Lexicalized Tree Adjoining Grammar

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Outline

- **Introduction**
- **Tree Adjoining Grammar**
- **Some Important TAG Properties**
- **Lexicalized Tree Adjoining Grammar**

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- Lexicalized Tree Adjoining Grammar

Motivation

Motivation is of linguistic and formal nature.

- Elementary objects are trees - structured objects and not strings.
- Structured objects are related with strong generative capacity. $\Rightarrow$ More relevant to linguistic description.
- TAG allow *factoring recursion* from the statement of linguistic dependencies
- Lexicalization of grammar formalism.

- TAG is tree-generating system $\Rightarrow$ the set of trees constitute the *object language*
- One well known normal form of grammars - Greibach Normal Form (GNF) is a kind of lexicalization.

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Definition

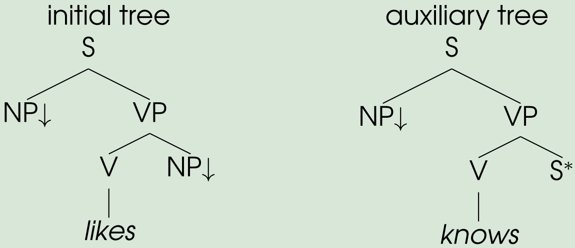
Tree Adjoining Grammar (TAG) is a quintuple (T, N, I, A, S).

- $T \ldots$ a finite set of terminal symbols
- $N \ldots$ a finite set of nonterminal symbols; $T \cap N = \emptyset$
- $I \ldots$ a finite set of initial trees
  - An initial tree is a phrase structure tree
- $A \ldots$ a finite set of auxiliary trees
  - An auxiliary tree is a phrase structure tree that has a leaf nonterminal node that is the same as its root symbol
- $S \ldots$ start symbol, $S \in N$

- Trees in I and A are called elementary trees.
- Parsing is done by two operations: substitution and adjunction.

An example of an initial and an auxiliary tree

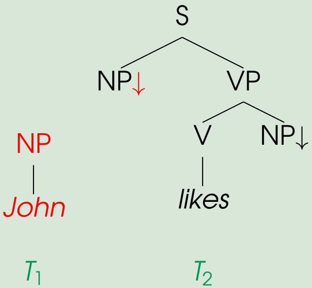
Example



- A nonterminal symbol marked by * is the foot node of an auxiliary tree.
- A nonterminal symbol marked by ↓ is a nonterminal node for substitution.

Substitution of an initial tree T_1 into a tree T_2 is to replace a substitution node in T_2 with T_1.

Example



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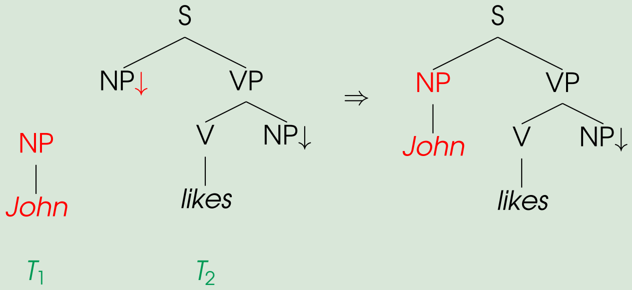
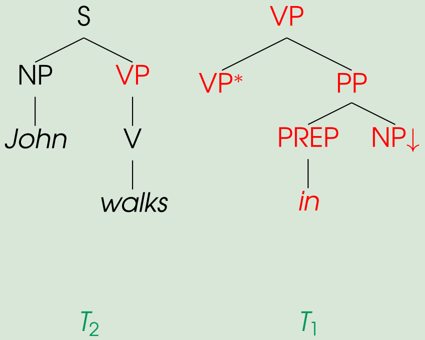


Adjoining an auxiliary tree T_1 into a tree T_2 is to inset T_1 into T_2 at the node that is the same as the root (and the foot) of T_1.

Example



Adjoining an auxiliary tree T_1 into a tree T_2 is to inset T_1 into T_2 at the node that is the same as the root (and the foot) of T_1.

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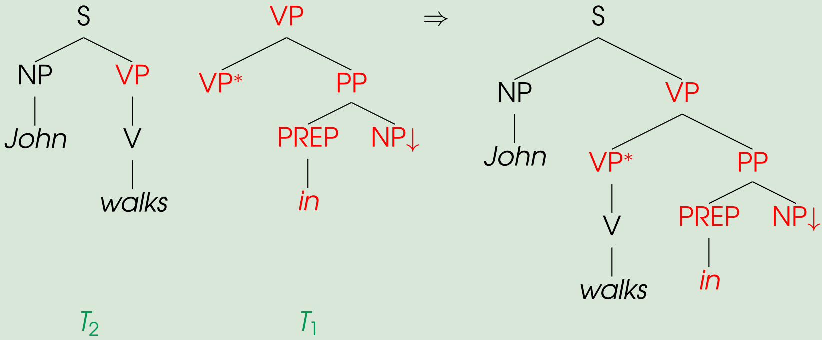


T_1 is adjoined at VP in T_2

Adjunction (Adjoining)

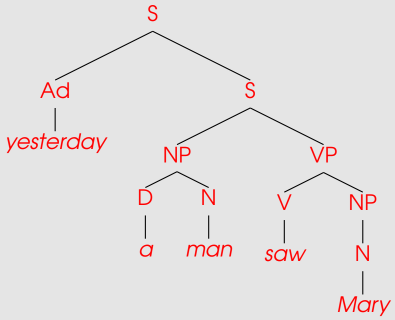
- Any adjunction on a node marked for substitution is *disallowed*.

Adjoining Constraints

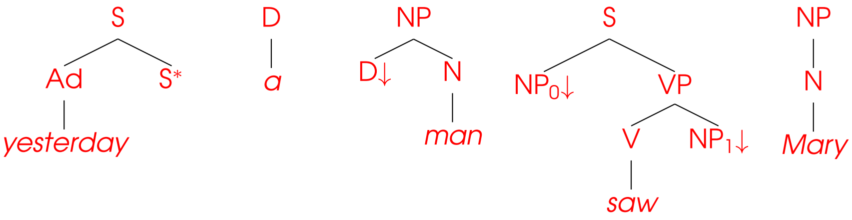
to have more precision for specifying which auxiliary trees can be adjoined at a given node.

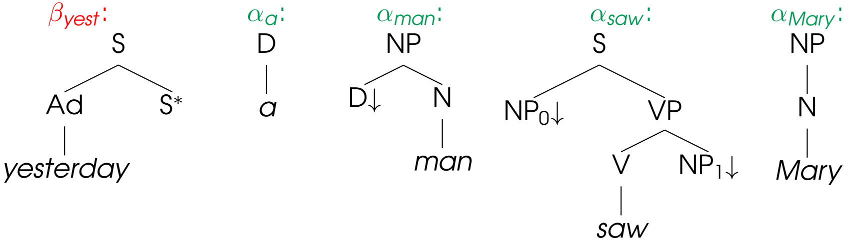
1. *Selective Adjunction* (S A(T)) - only members of a set $T \subseteq A$ of auxiliary trees can be adjoined on the given node, the adjunction of an auxiliary is not mandatory on the given node.
2. *Null Adjunction* (N A) - disallows any adjunction on the given node.
3. *Obligatory Adjunction* (O A(T)) - an auxiliary tree member of the set $T \subseteq A$ must be adjoined on the given node.

- These constraints on adjoining are needed for formal reasons in order to obtain some closure properties.

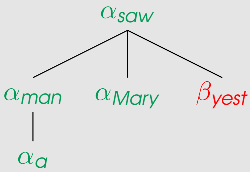


This tree yields the sentence *Yesterday a man saw Mary* and is derived from the following *elementary* trees:





Derivation tree for *Yesterday a man saw Mary.*



The order in which the derivation tree is interpreted has no impact on the resulting derived tree.

Derivation in TAG

Derived Tree

A tree built by composition of two others trees.

- the derived tree does not give enough information to determine how it was constructed
- adjunction and substitution are considered in a TAG derivation

Derivation Tree

It is an object that specifies uniquely how a derived tree was constructed.

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Tree Sets and String Languages

Tree Set of a TAG T_G

- Defined as the set of completed initial trees derived from some *S-rooted initial trees*.

$$T_G = \{t | t \text{ is derived from some S-rooted initial tree}\}$$

- Note that completed initial tree is an initial tree with no substitution nodes.

Tree String language of a TAG L_G

- Defined as the set of yields of all trees in the tree set.

$$L_G = \{w | w \text{ is the yield of some } t \text{ in } T_G\}$$

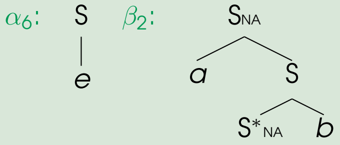
Some Properties of the Tree Sets and String Languages

- All closure properties of context-free languages (CFL) also hold for tree-adjoining languages (TAL).
- $CFL \subset TAL$
- TAL can be parsed in polynomial time.
- Tree-adjoining grammars generate some context-sensitive languages.

Some Properties of the Tree Sets and String Languages: Example 1

Example

Consider following TAG $G_1 = (\{a, e, b\}, \{S\}, \{\alpha_6\}, \{\beta_2\}, S)$

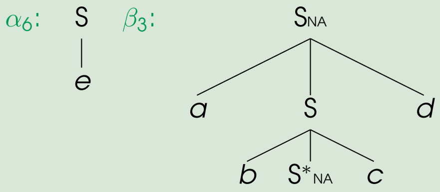


- G_1 generates the language $L_1 = \{a^n e b^n | n \geq 1\}$

Some Properties of the Tree Sets and String Languages: Example 2

Example

Consider following TAG $G_1 = (\{a, b, c, d, e\}, \{S\}, \{\alpha_6\}, \{\beta_3\}, S)$

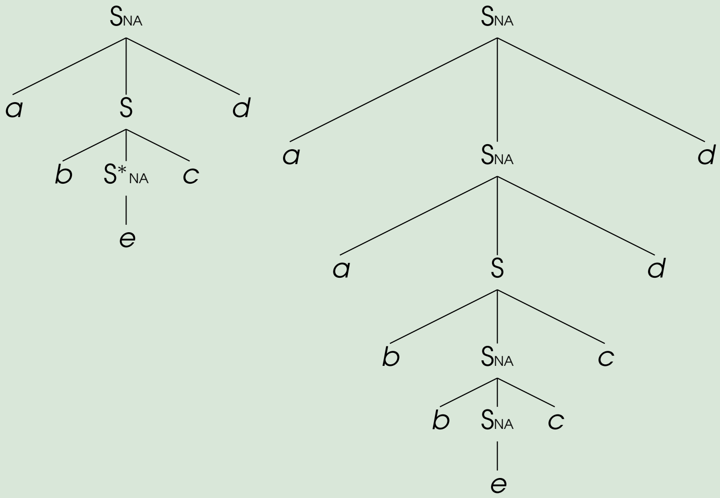


- G_1 generates the language $L_1 = \{a^n b^n e c^n d^n | n \geq 1\}$

Some Properties of the Tree Sets and String Languages: Example 2

Example

Some derived trees of G_2



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Lexicalized Grammar

- Each elementary structure is associate with a lexical item.
- The grammar consists of *lexicon*, where:
  - each lexical item is associated with a finite number of structures and
  - there are operations which tell how these structures are composed.

Definition

- A grammar is lexicalized if it consists of a finite set of structures each associated with a lexical item.
- Each lexical item is called the anchor of the corresponding structure.
- Grammar contains an operation or operations for composing the structure.

- LTAG is a TAG in which every elementary (initial and auxiliary) tree is anchored with a lexical item.

Notes

- The *anchor* must be overt (= not empty string).
- The structures defined by the lexicon are called *elementary structures*.
- Structures built up by combination of others are called *derived structures*.

The definition of Lexicalized Grammar implies the following proposition:

Proposition

Lexicalized grammars are finitely ambiguous.

Further, this closure property holds:

Closure under lexicalization

TAGs are closed under lexicalization.

Conclusion

Notes

- Lexicalization of grammars is of linguistic and formal interest.
- Rules should not be separated from their lexical realization.
- By using TAGs we can lexicalize the CFGs.
- Substitution and adjunction gives this possibility to lexicalize CFG.

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