A Frame-Based Semantics of the Dative Alternation in Lexicalized Tree Adjoining Grammars

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1. Introduction

It is well known that the meaning of a verb-based construction depends not only on the lexical meaning of the verb but also on its specific syntagmatic environment. Lexical meaning interacts with constructional meaning in intricate ways and this interaction is crucial for theories of argument linking and the syntax-semantics interface. These insights have led proponents of Construction Grammar to treating every linguistic expression as a construction (Goldberg 1995). But the influence of the syntagmatic context on the constitution of verb meaning has also been taken into account by lexicalist approaches to argument realization (e.g., Van Valin and LaPolla 1997). The crucial question for any theory of the syntax-semantic interface is how the meaning components are distributed over the lexical and morphosyntactic units of a linguistic expression and how these components combine. A grammar model that is able to capture phenomena of this type should be sufficiently flexible with respect to the factorization and combination of lexical and constructional units both on the syntactic and the semantic level.

We propose a novel framework for modelling such phenomena in a formally precise way which is suitable for computational processing. To this end, we integrate *Lexicalized Tree Adjoining Grammars* (LTAG, Joshi and Schabes 1997) with *Frame Semantics* and employ the technique of metagrammatical specification as introduced by Candito (1999) and Crabbé and Duchier (2005). The basic idea of the latter is to specify elementary syntactic trees as minimal models of sets of tree constraints. We extend this idea of constraint-based specification to the level of frame-semantic descriptions. That is, both, the elementary syntactic trees and their associated semantic frames are specified by constraints. This approach allows a strong factorization of the syntactic and semantic information. The so-called *elementary trees* defined by the constraints in the metagrammar constitute a finite set of trees. These trees can then be used to derive larger trees by substitution and adjunction. We illustrate our metagrammatical decomposition of syntactic trees and semantic frames by a case study on various aspects of the dative alternation in English, which is is well-known to be sensitive to lexical and constructional meaning components.

A specific charasteristics of LTAG is its *extended domain of locality*: In LTAG, the (non-recursive) elementary trees defined by the constraints in the metagrammar represent entire subcategorization frames and can therefore be locally linked to a semantic frame that encodes the

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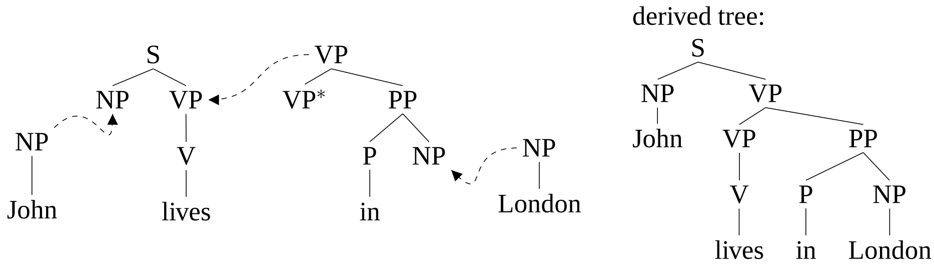

Figure 1: A sample derivation

semantic roles of all the participants of an event denoted by a predicate. This is possible because of the adjunction operation in the syntax that allows to separate two parts of an elementary tree by adjoining additional material in between. As a result, larger constructions can be identified in the form of elementary trees without committing oneself to completely fixed subtrees of the derived tree.

A long-term goal of the work described in this paper is the development of a grammar engineering framework that allows a seamless integration of lexical and constructional semantics. More specifically, the approach provides Tree Adjoining Grammars with a decompositional lexical and constructional semantics and thereby complements existing proposals which are focused on standard sentence semantics (cf. Gardent and Kallmeyer 2003; Kallmeyer and Romero 2008). From a wider perspective, the framework can be seen as a step towards a formal and computational account of some key ideas of Construction Grammar à la Goldberg, since the elementary trees of LTAG combined with semantic frames come close to what is regarded as a construction in such approaches. Frameworks with similar goals are Embodied Construction Grammar (Bergen and Chang 2005) and Sign-Based Construction Grammar (Michaelis to appear).

2. LTAG and grammatical factorization

2.1. Brief introduction to TAG

Tree Adjoining Grammar (TAG, Joshi and Schabes 1997) is a tree-rewriting formalism. A TAG consists of a finite set of trees (*elementary trees*). The nodes of these trees are labelled with non-terminals and terminals (terminals only label leaf nodes). Starting from the elementary trees, larger trees are derived by *substitution* (replacing a leaf with a new tree) and *adjunction* (replacing an internal node with a new tree). Sample elementary trees and a derivation are shown in Fig. 1. In this derivation, the elementary tree for *John* substitutes into the subject slot of the elmentary tree for *lives*, the *in* tree for the PP modifier adjoins to the VP node and *London* substitutes into the NP leave of the modifier tree.

In case of an adjunction, the tree being adjoined has exactly one leaf that is marked as the *foot node* (marked with an asterisk). Such a tree is called an *auxiliary* tree. To license its adjunction to a node *n*, the root and foot nodes must have the same label as *n*. When adjoining it to *n*, in the resulting tree, the subtree with root *n* from the old tree is attached to the foot node of the auxiliary tree. Non-auxiliary elementary trees are called *initial* trees. A derivation starts with an initial tree. In a final derived tree, all leaves must have terminal labels.

In a TAG, one can specify for each node whether adjunction is mandatory and which trees can be adjoined. The subscripts *NA* and *OA* indicate adjunction constraints: *NA* signifies that for this node, adjunction is not allowed while *OA* signifies that adjunction is obligatory.

2.2. Feature Structure Based TAG

In order to be able to capture syntactic generalizations in a more satisfying way, the non-terminal node labels in TAG elementary trees are usually enriched with feature structures. The resulting TAG variant is called *Feature-structure based TAG* (FTAG, Vijay-Shanker and Joshi 1988). In an FTAG, each node has a top and a bottom feature structure (except substitution nodes that have only a top). Nodes in the same elementary tree can share features (extended domain of locality). In contrast to the original TAG, an FTAG does not have separate adjunction constraints, since the constraints can be expressed by features.

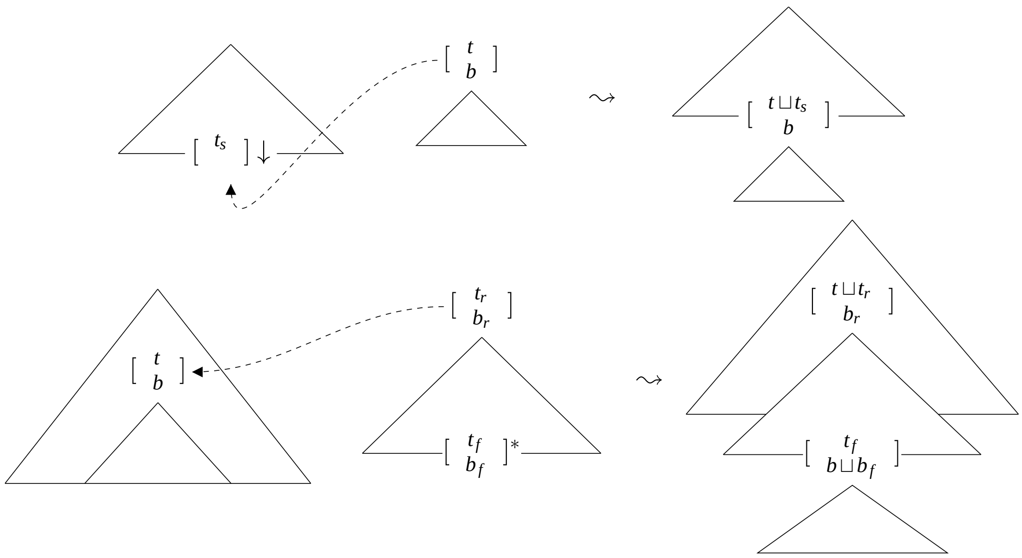

Figure 2: Feature structure unifications in FTAG

During substitution and adjunction, the following unifications take place (see Fig. 2): In a substitution operation, the top of the root of the new initial tree unifies with the top of the substitution node. In an adjunction operation, the top of the root of the new auxiliary tree unifies with the top of the adjunction site and the bottom of the foot of the new tree unifies with the bottom of the adjunction site. Furthermore, in the final derived tree, top and bottom must unify for all nodes.

Since nodes in the same elementary tree can share features, constraints among dependent nodes can be more easily expressed than in the original TAG formalism. See Fig. 3 for an example (the top feature structure is notated as a superscript, the bottom feature structure as a subscript of the respective node).

2.3. LTAG elementary trees

The elementary trees of a TAG for natural languages respect certain principles (Frank 2002; Abeillé 2002). Firstly, they are lexicalized, i.e., each elementary tree has at least one non-empty lexical item, its *lexical anchor*. A *lexicalized* TAG (LTAG) is a TAG that satisfies this condition for every elementary tree. Secondly, each elementary tree associated with a predicate contains argument slots (leaves with non-terminal labels, i.e., substitution nodes or foot nodes) for each of its arguments, i.e., for each of the elements it subcategorizes for, including the subject. Fur-

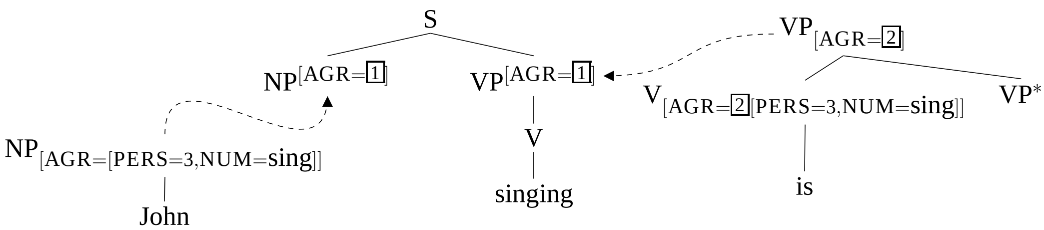

Figure 3: Agreement with feature structures

thermore, it contains argument slots only for the arguments of its lexical anchor, and for nothing else (*elementary tree minimality*, Frank 2002).

Most argument slots are substitution nodes, in particular the nodes for nominal arguments (see the elementary tree for *lives* in Fig. 1). Sentential arguments however are realised by foot nodes. The reason is that we want to be able to extract material from sentential arguments in long-distance dependencies such as (1). Such extractions can be obtained by adjoining the embedding clause into the sentential argument.

(1) Whom does Paul think that Mary likes?

As we have seen, the elementary trees of an LTAG are lexicalized and contain non-terminal leaves for all the arguments of their lexical head. Because of this extended domain of locality, LTAG is particularly well-suited for a frame-based compositional semantics. The semantic frame of a predicate specifies, among others, the thematic roles of its arguments. In LTAG, these can be immediately linked to the corresponding syntactic argument slots.

Concerning the modeling of the syntax-semantics interface, we follow approaches that link a single semantic representation (in our case, a semantic frame) to an entire elementary tree and which model semantic composition by unifications triggered by substitution and adjunction (Gardent and Kallmeyer 2003; Kallmeyer and Romero 2008). A simplified example that illustrates the locality of linking in this framework is given in Fig. 4. The substitutions trigger unifications between 1 and 3 and between 2 and 4 which leads to an insertion of the corresponding argument frames into the frame of *eats*.

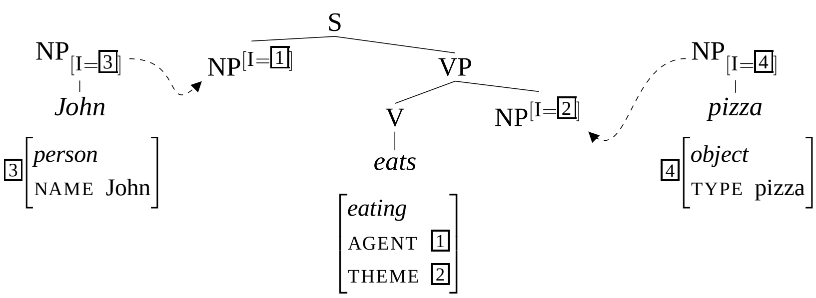

Figure 4: Syntactic and semantic composition for *John eats pizza*

2.4. Metagrammar and factorization

LTAG allows for a high degree of factorization inside the lexicon, i.e., inside the set of lexicalized elementary trees. Firstly, unanchored elementary trees are specified separately from their lexical anchors. The set of unanchored elementary trees is partitioned into *tree families* where each family represents the different realizations of a single subcategorization frame. For transitive verbs such as *hit*, *kiss*, *admire*, etc. there is a tree family (see Fig. 5) containing the patterns for different realizations of the arguments (canonical position, extraction, etc.) in combination with active and passive. The node marked with a diamond is the node that gets filled by the lexical anchor.

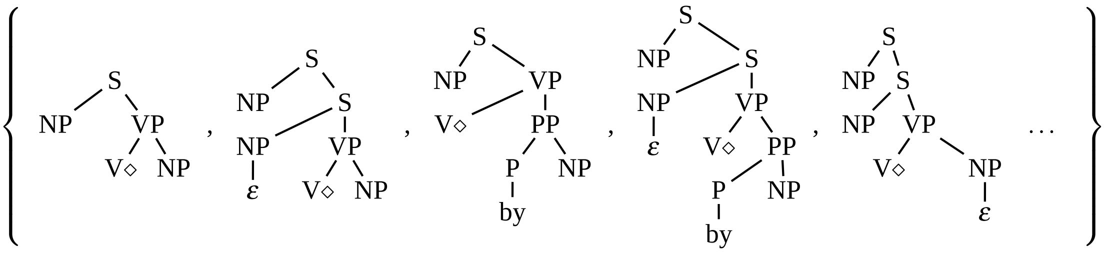

Figure 5: Unanchored tree family for transitive verbs

Secondly, unanchored elementary trees are usually specified by means of a *metagrammar* (Candito 1999; Crabbé and Duchier 2005) which consists of dominance and precedence constraints and category assignments. The elementary trees of the grammar are defined as the *minimal models* of this constraint system. The metagrammar formalism allows for a compact grammar definition and for the formulation of linguistic generalizations. In particular, the metagrammatical specification of a subcategorization frame defines the set of all unanchored elementary trees that realize this frame. Moreover, the formalism allows us to define tree fragments that can be used in different elementary trees and tree families, thereby giving rise to an additional factorization and linguistic generalization. Phenomena that are shared between different tree families such as passivization or the extraction of a subject or an object are specified only once in the metagrammar and these descriptions become part of the descriptions of several tree families.

Let us illustrate this with the small metagrammar fragment given in Fig. 6, which is of course very incomplete in that many tree fragments are missing and features are almost totally omitted. The first two tree fragments describe possible subject realizations: the subject can be in canonical position, immediately preceding the VP, or it can be extracted, with a trace in the canonical subject position. The class *Subj* comprises the different subject realizations. Similar classes exist for the different realizations of the object, while in Fig. 6 only the canonical position class is listed. Furthermore, there is a class for the *by*-PP in a passive construction. This is used only for passive, therefore the tree fragment contains a corresponding feature VOICE = *passive*. Besides these argument classes, our fragment contains two classes for active/passive morphology. Finally, the class *Transitive* specifies for each argument its different grammatical functions: the first argument can be the subject of an active sentence or the *by*-PP of a passive sentence or it can be omitted in a passive sentence.[1] The second argument can be the direct object or it can be promoted to a subject in a passive sentence. If we assume that the metagrammar

[1] We are computing minimal models, this is why the third possibility in the disjunction signifies that this argument is not realized.

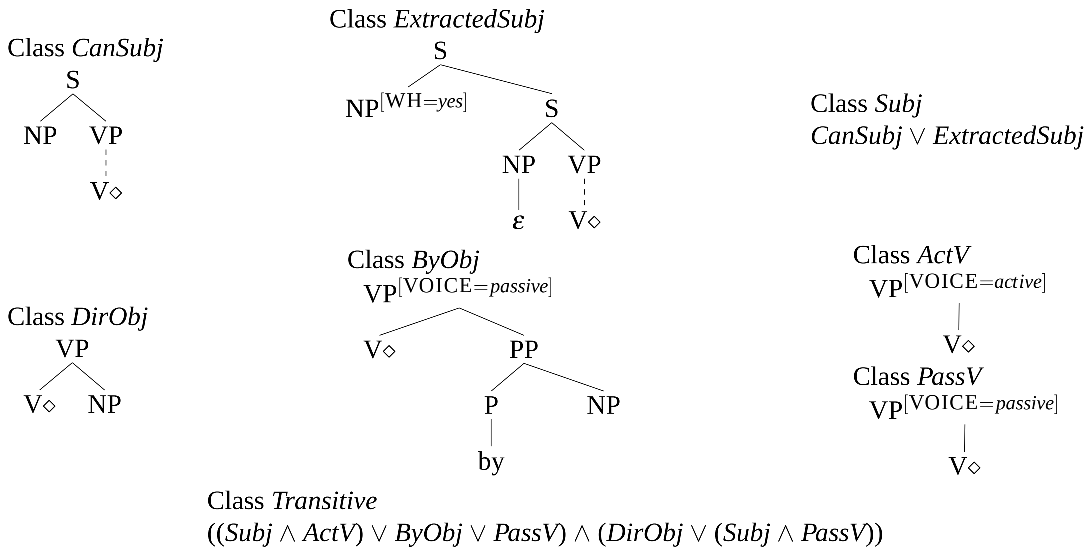

Figure 6: MG fragment for transitive verbs

constraints require the identification of the lexical anchor nodes, then the minimal models of this class are among others the first four tree in Fig. 5. Note that the difference between canonical subject and extracted subject is factored out in the class *Subj*, which can also be used for the definition of other tree families.

A similar factorization is possible within the semantics. The semantic contribution of unanchored elementary trees, i.e., constructions, can be separated from their lexicalization, and the meaning of a construction can be decomposed further into the meaning of fragments of the construction. Due to this factorization, relations between the different parts of a certain syntactic construction and the components of a semantic representation can be expressed.

In the following, we will use the metagrammar factorization of elementary trees in order to decompose the semantics of double object and prepositional object constructions.

3. Frame-based semantics and the dative alternation

3.1. Frame semantics and lexical decomposition

The program of Frame Semantics initiated by Fillmore (1982) aims at capturing the meaning of lexical items in terms of *frames*, which are to be understood as cognitive structures that represent the described situations or state of affairs. In their most basic form, frames specify the type of a situation and the semantic roles of the participants, that is, they correspond to feature structures of the kind used in Fig. 4 for representing eating situations. Frame semantics as currently implemented in the FrameNet project Fillmore et al. (2003) basically builds on such plain role frames, and it is a central goal of FrameNet to record on a broad empirical basis how the semantic roles are expressed in the morphosyntactic environment of the frame evoking word.

In contrast to pure semantic role approaches to argument realization, many current theories of the syntax-semantics interface are based on predicate decomposition and event structure analysis (cf. Levin and Rappaport Hovav 2005). These theories assume that the morphosyntactic realization of an argument depends crucially on the structural position of the argument within the decomposition. Two simple notational variants of such a decomposition of the causative

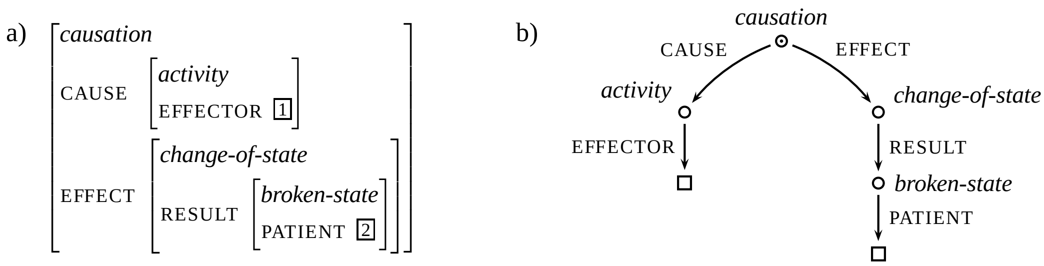

Figure 7: Possible frame representation for template (2).

verb *break* are shown in (2), formulated along the lines of Van Valin and LaPolla (1997) and Rappaport Hovav and Levin (1998), respectively.

(2) a. $[\mathbf{do}(x, \emptyset)]$ CAUSE [BECOME $\mathbf{broken}(y)$]
b. [[*x* ACT] CAUSE [BECOME [*y BROKEN*]]]

With respect to the goals of our project, a decompositional semantic representation is the natural choice since it allows us to associate specific components of the semantic representation with specific syntactic fragments. We integrate event structure decomposition with frame semantics.[2] That is, we use frames, understood as potentially nested typed feature structures with additional constraints, for representing decompositional templates of the sort shown in (2). Fig. 7a) shows a fairly direct translation of these templates into a frame representation.[3] The graph on the right of the figure can be regarded either as an equivalent presentation of the frame, or as a minimal model of the structure on the left if the latter is seen as a frame description. It is worth mentioning that there is also a fairly close relation of the decompositional frame representations to event logical formulas neo-Davidsonian style. For if each subframe is interpreted as representing a reified subcomponent of the described event, then the structure shown in Fig. 7 gives rise to a formula like (3).

(3) $\exists e \exists e' \exists e'' \exists s\, [\mathit{causation}(e) \wedge \mathrm{CAUSE}(e, e') \wedge \mathrm{EFFECT}(e, e'') \wedge \mathit{activity}(e') \wedge \mathrm{EFFECTOR}(e', x)$
$\wedge\ \mathit{change\text{-}of\text{-}state}(e'') \wedge \mathrm{RESULT}(e'', s) \wedge \mathit{broken\text{-}state}(s) \wedge \mathrm{PATIENT}(s, y)]$

Frames allow us to combine two central aspects of template-based decompositions and logical representations: Like decompositional schemas they are concept-centered and have inherent structural properties and like logical representations they are flexible and easily extensible by additional subcomponents and constraints.

3.2. Semantic properties of the dative alternation

The English dative alternation is concerned with verbs like *give*, *send*, and *throw* which can occur in both the double object (DO) and the prepositional object (PO) construction as exemplified by (4).

[2]Koenig and Davis (2006), who make a similar proposal, put emphasis on the fact that the part of the frame relevant for argument linking can be a proper subframe of the semantic representation associated with the expression in question. That is, the "referential node" of the frame need not coincide with the root of the frame. While we do not make use of this possibility in our analysis, we do not exclude it in principle.

[3]Note the different uses of CAUSE in (2) and Fig. 7. While in (2), CAUSE is basically used as a verb in that the activity "causes" the change of state, the use of CAUSE in the frame representation is that of a functional noun: the activity is the "cause" component of the causative scenario.

a)

$$\begin{bmatrix} \textit{causative-activity} & \\ \text{EFFECTOR} & \boxed{1} \\ \text{EFFECT} & \begin{bmatrix} \textit{motion} & \\ \text{THEME} & \boxed{2} \\ \text{DESTINATION} & \boxed{3} \end{bmatrix} \end{bmatrix}$$

b)

$$\begin{bmatrix} \textit{causation} & \\ \text{CAUSE} & \begin{bmatrix} \textit{activity} & \\ \text{EFFECTOR} & \boxed{1} \end{bmatrix} \\ \text{EFFECT} & \begin{bmatrix} \textit{motion} & \\ \text{THEME} & \boxed{2} \\ \text{DESTINATION} & \boxed{3} \end{bmatrix} \end{bmatrix}$$

c)

$$\begin{bmatrix} \textit{causation} & \\ \text{CAUSE} & \begin{bmatrix} \textit{activity} & \\ \text{EFFECTOR} & \boxed{1} \end{bmatrix} \\ \text{EFFECT} & \begin{bmatrix} \textit{change-of-loc} & \\ \text{RESULT} & \begin{bmatrix} \textit{loc-state} & \\ \text{THEME} & \boxed{2} \\ \text{LOCATION} & \boxed{3} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

Figure 8: Some frame representation options for caused motion.

(4) a. John sent Mary the book.
b. John sent the book to Mary.

The two constructions are traditionally associated with a ‘caused possession’ (4-a) and ‘caused motion’ (4-b) interpretation, respectively. These two interpretations have often been analyzed by decompositional schemas of the type shown in (5-a) and (5-b), respectively.

(5) a. $[\,[x \text{ ACT}] \text{ CAUSE } [y \text{ HAVE } z]\,]$
b. $[\,[x \text{ ACT}] \text{ CAUSE } [z \text{ GO TO } y]\,]$

In a similar vein, Krifka (2004) uses event logical expressions of the sort shown in (6) for distinguishing the two interpretations.

(6) a. $\exists e \exists s[\text{AGENT}(e,x) \wedge \text{CAUSE}(e,s) \wedge s : \text{HAVE}(y,z)]$
b. $\exists e \exists e'[\text{AGENT}(e,x) \wedge \text{CAUSE}(e,e') \wedge \text{MOVE}(e') \wedge \text{THEME}(e',y) \wedge \text{GOAL}(e',z)]$

Following the general outline sketched in the previous section, (6-b) could be translated into the frame representation shown in Fig. 8a). Version 8b), by comparison, is closer to template (5-b) if we take $[x \text{ ACT}]$ to represent the activity subcomponent of the caused motion event. Frame 8c) is a further variant based on the caused motion schema (7-b) taken from Van Valin and LaPolla (1997). In contrast to the frame versions in a) and b), this representation tries to make explicit the resulting change of location of the theme.

(7) a. $[\mathbf{do}(x,\emptyset)] \text{ CAUSE } [\text{BECOME } \mathbf{have}(y,z)]$
b. $[\mathbf{do}(x,\emptyset)] \text{ CAUSE } [\text{BECOME } \mathbf{be\text{-}at}(y,z)]$

The contrast between the DO and the PO variant and their respective interpretations has been observed to span a wider range of options than described so far. Rappaport Hovav and Levin (2008) distinguish three types of alternating verbs based on differences in the meaning components they lexicalize: *give*-type (*lend*, *pass*, etc.), *send*-type (*mail*, *ship*, etc.), and *throw*-type verbs (*kick*, *toss*, etc.).[4] They provide evidence that verbs like *give* have a caused possession meaning in both kinds of constructions. The *send* and *throw* verbs, by contrast, lexically entail a change of location and allow both interpretations depending on the construction they occur in. The *send* and *throw* verbs differ in the meaning components they lexicalize: *send* lexicalizes caused motion towards a destination, whereas *throw* encodes the caused initiation of motion and

[4]For simplicity, we do not consider verbs of communication nor do we take into account differences in modality as between *give* and *offer* (Koenig and Davis 2001).

	lexical meaning					PO pattern	DO pattern
	#args	result	punct.	manner	motion	(◇arrive)	(◇receive)
give	3	receive	yes	no	no	receive (arrive)	receive
hand	3	receive	yes	yes	yes	receive (arrive)	receive
send	3	leave ◇arrive	yes	no	yes	◇arrive	◇receive
throw	2	leave	yes	yes	yes	◇arrive	◇receive
bring	3	arrive	no	no	yes	arrive	receive

Table 1: Semantic classes of verbs in interaction with the DO and PO patterns.

the manner in which this is done. A destination is not lexicalized by *throw* verbs, which accounts for the larger range of directional PPs allowed for these verbs.

Beavers (2011) proposes a formally more explicit explanation of these observations based on a detailed analysis of the different types of results that determine the aspectual behavior of the verbs in question. He identifies four main types of results for ditransitive verbs: loss of possession, possession, leaving, and arrival. These results are associated with two different dimensions or "scales": The first two results belong to the "possession scale", the latter two results are associated with a location or path scale. Only *give* verbs lexicalize actual possession as a result. *Send* verbs and *throw* verbs, by contrast, do not encode actual possession nor do they encode prospective possession when combined with the PO construction. The result condition that makes these verbs telic even if the theme does not arrive at the destination or recipient is the leaving of the theme from the actor. That is, the aspectually relevant result consists in leaving the initial point of the underlying path scale.

With respect to the goals of the present study, the main question is how the constructional meaning interacts with the lexical meaning. The DO construction encodes *prospective* possession. Actual possession, however, must be contributed by the lexical semantics of the verb. This is the case for *give* verbs, which explains why there is no difference between the DO and the PO constructions for these verbs as far as caused possession is concerned. All other alternating ditransitive verbs show such a difference since only the DO pattern implies prospective possession.[5] Beavers (2011) draws a distinction between different types of caused possession verbs. Verbs such as *give* encode pure cause possession without necessarily motion or loss of possession involved. Verbs like *hand* and *pass*, by comparison, imply actual possession but also arrival of the theme via motion. The possession scale is "two-point" or "simplex" in that its only values are non-possession and possession. It follows that verbs which lexicalize caused possession are necessarily punctual since there are no intermediate "points" on this scale.

[5]The story is a bit more complicated: If the destination of the PO construction is human or human-like (e.g., an institution), there seems to be a conventional implicature that the (prospective) destination is also a (prospective) recipient, that is, (prospective) possession seems to be entailed in this case; cf. the examples in (i):

(i) a. John gave the package to Mary/*London.
b. John sent the package to Mary/London.
c. John threw the ball to Mary/the other side of the field.

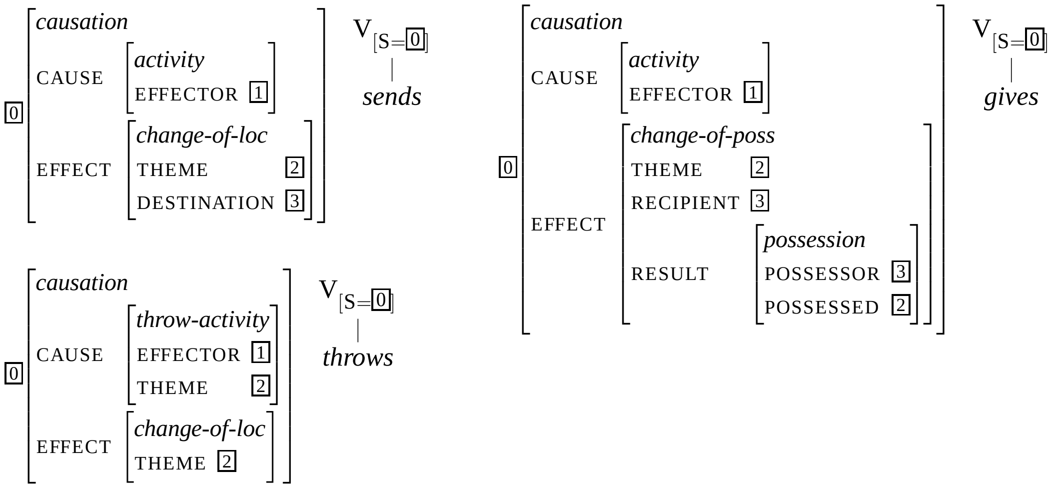

Figure 9: Possible frame representations for some of the lexical items in Table 1.

In contrast to *send* and *throw*, verbs like *bring* and *take* do encode arrival of the theme at the destination (Beavers 2011). That is, for these verbs of accompanied motion, the arrival is actual and not only prospective, and this property can be regarded as lexicalized since the verbs in question are basically three-place predicates. Accompanied motion verbs like *carry* and *pull*, which lexicalize a "continuous imparting of force", behave differently (Krifka 2004). They are basically two-argument verbs, i.e., they do not lexicalize a destination, and they are usually regarded as being incompatible with the DO pattern.[6]

In sum, the DO and PO constructions strongly interact with the lexical semantics of the verb.[7] Table 1, which builds on Beaver's analysis, gives an overview of the contribution of the lexicon and the constructions. Prospectivity is indicated by '$\Diamond$'. For some of the verbs listed in the table, possible frame semantic representations are given in Fig. 9. Consider the frame for *send*. The change of location subframe is meant to encode motion towards the destination without necessarily implying arrival. Actual arrival would be encoded by a resulting location state as in Fig. 8c), that is, in analogy to the representation of actual possession in the entry for *give*. The representation for *throw* differs from that for *send* in that *throw* lexicalizes a certain type of activity, here simply encoded by a subtype *throw-activity* of *activity*. Moreover, it is inherent in the given representation that the destination of the entity thrown is not part of the lexical meaning of *throw*.

4. Analysis of DO versus PO constructions

Modelling the above data in our approach calls for a sufficiently detailed decomposition of the semantics of verbs and constructions using frames represented as typed feature structures.

[6]The strict exclusion of the DO pattern for such verbs has been called into question by Bresnan and Nikitina (2010) on the basis of corpus evidence.

[7]The DO construction with caused possession interpretation also occurs for creation verbs with benefactive extension as in *bake her a cake* Goldberg (2010). The PO pattern requires a *for*-PP in theses cases, which will not be taken into account in the following.

Moreover, the semantic frames and their subcomponents are to be associated with morphosyntactic trees and tree fragments.

4.1. Unanchored elementary trees

Concerning the form of the syntactic elementary trees, we partly follow the choices made in the XTAG grammar (XTAG Research Group 2001). There is a tree family for ditransitive verbs with two NPs and a tree family for verbs selecting for an object NP and a PP in the XTAG grammar. In the PO construction we are interested in, the PP has to be a directional PP. It need not necessarily involve the preposition *to*, as illustrated by the examples in (8).

(8) a. He sends the boy into the house.
b. He throws the ball into the basket/at the boy.

The fact that some verbs are more restricted concerning the choice of the preposition than others is due to the interplay of the properties of the event participant determined by the verb and the properties determined by the preposition. In (9) for instance, we have a case where the lexical semantics of the verb tells us that we have a change of possession where the participant contributed by the PP is the possessor while the preposition *into* tells us that the NP embedded in the PP has to be some kind of container. In (9-a), the house can be a container but cannot fill the role of a possessor while in (9-b), the boy can be a possessor but is no container. We leave the exact frame-based modelling of such restrictions for future research.

(9) a. ?He gives the cake into the house.
b. *He gives the cake into the boy.

In contrast to our PO constructions that involve a directional PP without specifying the preposition, there are also constructions where a specific preposition is treated as a coanchor of the elementary tree. An example is the elementary tree for *remind of* as for instance in (10) where the preposition *of* is taken to be a coanchor of the elementary tree.

(10) This picture reminds me of my little dog.

The base trees of the DO and PO families are given in Fig. 10. The lower VP node in the PO tree is inspired by the XTAG choices. It serves to allow the adjunction of modifiers between the direct object and the PP object, as in (11), which would not be possible if the NP and the PP were sisters. The empty V-tree below this additional VP carries a *NA* (null adjunction) constraint. I.e., this node does not allow for adjunction.

(11) He sends his letters preferably to Susan.

The semantics of the DO construction is a caused possession meaning which gets further constrained when linking it to a specific lexical anchor. Fig. 11 shows how the unanchored tree for the verb is linked to its semantic frame. The identities between the I features in the syntactic tree and the thematic roles in the semantic frame provide the correct argument linking. As already mentioned, because of its extended locality, LTAG is able to perform this in a local way within the domain of the elementary trees. The semantics of the PO construction differs in that it expresses a caused motion instead of a caused possession. The linking of the unanchored tree for this construction to the corresponding semantic frame is shown in Fig. 12. The S feature

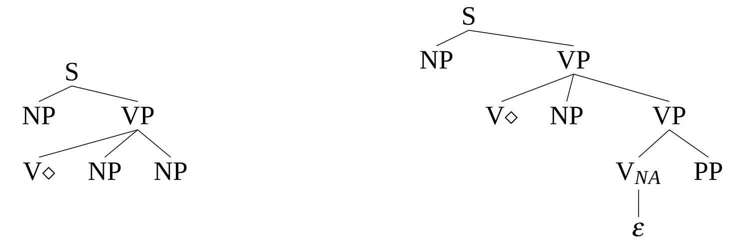

Figure 10: Base trees from the tree families for DO and PO verbs

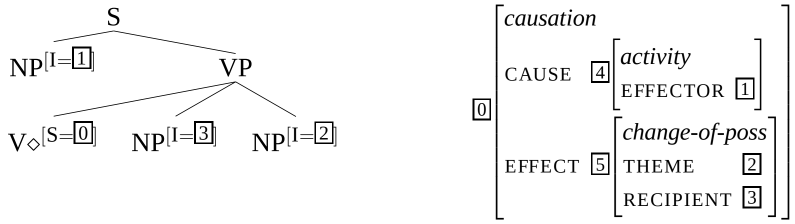

Figure 11: Unanchored elementary tree and semantics of the DO construction

of the V node describes a situation, its value is the frame of the elementary tree. When anchoring the tree with a lexical item, this feature unifies with the S feature of the lexical item and thereby guarantees unification of the lexical and the constructional frame.

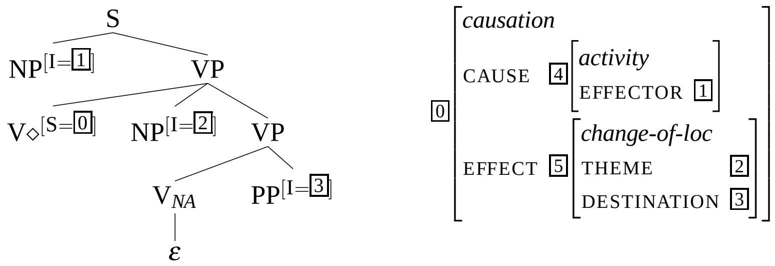

Figure 12: Unanchored tree and semantics of the PO construction

4.2. Metagrammar decomposition

The unanchored trees for the two constructions and their associated semantic frames can be further decomposed in the metagrammar. Some of the tree fragments in the metagrammar are used by both constructions, some are specific to one of them.

In the following, we restrict ourselves to the base trees when explaining the syntactic and semantic decomposition. Of course, other argument realizations are possible as well and should be taken into account in the metagrammar classes. For instance, the subject NP class *Subj* should not only contain the base subject realization shown on the left of Fig. 13 but also a tree fragment for an extraposed subject, for a wh-extracted subject, for a relativized subject etc. Some of these tree fragments will contribute different aspects to the semantics. We leave this aside for the moment, since the focus of this paper is on the dative alternation and its semantics. In this paper, we treat only the active base case, assuming that other cases can be captured along the lines sketched in Fig. 6.

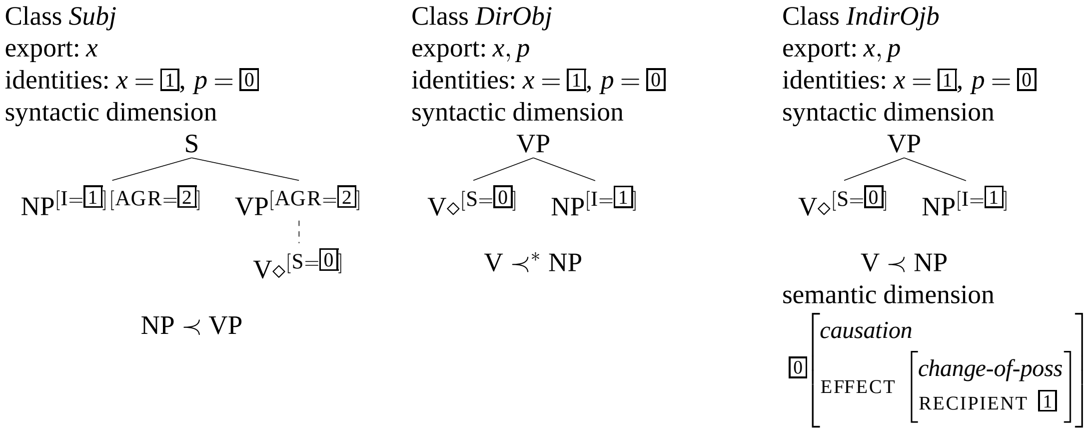

Figure 13: MG classes for subject, direct object and indirect object

Let us first consider the classes needed for the DO construction. There are classes that are just small tree fragments that do not use any other class. These are for instance the ones for the different arguments, namely for the subject NP, the direct object NP and the indirect object NP. The first two are fairly general, they occur in many of the elementary trees and do not constrain the semantics. The three argument classes are shown in Fig. 13. Each class has a name, a declaration of variables that one can refer to when using this class (the export variables), a list of equations, and a syntactic dimension and a semantic dimension (the latter is empty in the first two classes). The syntactic dimension contains a tree description that is depicted in the usual way in the figure. I.e., solid lines indicate immediate dominance, dotted lines indicate dominance and the order of sisters indicates linear precedence (but not necessarily immediate linear precedence). Furthermore, $\prec$ denotes immediate linear precedence while $\prec^*$ denotes linear precedence. In the class *Subj* for instance, the tree description tells us that there are three nodes n_1, n_2, n_3 with labels S, NP and VP such that n_2 has a top feature I with value $\boxed{1}$. Furthermore, n_1 immediately dominates n_2 and n_3 (depicted by the edges) and n_2 immediately precedes n_3. The picture is a little sloppy since it mixes node variabes with node categories. The realization of the third argument as an NP (i.e., the use of the class *IndirObj*) is responsible for the caused possession meaning. Therefore this class contributes a frame fragment in its semantics that tells us that the meaning is a causation whose effect is a change of possession where the argument contributed by this class denotes the recipient.[8]

Concerning the semantic dimension, we assume this to be a description of a typed feature structure. When we say "unification", speaking of combining frames in the metagrammar, we actually mean conjunction and feature value equation. So far, our impression is that we need only a simple feature logic without quantification or negation.

Now we combine our small tree fragments into larger ones, building further MG classes. We add a class for the verbal spine that takes care of the percolation of features (for instance AGR) along the verbal spine. This class combines with the subject class into the *InTransitive* class that in turn combines with classes for further arguments. The definition of the class for active transitive verbs is shown in Fig. 14. Note that we assume that, whenever we use a class, its meta-variables ($\boxed{0}$, $\boxed{1}$, etc.) get instantiated with fresh values. This avoids uninteded unifications.

[8]This is of course not the only way this syntactic fragment can be used; other classes for indirect objects with a different semantic contribution exist as well.

Class *VSpine*
syntactic dimension

$$\mathrm{VP}_{[\mathrm{AGR}=\boxed{1}]}$$
$$|$$
$$\mathrm{V}_{\diamond}^{[\mathrm{AGR}=\boxed{1}]}$$

Class *InTransitive*
export: p, arg_1
use classes V_1 =VSpine,
N_1 =Subj
identities: $V_1.V = N_1.V$,
$arg_1 = N_1.x$, $p = N1.p$

Class *Transitive*
export: p, arg_1, arg_2
use classes V_1 =InTransitive,
N_2 =DirObj
identities: $V_1.V = N_2.V$,
$p = N_2.p$, $arg_1 = V_1.arg_1$,
$arg_2 = N_2.x$

Figure 14: MG classes for transitive verbs

Class *DOConstr*
export: p
use classes V_1 =Transitive, N_3 =IndirOjb
identities: $p = N_3.p$
semantic dimension

$$p\begin{bmatrix} \textit{causation} & \\ \text{EFFECTOR} & V_1.arg_1 \\ \text{THEME} & V_1.arg_2 \\ \text{GOAL} & N_3.x \\ \text{CAUSE} & \begin{bmatrix} \textit{activity} & \\ \text{EFFECTOR} & V_1.arg_1 \end{bmatrix} \\ \text{EFFECT} & \begin{bmatrix} \textit{change-of-poss} & \\ \text{THEME} & V_1.arg_2 \end{bmatrix} \end{bmatrix}$$

Figure 15: MG class for the DO construction

The further combination with the class for the indirect object is shown in Fig. 15. The minimal model of *DOConstr* is the unanchored tree from Fig. 11. In addition to the frame shown in Fig. 11, we include a specification of the thematic roles on the top level of the frame that serves to obtain the correct identifications of event participants when unifying with the frame of the lexical anchor. We will come back to this when treating lexical anchoring in section 5.

Now let us consider the PO construction case. Here, the *Transitive* class is used again. For the third argument, we use the class *DirPrepObj* for a directional PP-argument. The PP contributes the goal of some change of location. The higher class *POConstr* arises from a combination of the *Transitive* class and the class for the directional PP. The change of location frame contributed by the PP is embedded under the EFFECT attribute of the frame of the verb and it is enriched with a role THEME that is the event participant contributed by the direct object. The class *POConstr* is given in Fig. 16. Concerning the highest class, we can define a class *DAltConstr* that is simple the disjunction of *DOConstr* and *POConstr*. This way, we obtain a single tree family containing trees for both constructions. Depending on whether we have a PP or a direct object, only the corresponding part of the family can be selected. The minimal referent of the class *DAltConstr* contains the two trees from Fig. 11 and Fig. 12.[9]

[9] As mentioned above the classes corresponding to elementary tree families usually have more than one minimal referent since all possible realizations of an argument (topicalization, extraposition, relativization, etc.) are taken into account.

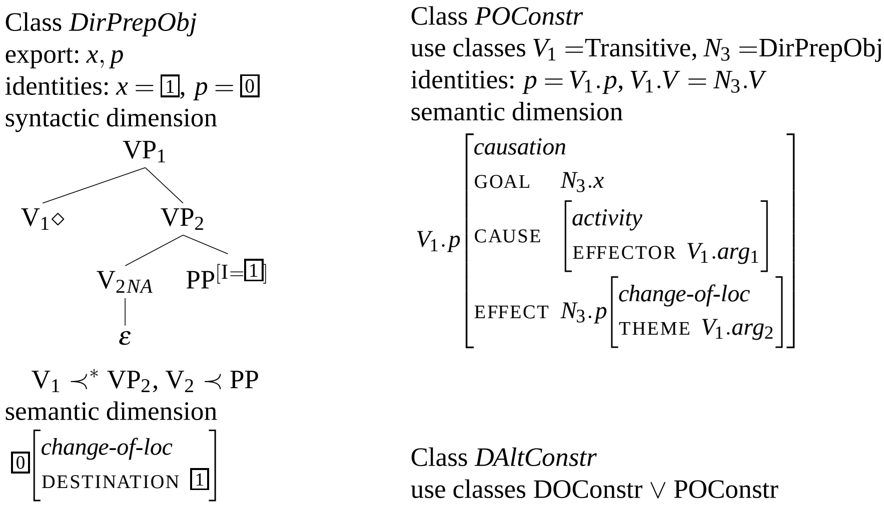

Figure 16: MG classes for the PO construction

5. Lexical anchoring for DO and PO constructions

Once the unanchored tree families are computed via compilation of the corresponding MG classes, these trees are anchored by lexical items. In other words, the lexical anchor is substituted into the anchor node.

The lexical anchor contributes parts of a semantic frame (see Fig. 9 above for some lexical items and their semantic frames). 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. An example is given in Fig. 17 that shows the lexical anchoring of the PO construction with the anchor *throws* (the top roles are omitted for reasons of space). The resulting anchored elementary tree has a semantic frame that is the unification of the frames 7 and 0.

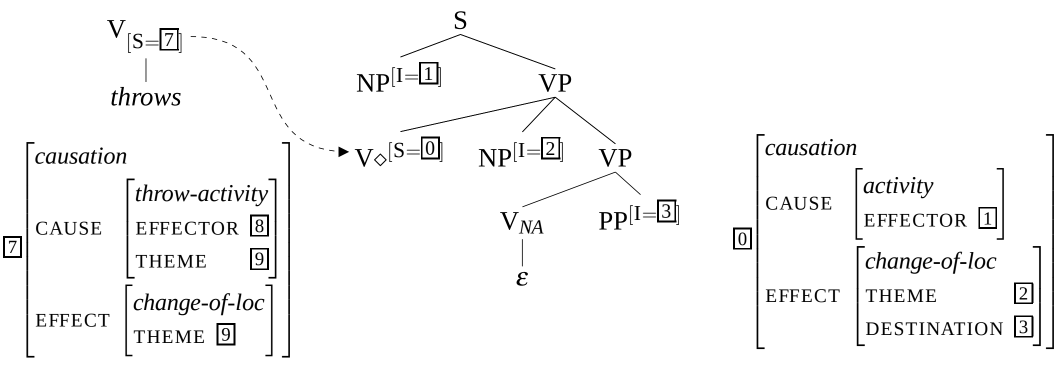

Figure 17: Lexical selection of the elementary tree for *throws* in the PO construction

The idea is of course that if the two frames (the lexical anchor frame and the construction frame) are contradictory, unification fails. However, in some cases where standard unification leads to a failure we actually want the two frames to unifiy. An example is the unification of the frame of *sends* that states that the verb expresses a causation whose effect is a change of lcoation and the frame of the DO construction that states that the effect of the causation is a change of possession. The two frames are given in Fig. 18. Even though they do not unify we want them to combine. The meaning of the combined frame (i.e., of the DO construction anchored with *sends*) is, roughly, a causation with effects along different dimensions or "scales": there is a change of location of the theme and at the same time the theme undergoes also a change of possession.

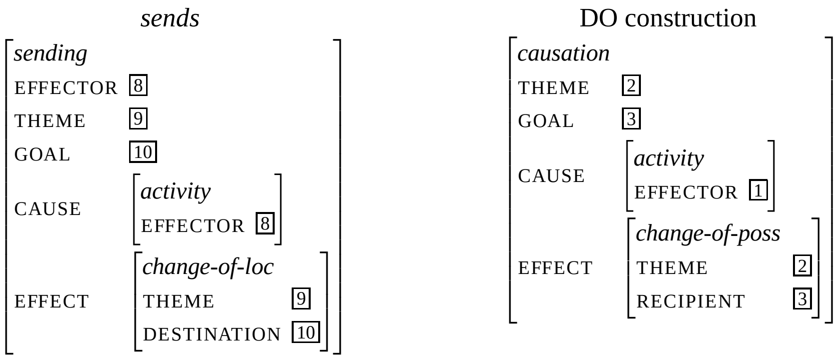

Figure 18: Lexical frame and construction frame of *sends* and the DO construction

There are different ways to avoid the mismatch between the two frames. One possibility is to use set-valued attributes and to assume a special set unification for these. In our case, the attribute EFFECT would have a set of changes as value. When unifying two such sets, the following strategy can be adopted: for two elements belonging to the respective sets, if they are of the same type or one is of a subtype of the other, they must unify and the result is part of the resulting set. Otherwise, we take the two elements to describe different aspects that should be considered as a conjunction. We therefore add each of them to the resulting set of frames. In our example, this would lead to the anchored tree in Fig. 19. Note that, in order to obtain the

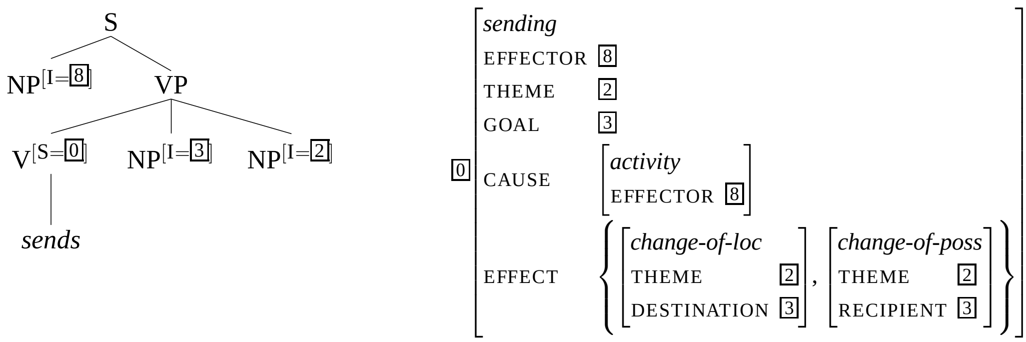

Figure 19: Anchored tree for *sends* with the DO construction

intended identifications between participants of events, we need the top roles here. They make sure the destination of the change of location is identified with the recipient of the change of possession since both are equal to the top goal of the frame.

An alternative approach, which does not require set-valued attributes, is to treat the diferent changes as two different perspectives on the effect of the causation event. Technically, the two perspectives could be realized by a CHANGE-OF-LOC subcomponent and a CHANGE-OF-POSS subcomponent of the EFFECT frame, respectively. But the details and the consequences of this solution have to be left to future research.

6. Conclusion

LTAG is a lexicalized tree grammar formalism with an extended domain of locality and rich possibilities for factorizing syntactic and semantic information on a metagrammatical level. In this paper, we propose to exploit this for an implementation of a detailed syntax-related semantic decomposition of both constructional and lexical meaning components. As a case study we have described a model for the dative alternation in English. Our LTAG analysis separates the lexical meaning contribution from the contribution of the construction taking advantage of LTAGs separation between unanchored elementary trees and lexical anchors. Furthermore, we have factorized the two constructions (double object and prepositional object) into smaller fragments, some of which are shared between the two constructions.

Our analyses have demonstrated that below the level of lexicalized elementary trees and their semantic representations, the metagrammar formalism in LTAG allows us to identify those fragments of syntactic structure that are the potential carriers of meaning. This is partly due to the abstraction from surface structure that comes with LTAG's adjunction operation and the resulting extended domain of locality. Even constructions that do not form a contiguous subtree in a larger derived tree can be described locally.

As semantic representations we have used frames in the sense of typed feature structures encoding rich semantic information. So far, it seems that the metagrammar descriptions of trees and frames can be rather simple in the sense of being first order tree/feature logics without quantification or negation. However, the formal properties of our framework need to be further investigated examining a larger range of semantic phenomena.

An important aspect of the work presented here is that we aim not only at theoretically modelling certain linguistic phenomena but also at implementing corresponding grammar fragments. The tools for implementing and testing LTAG grammars are already available though they need to be adapted to our needs concerning the feature logic we choose.[10]

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[10] We will use the metagrammar compiler XMG (`https://sourcesup.cru.fr/xmg/`) and the TAG parser TuLiPA (`https://sourcesup.cru.fr/tulipa/`).

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