Flexible Composition, Multiple Adjoining and Word Order Variation

Joan Chen-Main* and Aravind K. Joshi*[+]
*Institute for Research in Cognitive Science, and
[+]Dept of Computer and Information Science
University of Pennsylvania
Philadelphia, PA 19104-6228
{chenmain,joshi}@seas.upenn.edu

Abstract

Tree-Local Multi-Component TAGs (called hereafter just MC-TAG for short) are known to be weakly equivalent to standard TAGs, however, they can describe structures not derivable in the standard TAG. There are other variants of MC-TAG, such as MC-TAG with (a) flexible composition and (b) multiple adjoining of modifier (non-predicative) auxiliary trees that are also weakly equivalent to TAGs, but can describe structures not derivable with MC-TAG. Our main goal in this paper is to determine the word order patterns that can be generated in these MC-TAG variants while respecting semantic dependencies in the grammar and derivation. We use some word order phenomena such as scrambling and clitic climbing to illustrate our approach. This is not a study of scrambling or clitic climbing per se. We do not claim that the patterns of dependencies that are derivable are all equally acceptable. Other considerations such as processing will also come into play. However, patterns that are not derivable are predicted to be clearly unacceptable.

1 Introduction

This paper examines the different word orders that can be generated while maintaining the same word to word dependencies using several extensions of tree-local Multi-Component TAG (MC-TAG). We find that when the system is enriched to allow *flexible composition*, not all patterns can be derived beyond two levels of embedding. Flexible composition is the mirror operation to adjoining; if tree α adjoins into tree β, the combination can be alternatively viewed as tree β "flexibly" composing with tree α (Joshi et al. 2003, Kallmeyer and Joshi 2003). By enriching MC-TAG with this perspective of adjoining, some derivational steps which appear to permit components from the same MC-set to combine into different trees can be recast as abiding by tree-locality. Tree-local MC-TAGs with flexible composition have been investigated from the point of view of understanding the range of structures they can generate. Some of the phenomena where flexible composition has been useful include scope ambiguity and available readings in nested quantifications (Joshi et al. 2003, Kallmeyer and Joshi 2003), complex noun phrases in pied-piping and stranding of wh-phrases (Kallmeyer and Scheffler 2004), and binding (Ryant and Scheffler 2006). The full range of flexibility that can be allowed without going outside the weak generative capacity of standard LTAG is not known yet. In this paper, the flexible composition we explore is limited to reverse adjoining at the root.

Although our main focus is the generative capacity of MC-TAG with flexible composition, we also consider the effects of also permitting *multiple adjoining*, i.e. allowing more than one tree to adjoin into the same node (Schabes and Shieber, 1994), in an MC-TAG. We find that not all patterns can be derived beyond three levels of embedding. We also argue that multiple adjoining of components from the same MC-set is different in kind from multiple adjoining of components from different MC-sets.

Our investigation also includes a look at the effects of enforcing binary branching. The TAG composition operations, substitution and adjoining are binary, in the sense that each operation involves composing two trees into one, two structures into one. However, there is another dimension for this issue of binarization in TAG which does not arise in other systems, such as CFGs or Categorial Grammars, for example, as these are essentially string rewriting systems. In the case of TAG, we have a choice at the level of the elementary trees. We can require all elementary trees to be binary or we can allow some elementary trees to be non-binary. We find that binarizing the elementary trees results in additional nodes (in comparison to its non-binarized counterpart), allowing additional patterns to be derived in MC-TAG with flexible composition.[1]

Most of this paper is devoted to illustrating our approach using scrambling in German. We assume a single set of linguistic dependencies, and we consider the possible word orders when the dependencies are respected throughout the derivation. Lastly, we take a preliminary look at clitic climbing under the same approach.

2 German Scrambling

In subordinate clauses in Standard German, the canonical order of verbs and their subject arguments is a nested dependency order. However, other orderings are also possible. For example, in the case of a clause-final cluster of three verbs, the canonical order is as given in (1), $NP_1NP_2NP_3V_3V_2V_1$, but all other permutations of the NP arguments are also possible orderings.[2]

(1) NP_1 NP_2 NP_3 V_3 V_2 V_1
. . . Hans Peter Marie schwimmen lassen sah.
. . . Hans Peter Marie swim make saw
" . . . Hans saw Peter make Marie swim."

However, with an additional level of embedding, i.e. four NPs and four verbs, the situation is less clear both linguistically and formally. Some orderings, such as (2), are consistently taken to be (more) acceptable, while others, such as (3) are consistently dispreferred.

(2) NP_4 NP_1 NP_2 NP_3 V_4 V_3 V_2 V_1

(3) NP_3 NP_1 NP_4 NP_2 V_4 V_3 V_2 V_1

Interestingly, just as natural language appears not to permit all permutations of nouns at this deeper level of embedding, so too does tree-local MC-LTAG allow only certain permutations. (Becker et al.,1991, Rambow 1994, Joshi et al., 2000). Here, we closely examine the situation involving three levels of embedding. Twenty four orderings result from permuting the four nouns while keeping the verb order fixed.[3] Our focus is on making the formal predictions of a system that allows flexible composition precise. The linguistic dependencies we assume here are (a) that between a verb and its NP argument and (b) that between a verb and its VP argument. The former is respected by the standard TAG approach to verbs and their arguments: the set anchored by V_i includes a substitution node for NP_i. The latter is respected both by having a VP_{i+1} node in the set anchored by V_i as well as requiring the VP argument of V_i to be V_{i+1} throughout the derivation.[4] For example, tree sets for V_1 and V_3 can only combine with one another if one of them has combined with V_2 first. The task at hand is to see which variants of MC-LTAG derive which permutations, setting the stage to compare whether the sequences that require more powerful extensions align with dispreferred sequences.

3 Tree-Local MC-TAG Extensions

We take tree-local MC-LTAG as our starting point: all components belonging to the same MC-set must combine into a single elementary tree. In the linguistic context, there is always a constraint between the two components of an elementary tree set of an MC-TAG. Usually, there is an implied "top" and "bottom" tree, and we require the foot node of the top tree to dominate

[1] Conversely, when binarization eliminates nodes, e.g. binarizing a grammar that allowed nodes with a single nonterminal daughter, binarization is expected to decrease the possible derivations.

[2] Some permutations sound better with full NPs instead of proper names. Examples can be found in (Rambow 1994). Our purpose here is just to illustrate possible patterns.

[3] There are other patterns of scrambling, for example, N_1 N_2 N_3 V_1V_3 V_2, involving permutations of V's. We do consider these here for now.

[4] I.e. We adopt the strong co-occurrence constraint of Joshi et al (2000).

(but not immediately) the root node of the bottom tree. Using Grammar 1 in Figure 2 as an example, this means that the N_i component must be above the V_i predicative component in the derived phrase structure. The constraint may alternatively be a c-command relation. In any case, the constraint does not permit the immediate domination of the two components, i.e. the identification of the root node of the bottom tree by the foot node of the top tree.

An outcome of prohibiting immediate domination between the two components is that each component must target two distinct nodes for the composition to be valid. We further discuss this constraint in 4.2.

3.1 Permitting Flexible-composition

We first investigate the effect of allowing flexible composition, but only when adjoining would have taken place at a root. We do not consider reverse adjoining at internal nodes. Thus, if tree A flexibly composes into tree B, then it is the reverse of B adjoining into A's root.

Under this extension, we also do not allow flexible-composition at a node that also serves as a target for adjoining. For example, this prohibits the derivational steps in Figure 1: A and B are auxiliary trees with the same root and foot node labels. B adjoins into the root of C, and C flexibly composes at its root with A. If we take the notion of flexible-composition as "reverse adjoining" seriously, then allowing flexible-composition and adjoining at the same node would be multiple adjoining in disguise. In our example, the derivation shown is the same as adjoining both A and B into the root node of C. Some cases of flexible-composition and adjoining at the same node will be permitted under the multiple adjoining extension described below.

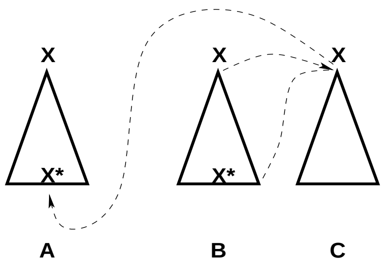

Figure 1: Flexible composition and adjoining at the same node. This is prohibited in TAG extensions without multiple adjoining.

3.2 Permitting Multiple-adjoining

What we mean by *multiple adjoining* is the Schabes and Shieber (1994) style multiple adjoining extended to apply to MC-sets: more than one component tree may adjoin into a host node so long as at most one of those trees is a predicative tree.[5] We follow Schabes and Shieber (1994) in assuming that the multiply-adjoined structures corresponding to modifiers may be in any order, but the order of the elementary trees in the final derived tree is determined by the order of adjoining: if tree A adjoins into a node X before tree B adjoins into the same node X, then tree A will be below tree B in the derived tree.[6] Additionally, since we require that components belonging to the same MC-set target distinct nodes, it follows that trees that target the same node belong to different MC-sets.

4 Non-binarized Phrase Structure

The grammar we first explore is shown in Figure 2. These tree sets are based on the tree-sets for a verb with two arguments given in Becker et al, (1991) which have been assumed for subsequent TAG approaches to German scrambling. A point of departure, however, is that these trees have more than one VP node. While we assume that the VP nodes belonging to the noun components do not carry the indexing information for the verb it is associated with, we do assume that both the root VP node and internal VP nodes, if any, of a predicative elementary tree carry the indexing information associated with the verb. This means that there is an additional potential "host" node for adjoining, and hence, each scrambled

[5] We treat the nouns as a type of modifier of the verb. I.e., we allow the following to adjoin into a single node: a) multiple noun components, or b) any number of noun components and one verb component. Since we have a different notion of modifier and predicate, we diverge from Schabes and Shieber (1994) by assuming predicative trees appear below modifier trees.

[6] Multiple-adjoining is related to tree-local MCTAG with shared nodes (SN-MCTAG) (Kallmeyer, 2005) in that a node which hosts adjoining is not seen as having disappeared in the tree-rewriting process. Rather, the host node and the root node of the tree being adjoined are identified, and the node is considered to belong to both trees. Thus, the targeted node is still available as a host for additional adjoining. SN-MCTAG also considers the foot node to have identified with the host node and to be available as a host for additional adjoining, unlike Schabes and Shieber (1994).

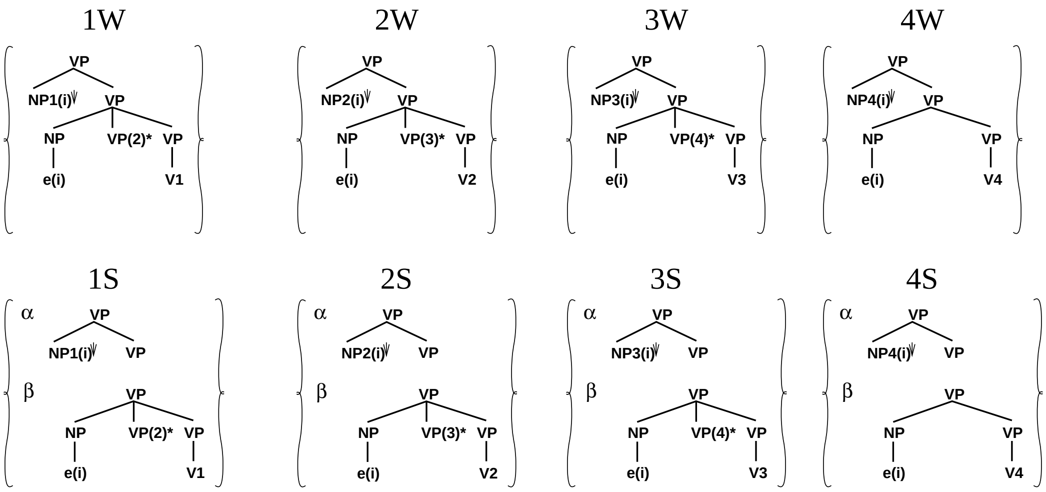

Figure 2: Scrambling Grammar 1. Each verb anchors a singleton set and a set with a two components

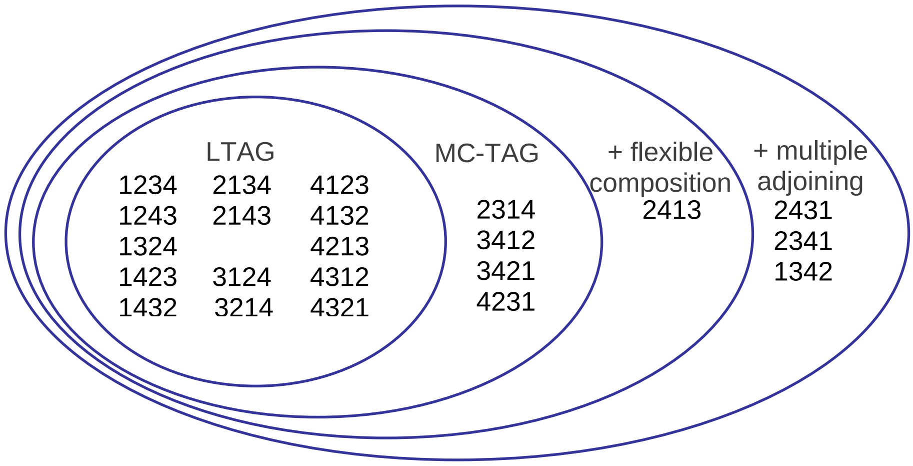

Figure 3: Derivable sequences given Grammar 1. MC-TAG with flexible composition derives structures for 15 permutations. Allowing multiple adjoining as well derives 22 permutations. The remaining 2 permutations require composition that is essentially ternary.

sequence may have more than one structural description. For example, consider the singleton sets in Grammar 1 for V_1 and V_2. The V_1 tree may adjoin into either the root node or the internal VP node of the V_2 tree and maintain semantic coherence. In contrast, we also assume that the noun components in Grammar 1 do not have host nodes for predicates. This has the effect of banning adjoining into the noun components in general: an NP_i component cannot combine into an NP_j component without leaving the structural predicate V_i component without a host to combine into.

4.1 Derivable Sequences

Figure 3 shows which sequences are derivable under which TAG extensions. Since we hold the sequence of verbs fixed, we use a number sequence to refer to the order of the NPs. E.g. 1234 is shorthand for $NP_1NP_2NP_3NP_4V_4V_3V_2V_1$.[7]

Given Grammar 1, fourteen sequences are derivable with LTAG (i.e. using only the singleton sets in Grammar 1), and four additional sequences are derivable with MC-LTAG. Since deriving one of the noun sequences in the case of three noun-verb pairs, 231, already requires MC-TAG, this is no surprise.

For this particular grammar, only one additional sequence is derivable as the result of extending MC-LTAG to include flexible composition. Since each tree has at most three host VPs,

[7] Note that not all of the subset relationships in Figure 3 and Figure 6 are obligatory. E.g. It is possible to allow multiple adjoining without allowing multi-component sets.

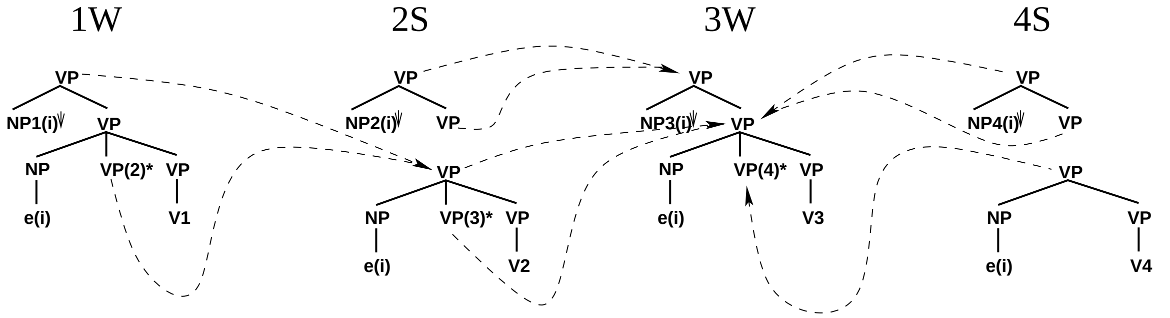

Figure 4: Derivation for 2341. Multiple-adjoining allows the upper components from 4S to target the internal VP node of 3W after 2S has already adjoined into the same node. Flexible composition allows the predicate component of 4S to combine into the foot node of 3W.

there is no tree in Grammar 1 into which two MC-sets can combine. Since a tree from Grammar 1 only hosts at most one MC-set, many derivations involving flexible composition can be recast using classic adjoining. Additionally, because the singleton sets' trees include more than one host VP for a higher verb, more than one semantically coherent derivation are actually available for some sequences, even in LTAG. When the system allows multiple-adjoining, three more sequences become derivable. Consider the derivation for 2341 in Figure 4. Flexible composition allows the singleton set anchored by V_3 to be the root-tree of the derivation (i.e. the root in the derivation structure) even though it is an auxiliary tree. The MC-set anchored by V_4 and that anchored by V_2 both combine into V_3. One component from each set targets the internal VP node in V_3's tree.

4.2 Underivable Sequences and Multiple Adjoining in MC-TAG

Two sequences remain underivable: 3142 and 3241. We also explore what kind of modification is needed to derive these sequences. We find that the type of adjoining that is needed has a ternary quality to it and we conjecture that deriving these sequences requires some sort of ternary composition. We refer to this "ternary" operation as *same-set multiple adjoining*: components belonging to the same MC-set are permitted to adjoin into the same host node. The difference between adjoining a "whole tree" into a single node and adjoining two components of the same set into a single node is that a non-predicative component from a different set is permitted to also adjoin into the same node, potentially separating the two components belonging to the same set. This is illustrated in Figure 5: A_1, C_1, and C_2 adjoin into the same node in B. E.g. Given Grammar 1, the NP_2 component can separate the top and bottom components of the set anchored by V_3 when all three components adjoin into the same node. Note that the need for same-set multiple adjoining to derive structures for these sequences is an observation about a formal system, not an argument that this system is needed to adequately model natural language. It is not clear that these scrambling sequences are actually accepted by German speakers. Thus, unlike flexible composition and non-same-set multiple adjoining, same-set multiple adjoining has not been linguistically motivated.

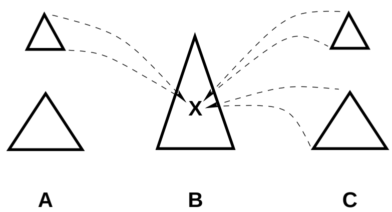

Figure 5: Flexible composition and adjoining at the same node. This is prohibited in TAG extensions without multiple adjoining.

Same-set multiple adjoining is not a case that arises in Schabes and Shieber (1994). Although nothing appears to rule same-set multiple adjoining out under the most straightforward extension of their approach to MC-TAG, we argue instead that it is a different kind of composition than multiple adjoining of components belonging to different sets and should not be permitted.

First, it is worth noting that while every LTAG derivation involving multiple adjoining can be recast as a derivation without multiple adjoining,[8] this is not the case for tree-local MC-TAG. If A_1 and C_1 adjoin into the same node in B, then by tree locality, A_2 and C_2 also adjoin into B. It is not possible to recast this as A_1 adjoining into C_1 before C_1 adjoins into B without violating tree-locality: A_2 must adjoin into B, not C. Nor is it part of a possible derivation for C_1 to adjoin into A_1 before A_1 adjoins into B, as tree locality will also be violated. This is relevant to the notions of simultaneous adjoining pursued in Schabes and Shieber (1994) and binary composition. In LTAG, viewing multiple-adjoining as the simultaneous insertion of multiple trees is not susceptible to the concern that tree composition is no longer binary, because the derivation can alternatively be viewed as a series of binary compositions.

However, whether we view same-set multiple adjoining as simultaneous or sequential composition into the same node address, the composition has a non-binary quality to it. Consider the sequential view of multiple adjoining: each tree is adjoined iteratively into the same node. If we abide by the Schabes and Shieber (1994) convention that order of adjoining determines the order of the trees that adjoin into the same node, then the ordering $C_1A_1C_2$ requires that C_2 adjoin into the host tree B first, the A_1 component to adjoin next, and the C_1 component to adjoin in last. Since the combination of components from the C set into the host tree has not been completed before a component from the A set is adjoined, this application of same-set multiple adjoining needs access to three MC-sets at once, A, B, and C.[9]

Now consider the simultaneous view of multiple adjoining. Recall that when MC-TAG is used in a linguistic context, there is an implied prohibition against immediate dominance of components belonging to the same set. Formally, there is no motivation for such a constraint. However, linguistically, the constraint is related to why MC-sets have been proposed at all. In use, one would be unlikely to motivate an MC-set unless it is assumed that each component targets a different node If all components of a set immediately dominated one another, the result would be indistinguishable from the adjoining of a single tree, and the motivation for an non-singleton MC-set in the grammar rather than a "whole tree" would be weakened. This prohibition against immediate dominance is violated when two components from the same set adjoin into the same node. The constraint can be satisfied, however, just in case a tree belonging to another set adjoins in between the two components of the first set, as when A_1 adjoins between C_1 and C_2. Thus, to satisfy the constraint against immediate dominance, every instance of same-set multiple adjoining requires at least three sets. It is in this sense that same-set multiple adjoining is “ternary” under the simultaneous view.[10]

5 Binarized Phrase-structure

Though Grammar 1 is empirically motivated, the tree structures lack a characteristic that has been assumed of phrase structures since the mid-eighties: these trees are not binary branching. Binary branching has been assumed for reasons such as linearizability (as in Kayne 1994) and as the result of the generative machinery. In many formalisms (e.g. combinatory categorical grammar (Steedman 1996), minimalist grammar (Stabler 1997), binary composition and binary branching are collapsed. In the TAG formalism, however, binary composition and binary branching can be separated. That is, the derivation is distinct from the derived phrase structure. Though the TAG operations are binary, the trees that they combine are not necessarily binary branching. Note, though, that enforcing binary branching phrase structure can easily be stated in TAG by requiring the kernel trees to be binary branching. Because TAG allows us to separate binary branching from binary composition, we can more clearly see the contribution of each by examining possible derivations in the case where binary branching is enforced vs. the case where binary branching is not enforced. The second grammar we consider is the binarized counterpart to the first grammar. This is shown in Figure 6.

[8] In Schabes and Shieber’s terminology, independent LTAG derivations can always be recast as dependent LTAG derivations, but not every independent MC-TAG derivation can be recast as a dependent MC-TAG derivation.

[9] Delayed tree-local MC-TAG (Chiang and Scheffler, 2008) permits access to more than two MC-sets at a time under certain conditions. To recast multiple adjoining of k components belonging to different non-singleton MC-sets as a delayed MC-TAG derivation requires allowing k delays

[10] The sequential view singles out these “interrupted” cases (but not same-set multiple adjoining in general) as the result of a non-binary operation. The simultaneous view rules out all same-set multiple adjoining as non-binary.

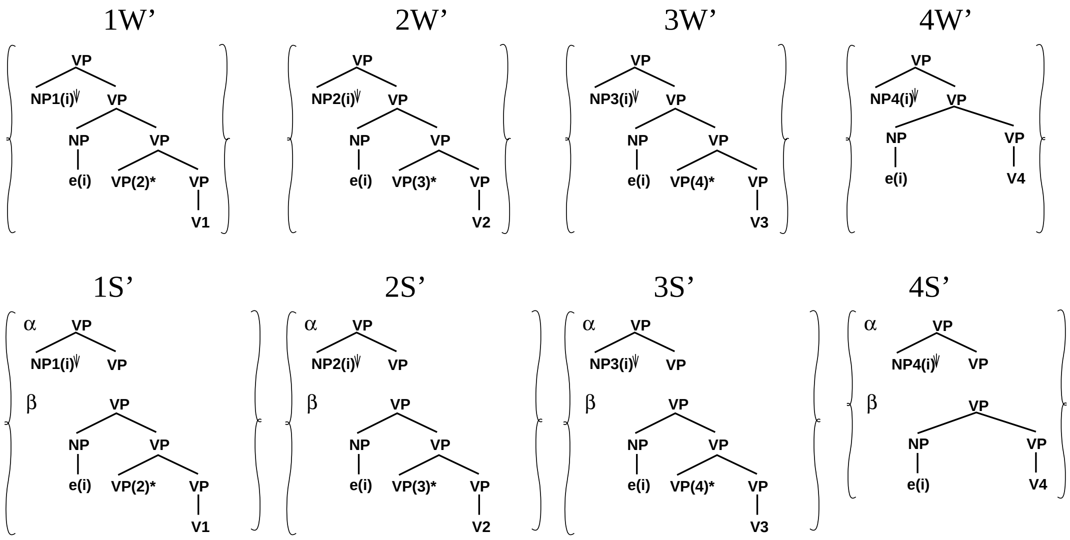

Figure 6: Scrambling Grammar 2. The binarized counterpart to Grammar 1

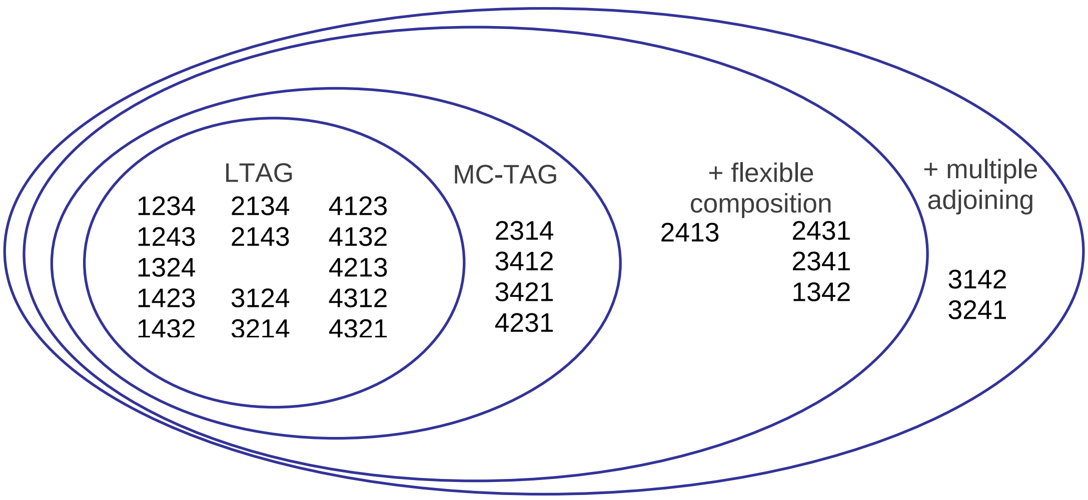

Figure 7: Derivable sequences given Grammar 2. Sequences which required multiple adjoining under Grammar 1 can be derived with MC-TAG with flexible composition. The two sequences requiring ternary composition under Grammar 1 can be derived when multiple adjoining is permitted.

Figure 7 shows which sequences require which TAG extensions given Grammar 2. The same sequences are derivable with LTAG and MC-TAG. However, allowing flexible composition now allows additional sequences to be derived. Because recasting ternary branching structure as binary branching increases the nodes available to adjoin into, adjoining components into the same node is no longer needed in some cases. The three sequences that required multiple adjoining in Figure 3 now only require flexible composition. Similarly, the two sequences that required same-set multiple adjoining under Grammar 1 can now be derived with the more restrictive multiple adjoining that requires all components adjoining into a node to belong to different sets.

6 Additional Levels of Embedding

With an additional level of embedding (i.e. 5 NPs), it is no longer the case that a binarized tree-local MC-TAG allowing flexible composition and multiple adjoining can generate all scrambling patterns. For example, the sequences 42351, 42531, and 43251 can be shown to be underivable using the following reasoning. Every derivation structure must have a root. This root must be a singleton set, i.e. a “whole” tree. By inspection, we can conclude that none of the

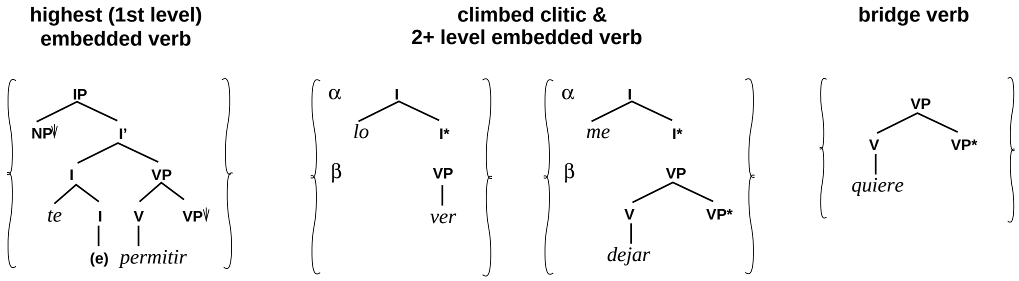

Figure 8: Grammar fragment for clitic climbing patterns. The highest embedded verb anchors a singleton set in which the clitic is climbed. Deeper embedded verbs and their climbed clitics are modeled with an MC-set. Bridge verbs are modeled with an auxiliary tree

available trees can be the root of a valid derivation for any of these three sequences. The difficulty stems from insufficient nodes to host predicates. While binarization does yield enough additional nodes to derive all sequences at three levels of embedding, it does not yield enough nodes at four levels of embedding.

7 Clitic Climbing and MC-TAG

In Romance languages, pronominal clitics can optionally appear post-verbally, as in (4), or higher in the clause, preceding the tensed verb, as in (5).

(4) V_0 V_1 NP_1 V_2NP_2
Quiere permitir-**te** ver-**lo**
wants to.permit-you to.see-it
'S/he wants to permit you to see it.'

(5) NP_1 NP_2 V_0 V_1 V_2
Te **lo** quiere permitir ver

As with scrambling, we approach (4) and (5) as different word orders, $V_0V_1NP_1V_2NP_2$ and $NP_1NP_2V_0V_1V_2$, that correspond to the same linguistic dependencies, (a) that between a verb and its clitic argument and (b) that between a verb and its VP argument. Given the grammar fragment in Figure 7, one can see how MC-TAG (without flexible composition or multiple-adjoining) allows the derivation of the clitic climbing patterns shown here. Note that the tree for *quiere* in Figure 7 can host additional verbs, allowing clitic climbing across an unbounded number of triggering verbs.

These examples are taken from Bleam (2000), who argues that although sentences involving two climbed clitics and two verbs, such as (6), can be generated with a tree-local MC-TAG, the additional level of embedding in (5) requires the power of set-local MC-TAG.

(6) **Te** **lo** permito ver
you it I.permit to.see
'I permit you to see it.'

Interestingly, while (5) and (6) show us that a cluster of two climbed clitics is permissible, sentence (7) is not. (7) involves three levels of embedding and a cluster of three climbed clitics, each of which is associated with a different verb. It is not clear whether the unacceptability of three climbed clitics results from a restriction on clitic climbing per se or whether it is due to other restrictions (e.g. on the clitic cluster template) (Bleam, p.c.) If, however, we assume that this unacceptability is strictly the result of the grammar rather than some other constraints on the output of the grammar, then the need for set-local MC-TAG dissolves.

(7) *Mari **me te** **lo** quiere permitir dejar ver.
Mari me you it wants to.permit to.let to.see
'Mari wants you to permit me to see it.'

Further, given the MC-TAG discussed above, $V_0V_1NP_1V_2NP_2$ and $NP_1NP_2V_0V_1V_2$ are derivable, but $NP_1NP_2NP_3V_0V_1V_2V_3$ is not. Above, we noted that assuming a grammar comprised of MC-sets of the type in Figure 7 predicts clitics can climb across an unbounded number of trigger verbs. However, this grammar cannot generate an unbounded number of climbed clitics. The tree for *permitir* does not have enough nodes to host a third clitic-verb MC-set. Thus, the unacceptability of (7) is expected.[11]

8 Conclusion

This paper shows that even when we enrich tree-local MC-TAG by allowing flexible composition and multiple adjoining, not all word order permutations are derivable for unbounded levels of embedding. Our claim is not that all derivable patters are equally acceptable, but that we expect underivable patterns to be clearly unacceptable.

We note three main observations from our study of scrambling. First, even MC-LTAG with flexible composition cannot derive all twenty four permutations of the NPs at three levels of embedding. Specifically, the extensions required to derive more difficult cases involve allowing different degrees of multiple adjoining. This is a desirable outcome, as it makes MC-LTAG with flexible composition a candidate for aligning with the linguistic judgments for scrambling.

Second, permitting components from the same MC-set to adjoin into the same node is a different kind of composition than the multiple adjoining of components belonging to different sets. Same-set multiple adjoining allows for more permutations, but it is linguistically unmotivated.

Third, for MC-LTAG with flexible composition, converting a grammar with non-binary branching elementary trees to a grammar in which binary branching is enforced allows additional scrambling patterns to be derived. Enforcing binary branching requires fewer modifications to MC-LTAG to derive all twenty four permutations. The additional derivations are possible because of the increase in the nodes available nodes to adjoin into. In fact, given enough nodes, the need for multiple-adjoining can be completely eliminated. In our case study, we consider the minimal additional branching required to enforce binary branching. This sets a bound on the additional nodes that can be added. With an additional level of embedding (i.e. 5 NPs), binary branching no longer provides enough nodes for generating all scrambling patterns using tree-local MC-TAG, even when both flexible composition and multiple adjoining are permitted.

Our first observation from our preliminary look at clitic climbing is that the patterns at up to two levels of embedding diverge from the patterns at deeper levels of embedding. Tree-local MC-TAG is sufficient for accounting for the patterns up to two levels of embedding, and also makes at least some correct predictions regarding possible patterns at three levels of embedding. This is similar to the scrambling case in that a tree-local MC-TAG generates all patterns for two levels of embedding, but not for three. This is relevant to a study on recursion being carried out by Joshi (2008, in prep).

Acknowledgements

We thank the XTAG group, in particular Lucas Champollion, Tatjana Scheffler, and Joshua Tauberer, as well as Stuart Shieber for helpful discussion and Tonia Bleam, Laia Mayol, and Irving Rodriguez-Gonzalez for Spanish data.

References

Becker, Tilman, Aravind K. Joshi and Owen Rambow. 1991. Long-distance scrambling and tree adjoining grammars. In: Fifth Conference of the European Chapter of the Association for Computational Linguistics, Berlin, pp. 21-26.

Bleam, Tonia. 2000. Clitic climbing and the power of Tree Adjoining Grammar. In Anne Abeillé and Owen Rambow, eds., Tree Adjoining Grammars: formalisms, linguistic analysis, and processing. CSLI Publications, Stanford, CA, pp. 193-220.

Chiang, David, and Tatjana Scheffler. 2008. Flexible Composition and Delayed Tree-Locality. *Proceedings of the Ninth International Workshop on Tree Adjoining Grammar and Related Formalisms (TAG+9)* Tübingen, Germany, 17-24.

Joshi, Aravind K.. 2008, in preparation Does recursion in language behave the same way as in formal systems? (preliminary version presented at *Recursion in Human Language*, University of Illinois, April, 2007).

Joshi, Aravind K., Tilman Becker and Owen Rambow. 2000. Complexity of scrambling: a new twist to the competence-performance distinction. In: Anne Abeillé and Owen Rambow (eds.). 2000. *Tree Adjoining Grammars. Formalisms, Linguistic Analysis and Processing.* CSLI Publications, Stanford, CA, pp. 167-181.

[11] Even when MC-TAG in enriched with a flexible composition perspective, Bleam's (2000) set-local MC-TAG analysis cannot be recast as a tree-local account, leading us to posit that (7) will remain underivable.

Joshi, Aravind K., Laura Kallmeyer and Maribel Romero. 2003. Flexible composition in LTAG: quantifier scope and inverse linking. In H. Bunt and R. Muskens, eds., *Computing Meaning* 3. Kluwer, Dordrecht.

Kallmeyer, Laura. 2005. Tree-local multicomponent tree adjoining grammars with shared nodes. *Computational Linguistics*, 31(2):187–225.

Kallmeyer, Laura and Aravind K. Joshi. 2003. Factoring predicate argument and scope semantics: underspecified semantics with LTAG. *Research on Language and Computation*, 1(1-2):3–58.

Kallmeyer, Laura and Tatjana Scheffler. 2004. LTAG Analysis for Pied-Piping and Stranding of wh-Phrases. *Proceedings of the Seventh International Workshop on Tree Adjoining Grammar and Related Formalisms (TAG+7)* Vancouver, Canada, 32-39.

Kayne, Richard. 1994. The anti-symmetry of syntax. The MIT-Press, Cambridge, MA.

Rambow, Owen. 1994. Formal and Computational Aspects of Natural Language Syntax. PhD thesis, University of Pennsylvania.

Ryant, Neville and Tatjana Scheffler. 2006. Binding of anaphors in LTAG. *Proceedings of the Eighth International Workshop on Tree Adjoining Grammar and Related Formalisms (TAG+8)*, Sydney, Australia, 65-72

Schabes, Yves and Stuart M. Shieber. 1994. An alternative conception of tree-adjoining derivation. *Computational Linguistics*, 20(1):91-124.

Stabler, Edward. 1997. Derivational Minimalism. In Retoré (ed.), *Logical Aspects of Computational Linguistics*. Springer. 68-95.

Steedman, Mark. 1996. *Surface Structure and Interpretation*. MIT Press, Cambridge, MA.

Weir, David J. 1988. Characterizing mildly context-sensitive grammar formalisms. PhD thesis, University of Pennsylvania.