

# Transition-based dependency parsing with topological fields

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# Background

Transition-based dependency parsing using a feed-forward neural network (Stenetorp, 2013, Chen and Manning, 2014):

- ▶ **Low time/memory complexity:** linear time in most transition-systems plus deterministic transition choice.
- ▶ **Little feature engineering:** the transition classifier uses concatenated embeddings of parts of the parser state as input.
- ▶ **High lexical coverage:** word embeddings extend implicitly learned selectional preferences beyond tokens in the training data.

# Problem

However, lack of global information:

- ▶ **Local features:** Only a small portion of the parser state is typically 'featurized'.
- ▶ **Lack of information:** Due to deterministic left-right processing, some features are not available to inform early attachments.

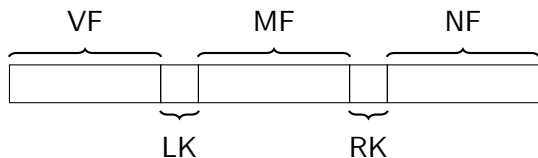
## Proposed solutions

- ▶ Retain a certain amount of competition between alternative analyses using a globally optimized model with beam search (Zhang and Clark, 2008).
- ▶ Featurize the complete parsing state by using recurrent neural networks (Dyer et al., 2015).

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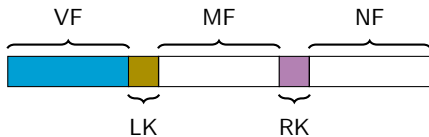
- ▶ Retain a certain amount of competition between alternative analyses using a globally optimized model with beam search (Zhang and Clark, 2008).
- ▶ Featurize the complete parsing state by using recurrent neural networks (Dyer et al., 2015).
- ▶ Can we find a linguistically-motivated alternative for parsing German?

# Topological field model of German



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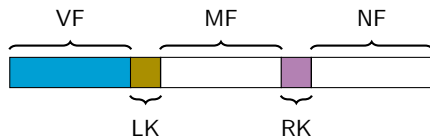
**Declarative clause with auxiliary/modal verb:**



- Finite verb
- Verb cluster
- Constituent required
- Constituent absent
- Optional

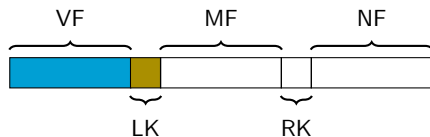
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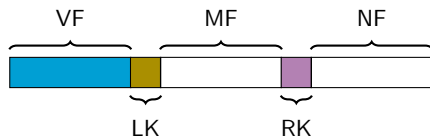
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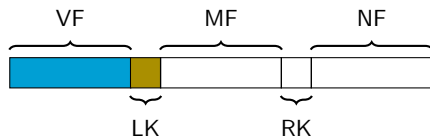
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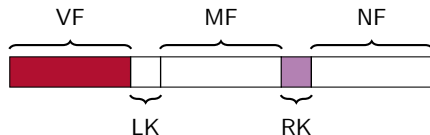


- Finite verb
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**Declarative clause without auxiliary/modal verb:**



**Verb-final subordinate clause:**



# Example

	<b>VF</b>	<b>LK</b>	<b>MF</b>	<b>RK</b>	<b>NF</b>
MC:	Gestern Yesterday	hat has	er häufiger he more-often	angerufen called	als heute than today
MC:	Er He	ruft calls	häufig frequently	an up	
SC:		der who	noch häufiger more often	anruft calls	als er than him

# Regularities in fields

Topological fields:

- ▶ Impose **restrictions**. For instance:
  - ▶ Only one constituent is typically allowed in the VF.
  - ▶ Multiple constituents are allowed in the MF and NF.
- ▶ Can be used to state **ordering preferences**.

# Topicalization

- ▶ German has a relatively free word order.
- ▶ Constituents with different grammatical roles can be topicalized.
- ▶ Leads to ambiguity between noun phrases:
  - ▶ Subject  $\leftrightarrow$  Direct object
  - ▶ Subject  $\leftrightarrow$  Predicative complement

# VF ambiguity

## Direct object ambiguity

- (1) [ die Tänzerin ]<sub>su</sub> versteht [ die Sprache der Bewegung ]<sub>obj</sub>  
the dancer understands the language of(-the) movement
- (2) [ die Tänzerin ]<sub>obj</sub> versteht [ die Sprache der Bewegung ]<sub>su</sub>  
the dancer understands the language of(-the) movement

## Predicative complement ambiguity

- (3) [ die Bayern ]<sub>su</sub> waren gestern [ ein Vorbild ]<sub>pred</sub>  
the Bavarians were yesterday a role-model
- (4) [ die Bayern ]<sub>pred</sub> waren gestern [ ein Vorbild ]<sub>su</sub>  
the Bavarians were yesterday a role-model

# Topicalization

Five most frequent relations from LK or RK to VF:

<b>Relation</b>	<b>%</b>
Subject	56.97
Prepositional phrase	18.54
Adverb	13.46
Direct object	4.17
Predicative complement	2.23

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If an NP populates the VF, its head should be attached as a subject, unless there is overwhelming evidence to the contrary.

## Separable verb prefixes

- ▶ Verbs in German can have separable prefixes.
- ▶ Complicating factor in parsing: prefixes are often also valid words by themselves:

(5) Sie bindet das Pferd [ fest ]<sub>SVP</sub> .  
She ties the horse tight .

(6) Das Buch ist [ fest ]<sub>ADV</sub> gebunden .  
The book is tightly bound .



## Separable verb prefixes

- ▶ A separated verb prefix is virtually always in the RK with its head in the LK:

<b>Dependency label</b>	<b>Head</b>	<b>Dep</b>	<b>%</b>
Separated verb prefix	LK	RK	99.95
	RK	RK	00.05

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	RK	RK	00.05

- ▶ Dependency relations from LK to RK:

<b>Dependency label</b>	<b>%</b>
Auxiliary verb	74.99
Separated verb prefix	20.16
Object infinitive	2.77
Conjunct	1.09
Adverb	0.85

# Field prediction as sequence labeling

## Motivation for LSTM:

- (7) Die neue Strecke wird , wie geplant , jetzt begrünt .  
The new stretch is , as planned , now being-greened .

## Motivation for bidirectional LSTM:

- (8) [die Siegerin]<sub>VF</sub> wurde disqualifiziert  
the winner was disqualified
- (9) [die Siegerin]<sub>MF</sub> zu disqualifizieren  
the winner to disqualify

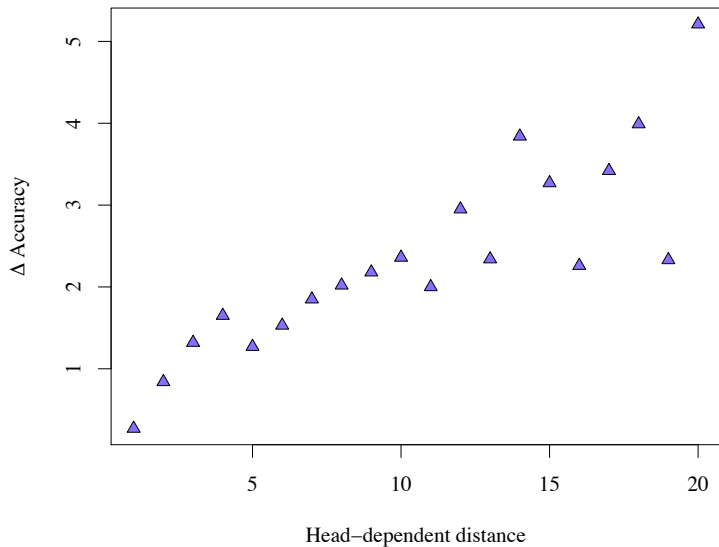
## Results dependency parsing

- ▶ Topological fields encoded using one-hot vectors as additional inputs.

<b>Parser</b>	<b>LAS</b>	<b>UAS</b>
De Kok 2015	89.49	91.88
Neural net + TFs	90.00	92.36
Neural net + gold TFs	90.42	92.76

- ▶ For more details on the model and evaluation, see the paper.

# LAS improvement by dependency length



# Wrap-up

## Conclusions

- ▶ Topological fields can be used to account for regularities in word order across different clause types of German.
- ▶ Access to topological fields can improve transition-based dependency parsing by providing more global information.

## Outlook

- ▶ Do models that featurize the full parser state (e.g. Dyer, et al. 2015) capture the same regularities?
- ▶ Explore similar ordering constraints/preferences for other languages:
  - ▶ The topological field model had been used to describe clause structure in other Germanic languages (e.g. Dutch, Haesery, et al., 1997 and Zwart, 2014).
  - ▶ Similar linear precedence constraints have been found for other languages (e.g. Slavic, Penn 1998).

Thank you!

## Results token field prediction

- ▶ Model input: concatenation of token and tag embeddings.
- ▶ Data from TüBa-D/Z r9, with field nodes projected on tokens.

<b>Parser</b>	<b>Accuracy (%)</b>
LSTM + LSTM	93.33
Bidirectional LSTM + LSTM	97.24



## Dependency relations with highest $\Delta$ LAS

<b>Dependency label</b>	<b>LAS <math>\Delta</math></b>
Coordinating conjunction (clausal)	11.48
Parenthesis	8.31
Dependent clause	3.49
Conjunct	3.38
Sentence root	2.92
Expletive es	2.71
Sentence	2.64
Comparative	1.87
Separated verb prefix	1.64
Direct object	1.59

# Dependency label inventory

- ▶ *Eine umfassende Constraint-Dependenz-Grammatik des Deutschen*, Killian Foth, 2006.
- ▶ 34 dependency labels.
- ▶ Extracted from constituency version of TüBa-D/Z (Versley, 2005).