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Tree Unification Grammar

Problems and Proposals for Topology, TAG, and German

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Abstract

This work presents a lexicalized grammar formalism which can be seen as a variant of multi-component tree adjoining grammar (TAG). This formalism is well-suited for describing the syntax of German because it relates a syntactic dependency graph with a hierarchy of topological domains. The topological phrase structure encodes the placement of verbal and nominal elements in the (ordered) field structure, just as in the classical topological analysis of the German sentence. This module constitutes an intermediate step between the semantic and the prosodic representations of the sentence and allows deriving cases of scrambling that are problematic for classical TAGs and for some phrase structure based formalisms.

Die deutsche Wortfolge ist nicht „frei", sondern denkbedingt.[2]

1 Introduction

This paper proposes yet another lexicalized tree grammar formalism in the TAG family with the purpose of capturing German word order phenomena, and yet another linearization system for dependency grammars based on the topological model of the German sentence. What sets this work apart from previous work is that the proposed formalism, Tree Unification Grammars, accomplishes both these tasks at the same time. Moreover, we see the purpose of a lexicalized tree grammar to serve as a syntactic correspondence module inside the Meaning-Text-Theory (MTT, Mel'čuk 1987).

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This paper has benefited greatly from discussions with Sylvain Kahane, Igor Mel'čuk, Hi-Yon Yoo, and Patrice Lopez. I assume the customary responsibility for content and shortcomings.
[2] *The German word order is not 'free', but thought-conditioned.* Drach 1937, page 26

In MTT, language is described as a (reversible) process of generating text (the actual spoken or written language) from meaning, which is thought of as a conceptual structure of what to say. On its way to become text, specific correspondence modules transform the meaning into different intermediate representations (See Figure 1). In the present work, we use a slightly revised version of MTT following Gerdes and Kahane 2001a: Between the phonological and the syntactic representation we stipulate the existence of a hierarchy of word domains, called *topological phrase structure*, to be introduced below, replacing the ‘morphological level’ in usual MTT.

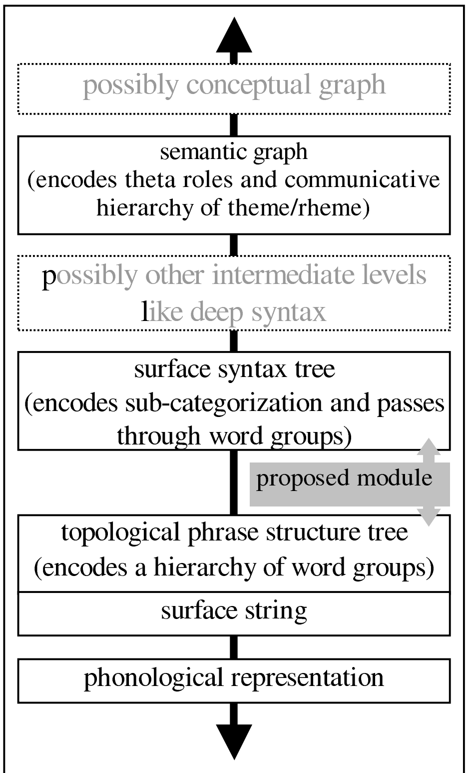

Figure 1: Structures in MTT

The line of argument of this paper goes as follows: The next two sections intend to justify why an adequate lexicalized tree grammar for German has to go far off the track of usual Tree Adjoining Grammars: In section 2, I recall briefly why a phrase structure view on German will not give satisfying insights in the functioning of the language. In section 3, I summarize the efforts that have been done to adopt TAG to German and vice versa. Section 4 gives a short introduction of an alternative view on phrase structure based on the classical topological model of the German sentence structures. This phrase structure does not itself carry any syntactic or semantic information, but it can easily be linked to a phonological analysis on one side and to an (unordered) syntactic dependency structure on the other side. In section 5, I then present some phenomena of German constituent formation, which are difficult to handle at the syntactic level. These constituents will be shown to be of different nature than syntactic constituents, and should be controlled on a semantic level, i.e. by the module in the MTT framework that links the semantic with the syntactic representation. We end up with a ‘lightened’ task of the syntactic module. This task will finally be shown to be accomplished by Tree Unification Grammars, to be defined and illustrated in sections 6 and 7.

The appearance of a topological structure in an MTT grammar, where phonology and syntax have to be joined, seems surprisingly natural: Erich Drach, the father of German sentence topology who coined today’s usual field names, also wrote the following lines in 1937: *Um Aufschluß zu geben,*

„wie eine gesprochene oder niedergeschriebene Äußerung als zutreffender Ausdruck des gemeinten Bedeutungserlebnisses zustande kommt," muß „von der Sprechdenk-Funktion, dem Schöpfungsakt des Satzes in der Seele des Sprechenden, ausgegangen werden: von der Beobachtung des Sprechens als Persönlichkeitsleistung und als sozialen Handelns.[3]*"*. A clear forerunner of the application of a topological structure in an MTT-framework.

2 Phrase structure and its shortcomings

Classical phrase structure tries to collapse syntactic and ordering information. This conception of the syntax of language is erroneous because it assumes that word order is always an immediate reflection of the syntactic hierarchy and that any deviation from this constitutes a problem, denoted by terms like *scrambling*[4].

Modern linguistic frameworks propose a double structure consisting at least of the basic syntactic structure (valency, functor-argument structure, f-structure, deep structure – we will use the term syntactic dependency) and a linear structure (surface structure, c-structure, phrase structure, precedence rules, etc.); some frameworks like LFG put this duality at the basis of their system, others, like HPSG unify the different structures (e.g. SYNSEM and DTRS) in one sign.

While the syntactic dependency gives rise to little controversy, the different phrase structures proposed for linearization constitute the bone of syntactic contention. The different approaches appear to be caught in the transformational thinking which assumes two closely related structures: An already-ordered deep structure holds functional information and transforms, via movements, into a surface structure which then still carries some functional information hidden in the nodes that have not gotten hold of any of the itinerant elements. Accordingly, a good surface phrase structure is one that carries as much functional information as possible, for it had been easy to obtain the surface structure by transformation from the deep syntax tree. For English, this attempt can go quite far; for languages with case however, the word order serves mainly to represent other communicative goals than functional recovery.

The attempts for a transformational grammar of German resulted in a great variety of surface phrase structures: Evers 1975's analysis puts all NP's on the highest possible node after the transformation from a deep struc-

[3] "For an explanation of how a spoken or written utterance becomes a correct expression of the meant significant experience, we have to hypothesize on the speech and thought function, on the act of creation of the sentence in the soul of the speaker: on the observation of the act of speaking as a personal achievement and as a social action." (Drach 1937, p.7)
[4] First used by Ross (1967).

ture. Müller 1999, on the contrary, advocates binary and right-combed phrase structure trees for his HPSG grammar. They all end up with surface phrase structures whose subtrees do not correspond to linguistic (functional, prosodic, semantic…) objects of their own, their justification relies on the transformational proximity to the deep structures.

3 German sentence topology

The classical analysis of German sentence structure (Drach 1937, Bech 1955) divides the sentence into a fixed sequence of fields, in which the syntactic elements are placed. We denote by *domain* a sequence of fields. The *main domain* of a declarative sentence consists of Vorfeld (VF), left bracket ('['), Mittelfeld (MF), right bracket (']') and Nachfeld (NF). We call the fields VF, MF, and NF *major fields*.

The idea is that words do not position themselves in relation to each other, but that they appear in the fields, which are present at every utterance. The field structure controls the possible orders by constraining the number of elements that they must hold.

Kathol 1995 proposes a formalization of the topological structure in HPSG, refining work of Reape 1994. He shows that this structure is independent of phrase structure and essential for linearizing German. However, based on the HPSG framework, he still needs to keep phrase structure for combining signs. In a sense, he keeps three levels of description: The domain structure (DOM) giving the linearization, the phrase structure tree (DTRS), representing how the structure has been build, and the dependency graph (encoded under SYNSEM), corresponding to the subcategorization.

Recent works in dependency grammar have tried to link directly the dependency structure to the placement of the words in different fields,[5] skipping the constituent structure underlying formalisms like HPSG. See Bröker 1998 for a lexicalized description of very simple phenomena based on modal logic, Duchier and Debusman 2001 for a description in constraint programming, and Gerdes and Kahane 2001a for a description of a topological hierarchy seen as a syntactic module of Meaning Text Theory. The development of Tree Unification Grammars is an attempt to lexicalize and fine-tune this latter approach.

Let us now turn to the ideas underlying the topological phrase structure: The algorithm of Gerdes and Kahane 2001a takes as input an unordered sur-

[5] The word order problem of many dependency analyses is somehow orthogonal to the problems of phrase structure grammars stated above: It is difficult to encode the linear ordering of the words into the dependency graph, since purely local rules (on the ordering of the dependents of a lexeme) are evidently not sufficient. See Lombardo and Lesmo 2000 for a short summary of the different attempts to define the 'right' degree of projectivity.

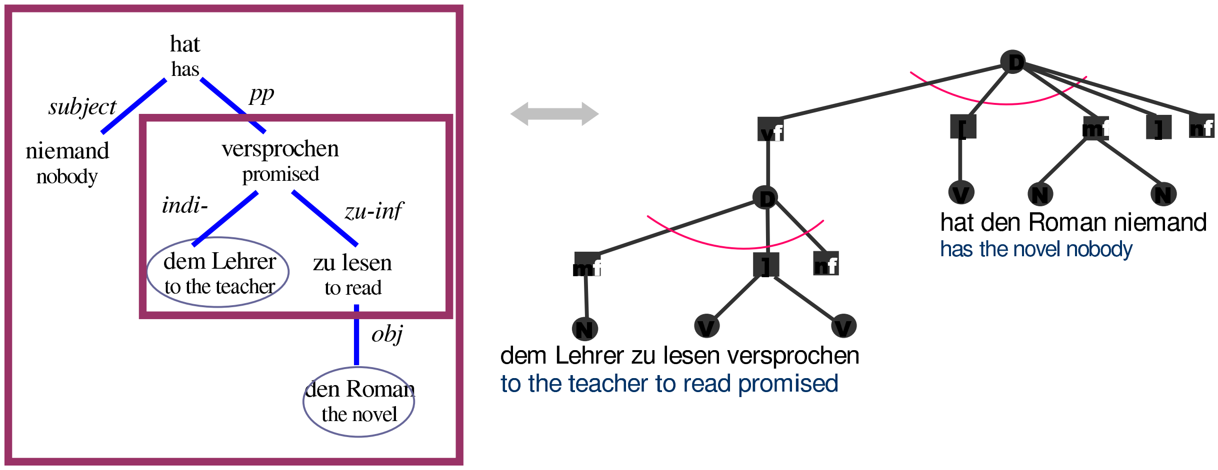

Figure 2: Correspondence syntax - topology

face syntactic dependency tree[6] with a markup of groupings of the words of the tree: The lexical elements are all part of a second hierarchy, indicating which elements will have to form a topological constituent. The meaning of these constituents and the underlying restrictions on their formation will be discussed in section 5. Out of this marked-up tree, we construct an ordered hierarchy of topological domains, the topological phrase structure, thus linearizing the words of the dependency tree.

As an illustration, consider Figure 2: The linearization will be done by placing the elements of the syntactic dependency tree into the main domain of the declarative sentence. We start from the root of the tree and place the finite verb in the left bracket. Its subject could go in one of the major fields, and it goes, for instance, into the Mittelfeld.

Essential to this analysis is that verbal complement can be placed in two ways into the topological structure: a verbal complement always go into the right bracket of a domain, but this domain can either be the existing domain of its verbal governor or, if the verb heads a grouping on its own, it can be a new embedded domain it creates in a major field of its governor or in a higher domain containing its governor. An embedded domain of non-finite verbs consists only of a Mittelfeld, a right bracket, and a Nachfeld. If it creates such a new domain, the domain as a whole behaves like a non-verbal complement of the verb. In the example, *versprochen* 'promised' heads a grouping and opens therefore a new embedded domain. This new domain, as it is headed by a past participle, can only go into the Vorfeld – a zu-infinitive could join any major field.

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[6] This approach uses a very 'surface' version of dependency. Since subject placement in German is identical for auxiliaries, raising and control verbs, we only encode actual syntactic sub-categorization: The controlled verb *zu lesen* does not control its deep subject *niemand/nobody*, and the subject belongs to the auxiliary or the past participle. See Figure 2.

The non-verbal dependent of the past participle, *dem Lehrer* 'to the teacher', is a part of the grouping of its governor, and consequently it has to stay in its governor's domain. Between the two major fields in the embedded domain, it chooses the Mittelfeld.[7] The next verbal dependent, the infinitive, could again create a new domain in one of the major fields of its governor's domain or of a domain containing its governor. The other choice is to join the right bracket of its governor's domain. In the example, the creation of a new domain is not possible because it is part of its governor's grouping. The infinitive has to stay in its governor's domain, and in this case, it must go directly to the left of its governor in the right bracket.

Now it remains only to place the last complement, "the novel". It can again go in one of the major fields of its governor's domain, or of a domain containing its governor. Since the grouping cuts it out of its governor's domain, it finds itself naturally in the higher domain, next to *niemand* in the Mittelfeld. All elements of the dependency tree have been positioned in the topological structure and the derivation is completed.

So we have linearized the (unordered) nodes of the dependency tree into sentence (1), a variation of Rambow 1994's main example[8].

(1) Dem Lehrer zu lesen versprochen hat den Roman niemand.
The teacher to read promised has the novel nobody.
Nobody has promised to the teacher to read the novel.

The other possible surface orders of German can be obtained with other groupings[9].

Consider also the other examples in Figure 3: In case A, the sentence is not further subdivided into groups, and the constructed topology consequently has no embedded domains. In case B, the infinitive and its complement form a group, and the corresponding domain could occupy any major field. In this example the domain goes into the Vorfeld, but starting from the same structure, we could also generate the surface string as in case C. This string is identical to the string in case A, i.e. a sentence can be topologically ambiguous. We have shown in Gerdes and Kahane 2001b, that this distinction is not a spurious ambiguity, but corresponds to different prosodic patterns of the same string, and thus to different linguistic structures. The pure dependency tree without the group mark-up does not capture this difference[10]

[7] NP's in the Nachfeld have a heaviness constraint, not discussed here. See for example Müller 1999 section 13.1.1.3

[8] *Reading the novel* is a better example than *repairing the fridge*, because we avoid confusion with the benefactive dative (*ihm das Fahrrad reparieren* vs. **ihm den Roman lesen).*

[9] The constraints on what can form a group are discussed in section 5.

[10] Topological structure A requires a very specific discourse context and is therefore more difficult to obtain than the three other examples. See Gerdes and Kahane 2001b for details.

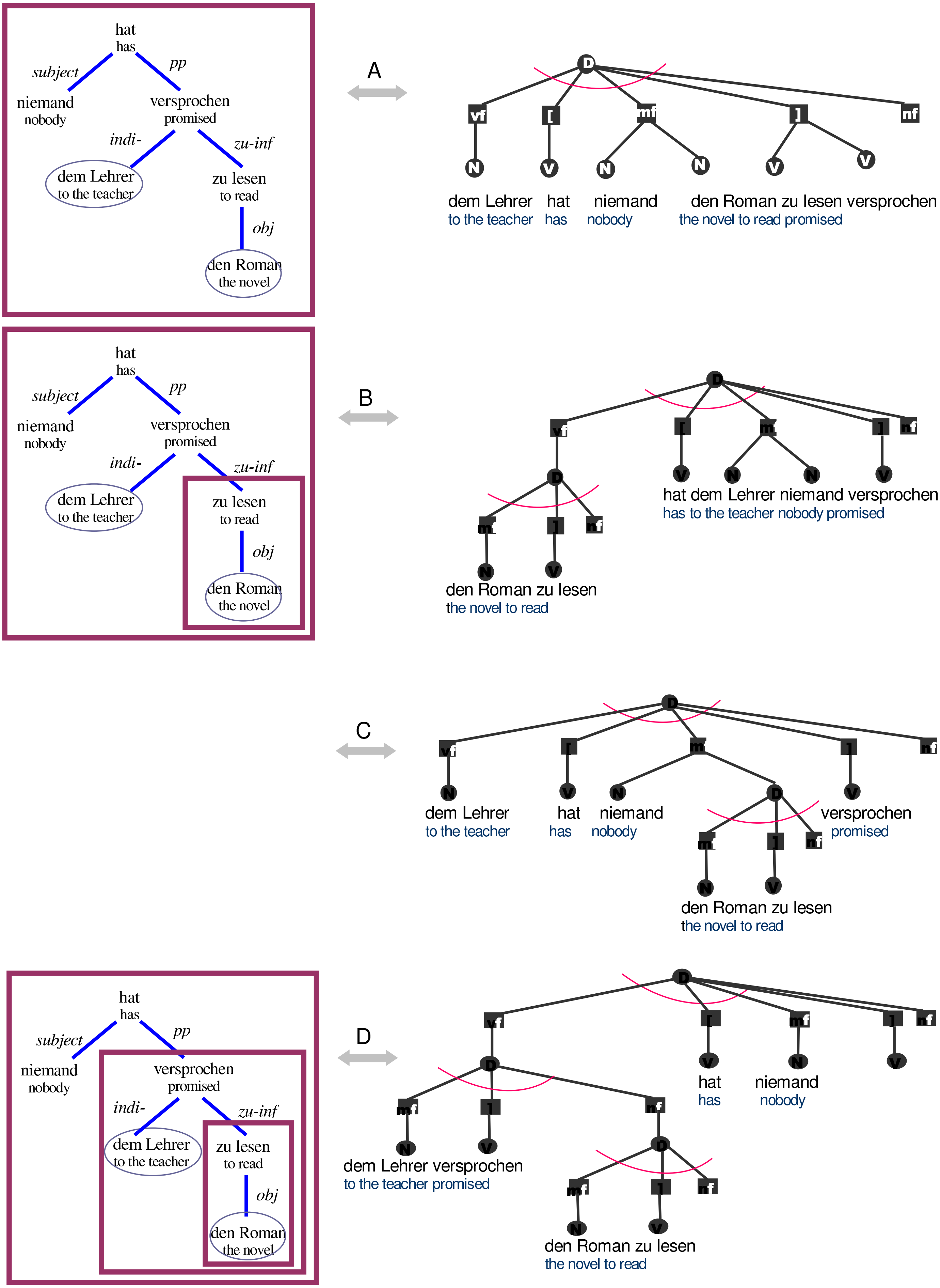

Figure 3

Syntactic dependency tree with group hierarchy and their corresponding topological phrase structure trees

The rules presented above constitute the backbone of a description of dependency linearization in a topological model. For details and finer-grained rules we refer to Gerdes and Kahane 2001a. I would just like to draw the reader's attention to the fact that I do not treat the structure of noun phrases in this work. In the syntactic dependency trees, NPs are represented without inner structure, evoking Tesnière's nuclei (Tesnière 1959), i.e. unstructured clusters of meaning. Of course, in the light of a topological analysis of German, it would be reasonable to explore the possibilities of analysing the NP as a specific kind of domain, from which extraction is possible under certain conditions just as from verbal domains.

4 TAGs and their shortcomings

A lexicalized TAG is a simple mathematical language model with nice computational properties: A lexical entry consists of elementary trees that combine with other trees by very simple rules to form the final phrase structure of the analyzed sentence. Noting down the steps taken yields a derivation tree, interpretable as a semantic dependency structure consisting of the lexical units. A complete analysis consists of the string, the attached derived tree, and the derivation tree. Becker et alii 91 called obtaining the correct objects *weak*, *strong*, and *derivational generative power*[11], respectively.

Different approaches have tried to construct a semantic structure during the TAG derivation: Synchronous TAGs construct a semantic tree in parallel to the usual derivation tree (which raises considerably the computational complexity of the formalism) (Shieber & Schabes 1990). Joshi and Kallmeyer 1999 give to TAG a restricted multi-component makeup, designed for scope interpretability of the derivation tree.

This latter approach presumes the goal of TAG to be a direct link between the surface string and a semantic structure. Equally, in the two important existing TAG grammars, XTAG (XTAG group, 1995) and FTAG (Abeillé 1991), the derivation trees are supposed to encode dependencies of a more profound level than simple syntactic sub-categorization; e.g. raising verbs, not carrying their subject in their elementary tree, are adjoined into the infinitives, resulting in a derived structure where the finite raising verb is not linked to the subject it agrees with, i.e. the raising verb is given the role of a pure modifier of the "main" verb. However, this "semantic-ambition"[12] of the derived tree falls far short of perfection when, for example, adjectives

[11] This notation disregards the fact that the derivation is part of the analysis that TAG attaches to a sentence, and it should simply be considered as a part of the *strong generative power*.

[12] It is at least a "deep-syntax-ambition", depending on where we place verbal valency questions.

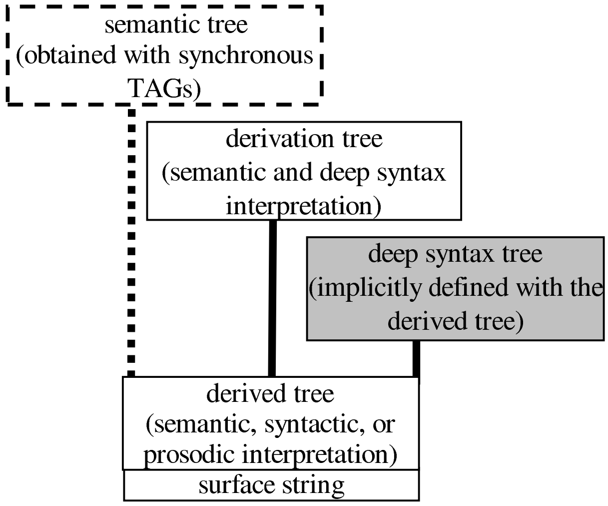

Figure 4: Structures in the standard TAG analysis

adjoin to one another and not to the noun (Schabes and Shieber 1994), or when the derived tree of control verb constructions does not encode the "controlled" link between subject and infinitive (Candito and Kahane 1998a). It seems much more reasonable to limit ourselves right from the start to a surface syntax dependency encoding exclusively surface syntactic relations. However, the writers of the LTAG-grammars did not have a choice: For example, the only way to cover long-distance relationships in the (single-component) TAG formalism is the adjunction of the matrix verbs, resulting in derived structures with mixed (semantic and syntactic) information content.

In this correspondence from the surface string to the (semantic) derivation tree, the role of the derived tree remains theoretically and computationally unclear: It attempts to resemble GB's surface syntactic tree as some empty nodes are marked with epsilons, but the deep syntactic tree whose element have been moved is never calculated. These trees inherit the handicap of GB's surface syntactic trees: Some nodes are simply computational necessities, others tend to represent semantic, syntactic, or prosodic units. For example, GB's surface syntactic trees need intermediate landing sites for the moving objects. TAG's derived tree has even more nodes whose subtrees do not correspond to syntactic entities: Each adjunction adds an additional node level into the derived structure and even elementary trees cannot be flat, because sister adjunction is not available. The nodes allow controlling adjunction between elements, and are vital in TAGs[13] mainly for expressing the linearization rules; they do not stem from linguistic observation[14]. The resulting mostly right-branching VP or NP structures are often justified with scope properties of adverbials or adjectives (see for example Schabes and Shieber 1994). In a sense, the *raison d'être* of the derived tree is that it al-

[13] The same holds for DTGs (Rambow et alii 1995) and GAGs (Candito, Kahane 1998b).

[14] Of course some linguist might really want to have these intermediate nodes in the phrase structure. All we can really say is that a linguistic description that does not have these nodes is not possible.

lowed us to obtain a semantically interpretable derivation tree; its status is not the representation of a linguistic entity.

However, even this compulsory open-mindedness of the LTAG writers concerning the derived tree does not suffice: No matter which derived tree we take, as long as TAG's strong cooccurrence constraint[15] is supposed to hold, we cannot obtain the predicate-argument structure of a double matrix construction with fronted inner argument in English (Rambow, Vijay-Shanker, Weir, 1995), and for German, Becker et alii, 1991, 1992 show that TAG cannot describe the 'scrambling' phenomena in a satisfying manner.

In spite of these drawbacks we should not give up right away the idea of a lexicalized tree grammar, more precisely a lexical grammar whose lexical entries can be combined in two manners in parallel: to form an ordered phrase structure and an unordered dependency tree. My objective is to use a lexicalized tree grammar as a module in an MTT approach, i.e. as the correspondence module between the topological and the (surface) syntactic structure of our linguistic representation. The existence of the different levels can be justified computationally by the simplicity of the two correspondence modules, one for obtaining a structure the other for translating it into the following structure. However, the levels can also be validated intuitively and psycho-linguistically by the expressiveness of the structures and their (possible) well-formedness rules. So I suppose a specific phrase structure (a topological hierarchy, which I tried to justify in section 3), and a specific dependency (only simple sub-categorization structures for agreement), and I'm looking for an algorithm that links the two structures compositionally (with corresponding substructures). We could call this capacity of a lexicalized grammar the *descriptive strong generative power*.

Since TAG cannot analyze German with any phrase structure and with a derived tree that encodes syntactic or semantic dependencies, it is clear *a fortiori* that TAGs (and its close relatives, which do not allow sister adjunction) lack the descriptive strong generative power for the topological model, i.e. the power to engender the desired topological structure and the surface syntax derivation tree in parallel. My goal is thus to define a lexicalized tree grammar with enough descriptive strong generative power for the relation between a surface syntax dependency and topology.

We will see that this grammar should also remedy another flaw of TAG: Since elementary trees of standard TAG have ordered branches, we obtain a combinatorial explosion of trees undistinguishable from syntactic ambiguity and thus a high information redundancy, in particular for freer word order languages like German.[16]

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[15] A predicate contains in its elementary tree at least one node for each of its arguments.

[16] One proposed solution, the metagrammar (Candito 1999), solves the practical aspects of grammar generation, but moves linguistic description out of the tree sets into the meta-

5 Communicative groups and topological well-formedness – dividing the tasks among the modules.

It is well known that the "freedom" of German (or any other case language's) word order is only relative to a given sub-categorization, when disregarding the context in which the sentence is uttered. So it is mostly agreed on that the speaker chooses one order of elements over another order, for example in the German Mittelfeld, to distinguish old information from new one, to distinguish what she talks about from what she says about it, to distinguish what she finds important from less important information. We call these distinctions *communicative structure*; a more commonly used term is 'information structure'[17].

5.1. Data on VP Fronting

It is less clear what kind of rules govern the formation of so called (partial) VPs. The problem stands out clearly when the VP takes the Vorfeld, because "*das ins Vorfeld verlegte Satzglied – gleichviel, wie es grammatisch verwendet sei – kann beliebig untergliedert werden. Immer jedoch bleibt es ein Ganzes*"[18] (Drach 1937, page 21). The examples in (2), (3), and (4) have an NP joining the past (or passive) participle to form one constituent in the Vorfeld. The first question is: What kind of entity is the Vorfeld in sentences like (2) and (3)?

(2) a. <u>Den Roman gelesen</u> hat Peter bisher nicht.
The novel (acc) read has Peter so-far not.
So far, Peter has not read the novel.
b. <u>Ein berühmter Geiger geworden</u> wäre er gerne.[19]
A famous violinist (nom) become, would he with-pleasure.
He would have liked to become a famous violinist

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grammar, reducing the elementary trees to some algorithmic side product. See Gerdes 2002 for details.

[17] I prefer the term 'communicative structure', because I do not know what information is. Moreover, the complex NP 'information structure' is ambiguous between the intended reading 'structure of the information' = 'structured information' and the reading 'structure that contains/gives information' = 'informative structure'. Interesting discussions on the terms in question can be found in Choi 1999 (section 3.2.2), Vallduví 1992 and Lambrecht 1994.

[18] "The phrase that is moved to the Vorfeld – however may be its grammatical use – can be subdivided arbitrarily. It always remains an entity."

[19] The contrast between (2b) and (4a), both fronted constituents with nominative arguments, goes to show that the distinction between the term *subject* and *nominative argument* is worthwhile.

(3) a. Ein Linguist angekommen ist (*sind) bisher nicht.[20]
A linguist (nom) arrived has so-far not.
So far, no linguist has arrived
b. Solche schönen Geschenke gemacht wurden (*wurde) mir noch nie.
Such nice presents (nom) offered were (*was) to-me so-far never.
I have never gotten any gifts that beautiful before.
c. Von Grammatikern angeführt werden auch Fälle mit dem Partizip intransitiver Verben.[21]
By grammarians cited are also cases with the participle of intransitive verbs.
Cases with the participle of intransitive verbs are also cited by grammarians.

(4) a. ?* Ein Linguist geschlafen hat bisher nicht.
A linguist (nom) slept has so-far not.
b. ?* Dieser Frau unterlaufen ist ein Fehler noch nie.
To-this woman (dat) slipped-in is a mistake so-far never.

5.2. Prosodic and Communicative Interpretation of the Data

One first answer to the question on the quality of these groups is that they certainly are prosodic constituents: The words in the Vorfeld form a group of words that does not support a pause in its midst and that obtains as a whole a typical melodic curve, depending on the context in which the sentence is uttered: As an answer to (5a), (2a) is only possible with a falling contour on the Vorfeld. This context makes the Vorfeld the rheme of the sentence and the falling contour is identified as typical rhematic accent.[22] Equivalently, when we put the sentence in a context where *den Roman gelesen* is of thematic character (5b), the Vorfeld can either have a flat prosodic curve, usually associated with non-prominent theme, or it can have a raising pitch accent on the last lexically stressed syllable, used in many languages for contrast and perseverance of a thematic element. We find identical data for questions (6) with (2b) as an answer.

(5) a. Was hat Peter noch nicht getan?
What hasn't Peter done yet?
b. Hat Peter den Roman gelesen?
Has Peter read the novel yet?

(6) a. Was wäre er gerne?
What would he like to be?
b. Wollte er ein berühmter Geiger werden?
Did he want to become a famous violinist?

These data indicate clearly that the grouping of the elements in the Vorfeld not only has a specific prosodic appearance, but also that this grouping

[20] The example is from Haider 1985.
[21] The examples are from Müller 1999.
[22] See Gibbon 1998.

as a whole plays a specific communicative role. This is another answer to our question.

To sum up we use an analysis based on two basic binary features, similar to Choi 1999's point of view: Theme/rheme[23] and prominence/non-prominence. The communicative role of the fronted VP can be thematic or rhematic; if the constituent is thematic, it can be prominent or non-prominent[24], if it is rhematic, it has to be prominent in order to be placed in the Vorfeld.[25]

5.3. Pushing the communicative responsibility on the semantic level

The next question is: What really is a communicative structure? It is clear that the prosodic group, the corresponding string, the corresponding domain, and the corresponding part of the syntactic tree, can all be said to possess this communicative feature, but where does it really come from, where does it materialize? At which level, in an MTT view of language, the communicative structure is created? I will not be capable of given a complete answer to the question, and I refer the interested reader to the book on communicative structure Mel'cuk 2001. I just want to give some indication, important for the justification of what follows: Many treatises on prosody analyze the prosodic patterns on a word-string base. They would say: "*Den Roman gelesen* carries the prosodic theme marking", and this is in a sense correct, as the string is one realization of the underlying speech act.

The present analysis of the German sentence, however, relies heavily on the existence of these groups in the syntactic dependency tree. In an MTT analysis of language, we have to wonder at which level the structures are instantiated. For this we have to distinguish the fronted constituents in (2) and (3) from the ungrammatical structures of (4), and we have to ask: At which level should we best instantiate the communicative grouping in order to capture easily the existing restrictions on these groupings?

Generally, all constituents can enter the fronted constituent except for subjects as in (4a), which leads to the idea that German non-finite verbs form VPs. There are nevertheless exceptions to this rule: Some NPs with other case marking than nominative are equally difficult to group with the verb, as

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23 Choi uses the terms *topic* and *focus*, ending up with *non-prominent focus*, which sounds to me like *defocalized focus*. I prefer *theme* and *rheme*, while using her binary feature *prominence*.

24 This is similar to Vallduví 1992 who distinguishes *topic* and *tail*.

25 A rough draft of the possible prosodic and communicative values of the Vorfeld constituent can already be found in Drach 1937: He notes that the Vorfeld can either be occupied by the *expressive position* (*Ausdruckstelle*) for "semantically non-empty words with a value of emotion or will", or by "minor information or a connector with given information". He does not yet explicitly state the possibility of filling the expressive position with given information, i.e. the *prominent theme* case.

demonstrated in (4b), where the dative NP and its verbal head cannot form a communicative entity. This arises in cases where the argument plays a very agentive role. Ergative verbs (3a) and verbs in their passive voice (3b) seem to tolerate being hooked to the subject (and deep object). The difficulty for all phrase structure based approaches, like for example HPSG, is that linearization, agreement, and the construction or the predicate argument structure is based on the phrase. For (3a,b) it has to be explained how and where the subject verb agreement is done: Does the whole fronted VP carry the agreement value or do 'spirits'[26] carry the information into the fronted VP? Inversely, the optional PP in (2c) has to be assigned the agent's θ-role of the verb (see Müller 2000).

In the whole, the semantic relation between predicate and noun appears to play a more important role in the restrictions on VP fronting than the nouns' actual case marking, as Webelhuth 1985 already observed. Unsurprisingly, it seems that when the speaker decides on the communicative grouping of her speech-act (theme/rheme, prominent/non-prominent), restrictions apply that rely on semantic information. (2c) shows that it does not suffice to simply block all communicative groupings of agent and predicate, but we only need one specific rule in the syntax-semantic interface for capturing the phenomenon:

(A) The absence of an agentive argument as well as the communicative grouping of the agentive argument with its predicate both trigger the passive construction.[27]

All this to conclude that our language model should place the emergence of the communicative grouping at the semantic level of representation (or even higher), because at this level the restrictions are easy to capture. The semantic module provides the correspondence between this semantic structure and a surface syntactic dependency tree. We are not concerned here with the detailed description of this module, however, when declaring that the restrictions on VP fronting are a semantic problem, we are obliged to show that the burden we put on the module is not too heavy.

5.4. What's left for the syntactic module?

In the (still unordered) surface dependency tree, agreement can be carried out independently of the subsequent actual surface order. Thus, our syntactic module, the linking of surface syntactic dependency and topological hierarchy, does not have to worry about the restrictions on the formation of embedded VPs. In the direction of synthesis, the module generates the possible

[26] Meurers 1999:*Raising Spirits (and assigning them case).*

[27] There are, of course other triggers of the passive construction, like e.g. discourse continuity, that are of no concern in this paper. I am unsure though which communicative, semantic, or discursive feature distinguishes the two surface realization of Figure 1.

word orders, which transform the given groupings into embedded domain structures, while the analysis reports the encountered grouping into the surface syntactic structure. It remains the duty of the semantic module to refuse the ungrammatical structures of the sentences in (4). This corresponds well to our intuition that the ungrammaticality of these sentences is of a different nature as for example the agreement clash in the ungrammatical variants of (3a) and (3b); it seems less clear that the sentences in (4) are really ungrammatical, it rather seems difficult to guess what the speaker wants to say.

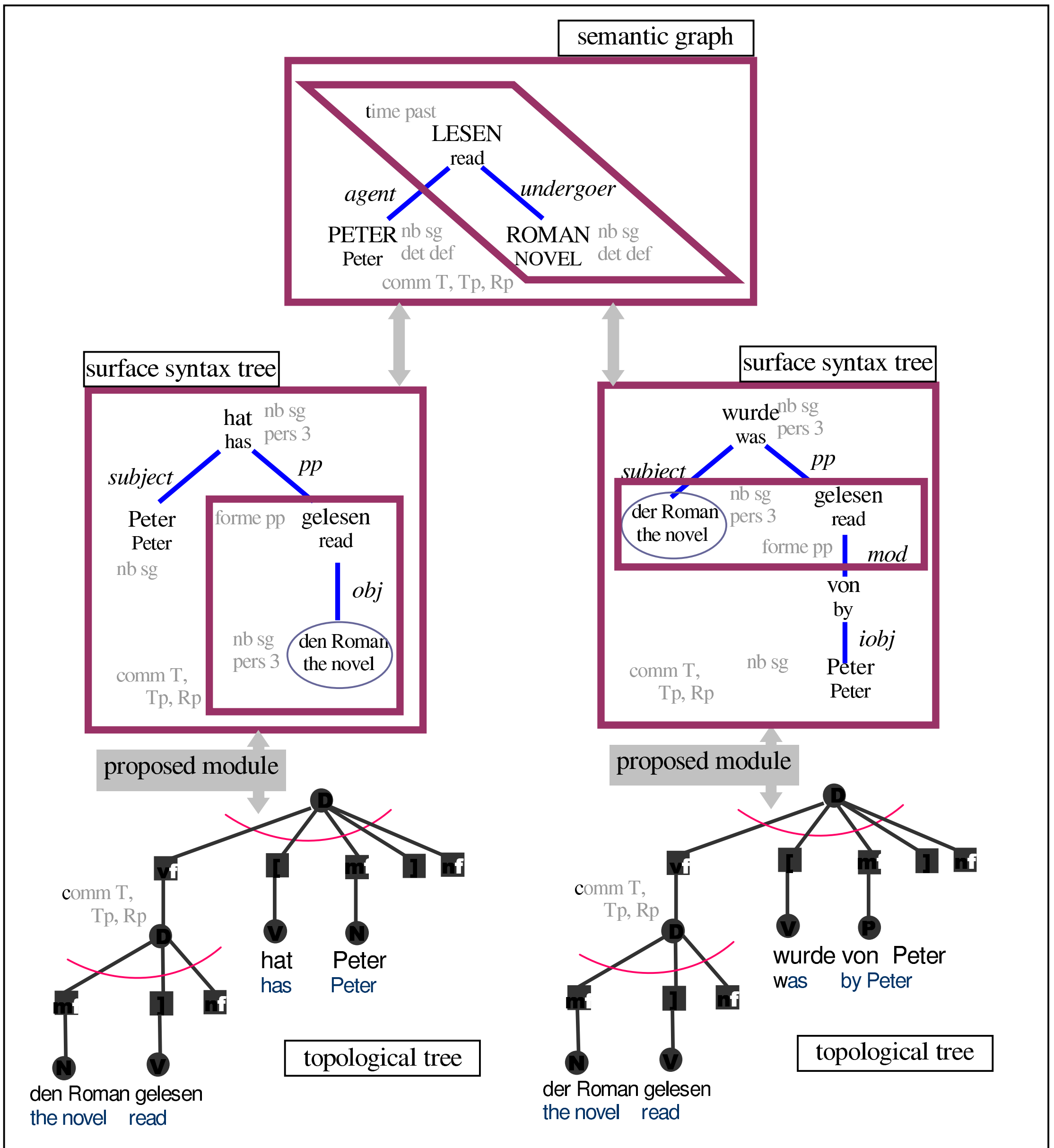

Figure 5: Schematic representations corresponding to grammatical sentences. Left: active diathesis. Right: passive diathesis.

As the analysis of the sentences reaches the syntactic module, where agreement was successfully checked, we will call sentences like those in (4) *syntactically well-formed*, and *semantically defective*. Equally, we were able to assign a topological structure to the ungrammatical versions of (3a) and (3b), the clash arises when agreement is checked on the syntactic level. We will call these sentences *topologically well-formed* and *syntactically defective*.

5.5. Examples of correspondences

Accordingly, I advocate analyzing a grammatical German sentence as a compositional correspondence between at least three representations with specific well-formed conditions. Figure 6 shows the simplified structures for two grammatical sentences given as written text. These sentences correspond in our analysis to the same semantic representation. The reason is that our semantic representation is much simplified and not fine grained enough to capture the choice of the diathesis. Equally, our syntactic representation does not get hold of all word order variation inside one field, and two surface orders can correspond to the same syntactic representation.

As written text contains no indication on the prosodic structure of the Vorfeld constituent, its communicative features remain underspecified in the possible values a Vorfeld constituent can get (non-prominent theme (T), prominent theme (Tp), prominent rheme (Rp)). An input from the prosodic module (a speech analyzer) would specify the melodic pattern, and the value of the communicative feature could be instantiated.[28]

[28] I believe that the fields and domains in the topological hierarchy of the German sentence are reflections of prosodic groupings involved in the linearization process. The topological analysis is in a sense a compromise to capture word order with a prosodic tool. In fact, the Mittelfeld and the Nachfeld are certainly not prosodic units. We could revolutionize the topological model and stipulate for example the replacement of the Mittelfeld by finer grained fields of precise communicative and prosodic value, corresponding to what can happen as melodic scheme in the Mittelfeld: The field for the prominent theme, the field for Rp, the field for the theme, and for the rheme. However, for the moment we want to build an analyzer that analyzes strings and words without prosodic information. The partition of the Mittelfeld would mainly lead to a great amount of ambiguities on the topological level. So we have to stick to what is observable in written text: the verbal brackets, and a heap of many different structures in between.

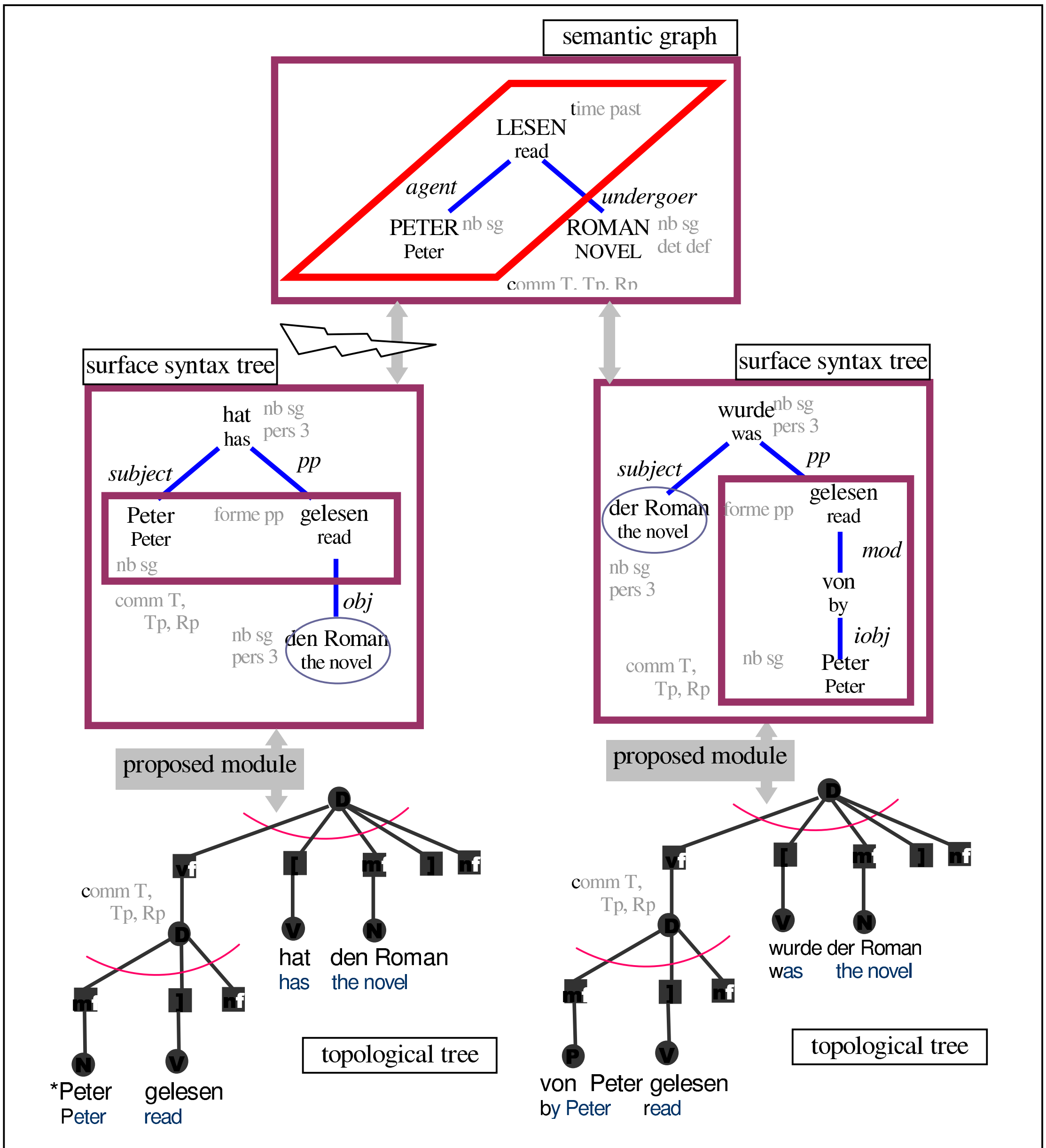

Figure 6
Left: Schematic representation of a syntactically correct and semantically defective sentence
Right: Schematic representation of a grammatical sentence with passive diathesis.

The left hand analysis of Figure 6 shows a semantically defective sentence. We can construct a topological phrase structure and we can transform this structure into a syntactic structure. The semantic module, however, fails, as it has to transfer a grouping of verb and subject into a grouping of predicate and agent, what is forbidden with rule (A). This grouping of predicate and agent is possible with the passive construction, what is shown in the derivation on the right hand side.

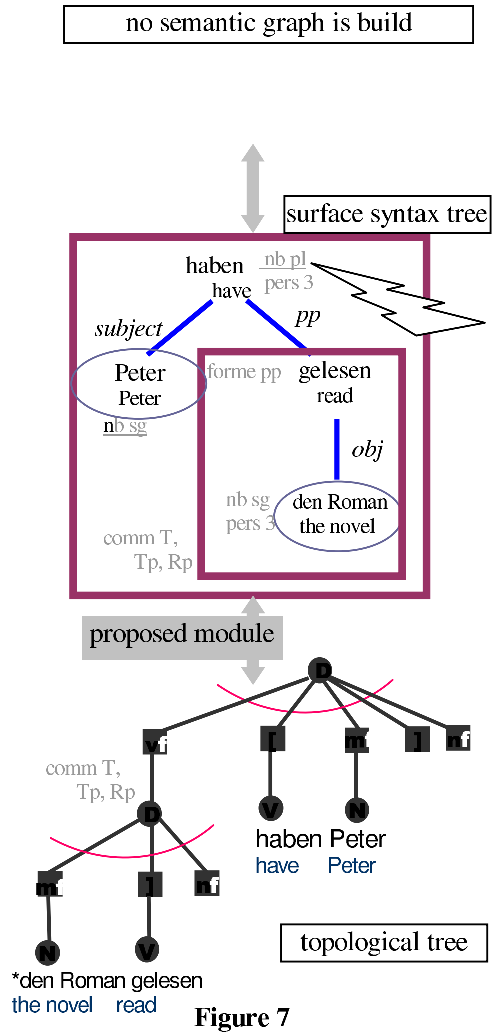

Figure 7

Schematic representations corresponding to a syntactically defective sentence: Agreement problem

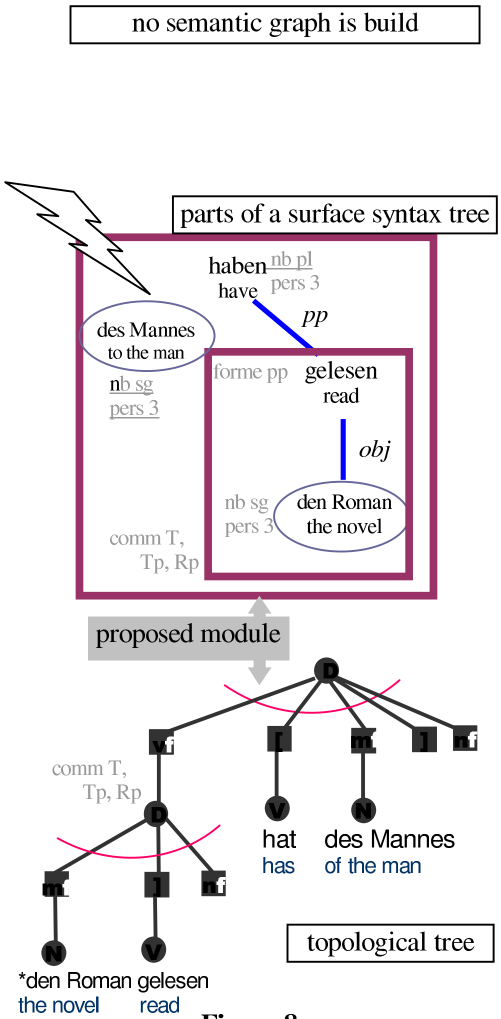

Figure 8

Schematic representations corresponding to a syntactically defective sentence: Valency problem

Figures 7 and 8 show syntactically defective sentences. Nonetheless, they are topologically well formed, for the agreement problem of Figure 7 does not prevent the syntactic module to produce a topological phrase structure and even to construct a syntactic dependency tree out of it. It’s the well-formedness condition of the syntactic level that will check the subject verb agreement.

The case of Figure 8 is different: Since the genitive NP is not a syntactic argument of the auxiliary, we cannot establish a syntactic relation between them. Either we say that in this case a syntactic structure cannot be created, or we conclude that the unconnected parts are a syntactic structure that does not fulfill the well-formedness condition of connectedness.[29]

Figure 9 shows a topologically defective sentence. *Den Roman* and *Peter* cannot create a new domain that could offer a landing site for both of them in the Vorfeld, and a connected topological tree cannot be constructed.

At this point, we have seen a sufficient number of illustrations of the syntactic module at work, the next step being the formalization of the corresponding algorithm.

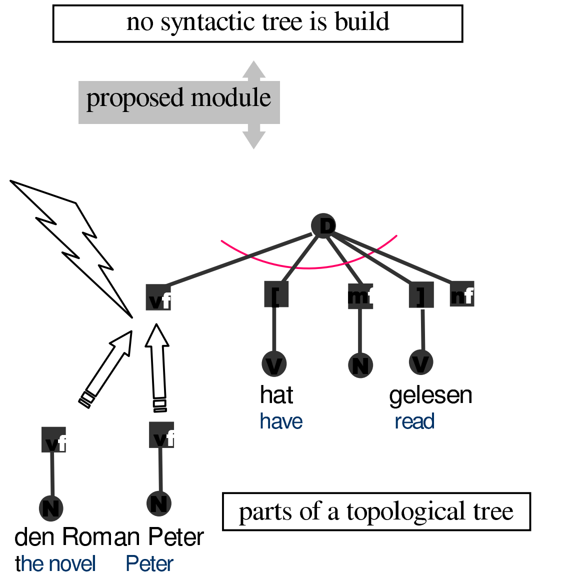

Figure 9
Schematic representations corresponding to a topologically defective sentence

6 Giving German a TUG

In what follows, I introduce a new lexicalized tree grammar in the TAG family based on superposing and unifying tree structures. We call the formalism Tree Unification Grammar (TUG).

In the preceding sections I defined what the algorithm of the syntactic module is supposed to perform: Taking a string of words, building a topological phrase structure on it, and building compositionally in parallel a surface syntactic dependency tree. In addition, the grouping of lexical heads into one topological domain (with its eventual communicative feature value) should be passed on, and marked on the dependency tree. We would like to perform the task of building the topological phrase structure with a simple combination procedure of lexicalized tree chunks, taking Tree Adjoining

[29] For the sentence of Figure 8, the situation would be different without the genitive NP. The syntactic structure would be connected and well-formed since no agreement feature can clash. The semantic module however will remark the lack of an agentive argument of the LESEN 'read' semanteme. This view allows as well an elegant description of constructions with 'subjectless' verbs like in (i): For the third person singular form *hat* 'has' the subject remains optional. The semantic module passes a nominative argument into the agent position only if it agrees in number and person.

(i) Mir hat gegraut.
To me (dat.) has dreaded
I dreaded.

Grammars as a model. Moreover, the construction has to be compositional in the sense that the successful combination of two lexical entries on the topological level should find its immediate reflection in the surface syntactic dependency tree.

TUG is principally a lexicalization of the algorithm for the topological phrase structure analysis of German presented in Gerdes and Kahane 2001a. It borrowed notions and ideas from TAGs and its relatives: DTGs (Rambow et alii 1995) address the same problem of the so-called long distance dependencies that are not peripheral (like wh-extraction, which TAGs can handle) but in the middle of the phrase structure (scrambling). The AES of Alexis Nasr 1996 place for the first time the lexical tree grammar in a Meaning-Text framework, and bubble grammars and GAGs (Kahane, 1997, Candito and Kahane 1998b), just as TUGs, address the problem of the link between a dependency grammar and an ordered phrase structure. An attempt to describe a complete Meaning-Text grammar lexically can be found in Kahane 2001. The task of TUGs is merely to serve as a correspondence module between syntactic dependency and topological phrase structure:

6.1. The definition

Let V be an alphabet, let $D \in V$ be a distinguished letter, let W be the set of words.

We call tree nodes *atoms* if they are distinguished by a label L out of V and by a binary color feature. This feature can take the value full (i.e. ■ ●, the distinction of square and round atoms is for better readability only), or empty (○). Atoms can further have a simple (non-embedded) feature structure. Features of empty nodes can also be *functional features*, to be defined below. Two atoms can unify iff they have the same label and their features unify.

A TUG *elementary tree* has atoms as its nodes. Leave atoms can be lexicalized in the sense that they are associated to a word form. The edges of an elementary tree can be supplied with right or left *sister adjunction exclusion*. For instance, the tree α of Fig. 10 has no adjunction exclusion. The tree β does not allow the atom b to have a left sister; the list of children of the atom x will always start with b. In the same way, in tree γ, atoms a and b will al-

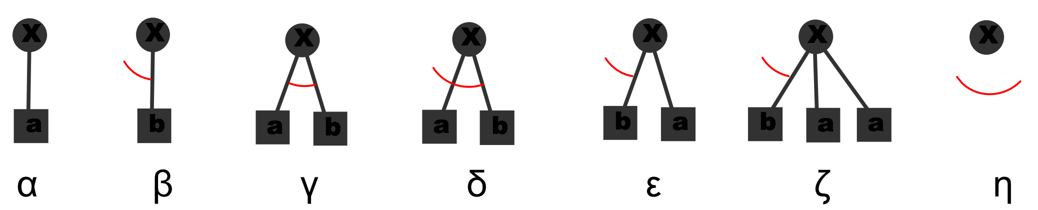

Figure 10: examples for tree unification

ways be direct neighbors, and in tree δ, *a* and *b* will always remain at the end of the list of children of atom *x*.

Two elementary trees κ and λ can *unify* into one tree iff the root atom *N* of one of the trees, say κ, unifies with a (possibly interior) atom *M* of tree λ, and the adjunction exclusions of *N* and *M* allow an ordering of their children. If a child atom of M, M', unified with a child of N, N', their respective children must again be able to find an arrangement on their order, and so on for all the descendents.

As an example, we observe that trees α and β can only unify to tree ε. Equally, the unification of α with ε can yield ε itself (if the features of the two can be unified). However, the two *a*-atoms of α and ε don't have to combine together; they can also combine to structures like ζ, as there is no adjunction exclusion around the *a*-atom of ε. In the same manner, it is possible to block a node from having any children, as in example η.

A *lexical entry* in TUG consists of a word w∈W and a finite set of elementary trees, with one of the trees being lexicalized with word w. The leaf node carrying the word w is called *lexical head*.

In standard TAG, the derivation tree just records which node was substituted or adjoined into which other node. The case for TUG is less simple, as the atom unification is not directional, not unique, and non-local in the sense that an elementary tree can unify with branches "belonging" to different elementary trees. This implies that the connection between the topological level, constructed out of the elementary trees, and the derived dependency has to be encoded specifically.

For this reason, we introduce a special feature, called *functional feature*, marked with an arrow and a name of the dependence link to construct: Let ↓*f* be a functional feature of an (empty) atom *N* being part of the lexical entry of *word1*. Then, an atom *M* being part of the lexical entry of *word2* can unify with *N* iff the lexeme *word1* is connected to a set containing *word2* by a dependency link with name *f*. In this way, atoms *N* and *M* in figure 11 unify iff we obtain *dependency 1*. Equally, the unification of the three atoms *N*, *M* and *O* corresponds to *dependency 2*.

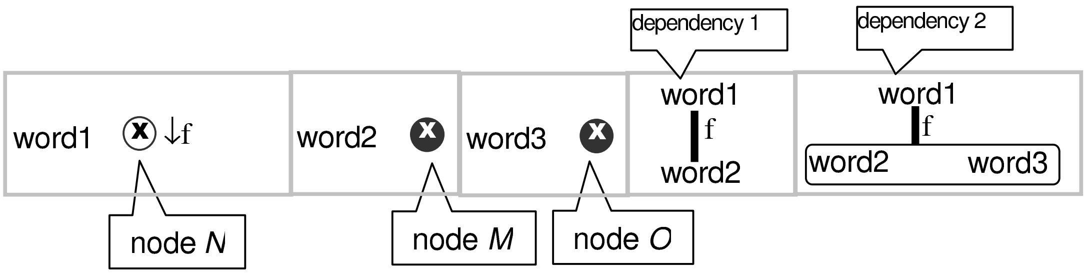

Figure 11: functional features

The dependency tree is equipped with a simple non-intersecting hierarchy of communicative groupings of words. In order to obtain the correspondence of domains on the topological level and the grouping on the syntactic level, we have to stipulate additionally: All lexical heads being directly dominated by the same atom D get grouped together on the syntactic level, and this grouping obtains the feature structure of the atom D.

A topological derivation of sentence *P* is complete iff[30]

- a topological field structure under a node *D* can be created over *P*, using up all involved elementary trees
- all empty atoms have been superposed by full atoms
- the functional features relate the structure to a connected dependency tree *T*.

6.2. Where do well-formedness conditions belong?

You may have noticed that the correspondence between topological field structure and dependency in TUG is somewhat asymmetrical: We only have a well-formedness condition on the topological side. The syntactic TUG module will be able to construct a dependency tree for sentence (7), and it is up to the next step in the analysis to enforce the well-formedness condition. Note however, that another syntactically defective sentence, the example of Figure 8, here repeated as (8) will not be assigned a dependency tree, because the phrase *des Mannes* remains unconnected to the other parts of the syntactic dependency tree.

(7) *Den Roman gelesen haben Peter.
The novel read have Peter.

(8) *Den Roman gelesen hat des Mannes.
The novel read has of the man.

It would be easy to make the module symmetrical by joining the enforcement of well-formedness to the condition of a successful derivation. We have good reasons though not to do so:

In a view of a Meaning Text Module as a whole, we have a chain of representations (R) with well-formedness conditions followed by transfer modules (T) followed by representations (R) with conditions etc. If we want to cut the chain RTRTRTR… into equal parts, we could take RT or TR, both are asymmetrical. Suppose moreover, we start the language generation process from a well-formed conceptual representation. We then have to start with a transfer module and add a well-formedness module for the following representation. In the sense of parsing, this gives a module constructing a representation and transferring it into the following deeper representation, exactly what TUG does.

[30] Equivalently: *a topological linearization of the dependency tree T is complete iff…*

7 A toy TUG for German

We will present a simple TUG with the lexical entries of sentence (1), which will allow us to obtain all the word order variations possible.

The auxiliary *hat* has two different lexical entries, depending on whether or not its verbal dependent opens a new domain. In the first entry, the auxiliary opens a main domain and its lexical head is the verb that occupies alone the left bracket of this domain. The empty atom of the Vorfeld indicates that this place has to be taken by some element, but we do not have any information about the properties of this object yet to come. The adjunction constraints on the left bracket make the auxiliary the only element occupying this field. The Mittelfeld is empty and has no restrictions on adjunction. The right bracket expects the verbal dependent of the auxiliary, the past participle. The right adjunction constraint on the right bracket says that the past participle will be the rightmost element of this field. The functional feature ↓pastp will create a dependence link in our syntactic structure from the word *hat* to the past participle that will take this place. Only elements with the form feature having the value pastp will be able to unify with this node. The Nachfeld is as the Mittelfeld open for any kind of unification. The lexical entry of *hat* contains another elementary tree, not connected with the lexical head: the elementary tree awaiting the subject[31]. The root node of this tree is marked *xf*, standing for the disjunction Vorfeld, Mittelfeld, or Nachfeld, and this tree will thus open a place for the subject in any major field of any domain.

[31] See footnote 29 for a discussion of why this elementary tree could be considered optional for the form *hat* ‘hat’.

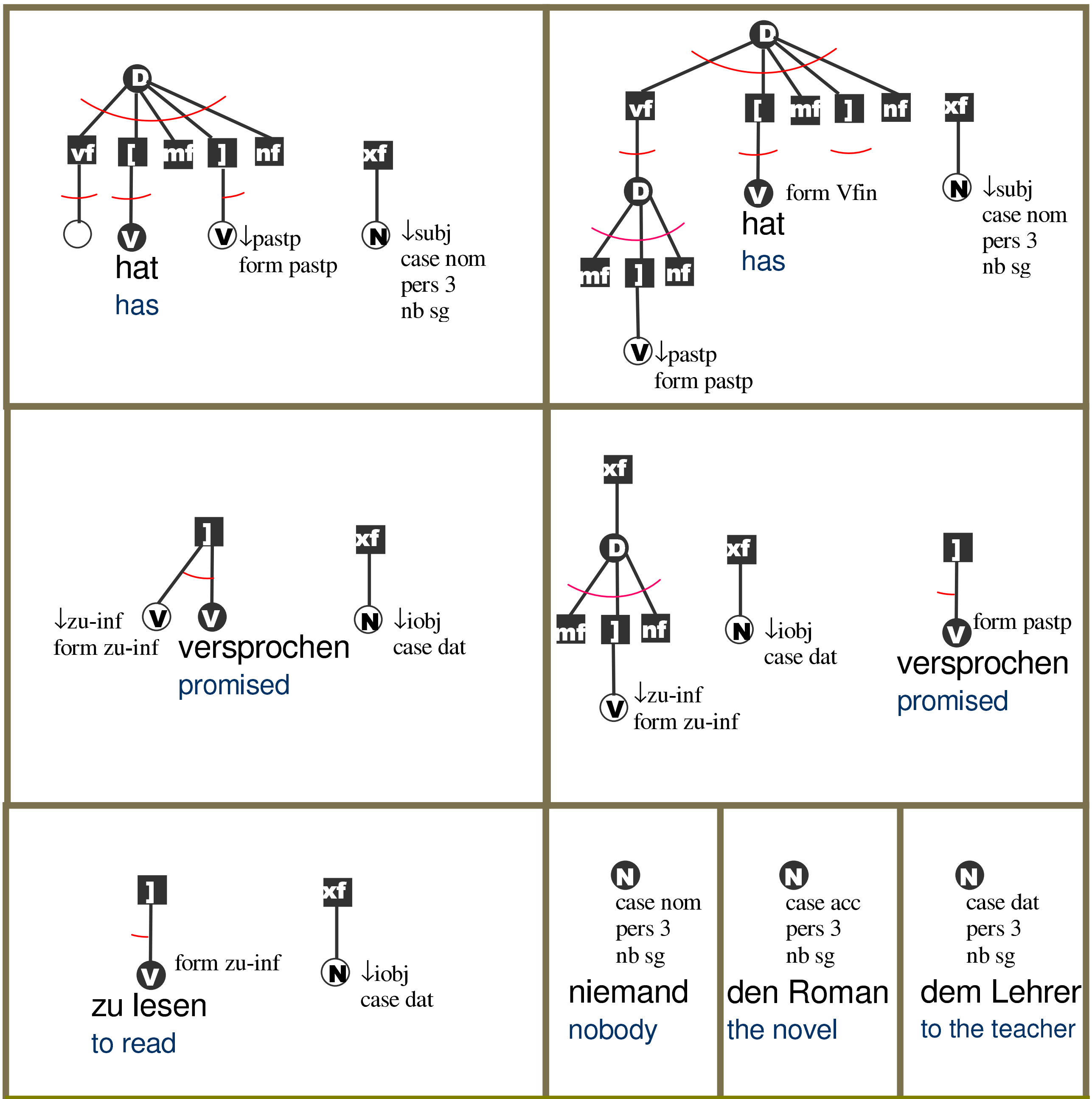

Figure 12
Lexical entries of a TUG grammar

The second possible lexical entry applies in the case that the past participle opens its own domain. Since it can only do so in the Vorfeld, we can already prepare the structure awaiting the past participle in the embedded domain in the Vorfeld. In this case the right bracket is completely blocked, because only a direct verbal dependent of *hat* can take this place, indirect verbal dependents will have to join their mother's domain or open their own domain.

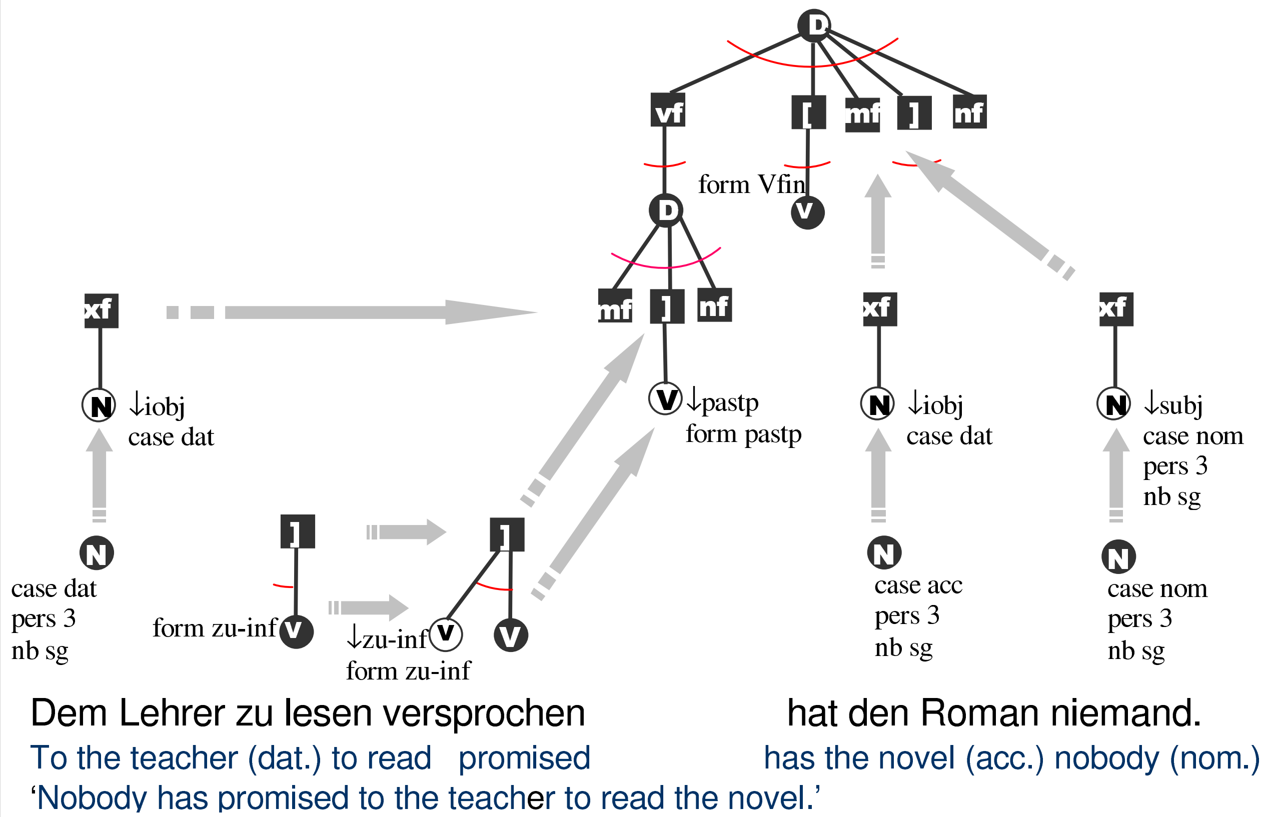

Figure 13: Parsing a sentence with TUG

The past participle *versprochen* has again two lexical entries, one for the case where its verbal dependent joins its right bracket, the other for the case where this dependent creates its own domain. As *versprochen* is a non-finite verb form, it always takes the right bracket, but in the first case, it waits for a zu-infinitive to join its right bracket, in the second case, it has to be the leftmost element of the right bracket, and the zu-infinitive will have its own domain.

Zu lesen does only have one lexical entry, as it does not govern any verbal element that could open a new domain. The entries of the nouns are just atomic trees, since the complex interior structure of noun phrases is not of our concern here.

7.1. Parsing and generation.

We will now show how a sentence can be parsed using the TUG defined above. The arrows[32] in Figure 13 indicate the unification of the atoms of the

[32] Of course the unification of atoms is non-directed. The arrows try to indicate the direction of the dependency and have no algorithmic meaning.

involved lexical entries to form a connected topological tree. The result is precisely the desired correspondence shown in Figure 2.

Of course, TUG can also parse syntactically and semantically defective sentences, as it is only concerned with topological well-formedness and the transfer to the syntactic level.

Inversely, we generate all grammatical sentences word orders for a well-formed syntactic dependency tree that itself is in correspondence with a well-formed semantic graph. If however the syntactic dependency is not well formed or descending from a defective semantic graph, the resulting sentences may be ungrammatical, because we do not have any criteria in TUG to test the well-formedness of the syntactic representation.

8 Conclusion and outlook

The TUG formalism allows us to derive in parallel the topological phrase structure and the corresponding surface syntactic dependency tree. It constitutes a correspondence model that can be seen as part of a bigger Meaning-Text model of language.

In spite of the high number of order possibilities for a given subcategorisation scheme, word forms need only a very limited number of different lexical entries, a clear advantage compared with standard TAGs.

It is beyond the scope of this article to show that the formalism is particularly apt for other complex syntactic phenomena, among them exceptional case marking verbs, verbal pied piping, and order variations in the verbal complex.

Ongoing research is carried out on the following points:

- The meaning of the notion ‘topology’. In particular the link of topology and prosody have to be further explored.
- The representation of noun phrases in the topological model. It seems reasonable to suppose that similar processes are at work inside the noun phrase. A unified model could prove particularly useful for an analysis of the extraction out of noun phrases.
- The utility of the topological model for other languages, in particular languages that have like German case marking but the free word order is limited by fixed places in the sentence structure, like for example Japanese and Korean.
- The computational complexity. A very important question for the utility of the TUG formalism as a whole will be its computational complexity. The unification of two TUG trees is in fact equivalent to the unification of one ordered embedded feature structure into another one (the unification does not have to be done on the outer feature structures). Parsing

TUGs can be seen as a pattern-matching problem in such feature structures. Without any restrictions, TUGs appear to need exponential time, but it seems reasonable that some restrictions can be laid out that will limit this complexity.

- Implementation. For the moment, only a generation model of Gerdes and Kahane's algorithm is implemented (Gerdes 2001). We will implement TUG as soon as the work on the algorithmic properties is sufficiently advanced.
- The utility of a metagrammar. It may be useful for the development of a real scale grammar to represent the grammatical phenomena in a hierarchy of grammatical features from which the elementary trees can be automatically generated (Candito 1999). It might be possible to reuse or extent the TAG metagrammar for German (Gerdes 2002).

The process itself of the development of TUGs seems to me to be of fundamental importance:

The first step in the direction of understanding natural language has to be observation and description of the observed phenomena. Only then, we should start with formalization. The formalization can have an effect on how we see language, but it may not determine it. Many formalisms, like TAGs, came the other way: They were simple and nice mathematical descriptions that were thought of as useful for natural language. The result is often a system functioning well for basic phenomena, but difficult to improve substantially since it is lacking descriptive linguistic power. TUG, on the contrary, is build in order to obtain precisely the desired structures, needed for our view on German word order.

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