Language modeling with tree-adjoining grammars

Day 2

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erc TreeGraSP

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hhu Heinrich Heine Universität Düsseldorf

Recall: definition of TAG

Tree Adjoining Grammar (TAG)

A Tree Adjoining Grammar is a tuple $G = \langle N, T, I, A, O, C \rangle$:

T and N are disjoint alphabets of terminals (T) and non-terminals (N),

I is a finite set of **intial trees**, and

A is a finite set of **auxiliary trees**.

$O : \{v \mid v \text{ is a node in a tree in } I \cup A\} \rightarrow \{1, 0\}$ is a function, and

$C : \{v \mid v \text{ is a node in a tree in } I \cup A\} \rightarrow \mathcal{P}(A)$ is a function.

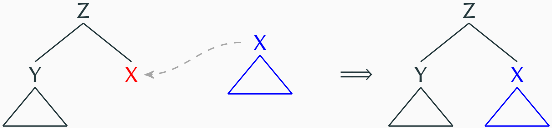
The trees in $I \cup A$ are called **elementary trees**.

Let v be a node in $I \cup A$:

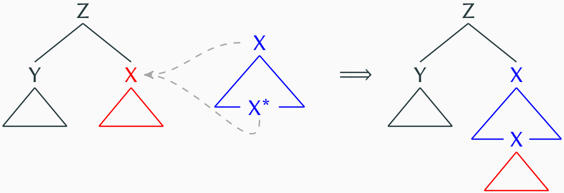
- **obligatory adjunction (OA)**: $O(v) = 1$
- **null adjunction (NA)**: $O(v) = 0$ and $C(v) = \emptyset$
- **selective adjunction (SA)**: $O(v) = 0$ and $C(v) \neq \emptyset$ and $C(v) \neq A$

Recall: operations in TAG

Substitution: replace a non-terminal leaf node with another tree



Adjunction: replace a non-terminal node with an auxiliary tree



Recall: the ideal grammar formalism

TAG is **mildly context-sensitive**

- generates the context-free languages
- generates cross-serial dependencies (i.e. ww)
- constant growth (or semi linear, no a^{2^n})
- polynomial time parsing ($\mathcal{O}(n^6)$)

[Joshi 1985, Schabes 1990, Joshi & Schabes 1997, Kallmeyer 2010]

TAG can **strongly lexicalize** finitely ambiguous CFG.

[Schabes 1990, Joshi & Schabes 1997]

TAG is linguistically, computationally and psycholinguistically **adequate**.

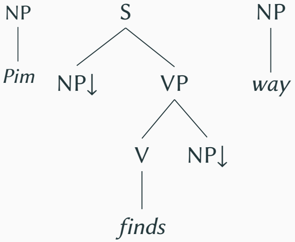
Example TAG

$G_{TAG} = \langle N, T, I, A \rangle$, where

$N = \{\text{S, NP, VP, V, Adv, Det}\}$

$T = \{\textit{finds, the, pim, always, way}\}$

$I = \{$



$\}$

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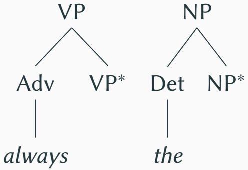

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XP↓: substitution node
XP*: footnote

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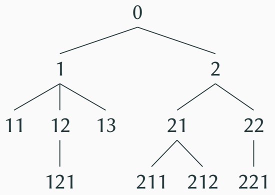
- **derivation tree** in TAG
  - uniquely describes a TAG derivation
  - the derivation tree contains:
    - **nodes** for all elementary trees used in the derivation,
    - **edges** for all adjunctions and substitutions performed throughout the derivation,
    - **edge labels** indicating the target node of the rewriting operation

Derivation trees

For the node addresses of elementary trees, **Gorn addresses** are used:

- the root has address ϵ (or 0)
- the n^{th} daughter of the node with address p has address pn.



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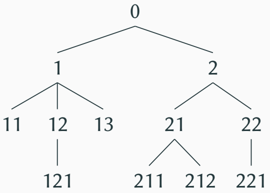
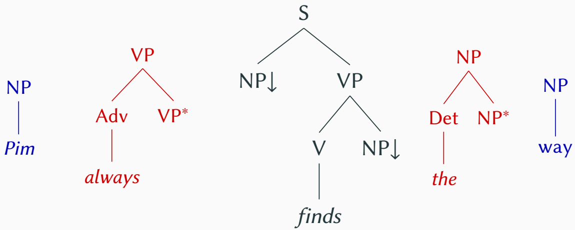


Derivation tree

Whenever an elementary tree γ rewrites the node at Gorn address p in the elementary tree γ', there is an edge from γ' to γ labeled with p.

Example derivation



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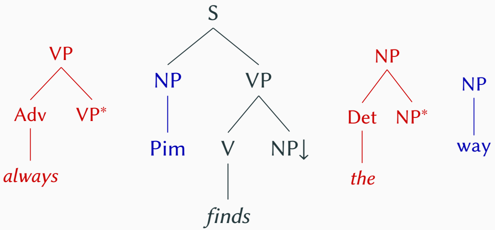

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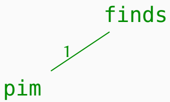

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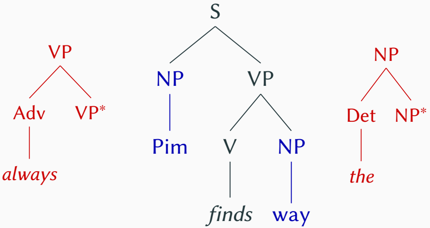

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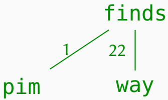

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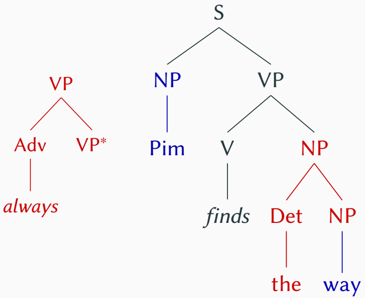

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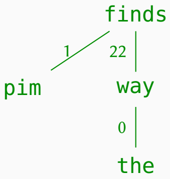

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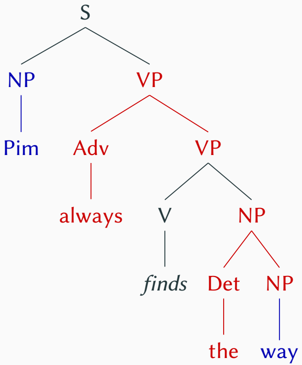

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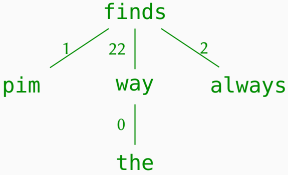

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Linguistic analyses with LTAG

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⇒ Design principle of economy

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⇒ TAG → LTAG: Lexicalized Tree-Adjoining Grammar

[Schabes & Joshi 1990, Joshi & Schabes 1991]

(Recall: reasons for lexicalization!)

Syntactic design principles (2): FTH

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“syntactic dependency”

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“expressed within an elementary tree”

- terminal leaf (i.e. lexical anchor)
- nonterminal leaf (substitution node and footnode)
- marking an inner node for obligatory adjunction

⇒ extended domain of locality

Complex primitives

Complicate locally, simplify globally.

"[...] start with complex (more complicated) primitives, which capture directly some crucial linguistic properties and then introduce some general operations for composing these complex structures (primitive or derived). What is the nature of these complex primitives? In the conventional approach the primitive structures (or rules) are kept as simple as possible. This has the consequence that information (e.g., syntactic and semantic) about a lexical item (word) is distributed over more than one primitive structure. Therefore, the information associated with a lexical item is not captured locally, i.e., within the domain of a primitive structure."

[Joshi 2004]

Syntactic design principles (3): CETM

Condition on Elementary Tree Minimality (CETM)

The syntactic heads in an elementary tree and their projections must form the extended projection of a single lexical head.

[Frank 2002]

Note: We only use simple, non-extended projections!

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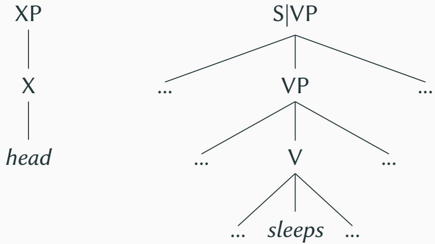

Syntactic design principles (4): θ-Criterion for TAG

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Syntactic design principles (4): θ-Criterion for TAG

θ-Criterion (TAG version) **[Frank 2002]**

a. If H is the lexical head of an elementary tree T,
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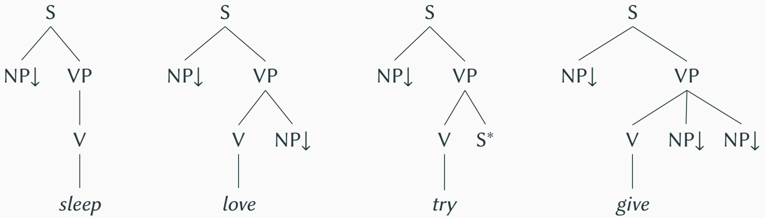

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Design principle of economy

The elementary trees are shaped in such a way, that the size of the elementary trees and the size of the grammar is minimal.

Sample derivations: NP and PP complements

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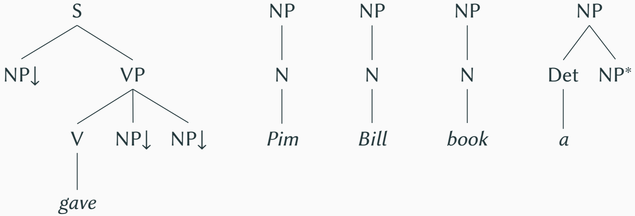

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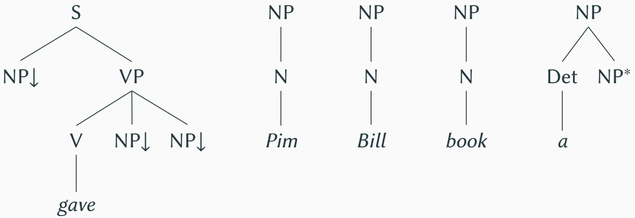
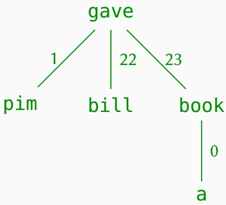


Derivation tree:



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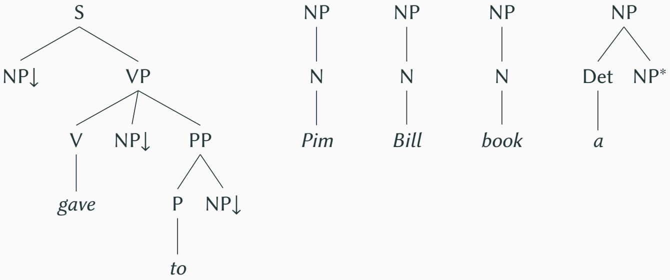

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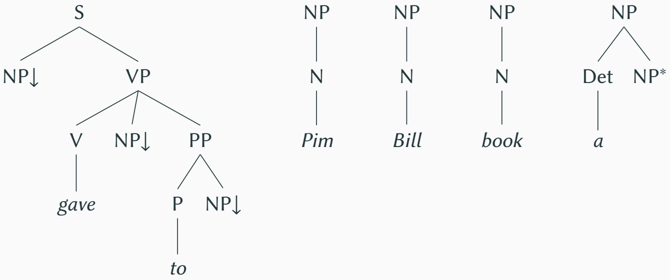

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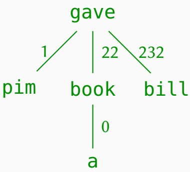

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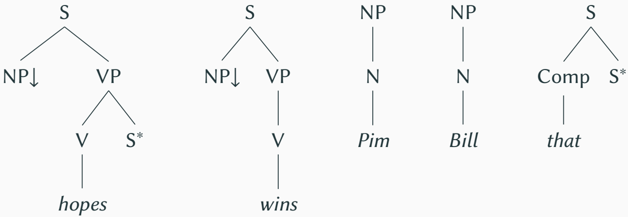

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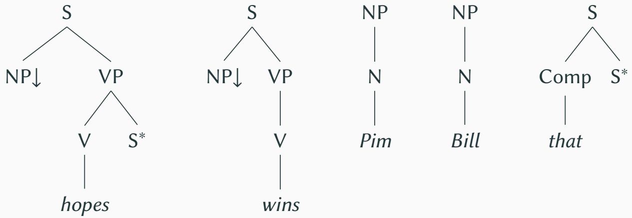

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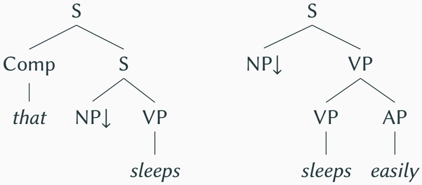

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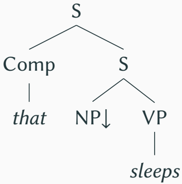
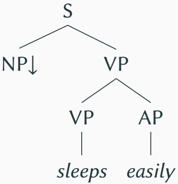
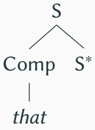
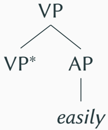




- or by separate auxiliary trees (e.g., XTAG grammar)





⇒ Footnodes/Adjunctions indicate both complementation and modification.

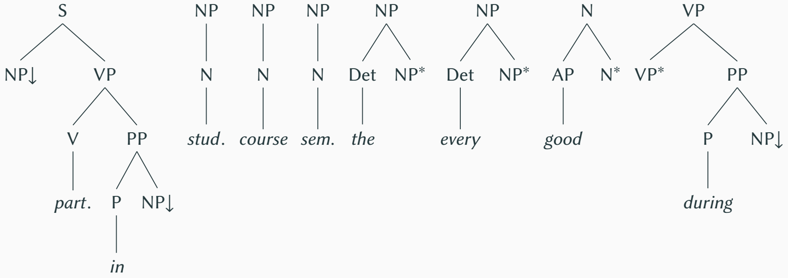
⇒ Enhancement of the CETM

[see Abeille & Rambow 2000]

Sample derivations: Modifiers

(4) The good student participated in every course during the semester.

Elementary trees:



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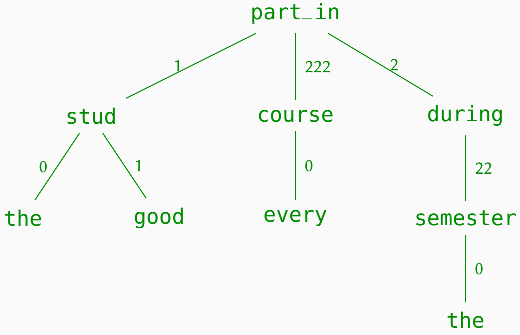

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- also: definiteness agreement (Hungarian), ...

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- combining constituents ⇒ **unify** feature structures

Unification

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For any feature structure F: $F \sqcup [\,] = [\,] \sqcup F = F$

⇒ The empty feature structure is the **identity element** for unification

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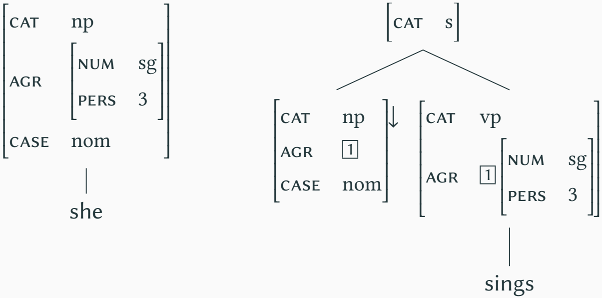

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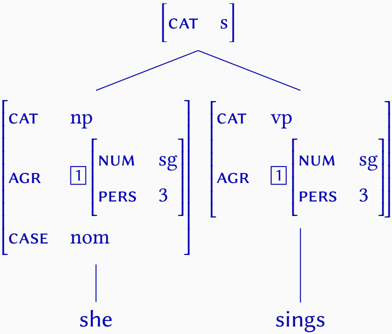

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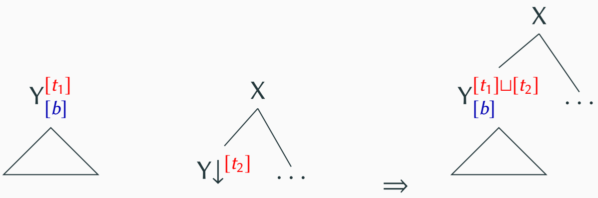
FTAG: Substitution

Substitution in FTAG

The top features of the root of the tree to substitute unify with the top features of the substitution node.

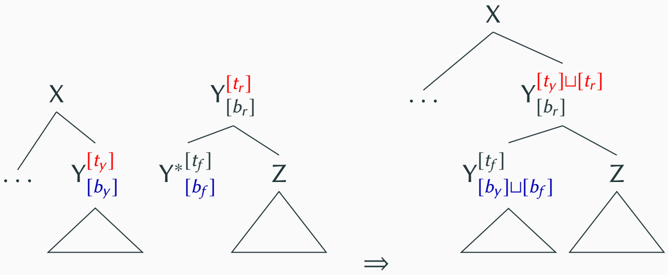


- substitution nodes (Y↓) have only top features

FTAG: Adjunction

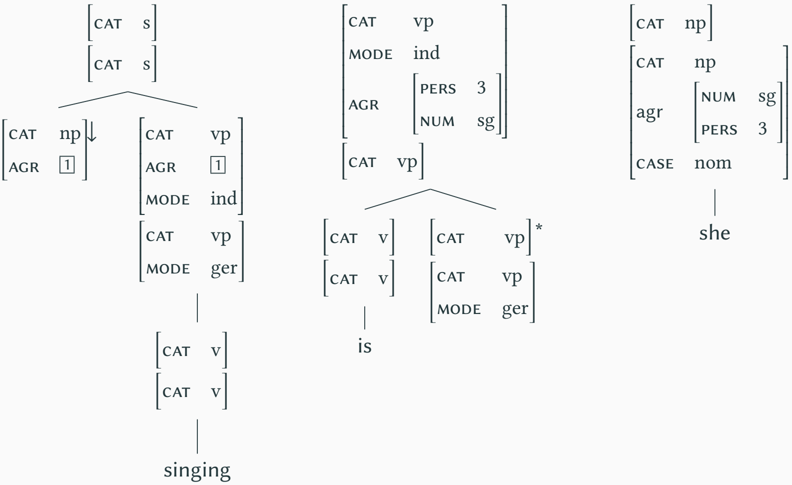
Adjunction in FTAG

The top features of the root of the auxiliary tree unify with the top features of the adjunction node, and the bottom features of the footnode of the auxiliary tree unify with the bottom features of the adjunction node.



FTAG Example: *She is singing.*

Obligatory adjunction: feature mismatch between top and bottom



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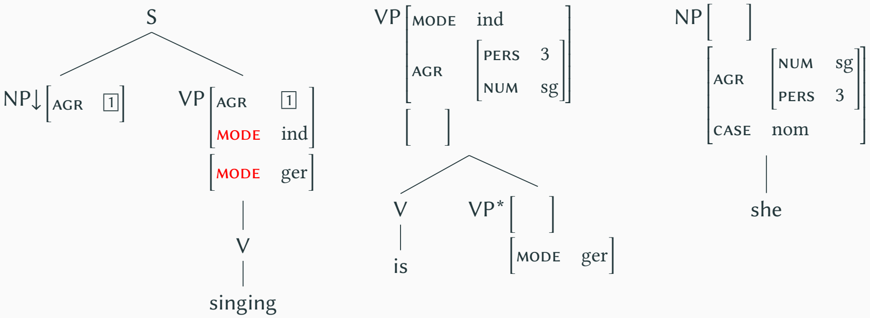

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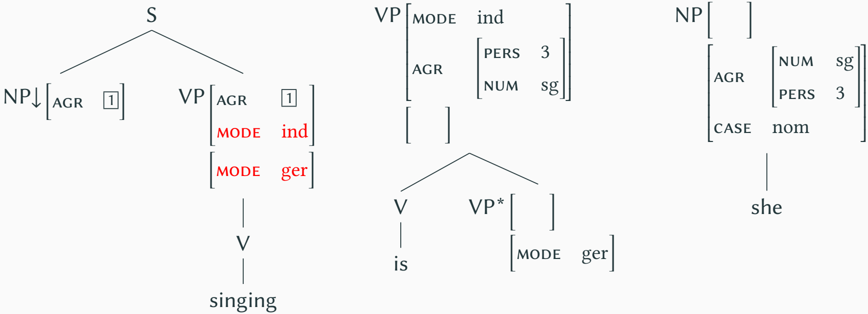

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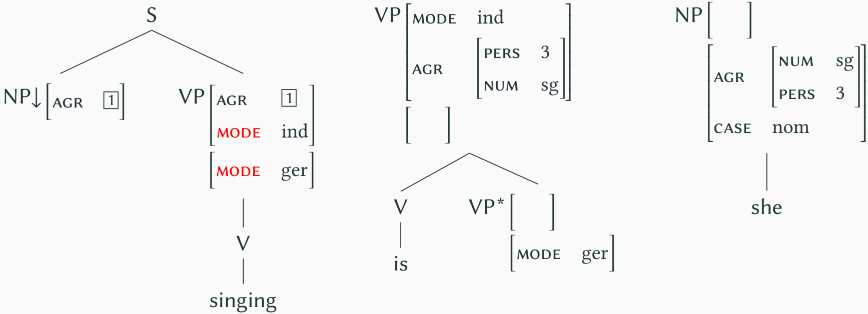

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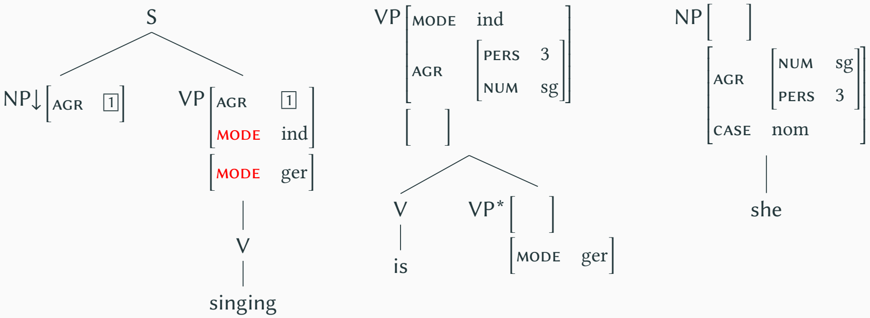

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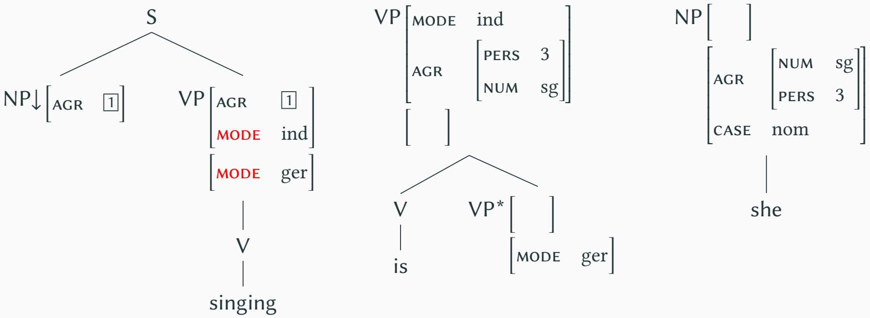

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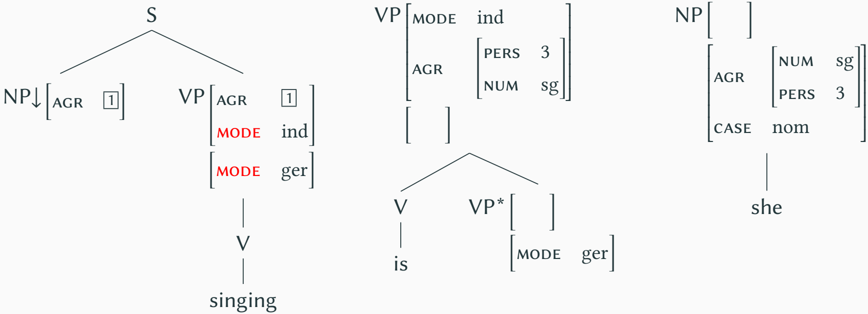

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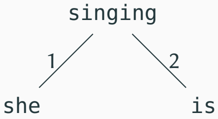

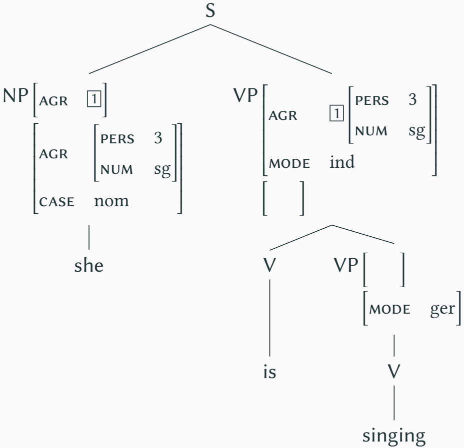

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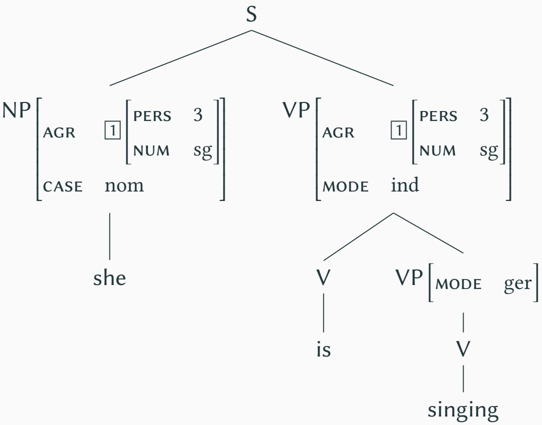

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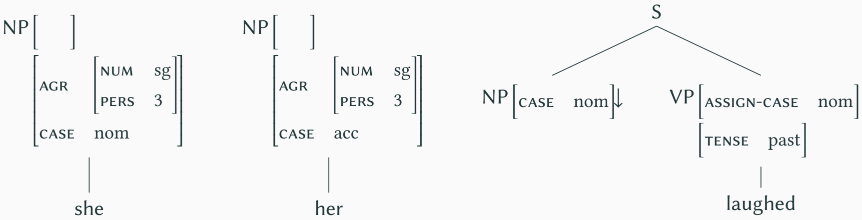

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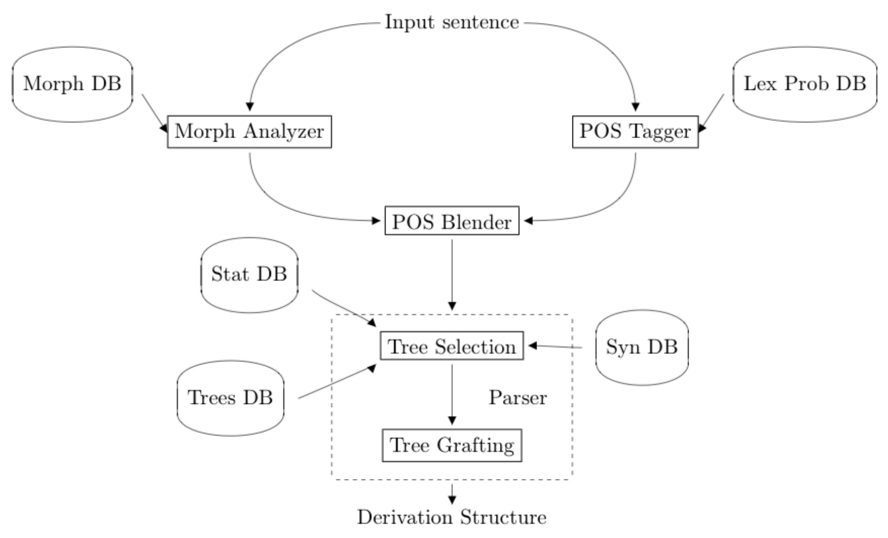
- the architecture of the XTAG-grammar

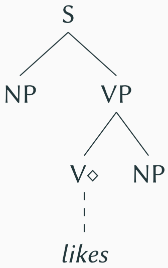
Morph Database	inflected form → root form, POS, inflectional information
Syntactic Database	root form, POS → list of tree templates or or tree families, list of feature equations
Tree Database	list of tree templates and tree families

The architecture of the XTAG-grammar



Lexical insertion

- drawing an edge between the lexical anchor and the lexical insertion site
- prior to substitution and adjunction
- the feature structures of the **lexical anchor** and the **insertion site** unify



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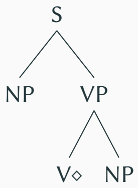
tree template for the declarative transitive verb (α`nx0Vnx1`):



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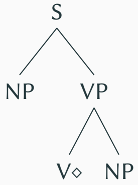

A tree family

- is a set of tree templates
- represents a subcategorization frame, and

  contains all syntactic configurations the subcategorization frame can be realized in

Example: α`nx0Vnx1` $\in$ `Tnx0Vnx1`

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Some figures

[Prolo 2002]

subcat. group	no. of families	no. of trees
intransitive	1	12
transitive	1	39
ditransitive	1	46
light verb constr.	2	53
⋮	⋮	⋮
TOTAL:	57	1008

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