Introduction to dependency parsing

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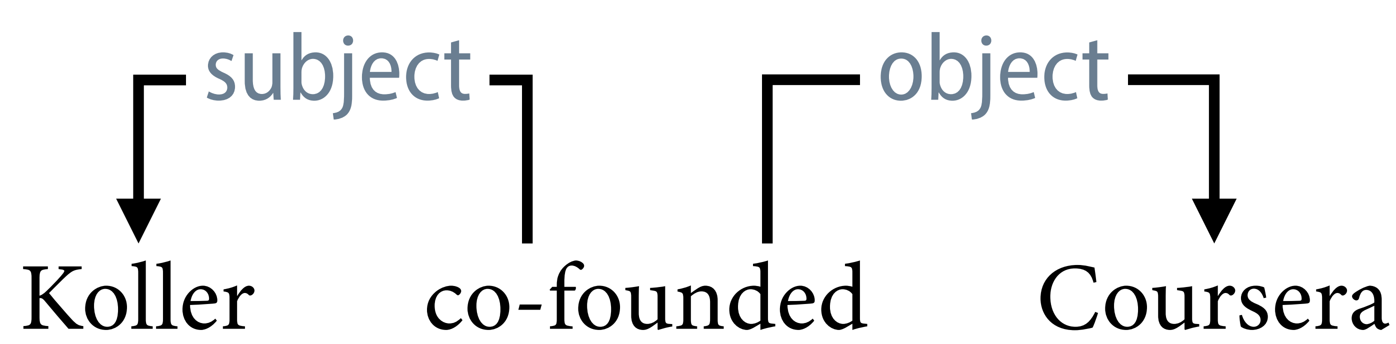
Dependency parsing

- **Syntactic parsing** is the task of mapping a sentence to a formal representation of its syntactic structure.
- We focus on representations in the form of **dependency trees**.



- A syntactic dependency is an asymmetric relation between a **head** and a **dependent**.

universaldependencies.org

Current UD Languages

Information about language families (and genera for families with multiple branches) is mostly taken from WALS Online (IE = Indo-European).

Afrikaans	1	49K	IE, Germanic
Akkadian	1	1K	Afro-Asiatic, Semitic
Albanian	1	<1K	IE, Albanian
Amharic	1	10K	Afro-Asiatic, Semitic
Ancient Greek	2	416K	IE, Greek
Arabic	3	1,042K	Afro-Asiatic, Semitic
Armenian	1	52K	IE, Armenian
Assyrian	1	<1K	Afro-Asiatic, Semitic
Bambara	1	13K	Mande
Basque	1	121K	Basque
Belarusian	1	13K	IE, Slavic
Bhojpuri	2	4K	IE, Indic
Breton	1	10K	IE, Celtic
Bulgarian	1	156K	IE, Slavic
Buryat	1	10K	Mongolic
Cantonese	1	13K	Sino-Tibetan
Catalan	1	531K	IE, Romance
Chinese	5	285K	Sino-Tibetan
Classical Chinese	1	74K	Sino-Tibetan
Coptic	1	40K	Afro-Asiatic, Egyptian
Croatian	1	199K	IE, Slavic
Czech	5	2,222K	IE, Slavic
Danish	2	100K	IE, Germanic
Dutch	2	306K	IE, Germanic
English	9	620K	IE, Germanic
Erzya	1	15K	Uralic, Mordvin
Estonian	2	465K	Uralic, Finnic
Faroese	1	10K	IE, Germanic
Finnish	3	377K	Uralic, Finnic
French	8	1,157K	IE, Romance
Galician	2	164K	IE, Romance
German	4	3,753K	IE, Germanic
Gothic	1	55K	IE, Germanic
Greek	1	63K	IE, Greek
Hebrew	1	161K	Afro-Asiatic, Semitic

Dependency trees

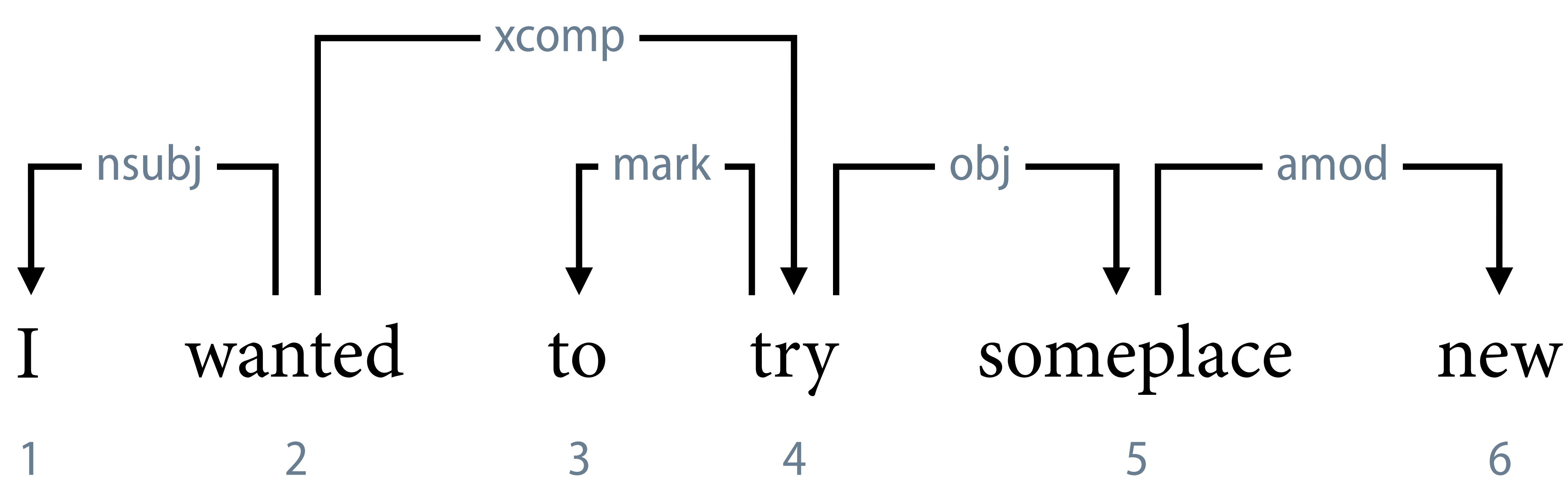
- A **dependency tree** for a sentence x is a digraph $G = (V, A)$ where $V = \{1, \ldots, |x|\}$ and where there exists a $r \in V$ such that every $v \in V$ is reachable from r via exactly one directed path.

- The vertex r is called the **root** of G.

- The arcs of a dependency tree may be labelled to indicate the type of the syntactic relation that holds between the two elements.

  Universal Dependencies v2 uses 37 universal syntactic relations (list).

Representation of dependency trees



word position	1	2	3	4	5	6
head position	2	0	4	2	4	5
dependency relation	nsubj	root	mark	xcomp	obj	amod

Two parsing paradigms

- **Graph-based dependency parsing**

  Cast parsing as a combinatorial optimisation problem over a (possibly restricted) set of dependency trees.

- **Transition-based dependency parsing**

  Cast parsing as a sequence of local classification problems: at each point in time, predict one of several parser actions.

Graph-based dependency parsing

- Given a sentence x and a set $Y(x)$ of candidate dependency trees for x, we want to find a highest-scoring tree $\hat{y} \in Y(x)$:

$$\hat{y} = \arg\max_{y \in Y(x)} \text{score}(x, y)$$

- The computational complexity of this problem depends on the choice of the set $Y(x)$ and the scoring function.

The arc-factored model

- Under the **arc-factored model**, the score of a dependency tree is expressed as the sum of the scores of its arcs:

$$\hat{y} = \underset{y \in Y(x)}{\arg\max} \sum_{a \in y} \text{score}(x, a)$$

head–dependent arc

- The score of a single arc can be computed by means of a neural network that receives the head and the dependent as input.

for example, a simple linear layer: $\text{score}(x, h \rightarrow d) = [\boldsymbol{h} \,;\, \boldsymbol{d}] \cdot \boldsymbol{w} + b$

Computational complexity

- Under the arc-factored model, the highest-scoring dependency tree can be found in $O(n^3)$ time (n = sentence length).

  Chu–Liu/Edmonds algorithm; McDonald et al. (2005)

- Even seemingly minor extensions of the arc-factored model entail intractable parsing.

  McDonald and Satta (2007)

- For some of these extensions, polynomial-time parsing is possible for restricted classes of dependency trees.

Transition-based dependency parsing

- We cast parsing as a sequence of local classification problems such that solving these problems builds a dependency tree.
- In most approaches, the number of classifications required for this is linear in the length of the sentence.

Transition-based dependency parsing

- The parser starts in the **initial configuration**.

  empty dependency tree

- It then calls a classifier, which predicts the **transition** that the parser should make to move to a next configuration.

  extend the partial dependency tree

- This process is repeated until the parser reaches a **terminal configuration**.

  complete dependency tree

Training transition-based dependency parsers

- To train a transition-based dependency parser, we need a treebank with gold-standard dependency trees.
- In addition to that, we need an algorithm that tells us the gold-standard transition sequence for a tree in that treebank.
- Such an algorithm is conventionally called an **oracle**.

Comparison of the two parsing paradigms

Graph-based parsing	**Transition-based parsing**
slow (in practice, cubic in the length of the sentence)	fast (quasi-linear in the length of the sentence)
restricted feature models (in practice, arc-factored)	rich feature models defined on configurations
features and weights directly defined on target structures	indirection – features and weights defined on transitions