Computing Semantic Representation: Towards ACG Abstract Terms as Derivation Trees
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To cite this version:
Sylvain Pogodalla. Computing Semantic Representation: Towards ACG Abstract Terms as Derivation Trees. Proceedings of the 7th International Workshop on Tree Adjoining Grammar and Related Formalisms (TAG+7), 2004, Vancouver, BC, Canada. pp.64-71. inria-00107768

HAL Id: inria-00107768
https://inria.hal.science/inria-00107768v1
Submitted on 13 Dec 2006

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Abstract

This paper proposes a process to build semantic representation for Tree Adjoining Grammars (TAGs) analysis. Being in the derivation tree tradition, it proposes to reconsider derivation trees as abstract terms (λ-terms) of Abstract Categorial Grammars (ACGs). The latter offers a flexible tool for expliciting compositionality and semantic combination. The chosen semantic representation language here is an underspecified one. The ACG framework allows to deal both with the semantic language and the derived tree language in an equivalent way: as concrete realizations of the abstract terms. Then, in the semantic part, we can model linguistic phenomena usually considered as difficult for the derivation tree approach.

Introduction

When dealing with the computation of semantic representation for TAG analysis, two main approaches are usually considered. The first one gives the derivation trees a central role for the computation (Schabes and Shieber, 1994; Candito and Kahane, 1998; Kallmeyer, 2002; Joshi et al., 2003), and the second one relies on a direct computation on the derived tree (Frank and van Genabith, 2001; Gardent and Kallmeyer, 2003).

The present article wants to explore the intuition that the two approaches are indeed bound: derivation trees are a specification of the operations that are to be processed, but the derived trees hold the precise descriptions of these operations. We propose to exhibit those operations by separating them from the syntactic trees. Then, under the specifications given by the derivation trees, we show how to build the semantic representations.

The tools we use for this purpose are Abstract Categorial Grammars (ACGs) (de Groote, 2001). The main feature of an ACG is to generate two languages: an abstract language and an object language. Whereas the abstract language may appear as a set of grammatical or parse structures, the object language may appear as its realization, or the concrete language it generates. For instance, (de Groote, 2002) proposes as object language the tree language of TAGs (encoded in linear λ-terms) and, as abstract language, a tree language (also encoded in linear λ-terms) and very close to the derivation tree language. In this paper, we use the same abstract language, and, as object language, λ-terms that encode underspecified semantic representation as in (Bos, 1995; Blackburn and Bos, 2003). Thus, we realize our program to separate the computation specification and the operation definition. As for Montague’s semantics, missing information is represented by bound λ-variables and replacement and variable catching by application instead of unification (as in (Frank and van Genabith, 2001; Gardent and Kallmeyer, 2003)).

The next section briefly describes the underlying principles of ACGs. Then we show how syntactic parts of TAGs are modelled and how we translate, through the abstract terms (our derivation trees), the combination of intial and auxiliary trees to their semantic representations by means of some examples.

1 ACG Principles

An ACG $\mathcal{G}$ defines:

1. two sets of typed λ-terms: $\Lambda_1$ (based on the typed constant set $C_1$) and $\Lambda_2$ (based on the typed constant set $C_2$);

2. a morphism $\mathcal{L} : \Lambda_1 \rightarrow \Lambda_2$;

3. a distinguished type $S$.

(de Groote, 2001) defines both $\Lambda_1$ and $\Lambda_2$ as sets of linear λ-terms. In this paper, we use simply typed λ-terms for $\Lambda_2$, using the translation of intuitionistic logic into
linear logic $A \rightarrow B = (\forall A) \rightarrow B$ (Girard, 1987; Danos and Cosmo, 1992). We don’t elaborate on that subject in this paper, but it does not change the main properties of ACGs\(^1\). Then the abstract language $A(G)$ and the object language $O(G)$ are defined as follows:

$$A(G) = \{ t \in A_1 | t : S \}$$

$$O(G) = \{ t \in A_2 | \exists u \in A(G) \ t = \mathcal{L}(u) \}$$

Note that $\mathcal{L}$ binds the parse structures in $A(G)$ to the concrete expressions of $O(G)$. Depending on the choice of $A_1$, $A_2$ and $\mathcal{L}$, it can map for instance derivation trees and derived trees for TAGs (de Groote, 2002), derivation trees of context-free grammars and strings of the generated language (de Groote, 2001), derivation trees of \(m\)-linear context-free rewriting systems and strings of the generated language (de Groote and Pogodalla, 2003). Of course, this link between an abstract and a concrete structure can apply not only to syntactical formalisms, but also to semantic formalisms.

The main point here is that ACGs can be mixed in different ways: in a transversal way, were two ACGs use the same abstract language, or in a compositional way, were the abstract language of an ACG is the object language of an other one. In this paper, as described in figure 1, we use different ACGs and some composition with $G$: $A_2$ is the tree language of TAGs, $A_1$ the tree language of our derivation trees. For $G'$, we have the same abstract language and $A_2'$ is the underspecified representation language. In dotted lines is a composition presented in (de Groote, 2001) between strings and derivation trees we do not use here.

![Figure 1: Moving from an object language to another](image)

Note that in the adjunction operation, the auxiliary tree is a parameter. But it also has a higher-order type, that

\[^1\]In particular, this means that, provided there is no vacuous abstraction in $\mathcal{L}(C_1)$ and every $c \in \mathcal{L}(C_1)$ is such that it has $t \in C_2$ as subterm, we can decide if, for $u \in A_2$ if $u \in O(G)$ and what is (are) the antecedent(s) (Pogodalla, 2004).

\[^2\]For instance, the type of $c_{\text{every}}$ should be $\text{Det}_A \rightarrow N_A \rightarrow N_S$.

2 TAGs as ACGs

This section refers to (de Groote, 2002), which proposes to encode TAGs into ACGs. Given a TAG $G$, $A_1$ is build as follows:

- for every non-terminal symbol $X$, there are two types $X_S$ and $X_A$ standing for places where substitution and adjunction can occur respectively;

For instance, given the trees of table 1, we have the constants and their types (for concision, we suppress parameters that are not used in the next examples of this paper, namely nodes where no adjunction occur\(^2\)):

$$c_{\text{every}} : N_A \rightarrow N_S$$

$$c_{\text{dog}} : N_A \rightarrow N_S \rightarrow N_S \rightarrow S$$

$$c_{\text{chases}} : S_A \rightarrow VP_A \rightarrow N_S \rightarrow N_S \rightarrow S$$

$$c_{\text{usually}} : VP_A \rightarrow VP_A$$

![Table 1: Examples of elementary trees](image)

To completely define the ACG $G$, we need to define $A_2$ and $\mathcal{L}$. The types of $A_2$ are made of the single type $\tau$, representing the type of trees. For any non-terminal symbol $X$, there are constants $X_0, \ldots, X_i$, where $i$ is the maximal number of children of the $X$ nodes in the elementary trees. For any terminal symbol $X$ in $G$, there is a constant $X : \tau \in C_2$. Then $\mathcal{L}$ is defined by sending any $X_S$ type to the type $\tau$, and any $X_A$ types to the type $\tau \rightarrow \tau$. Corresponding to the trees of table 1, we have for instance:

$$\mathcal{L}(I_X) = \lambda x. x : \tau \rightarrow \tau$$

$$\mathcal{L}(c_{\text{every}}) = \lambda x. N_S(every x) : \tau \rightarrow \tau$$

$$\mathcal{L}(c_{\text{dog}}) = \lambda N.N(N_{\text{dog}}) : (\tau \rightarrow \tau) \rightarrow \tau$$

$$\mathcal{L}(c_{\text{chases}}) = \lambda SV. \lambda x. \lambda y. S_2(x(V P_{\text{chases}} y))) : (\tau \rightarrow \tau) \rightarrow (\tau \rightarrow \tau) \rightarrow \tau \rightarrow \tau \rightarrow \tau \rightarrow \tau$$

Note that in the adjunction operation, the auxiliary tree is a parameter. But it also has a higher-order type, that
is a function from trees to trees. We let the reader check that \( L(c_{\text{chases}}, I_S I_P(c_{\text{dog} \text{every}})(c_{\text{cat} \text{some}})) \) correspond the derived tree associated to every dog chases some cat of figure 2.

![Figure 2](image-url)

We note two important things. First, the abstract terms, as \( c_{\text{chases}}, I_S I_P(c_{\text{dog} \text{every}})(c_{\text{cat} \text{some}}) \) can be represented by a tree structure where the children of a node are its arguments. Then erasing the \( I_X \) arguments, and directing the edges downward if the argument is of type \( X_G \) and upward if the argument is of type \( X_A \), we get the usual notion of derivation tree. Second, the auxiliary trees are modelled as higher-order function. We use the same approach in our semantic modelling, getting some type raising, as in Montague’s semantics. But let us precise the ACG we use for the semantic representation.

3 Semantic representation for TAGs as ACGs

The semantic representation language we use is an underspecified one presented in (Bos, 1995; Blackburn and Bos, 2003): the predicate logic “unplugged”. The aim of this language, the underspecified representation language (URL) is to specify in a single formula the possible formulas of the semantic representation language (SRL) associated to an ambiguous expression. For instance, the expression every dog chases a cat has the two possible meanings:

\[
\forall x (\text{dog}(x) \Rightarrow \exists y (\text{cat}(y) \land \text{chases}(x, y))) \\
\exists y (\text{cat}(y) \land \forall x (\text{dog}(x) \Rightarrow \text{chases}(x, y)))
\]

To mark the difference between the SRL and the URL, both being first order languages, we translate the usual first order logic symbols of SRL. This translation is straightforward, using boldface symbols (e.g., \( \text{All}, \text{And}, \text{Imp}, \) etc.). In SRL, the two previous formulas are restated as follows:

\[
\text{All}(x, \text{Imp}(\text{dog}(x), \text{Some}(y, \text{And}(\text{cat}(y), \text{chases}(x, y)))))) \\
\text{Some}(y, \text{And}(\text{cat}(y), \text{All}(x, \text{Imp}(\text{dog}(x), \text{chases}(x, y)))))
\]

Both these formulas have the property that:

- they have at least two subformulas: one quantified by \( \text{All} \), one quantified by \( \text{Some} \);
- \( \text{chases}(x, y) \) is a subformulas of the two quantified subformulas.

The URL relies on the specification of subformula constraints that the SRL formulas have to satisfy, and the two SRL formulas above can be described by the following URL formula:

\[
\exists h_0 h_1 l_2 l_3 l_4 l_5 l_6 l_7 x y (l_1 : \text{All}(x, l_2) \\
\land l_2 : \text{Imp}(l_3, h_1) \land l_3 : \text{dog}(x) \land l_4 : \text{Some}(y, l_5) \\
\land l_5 : \text{And}(l_6, h_2) \land l_6 : \text{cat}(y) \\
\land l_7 : \text{chases}(x, y) \land h_1 \geq l_7 \land h_2 \geq l_7 \land h_0 \geq l_1 \\
\land h_0 \geq l_4)
\]

illustrated in figure 3. The syntax of URL is basically the same that first-order logic, except that if atomic formulas remain the same, formulas are built from holes and labels, the latter being used as place holder for logical formulas in the underspecified representation language. We use the usual logical symbols (\( \exists, \land \)), an infix predicate \( \geq \) to specify the constraints and an infix operator : for URL. The symbol \( h \geq l \) imposes the constraint for a formula that is associated to \( l \) to be a subformula of the one associated to \( h \). \( l : p \) indicates that a predicate \( p \) of SRL is labelled in URL by \( l \).

![Figure 3](image-url)
• the types we use are $e, h, l, p, t$ where $e$ stands for entities, $h$ for holes, $l$ for labels, $p$ for predicate of the logical language and $t$ for truth values;

• the constants are $\geq, :, \exists h, \exists e, \exists x, \land, \text{Imp, And, Some, All}$ and the set of the predicate symbols of the logical language (dog, chases, etc. in the examples). Their types are described in Table 2.

Note we have three existential quantifiers $\exists h, \exists e, \exists x$, but we usually note them only $\exists$. Moreover, to keep with the usual logical notation we write $\exists x P$ instead of $\exists(\lambda x. P)$ where $x$ is a free variable of $P$.

Finally, to define the ACG $G'$, we need the lexicon $L'$. It transforms the types from $A_1$ as follows:

$$L'(N_S) = (e \rightarrow h \rightarrow l \rightarrow t) \rightarrow (h \rightarrow l \rightarrow t)$$

$$L'(N_A) = (e \rightarrow h \rightarrow l \rightarrow t) \rightarrow (h \rightarrow l \rightarrow t)$$

$$L'(S_S) = h \rightarrow l \rightarrow t$$

$$L'(S_A) = (e \rightarrow h \rightarrow l \rightarrow t) \rightarrow (h \rightarrow l \rightarrow t)$$

$$L'(V_P) = (h \rightarrow l \rightarrow t) \rightarrow (h \rightarrow l \rightarrow t)$$

Contrary to $A_2$, the model derived trees and generates linear terms, we use in $A_2$ non-linear terms, as the intuitionistic $\rightarrow$ shows. The definition of $L'$ on the terms justifies it. We shall introduce this definition in the next sections, illustrating different linguistic phenomena.

3.1 Quantification

We start with the classical example of quantification. When dealing with quantifiers as adjunct (Abeillé, 1993), where quantifier is adjoined to the noun, quantifiers are separated from the verb by the noun in the derivation trees. Then the problem of the proposition coming from the VP to be part of the scope of the quantifiers arises.

(Kallmeyer, 2002) proposes to enrich the derivation trees with additional links to take this kind of linking into account.

We propose to deal with this kind of problems following the Montague’s approach of quantification (Montague, 1974): the subject is an argument of the verb, but it is also a higher order function which has the verb predicate as argument. So the lexicon for the ACG $G'$ could define:

$$L'(\text{c_{dog}}) = \lambda p. \lambda h. \exists h_1 l_1 l_2 l_3 v_1 (h \geq l_2)$$

It’s easy to check that the translation from the abstract term, or the derivation tree in our sense, $t = c_{\text{chases}} I_S l_P (c_{\text{dog every}}) (c_{\text{cat some}})$ by $L'$ has the expected form:

$$L'(\text{c_{dog every}}) = \lambda p. \lambda h. \exists h_1 l_1 l_2 l_3 v_1 (h \geq l_2)$$

$$\land \exists h_1 l_1 l_2 l_3 : \text{Imp}(l_1, h_1)$$

$$\land h_1 \geq l \land h \geq l_1 \land l_1 : \text{dog}(v_1)$$

$$\land p v_1 h l$$

$$L'(\text{c_{cat some}}) = \lambda p. \lambda h. \exists h_1 l_1 l_2 l_3 v_1 (h \geq l_2)$$

$$\land \exists h_1 l_1 l_2 l_3 : \text{And}(l_1, h_1)$$

$$\land h_1 \geq l \land h \geq l_1 \land l_1 : \text{cat}(v_1)$$

$$\land p v_1 h l$$

$$L'(\text{chases}) = \lambda s. \lambda o. (\lambda y h l v. h \geq l'$$

$$\land l' : \text{chases}(x, y)$$

Hence for $L'(t)$ we have:

$$\lambda h. \exists h_1 l_1 l_2 l_3 v_1 (h \geq l_2 \land l_2 : \text{All}(v_1, l_3)$$

$$\land \exists h_1 l_1 l_2 l_3 : \text{Imp}(l_1, h_1)$$

$$\land h_1 \geq l \land h \geq l_1 \land l_1 : \text{dog}(v_1)$$

recovering the one from the figure 3 (modulo variable renaming).

To deal with quantification in this example, we don’t add any extra-link to the derivation tree (or abstract term) ones, contrary to (Kallmeyer, 2002). Both the subject (the $s$ variable in $L'(c_{\text{chases}})$) and the object parameter (the $o$ variable) are considered as the real functionals, applied to the relation chases as in $s(\cdots (o \cdots \text{chases}(x, y) \cdots ))$. This implies that $N_s$ and $N_p$ have higher-order types (see also the semantic term associated to entities in section 3.4). This is reminiscent to Montague’s approach (Montague, 1974).

A term like $L'(c_{\text{chases}})$ also shows the exact contribution of every node. For instance, the $b$ variable stands for the semantic contribution of the $S$ node, whereas the $a$ variable stands for the semantic contribution of the $VP$. That is the former can act both on the predicate and its argument (see the type of $L'(S_A)$), whereas the latter can only modify the whole relation. The next sections illustrate this point, with adverbs and raising verbs. Then, modelling verbs with phrasal arguments, we show how the $b$ variable can act.

In the sequel of the paper, whenever we introduce a new term which has a similar constrution to a previous one, we don’t give its explicit definition (e.g. loves, similar to chases).

3.2 Adverbs

In the semantic representation we associate to $c_{\text{chases}}$ in the previous section, we see, between the subject $s$ and the “VP relation”, an argument $a$. Its type ($L'(V_P) = (h \rightarrow l \rightarrow t) \rightarrow (h \rightarrow l \rightarrow t)$) shows it is a verb modifier. So let us introduce a new constant $c_{\text{unarily}} : V_P A \rightarrow$
where every subformula of the label that could also be adjoined to this node (for instance an opaque. Hence its associated term in as for adverbs, except that this time it is not considered as adverbs. We can use exactly the same semantic encoding is not other possibles modifiers. In this case, the argument of the label of the verb predicate to there are adverbs that would not have this opaque be-

Going upward in the syntactic tree, we can now try to model expressions that act on S nodes like claims (see
table 3). Coming back to our modelling of chases, we had a b argument of type \( \mathcal{L}'(S_A) = (e \rightarrow h \rightarrow l \rightarrow t) \rightarrow (e \rightarrow h \rightarrow l \rightarrow t) \). So we can associate to a term in \( N_S \rightarrow S_A \rightarrow S_A \in \Lambda_1 \) a term in \( \Lambda_2' \):

\[
\lambda b.\lambda x.\lambda h.\exists h_1(\exists l_1 \geq l_1 \land \exists h'_1 \geq h'_1 \land \exists t_1 \geq l_1 \land \exists t'_1 \geq l'_1) \text{ which specifies that } x \text{ claims something, the latter being dominated by } h_1 \text{ (hence claims).}
\]

So for instance, an expression Paul claims John loves Mary would give the abstract term \( c_{\text{loves}}(c_{\text{claims}}(P, h_1) \land \text{loves}(j, m)) \) and its underspecified representation (\( \mathcal{L}'(c_{\text{Paul}}) = \lambda P.Pp \)):

\[
\lambda x.\lambda y.\lambda h.\exists h_1(\exists l_1 \geq l_1 \land \exists h'_1 \geq h'_1 \land \exists t_1 \geq l_1 \land \exists t'_1 \geq l'_1)
\]

As mentioned in (Gardent and Kallmeyer, 2003), there are adverbs that would not have this opaque behaviour and rather pass the label of the verb predicate to other possibles modifiers. In this case, the argument of a is not \( l_1 \), but simply \( l \). We illustrate it in the next example, even if not on adverbs.

### 3.3 Raising Verbs

Raising verbs like seems have been modelled in TAGs as adverbs. We can use exactly the same semantic encoding as for adverbs, except that this time it is not considered as opaque. Hence its associated term in \( \Lambda_2' \) is:

\[
\lambda c.\lambda r.\lambda h.\exists h_1(\exists l_1 \geq l_1 \land \exists h'_1 \geq h'_1 \land \exists t_1 \geq l_1 \land \exists t'_1 \geq l'_1)
\]

### 3.4 Verbs with Phrasal Arguments

Going upward in the syntactic tree, we can now try to model expressions that act on S nodes like claims (see

| Table 2: Typing of constants of \( \Lambda_2' \) |
|------------------|------------------|------------------|------------------|
| \( VP_A \in C_1 \). We can associate it, with \( \mathcal{L}' \), to the term: |
| \( \lambda a.\lambda r.\lambda h.\exists h_1(\exists l_1 \geq l_1 \land \exists h'_1 \geq h'_1 \land \exists t_1 \geq l_1 \land \exists t'_1 \geq l'_1) \) |
| \( \wedge \lambda l_1 \geq l_1 \land \lambda h'_1 \geq h'_1 \land \lambda t_1 \geq l_1 \land \lambda t'_1 \geq l'_1) \) |
| where every subformula of \( h'_1 \) is a subformula of \( A \). Since \( h'_1 \) dominates \( l_1 \) which is the label of \( U \), \( U(h_1) \) is always a subformula of \( A \). |
| As mentioned in (Gardent and Kallmeyer, 2003), there are adverbs that would not have this opaque behaviour and rather pass the label of the verb predicate to other possibles modifiers. In this case, the argument of a is not \( l_1 \), but simply \( l \). We illustrate it in the next example, even if not on adverbs. |

### 3.4 Verbs with Phrasal Arguments

Going upward in the syntactic tree, we can now try to model expressions that act on S nodes like claims (see

| Table 3: Few more trees |
|------------------|------------------|------------------|------------------|
| claims |
| seems |
| to love |
if the syntactic properties of the infinitive to love (see table 3) really differs from the ones of loves, their semantic counterpart only differs in the order of argument (and an extra \(\mathcal{L}(S_A)\) whose role should be precised). We can naturally associate to \(\mathcal{L}'(c_{to\, loves})\) the term:

\[\lambda baos.s(b(\lambda x.a(o(\lambda yhl'.h' \geq l' \land l') : \text{loves}(x, y))))\]

Then analyzing a long distance dependency Mary Paul claims John seems to love is the same as analyzing the previous example, except that the \(I_{vp}\) term is replaced by \(c_{seems}\) and the order of the other arguments is exchanged: \(c_{loves}(c_{claims}c_{Paul})(c_{seems}I_{vp})c_{Mary}c_{John}\). The contribution of \(\mathcal{L}'(c_{seems}I_{vp})\) to \(\mathcal{L}'(c_{loves})\) is just adding the conjunction of (modulo the variable renaming) \(\exists h_2 l_2(h_1 \geq l \land l') : \text{loves}(j, m) \land h_1 \geq 2 \land l_2 : \text{seems}(h_2) \land h_2 \geq l')\) instead of only \(h_1 \geq l \land l') : \text{loves}(j, m))\) so that we finally have:

\[\lambda hl.\exists l_1 h_1(h \geq l_1 \land l_1 : \text{claims}(p, h_1) \land \exists h_2 l_2(h_1 \geq l \land l_2 : \text{loves}(j, m) \land h_1 \geq l_2) \land l_2 : \text{seems}(h_2) \land h_2 \geq l)\]

which is the expected result.

### 3.5 Wh-questions

This section provides an example of an adjunction occurring on the root node of an auxiliary tree which is itself adjoined to a third tree. The expression who does Paul think John said Bill liked, can be analyzed with the constants \(c_{who} : \text{WH}_S \in \Lambda_1\) and \(c_{liked} : S_A \rightarrow VP_A \rightarrow \text{WH}_S \rightarrow N_S \rightarrow S_S \in \Lambda_1\), that correspond to the trees of figure 4. The two other constants \(c_{does\, think}\) and \(c_{said}\), corresponds to the auxiliary trees of the same figure and the derivation tree is \(c_{liked}(c_{who}c_{liked}(c_{does\, think}c_{Paul}I_S))I_{vp}c_{who}c_{Bill}\).

Then, we can extend \(\mathcal{L}'\) as follows:

\[\mathcal{L}'(c_{who}) = \lambda phl.\exists v_1 h''_1 l''_1(h \geq l''_1 \land l''_1 : W(v_1, h''_1) \land h''_1 \geq l \land pv_1 h''_1 l)\]

\[\mathcal{L}'(c_{liked}) = \lambda baos.a(b(\lambda yhl.\exists xh.l(h \geq l \land l : \text{liked}(x, y))))\]

\[\mathcal{L}'(c_{said}) = \lambda sbr.b(\lambda y.s(\lambda xhl.\exists h l_1(h \geq l_1 \land l_1 : S(x, h_1) \land h_1 \geq l \land ryhl_1)))\]

\[\mathcal{L}'(c_{does\, think}) = \lambda sbr.b(\lambda y.s(\lambda xhl.\exists h' l_1(h \geq l' \land l' : T(x, h'_1) \land h'_1 \geq l \land ryh'_1)))\]

which is the expected one, with \(W\) binding the variable \(v_1\) and dominating \(T\), itself dominating \(S\), itself dominating \(\text{liked}(b, v_1)\).

### 3.6 Control Verbs

Control verbs, as presented in (Gardent and Kallmeyer, 2003) or (Frank and van Genabith, 2001), with adjunc-
tion on a S node (see table 4) to produce an expression like John tries to sleep, with the adjunction of tries to on sleep, is a problem for our approach.

Indeed, it is build from the term $c_{sleep} (c_{tries to} l_{vp} c_{John} l_{s}) l_{vp}$ and the typing discipline makes $t = c_{tries to} l_{vp} c_{John} l_{s}$ of type $S_A$, hence $L'(t)$ of type $(e \rightarrow h \rightarrow l \rightarrow t) \rightarrow e \rightarrow h \rightarrow l \rightarrow t$. If it is clear that the first argument of type $(e \rightarrow h \rightarrow l \rightarrow t)$ concerns the sleep predicate (with something like $\lambda x h l. h \geq l \land l : sleep(x)$), the result should not have any $e$ possible argument (it has been filled with $j$).

In other worlds, if we look at adjunctions on S nodes in previous sections, the subtrees always lack an N (John seems to love x, or John said Bill liked x) and are always transformed into a subtree lacking an N too (Paul claims John seems to love x, or does Paul think John said Bill liked x). This is not the case anymore with control verbs where the subtree for $x$ sleep turns into John tries to sleep.

So control verbs cannot be dealt with directly that way with our techniques. We need for instance to differentiate the $S_A$ type into the usual one $(e \rightarrow h \rightarrow l \rightarrow t) \rightarrow e \rightarrow h \rightarrow l \rightarrow t$ and another one $(e \rightarrow h \rightarrow l \rightarrow t) \rightarrow e \rightarrow h \rightarrow l \rightarrow t$. This could be done with a special $S_{pro}$ node, or with an extended type system (for instance additives of linear logic to manage disjunctive types). But this requires further investigation and goes beyond this article.

Table 4: Derived trees for control verbs

| S       | VP    | Pro   | VP |
|---------|-------|-------|----|
| N       | S*    | tries to | sleep |

Conclusion

We propose to reconsider semantic representation computation for TAG from the derivation trees. But derivation trees here are understood as abstract terms of ACGs, even if the informations born by each of the formalism are essentially the same. Whereas they hold the specification of how trees should combine, the locality of computing the meanings held by the different nodes is described in the object vocabulary. It obviates the addition of extra links to manage scoping and shows that derivation trees, by themselves, are enough, even if further investigation are required to handle control verbs.

It also clearly defines the compositional aspects of building semantic representations with a clear and modular distinction between syntax and semantics. The latter point lacks in the derived tree approaches. Moreover, the mathematical primitives we use are very simple (if expression not always are) and are the same both on the syntactic and the semantic side, and no external principles need to be added.

So, from the ACG point of view, both syntax and semantics are dealt with in an equivalent way: as object languages of the same abstract language. This is interesting because the computation engine to go from the object language to the abstract language in an ACG does not depend on the object language. So the underlying process remains the same for all that cases:

- to compute a derived tree, then a derivation tree, from a string;
- to compute a derivation tree from a URL formula;
- to compute a derived tree, then a string, from a derivation tree;
- to compute an URL formula from a derivation tree.

So that going from one to the other (parsing or generation, in the usual sense) is as difficult (or as easy) as going the other way. Of course, on the semantic side, it means the initial point is an URL formula, and it gives no hint on how to build it from an SRL formula, nor on how to deal with the logical equivalence (be it on the SRL or on the URL level).

Finally, it underlines the interesting feature of ACG to transport or transmit structures from one language to another, illustrated between a syntactic formalism and a semantic formalism for TAGs. As suggested by an anonymous referee, the same approach could be used to provide semantic representations to expressions belonging to $m$-linear context-free languages, since abstract terms have already been proposed for them (de Groote and Pogodalla, 2003).

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