsing,
dependency parsing has to deal with ambiguity.



UPPSALA
UNIVERSITET

Ambiguity

Just like phrase structure parsing,
dependency parsing has to deal with ambiguity.



UPPSALA
UNIVERSITET

Disambiguation

- We need to disambiguate between alternative analyses.
- We develop mechanisms for scoring dependency trees, and disambiguate by choosing a dependency tree with the highest score.

UPPSALA UNIVERSITET

Scoring models and parsing algorithms

Distinguish two aspects:

- Scoring model:

  How do we want to score dependency trees?

- Parsing algorithm:

  How do we compute a highest-scoring dependency tree under the given scoring model?

UPPSALA UNIVERSITET

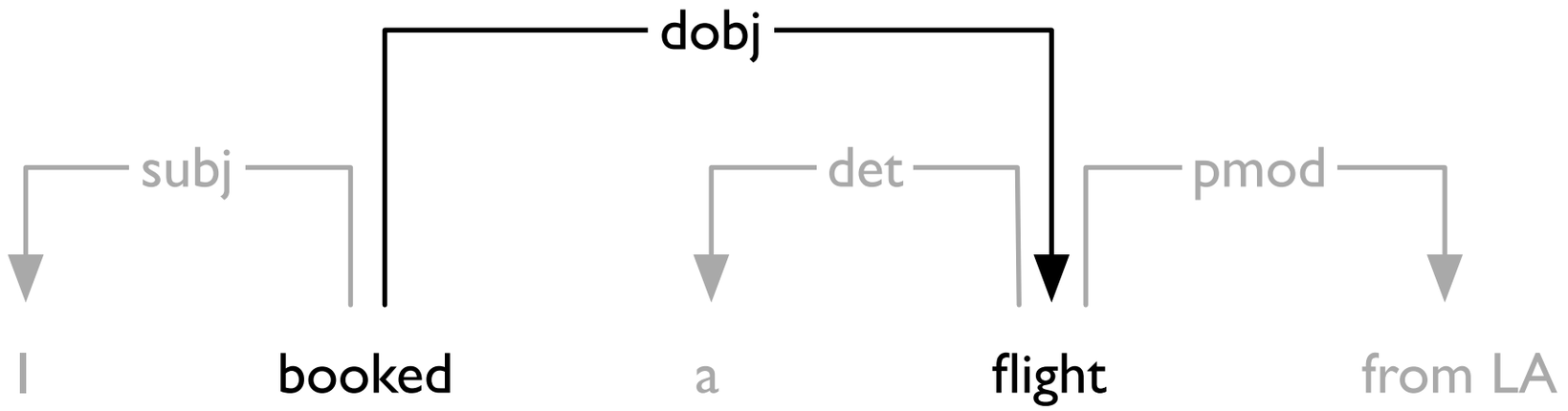
The arc-factored model

- Split the dependency tree *t* into parts $p_1, ..., p_n$, score each of the parts individually, and combine the score into a simple sum.

$$\text{score}(t) = \text{score}(p_1) + \ldots + \text{score}(p_n)$$

- The simplest scoring model is the arc-factored model, where the scored parts are the arcs of the tree.

Features



- To score an arc, we define features that are likely to be relevant in the context of parsing.
- We represent an arc by its feature vector.

Examples of features

- ‘The head is a verb.’
- ‘The dependent is a noun.’
- ‘The head is a verb
  and the dependent is a noun.’
- ‘The head is a verb
  and the predecessor of the head is a pronoun.’
- ‘The arc goes from left to right.’
- ‘The arc has length 2.’

Feature vectors

Implementation of feature vectors

- We assign each feature a unique number.
- For each arc, we collect the numbers of those features that apply to that arc.
- The feature vector of the arc is the list of those numbers.

  Example: [1, 2, 42, 313, 1977, 2008, 2010]

Feature weights

- Arc-factored dependency parsers require a training phase.
- During training, our goal is to assign, to each feature f_i, a feature weight w_i.
- Intuitively, the weight w_i quantifies the effect of the feature f_i on the likelihood of the arc.

How likely is is that we will see
an arc with this feature in a useful dependency tree?

Feature weights

We define the score of an arc $h \rightarrow d$ as the weighted sum of all features of that arc:

$$\text{score}(h \rightarrow d) = f_1 w_1 + \ldots + f_n w_n$$

UPPSALA UNIVERSITET

Training using structured prediction

- Take a sentence *w* and a gold-standard dependency tree *g* for *w*.
- Compute the highest-scoring dependency tree under the current weights; call it *p*.
- Increase the weights of all features that are in *g* but not in *p*.
- Decrease the weights of all features that are in *p* but not in *g*.

Training using structured prediction

- Training involves repeatedly parsing (treebank) sentences and refining the weights.
- Hence, training presupposes an efficient parsing algorithm.
- Next time we will look at parsing algorithms for the arc-factored model.

UPPSALA UNIVERSITET

Higher-order models

- The arc-factored model is a first-order model, because scored subgraphs consist of a single arc.
- An nth-order model scores subgraphs consisting of (at most) n arcs.
  - Second-order: siblings, grand-parents
  - Third-order: tri-siblings, grand-siblings
- Higher-order models capture more linguistic structure and give higher parsing accuracy.

Summary

- The term ‘arc-factored dependency parsing’ refers to dependency parsers that score a dependency tree by scoring its arcs.
- Arcs are scored by defining features and assigning weights to these features.
- The resulting parsers can be trained using structured prediction.
- More powerful scoring models exist.