Constituent Coordination in HPSG

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Computational Linguistics at the University of the Saarland
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Abstract
In this paper we propose a treatment of constituent coordination within the framework of Head-driven Phrase Structure Grammar (HPSG). In contrast to former approaches which assume that a coordinated construction is either a headless or a multi-headed structure, we take the position that the conjunction is a functional category which functions as the head of the coordinate phrase. Under this assumption, the internal structure of ordinary and complex coordinate Constituents can be described with the existing inventory of principles and rules in HPSG. Coordination of unsaturated conjuncts is controlled by the lexical entry for the conjunction and without any additional rules or modifications.

1 Introduction
A largely unresolved problem in language processing is the integration of coordination phenomena into a theory for the description and formalization of natural language. Approaches in different formalisms either confine themselves to a specific and delimited field within coordination, or they stipulate a considerable modification of the underlying syntactic theory.

1 I would like to thank Gregor Erbach, Reinhard Karger, Karel Oliva, Hans Uszkoreit and Birgit Wesche for critical remarks. I am especially grateful to Sergio Balari Ravera and Klaus Netter for discussions and helpful comments.
2 E.g., [Sag et al 85], [Proudian / Goddeau 87].
3 E.g., [Cooper 90].
In this paper we propose an analysis for the treatment of constituent coordination which comprises not only coordination of maximal but also of non-maximal constituents, i.e., constituent coordination with unsaturated argument slots. Our analysis will be embedded in the linguistic and formal framework of Head-driven Phrase Structure Grammar (HPSG) as presented in [Pollard/ Sag 87] and [Pollard / Sag 91]. Due to a high degree of declarativity and a rich inventory of descriptive means based on unification, HPSG ranks among the standard grammar formalisms used in machine language processing. In various experimental systems large grammatical areas have been worked out and implemented in the last few years.

First of all, we have to discuss the internal structure of the coordinate constituent. In the next section we will argue that the conjunction as a functional category functions as the head of a coordinate phrase. Through this assumption specific properties of coordination can be captured and formalized without additional rules and without modifying essential principles.

We will show how relevant syntactic features (head features) of the constituent as a whole are computed and inherited via the Head Feature Principle (HFP). For instance, it has to be guaranteed that for (la-c) the values for person and number are instantiated correctly:

1a  both you and I have made fools of ourselves
1b  * both you and I have made fools of yourselves
1c  * both you and I have made fools of myself

As mentioned above, not only maximal but also unsaturated constituents can be coordinated. It has to be ensured that for the coordination of non-maximal constituents, e.g., verbal heads, the subcategorization information of all conjuncts is compatible. Furthermore, this information has to be available at the resulting constituent to exclude ungrammatical constructions like (2c) and (2d).

2a  the professor [read the article] and [wrote a review]
2b  the professor [read] and [edited] the article
2c  *the professor [edited the article] and [read]
2d  * der Professor [lobt] und [dankt] den / dem Studenten
   the professor praises and thanks the[acc] / the[dat] student[acc/dat]

In section 3 we will illustrate the inheritance of unsaturated argument slots of the conjuncts only by means of the respective lexical entry for conjunctions and by making crucial use of the notion of structure sharing that unification based theories like HPSG allow for. The Subcategorization Principle (SP) in HPSG provides for the correct number and composition of conjuncts and conjunction (3) as well as for embedded coordination and enumeration, and combinations of the two (section 4).

3a  *the professor and [edited] the article
3b  *the professor [read] [edited] the article

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4 Some familiarity with the architecture and the essential principles of HPSG has to be presupposed.
5 The Head Feature Principle controls the percolation of head features:
   Head Feature Principle ([Pollard / Sag 91], p.25)
   The HEAD value of any headed phrase is structure-shared with the HEAD value of the head daughter.
6 The Subcategorization Principle is, very generally spoken, responsible for determining the subcategorization requirements of a head:
   Subcategorization Principle ([Pollard / Sag 91], p.25)
   In a headed phrase (...), the SUBCAT value of the head daughter is the concatenation of the phrase's SUBCAT list with the list (in order of increasing oliqueness) of SYNSEM values of the complement daughters.
2 Conjunction as a Functional Head

In the following we will briefly discuss three more or less plausible assumptions about the head of a coordinate constituent analogous to the verbal or nominal head of a VP or NP.

A.) A complex coordinate constituent X consisting of conjuncts Y1 and Y2 is regarded as a headless phrase. This assumption is made by [Cooper 90] in his analysis of coordination in HPSG. Cooper distinguishes between the phrasal types headed-phrase and coordinate-phrase. As a consequence, syntactic principles such as the SP and HFP cannot be applied to instances of the type coordinate-phrase since they are defined by referring to the concept of a head. Therefore his approach takes the position that the syntax of coordination differs from non-coordination syntax to such a degree that non-language-specific principles have to be re-formulated.

B.) Regarding Y1 as well as Y2 as heads is a second possibility chosen for example by [Sag et al 85]. This assumption shows the disadvantages that

• the complex constituent X has more than one head;
• the syntactic status of the conjunction is not clear: the conjunction is neither subcategorized for by any of the heads nor is it a complement but nevertheless obligatory.

C.) Finally, the conjunction itself is considered as the head of the coordinate structure. In favour of this analysis we make the observation that

• the conjunction X subcategorizes for the conjuncts Y1 and Y2 such that the subcategorization properties of X make sure that the structure contains at least two conjuncts;
• it is possible to percolate relevant information to the phrasal projection via the HFP;
• Linear Precedence rules can be defined relative to the head of the constituent, i.e., by referring to the position of the head with respect to its complements.

At first sight one can argue in contrast to this hypothesis that

• being syntactically as well as semantically underspecified, a conjunction is not a "real head";
• relevant head features like information about inflection and category are not encode in the conjunction but in its complements Y1 and Y2.

However, these objections show nothing but that a conjunction is certainly not a lexical head for the simple reason that, in contrast to lexical categories like A, V or N, it carries almost no syntactic or semantic information. If our theory allows for functional heads, as for example the Government & Binding Theory or HPSG do in the case of complementizers, then a

7 In this paper we ignore conjunctions without a preceding conjunct.
8 The term functional head is used slightly differently in GB theory. We cannot go into that in more detail, here.
9 In [Pollard / Sag 87], p. 53, only a MAJOR-feature, i.e., only lexical heads are admitted in the theory: (...) each phrase contains a certain word which is centrally important in the sense that it determines many of the syntactic properties of the phrase as a whole; that word is called the lexical head of the phrase.

In [Pollard / Sag 91], S.15, they introduce the types substantive und functional:

The appropriate values for head are divided into the two sorts substantive (subst) and functional (funct). Subsorts of the sort substantive are noun, verb, adjective, and preposition, whereas determiner, and marker (e.g. complementizers) are the two subsorts of the sort functional (...)
conjunction is a good candidate for that type of category. As a complementizer, a conjunction being an operator does not bear "autonomous" semantic information. To both elements one cannot refer with a pro-form which is possible when referring to a verb or a noun. Both are members of a closed class of words which means that morphological processes do not add new elements to these classes.

A lexical head, like a verb, carries relevant head features of the whole phrase and passes these features up to its mother node via the HFP. In a phrase with a functional head, however, it is the syntactic properties of the complements that have to be inherited. If, for instance, a complementizer like "that" takes as a complement a finite sentence, then this information (FINIT +) has to be made available at the resulting constituent. But how is it possible to handle inheritance of information of complements without cancelling the HFP or replacing it by another principle?

[Netter 92] suggests to split up the HEAD feature into MINOR and MAJOR features such that categories can be defined for both classes of properties. Typical MAJOR features are NUM, CASE, or TENSE, i.e., features of lexical categories. The value of the attribute MINOR indicates the syntactic category of a functional head. The value of the functional head's MAJOR attribute is identical with the MAJOR value of the complement: the head shares its syntactic information with the complement. All HEAD features, be they of type MAJOR or of type MINOR, are inherited via the HFP. Functional categories like conjunctions or complementizers are instances of the type functional-type.

\[
\text{coord-conj-type (preliminary version)}
\]

Different to a complementizer, a conjunction subcategorizes not for one but for two complements. An obvious thing to do would be to unify the MAJOR value of the head with those of both complements. However, this assumption turns out to be too restrictive excluding well-formed coordinate structures with non-identical syntactic features of the conjuncts (cf. la). Given that firstly the syntactic properties of complements of a conjunction can be different (or identical as a special case) and that secondly the MAJOR features of the head can be computed from the MAJOR feature of both complements, then the MAJOR specification of the head is a function of both complements' MAJOR specifications:

\[
\text{coord-conj-type (preliminary version)}
\]

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10 The concept of a functional head is close to a functor in Categorial Grammar and Categorial Unification Grammar. Cf. for instance [Uszkoreit 86]; the conjunction "and" is a functor that takes one argument to the right. The result is a functor that takes an argument to the left. Unsaturated argument slots of the arguments themselves are inherited by the resulting category.

11 We use the following abbreviations: "S": SYNSEM; "L": LOC; "C": CAT; "SC": SUBCAT.
Evidence for a right branching structure, which we assume here, is also given by sentence initial conjunctions that form a constituent with a conjunct on the right hand side ("and the professor has told us ...") but never with a conjunct on the left hand side.

Two LP-rules ensure the correct order of head and complements. A lexical conjunction has to be to the left of its complements whereas a non-lexical node of type conj follows the complement.

(7) LP-rules for coordination:
1. conj [lex+] < C
2. C < conj [lex-]

3 Subcategorization

In coordinations each of the conjuncts have to have the same degree of saturation. In sentences 8a-d lexical heads of the same category having still one element on their Subcategorization list are coordinated. In principle the number of unsaturated argument slots is open (8e) under the condition that the case requirements of the missing arguments are identical (cf. 2d).  

Note that the respective lexical heads in (8a-e) within each example all govern the same case.

8a  daß der Professor den Artikel [las und redigierte]
that the professor the article[acc] [read and edited]
8b  dieser Mann ist seiner Frau [treu und ergeben]
this man is his wife[dat] [faithful and devoted]
8c  er sucht verzweifelt [in, unter und hinter] dem Schrank
he searched desperately [in, under and behind] the cupboard[dat]
8d  die [Besetzung und Eroberung] der Stadt

Interesting enough, lexical heads of different categories behave heterogeneously in German with respect to syntactic identity requirements of unsaturated complements of the conjuncts. Adjectives missing an argument with different case information can be coordinated if both case forms coincide phonologically:

dieser Mann war seiner Frau einerseits überdrüssig und andererseits hörig
this man was his wife[dat / gen] on the one hand weary and on the other hand enslaved
* diese Frau war ihres Mannes einerseits überdrüssig und andererseits hörig
this woman was her husband[gen] on the one hand weary and on the other hand enslaved

(note that "überdrüssig" governs genitive whereas "hörig" governs dative).
Prepositions governing different cases are even more generous. They can be coordinated even if the common argument is not phonologically ambiguous with respect to case marking under the condition that the NP is more adjacent to the preposition that subcategorizes for its case:

du bist jederzeit willkommen, mit und ohne Kinder
you are welcome anytime, with and without children[acc]
*du bist jederzeit willkommen, mit und ohne Kindern
you are welcome anytime, with and without children[dat] (note that "mit" governs dative whereas "ohne" governs accusative).
the [occupation and capture] (of) the city[gen]

falls der Autor der Stiftung die Manuskripte [geschenkt oder vererbt] haben sollte
in case the author the foundation[dat] the manuscripts[acc] [given as a present or bequeathed]

have should
in case the author should have given the manuscripts to the foundation as a present or that he

has bequeathed them to the foundation

In (8a) for instance, "und" takes as complements two verbs. Both have still one argument on their
subcategorization list which is NP[acc] in both cases. Still missing an NP[acc], the coordinate
constituent "las und redigierte" has exactly the same subcategorization requirements as each of its
conjuncts. To sum up, we have to consider the following generalizations:

- a conjunction subcategorizes for two complements;
- the complements may have unsaturated argument slots;
- the type and number of these unsaturated arguments have to be identical;
- the SUBCAT information on the complements has to be available at the resulting
correspondent; to be more precise, the SUBCAT information of the complements is the
SUBCAT specification of the coordinate constituent itself.

The lexical entry for "und" shows how these requirements are met by making use of the
Subcategorization Principle without any additional rules:

(9)

\[
\begin{array}{c}
\text{PHON} < \text{und}> \\
\text{SYNSEM} \text{ LOC} \text{ CAT} \text{ SUBCAT append} ( < \text{LOC} \text{ CAT} \text{ SUBCAT [1,} \\
\text{LOC} \text{ CAT} \text{ SUBCAT [1,} \\
\text{I]})
\end{array}
\]

(10)

\[
\begin{array}{c}
\text{PHON} < \text{las und redigierte}> \\
\text{SILICISC < [1]>}
\end{array}
\]

\[
\begin{array}{c}
\text{PHON} < \text{las}> \\
\text{SILICISC < [1]>}
\end{array}
\]

\[
\begin{array}{c}
\text{PHON} < \text{und redigierte}> \\
\text{SILICISC < [3, 1]>}
\end{array}
\]

\[
\begin{array}{c}
\text{PHON} < \text{und}> \\
\text{SILICISC < [2, 3, 1]>}
\end{array}
\]

\[
\begin{array}{c}
\text{PHON} < \text{redigierte}> \\
\text{SILICISC < [1] NP [acc]>}
\end{array}
\]

In (9), the SUBCAT list of the conjunction is computed through a function which concatenates the
subcategorization for the two conjuncts with the subcategorization of the two conjuncts. The
SUBCAT list of the conjunction contains as members not only the conjuncts but in addition the
SUBCAT value of the conjuncts. Through coindexation of the SUBCAT value of the two

13 The solution of *raising of subcategorized elements* we propose here employs the same technique [Hinrichs /
Nakazawa 92] introduce for handling SUBCAT information of complex verbs in HPSG. In their analysis, the
SUBCAT value of auxiliaries is specified by appending the infinitival verb complement and the SUBCAT value
which the verbal complement itself carries.
conjuncts identity of the degree of saturation is enforced. By appending it to the list of two conjuncts, it is guaranteed that the SUBCAT requirements of the conjuncts are satisfied simultaneously. Thus, it is possible that one single argument like "den Artikel" serves as the complement of two verbs, such that it unifies with two complements at the same time. This is achieved by "melting" together the argument slots of "las" and "redigierte" within the coordinate constituent. (10) illustrates the coordination of two unsaturated lexical heads ("daß der Professor den Artikel las und redigierte" / "that the professor read and edited the article"). Every conjunction is an instance of type coord-conj-type, defined as follows:

(11) Coord-conj-type, final version (cf. 5 and 9)

4 Multiple Coordination

Not only lexical but also functional categories can be coordinated as for example the complementizers "bevor", "während" oder "weil", "obwohl" in (12a,b).14 If the complementizer is regarded as the head of a sentence, then (12c) is also an example for coordinating constituents with functional heads.15

12a der Professor war sehr skeptisch, [bevor] und [während] er den Artikel las

the professor was very sceptical [before] and [while] he read the article

12b er trennte sich von seiner Frau, [obwohl] und [gerade weil] er sie sehr liebte

he separated from his wife [though] and [because] he loved her very much

12c the professor was very sceptical [before he read the article] and [after he had finished it]

Constituents specified as MINOR conj (i.e., with a conjunction being the head) can be coordinated only if they are maximal, as the difference between (13a,b) and (13c) shows:

13a * [und Maria] und [und Peter]

13b * [und] oder [oder]

13c [ [Hans und Maria] und [Peter und Gabi] ] spielten gemischtes Doppel gegeneinander

[Hans and Maria] and [Peter and Gabi] ] played mixed doubles

If only maximal coordinate constituents qualify as potential conjuncts, the problem arises how to define a coordinate constituent as being maximal. The crucial property of maximal phrases is their having an empty SUBCAT list which is not necessarily the case with a coordinate phrase. The phrase "las und redigierte" for instance is maximal in the sense that the conjunction "und" has taken its conjunct complements. On the other hand, there is still one element on the SUBCAT list which is the missing complement of the conjuncts. However, in contrast to the

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14 See [Warner 89] for the problem of "minor categories" in GPSG.

15 In [Pollard / Sag 91] complementizers are not heads but markers which resemble heads inasmuch as they select the phrases that they mark. The MARKING value of the complementizer (e.g. "that") is structure-shared by the mother.
unsaturated constituents "und" or "las und" or "und redigierte", "las und redigierte" can be selected perfectly well as a conjunct within a coordinate phrase:

14  daß der Professor den Artikel [ [zuerst las und redigierte] und [schließlich doch ablehnte] ]
that the professor the article [ [first read and edited] and [finally rejected] ]

The significant property of a phrase like "las und redigierte" is not that its SUBCAT list is empty but rather that the list contains exactly the same information as the list of both complement daughters. All other complements - the conjuncts themselves - are already bound. This constraint can be captured by requiring that, if a phrasal sign has the head feature MINOR conj, it can become a complement within a coordinate structure only if it is an instance of type coord-max-type.

(15) Maximal coordination type (coord-max-type)

So far we have discussed only coordination which is multiple in the sense that a conjunct itself can be defined recursively as a coordinate structure with a conjunction as a head. This holds for a sentence like 13c that is structurally ambiguous. A coordination, on the other hand, which is multiple because it contains enumerated conjuncts is not a hierarchical but rather a flat structure.

At first sight, a list could be an appropriate representation for enumeration. A conjunction does not subcategorize for two conjuncts and its complements but for a list with at least two complements such that exactly one conjunct follows the conjunction whereas all other conjuncts precede it. Under this assumption, the problem arises that the SUBCAT list of the conjunction consists of two lists, each of arbitrary length: first, the list of the conjuncts and second, the list of the conjunct complements. It is not clear how to identify the end of the first and the beginning of the second list.

This problem does not arise if we allow for a right-branching binary structure such that the comma (or intonation markers)\(^\text{16}\) has a similar function as a lexical conjunction. Evidence for this analysis can be derived from the fact that

- a comma or an empty head functions as a placeholder for a conjunction with respect to the semantic information it carries. E.g., "Hans, Peter, Paul und Mary" is understood as "Hans und Peter und Paul und Mary" but not as "Hans oder Peter oder Paul und Mary";
- in contrast to the structure we suggested for multiple coordination with conjuncts, a right-branching binary structure for enumeration is non-ambiguous. Moreover, clearly, "John, Peter, Paul und Mary" does not impose any "grouping" on the conjuncts such as "[Hans und Peter] und [Paul und Mary]".

In order to exclude ungrammatical sentences without a lexical conjunction directly preceding the conjunct, we have to add the condition that the first (or right-hand) complement of the comma (or of the empty head) is a structure that already contains a lexical conjunction. The comma or empty head are instances of the type coord-eps-type.

\(^{16}\) Alternatively we could also assume an empty head.
Thus, only well-formed structures like 17a are allowed where the head feature MINOR conj is introduced at the bottom of the tree. "Peter and Mary" is an appropriate first complement. 17b is excluded by the requirement that the head of type coord-eps-type takes only a complement that is specified for MINOR conj which is not fulfilled by the NP "Mary".

Furthermore, to exclude "Hans, Peter, und Mary" we have to require that the first complement of a comma or empty head is maximal in the sense that it is an instance of type coord-max-type. (In English, of course, "John, Peter, and Mary" is grammatical)

4 Conclusion

In this paper we suggested an analysis for constituent coordination where the conjunction is the functional head of the structure. The crucial advantage is that mechanisms specific to coordination can be described and controlled locally and that universal principles of our theory do not have to be re-formulated in order to administrate the inheritance of the head feature and the saturation of complements. In particular, the approach has the following advantages:

- Head features are inherited via the HFP as usual. Special functions which are responsible for computing coordination specific values are defined in the lexical entry or in the type definition. By keeping these functions local
  - language-specific differences can be captured in the respective type definition;
  - differences specific to single conjuncts are described in the lexical entries (e.g. different functions for the NUM value for "und" and for "oder").
- The SP controls the correct number and composition of conjuncts which is possible only because conjunction and conjuncts are instances of a head-complement-structure.
- In the type definition of conjunctions we specify that
appropriate conjuncts have the same degree of saturation;
- information about unsaturated arguments of the conjuncts is available at the resulting category.

We sketched the theoretical and formal framework for the treatment of constituent coordination without saying anything about Right Node Raising or Gapping. Following a proposal made by Wesche that Right Node Raising is analysed with a SLASH feature, it seems that our approach is applicable to RNR under the condition that the SLASH information of both conjuncts, which is not a head feature, is structure-shared by the conjunction. Thus, the Head Filler Rule in HPSG would have to apply only to the coordinate structure as a whole and not to each of the conjuncts.

5 References


