Abstract

Tree Adjoining Grammars (TAG) are known not to be powerful enough to deal with scrambling in free word order languages. The TAG-variants proposed so far in order to account for scrambling are not entirely satisfying. Therefore, an alternative extension of TAG is introduced based on the notion of node sharing. Considering data from German and Korean, it is shown that this TAG-extension can adequately analyse scrambling data, also in combination with extraposition and topicalization.

1 Introduction

1.1 LTAG and scrambling

Lexicalized Tree Adjoining Grammars (LTAG, (Joshi and Schabes, 1997)) is a tree-rewriting formalism. An LTAG consists of a finite set of trees (elementary trees) associated with lexical items. Larger trees are derived by substitution (replacing a leaf with a new tree) and adjunction (replacing an internal node with a new tree). LTAG elementary trees represent extended projections of lexical items and encapsulate all syntactic arguments of the lexical anchor. They are minimal in the sense that only the arguments of the anchor are encapsulated, all recursion is factored away.

Roughly, scrambling is the permutation of elements (arguments and adjuncts) of a sentence (we use the term scrambling in a purely descriptive sense without implying any theory of movement). A special case is long-distance scrambling where arguments or adjuncts of an embedded infinitive are ‘moved’ out of the embedded VP. This occurs for instance in languages such as German, Hindi, Japanese and Korean. These languages are therefore often said to have a free word order. Consider for example the German sentence (1). In (1), the accusative NP es is an argument of the embedded infinitive zu reparieren but it precedes der Mechaniker, the subject of the main verb verspricht and it is not part of the embedded VP. It has been argued that in German there is no bound on the number of scrambled elements and no bound on the depth of scrambling (i.e., in terms of movement, the number of VP borders crossed by the moved element). (See for example (Rambow, 1994a; Meurers, 2000; Müller, 2002) for descriptions of scrambling data.)

(1) ... dass [es]₁ der Mechaniker [t₁ zu reparieren] verspricht ...
... that it the mechanic to repair promises ‘... that the mechanic promises to repair it’

As shown in (Becker et al., 1991), TAG are not powerful enough to describe scrambling in German in an adequate way. By this we mean that a TAG analysis of scrambling with the correct predicate-argument structure is not possible, i.e., an analysis with each argument attaching to the verb it depends on.

Let us consider the analysis of (1) in order to get an idea of why scrambling poses a problem for TAG. If we leave aside the complementizer dass, elementary trees for verspricht and reparieren might look as shown in Fig. 1. In the derivation, the verspricht-tree adjoins to the root of the reparieren-tree and the NP der Mechaniker is substituted for the subject node of verspricht.¹ This leads to the third tree in Fig. 1. When adding es, there is a problem: it should be added to reparieren since it is one of its arguments. But at the same time, it should precede Mechaniker, i.e., it must be adjoined either to the root or to the NP nom node in the derived tree. The root node belongs to verspricht and the NP nom node belongs to Mechaniker. Consequently, an adjunction to one of them would not give the desired predicate-argument structure. If it was only for (1), one could add a tree to the grammar

¹The fact that der Mechaniker is at the same time logical subject of reparieren is accounted for in the semantics, see for example (Gardent and Kallmeyer, 2003).
for reparieren with a scrambled NP that allows adjunction of verspricht between the NP and the verb. But as soon as there are several scrambled elements that are arguments of different verbs, this does not work any longer. In general, it has been shown (Joshi et al., 2000) that adopting specific elementary trees it is possible to deal with a part of the difficult data: TAG can describe scrambling up to depth 2 (two crossed VP borders). But this is not sufficient. Even though examples of scrambling of depth > 2 are rare, they can occur (see Kulick, 2000).

### 1.2 TAG variants proposed for scrambling

The problem of long-distance scrambling and TAG is the fact that the trees representing the syntax of scrambled German subordinate clauses do not have the simple nested structure that ordinary TAG generates. In TAG, according to the Condition on Elementary Tree Minimality (CETM, (Frank, 1992)) (positions for) all of the arguments of the lexical anchor of an elementary tree are included in that tree. But in the scrambled tree the arguments of several verbs are interleaved freely. All TAG extensions that have been proposed to accommodate this interleaving involve factoring the elementary structures into multiple components and inserting these components at multiple positions in the course of the derivation.

One of the first proposals made was an analysis of German scrambling data using non-local MCTAG with additional dominance constraints (Becker et al., 1991). However, the formal properties of non-local MCTAG are not well understood and it is assumed that the formalism is not polynomially parsable. Therefore this approach is no longer pursued but it has influenced the different subsequent proposals.

An alternative formalism for scrambling is V-TAG (Rambow, 1994a; Rambow, 1994b; Rambow and Lee, 1994), a formalism that has nicer formal properties than non-local MCTAG. V-TAG also use multicomponent sets (so-called vectors) for scrambled elements, in this it is a variant of MCTAG. Additionally, there are dominance links between the trees of one vector. In contrast to MCTAG, the trees of a vector are not required to be added simultaneously. The lexicalized V-TAGs that are of interest for natural languages are polynomially parsable. Even though the formalism does not pose the problems of non-local MCTAG in terms of parsing complexity, it is still a non-local formalism in the sense that, as long as the dominance links are respected, arbitrary nodes can be chosen to attach the single components of a vector. This makes the formalism harder to understand than local TAG-variants since one needs a more global picture of what is going on in a derivation. Furthermore, in order to formulate certain locality restrictions (e.g., for wh-movement and also for scrambling), one needs an additional means to put constraints on what can interleave with the different trees of a vector or in other words constraints on how far a dominance link can be stretched. V-TAG allows to put integrity constraints on certain nodes that disallow these nodes to occur between two trees linked by a dominance link. This has the effect that these nodes act as barriers. This explicit marking of barriers is somewhat against the original appealing TAG idea that such constraints result from the CETM which imposes the position of the moved element and the verb it depends on to be in the same elementary structure, and from the further possibilities to combine this structure. In other words, in local formalisms with an extended domain of locality such as TAG or tree-local and set-local MCTAG such constraints result from the form of the elementary structures and the locality of the derivation.

D-tree substitution grammars (DSG, Rambow, Vijay-Shanker, and Weir, 2001) are another TAG-variant one could use for scrambling. DSG are a description-based formalism, i.e., the objects a DSG deals with are tree descriptions. A problem with DSG is that the expressive power of the formalism is probably too limited to deal with all natural language phenomena: according to (Rambow et al., 2001) it ‘does not appear to be possible for DSG to generate the copy language’. This means that the formalism is probably not able to describe cross-serial dependencies in Swiss German. Furthermore, DSG is non-local and therefore, as in the case of V-TAG, additional constraints (so-called path constraints) have to be put on material interleaving with the different parts of an elementary structure.

Another TAG-variant proposed in order to deal with scrambling are Segmented Tree Adjoining Grammars (SegTAG, Kulick, 2000). SegTAG can generate the copy language and therefore describe cross-serial dependencies. But the formalism uses a rather complex operation on trees, segmented adjunction, that consists partly of a standard TAG adjunction and partly of a kind of tree merging or tree unification. In this operation, two different things get mixed up, the more or less resource-sensitive adjoining operation of standard TAG where sub-
trees cannot be identified, and the completely different unification operation. Furthermore, the formal properties of SegTAG are not clear. Kulick suggests that SegTAGs are probably in the class of LCFRS but there is no actual proof of this. However, if SegTAG is in LCFRS, the generative power of the formalism is probably too limited to deal with scrambling in a general way. In order to treat scrambling up to a certain depth, Kulick therefore allows certain extensions of SegTAG.

All these TAG variants are interesting with respect to scrambling and they give a lot of insight into what kind of structures are needed for scrambling. But, as explained above, none of them is entirely satisfying. The most convincing one is V-TAG since this formalism can deal with scrambling, it is polynomially parsable and the set of languages it generates contains the set TAL of all tree adjoining languages (in particular the copy language). But, as already mentioned, V-TAG has the inconvenience of being a non-local formalism. For the reasons explained above, it is desirable to find a local TAG extension for scrambling (as opposed to the non-locality of derivations in V-TAG, DSG and non-local MCTAG) such that locality constraints for movements follow only from the form of the elementary structures and from the local character of derivations. This paper proposes a local TAG-variant that can deal with scrambling, at least with an arbitrarily large set of scrambling phenomena, that is polynomially parsable and that properly extends TAG in the sense that TAL is a proper subset of the languages it generates.

In section 2, tree-local MC-TAG with shared nodes (SN-MCTAG) and in particular restricted SN-MCTAG (RSN-MCTAG) are introduced. Section 3 to 5 show the analyses of different word order variations using this formalism, namely scrambling, extraposition and topicalization, considering data from German and Korean.

2 Tree-local MCTAG with shared nodes (SN-MCTAG)

To illustrate the idea of shared nodes, consider again example (1). In standard TAG, nodes to which new elementary trees are adjoined or substituted disappear, i.e., they are replaced by the new elementary tree. E.g., after the derivation steps shown in Fig. 1, the root node of the reparieren tree does not exist any longer. It is replaced by the verspricht tree and its daughters have become daughters of the foot node of the verspricht tree. I.e., the root node of the derived tree is considered being part of only the verspricht tree. Therefore, an adjunction at that node is an adjunction at the verspricht tree. However, this standard TAG view is not completely justified: in the derived tree, the root node and the lower VP node might as well be considered as belonging to reparieren since they are results of identifying the root node of reparieren with the root and the foot node of verspricht. Therefore, we propose that the two nodes in question belong to both, verspricht and reparieren. In other words, these nodes are shared by the two elementary trees. Consequently, they can be used to add new elementary trees to verspricht and (in contrast to standard TAG) also to reparieren.

We use a multicomponent TAG (MCTAG, Joshi, 1987; Weir, 1988). This means that the elements of the grammar are sets of elementary trees. In each derivation step, one of these sets is chosen and the trees in this set are added simultaneously (by adjunction or substitution) to different nodes in the already derived tree. We assume tree-locality, i.e., the nodes to which the trees of such a set are added must all belong to the same elementary tree. Standard tree-local MCTAGs are strongly equivalent to TAG but they allow to generate a richer set of derivation structures. In combination with shared nodes, tree-local multicomponent derivation extends the weak generative power of the grammar.

Let us go back to (1). Assume the tree set on the left of Fig. 2 for es. Adopting the idea of shared nodes, this tree set can be added to reparieren using the root of the already derived tree for adjunction of the first tree and the NP acc node for substitution of the second tree. The operation is tree-local since both nodes are part of the reparieren tree.

In general, the notion of shared nodes means the following: When substituting an elementary tree α into an elementary tree γ, in the resulting tree, the root node of the subtree α is considered being part of α and of γ. When adjoining an elementary β at a node that is part of the elementary trees γ₁, ..., γₙ, then in the resulting tree, the root and foot node of β are both considered being part of γ₁, ..., γₙ and β. Consequently, if an elementary γ' is added to an elementary γ and if there is then a sequence of adjunctions at root or foot nodes starting from γ', then each of these adjunctions can be considered as an adjunction at γ since it takes place at a node shared by γ, γ' and all the subsequently adjoining trees. In Fig. 2 for example the es-tree is adjoined to the root of a tree that was adjoined to reparieren. Therefore this adjunction can be

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²More precisely, only the root of the new elementary tree and eventually (i.e., in case of an adjunction) the foot node get identified with the node the new tree attaches to. But there is no unification of whole subtrees.

³Actually, in a Feature-Structure Based TAG (FTAG, (Vijay-Shanker and Joshi, 1988)), the top feature structure of the root of the derived tree is the unification of the top of the root of verspricht and the top of the root of reparieren. The bottom feature structure of the lower VP node is the unification of the bottom of the foot of verspricht and the bottom of the root of reparieren. In this sense, the root of the reparieren tree gets split into two parts. The upper part merges with the root node of the verspricht tree and the lower part merges with the foot node of the verspricht tree.
considered being an adjunction at reparieren. An adjunction at a node where other trees already have been added (e.g., this adjunction of es to the root of reparieren) is called a secondary adjunction while a first adjunction at a node is called a primary adjunction.

Concerning formal properties, SN-MCTAG is hard to compare to other local TAG-related formalisms since arbitrarily many trees can be added by secondary adjunction to a single elementary tree. Therefore, we define a restricted version, restricted SN-MCTAG (RSN-MCTAG) that limits the number of secondary adjunctions to an elementary tree by allowing secondary adjunction only in combination with at least one simultaneous primary adjunction or substitution. E.g., in Fig. 2, es is secondarily adjoined to reparieren while the second element of the tree set is primarily added (substituted) to reparieren.

Obviously, all tree adjoining languages can be generated by RSN-MCTAGs since a TAG is an MCTAG with unary multicomponent sets. It can be shown that for each RSN-MCTAG of a specific type, an equivalent simple Range Concatenation Grammars (RCG, (Boullier, 1998; Boullier, 1999)) and therefore an equivalent LCFRSs (linear context-free rewriting systems, (Weir, 1988)) can be constructed. LCFRSs are mildly context-sensitive and in particular polynomially parsable and therefore, this also holds for these specific RSN-MCTAGs. For a formal definition of SN-MCTAG and RSN-MCTAG and a sketch of the proof of the mildly context-sensitivity see (Kallmeyer, 2004). The additional restriction imposed on RSN-MCTAG in order to obtain the equivalence to LCFRS puts a limit on the complexity of the scrambling data one can analyze. This limit however is variable in the sense that an arbitrarily large limit can be chosen. Consequently, based on empirical studies, the limit can be chosen such that all scrambling data are covered that are assumed to occur in real texts. In this respect, RSN-MCTAG differs crucially from TAG where the limit is fixed (scrambling up to depth 2 can be described and nothing more). In this sense one can say that RSN-MCTAG can analyze scrambling in general since it can analyze any arbitrarily large finite set of scrambling data.

There are mainly two crucial differences between SN-MCTAG and V-TAG: firstly, in V-TAG the adjunctions of auxiliary trees from the same set are not required to be simultaneously. In this respect, V-TAG differs from standard MCTAG in general. Secondly, V-TAG is non-local in the sense of non-local MCTAG while RSN-MCTAG is local, even though the locality is not based on the parent relation in the TAG derivation tree as it is the case in standard local MCTAG. As a consequence of the locality, in contrast to other TAG variants for scrambling, we do not need dominance links in RSN-MCTAG. The locality condition put on the derivation sufficiently constrains the possibilities for attaching the trees from elementary tree sets: different trees from a tree set attach to different nodes of the same elementary tree, so the dominance relations between these different nodes are crucial for the dominance relation between the different trees from the tree set. Because of this dominance links are not necessary. This is different of course for non-local TAG-variants such as V-TAG or DSG where one can in principle attach the different components of an elementary structure at arbitrary nodes in the derived tree.

3 Scrambling

In many SOV languages, such as German, Hindi, Japanese and Korean, constituents (argument or adjunct) display a larger freedom in term of ordering in clauses. This phenomenon is called scrambling. (See (Uszkoreit, 1987) for a description of word order in German and (Lee, 1993) for Korean.) The constituents of the lower clause can even occur in the upper clause, (so-called long distance scrambling). E.g., the arguments es and jadoncha-lul of the embedded verb move into the upper clause in German (1), repeated as (2)a., and in the Korean sentence (2)b.

(2) a. ... dass es1 der Mechaniker [t1 zu reparieren] verspricht

b. jadoncha-lul1 keu-ka [t1 surihakess-tako] the caracc heacc [t1 repair-to] yaksokhaessta promises ‘He promises to repair the car’

Generally, in both languages, it is assumed that there is no bound on the number of elements that can scramble in one sentence, and there is no bound on the distance over which each element can scramble. In the following we will show how RSN-MCTAG allows to deal with long distance scrambling. Elementary trees for word order variations of (3) are shown in Fig. 3. We propose
single trees for non-scrambled elements, and tree sets for scrambled elements.

(3) ... dass er dem Kunden [[das Auto zu reparieren] zu versuchen] verspricht
   ... that he promisses the customer to try to repair the car

(4) ... dass er das Auto dem Kunden [[t1 zu reparieren] zu versuchen] verspricht
   'He said that the customer promised to repair the car'

Consider (4) where the most deeply embedded NP_{acc} das Auto is scrambled into the upper clause. For das Auto, the tree set is used. Further, we also use tree sets for the NP_{dat} dem Kunden which intervenes between the scrambled argument and its clause, and for the VP clause reparieren of which argument is scrambled over a clause of depth ≥ 2. For the non-scrambled NP_{nom} er, and for the non-scrambled VP versuchen, single trees are used. Fig. 4 shows the different derivation steps for (4). First, verspricht and versuchen are combined by substitution. In the resulting derived tree (on the right top of the figure), the bold VP node is now shared by verspricht and versuchen. Then the auxiliary tree in the tree set for reparieren adjoins to the shared node. This is a primary adjunction at versuchen. The initial tree is substituted for the VP leaf of versuchen. The former root node of the reparieren auxiliary tree, i.e., the bold VP node in the tree in the middle of the bottom of the figure, is now shared by verspricht, versuchen and reparieren. The next secondary adjunctions can occur at this new shared node: dem Kunden is added as sketched in the figure, and then das Auto is added in the same way. The tree for er is added into the substitution slot in the verspricht tree.

Note that a scrambled elements always adjoins to a VP node and the scrambled element is to the left of the foot node. Therefore it precedes everything that is below or on the right of the VP node to which it adjoins. Consequently, given the form of the verbal elementary trees in Fig. 3 where the verb is always below or right of all VP nodes allowing adjunction, the order $x \, v$ for an $x$ being a nominal or a verbal argument of $v$ is always respected.

Since all scrambled elements attach to a VP node in the elementary tree of the verb they depend on, they cannot attach to the VP of a higher finite verb that embeds the sentence in which the scrambling occurs. Therefore, this analysis correctly predicts that scrambling can never proceed out of tensed clauses. In other words, a barrier effect is obtained without posing any explicit barrier as it is done in V-TAG. Instead, the locality of scrambling is a consequence of the form of the elementary trees and of the locality of the derivations.

In contrast to German, Korean allows scrambling out of a tensed clause. For example, in (5) the argument jadoncha-lul is scrambled out of a tensed clause. This difference can be captured by using in Korean the node label $S$ instead of VP for the root and the foot node in the auxiliary trees for scrambling.⁴

(5) jadoncha-lul1 keu-ka [kokaek-i $t_1$
   the car_{acc} he_{nom} [the customer_{nom} $t_1$
   buy-that] said
   'Hesaid that the customer bought the car'

4 Extrapolation

In German and Korean, clausal arguments can optionally appear behind the finite verb. This is called extrapolation. E.g., in (6), the reparieren VP occurs behind the finite verb verspricht. The same goes for the Korean extrapolation (7).

(6) ... dass er_{nom} dem Kunden_{dat} $t_1$ verspricht, [das Auto_{acc}
   zu reparieren]$_1$
   '... that he promises the customer to repair the car'

(7) keu-ka_{nom} kokaek-eky_{dat} $t_1$ yaksokhassta, [jadoncha-
   lul_{acc} surihakess -tako]$_1$
   'He promises the customer to repair the car'

⁴One aspect we did not consider in this paper but that definitively needs to be spelled out is the fact that in both languages, German and Korean, not all verbs allow scrambling to the same degree. In German, this is related to the difference between obligatorily and optionally coherent verbs (see (Meurers, 2000; Müller, 2002)). These facts probably can be modelled using specific features that control the scrambling possibilities of a verb.
Extraposition is doubly unbounded, as it is the case for scrambling. In order to analyze extraposition, we propose tree sets as the one for reparieren in Fig. 5. They resemble to those for scrambling except that the foot node is on the left because the extraposed material goes to the right of the finite verb. For the NP arguments in (6), we use the single trees shown in Fig. 3. The derivation for (6) is as sketched in Fig. 5.

The following differences between German and Korean are observed: both languages allow extraposition of complete VPs. Furthermore, in German, infinitives without their arguments can be extraposed (so-called third construction, see (8)a), which is not possible in Korean (see (9)a). In Korean however, arguments of embedded verbs can be extraposed while leaving their verb behind (see (9)b), which is not possible in German (see (8)b).

To account for the difference between (8a) and (9a), we disallow the adjunction of scrambled elements at the root nodes of Korean auxiliary extraposition trees. For (9b), in Korean, we propose additional tree sets for extraposed NPs. They are similar to the tree sets for scrambled NPs in Fig. 3, except that the foot node is on the left. Such tree sets do not exist in German.

5 Topicalization

Korean topicalization is realized with the topic marker -nun(-un). The topicalized constituent has to appear in the beginning of clauses, e.g., jadoncha-nun in (10a.); an element marked by -nun(-un) can also appear in sentence medial position e.g., jadoncha-nun in (10b). It is perceived, in Korean, that an element with -nun(-un) in sentence initial position receives the theme reading, i.e., topicalization, and the counterpart in sentence medial position the contrastive reading. To describe topicalization movement, a topic argument may be inserted into the verbal projection tree at [Spec, CP] (see, e.g., (Suh, 2002)).

6In German, even arguments of embedded VPs can be left behind as in ... dass er [es] verspricht, [[t1 zu reparieren] zu versuchen]. For such cases, we propose an additional VP node on the spine of extraposed infinitives where deeper embedded infinitives can be added. For reason of space, we will not go into the details here.
German *topicalization* is more strict. German exhibits the verb second effect (V2), i.e., the finite verb (main verb or auxiliary) occupies the second position in the clause. This divides the clause into two parts: the part before the finite verb, the *Vorfeld* (VF), and the part between the finite verb and non-finite verb, the *Mittlefeld* (MF). The VF must contain exactly one constituent. This constituent is considered having moved into the VF. This movement is called *topicalization*. E.g., in (11) the auxiliary verb *hat* appears in second position, the NP$_{acc}$ *das Buch* that moved from the MF into the first position is topicalized.

\begin{romanlist}
\item das Buch$_2$ hat ihm; niemand $[t_1 t_2 zu geben]$ versucht. \\
\quad the book has him nobody $[t_1 t_2 to give]$ tried.
\end{romanlist}

\begin{romanlist}
\item keu-ka jadoncha-nun kuiphakess-tako yaksokhas-ta.
\item ‘He promises to buy the car’
\end{romanlist}

\begin{romanlist}
\item [CP] $[CP]$ root node shared between the old tree and the newly added tree.
\item Finally, the topicalized element is adjoined to the root node.
\end{romanlist}

6 Conclusion

Since TAG are not powerful enough to describe scrambling data in free word order languages, alternative formalisms are needed. The proposals made so far in the literature are not entirely satisfying. Therefore, we developed a new TAG extension, restricted MCTAG with shared nodes (RSN-MCTAG). The basic idea is that, after having performed an adjunction or substitution at some node, this node does not disappear (as in standard TAG) but instead, in the resulting derived tree, the node is shared between the old tree and the newly added tree. Consequently, further adjunctions at that node can be considered being adjunctions at either of the trees. In combination with tree-local multicomponent derivation, this modification of the TAG derivation gives sufficient additional power to analyse the difficult scrambling data.

Considering data from German and Korean, we showed that RSN-MCTAG can adequately analyse scrambling data, also in combination with extraposition and topicalization. The analyses proposed in the paper treat long-distance scrambling, long-distance extraposition and long-distance topicalization and they take into account the differences German and Korean exhibit with respect to these phenomena.

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Figure 6: Derivation for (11) ... das Buch hat ihm niemand zu geben versucht