Grammatical Functions, Discourse Referents and Quantification

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ABSTRACT

A new algorithm is proposed which transforms f-structures into discourse representation structures (DRSs). Its primary features are that it works bottom up, that it is capable of translating f-structures without pre imposing any arbitrary order on the attributes occurring in it, and that it handles indeterminacy of scoping by using sets of translations. *The* approach sheds light on how an efficient interaction of different components of a natural language processing model can be achieved.

I INTRODUCTION *)

The informational content of a sentence is determined not only by its linguistic form, but also by a number of contextual factors. Thus within any compositional approach to semantics the control structure for the functional composition must not be determined exclusively by the syntactic structure of the phrase. The present approach is based on two levels of representation, that 'mediate' between the linguistic form of a sentence and its denotation(s) (in a model).

F-structures constitute, the first level. They have the property that the unraveling of the grammatical roles of a sentence is already achieved, while the quantifier scope relations are not yet represented. This is basically due to the use of grammatical functions as theoretical primitives ([1].[3]).

The second level accounts for the dependency of (the construction of the interpretation) of a sentence on factors which are not purely syntactic. It consists of DRSs in which the scope relations will be treated. The central property of DRSs is that the part of sentence or text from which they derive acts as a context which guides the interpretation of the parts following it. This property of DRSs is based mainly on their containing discourse referents ([4]). It leads to a dynamic creation of interpretations of sentences.

We will show how to formulate a translation meciianism which allows for arbitrary scope relations not only within the limit of a clause nucleus but also within the various clause nuclei in which an NP can play a role by means of functional control. Possible non-syntactic scope restrictions can thus be licensed by additional constraints derived from various other features of the surface string, the semantics, or pragmatics.

The central feature of the translation algorithm Is, loosely speaking, to replace the grammatical functions in the f-structure by the discourse referents which have been made available (for subsequent reference) by the values of the grammatical functions, i.e. the f-structures representing NPs. These f-structures themselves are translated into DRSs which are partial in the sense that there are (in general) still conditions or sub-DRSs missing in order to be interpretable. We will define some principles for the translation into and completion of partial DRSs.

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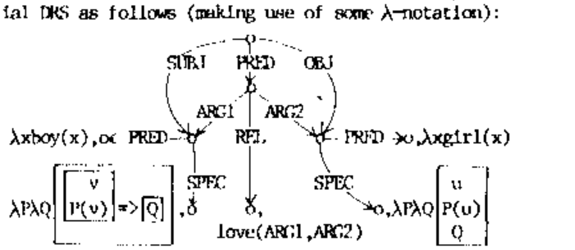
II EXAMPLE

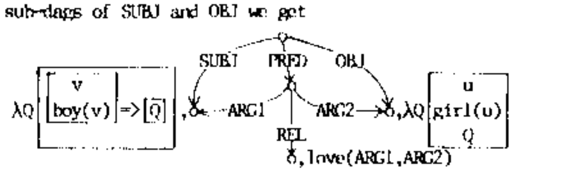
But before stating the exact definitions let us illustrate the algorithm by

(1) Every boy loves a girl

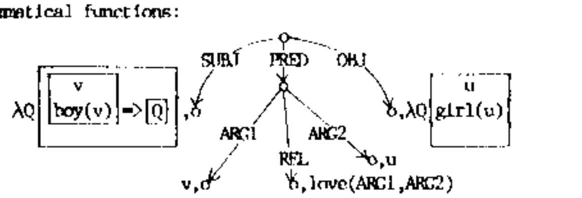
In order to give a graphic representation of the interplay between syntax and semantics we will represent f-structures as directed acyclic graphs (dag), the nodes Ci of which are associated with the translations of the f-structures rooted in Ci. The procedure works bottom-up (i.e. from inside the f-structures out). First, we associate with every leaf node a partial DRS as follows (making use of some λ-notation):



After ordinary λ-conversion of the SPEC-PRED combinations in the sub-dags of SUBJ and OBJ we get



Transformation of this dag into a tree is achieved by splitting the nodes which are the values of the grammatical functions and ARGi so that the discourse referents occurring in the partial DRSs are associated with the new nodes of the ARGi attributes and the partial DRSs themselves with the nodes of the grammatical functions:



After pruning the attributes we get the following set of expressions which is to be associated with the root node of the tree.

$$(2)\quad \left\{ \lambda Q \left[\boxed{\begin{array}{c} v \\ \mathrm{boy}(v) \end{array}} \Rightarrow \boxed{Q} \right],\ \mathrm{love}(v,u),\ \lambda Q \left[\begin{array}{c} u \\ \mathrm{girl}(u) \\ Q \end{array} \right] \right\} \quad {}^{*)}$$

This set allows for two different sequences of λ-conversion, yielding the two desired readings

$$(3)\quad \left[\boxed{\begin{array}{c} v \\ \mathrm{boy}(v) \end{array}} \Rightarrow \boxed{\begin{array}{c} u \\ \mathrm{girl}(u) \\ \mathrm{love}(v,u) \end{array}} \right] \qquad (4)\quad \left[\begin{array}{l} u \\ \mathrm{girl}(u) \\ \boxed{\begin{array}{c} v \\ \mathrm{boy}(v) \end{array}} \Rightarrow \boxed{\mathrm{love}(v,u)} \end{array} \right]$$

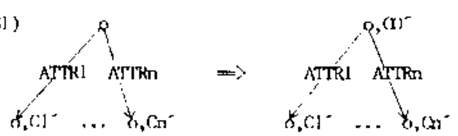
The example shows that we have to formulate two principles, one for the transduction of the dag into a tree, the other for calculating the partial translation of an arbitrary non-terminal tree node given the partial translations associated with its daughter nodes. Both principles will be local in the sense that only local trees and dags are used in their formulation.

III THE ALGORITHM

First we have to give the precise definition of partial DRSs. The usual definition of a DRS K as a pair consisting of a set of discourse referents U(K) and a set of conditions CON(K), together with Kamp's accessibility relation (cf. [4]), allows for the abstraction of discourse referents, predicates and (sets of) conditions. We therefore define partial DRSs inductively as follows.

Def. (a) Every DRS $K = \langle U(K), CON(K) \rangle$ is a partial DRS .
(b) If u is a discourse referent occurring in conditions c1,...,cn of CON(K) but not in any of the universes that are accessible from K, then
$\lambda uK = \langle U(K), \lambda uCON(K) \rangle$ is a partial DRS, where
$\lambda uCON(K) = \{\lambda uci \mid i=1,\ldots,n\} \cup CON(K) \setminus \{ci \mid i=1,\ldots,n\}$.
(c) If P is a variable over partial DRSs of the form λuK´ with u and c1,...,cn as under (b), then $\lambda PK = \lambda P\langle U(K), CON(K) \cup P(u) \rangle$ is a partial DRS.
(d) If Q is a variable over DRSs, then
$\lambda Q = \lambda Q\langle U(K), CON(K) \cup Q \rangle$ is a partial DRS.

Suppose now we have a semantic interpretation schema with attribute names ATTR1,...,ATTRn

(SIS1) 

where the translations C1´,...,Cn´ are already given as sets of partial DRSs. Suppose further that C1´,...,Cn´ are singletons, i.e. contain exactly one partial DRS. Then C0´ is calculated from them by the following principle.

<u>Functional application principle for sets of partial DRSs</u>
Given a set KK = {K1,...,Kn} of partial DRSs, then the set FA(K1,...,Kn) consists of those elements which belong to the transitive closure of KK under the operation of <u>functional application</u> fa defined by:
(a) $fa(\lambda uK, v) = fa(\lambda uCON(K), v) = K[v/u]$, where u and v are discourse referents and K[v/u] is the result of replacing every occurrence of u in CON(K) by v.
(b) $fa(\lambda PK, \lambda u´K´) =$
$\langle U(K) \cup U(K´), CON(K) \setminus P(u) \cup fa(\lambda u´CON(K´), u) \rangle$, where P is a variable over partial DRSs of the form λuK and u and u´ are discourse referents.
(c) $fa(\lambda QK, K´) = \langle U(K) \cup U(K´), CON(K) \cup CON(K´) \rangle$, where Q is a variable over DRSs.

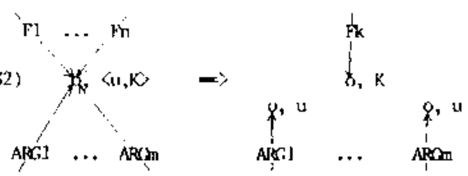
Def. (a) A DRS K is <u>closed</u> if all discourse referents occurring in CON(K0) for some sub-DRS K0 of K are introduced in some universe U(K1) accessible form K0.

This allows us to finish the interpretation of (SIS1): We supposed that all C1´,...,Cn´ were singletons. If we now admit non-singletons among the Ci´ then C0´ is calculated as the union of all FA(C1´´,...,Cn´´) with Ci´´ belonging to Ci´. But we restrict the occurrence of non-singletons to such sets Ci´ for which all Ci´´ are closed.

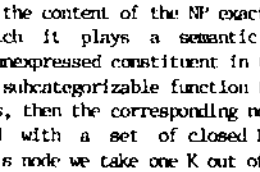
What we have not explained yet is how the semantic predicate gets the correct discourse referent as its value.

Def. A <u>DRS with distinguished discourse referent</u> u is a pair ⟨u,K⟩, where u is a discourse referent introduced in K and K is a partial DRS.

This allows us to formulate the second interpretation schema. Its task is to disambiguate the role of the nodes in the dag which are values of more than one attribute. In every such configuration at least as many grammatical functions Fj occur as there are ARGi. We will restrict ourselves to the treatment of grammatical functions and argument positions ([2]).
Suppose first that the node is the value of a subcategorizable function and is of NP-type, i.e. the associated translation is a partial DRS with distinguished discourse referent u. Then for m =< n and 1 =< k =< n we have

(SIS2) 

That is, every argument position is filled up by the distinguished discourse referent, and only one of the grammatical functions gets the content of the NP, i.e. determines the position of the introduction of the discourse referent in the hierarchy of the whole DRS. The edges of the other grammatical functions are erased. This allows for the introduction of the content of the NP exactly in those clause nuclei in which it plays a semantic role by force of controlling an unexpressed constituent in them. If the node is the value of a subcategorizable function the value of which is a clause nucleus, then the corresponding node in the dag has been associated with a set of closed DRSs KK. In order to disambiguate this node we take one K out of KK, associate it with the ARGi attribute, and prune the grammatical function F.

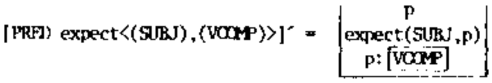
(SIS3) 

*) In contrast to the set of at least two s-structures which Halvorsen's algorithm ([3]) would produce, we have still just one representation of the sentence. The reason is that in [3] the attributes (corresponding to the arguments of the verb) are linearly ordered in the s-structures, and therefore, a quantifying-in device is used.

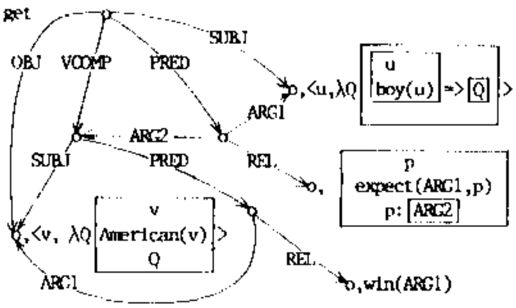
Of course the translation of the PRED has to introduce a discourse referent p specified by K. For the interpretation of (5) we translate the

(5) Every boy expects an American to win

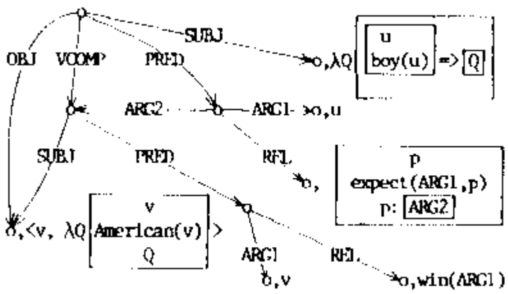
entry for expect by



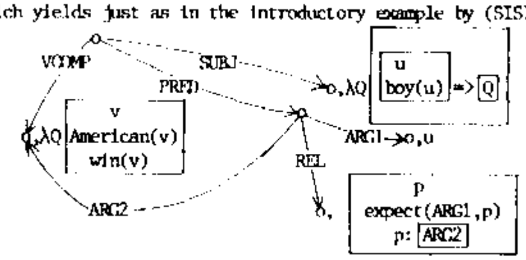
and get



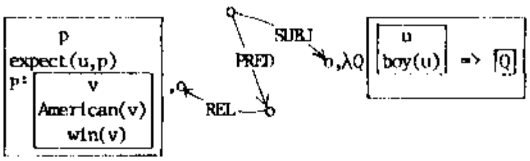
After two applications of (SIS2), where we choose Fk to be t SUBJ (in both cases), we have



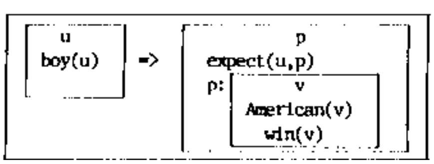
which yields just as in the introductory example by (SIS1)



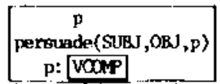
This is further reduced by (SIS3)



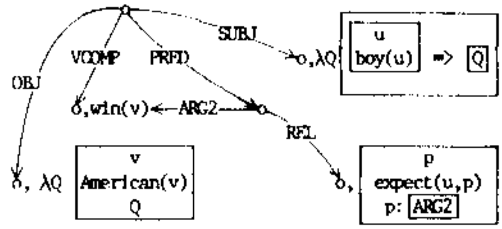
so that we finally get



Before we calculate the other two readings for (5) we want to note that in the case of Equi verbs the requirement that only closed DRSs are accepted as a translation excludes the derivation just outlined. Remember that the lexical entry for e.g. persuade also subcategorizes for the OBJ and hence yields the translation

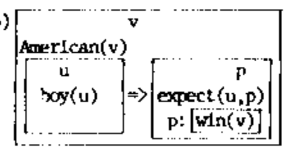


in which the object position would not have been bound by the discourse referent v introduced by an American. Only the following two calculations will be applicable to both types of verbs. If we had taken the OBJ in the application of (SIS2) above we would have got

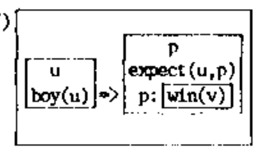


and then (6), if the value of the PRED is converted with the value of the SUBJ first; or, if one converts the value of the PRED first into the value of the OBJ one gets the third and last reading (7) of this sentence.

(6)



(7)



IV CONCLUSION

It has been shown how grammatical functions and discourse referents can be used in the translation process from linguistic form to discourse representations. The algorithm described accounts for the dynamics of the construction of interpretations of sentences, determined not only by syntactic configurations, but also by contextual means, semantics, or pragmatics.

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