

## REMARKS ON PLURAL ANAPHORA\*

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### ABSTRACT

The interpretation of plural anaphora often requires the construction of complex reference objects (RefOs) out of RefOs which were formerly introduced not by plural terms but by a number of singular terms only. Often, several complex RefOs can be constructed, but only one of them is the preferred referent for the plural anaphor in question. As a means of explanation for preferred and non-preferred interpretations of plural anaphora, the concept of a Common Association Basis (CAB) for the potential atomic parts of a complex object is introduced in the following. CABs pose conceptual constraints on the formation of complex RefOs in general. We argue that in cases where a suitable CAB for the atomic RefOs introduced in the text exists, the corresponding complex RefO is constructed as early as in the course of processing the antecedent sentence and put into the focus domain of the discourse model. Thus, the search for a referent for a plural anaphor is constrained to a limited domain of RefOs according to the general principles of focus theory in NLP. Further principles of interpretation are suggested which guide the resolution of plural anaphora in cases where more than one suitable complex RefO is in focus.

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### 1. INTRODUCTION

Most approaches to processing anaphora concern themselves mainly with the case of singulars and deal only peripherally with the complications of plurals. An analysis of plural anaphora should answer the following additional questions:

- 1) How are the referents of plural terms represented by discourse entities (internal proxies)?
- 2) How is the link between plural anaphora and suitable antecedent discourse entities established?
- 3) How are complex discourse entities constructed from atomic ones?
- 4) When are complex discourse entities constructed in the process of text comprehension?

The present paper addresses primarily the third and fourth questions. However, we will give some sketchy answers to the first and second questions as well.

We consider only two-sentence texts in which the second sentence contains an anaphoric pronoun that refers to entities introduced in the first sentence by various constructions:

- (1) a. The children were at the cinema.  
They had a great time.
- b. Michael and Maria were at the cinema.  
They had a great time.
- c. Michael was at the cinema with Maria.  
They had a great time.
- d. Michael met Maria at the cinema.  
They had a great time.

The question is: To which entities, i.e. complex discourse entities, does the plural anaphor they refer? Surely in (1.a) to the one corresponding to the children, and in (1.b), (1.c) and (1.d) to Michael and Maria. Up to now, most analyses of plural anaphora

investigate cases of the (1.a)- or (1.b)-type, i.e. those in which the complex object is introduced explicitly, either by a simple plural NP or by a conjunction of singular or plural NPs (which in both cases yields a plural NP as well).

## 2. A SKETCH ON PLURALITY

We assume – as is common in most recent approaches to anaphora in AI and linguistic semantics (e.g. Webber 1979, Kamp 1984) – a representation level of discourse referents, which are internal proxies of objects of the real (or a possible or fictional) world. These discourse entities, called reference objects (RefOs), are stored and processed in a net-like structure, called a referential net (RefN), which links RefOs and designations. (For a detailed description see Habel 1982, 1986a, 1986b and Eschenbach 1988.) The term "RefO" is, when strictly used, a technical notion which is employed in the framework of our formalism only. For reasons of simplicity of exposition, we do not want to restrict the use of "RefO" to this formalism in the present paper, but rather apply the term to referents also, i.e. the objects to which names, descriptions and pronouns refer.

RefOs for complex objects are constructed by means of a sum operation (Link 1983), so that with respect to (1.b), we have the following entries (among others) in the RefN.

$r_1$	-	Michael
$r_2$	-	Maria
$r_3$	=	$r_1 \oplus r_2$

The sum operation (symbolized by  $\oplus$ ) is the semantic counterpart of the NP-connective and. It defines a semi-lattice (Link 1983, Eschenbach 1988). By means of this structure, both complex and atomic RefOs can be seen as objects of the same logical type and are accessible by the same set of referential processes. No operations on RefOs other than the sum operation will be considered in the present context.

## 3. CONSTRAINTS ON SUM FORMATION

Sentences like (1.a) and (1.b) demonstrate that complex discourse referents can be created by plural NPs. But there are other

linguistic indicators for the creation of complex RefOs.<sup>1</sup> The anaphoric pronoun they of (1.c) and (1.d) as well as (1.b) refers to a corresponding complex RefO. It is obvious that besides conjunctions (e.g. and), some prepositions and verbs trigger processes of sum formation (with-PPs and meet are outstanding examples of these types of constructions.) In (1.c), Michael ... with Maria triggers the formation of Michael  $\oplus$  Maria. But consider the following texts:

- (2) a. Michael and Maria were at the park with Peter.  
In the evening they were at a garden party.
- b. Michael and Maria were at the park with their frisbee.  
In the evening they were at a garden party.

In (2.a) it is possible that they refers to Michael  $\oplus$  Maria  $\oplus$  Peter. But in (2.b) they is preferably linked to Michael  $\oplus$  Maria; even if Michael and Maria happened to take their frisbee to the garden party, we would not want to claim that the plural anaphor they in (2.b) refers to a complex discourse entity consisting of Michael, Maria *and* the frisbee. In the preferred reading of (2.b), the frisbee is excluded from the antecedent of the anaphor.

We have to explain why with-PPs only cause sum formation in certain cases. The proposed solution to this problem is the concept of a Common Association Basis (CAB), which is introduced in Herweg (1988). The CAB is an extension of the Common Integrator (CI), which Lang (1984) developed in his general theory of coordinate conjunction structures.

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<sup>1</sup> The assumption of indicators and constraints contrasts to the less restrictive assumption of Frey & Kamp's (1986) DRT-oriented analysis of plural anaphora, in which they claim that "any collection of available reference markers, whether singular or plural, can be 'joined together' to yield the antecedent with which the pronoun can be connected" (p. 18).

Grouping by with depends on the condition that "x with y" leads to "x  $\oplus$  y" only in those cases in which a CAB-relation is fulfilled. The most relevant constraint given by CAB is the condition that x and y are instances of the same ontological type at the most fine-grained level. This means two humans are good candidates to form a complex RefO, whereas a frisbee, which does not fall under the ontological type of humans or animate objects, and the human players are not.

CAB constraints apply not only to cases like (1.c) and (2.b), but to sum formation in general. Consider this example:

- (3) Michael and his frisbee were at the park.

Here the conjunction explicitly forces the sum formation of objects of different ontological types. This is at least unusual and has a strange effect. However, explicit conjunction by and presupposes the existence of a suitable CAB for the conjoined entities. The addressee must assume that the conjunction in (3) involves an instruction to derive such a CAB (or simply concede that one exists). Thus, to make conjunctions like the one in (3) acceptable and natural, one normally has to assume a CAB which is not explicitly specified or immediately derivable from the information conveyed in the sentence itself but which is given by the preceding or extralinguistic context. In (3), the required CAB might simply be something like 'the entities desperately being looked for by Michael's children'. In isolation however, forced sum formations like the one in (3) must be considered marginally acceptable.

We now have the following situation: Grouping depends on properties of the RefOs in question, namely whether a CAB exists which constitutes a conceptual relation among the RefOs with respect to situational parameters given, for example, by predicative concepts. Furthermore, it is obvious that world knowledge and the theme of the discourse give evidence for which (complex) RefO is most appropriate as the antecedent of an anaphoric pronoun. We will propose that these factors can be handled by CABs as well.

This leads us to Herweg's (1988) Principle of Connectedness:

All sub-RefOs of a complex RefO must be related by a CAB.

Now consider example (1.d). It shows that some lexical concepts possess what we call grouping force, i.e. they trigger sum formation with respect to atomic RefOs. The grouping force of a lexical concept can be seen as a special case of a CAB. Without going into details of the representation formalism we can formulate the relevant sum formation processes by this rule:

If "x meets y", then construct the complex RefO  $x \oplus y$ .

The status of this sum formation rule is similar to that of classical inference rules, which are used for bridging processes in the sense of Clark (1975). Not all verbs possess a grouping force as strong as meet; e.g. the grouping force of watch is considerably lower. Consider:

- (4) a. Michael met Peter and Maria in the pub. They had a great time.  
 b. Michael watched Peter and Maria in the pub. They had a great time.

In (4.b), the sum of Maria and Peter is significantly preferred to the sum including Michael as the antecedent of they. In (4.a), there presumably is a preference to the opposite, i.e. to link they to the sum consisting of all three persons. In contrast to highly associative verbal concepts like meet, watch must be classified as a dissociative element which does not constitute a CAB for its arguments but induces a conceptual separation. Part of the explanation for this property of watch is to be seen in the (normally understood) local separation of subject and object in the situation described. Again in contrast to meet, this local separation usually prevents an interaction or some other kind of contact which allows one to assume a suitable link (i.e. a CAB) for the persons introduced based on properties of the situation which the sentence describes.

#### 4. ANAPHORA RESOLUTION AS A SEARCH PROCESS?

Many classical approaches to anaphora resolution are based on search processes.

Given an anaphor, a set of explicitly introduced referents is searched for the best choice.<sup>2</sup> The crucial point is: "How to determine the set of possible antecedents?"

The most simple solution is the history list "of all referents mentioned in the last several sentences" (Allen 1987, p. 343). Note that most DRT-based anaphora resolution processes (Kamp 1984, Frey & Kamp 1986) by and large follow this line, with a few modifications concerning structural conditions in terms of an accessibility relation.

But there is also a different perspective whose key notion is the well-established concept of focus (see e.g. in Computational Linguistics Grosz & Sidner 1986)<sup>3</sup>. As is shown by psychological experiments (a detailed overview is given by Guindon 1985), a very limited number of discourse referents are focussed. Referents in the focus, which can be described in psychological terms as short term memory (see Guindon), are quickly accessed; especially pronouns are normally used to refer to items in the focus and therefore extensive search is mostly unnecessary. The most relevant question with respect to focus is "Which items are currently in the focus?"<sup>4</sup>. Answers

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<sup>2</sup> Note that the unspecificity of pronouns seldom allows the triggering of bridging inferences (see Clark 1975) to select referents which are only implicitly introduced.

<sup>3</sup> Cf. Bosch (1987) and Allen (1987; chap. 14). Both give convincing arguments against the simplistic view of identifying anaphora resolution with searching. Since we address matters of pronominal anaphora only, we here assume a rather simple concept of focus. Further differentiations (e.g. Garrod & Sanford's (1982) division of focus into an explicit and implicit component) which might become necessary if non-pronominal anaphora are investigated as well are out of the scope of the present paper.

<sup>4</sup> A question closely related to this, namely at which point of time and in what

to this question determine which referents can be antecedents of pronouns.

## 5. PLURALS IN FOCUS

Following the line of argumentation in section 4, the possibility of a reference to a complex RefO with a plural pronoun as in (1) means that such a complex RefO is in the focus after processing the first sentence. Thus it is worth taking a closer look at the question as to when a complex RefO is formed. There are essentially two opportunities to construct a complex RefO from atomic RefOs: it can be constructed and put into the focus when the atomic RefOs are mentioned, or the construction might be suspended until an anaphor triggers the sum formation.<sup>5</sup> The second solution has some undesirable consequences; the worst is that the methods of resolving plural anaphora and singular anaphora must be completely different. Since the complex RefOs would not be in the focus, a direct access to the focussed entities could not solve the problem. In such cases, the construction process would be triggered during anaphora resolution. Thus the processing of they with respect to Michael (...) with Maria in (1.c) and Michael met Maria in (1.d) should be more complicated than the cases of the children or Michael and Maria, an assumption for which no evidence exists as yet.

Therefore, we take the former choice of constructing the complex RefO while processing the atomic RefOs. Again, this suggests two possibilities, namely to construct the complex RefO and put only this into the focus, or to introduce both the complex and the atomic RefOs into the focus. As a working hypothesis, we propose the latter procedure, since the sentences like (5),

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way the focus is updated, is not relevant as long as we confine ourselves to texts containing only two sentences. However, it becomes important when the analysis is expanded to multiple sentence texts.

<sup>5</sup> This distinction corresponds to Charniak's (1976; p. 11) well-known dichotomy of read-time and question-time inferences.

which contain singular anaphora (cf. (1)), are fully coherent:

- (5) a. Michael and Maria were at the cinema.  
He/She had a great time.
- b. Maria was at the cinema with Michael.  
He/She had a great time.
- c. Michael met Maria at the cinema.  
He/She had a great time.

That these findings do not depend on linguistic introspection only is established by processing-time experiments, which are reported in Müsseler & Rickheit (1989).<sup>6</sup> The initial results of the experiments suggest that the complexities of processing singular or plural anaphora (of sentences like (1) vs. (5) are not significantly different<sup>7</sup>. The anaphoric accessibility of the complex RefOs which are introduced by the sentences listed above is by no means worse than the accessibility of the atomic RefOs.

Let us summarize the discussion so far:

There are linguistic concepts – such as conjunctions, prepositions and lexical concepts – which trigger the construction of complex RefOs. The atomic RefOs as well as the complex RefO (which is formed by

the sum operation) are introduced into the focus. Thus, resolution of anaphora can be performed by processes on the focus not involving extensive search.

## 6. FURTHER PRINCIPLES OF ANAPHORA RESOLUTION

Further interesting problems can be observed in the interaction of concepts which possess grouping capacity. Consider:

- (6) a. Michael and Maria picked up Peter and Anne from the station.  
They were happy to see each other again.
- b. Michael and Maria picked up Peter and Anne from the station.  
They were late.

Here the following atomic and complex RefOs exist:

$$\begin{aligned} r_1 & - \text{Michael} \\ r_2 & - \text{Maria} \\ r_3 & - \text{Peter} \\ r_4 & - \text{Anne} \\ r_5 & = r_1 \oplus r_2 \\ r_6 & = r_3 \oplus r_4 \\ r_7 & = r_5 \oplus r_6 = r_1 \oplus r_2 \oplus r_3 \oplus r_4 \end{aligned}$$

In the preferred interpretation, they in (6.a) refers to  $r_7$ , in (6.b) either to  $r_5$  or  $r_6$ . It follows from this analysis that more than one complex RefO can be in focus. Which one is the most appropriate to link to the pronoun depends on two principles (see Herweg 1988):

Principle of Permanence:

It is prohibited (unless the text explicitly requires it) to link the plural pronoun to a proper sub-RefO of a complex RefO in focus. Reference to a sub-RefO is only possible if it was introduced explicitly into the discourse model by a previous inference.

Principle of Maximality:

The plural anaphoric pronoun should be linked to the maximal sum of appropriate RefOs with respect to a suitable CAB, unless the text contains explicit evidence to the contrary.

The interaction of the principles of Connectedness, Permanence and Maximality can lead to correct and natural anaphora resolution in (6). For (6.a), maximality and per-

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<sup>6</sup> Müsseler's and Rickheit's research at the University of Bielefeld is also carried out in a project in the DFG-Program "Kognitive Linguistik". This project collaborates with ours on reference phenomena from computational and psycholinguistic points of view.

<sup>7</sup> This holds at least for cases where the antecedent of the singular anaphor is in subject/topic position. Questions concerning the accessibility of singular antecedents in non-subject/non-topic positions are not definitely settled as yet (see Müsseler & Rickheit 1989). Since Müsseler's and Rickheit's experiments are confined to German, which has a single form sie for 3rd pl. pronoun (they) and 3rd sg. fem. pronoun (she), not all of their results on the processing-time of singular anaphora with antecedents in different structural positions can be applied to English.

manence require a maximal sum, which is  $r_7$ ; in (6.b), knowledge about the situations of picking someone up and being late excludes  $r_7$  (i.e. no CAB can be established which is simultaneously satisfied by all atomic parts of  $r_7$ ; therefore, the condition of connectedness is not fulfilled) and thus gives evidence for a sub-RefO, namely either  $r_5$  or  $r_6$ . The principle of Permanence excludes other combinations of atomic RefOs, such as  $r_1 \oplus r_3$ ,  $r_2 \oplus r_3$ , etc. Whether  $r_5$  or  $r_6$  is chosen at last can not be decided on the basis of the above mentioned principles alone. These examples show that a conflict resolution strategy is needed, as is not unusual for such principles.

## 7. IMPLEMENTATION

The RefN-processes and sum formation are currently being implemented in Quintus-PROLOG on a MicroVax workstation. The present implementation allows one to represent and create RefOs and (1) their descriptions by way of designators (internal proxies for names and definite NPs), (2) their descriptions by way of attributes, which specify properties (sorts) of the represented objects themselves (not their designations) and relations between them. E.g. sums are represented by the use of attributes to RefOs.

The set of RefOs with their descriptions can be structured, so that different RefNs, whether or not they are independent from each other or related by shared RefOs, may be represented in parallel.

The representation of a sample text within the formalism is being worked. The transfer of segments of the text into simple nets is not being done automatically but by hand.

For each anaphor, a corresponding RefO is created but specially marked as an anaphoric RefO. This is intended to trigger the automatic resolution of anaphora.

In the near future, it is planned to

- determine the potential antecedent-referents for an anaphor out of the set of all RefOs which are available;
- define the requirements concerning the representation of focus; it is planned to test different formats of representation;

- structure the nets in order to represent CABs.

The function of the last two steps mentioned is to put further restrictions on the set of potential antecedent-referents for a given anaphor.

## 8. SUMMARY

Compared to the case of singular pronouns, the resolution of anaphoric plural pronouns requires an additional step of processing: the sum formation. It is guided by various grammatical and lexical evidence, which is accumulated to form a common association basis (CAB). The principle of connectedness controls the sum formation, by which the restriction to a very limited number of complex RefOs is possible. The role of focus with respect to plural anaphora is similar to the singular case, but poses the question as to when the sum formation is carried out in the process of text comprehension. The resolution processes of the singular and plural cases can be made identical by assuming that, in cases where a suitable CAB is available, the sum formation takes place early, i.e. while processing the antecedent sentence(s). The principles of Permanence and Maximality are two principles which are valid especially for plural anaphora.

The use of CABs and the mentioned principles of sum formation is a way to avoid the inadequacies of prior approaches to plural anaphora, which mostly seem to follow the motto "Anything goes".

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