Coordination and multi-relational modelling: 'X and X' revisited

F. Grootjen, V. Kamphuis and J. Sarbo

Computing Science Institute & Dept. of Language and Speech
University of Nijmegen, P.O. Box 9010, 6500 GL Nijmegen, The Netherlands

Abstract

A relational model of language is developed which unifies traditional features of X-bar theory with lexicon based modelling. It is argued that such a model provides the appropriate basis for handling problematic cases of non-constituent coordination and gapping. A prototype implementation is discussed on the basis of six representative examples, corpus-based.

1. Introduction

The standard approach to coordination describes coordinate structures in terms of identical conjuncts: X $\rightarrow$ X and X (henceforth: the 'X and X'-approach). In the context of this approach, there is some discussion as to the nature of the conjuncts X. The original view takes X to be a syntactic category; however, there are many examples illustrating that this view cannot be upheld. More successful alternatives describe conjuncts in terms of syntactic functions (e.g. Dik, 1968), syntactic features (e.g. GPSG, Sag *et al.*, 1985), categorial type (Categorial Grammar, e.g. Steedman, 1990) or a combination of these, but not all problems are solved. This is particularly true when conjuncts contain *fragments* of one or more constituents, as in some forms of conjunction reduction and gapping, or when standard hierarchical structure is disrupted. As yet, such cases seem to fall outside the scope of the 'X and X'-approach, as there seems to be no level of abstraction at which the conjuncts can be described (Kamphuis, 1998). Systematic analysis of the surface structure of such conjuncts showed the relevance of the syntactic relations that their component parts are involved in. Once this level of abstraction is taken into account, the full range of coordinate structures follows from a single rule, and the 'X and X'-approach can be maintained.

For the sake of clarity we add that our approach aims at an analysis in terms of surface structure. In this article we restrict ourselves to instances of binary coordination with the coordinator *and*.

2. The nature of the problem

We discuss the relevant features of the problem on the basis of the following cases, derived from a corpus of contemporary British fiction and non-fiction text.

1. ...the change from *belief in, and fear of*, an awe-inspiring and vindictive God to a conviction (...) that there is no God provides a feeling of relief.
2. Thus a worker may be *lazy and slow in a firm where he feels victimized, and a keen and enthusiastic labourer in one that he likes*.
3. *The primary, and in some respects the secondary* groups are exactly the opposite in their characteristics.
4. ... *mesodermal cells characteristically migrate to the centre of the mass and ectodermal ones to the outside.*

The coordinate structures in these sentences contain increasingly complex instances of incompleteness and disruption of regular hierarchical structure. In (1), the conjuncts 'belief in' and 'fear of' consist of the Noun Phrase head, together with the first element of the PP-postmodifier, the preposition. These are not located under a single node in any representation of standard syntactic structure. Some models describe coordinate structures of this kind by referring to elements that are lacking with respect to an immediately higher level of hierarchical structure (e.g. by means of GPSG and HPSG's feature SLASH which refers to missing constituents). However, this solution does not always apply. In (2), the conjuncts seem to contain an additional, adverbial-like element with respect to some level of hierarchical structure, rather than one that is lacking. The two categories within the conjuncts are each complete, but not directly related to each other. Rather, they are related in *different* ways to the context of the coordinate structure as a whole (the first part of each conjunct as subject complement; the second part as adverbial). Choosing a level of abstraction to define these conjuncts is not so straightforward, even though some parallelism in structure remains. This parallelism is no longer present in (3), in which the insert occurs in the second conjunct only. Repetition of the determiner forces interpretation of the insert at sentence level, rather than as modifier to the adjective 'secondary'; nevertheless the coordinate structure is noun phrase internal. The example shows lack of parallelism as well as a clear mix of hierarchical levels. (4) contains a case of *gapping*, which always shows such lack of parallelism. As the example shows, gapping cannot merely be defined as the avoidance of repetition of elements (the preposition 'to' is repeated).

The examples illustrate that the conjuncts of a coordinate structure may contain multiple nodes (1-4); that these nodes need not be describable in terms of a single level of hierarchical structure (2-4); that the conjuncts need not be parallel in structure (3,4), and finally, that the nodes in a conjunct need not be structurally contiguous (4).

In looking for the common factor that determines the surface structure of conjuncts, it can be observed that placement of individual conjuncts in the sentential context resolves all structural irregularities.[1] For example, the combination of the conjunct 'fear of' and the following context 'an awe-inspiring and vindictive God' yields an ordinary NP-structure. This applies to all cases, including the one of gapping when the first conjunct is analysed as containing part of the (left) context. Whereas regular constituents in hierarchical structure are characterised by *constituent internal* relations, the surface structure of conjuncts seems to be determined by *external* ones. Put differently, the conjuncts of a coordinate structure do not necessarily correspond to regular units of description themselves, but create such units together with (part of) their context.

What is needed, then, is a way to describe the units contained in the conjuncts by referring to their potential relation with their context, rather than by saying what kind of unit the conjuncts are themselves. This requires a shift in perspective. Traditionally, linguistic modelling takes the

[1] Cf. the "substitutional generalization" mentioned by Sag et al. 1985:160; see also (Kamphuis, 1998).

definition of different, self-contained units of description as its starting point. Larger clusters are defined by relating such units recursively, and are again self-contained. A different picture emerges when units are not considered *in themselves*, but only in relation to other units. This means that the description of the different units of analysis refers to their *potential participation* in such relations, always. Larger clusters need no longer be internally related per se, as each element still has individual status with respect to its relational potential. In this view, language units are looked at as *inherently* interacting symbols, and language structure is found as the web of their relations. We argue that a modelling method of the latter type provides the appropriate basis for handling coordination.

3. Relational modelling

In relational modelling *every* unit is associated with information concerning the potential relation(s) it can participate in. Therefore, it is possible to describe the units contained in conjuncts in relation to the context that precedes and follows the coordinate structure in the input.

There are different possibilities for referring to the relations that hold between the syntactic units of description. One option is to take the concept of syntactic function in the sense of e.g. (Quirk *et al.*, 1985) and apply this to the relation as a whole, rather than associate it with one of the participants in the relation. E.g. in the sentence *Mesodermal cells characteristically migrate to the centre of the mass* (cf. example 4) there is a subject relation between 'cells' and 'migrate'; a modifier relation between 'mesodermal' and 'cells'; a determiner relation between 'the' and 'centre', etc. This approach is suggested by Link Grammar (Sleator & Temperley, 1993).

With respect to the description of coordinate structures, there seems to be some support in the data for use of a more abstract type of relation. As the following examples show, the relation between conjuncts and context need not be the same on the functional level.

5. But Vivie has been to Newnham and owns a trained mind, capable of *standing back from and analysing* sentiment.
6. He was *laughing and very happy*.

In (5), the noun 'sentiment' functions as complement to the preposition 'from' in the first conjunct, and as direct object to the verb 'analysing' in the second. In (6), the first conjunct stands in a verbal relation with respect to the auxiliary 'was', whereas the second conjunct stands in a subject complement relation to the same verb, functioning as copula (neutralisation).[2]

This problem can be solved by taking into account the different syntactic properties of functional relations, for example, with reference to optional or obligatory realisation of functions. For this purpose, we may refer to the relations traditionally reflected by the different levels of the X-bar scheme. In view of the fact that we are dealing with an analysis in terms of surface structure, we translate the *configurational* definition of the three relations into a definition of the *syntactic properties* associated with each unit, according to the following criteria:

- Can a unit occur in different syntactic environments ('syntactic independence'), or is it bound to a specific use? For instance, a PP can function as a modifier to a verb, or a noun,

[2]GPSG and HPSG handle this type of coordinate structure by means of the feature [+PRD], that generalises over nominal and verbal complements in the context of the verb 'be'. However, instances of neutralisation are not restricted to the context of the verb 'be'.

or an adjective, or as an argument to a verb. An article, on the other hand, always occurs in the context of a noun (or nominal element).
- Is the syntactic nature of the combination of units determined by one or both participants in the relation?

According to these criteria, the different hierarchical levels of the X-bar scheme can be characterised as follows:[3]

- *Subcategorisation:* the relation between a head and its obligatory arguments. Both participants in the relation are syntactically independent. Their combination yields a unit that syntactically differs from each of them (cf. X + subcategorised arguments yields $\overline{\mathrm{X}}$).
- *Modification:* the relation between a head and its optional adjuncts. Both participants in the relation are syntactically independent. Their combination yields a unit with syntactic properties similar to those of the head (cf. $\overline{\mathrm{X}}$ + adjuncts yields $\overline{\mathrm{X}}$).
- *Specification:* the relation between a specifier and its head. The specifier has no independent syntactic status with respect to the head, i.e. it only occurs in the context of a head of a specific type. Their combination yields a unit that syntactically differs from each of them (cf. $\overline{\mathrm{X}}$ + specifier yields $\overline{\overline{\mathrm{X}}}$).

Each pair can typically be analysed as functor and argument, the functor being the head in the case of subcategorisation, and the non-head (modifier and specifier) in the two other relations.

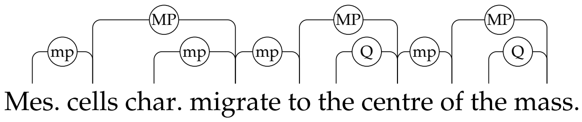
In this way, generalisation across different functions yields a more abstract classification of relations. Under this analysis, the relations in (5) between preposition and noun and between transitive verb and noun are identical (subcategorisation). The same applies to (6). We argue that a relational approach that refers to the syntactic properties associated with the relations of the X-bar scheme creates the appropriate level of abstraction for describing coordination. In order to avoid confusion with traditional X-bar modelling, we refer to the relations as Major Predication (for Subcategorisation), minor predication (for Modification) and Qualification (for Specification) respectively. With respect to the treatment of subjects, we note that the syntactic definition given above is in line with other surface structure approaches that treat subjects as subcategorised by the verb.[4]

4. A first sketch of the algorithm

In a syntactically well-formed sentence, all units are related to each other by means of one of the relations Major Predication (MP), minor predication (mp) or Qualification (Q). The aim of the parsing algorithm is to find these relations in the input string. To minimise the linguistic knowledge of the algorithm itself, it refers to a dictionary that specifies different units according to their relation potential (i.e. their combinatorial properties). For example, an intransitive verb may take part in an MP-relation as functor, and in an mp-relation as argument. Specific conditions with respect to the partner in the relation are specified when applicable (e.g. the direction in which it is to be found). The relation potential of derived units is determined jointly by that of their composite parts and the nature of the relation connecting them. Finally, we note that technically, relations will be represented as binary relations.

[3] The fourth possibility allowed by the combination of these criteria seems uninstantiated in the X-bar scheme.
[4] Traditional X-bar theory treats subjects as specifiers on the level of sentence (Harlow, 1996).

To illustrate, let us again discuss example 4 up to the coordinator. Working from left to right, the algorithm will find an mp-relation between 'mesodermal' and 'cells' and between 'characteristically' and 'migrate'; an MP-relation between '(mesodermal) cells' and '(characteristically) migrate'; a Q-relation between 'the' and 'centre', followed by their Major Predication with 'to', followed by an mp-relation between 'to (the centre)' and 'migrates';[5] a Q-relation between 'the' and 'mass', followed by their Major Predication with 'of', followed by an mp-relation between 'of (the mass)' and 'centre'. The result of the analysis is displayed below.



Note that units can be involved in multiple relations. We allow one of the participants in a relation (e.g. 'cells') to be the *representative* for the derived unit the relation creates ('mesodermal cells'). The default representative of a relation corresponds to the head as defined earlier. Once a relation is established, only the representative may participate in another relation. In the listing above, non-representative units within a relation are between parentheses.

5. Algorithmic aspects of coordination

We will illustrate coordination principles using the abstracted phrase structure of example 2. Trying to describe this coordination using the standard 'X and X'-approach fails, since the conjuncts do not form a single node (their composite parts stand in relation to the verb rather than to each other). The essential point in our view is that not units are coordinated, but relations.

Since both the AJP and NP are in the same way related to V (both form an MP-relation with the verb) their relations can be coordinated. The same applies to the two PPs (and their minor predications). Notice the role of the verb in this example: it is the shared unit of the coordinated relations. This unit (henceforth called *base unit*) plays an important part in the coordination algorithm.

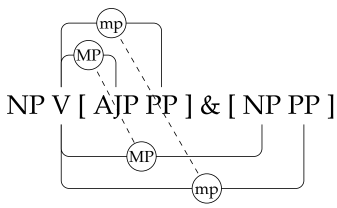


Figure 1: The coordination of relations

Resuming, the relational approach is different in the following respects:

- There is no need for naming and identifying unrelated parts of conjuncts.
- It allows coordination of multiple units since the description of coordination rests on the presence of a base unit, and base units may be involved in multiple relations.
- It requires that coordinated relations are of the same type (the 'X and X' scheme refers to the level of relations, not of units).

The coordination algorithm is built around the parsing algorithm for non-coordinated sentences. To illustrate the algorithm's behaviour we take example 4 again. Upon reading the coordinator 'and' the algorithm first localises the base unit. Assume that this precedes the coordinator (as in this example).[6] The base unit can be found by going back in the input and testing each unit. Since the base unit participates in all coordinated relations, the algorithm can test a unit as follows:

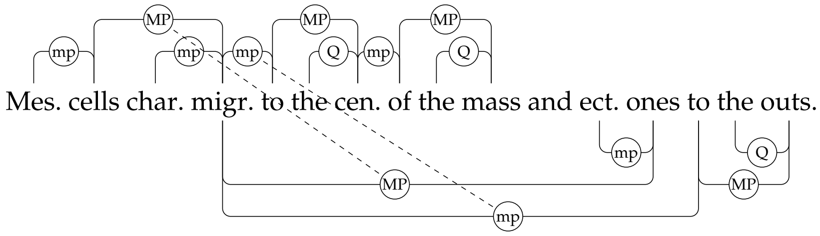
[5]The double role of prepositions is marked in the dictionary by the requirement that they participate in two relations: an MP (with their complement), and an mp (with the item the resulting PP modifies).

[6]If the base unit follows the coordinator, the algorithm will start to locate it upon reading the entire input.

- conceptually disconnect all units related to the unit being tested;
- resume the parsing process, while ignoring the coordinator;
- upon reaching end-of-sentence, check if the relations established with this unit are of the same type as the disconnected ones. If so, the test succeeds, otherwise it fails.

In our example the algorithm eventually tests 'migrate'[7] and conceptually disconnects the MP-relation with '(mesodermal) cells' and the mp-relation with 'to (the centre of the mass)'. The algorithm then finds an mp-relation between 'ectodermal' and 'ones'; an MP-relation between '(ectodermal) ones' and 'migrate'; a Q-relation between 'the' and 'outside'; and an MP-relation between 'to' and '(the) outside' followed by an mp-relation between 'migrate' and 'to (the outside)'. The comparison of the newly created relations of 'migrate' with the conceptually disconnected ones shows their isomorphism.

The algorithm now constructs a mathematical embedding of the relations preceding and following the coordinator. On the basis of this embedding the relational structure (shown on the right) may be enhanced by inheritance, e.g. the mp-relation with 'of the mass' may be inherited from '(the) centre' to '(the) outside'.



6. Summary

It is argued that a relational model of language unifying traditional features of X-bar theory with lexicon based modelling provides the appropriate basis for handling coordination. An algorithm is outlined, and a prototype illustrated using problematic, corpus-based examples. Future research focuses on the application of the relational approach to other problematic areas of linguistic description, e.g. discontinuity.

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[7] Syntactically, there are other base unit candidates. We only discuss the contextually appropriate one.