One More Perspective on Semantic Relations in TAG

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1. Introduction

It has often been noted that the derivation trees of "standard" TAG grammars for natural languages (Group, 1998) resemble semantic dependency trees (Mel'ĉuk, 1988). More interesting, from a formal perspective, are the ways in which the derivation trees and the dependency trees diverge for certain problematic constructions. The desire to fix these cases has led to a variety of proposals for modifying or extending the TAG formalism ranging from Tree-Local Multi-component TAGs (TL-MCTAG) and Set-Local Multi-component TAGs (SL-MCTAG), through reconceptualization of the adjoining operation (Schabes and Shieber, 1994), through D-Tree Grammars (DTG) (Rambow, Vijay-Shanker and Weir, 1995) and Graph-driven Adjunction Grammar (GAG) (Candito and Kahane, 1998b), through reformalization of elementary trees in terms of C-Command rather than domination (Frank, Kulick and Vijay-Shanker, 2000), through the use of Meta-Grammars (Dras, 1999; Dras, Chiang and Schuler, To Appear), and through interpreting the semantic relations in a predicate-argument structure derived, but distinct, from the derivation trees (Joshi and Vijay-Shanker, 1999; Schuler, 1999). In this note, we look at some of these problematic constructions from yet another formal perspective—a mild extension of TAGs with well-constrained generative capacity which allows semantic dependency to be expressed as a relation orthogonal (in a quite literal sense) to constituency and linear precedence.

We should be clear at the outset, our focus is nearly exclusively formal—we explore ways of expressing these relationships in the extended formalism without pursuing their potential linguistic repercussions. Neither is our account exhaustive. There are problematic constructions that have not yet yielded to this approach. Our goal is to introduce the techniques involved, to explore their limits and, possibly, open up discussion of their linguistic consequences.

We will look five at examples from the literature:

1. roasted red peppers.

2. Does Gabriel seem to eat gnocchi?

3. Does Gabriel seem to be likely to eat gnocchi?

4. What does Mary think that John seems to eat?

5. That Paul has to stay surprised Mary.

Again, our intent is not to offer novel linguistic analyses of these constructions—we have attempted to take our analyses directly from the literature. Rather, we offer slightly different formal interpretations of those analyses, ones that seem to work out without seriously distorting the original spirit of TAG.

2. Generalized Tree-Adjoining Grammar

The mechanism we employ is a form of higher-order adjunction obtained as a natural extension of the Generalized Tree-Adjoining Grammar of Rogers (Rogers, 1999). GTAG starts with an interpretation of adjunction as concatenation of local three dimensional tree-like structures in direct analogy with the concatenation of local (two dimensional) trees characteristic of CFGs. One consequence of this perspective is that, as with CFGs, the derivation structures and the derived structures are the same: they are, in essence, the structures one obtains by expanding the nodes in a standard TAG derivation tree to instances of the elementary trees they represent. A second consequence is that it is an easy step to extend these three dimensional grammars in a way that is analogous to the way that CFGs are extended to admit regular expressions on the rhs of productions in GPSG. Here we allow the yields of the local three dimensional trees to form any local set. Finally, the generalization from two dimensional grammars to three dimensional grammars suggests a natural generalization to higher dimensions. This leads to an infinite hierarchy of grammar types (Rogers, To Appear) which are equivalent, in weak generative power, to the grammars in Weir's Control Language Hierarchy (Weir, 1992).
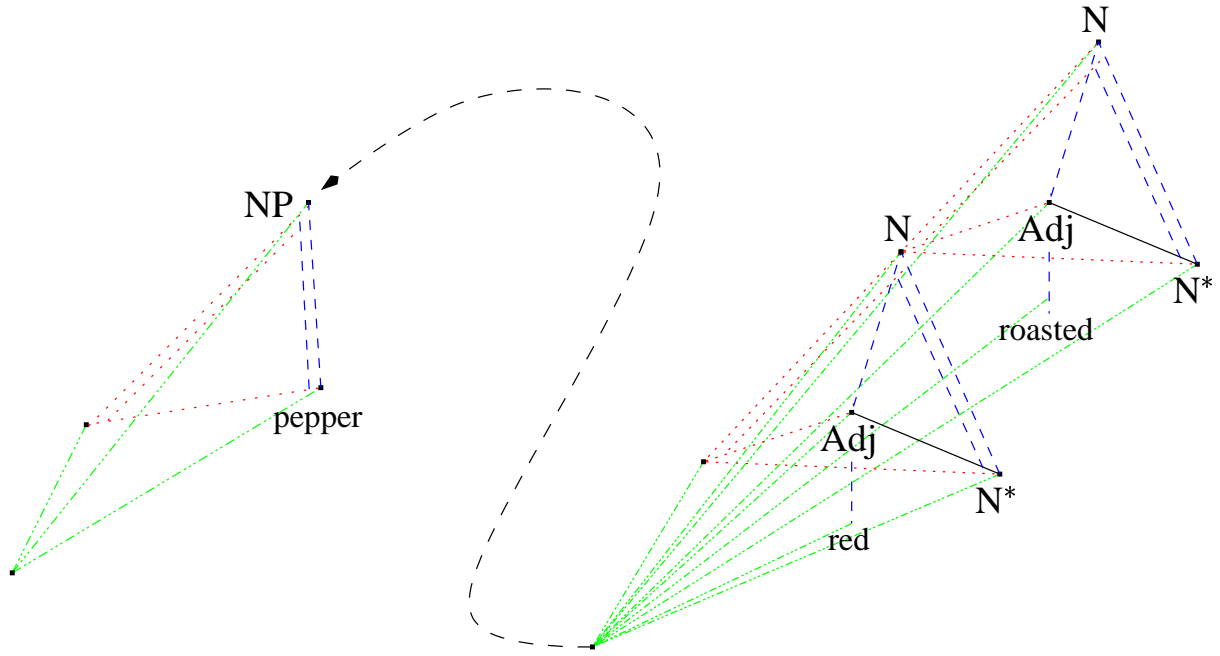
N

N   Adj

                                N*

                        roasted

                Adj

                        N*

                    red

Concatenation of four-dimensional elementary structures

N

N   Adj

                    N*

            roasted

NP   Adj

                N*

        red
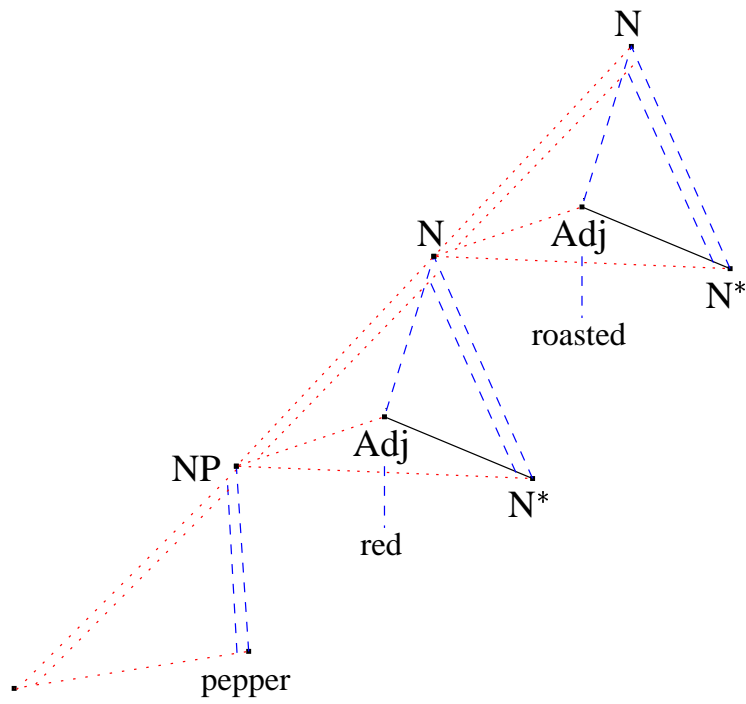
        pepper

Three-dimensional yield

Figure 1: roasted red pepper

We will use the four dimensional grammars, not because of their additional weak generative capacity, but, rather, because the fourth dimension allows us to encode semantic relations independently of the relations—linear precedence, domination, and the relation expressed in the derivation trees—already built into TAG. The fundamental operation of the four dimensional grammars (concatenation of local four dimensional trees) is equivalent to adjunction of three dimensional trees. Again at this level, we can allow the yields of the local four dimensional trees to form any local set of three dimensional trees.

3. Multiple Modifiers

The issue in (1) (Schabes and Shieber, 1994) is the multiple modifiers of pepper. In the standard TAG account *red* adjoins into *roasted* and the derived auxiliary tree then adjoins into *pepper*. The correct semantic relationship, however, is a direct relation between *pepper* and each of modifiers *red* and *roasted*. Schabes and Shieber (Schabes and Shieber, 1994) suggest relaxing the notion of adjunction for modifier trees to allow both *red* and *roasted* to adjoin into the same node of *pepper*. Rambow, Vijay-Shanker and Wier (Rambow, Vijay-Shanker and Weir, 1995) employ a similar mechanism called *sister adjunction*. In our approach (Fig. 1 [1]), we retain the standard adjunction of the one modifier tree into the other, but we do this in the elementary structure: the concatenation of the three-dimensional structures representing the modifiers forms the three-dimensional yield of a single four-dimensional local tree. This, then, adjoins as a whole into the elementary structure for *pepper*. The result is a local relationship, in the fourth dimension, between each of the modifier trees and the noun tree.

4. Raising Verbs and Sub-Aux Inversion

The issue in (2) is the interaction of the raising verb and the subject-aux inversion. In standard TAG accounts *does* and *seems* cannot occur in the same elementary tree. This leads either to a violation of CETM (in practice) or to a TL-MCTAG account or, in DTG, to the use of subsertion to interleave two underspecified trees. Our account depends on reinterpreting the elementary structure of *eat* as a four dimensional structure in which the yield, in effect, represents the subject as being adjoined into the root of the $[_{VP}eat]$.[2] This allows the structure for *does seem* to adjoin in the fourth dimension at that root node, in effect simultaneously adjoining (in the third dimension) *does seem* into the root of $[_{VP}eat]$ and the subject into the root of $[_{VP}seem]$. Once again, we have a local semantic relationship between the two elementary structures in the fourth dimension. More importantly, *does* and *seems* inhabit the same elementary structure but, in effect, wrap around the subject in the three dimensional yield.

5. Multiple Raising Verbs

In example (3) (Frank, Kulick and Vijay-Shanker, 2000) the problem of the last example is exacerbated by multiply nested raising verbs. Frank, Kulick and Vijay-Shanker (2000) point out that, under the usual assumption that adjunction at the foot of a structure is prohibited, this sentence cannot be obtained from elementary structures that observe the CETM even by TL-MCTAG.

Given our interpretation of (2), the account of (3) follows with little additional complication. The *does seem* structure simply attaches to the *to be likely* structure which then attaches to the *eat* structure. Following the three-dimensional spines in taking the three-dimensional yield, the subject ends up attaching to the root of $[_{VP}seem]$. Following the two-dimensional spines in taking the the two-dimensional yield of the result, the composite $[does\ Gabriel\ seem]$ effectively adjoins into the root of the $[_{VP}to\ be\ likely]$.

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1. In interpreting the figures, the solid lines represent adjacency in the first dimension (string adjacency), the dashed lines represent adjacency in the second dimension (immediate domination), the dotted lines represent adjacency in the third dimension (the adjunction relationship) and the dash/dot-dot-dot lines represent adjacency in the fourth dimension. In addition, spines are marked, in each of the second and third dimensions, by doubling the lines. (Spines are trivial in the first dimension and irrelevant in the major dimension.) The significance of the spines is that the maximal point in the spine marks the *foot* of the structure. As in standard TAG, the foot is the point at which the structure dominated by the point of adjunction is attached in forming the $(n-1)$-dimensional yield of an n-dimensional structure.

2. Since there is no identification of the root and foot nodes with the node at which they adjoin we are free to label these nodes independently. We leave open the question of appropriate label for the root node of the *eat* structure. Note that the relaxation of the requirement that the root/foot/node of adjunction bear the same label is not new here—it was effectively abandoned at least by the introduction of FTAG. Formally, if we allow either features or adjunction constraints, the labeling constraint has no substantive effect on the generative capacity.
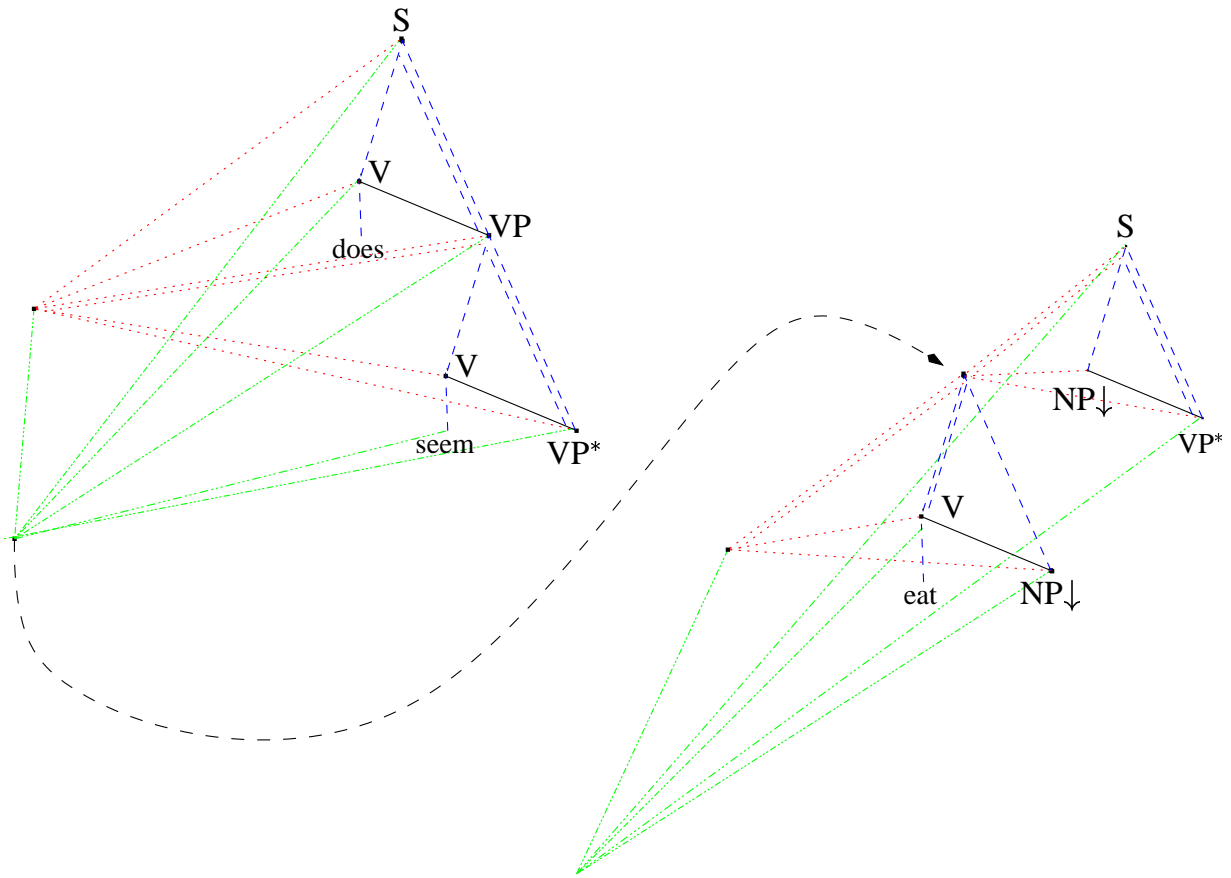
Concatenation of four-dimensional elementary structures
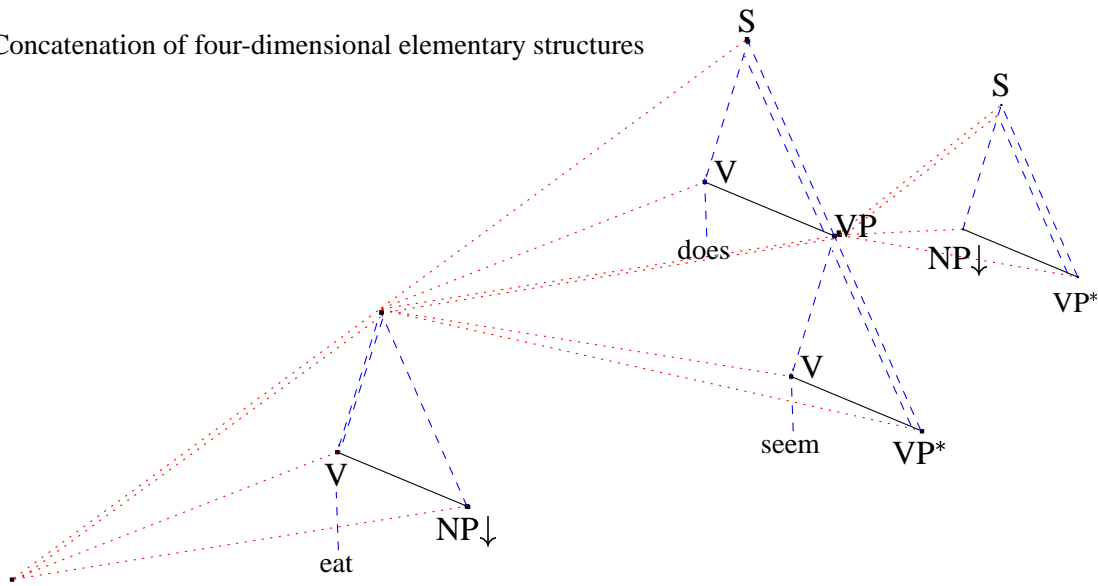
Three-dimensional yield
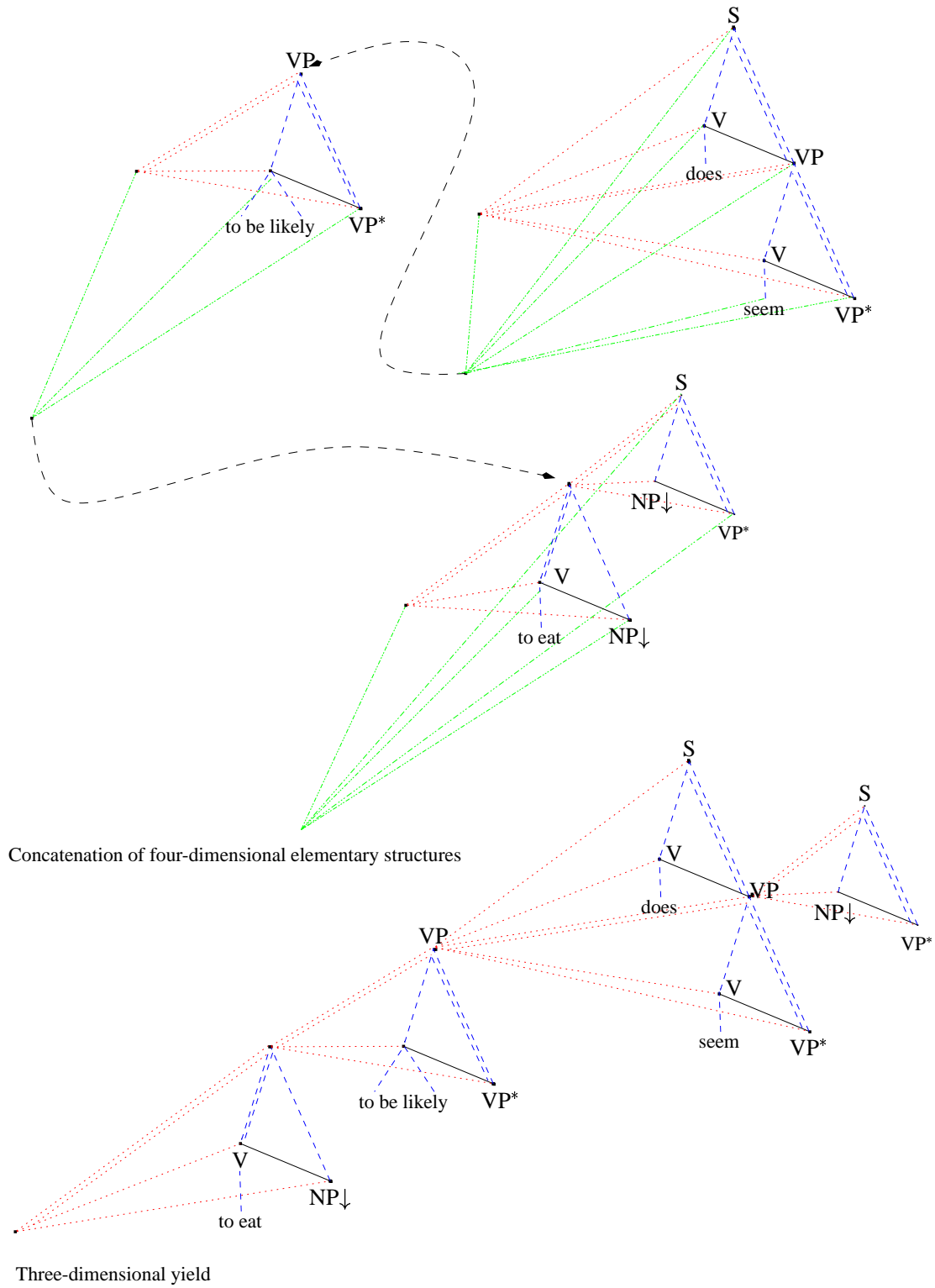
Figure 2: Does Gabriel seem to eat gnocchi

Concatenation of four-dimensional elementary structures

Three-dimensional yield

Figure 3: Does Gabriel seem to be likely to eat gnocchi

6. Interaction of Bridge and Raising Verbs

The fundamental issue in example (4 (Dras, Chiang and Schuler, To Appear) is, again, the inconsistency between the relations expressed in the derivation tree of the standard TAG account and the semantic relations between the constituent phrases. Standardly, the tree for *seems* adjoins into the tree for *eat* at the root of [$_{VP}$to eat] and the tree for *think* adjoins into the *eat* tree at the root of [$_S$John to eat]. Consequently, there is no direct relationship between the *think* structure and the *seem* structure. Dras, Chiang and Schuler (To Appear) get the desired relationships (*think—seem—eat*) by using a two-level TAG in which the elementary trees of the first-level TAG are generated by a second-level TAG.

As we note below, this approach is pretty much equivalent to adopting a fourth dimension. Working within the current framework, this analysis turns out to be only slightly more complicated than the last. The interesting issue here is the complementizer *that* which belongs in the same initial structure as seem, but which needs to be separated from *seem* by the subject in the final two-dimensional structure. Here, again, we resort to attaching, in the third-dimension, the complementizer to the root of the [seem] substructure in much the same way that we attach the subject to the root of the VP in the main verb structure. With this configuration, the complementizer and *seem* are in the same elementary structure but can be wrapped around the *does Mary think* structure in the same way that *John* and *to eat* do.

Finally, note that, in this case, the root of the [$_{VP}$think] tree already has the *Mary* tree attached. Rather than pass the three-dimensional spine through that node, we pass it through the VP* node. Hence, *that* and *John* end up following the entire yield of *does Mary think* rather than being embedded in the middle of it.

7. Modifiers of Sentential Subjects

The final example (5) is from Candito and Kahane (1998a). It is also treated in Schuler (1999). The standard TAG account has *have to* adjoining into *stay* and the result substituting into *surprise*. But, adopting the semantic account that it is the fact that Paul *has to* stay that is surprising, we would expect to find direct semantic relations between *surprise* and *have to* and between *have to* and *stay*. To capture this, we can let the *stay* structure attach at the three-dimensional root of the *has to* structure and attach the *has to* structure at the S substitution node of the *surprise* structure. When these are collapsed to three dimensions, the *has to* structure ends up attached at the three-dimensional foot of the *stay* structure, which properly places it between *Paul* and *stay* in the two-dimensional yield.

One of the potentially attractive aspects of this formal interpretation is that it is equally possible to attach *has to* to *stay* (at the root of [$_{VP}$stay]) from which one obtains a reading in which it is the fact that what Paul has to do is to stay that is surprising.

8. Conclusions and Relationship to Other Approaches

For each of the problematic constructions we started with, we have obtained structural configurations that express the intended semantic relationships directly while preserving the CETM in atomic, fully specified elementary structures. Moreover the semantic relations are consistently expressed in one particular structural relation, that of adjacency in the fourth dimension of our structures. While the notion of grammars over four dimensional objects may seem conceptually obscure, one can dispell much of that obscurity if one simply considers each dimension to represent a single type of relationship. Our structures have four dimensions solely because there are four types of relationship we need to express.

While each of the configurations we have proposed has been tailored to the needs of the construction we were attempting to capture, there does seem to be considerable regularity in the way the the elementary structures are arranged. Although we have made no attempt to motivate these structures on linguistic grounds, none of them seems completely beyond the pale. Whether the potential for overgeneration can be constrained in a principled way remains to be seen, but the fact that, at least in one case, a potential alternation reflects a corresponding ambiguity in the semantics is a little encouraging.

Formally, our approach is closest to that of Dras, Chiang and Schuller's use of Multi-Level TAGs (Dras, Chiang and Schuler, To Appear), in that both accounts employ mechanisms equivalent to the second level of Wier's Control Language Hierarchy. From our perspective, the structures generated by Multi-Level TAGs, in a sense, conflate relations of different type by encoding them with the same formal relation. This leads to structures that are quite complex and of less than ideal transparency. In clearly distinguishing the semantic relations from the syntactic
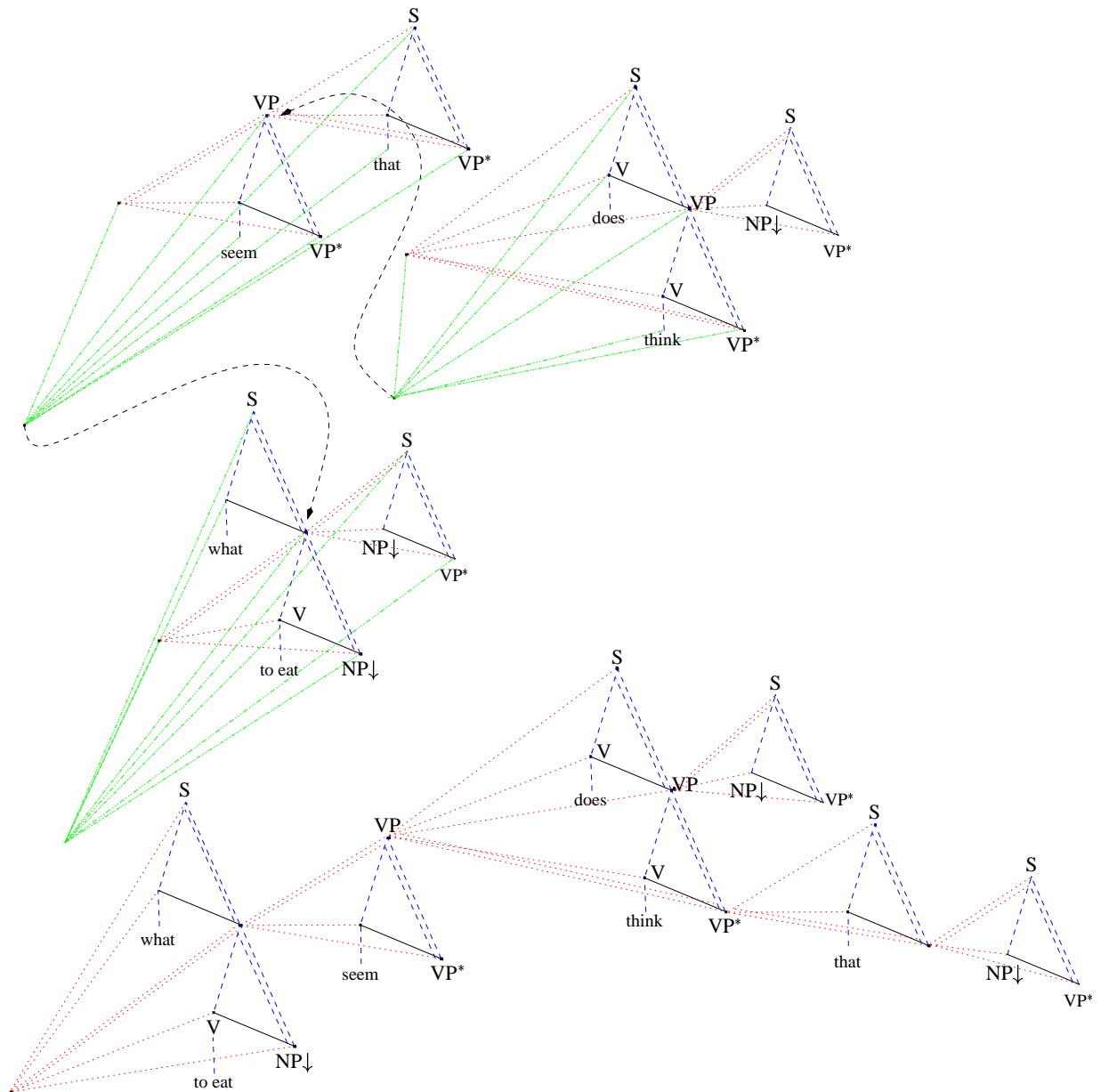
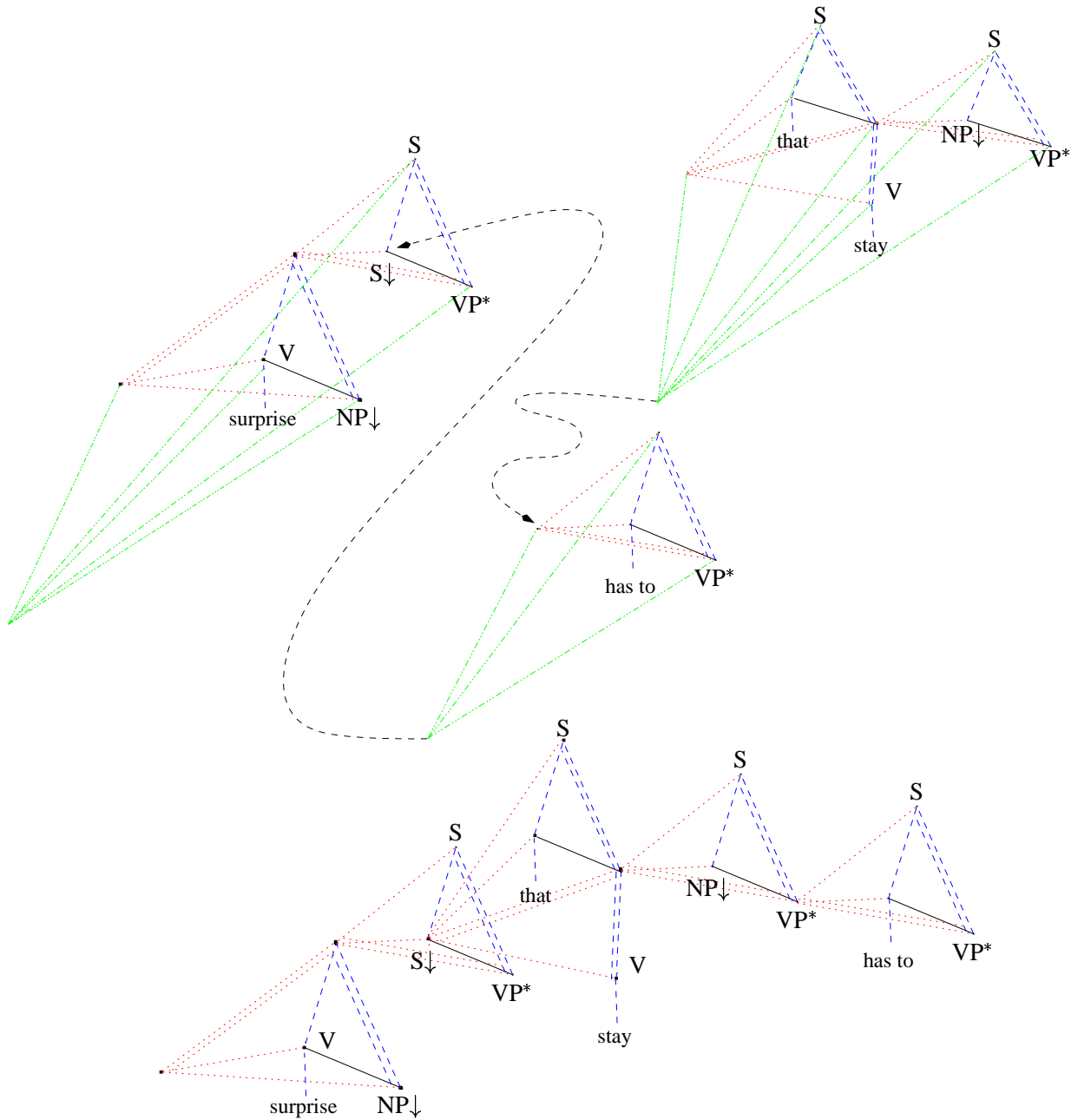Figure 4: What does Mary think that John seems to eat

Figure 5: That Paul has to stay surprised Mary

ones, our approach is, perhaps, more closely related to that of Joshi and Vijay-Shanker (Joshi and Vijay-Shanker, 1999) in which semantic relations are not read directly off of the derivation trees but are rather expressed directly in semantic structures derived from those trees. In our approach, however, we preserve the original intuition that the structures generated by the syntactic analysis might directly express the semantic relationships.

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