

Tree-Adjoining Grammars: Theory and implementation

Day 2

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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 **initial 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.

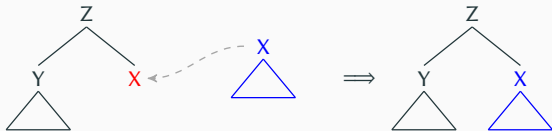
The trees in $I \cup A$ are called **elementary trees**.

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

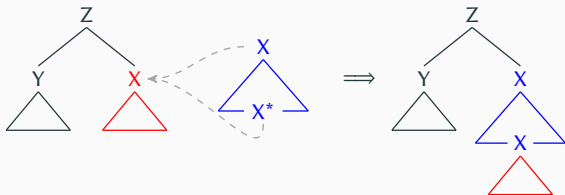
- **obligatory adjunction (OA):** $O(v) = 1$
- **null adjunction (NA):** $O(v) = 0$ and $C(v) = \emptyset$
- **selective adjunction (SA):** $O(v) = 0$ and $C(v) \neq \emptyset$ and $C(v) \neq A$

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 ($O(n^6)$)

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

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

[Schabes 1990, Joshi & Schabes 1997]

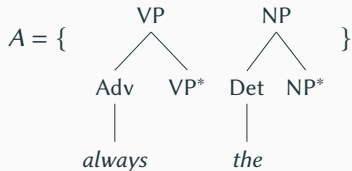
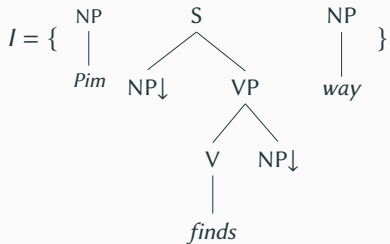
TAG is linguistically, computationally and psycholinguistically **adequate**.

Example TAG

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

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

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



XP↓: substitution node

XP*: foot node

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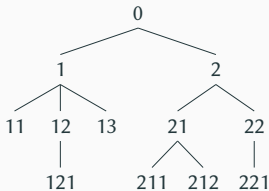
Derivation in TAG

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- **derived tree** in TAG
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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:

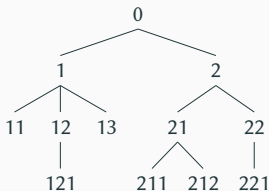
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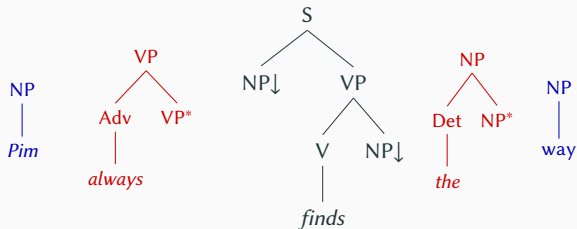


Derivation tree

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 .

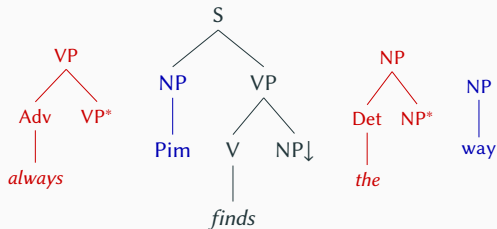
Important: the Gorn addresses always refer to position in the elementary trees, not in the (partially) derived tree.

Example derivation

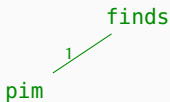


Derivation tree:

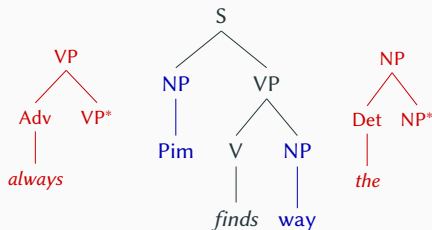
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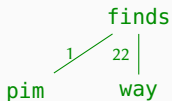
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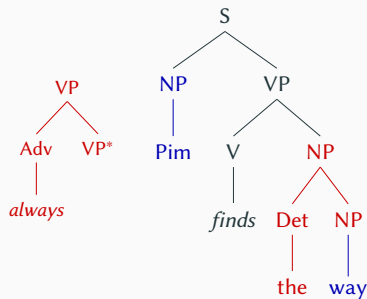
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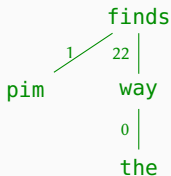
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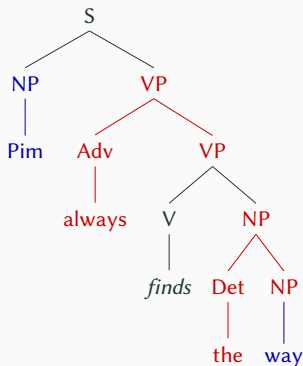


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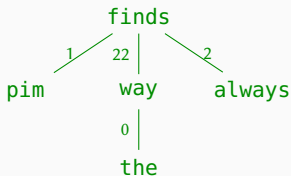


Example derivation

Derived tree:



Derivation tree:



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syntactic/semantic properties
of linguistic objects



elementary trees

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\Rightarrow Syntactic design principles

[Frank 2002]

- Lexicalization
- Fundamental TAG Hypothesis (FTH)
- Condition on Elementary Tree Minimality (CETM)
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[Abeille & Rambow 2000]

Linguistic analyses with LTAG

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Syntactic design principles (1): Lexicalization

Each elementary tree has at least one non-empty lexical item, its **lexical anchor**.

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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

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!

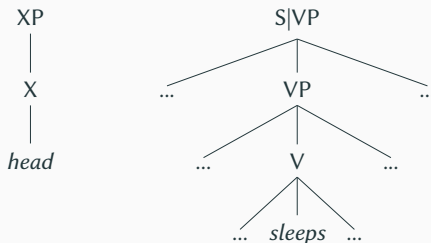
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The semantic relationship of an argument with its predicate is expressed through the assignment of a role by the predicate to the argument.

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- *Bart kicked the ball.*
 - *kicked* \leadsto predicate
 - *Bart* \leadsto AGENT
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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,
H assigns all of its θ -roles in T.
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⇒ Valency/subcategorization is expressed only with non-terminal leaves!

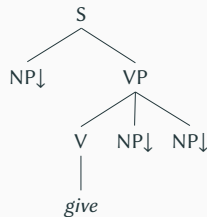
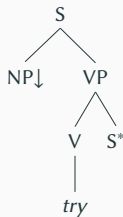
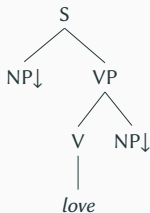
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Design principle of economy

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

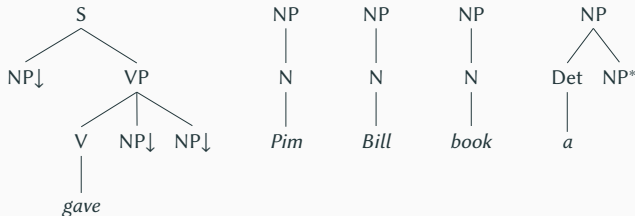
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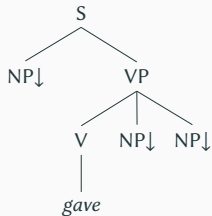
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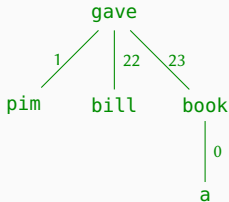
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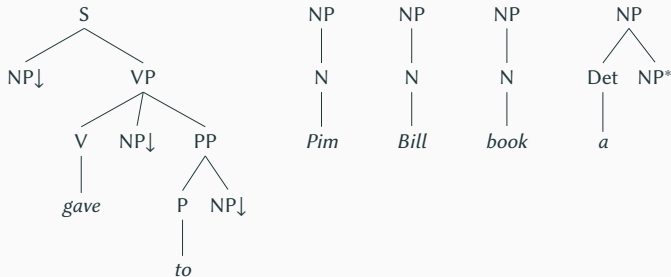
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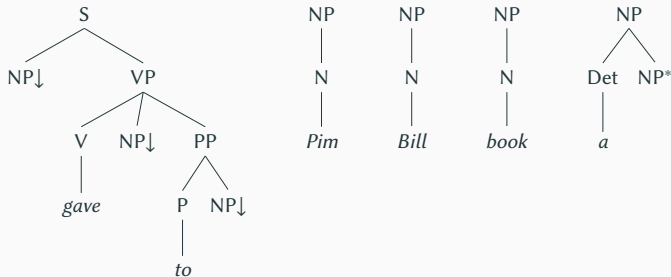
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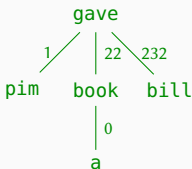
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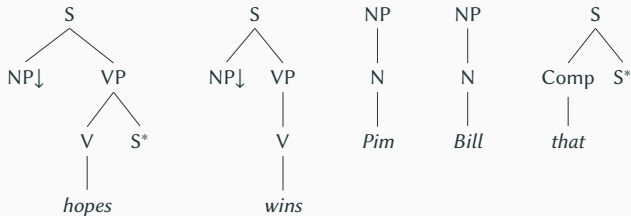
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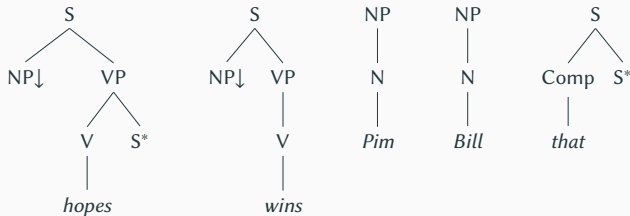
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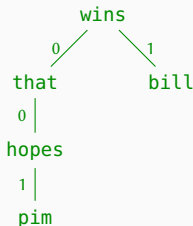
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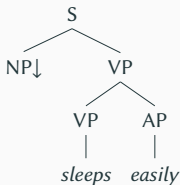
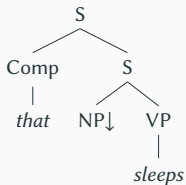
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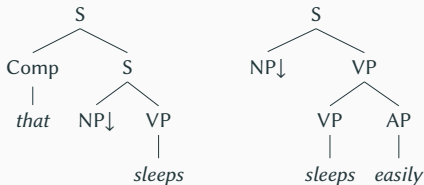
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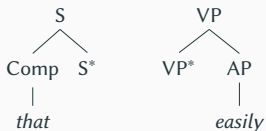
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- or by separate auxiliary trees (e.g., XTAG grammar)



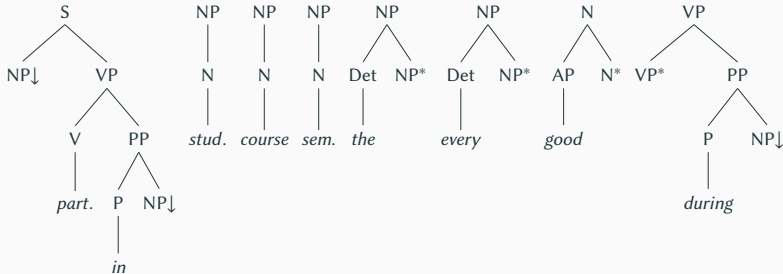
⇒ Footnodes/Adjunctions indicate both complementation and modification.

⇒ Enhancement of the CETM

Sample derivations: Modifiers

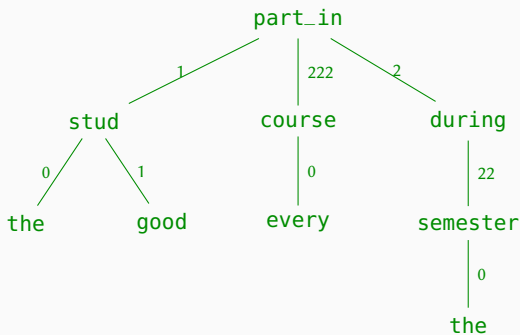
- (4) The good student participated in every course during the semester.

Elementary trees:



Sample derivations: Modifiers

Derivation tree:



Feature structures

- generalizing agreement and case marking
- modelling adjunction constraints (TAG specific)

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

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- partial operation \Rightarrow unification can fail

$$\begin{bmatrix} \text{CAT} & \text{np} \\ \text{NUM} & \text{sg} \end{bmatrix} \sqcup \begin{bmatrix} \text{CAT} & \text{np} \\ \text{NUM} & \text{pl} \end{bmatrix} = \text{FAIL}$$

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$$\left[\begin{array}{cc} \text{CAT} & \text{vp} \\ \text{AGR} & \left[\begin{array}{cc} \text{NUM} & \text{pl} \end{array} \right] \end{array} \right] \sqcup \left[\begin{array}{cc} \text{CAT} & \text{vp} \\ \text{AGR} & \left[\begin{array}{cc} \text{PERS} & 3 \end{array} \right] \end{array} \right] = \left[\begin{array}{cc} \text{CAT} & \text{vp} \\ \text{AGR} & \left[\begin{array}{cc} \text{NUM} & \text{pl} \\ \text{PERS} & 3 \end{array} \right] \end{array} \right]$$

- partial operation \Rightarrow unification can fail

$$\left[\begin{array}{cc} \text{CAT} & \text{np} \\ \text{NUM} & \text{sg} \end{array} \right] \sqcup \left[\begin{array}{cc} \text{CAT} & \text{np} \\ \text{NUM} & \text{pl} \end{array} \right] = \text{FAIL}$$

- underspecified feature values

$$\left[\begin{array}{cc} \text{CAT} & \text{np} \\ \text{CASE} & \text{nom} \mid \text{acc} \end{array} \right] \sqcup \left[\begin{array}{cc} \text{CAT} & \text{np} \\ \text{CASE} & \text{acc} \end{array} \right] = \left[\begin{array}{cc} \text{CAT} & \text{np} \\ \text{CASE} & \text{acc} \end{array} \right]$$

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

\Rightarrow The empty feature structure is the **identity element** for unification

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TAG with feature structures

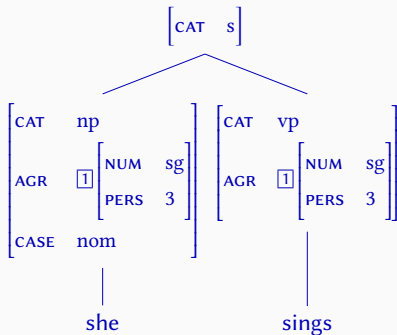
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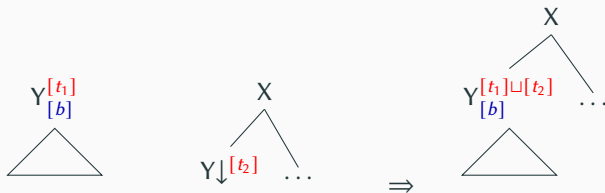
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FTAG: Substitution

Substitution in FTAG

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

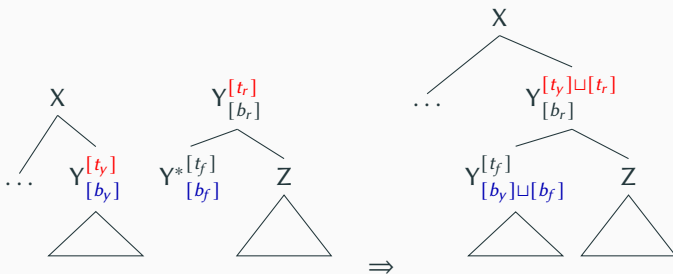


- substitution nodes ($Y\downarrow$) have only top features

FTAG: Adjunction

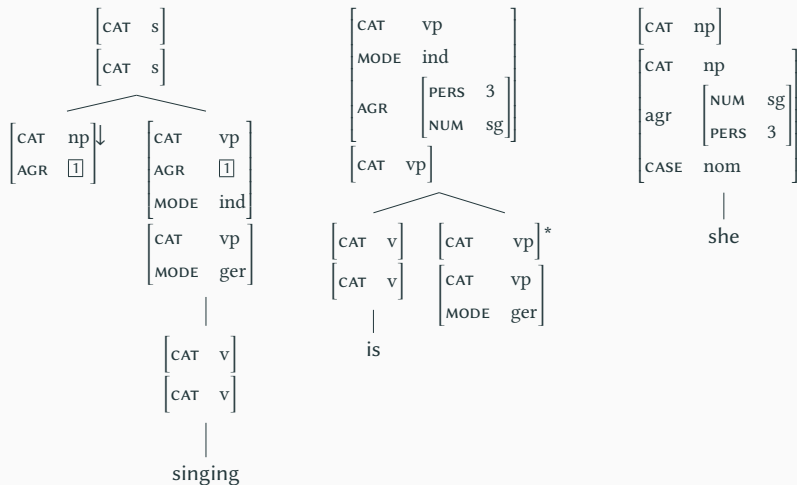
Adjunction in FTAG

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.

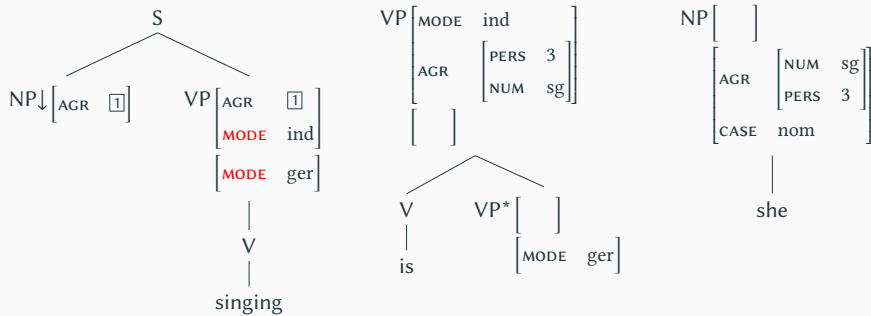


FTAG Example: *She is singing.*

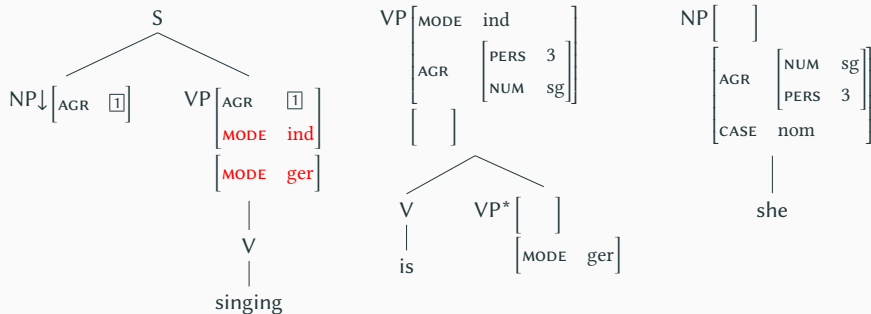
Obligatory adjunction: feature mismatch between top and bottom



FTAG Example: *She is singing.*

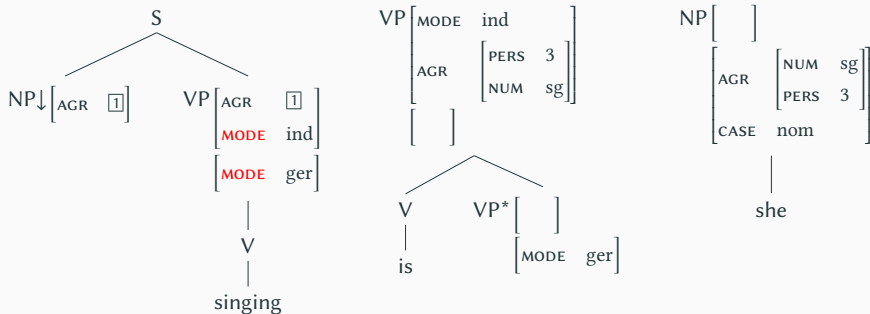


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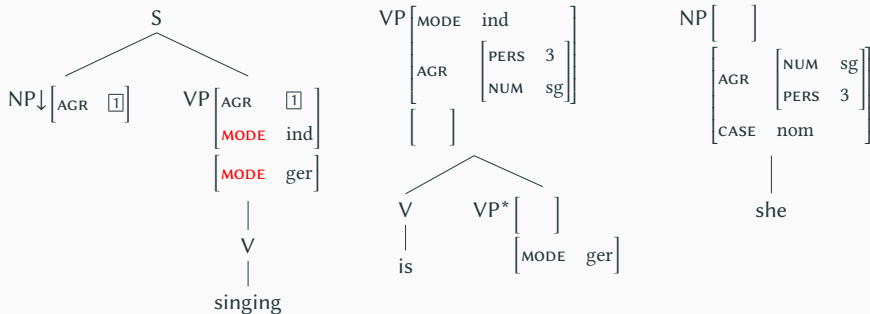
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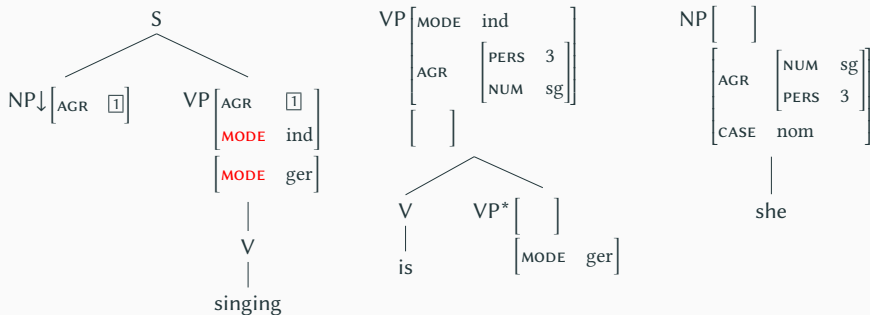
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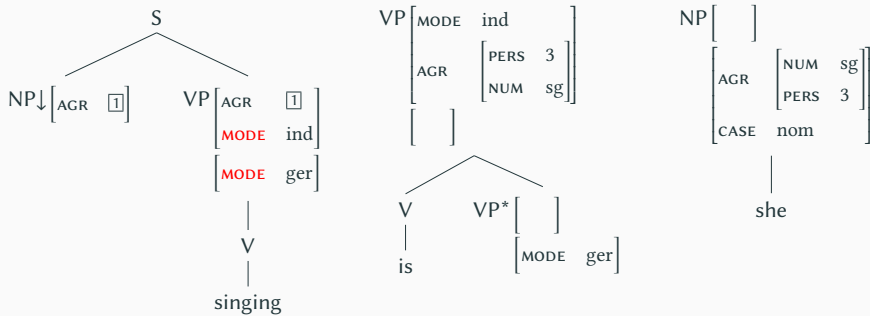
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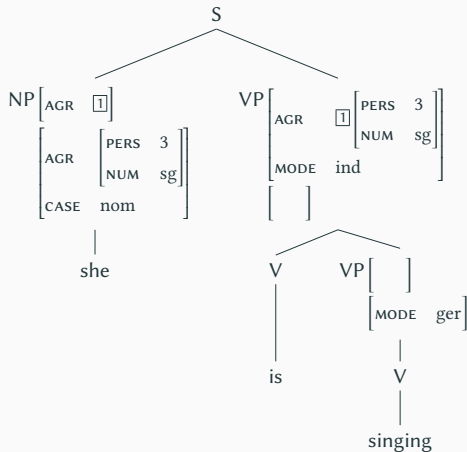
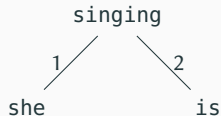
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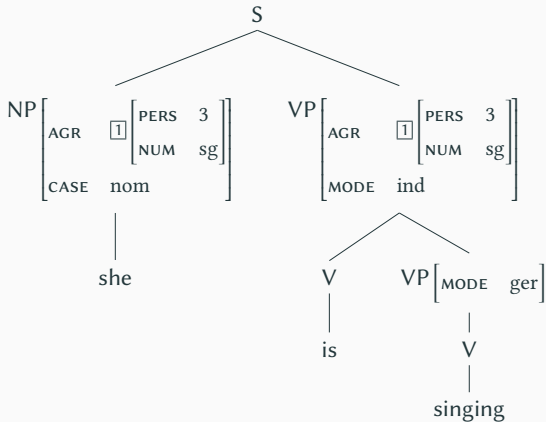
FTAG Example: *She is singing.*

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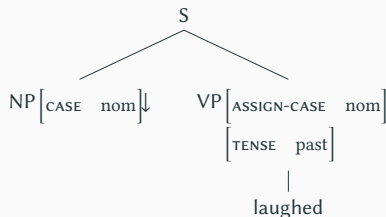
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The XTAG-project

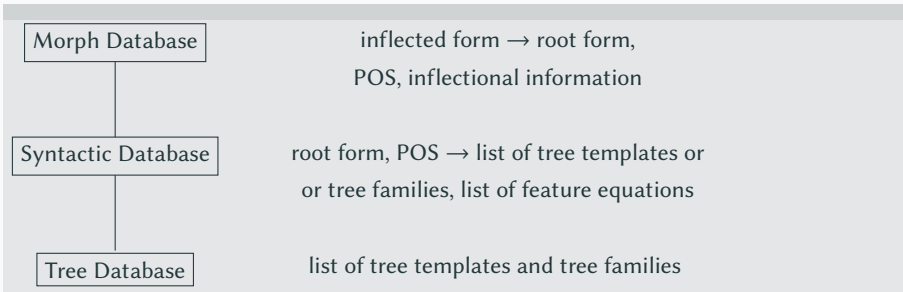
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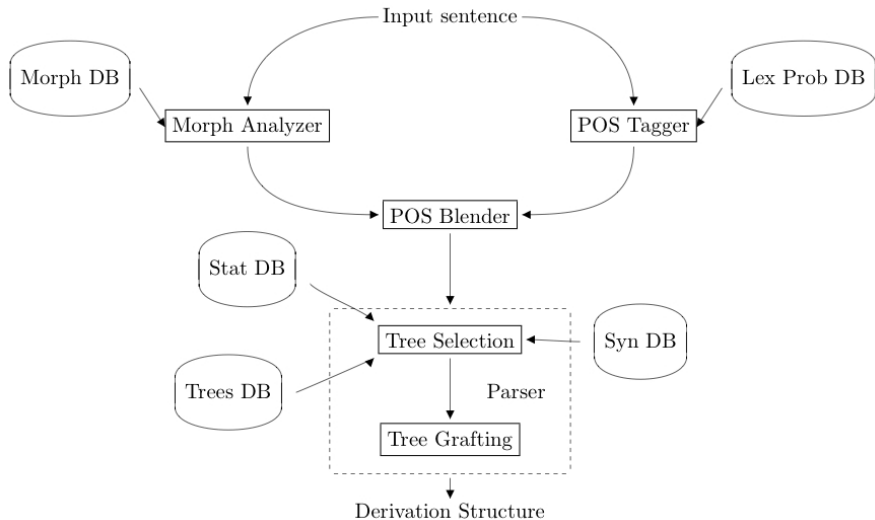
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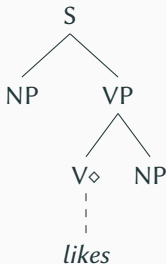


The architecture of the XTAG-grammar



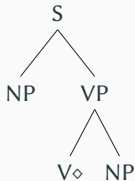
Lexical insertion

- 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



The architecture of the XTAG-grammar

tree template for the declarative transitive verb ($\alpha x_0 V x_1$):



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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: $\alpha n x 0 V n x 1 \in T n x 0 V n x 1$

Tree families

Example tree families

- intransitive: Tnx0V

tree templates: base tree, wh-moved subject, imperative, determiner gerund,
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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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