Syntax-Driven Semantic Frame Composition in Lexicalized Tree Adjoining Grammars

Laura Kallmeyer

(joint work with Rainer Osswald)

SFB 991, Heinrich-Heine Universität Düsseldorf

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Overview

1. Motivation: Constructions contribute to meaning
2. Modelling constructions with Lexicalized Tree Adjoining Grammars
3. Semantic (de)composition: Directed motion expressions
4. Semantic (de)composition: Dative alternation
5. Factorization in the lexicon: Metagrammar
6. Conclusion

[Kallmeyer and Osswald, 2014]

Motivation (1)

- The meaning of a verb-based construction does not only depend on the lexical meaning of the verb but also on its specific syntagmatic environment.
- This has led Construction Grammar to treating every linguistic expression as a construction [Goldberg, 1995].
- The influence of the syntagmatic context on the constitution of verb meaning has also been taken into account by lexicalist approaches to argument realization [Van Valin and LaPolla, 1997].

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- The influence of the syntagmatic context on the constitution of verb meaning has also been taken into account by lexicalist approaches to argument realization [Van Valin and LaPolla, 1997].

Question: How are the meaning components distributed over the lexical and morphosyntactic units of a linguistic expression and how do these components combine?

Motivation (2): Dative alternation

Verbs like *give*, *send*, and *throw* can occur in both the double object (DO) and the prepositional object (PO) construction:

(1) a. John sent Mary the book. (DO)
    b. John sent the book to Mary. (PO)

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These constructions are traditionally associated with a ‘caused possession’ (1-a) and ‘caused motion’ (1-b) interpretation, respectively [Goldberg, 1995].

(2) a. $\exists e \exists e' \exists s[\text{CAUSATION}(e) \wedge \text{CAUSE}(e, e') \wedge \text{AGENT}(e', x) \wedge \text{EFFECT}(e, s) \wedge s : \text{HAVE}(y, z)]$ (DO)
    b. $\exists e \exists e' \exists e''[\text{CAUSATION}(e) \wedge \text{CAUSE}(e, e') \; \text{AGENT}(e', x) \wedge \text{EFFECT}(e, e'') \wedge \text{MOTION}(e'') \wedge \text{THEME}(e'', y) \wedge \text{GOAL}(e'', z)]$(PO)

Motivation (3): Dative alternation

Representation as frames:

DO frame:

$$\begin{bmatrix} \textit{causation} & \\ \text{CAUSE} & \begin{bmatrix} \textit{event} & \\ \text{AGENT} & \boxed{1} \end{bmatrix} \\ \text{EFFECT} & \begin{bmatrix} \textit{possession} & \\ \text{POSSESSOR} & \boxed{3} \\ \text{THEME} & \boxed{2} \end{bmatrix} \end{bmatrix}$$

$$\exists e \exists e' \exists s [\text{CAUSATION}(e) \\ \wedge\ \text{CAUSE}(e, e')\ \wedge\ \text{AGENT}(e', x) \\ \wedge\ \text{EFFECT}(e, s)\ \wedge\ s : \text{HAVE}(y, z)]$$

PO frame:

$$\begin{bmatrix} \textit{causation} & \\ \text{CAUSE} & \begin{bmatrix} \textit{event} & \\ \text{AGENT} & \boxed{1} \end{bmatrix} \\ \text{EFFECT} & \begin{bmatrix} \textit{motion} & \\ \text{THEME} & \boxed{2} \\ \text{GOAL} & \boxed{3} \end{bmatrix} \end{bmatrix}$$

$$\exists e \exists e' \exists e'' [\text{CAUSATION}(e) \\ \wedge\ \text{CAUSE}(e, e')\ \text{AGENT}(e', x) \\ \wedge\ \text{EFFECT}(e, e'')\ \wedge\ \text{MOTION}(e'') \\ \wedge\ \text{THEME}(e'', y)\ \wedge\ \text{GOAL}(e'', z)]$$

Motivation (4): Directed motion

Directional expressions in English can be constructed from verbs of motion and directional PPs. The relevant constructions include intransitive verbs of motion (3) as well as transitive verbs of caused motion and transport (4).

(3) a. Mary walked to the house.
    b. The ball rolled into the goal.

(4) a. John threw/kicked the ball into the goal.
    b. John pushed/pulled the cart to the station.
    c. John rolled the ball into the hole.

Motivation (5): Directed motion

The motion verb does not lexicalize a *goal*.

(5) a. Mary ran.
 b. Mary ran to the house.

(6) a. $\exists e[\text{MOVE}(e) \wedge \text{AGENT}(e,x)]$ (motion)
 b. $\exists e[\text{MOVE}(e) \wedge \text{AGENT}(e,x) \wedge \text{GOAL}(e,y)]$
 (directed motion)

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Corresponding frames:

$$\begin{bmatrix} \textit{motion} \\ \text{AGENT} \ \boxed{1} \end{bmatrix} \qquad \begin{bmatrix} \textit{motion} \\ \text{AGENT} \ \boxed{1} \\ \text{GOAL} \ \boxed{2} \end{bmatrix}$$

Motivation (6)

Question: How can we characterize the relevant constructions?

- DO construction: a verb having a subject NP, a dative NP and a direct object NP
- PO construction: a verb having a subject NP, a direct object NP and a *to*-PP
- Directed motion: a verb with a subject NP and a directional PP

Motivation (7)

Constructions can be discontinuous in a sentence. I.e., in the syntactic tree, they can cover different tree fragments that are not connected.

(7) a. Whom does Mary want John to send the letter?
   b. John sends his letters always to Mary.
   c. He ran every day to the river.

⇒ we need an extended domain of locality

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Our proposal: **Lexicalized Tree Adjoining Grammars**.

Constructions and LTAG (1)

Tree Adjoining Grammars (TAG) [Joshi/Schabes 1997]:

Tree-rewriting system: set of *elementary* trees with two operations:

Adjunction: replacing an internal node with a new tree.

Substitution: replacing a leaf with a new tree.

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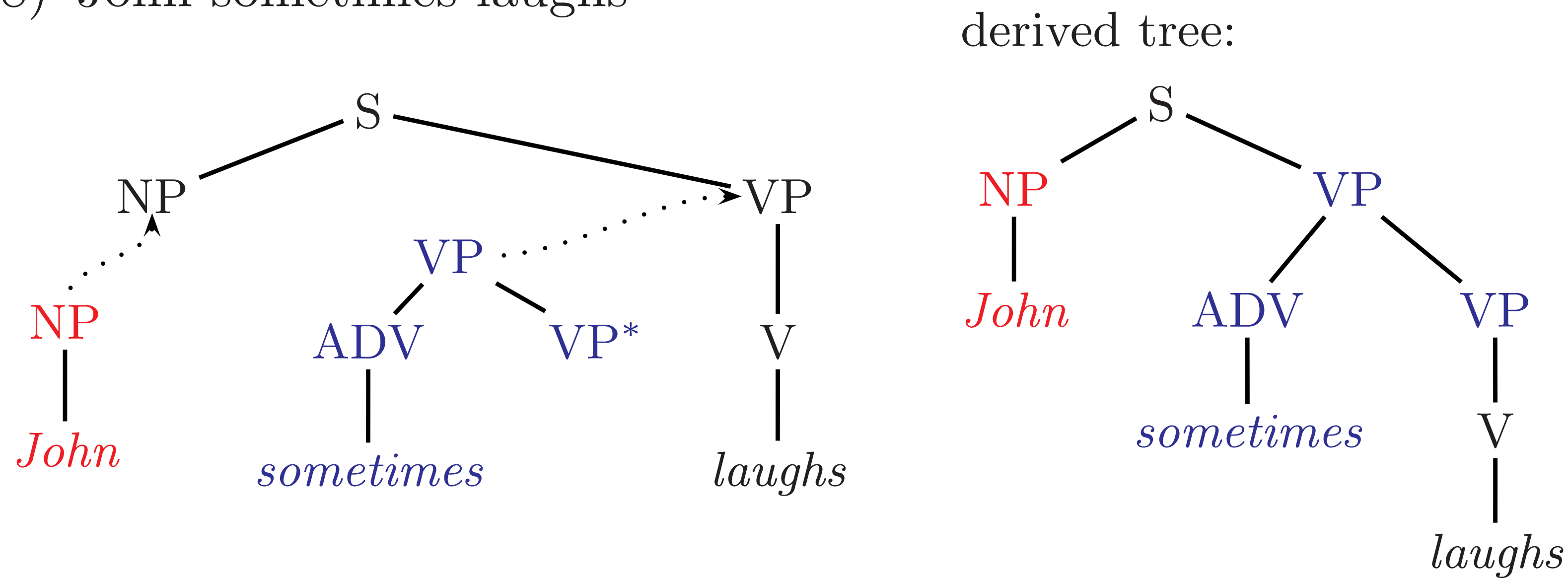
Adjunction: replacing an internal node with a new tree.

Substitution: replacing a leaf with a new tree.

(8) John sometimes laughs



Constructions and LTAG (2)

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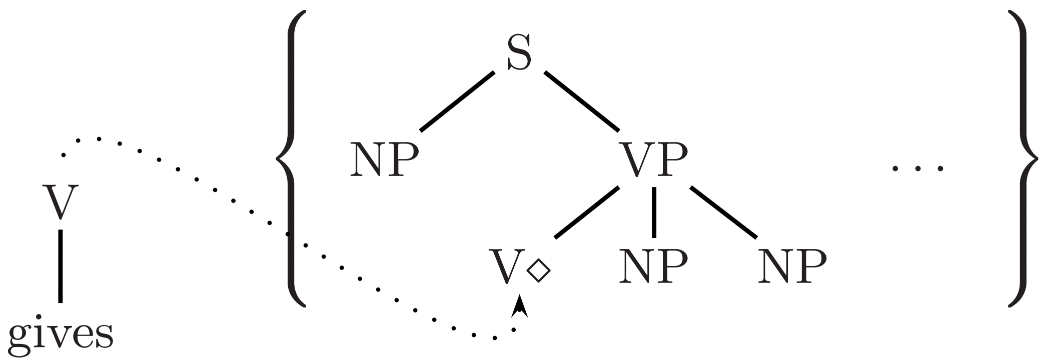
- Recursive parts are put into separate elementary trees that can be adjoined (Factoring of recursion, FR)
- Elementary trees can be arbitrarily large, in particular (because of FR) they can contain elements that are far apart in the final derived tree (Extended domain of locality)
- The elementary tree of a lexical predicate contains slots (non-terminal leaves) for all arguments of the predicate, for nothing more.

Constructions and LTAG (3)

- In a TAG, the trees are organized in tree families.

  Tree families group together trees belonging to the same subcategorization frame.

- The lexicon is further split into unanchored tree families and separate lexical anchors selecting for the tree families.



Constructions and LTAG (4)

There are several reasons why LTAG seems a good candidate for a construction-based semantics:

- LTAG's extended domain of locality allows to acces all the syntactic slots that correspond to the semantic roles specified within the frame of a predicate since they are part of the same elementary tree.

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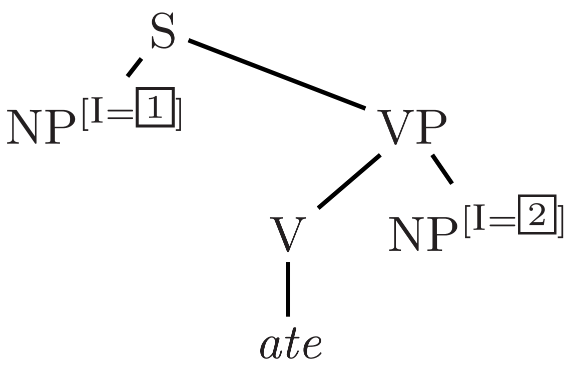
Example:



$$\begin{bmatrix} \textit{eating} & \\ \text{AGENT} & \boxed{1} \\ \text{THEME} & \boxed{2} \end{bmatrix}$$

Constructions and LTAG (5)

- LTAG's unanchored tree families can be regarded as constructional patterns.
- From a constructionist point of view, constructions by themselves can provide aspects of meaning.

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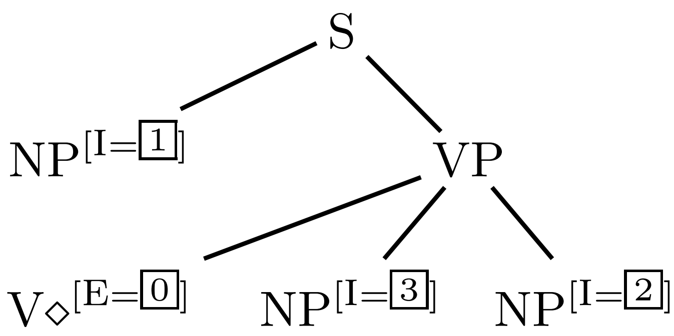
Example: DO construction ≈ caused change of possession



$$\boxed{0}\begin{bmatrix} \textit{causation} & \\ \text{CAUSE} & \begin{bmatrix} \textit{activity} \\ \text{ACTOR} \ \boxed{1} \end{bmatrix} \\ \text{EFFECT} & \begin{bmatrix} \textit{change-of-possession} & \\ \text{THEME} & \boxed{2} \\ \text{RECIPIENT} & \boxed{3} \end{bmatrix} \end{bmatrix}$$

Constructions and LTAG (6)

We assume a syntax-semantics interface where

- each elementary tree is linked to a semantic frame,
- semantic frames are typed feature structures with additional relations between their nodes, and
- semantic composition consists of unifications triggered by substitution and adjunction

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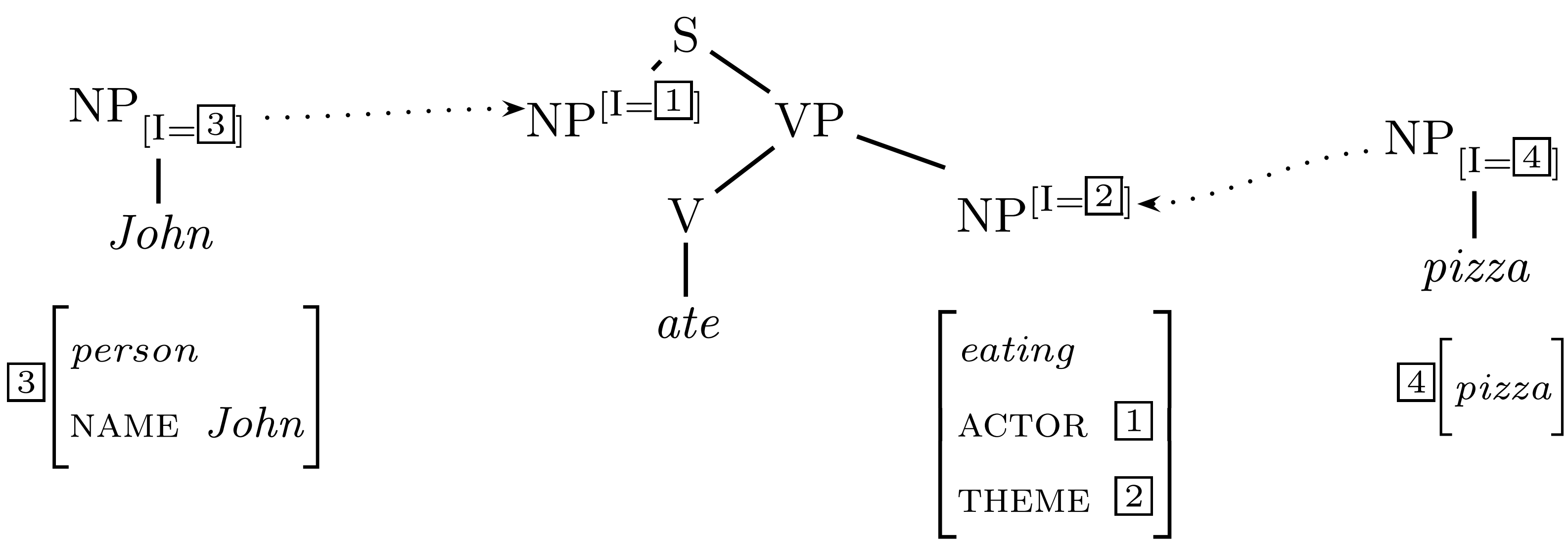


Semantic (de)composition: Directed Motion (1)

(9) a. John walked into the house.
    b. Mary danced into the room.

Lexical semantics of *walk* and *dance*:

walk

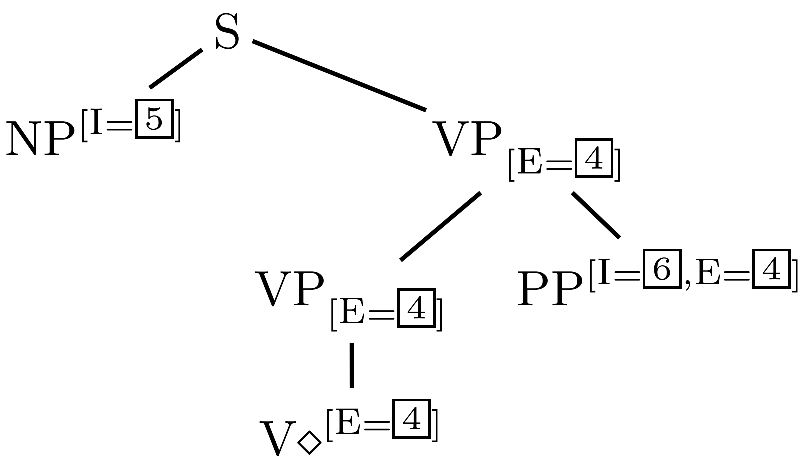
$$\begin{bmatrix} \textit{locomotion} & \\ \text{ACTOR} & \boxed{1} \\ \text{MOVER} & \boxed{1} \\ \text{MANNER} & \textit{walking} \\ \text{PATH} & \begin{bmatrix} \textit{path} & \\ \text{STARTP} & \top \\ \text{ENDP} & \top \end{bmatrix} \end{bmatrix}$$

dance

$$\begin{bmatrix} \textit{activity} \wedge \textit{motion} & \\ \text{ACTOR} & \boxed{1} \\ \text{MOVER} & \boxed{1} \\ \text{MANNER} & \textit{dancing} \end{bmatrix}$$

Semantic (de)composition: Directed Motion (2)

Directed motion construction:



$$\boxed{4}\begin{bmatrix} \textit{bounded-translocation} & \\ \textsc{mover} & \boxed{5} \\ \textsc{goal} & \boxed{6} \\ \textsc{path} & \text{path} \end{bmatrix}$$

The PP argument introduces a GOAL.

Semantic (de)composition: Directed Motion (2)

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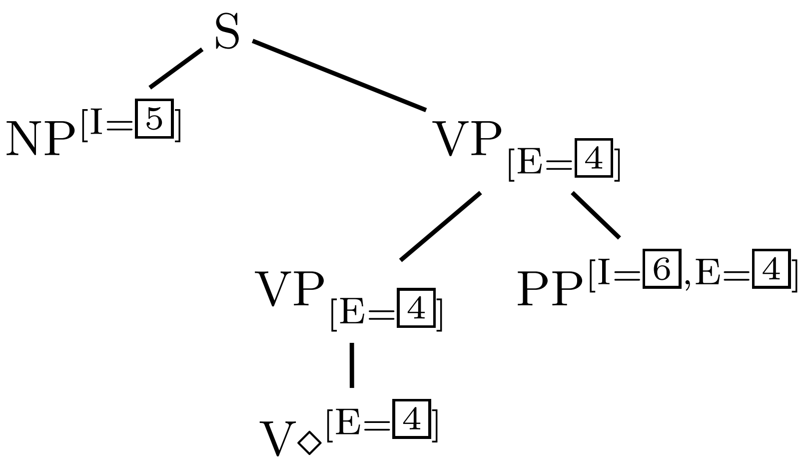


$$\boxed{4}\begin{bmatrix} \textit{bounded-translocation} & \\ \text{MOVER} & \boxed{5} \\ \text{GOAL} & \boxed{6} \\ \text{PATH} & \text{path} \end{bmatrix}$$

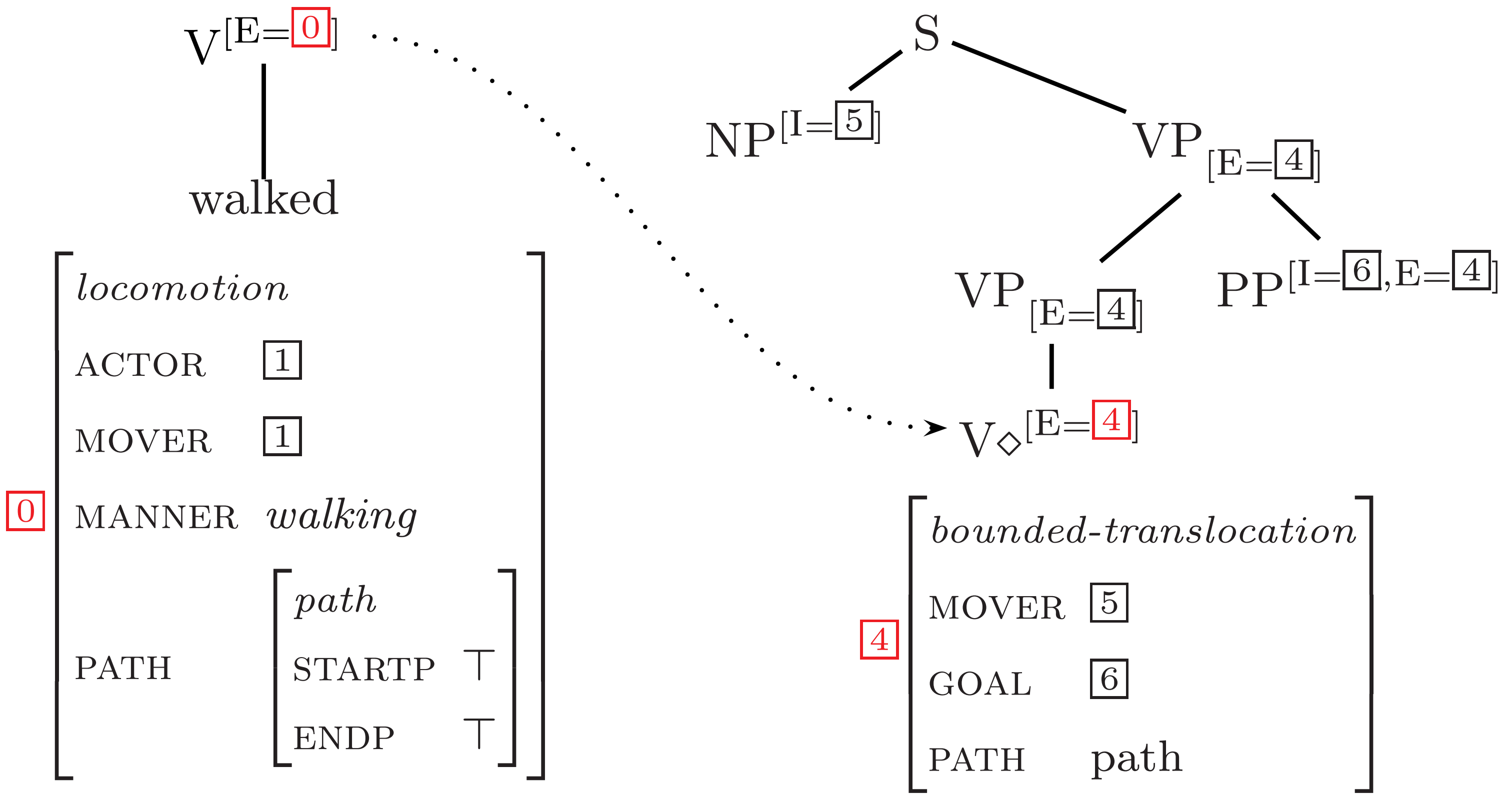
The PP argument introduces a GOAL.

Such a tree can be used for

(10) a. Mary walked/danced into the room.
b. The ball rolled into the goal.

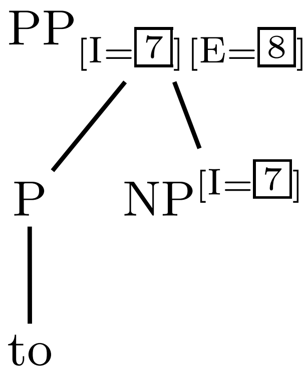
Semantic (de)composition: Directed Motion (3)

Lexical anchoring:



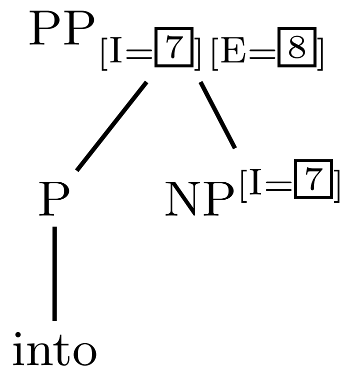
Semantic (de)composition: Directed Motion (4)

Elementary trees for some directional prepositions:



$$\boxed{8}\begin{bmatrix} \textit{bounded-translocation} & & \\ \text{PATH} & \begin{bmatrix} \textit{path} \\ \text{ENDP}\ \boxed{1} \end{bmatrix} & \\ \text{GOAL} & \boxed{7}\begin{bmatrix} \text{AT-REGION}\ \boxed{2} \end{bmatrix} & \end{bmatrix}$$

$$\textit{part-of}(\boxed{1}, \boxed{2})$$

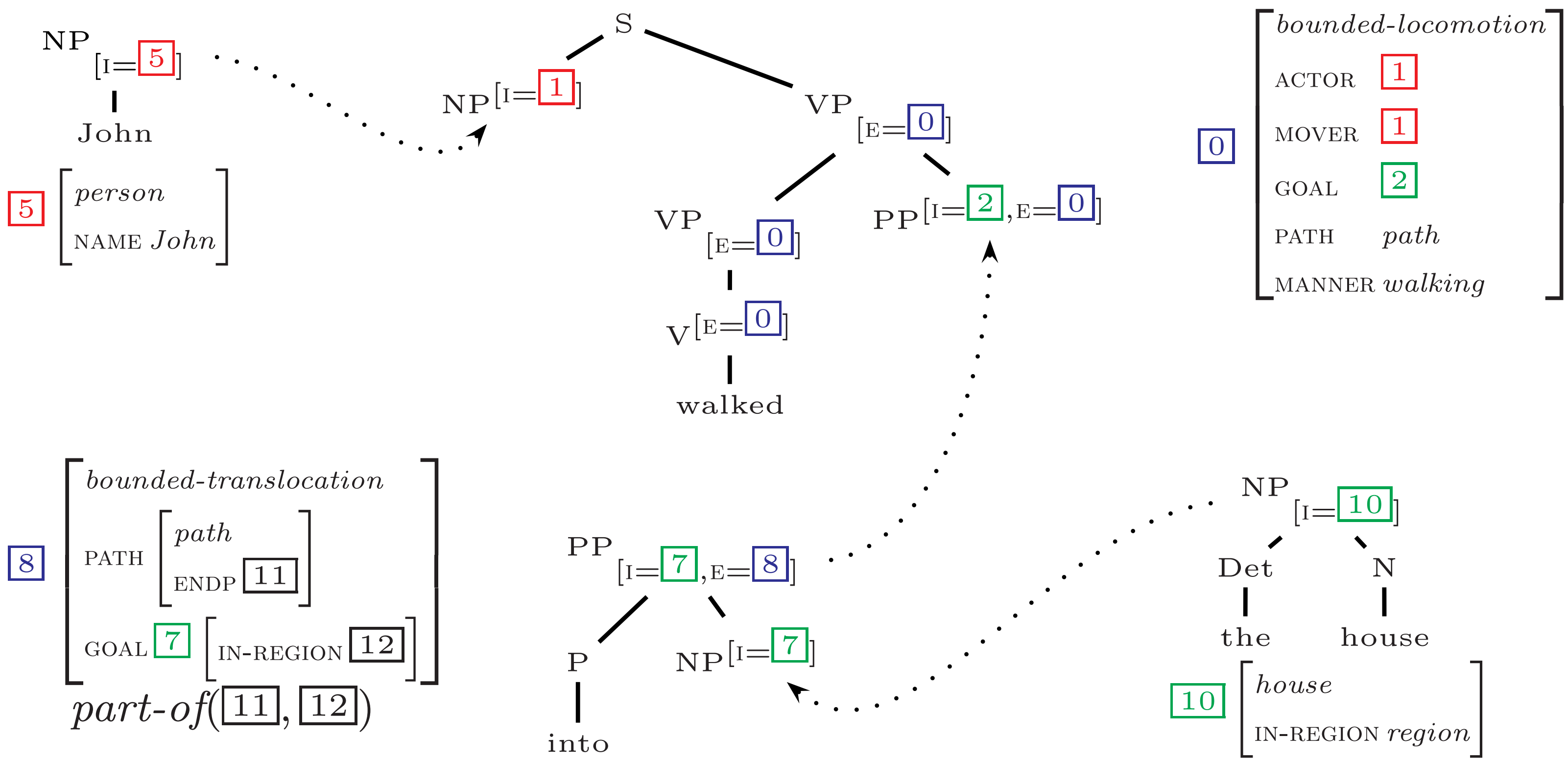


$$\boxed{8}\begin{bmatrix} \textit{bounded-translocation} & & \\ \text{PATH} & \begin{bmatrix} \textit{path} \\ \text{ENDP}\ \boxed{1} \end{bmatrix} & \\ \text{GOAL} & \boxed{7}\begin{bmatrix} \text{IN-REGION}\ \boxed{2} \end{bmatrix} & \end{bmatrix}$$

$$\textit{part-of}(\boxed{1}, \boxed{2})$$

Semantic (de)composition: Directed Motion (5)

(11) John walked into the house



Semantic (de)composition: Directed Motion (6)

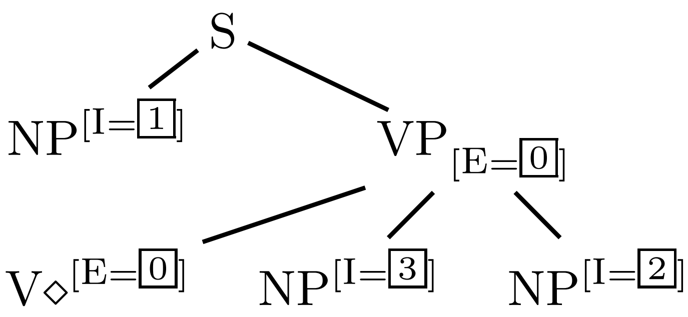
Resulting frame for *John walked into the house*

$$
\boxed{0}\begin{bmatrix}
\textit{bounded-locomotion} & & \\
\textsc{actor} & \boxed{1} & \begin{bmatrix} \textit{person} & \\ \textsc{name} & \textit{John} \end{bmatrix} \\
\textsc{mover} & \boxed{1} & \\
\textsc{goal} & \boxed{2} & \begin{bmatrix} \textit{house} & \\ \textsc{in-region} & \boxed{12} \end{bmatrix} \\
\textsc{path} & \begin{bmatrix} \textit{path} & \\ \textsc{endp} & \boxed{13} \end{bmatrix} & \\
\textsc{manner} & \textit{walking} &
\end{bmatrix}
$$

part-of($\boxed{13}$, $\boxed{12}$)

Semantic (de)composition: Dative alternation (1)

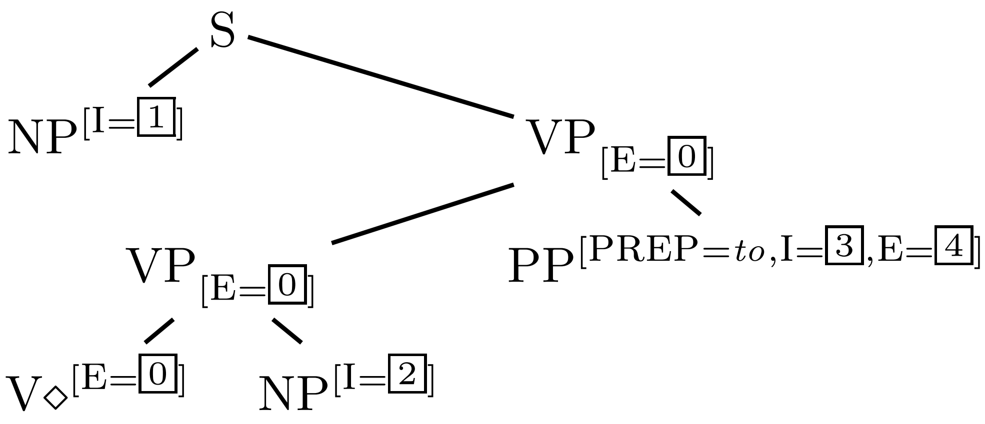
DO construction:



$$\boxed{0}\begin{bmatrix} \textit{causation} & \\ \textsc{cause} & \begin{bmatrix} \textit{activity} & \\ \textsc{actor} & \boxed{1} \end{bmatrix} \\ \textsc{effect} & \begin{bmatrix} \textit{change-of-possession} & \\ \textsc{theme} & \boxed{2} \\ \textsc{recipient} & \boxed{3} \end{bmatrix} \end{bmatrix}$$

Semantic (de)composition: Dative alternation (2)

PO construction:



$$\boxed{0}\begin{bmatrix} \textit{causation} & \\ \text{CAUSE} & \begin{bmatrix} \textit{activity} \\ \text{ACTOR} \ \boxed{1} \end{bmatrix} \\ \text{EFFECT} & \boxed{4}\begin{bmatrix} \textit{bounded-translocation} & \\ \text{MOVER} & \boxed{2} \\ \text{GOAL} & \boxed{3} \end{bmatrix} \end{bmatrix}$$

Semantic (de)composition: Dative alternation (3)

Semantic differences between verbs like *give*, *send* and *throw* [Rappaport Hovav and Levin, 2008, Beavers, 2011]:

- *give*: pure caused possession, no implication of motion.
- *hand*: caused possession and motion of the theme to the destination.
- *send*: caused motion towards a destination but not necessarily arrival.
- *throw*: caused motion, existence of destination is not lexicalized.

Semantic (de)composition: Dative alternation (4)

throw

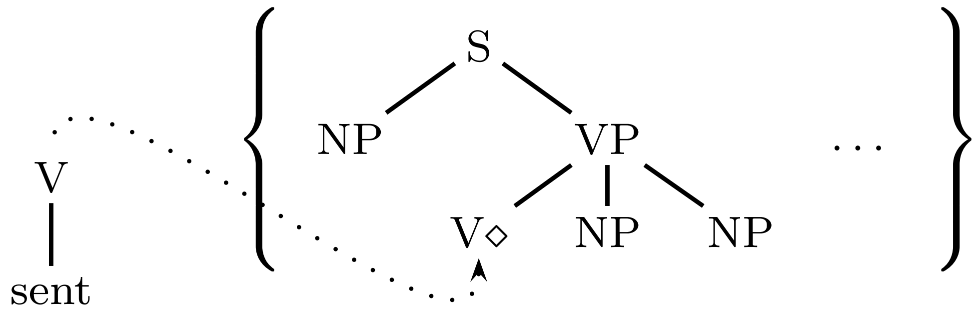
$$
\begin{bmatrix}
\textit{onset-causation} & \\
\text{CAUSE} & \begin{bmatrix} \textit{activity} & \\ \text{ACTOR} & \top \\ \text{THEME} & \boxed{1} \\ \text{MANNER} & \textit{throwing} \end{bmatrix} \\
\text{EFFECT} & \begin{bmatrix} \textit{translocation} & \\ \text{THEME} & \boxed{1} \\ \text{MOVER} & \boxed{1} \end{bmatrix}
\end{bmatrix}
$$

give

$$
\begin{bmatrix}
\textit{causation} & \\
\text{CAUSE} & \begin{bmatrix} \textit{activity} & \\ \text{ACTOR} & \top \end{bmatrix} \\
\text{EFFECT} & \begin{bmatrix} \textit{change-of-possession} & \\ \text{THEME} & \boxed{1} \\ \text{RECIPIENT} & \boxed{2} \\ \text{RESULT} & \begin{bmatrix} \textit{possession} & \\ \text{POSSESSOR} & \boxed{2} \\ \text{POSSESSED} & \boxed{1} \end{bmatrix} \end{bmatrix}
\end{bmatrix}
$$

Semantic (de)composition: Dative alternation (5)

Lexical anchoring



- Because of the unifications of the syntactic S features on the V nodes, the frames of the unanchored tree and of the lexical anchor unify.
- In some cases, the two frames have different types and apparently do not unify.

Semantic (de)composition: Dative alternation (6)

Example:

sent

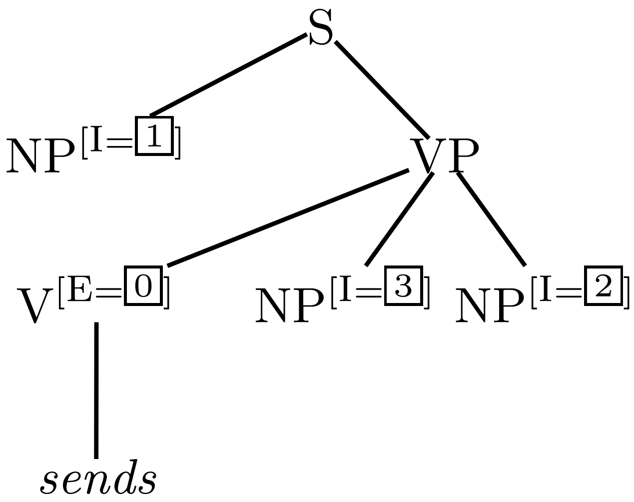
$$\begin{bmatrix} \textit{causation} & \\ \text{CAUSE} & \begin{bmatrix}\textit{activity} & \\ \text{ACTOR} & \top\end{bmatrix} \\ \text{EFFECT} & \begin{bmatrix} \textit{bounded-transloc.} & \\ \text{THEME} & \boxed{1} \\ \text{MOVER} & \boxed{1} \\ \text{GOAL} & \top \end{bmatrix}\end{bmatrix}$$

DO construction

$$\begin{bmatrix} \textit{causation} & \\ \text{CAUSE} & \begin{bmatrix}\textit{activity} & \\ \text{ACTOR} & \top\end{bmatrix} \\ \text{EFFECT} & \begin{bmatrix} \textit{change-of-possession} & \\ \text{THEME} & \top \\ \text{RECIPIENT} & \top \end{bmatrix}\end{bmatrix}$$

Semantic (de)composition: Dative alternation (7)

But: we allow for multiple types and therefore, unfication is actually possible. Resulting anchored tree:



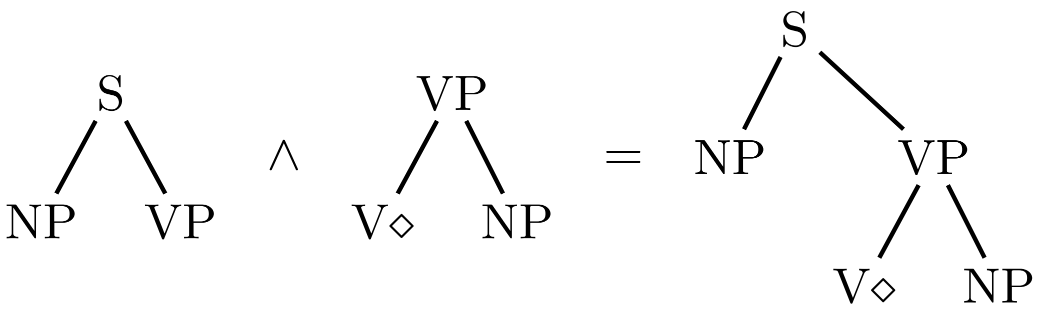
$$\boxed{0}\begin{bmatrix} \textit{causation} & \\ \textsc{cause} & \begin{bmatrix} \textit{activity} \\ \textsc{actor}\ \boxed{1} \end{bmatrix} \\ \textsc{effect} & \begin{bmatrix} \textit{transloc.} \wedge \textit{change-of-poss} & \\ \textsc{mover} & \boxed{2} \\ \textsc{theme} & \boxed{2} \\ \textsc{goal} & \boxed{3} \\ \textsc{recipient} & \boxed{3} \end{bmatrix} \end{bmatrix}$$

Semantic (de)composition: Dative alternation (8)

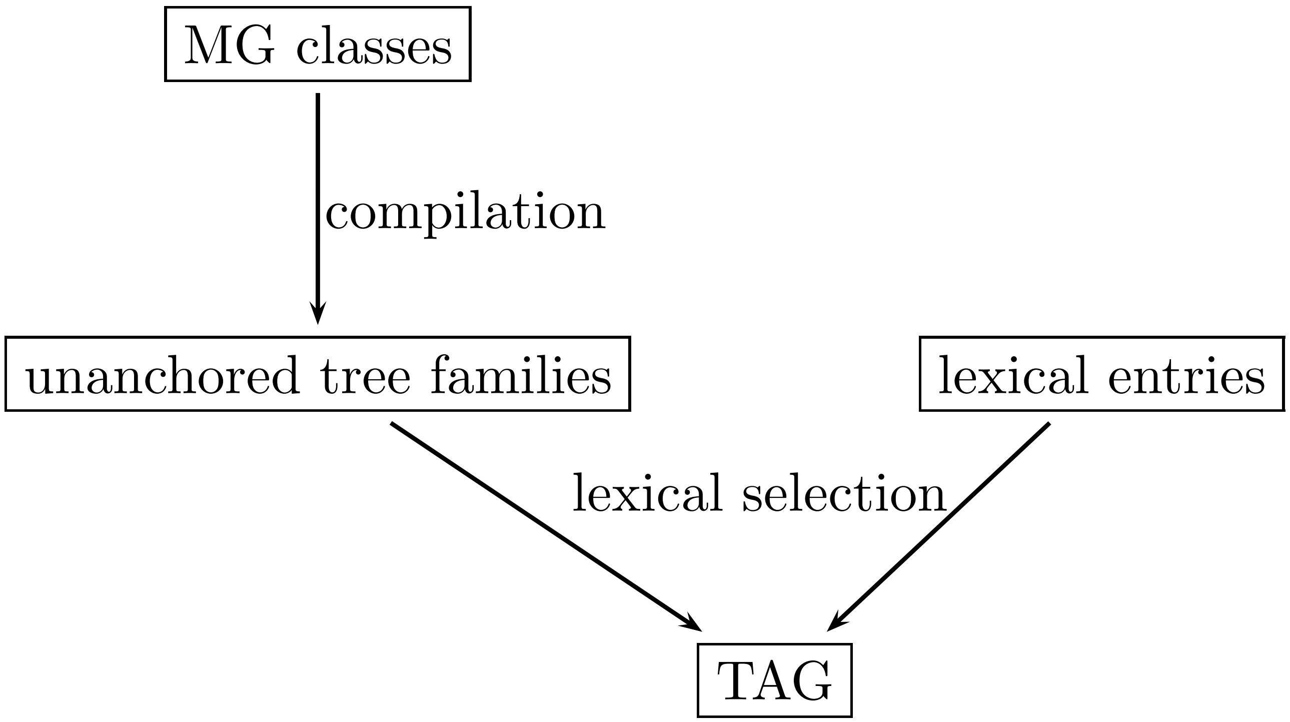
- The effected event can be characterized as a conjunction of the types *bounded-translocation* and *change-of-possession*.
- The appropriate matching of the semantic roles is enforced by additional constraints on the features.
- In the result of the unification, a participant can thus have different semantic roles that reflect the ways in which it is involved in the different characterizations of the event.

MG Factorization (1)

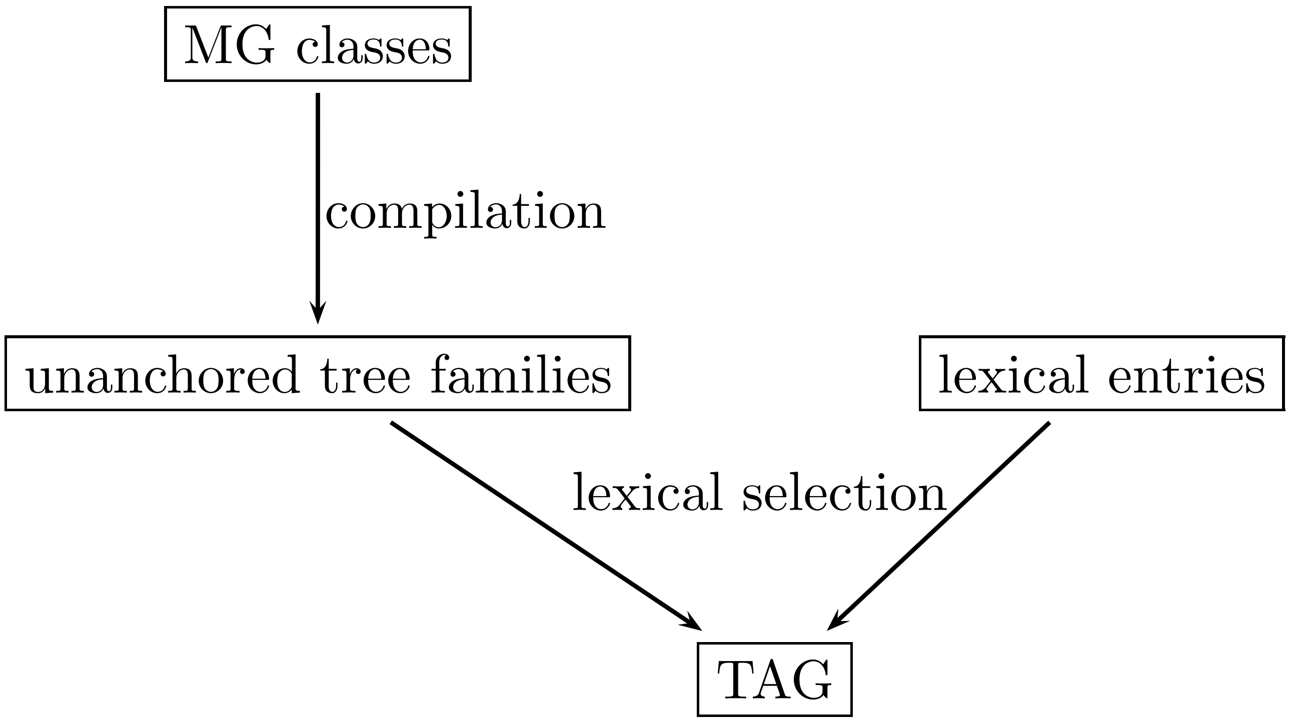
- In order to produce and maintain a consistent LTAG of a considerable coverage, one uses a metagrammar (MG) [Candito 1999, Crabbe/Duchier 2005].
- An MG contains factorized descriptions of unanchored elementary trees. It defines a set of tree fragments (MG classes) that can be used in other MG classes.
- This way, an unachored elementary tree family is the denotation of an MG class that makes use of a series of other, smaller tree fragments in the MG.



MG Factorization (2)

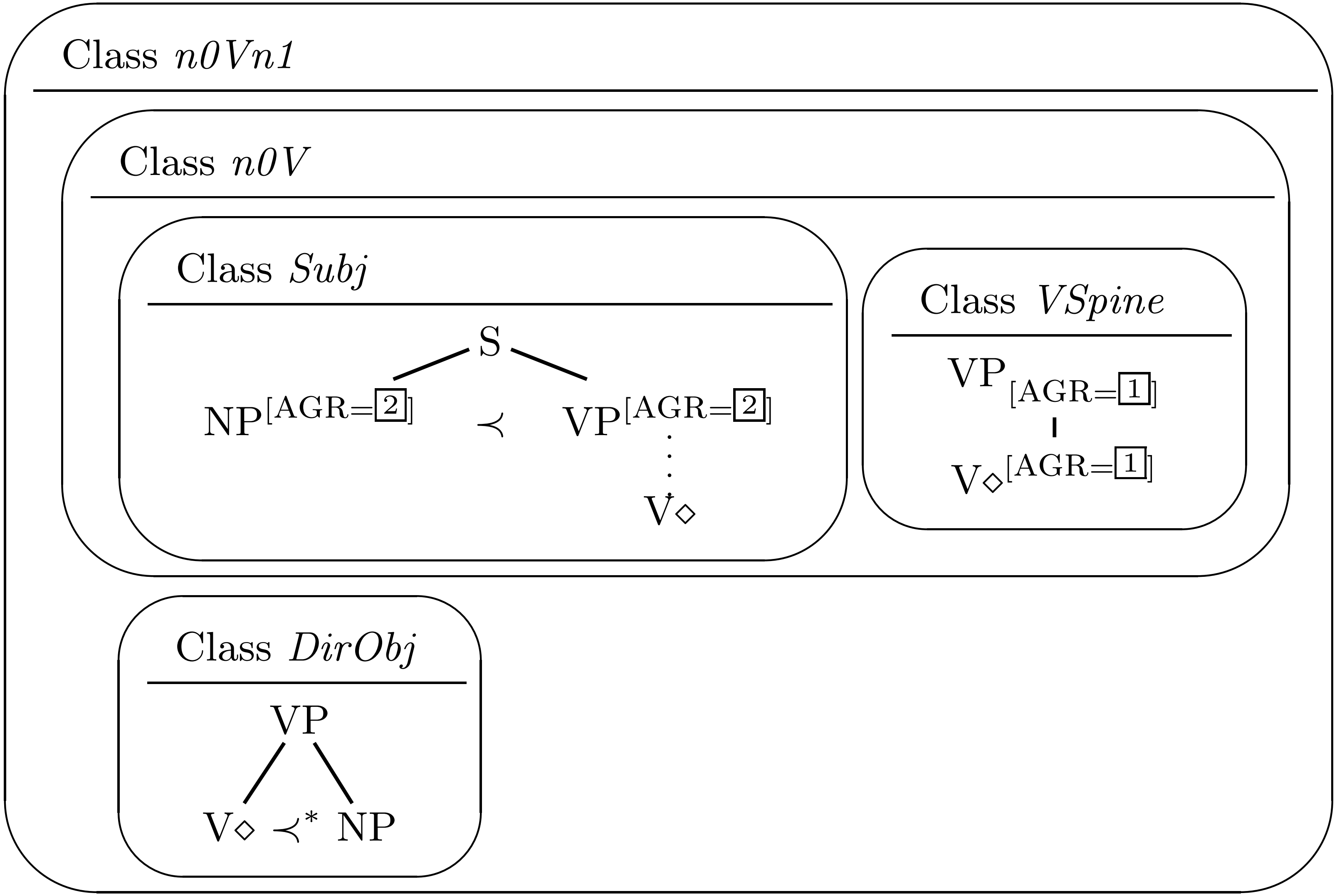


MG Factorization (2)



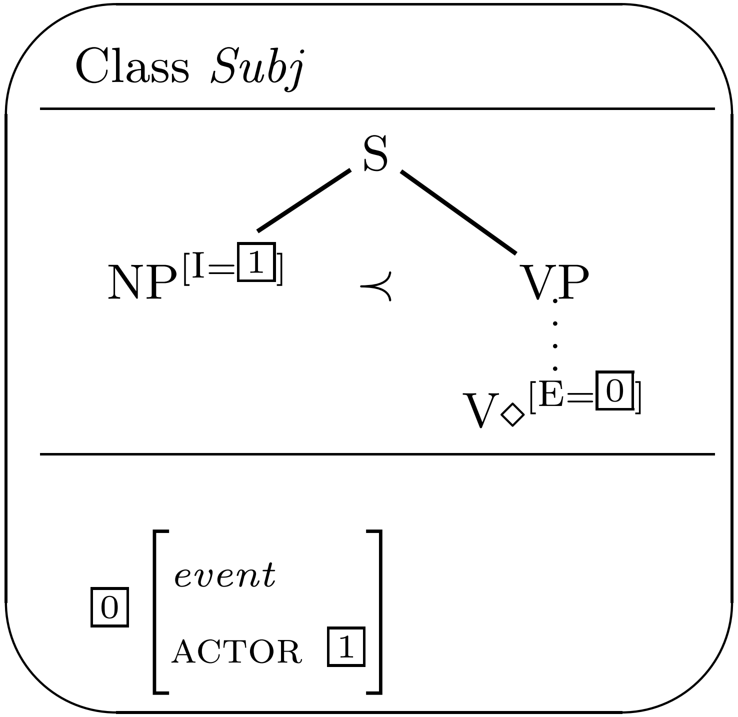
Advantage of MGs for TAG from a linguistic point of view: The MG allows to express and implement lexical generalizations.

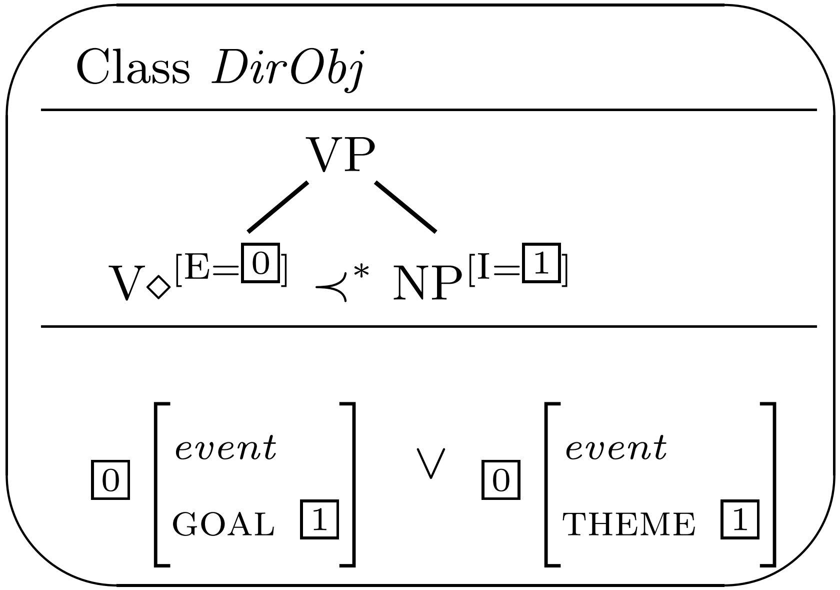
MG Factorization (3)



MG Factorization (4)

Frame decomposition in the metagrammar: Subject and direct object





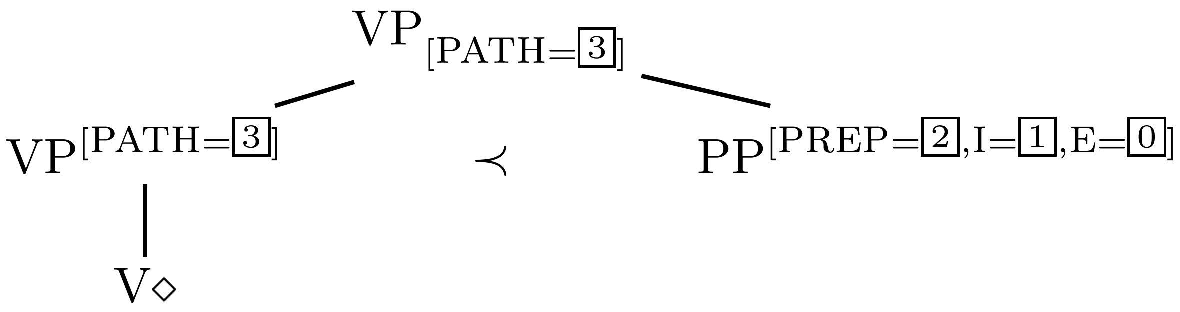
MG Factorization (5)

Frame decomposition in the metagrammar: Directional PP

Class *DirPrepObj*

export: e, i, $prep$

identities: $e = \boxed{0}$, $i = \boxed{1}$, $prep = \boxed{2}$



$$\boxed{0}\begin{bmatrix} \textit{bounded-translocation} \\ \text{GOAL} \ \boxed{1} \\ \text{PATH} \ \boxed{3} \end{bmatrix}$$

MG Factorization (6)

Frame decomposition in the metagrammar: Directional PP

Class *n0Vpp(dir)*

identities: $C_1.e = C_2.e$

Class C_1 =*n0V*	Class C_2 =*DirPrepObj*
export: e	export: e, i, *prep*
identities: $e = \boxed{0}$	identities: $e = \boxed{0}$, ...
...	...

MG Factorization (7)

Frame decomposition in the metagrammar: *to*-PP in PO construction

Class *DirPrepObj-to*

---

export: e, i

---

identities: $e = C_1.e$, $i = C_1.i$, $C_1.prep = to$

Class C_1 =*DirPrepObj*

---

export: e, i, *prep*

. . .

MG Factorization (8)

Frame decomposition in the metagrammar: DO and PO construction

Class *DOPOConstr*

identities: $C_1.e = \boxed{0}$, $C_2.e = \boxed{3}$

Class C_1 =*n0Vn1*

export: e

...

Class C_2 =*IndirObj* $\vee$ *DirPrepObj-to*

export: e, i

...

$$\boxed{0}\begin{bmatrix} \textit{causation} & \\ \text{ACTOR} & \boxed{1} \\ \text{THEME} & \boxed{2} \\ \text{CAUSE} & \begin{bmatrix} \textit{activity} & \\ \text{ACTOR} & \boxed{1} \end{bmatrix} \\ \text{EFFECT} & \boxed{3}\begin{bmatrix} \textit{undergoing} & \\ \text{THEME} & \boxed{2} \end{bmatrix} \end{bmatrix}$$

MG Factorization (9)

The class for directional PPs is used in different contexts:

- In the directed motion case, it contributes the goal of the main event described by the verb.

  (12) John walks into the room.

- In the caused motion case (see [Kallmeyer and Osswald, 2014]) it constrains the embedded effected event.

  (13) John rolls the ball into the goal.

- In the PO construction, it also contributes to the characterization of the embedded effected event.

  (14) John gives the ball to Mary.

Conclusion

- We aim at giving a detailed analysis of the (de)composition of the meaning of verbs and verb-based constructions.
- LTAG's extended domain of locality allows a straightforward description of constructions as unanchored elementary trees.
- These constructions are combined with the meaning of the verbal head in the process of lexical anchoring.
- The metagrammar allows for further factorization and generalization in the lexicon.
- We have treated two test cases in order to show how the approach works, directed motion expressions and the dative alternation.

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