Data-Driven Parsing with Discontinuous Structures

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Overview

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1. Introduction
2. Data-Driven Parsing with Discontinuous Structures
   - The Data
   - Parsing
   - Making it Faster
3. Going Further
   - Related work
   - Future work
   - Extract a grammar yourself

Overview

Constituency Parsing

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- Determine whether a sentence is admissible given a specific grammar, and find the corresponding structure
- Different strategies: Top-down/bottom-up, directional/non-directional, ...

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Non-directional bottom-up (CYK)

$$\begin{array}{c} S \rightarrow NP\ VP \\ VP \rightarrow V\ NP \\ VP \rightarrow VP\ PP \\ NP \rightarrow Det\ N \\ NP \rightarrow \mathit{John} \\ NP \rightarrow \mathit{Sandy} \\ NP \rightarrow \mathit{Mary} \\ V \rightarrow \mathit{sees} \\ \ldots \end{array}$$

John *sees* *Sandy*

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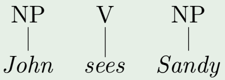

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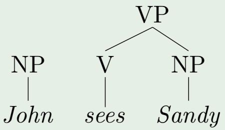

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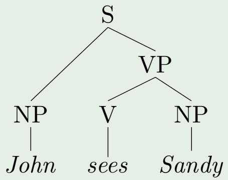


Data-Driven Constituency Parsing

To make parsing data-driven, instead of writing a grammar by hand:

- use a collection of structures which can be interpreted as parse trees of the grammar formalism we are using
- use an algorithm on it which infers the grammar rules which have been used to create a given parse tree
- equip the rules with probabilities (conditional probabilities from rule counts)
- use probabilities for disambiguation

Data

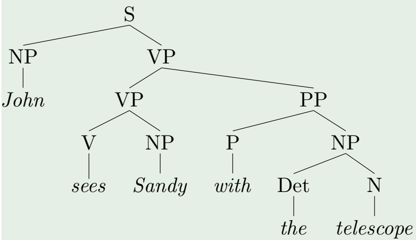
Treebanks are

- corpora in which sentences are annotated with syntactic information
- very small ones contain a few thousand, large ones up to 100k sentences
- typically created from easily accessible text such as news text

Treebank annotation

- mostly aims at neutrality concerning linguistic theories, does not always succeed
- however often has an easily accessible context-free annotation backbone

Grammar Extraction Example



$$
\begin{array}{c}
\text{S} \rightarrow \text{NP VP} \\
\text{NP} \rightarrow \textit{John} \\
\text{VP} \rightarrow \text{VP PP} \\
\text{VP} \rightarrow \text{V NP} \\
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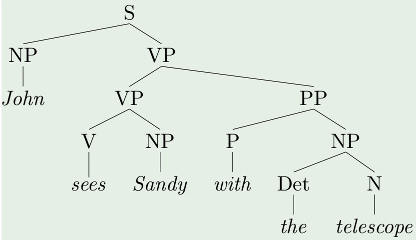

S → NP VP	1.0
NP → *John*	0.333
VP → VP PP	0.5
VP → V NP	0.5
PP → P NP	1.0
V → *sees*	1.0
NP → *Sandy*	0.333
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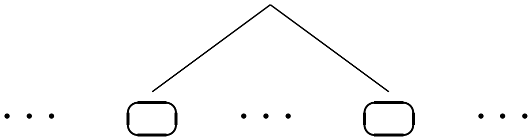
...	

Discontinuous Structure in Natural Language

A sequence of words which is discontinuous but forms a linguistically meaningful unit.



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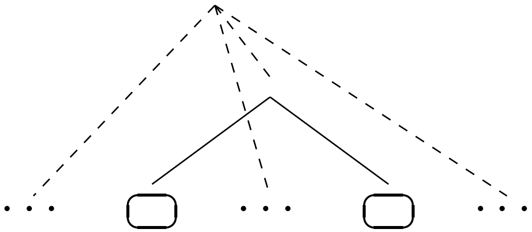

Discontinuity

Examples: German

- Extraposed relative clauses

(1) wieder treffen *alle Attribute* zu, *die auch*
again match *all attributes* VPART *which also*
sonst immer passen
otherwise always fit
'Again, the same attributes as always apply.'

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- Extraposed relative clauses

(1) wieder treffen *alle Attribute* zu, *die auch sonst immer passen*
again match *all attributes* VPART *which also otherwise always fit*
'Again, the same attributes as always apply.'

- Topicalization

(2) *Der CD* wird *bald* ein Buch *folgen*
The CD will *soon* a book *follow*
'The CD will soon be followed by a book.'

Discontinuity

Discontinuity is frequent in natural language, not only in languages with a relatively free word order.

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- Relative clause

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Examples: English

- Relative clause

  (3) They sow *a row of male-fertile plants* nearby, *which then pollinate the male-sterile plants.*

- Long extraction

  (4) Those chains include Bloomingdale's, *which* Campeau recently said *it will sell.*

Annotation in the Penn Treebank

"Movement": Indirect annotation w/ trace nodes and coindexation

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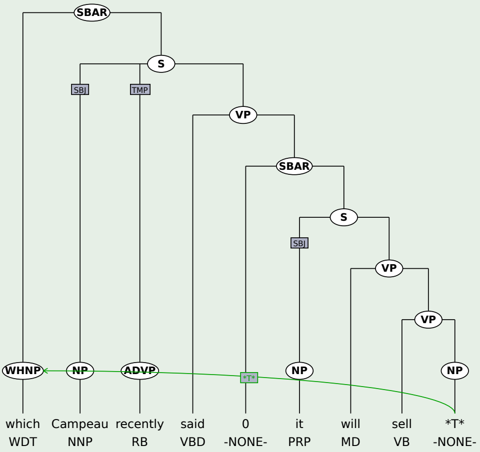

Annotation in the German NeGra/TIGER Treebanks

Direct annotation using crossing branches

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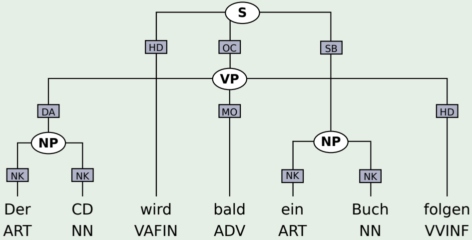

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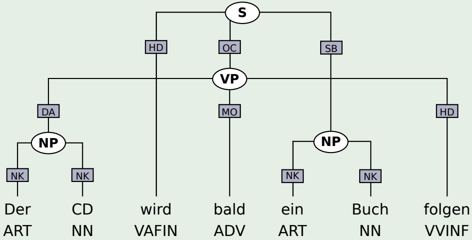

Penn-Treebank-style annotation can be converted into this format [Evang and Kallmeyer, 2011]

Quantifying Discontinuity

Discontinuity measures for constituent structures:

- Gap degree
- Well-nestedness/Ill-nestedness

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Notion of yield

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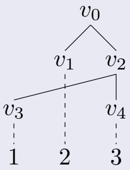


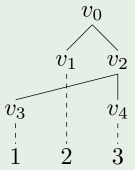
$$\pi(v_2) = \{1, 3\}$$

Gap Degree

- **Blocks** of a node v: the number of maximal continous sequences in $\pi(v)$
- **Block degree** of v: the number of blocks of v
- *Gap degree of* $v + 1 =$ *block degree of* v

Gap Degree Example

Example



set of blocks of v_2:

Gap Degree Example

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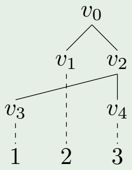

set of blocks of v_2: $\{\{1\}, \{3\}\}$
block degree of v_2

Gap Degree Example

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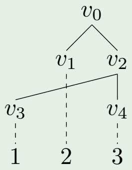

set of blocks of v_2: $\{\{1\}, \{3\}\}$
block degree of $v_2 = 2$

Well-Nestedness

Well-nestedness

There are no **disjoint** yields $\pi(v_1), \pi(v_2)$ of nodes v_1, v_2 such that $\pi(v_1), \pi(v_2)$ interleave.

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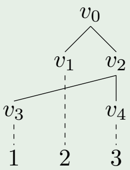
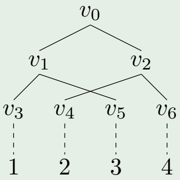


$\rightarrow$ well-nested

Ill-Nestedness

Example



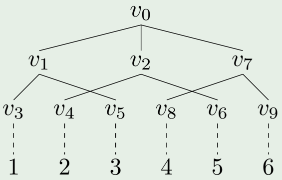
$\rightarrow$ 1-ill-nested

k-ill-nestedness

There exist disjoint yields $\pi(v), \pi(v_1), \ldots, \pi(v_k)$ of nodes $v, v_1, \ldots, v_k$ in a syntactic structure such that $\pi(v_1), \ldots, \pi(v_k)$ interleave with $\pi(v)$.

Ill-Nestedness

Example



$\rightarrow$ 2-ill-nested

k-ill-nestedness

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Empirical Investigation

		NeGra		TIGER	
total		20597		40013	
gap degree	0	14,648	72.44%	28,414	71.01%
gap degree	1	5,253	24.23%	10,310	25.77%
gap degree	2	687	3.30%	1,274	3.18%
gap degree	3	9	0.04%	15	0.04%
gap degree	≥ 4	–	–	–	–
well-nested		20339	98.75%	39573	98.90%
1-ill-nested		258	1.25%	440	1.10%
2-ill-nested		–	–	–	–

What about Data-Driven Parsing?

Remember

- Data-driven parsing requires grammar extraction
- However, CFG only supports *continuous* constituents

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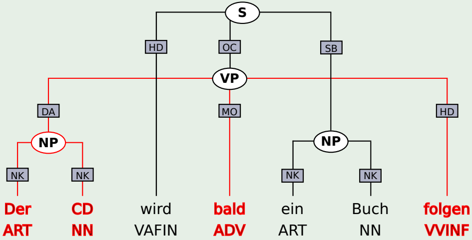
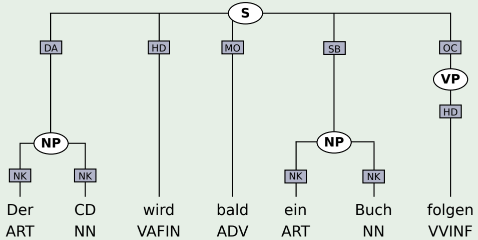
No (P)CFG from discontinuous constituents!



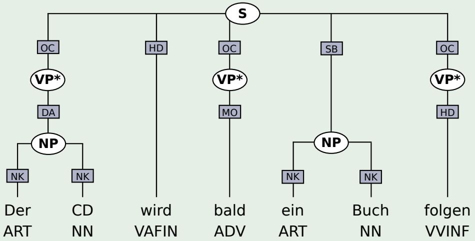
Resolving Crossing Branches (1)

Reattach non-head children of discontinuous nodes



Resolving Crossing Branches (2)

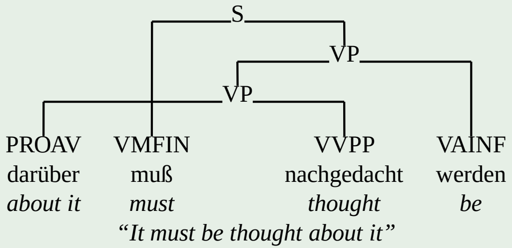
Introduce non-terminals per continuous block [Boyd, 2007]



What now?

- Resolving crossing branches $\rightsquigarrow$ discarding annotation
- What can we do?

Constituency trees: GF extraction



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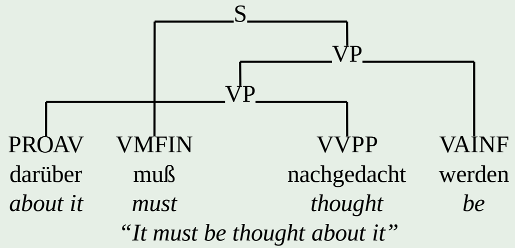
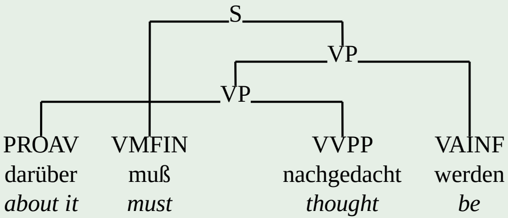



```
cat VP; VAINF;
```

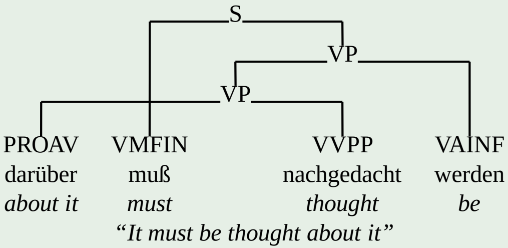
Constituency trees: GF extraction



“It must be thought about it”

```
cat VP; VAINF;
fun funVP : VP -> VAINF -> VP
```

Constituency trees: GF extraction

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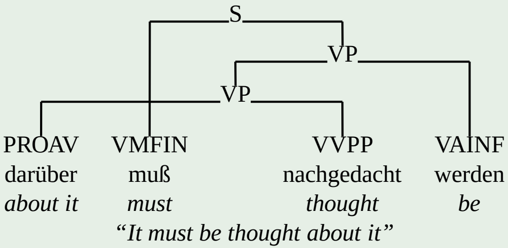


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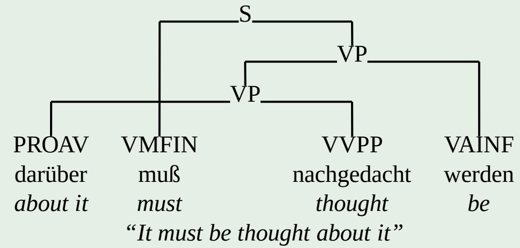


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$$\text{VP2}(\text{X}_1, X_2 X_3) \rightarrow \text{VP2}(\text{X}_1, \text{X}_2)\ \text{VAINF}(\text{X}_3)$$

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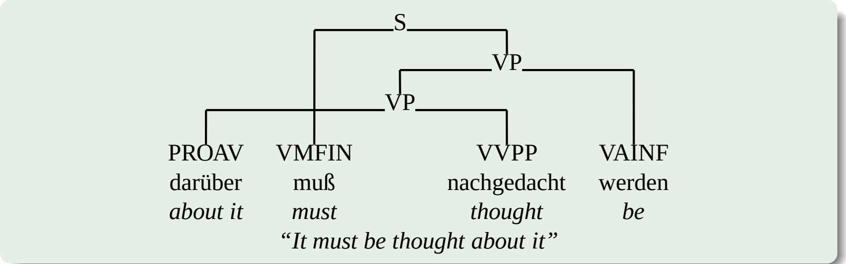
Constituency structure: The LCFRS rules

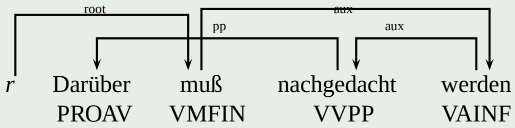


$$S_1(X_1X_2X_3) \rightarrow VP_2(X_1, X_3)\ VMFIN(X_2)$$
$$VP_2(X_1, X_2X_3) \rightarrow VP_2(X_1, X_2)\ VAINF(X_3)$$
$$VP_2(X_1, X_2) \rightarrow PROAV(X_1)\ VVPP(X_2)$$

Handling of lexicon left out

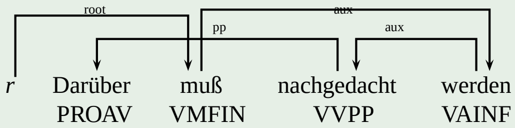
Dependency structure

- Instead of hierachical constituent structure, use labeled dependencies between words
- Each word has a single *head* and zero or more *dependents*
- Example: “nachgedacht” is the head of “darüber” and a dependent of “werden”

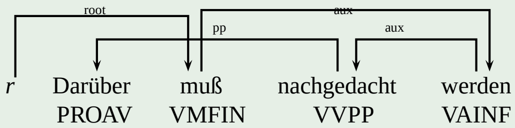


Dependency structure

- Note: Assume extra root node (position 0)
- Yield of a word: Set of own position index and all position indices of words reachable from it
- Example: Yield of “werden” is $\{1, 3, 4\}$
- Gap degree and well-nestedness work here, too; a structure with gap degree 0 (resp. ≥ 1) is called “projective” (resp. ”non-projective”)



Dependency structures: LCFRS extraction



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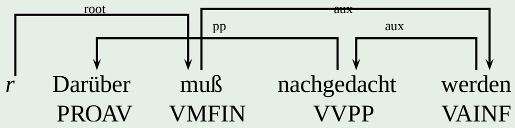

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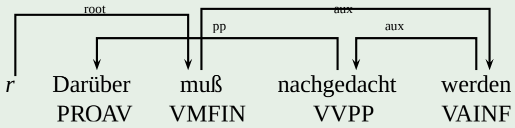

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root → aux VMFIN

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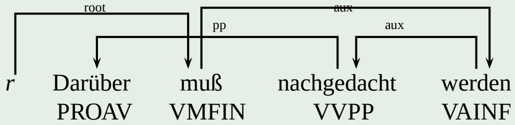

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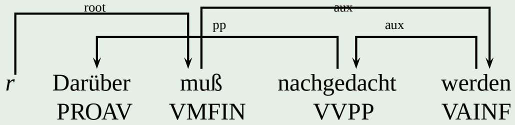

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- Argument of other RHS non-terminals: One one-variable argument per continuous block

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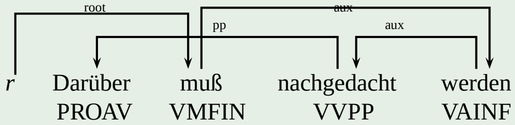

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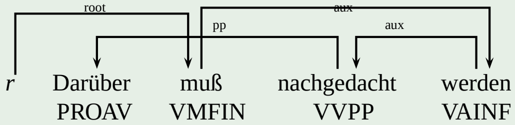
- Argument of other RHS non-terminals: One one-variable argument per continuous block

root $\rightarrow$ aux(X_1,X_3) VMFIN(X)

Dependency structures: LCFRS extraction



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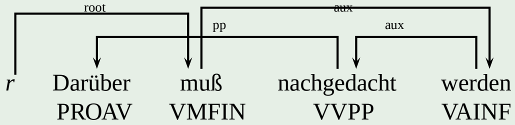

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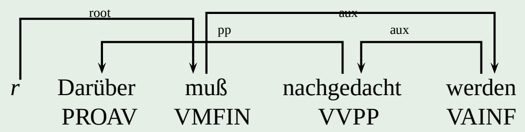
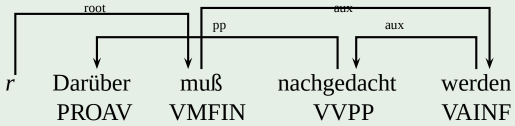
Dependency structures: The LCFRS rules



Dependency structures: The LCFRS rules



$$
\begin{aligned}
\mathrm{pp}(X) &\rightarrow \mathrm{PROAV}(X) \\
\mathrm{root}(X_1X_2X_3) &\rightarrow \mathrm{aux}(X_1,X_3)\ \mathrm{VMFIN}(X_2) \\
\mathrm{aux}(X_1, X_2) &\rightarrow \mathrm{pp}(X_1)\ \mathrm{VVPP}(X_2) \\
\mathrm{aux}(X_1, X_2X_3) &\rightarrow \mathrm{aux}(X_1, X_2)\ \mathrm{VAINF}(X_3) \\
\mathrm{top}(X_1) &\rightarrow \mathrm{root}(X_1)
\end{aligned}
$$

Optimization?

- Discontinuous constituency trees and non-projective dependencies directly interpretable as LCFRS derivations
- However, treebank grammars do not perform well [Charniak, 1996]
- Luckily proximity to PCFG can be exploited

Manual label splitting

- We have seen before how to extract a grammar
- Problem: Some labels are too coarse
- Manual splitting using linguistic criteria can help [Klein and Manning, 2003b, Versley, 2005]

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Splits

- NP split: To all NP labels, we add their respective grammatical function label
- S relative clauses split: We change the label of all relative clauses from S to S-RC.

Binarization: CFG CNF

Binarization reduces length of RHSs (*rank*) to two, lower complexity for CYK parsing

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$A \rightarrow B\ C\ D\ E$

$\rightsquigarrow A \rightarrow B\ @_1,\ @_1 \rightarrow C\ D\ E$

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- Leave one non-terminal on the RHS of the original rule and introduce a unique non-terminal which rewrites to the other non-terminals
- Repeat until all productions have rank 2
- Note: with unique non-terminals, binarized grammar is equivalent to the unbinarized one

$A \rightarrow B\ C\ D\ E$
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Binarization: LCFRS

- Works like CFG reduction to Chomsky Normal Form plus handling of linearization
- Different re-orderings of the RHS before binarization give different binarization techniques from the PCFG literature

Binarizations

- *Left-to-right*: Binarize strictly left-to-right.
- *Head-outward binarization* [Collins, 1999]:
  - *Head marking* with Collins-style head-rules
  - Expand head first, then sisters to the left, then to the right, or vice versa
- *Optimal binarization*: minimal fan-out and number of variables per production and binarization step

Markovization

- Generalize grammar by adding markovization
- Use a single base binarization non-terminal instead of unique ones
- Information from rule occurrence in treebank added to binarization non-terminals

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Markovization

- Markovization information for bin. non-terminal that comprises original RHS elements $A_i \dots A_m$:
  - Vertical: First v elements of path from A_i to root
  - Horizontal: First h elements of $A_i \dots A_0$

Training

- Eventually, we need a probabilistic grammar.

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Training

- Count all rule/label occurrences
- Estimate probabilities with Maximum Likelihood Estimation
- Works as for PCFG, sum of probabilities for rules with same LHS must be 1

Example

After extraction and head marking

$VP_2(X_1X_2, X_3X_4) \rightarrow ADV1(X_1)VVPP1'(X_2)PPER1(X_3)ADV1(X_4)$
occurring below S_1

Binarized

- Head-outward binarization, unary top and bottom
- Markovization with $v = 2, h = 1$

$VP_2(X_1, X_2) \rightarrow @^\wedge VP_2^\wedge S_1\text{-}ADV_1|_2(X_1, X_2)$
$@^\wedge VP_2^\wedge S_1\text{-}ADV_1|_2(X_1, X_2X_3) \rightarrow @^\wedge VP_2^\wedge S_1\text{-}PPER_1|_2(X_1, X_2)\ ADV_1(X_3)$
$@^\wedge VP_2^\wedge S_1\text{-}PPER_1|_2(X_1, X_2) \rightarrow @^\wedge VP_2^\wedge S_1\text{-}ADV_1|_1(X_1)\ PPER_1(X_2)$
$@^\wedge VP_2^\wedge S_1\text{-}ADV_1|_1(X_1, X_2) \rightarrow ADV_1(X_1)\ @^\wedge VP_2^\wedge S_1\text{-}VVPP_1|_1(X_2)$
$@^\wedge VP_2^\wedge S_1\text{-}VVPP_1|_1(X_1) \rightarrow VVPP_1(X_1)$

Actual parsing

rparse (http://phil.hhu.de/rparse)

- CYK Parser with weighted deductive parsing [Seki et al., 1991, Nederhof, 2003]

GF (http://www.grammaticalframework.org)

- Main difference: left-to-right and prefix valid, means binarization is done "on-line"

Disco-DOP (http://www.github.com/andreasvc/disco-dop)

Disco-DOP [van Cranenburgh et al., 2011] integrates LCFRS parsing with Data-Oriented Parsing [Bod and Scha, 1996]

Qualitative behavior

Constituents: OK

- Results lie in the vicinity of results of state-of-the-art PCFG parsing (plus crossing branches)
- Unfortunately no standard test suite for long distance dependencies yet

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Dependencies: Bad

Low results. Possible reasons:

- Lack of graph-global features
- Unsuitable arc labeling scheme

The Problem

- Parsing complexity for binary k-LCFRS: $\mathcal{O}(n^{3k})$.
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Too slow already with less than 30 words per sentence

The solutions

- Use A^* search with outside estimates [Maier and Kallmeyer, 2010]
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All of these can be combined!

Related work

Related work aiming at producing parse trees with non-local information:

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- Pre-/post-processing of PCFG parses:
  - [Dienes and Dubey, 2003]: Preprocessing: Inject traces in parser input (ML)
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- Dependency parsing:
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- Formalisms directly encoding discontinuities in derived trees:
  - [Plaehn, 2004]: First, using Discontinuous Phrase Structure Grammar (DPSG), up to 15 words
  - [Levy, 2005]: Comparable setup to rparse, but no results reported

Where to go from here

- More improvements from the PCFG world:
  - *LCFRS-LA* with automatic category splitting
  - Approximations of LCFRS parsing ("beam search") which raise speed while maintaining output quality
- Create more data, e.g. an evaluation suite for discontinuous structures
- Investigate the impact of discontinuous structures in downstream applications

How to get a GF from TIGER

1. Get the TIGER treebank from `http://www.ims.uni-stuttgart.de/forschung/ressourcen/korpora/tiger.html`
2. Get rparse from `http://phil.hhu.de/rparse`, Compile rparse using ant
3. Run rparse with
   ```
   java -jar rparse.jar -doTrain -train [TIGERfile]
   -trainIntervals 1-10 -trainSave [output-dir]
   -trainSaveFormat gf -trainExtractOnly
   ```
4. Check GF files in your output directory
5. Import the concrete syntax into GF

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