Data-oriented Parsing with Lexicalized Tree Insertion Grammars

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Two Topics

- Exploring HPSG-treebanks for Probabilistic Parsing: HPSG2LTIG
  - completed work
- Exploring Multilingual Dependency Grammars for LTIG parsing
  - work in progress

Exploring HPSG-treebanks for Probabilistic Parsing: HPSG2LTIG

- joined work with Berthold Crysmann (currently at Uni. Bonn)

- to appear as
  - Günter Neumann and Berthold Crysmann Extracting Supertags from HPSG-based Tree Banks. S. Bangalore and A. Joshi (eds): Complexity of Lexical Descriptions and its Relevance to Natural Language Processing: A Supertagging Approach, MIT press, in preparation (prob. Autum, 2009)

Motivation

- Grammar compilation or approximation well-established technique for improving performance of Unification-based Grammars, such as HPSG
  - Kasper et al. (1995) propose compilation of HPSG into Tree-adjoining grammar
  - Kiefer & Krieger (2000) have derived CFG from the LinGO ERG via fixpoint computation
  - Currently no successful compilation of German HPSG into CFG

Motivation

- Corpus-based specialisation of a general grammar,
  - efficiency
  - domain adaptation
  - e.g., Samuelsson, 1994; Rayner & Carter, 1996; Neumann, 1994; Krieger, 2005; Neumann & Flickinger, 2002

Stochastic Lexicalised Tree Grammars

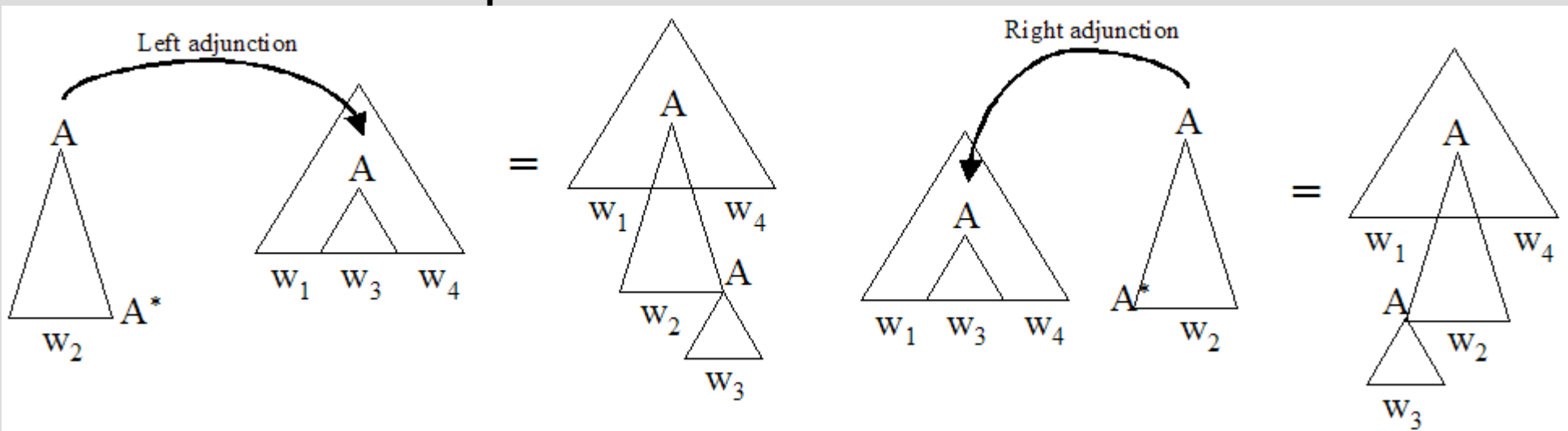
- Neumann & Flickinger (2002) derive a Lexicalised Tree Substitution Grammar from the LinGO English Resource Grammar
  - Data-driven method
  - Parse trees from original grammar are decomposed into subtrees
  - Decomposition guided by HPSG's head feature principle
  - Result is Stochastic Lexicalised Tree Substitution Grammar (no recursive adjunction)
  - Speed-up: factor 3 (including replay of unifications)

Factorisation of modification

- proposed in context of TAG induction from treebanks, e.g., Hwa (1998); Neumann (1998); Xia (1999); Chen & Shanker (2000); Chiang (2000);
  - task: reconstruct TAG derivation from CF tree
  - treebank are heuristically and manually extended with the notions of head, argument, and adjunct

Lexicalised Tree Insertion Grammars (LTIG)

- LTIG Schabes & Waters, (1995) is a restricted form of LTAG, where
  - auxiliary trees are only left- or right-adjoining, no wrapping
  - no right-adjunction to nodes created by left-adjunction is allowed, and, vice versa
  - Generative power of LTIG is context-free



Stochastic LTIG

- Initial trees with root α
  - sum(α): $P_i(\alpha) = 1$
- Substitution
  - sum(α): $P_s(\alpha|\eta) = 1$
- Adjunction of left/right auxtrees witgh root β
  - sum(β): $P_a(\beta|\eta) + P_a(\text{NONE}|\eta) = 1$

DFKI German HPSG Treebank

- Large-scale competence grammar of German
  - Initially developed in Verbmobil by Müller & Kasper (2000)
  - Ported to LKB (Copestake, 2001) and PET (Callmeier, 2000) platforms by Müller
  - Since 2002, major improvements by Crysmann (2003, 2005)
- Initial HPSG-treebanking effort Eiche
  - based on Redwoods-technology (Oepen et al. 2002)
  - treebank based on a subset of German Verbmobil corpus

Challenges for German: Scrambling

- Almost free permutation of arguments in clausal syntax

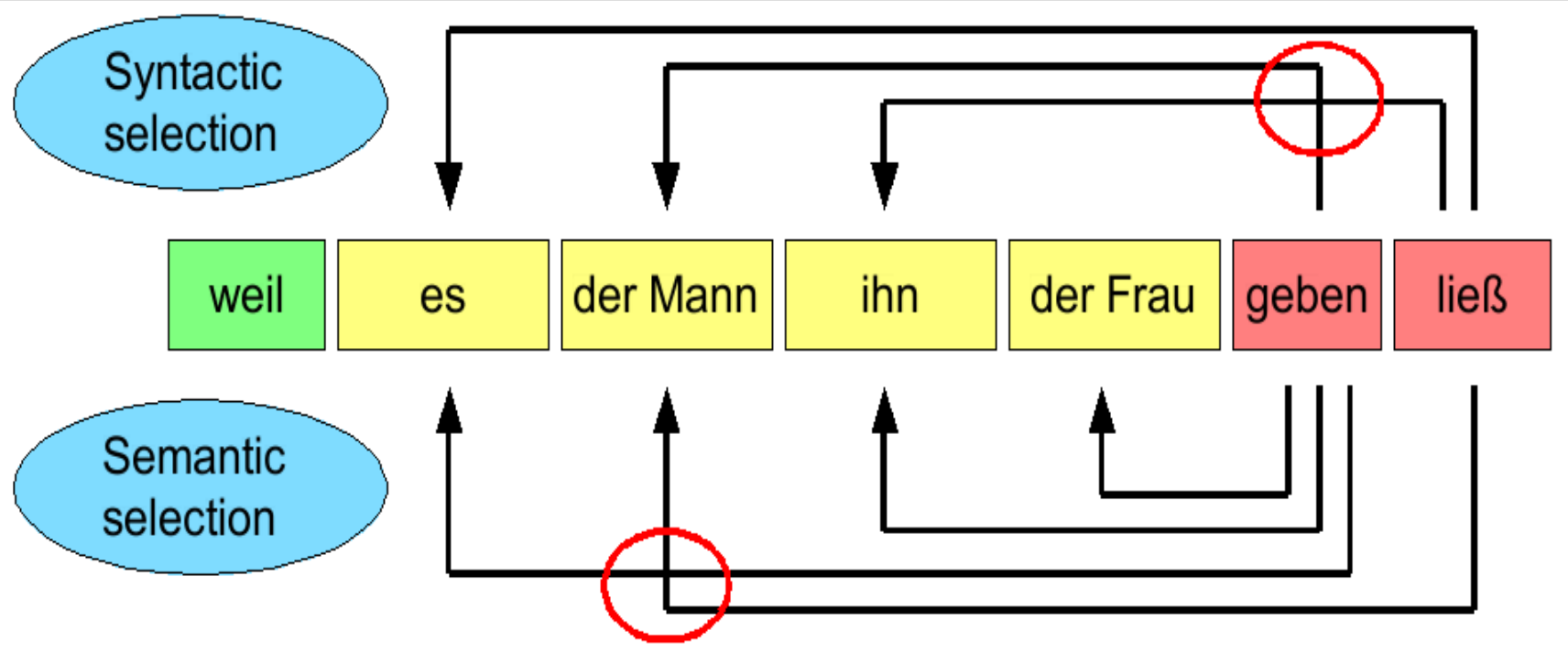
weil	der Mann	der Frau	das Buch	gab
weil	das Buch	der Mann	der Frau	gab
weil	der Mann	das Buch	der Frau	gab

- Interspersal of modifiers anywhere between arguments

weil	gestern	der Mann	der Frau	das Buch	gab
weil	der Mann	gestern	der Frau	das Buch	gab
weil	der Mann	der Frau	gestern	das Buch	gab
weil	der Mann	der Frau	das Buch	gestern	gab

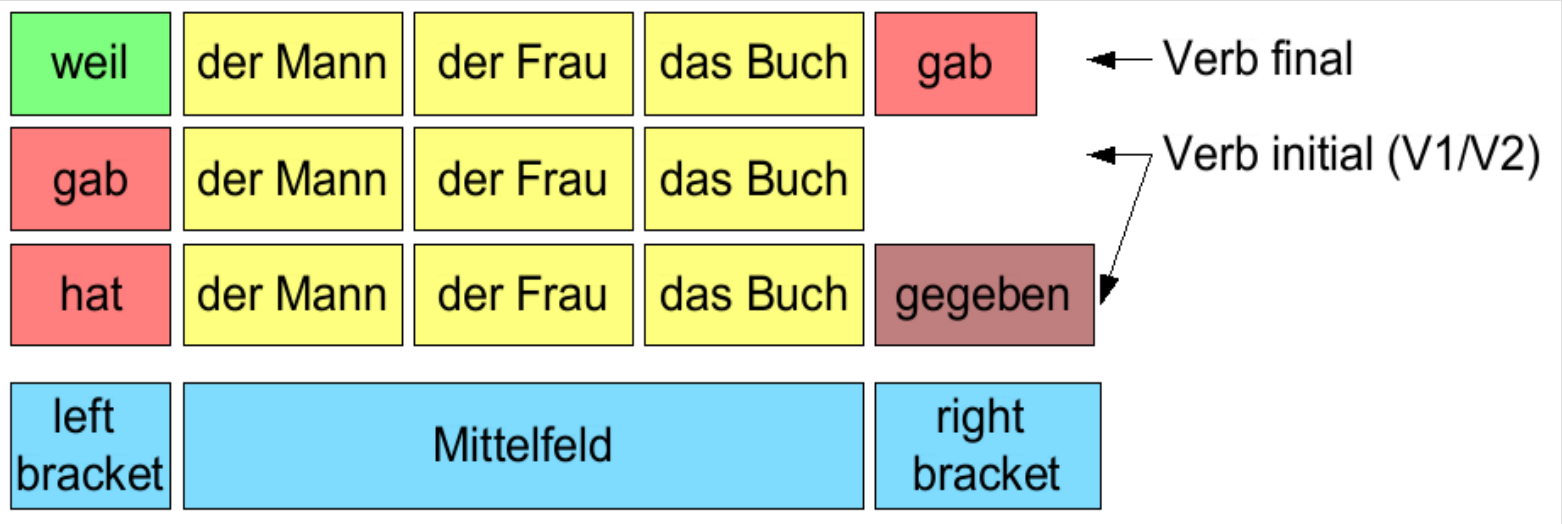
Challenges for German: Complex predicates

- Complex predicate formation in verb cluster
- Permutation of arguments from different verbs



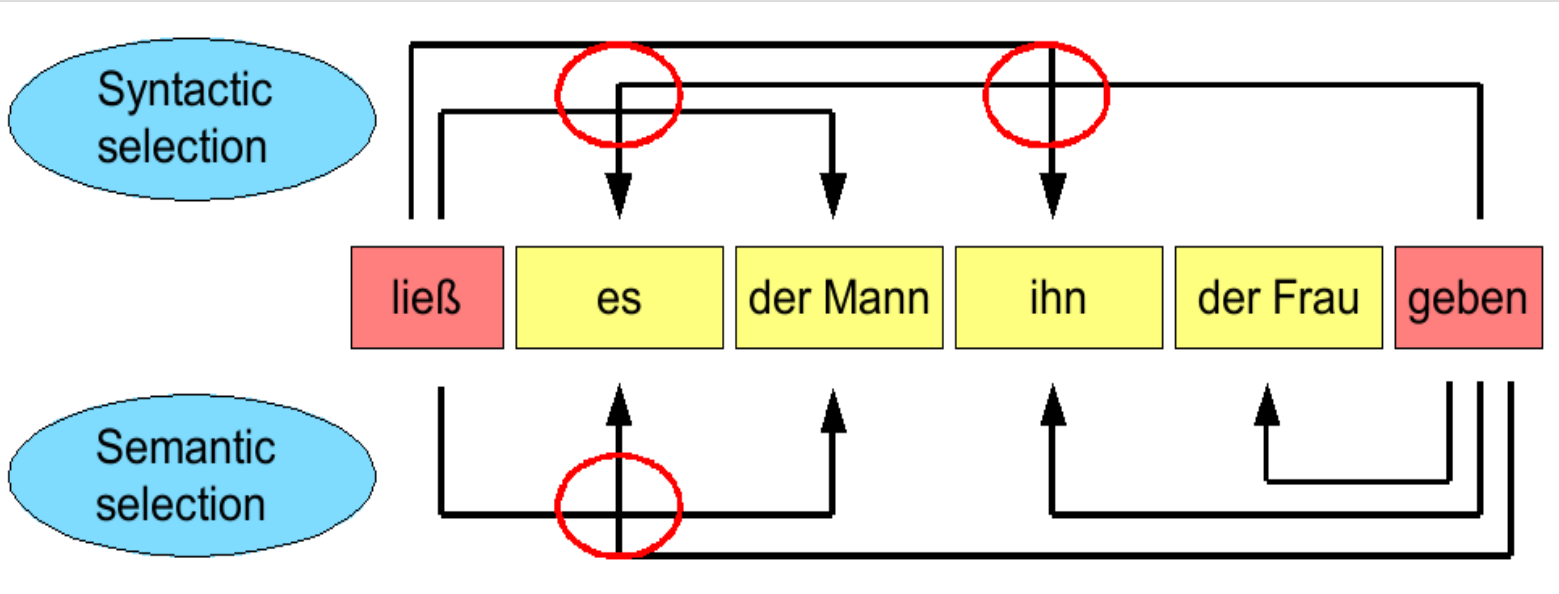
Challenges for German: Verb „movement“

- Variable position of finite verb
  - V1/V2 in matrix clauses
  - V-final in embedded clauses
- initial verb related to final cluster by verb movement



Challenges for German: Discontinuous complex predicates

- Complex predicates may be discontinuous
- Argument structure only partially known during parsing
  - Number of upstairs arguments
  - Position of upstairs arguments (shuffle)



German HPSG: Overview

- German HPSG highly lexicalised
  - Information about combinatorial potential mainly encoded at lexical level
  - Syntactic composition performed by general rule schemata
- Grammar version Aug 2004
  - 87 phrase structure rules (unary & binary)
  - 56 lexical rules + 213 inflectional rules
  - over 280 parameterised lexical leaf types
    - parameters for verbs include selection for complement case, form of preposition, verb particles, auxiliary type etc.
    - nominal parameters include inherent gender
  - over 35.000 lexical entries

Rule backbone

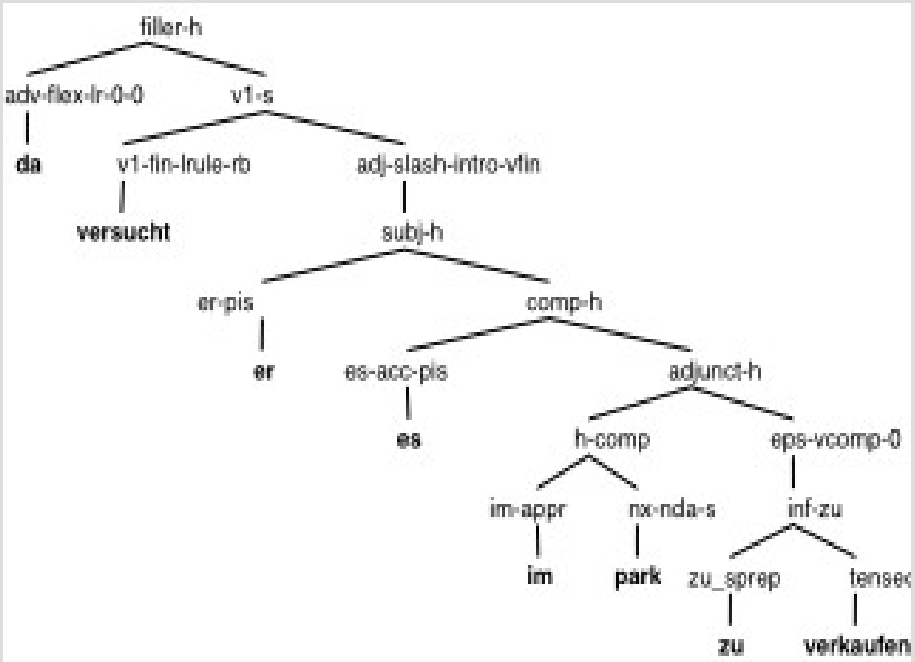
- Rule schemata define CF-backbone
- Rule labels represent composition principles
  - (encoded as TFS), e.g., h-comp, h-subj, h-adjunct
- No segregation of dominance and precedence:
  - grammar defines both head-initial and head-final variant of basic schemata, e.g., h-comp and comp-h
- Argument composition & scrambling
  - lexical permutation of subcat lists
  - shuffle of upstairs and downstairs complements, e.g., vcomp-h-0 ... vcomp-h-4
- Movement
  - Fronting implemented as slash percolation
  - Verb movement

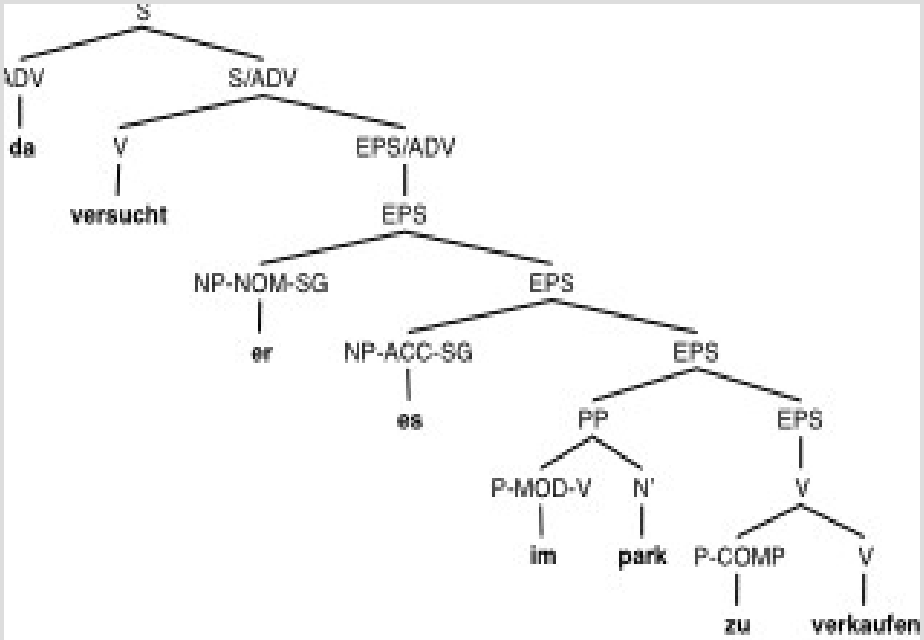
Eiche treebank

- Automatic annotation of in-coverage sentences by HPSG-parser
- Manual selection of best parse with Redwoods-tools
- Treebank built on subset of Verbmobil corpus
  - average sentence length (in coverage): 7.9
  - distinct trees: 16.1
  - only unique sentence strings included
    - minimise annotation effort
    - low redundancy

Eiche treebank

- Rule backbone constitutes primary treebank data
  Full HPSG-analysis can be reconstructed deterministically
- Secondary tree representation with conventional node labels
  - encodes salient information represented in AVM associated with each node (e.g., category, slash, case, number)
  - isomorphic to derivation tree





Extraction method

- Experiment based on David Chiang's TIG parser, Chiang (2000)
- Classification of rules and rule daughters according to head, argument, or modifier status (cf. Magerman, 1995)
- HPSG2LTIG Conversion (following, Chiang):
  - Adjunct daughters (adjunction)
    excise tree below adjunct to form a initial adjoined tree
  - Argument daughters (substitution) excise tree below argument daughter to form initial tree, leaving behind a substitution node
  - Auxiliary trees

Extraction method

- Classification according to head, argument, or modifier status straightforward and transparent
  - treebank rooted in a rich declarative grammar
  - close correspondence of relevant distinctions to HPSG composition principles
  - no heuristics (or „recovery“ of linguistic theory)
- Specification based on rule-backbone
- Automatic expansion with secondary labels
  - derivation trees
    fold isomorphic trees into one
  - head rules and argument rules
    expand conversion rules defined on backbone by secondary labels found in treebank

Experiment 1

- 10-fold cross-validation over 3528 sentences from Verbmobil corpus
- Anchors of extracted trees (LEX) are highly specific preterminals including POS information, morphosyntax (case, number, gender, person, tense, mood), valency etc.
- Precision and recall satisfactory for lexically covered sentences
- No parses for out-of-vocabulary items
  owing to corpus size and specificity of preterminals, derived grammar not robust w.r.t. lexical coverage

Anchor	Cov.	LR(tot.)	LP(tot.)	LR(cov.)	LP(cov.)
LEX	77.47	57.68	77.07	77.33	78.27
POS	98.12	76.42	78.36	77.92	78.44

Experiment 2

- 10-fold cross-validation over 3528 sentences from Verbmobil corpus
- Anchors of extracted trees (POS) only encode POS information
- Recall and precision satisfactory
- Valency and morphosyntactic information still encoded by way of tree derivation, including inflectional rules

Anchor	Cov.	LR(tot.)	LP(tot.)	LR(cov.)	LP(cov.)
LEX	77.47	57.68	77.07	77.33	78.27
POS	98.12	76.42	78.36	77.92	78.44

Discussion

- Parseval measures achieved by derived LTIG comparable to performance of treebank-induced PCFG parsers:
  - Dubey & Keller, 2003 have trained a PCFG on subset of German NEGRA corpus, reporting 70.93% LP & 71.32% labelled recall (coverage: 95.9%)
  - Similar results obtained by Müller et al. (2003) on the same corpus (LP: 72.8%; LR: 71%)

- Current probabilistic parsing results for German in general less satisfactory than for English (cf. Dubey & Keller, 2003; Levy & Manning, 2003)
  differences most probably related to typological difference between languages

Summary

- First successful subgrammar extraction for German HPSG
- Method based on Chiang (2000) TAG extraction from Penn treebank
  - Definition of head-percolation and argument rules driven by HPSG principles, not heuristics
  - No treebank transformation necessary
- Performance of initial experiments promising: > 77% LP & LR

Future work

- Experiment with generalised/specialised node labels
- Multiply-anchored elementary trees
- Different parsing schemas

- Points to my current work

Using Dependency Treebanks as a source for extracting LTIGs

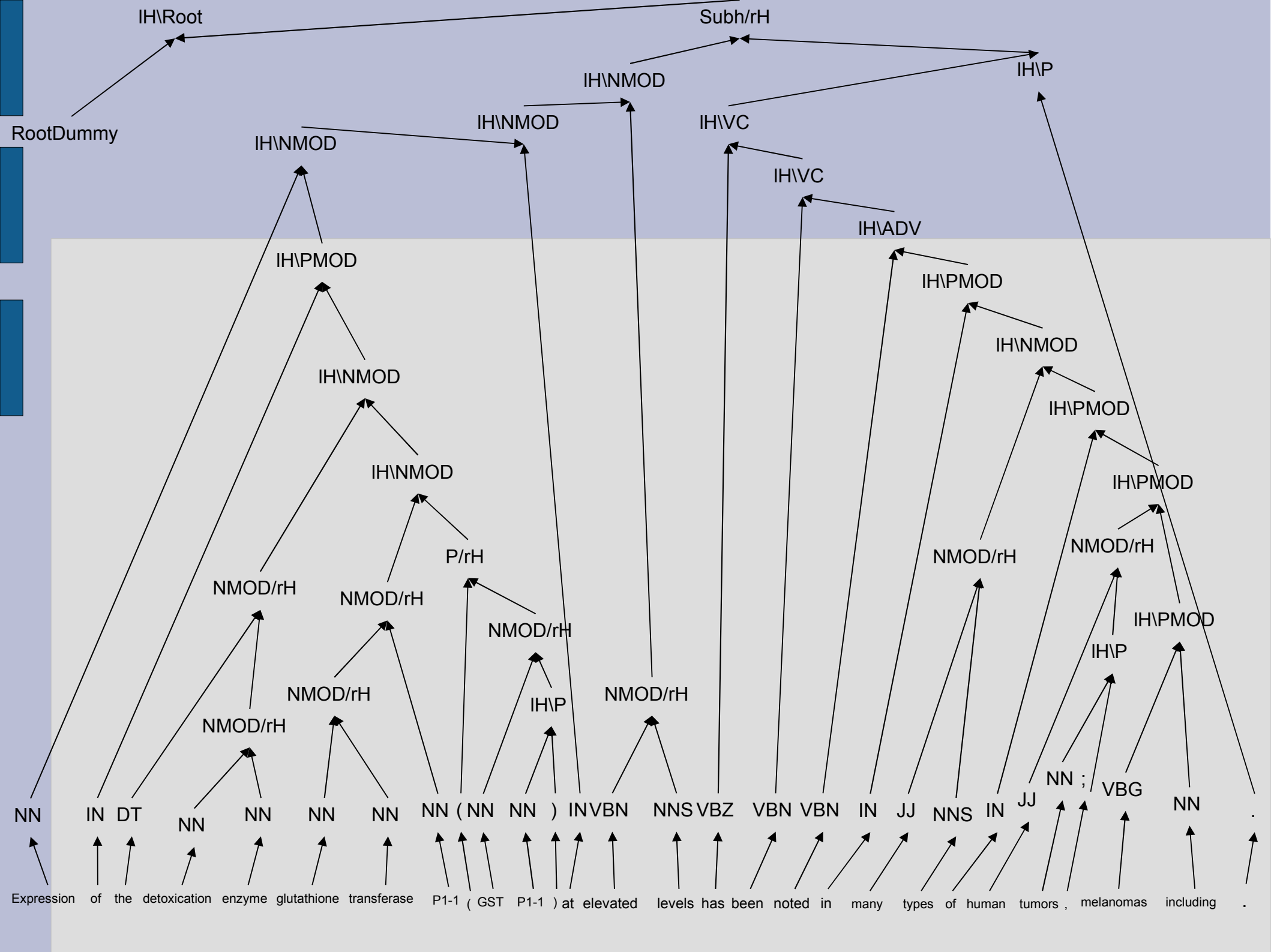
- There exists a number of dependency treebanks for different languages.
- They explicitly represent head/mod relationships.
- There is a natural relationship between dependency trees and derivation trees in TAG formalism.
- Might provide a tree decomposition operation for free.
- Try avoding any language specific properties.

Starting point

- Dependency treebanks encoded in the so called CoNLL tree format.
- Transformation of CoNLL format into a PennTB like CF tree format.

Example CoNLL tree

1	Expression	_		NN	NN	_	16	SBJ	_	_
2	of		_	IN	IN	_	1	NMOD	_	_
3	the		_	DT	DT	_	5	NMOD	_	_
4	detoxication	_		NN	NN	_	5	NMOD	_	_
5	enzyme		_	NN	NN	_	2	PMOD	_	_
6	glutathione	_		NN	NN	_	7	NMOD	_	_
7	transferase	_		NN	NN	_	8	NMOD	_	_
8	P1-1		_	NN	NN	_	5	NMOD	_	_
9	(		_	(	(	_	11	P	_	_
10	GST		_	NN	NN	_	11	NMOD	_	_
11	P1-1		_	NN	NN	_	8	NMOD	_	_
12	)		_	)	)	_	11	P	_	_
13	at		_	IN	IN	_	1	NMOD	_	_
14	elevated	_		VB	VBN	_	15	NMOD	_	_
15	levels		_	NN	NNS	_	13	PMOD	_	_
16	has		_	VB	VBZ	_	0	ROOT	_	_
17	been		_	VB	VBN	_	16	VC	_	_
18	noted		_	VB	VBN	_	17	VC	_	_
19	in		_	IN	IN	_	18	ADV	_	_
20	many		_	JJ	JJ	_	21	NMOD	_	_
21	types		_	NN	NNS	_	19	PMOD	_	_
22	of		_	IN	IN	_	21	NMOD	_	_
23	human		_	JJ	JJ	_	24	NMOD	_	_
24	tumors		_	NN	NNS	_	22	PMOD	_	_
25	,		_	,	,	_	24	P	_	_
26	including	_		VB	VBG	_	24	NMOD	_	_
27	melanomas	_		NN	NNS	_	26	PMOD	_	_
28	.		_	.	.	_	16	P	_	_


IH\Root
Subh/rH
IH\NMOD
IH\P
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IH\ADV
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NMOD/rH
NN IN DT NN NN NN NN NN (NN NN) IN VBN NNS VBZ VBN VBN IN JJ NNS IN JJ NN ; VBG NN .
Expression of the detoxication enzyme glutathione transferase P1-1 (GST P1-1) at elevated levels has been noted in many types of human tumors , melanomas including .

More formally: CoNLL trees

- A CoNLL dependency tree is a sequence S of connected nodes s_i, $(1 \leq i \leq len(S))$ each of form:
  - <M,H,Dep>
    - „encoding the most relevant information“
    - where M and H are indices of elements s_M, $s_H \in S$
    - Dep is the dependency relation between s_M, s_H
    - if H < M, we say that the head element is in left direction (denoted as LH); analogous for right head we use RH
  - <0,ε,ε> for hidden root node

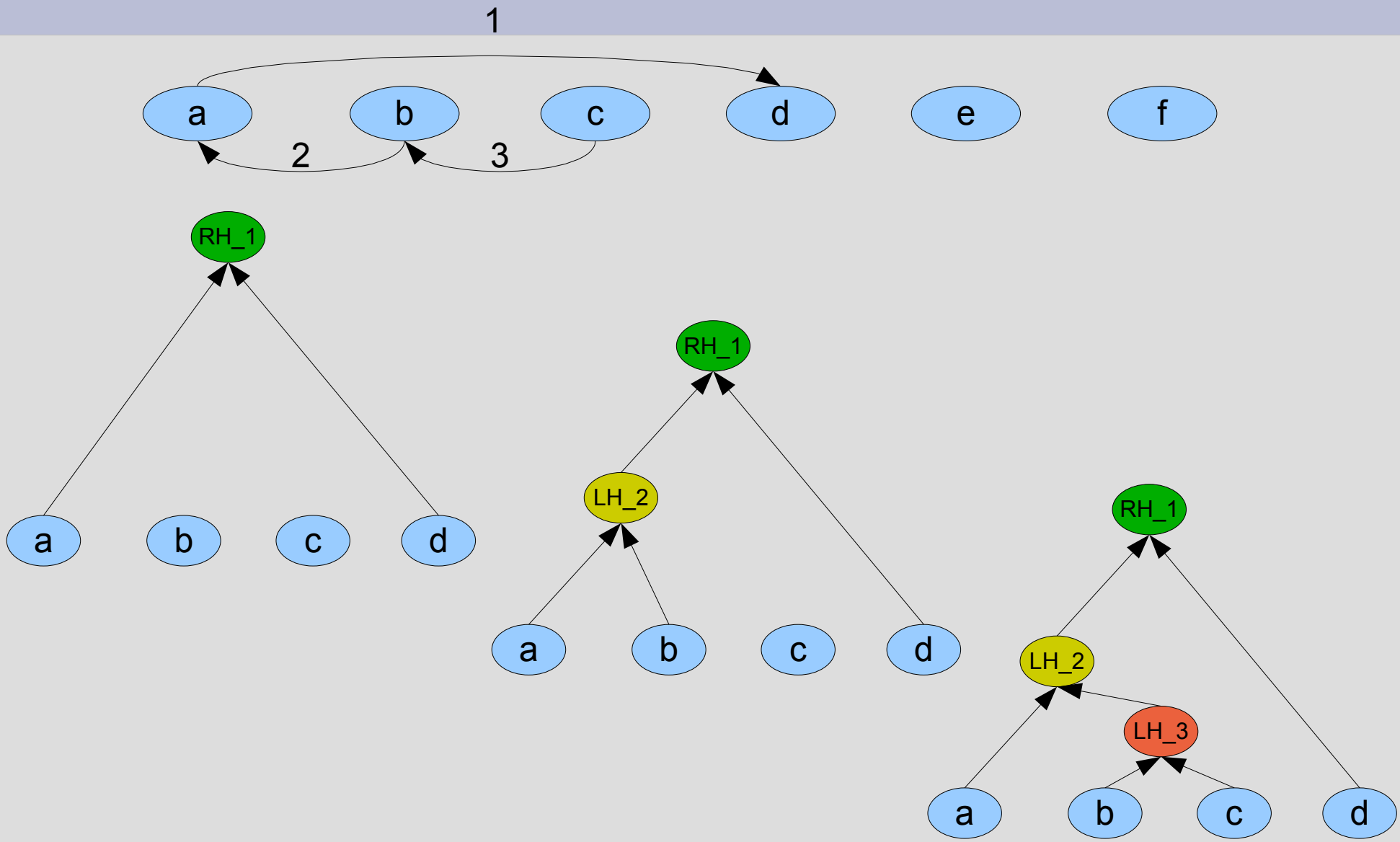
More formally: CF trees

- I call a target CF tree „linear dependency tree“ (LDT) ,
- and define it as a binary tree over a ranked alphabet Σ :
  - x, where $x \in \sum_0$ (terminal elements)
  - $x(t_1,t_2)$, where $x \in \sum_2$ (nonterminal elements)
  - t_1, t_2 are trees over Σ
- For the node labelling
  - $x \in \sum_2$ are further divided into disjoint sets
    - x_{LH_Dep}, x_{RH_Dep}
  - $x(t_1,t_2)$ into $x_{RH\_Dep}(t_M,t_H)$ and $x_{LH\_Dep}(t_H,t_M)$

The Transformation Algorithm

- Core idea:
  - Traverse a CoNLL sequence from left to right and construct a LDT incrementally bottom-up from the modifier elements to its heads.
- Note:
  - In general the head element of a modifier is not the adjacent right/left element, but might be a long-distant right/left element.
- Because LDT is constructed bottom-up
  - it migth be that a tree must be adjoined into a larger tree.

Example



Ensuring proper spans

- It might happen that for a newly created nonterminal node the yield is not proper
  - if the right pos of node i, which stands left to another node j is greater than the left pos. of j
- Then:
  - create a new node with a trace element in order to ensure reversible mapping from LTD2CoNLL
  - copy and move corresponding subtrees

Extraction of LTIG from LTD

- Straightforward
  - cut of non-head subtrees
  - then define aux-trees as those which have a left/right yield node with same label as root

- Example LTIG-trees from Tiger TB:

```
((RH_CVC (:SUBST . LH_NK) (RH_PM (PTKZU "zu") (VVINF "bringen"))) 4
 . 0.26666668)
((LH_NK (:RFOOT . LH_NK) (NN "Kurs")) 3 . 7.433102e-4)
```

Parsing: Efficient Early-style LTIG parser

- Based on Schabes & Waters, 1995
- Extensions:
  - supports (disconnected) multi word lexical anchors
    - recursive trie traversal for lexical tree lookup
  - supports simultaneous adjunction at a single node
  - supports sharing nodes between trees
    - computes very compact forest of readings
  - two step unfolding of forest
    - extract all possible LTIG derivations (only anchors+tree indices)
    - expand indices to trees taking into account the LTIG operations that have been used

External form gramm

Example trees from S&W, 95;
Same format for hand-crafted grammars & TB-based grammars;
When reading in, a lot of efficient indices are created;

Show Negra trees

```
(setq *start-symbols* '(s np))
(setq *ltig* '(
((s (:subst . np) (vp (v saw) (:subst . np))) 1 . 0.75)
((s (:subst . np) (vp (v saw)) (:subst . np)) 1 . 0.25)
((np (:subst . det) (n boy)) 1 . 0.5)
((det a) 1 . 0.5)
((n a) 1 . 0.5)
((np (:subst . det) (n woman)) 1 . 0.5)
((np (:subst . n) (n woman)) 1 . 0.5)
((vp (v seems) (:lfoot . vp)) 1 . 0.5)
((vp (:rfoot . vp) (adv smoothly)) 1 . 0.5)
((vp (:rfoot . vp)  (adv above) (:subst . np) ) 1 . 0.5)
((vp (:rfoot . vp) (adv above)) 1 . 0.5)
((vp (XP (:rfoot . vp) (TO to)) (YP (adv slowly))) 1 . 0.5)
((n  (adj nice) (:lfoot . n)) 1 . 0.25)
((n  (adj tall) (:lfoot . n)) 1 . 0.5)
((n  (adj pretty) (:lfoot . n)) 1 . 0.25)((vp (XP (:rfoot . vp)) (adv slowly)) 1 . 0.5)
))
```

Examples of parsing

- Extracting LTIG from first 1000 Tiger dependency trees
  - show LTIG grammar
  - do parsing
  - display trees
- Parsing time:
  - ~0,0372 sec/sentence computing & expanding all readings
  - ~17 words/sentence (ranging from 2 - 58)

Length of each sentence

(2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 3 3 3 3 3 3 3 3 3 3 3 3 3 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
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Next steps

- Transformation
  - Check, whether for works for arbitrary non-projective cases (formally)
- Experiments with as many languages as possible
- Parsing
  - Improve tree filtering
  - Almost parsing ala Bangalore
  - Use of global statistical model ala Finkel et al. 2008 (they're using CRF)