Chains and the Common Ground

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Abstract

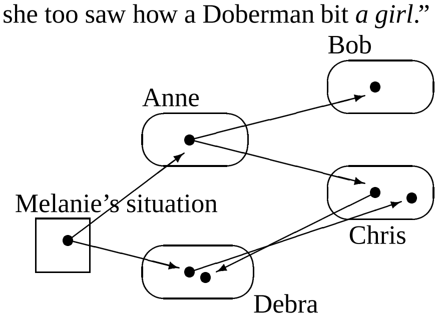
In this paper we provide a description of how the iterated specific use of an indefinite NP can lead to the establishment of referential chains across dialogues and dialogue participants. We describe how they introduce discourse referents, how they are related to the common ground, and how this common ground can be represented by the dialogue participants. Of central concern is the methodological part. We combine methods known from dynamic semantics/DRT on the one side, and theories for multi–agent systems on the other. The last part provides us with a natural, and non–ad hoc model for mutual information, and the interpretation of dialogue acts.

1. Introduction

This is an investigation into the pragmatics of chains in dialogue which are established through sequences of specific uses of indefinite descriptions by different speakers, which are linked to one another, and which are related to the same object.

We can assume that basically each use of an indefinite NP introduces a new discourse referent into the knowledge base of the hearer. We may use here a DRT-like mechanism (Kamp & Reyle 1993; v. Eijck & Kamp 1997) which describes the way a hearer interprets an assertion by the speaker. What is of special interest in the case of the described chains, is that they build a connection between different dialogues, and therefore between different dialogue participants.

(1) Two passenger, Anna and Debra, observe how a Doberman bites a young girl, Melanie. The next day Anna meets Bob and Chris. They sit together, and she tells them that yesterday she saw how *a* young *girl* was bitten by a Doberman. Some weeks later, Chris meets Debra, and they come to talk about dangerous dogs. Debra tells him: "Last week, I witnessed how such a dog bit *a* little *girl*." Chris: "Oh, really! Anne told me that she too saw how a Doberman bit *a girl*."



Here, we have two dialogues, one between Anna, Chris and Bob, the other between Debra and Chris. One and the same object, Melanie, is the source for a branching chain. For subsequent dialogues, it will be necessary for the involved persons to keep track with whom they share which referent.

The problems here are closely related to the phenomena handled in the theory on *First Order Information Exchange* developed by *P. Dekker* (Dekker 1997).

He starts out with examples like

(2) A: Yesterday, a man ran into my office, who inquired after the secretary's office.

B: Was he wearing a purple jogging suit?

A: If it was Arnold he was, and if it was somebody else he was not.

He observes that A's answer sounds strange, even if we assume that there was more than one person coming into the office, one of them Arnold. Dekker claims here that

> All natural language terms (definite and indefinite noun phrases alike), are assumed to relate to specific subjects in the information state of a speaker. Indefinite noun phrases which set up discourse referents in a felicitous way, must refer to specific subjects in the information state of the speaker, although they may provide no clue so as to which of his own subjects a speaker refers to. (Dekker & van Rooy 1999)

Dekker and van Rooy developed this approach further to handle belief attributions. The meaning of a discourse like "*Melanie is a 12 years old girl. Chris believes that some dog bit her.*" can be described by a DRS like:

$$\begin{array}{|c|}\hline x, y, yx, yz \\ \hline \\ \text{Melanie}(x) \\ \text{twelve-years-old-girl}(x) \\ \text{Chris}(y) \\ y : \begin{array}{|c|}\hline x, z \\ \hline \text{dog}(z) \\ \text{bit}(z, x) \\ \hline \end{array} \\ x \text{ is the source of } yx \\ \\ \hline \end{array}$$

This framework can be developed straight forward to be able to describe the building of chains across dialogues and dialogue participants. We will do this in a framework of *Multi–Agent Systems*, see (Fagin e.al. 1995). I.e. we will describe the dialogues and the updates of knowledge bases of the participants as games. This has the advantage that we can exploit standard techniques to define the information an agent has in a certain dialogue situation in a possible worlds framework, and we get the usual definition of mutual knowledge. For technical reasons we will develop the theory as a *possibility approach*, see (Gerbrandy & Groeneveld 1997). One effect will be that the *source*–relation, which is a primitive relation in the theory of Dekker and van Rooy, is defined through the rules of the dialogue games.

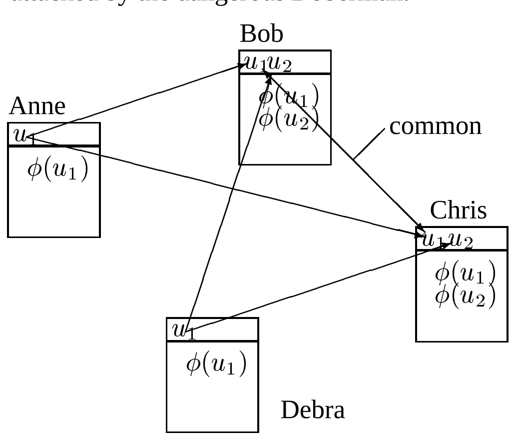
2. Definite Reference and the Common Ground

The relation between established chains and the use of definite descriptions is of special interest, because it forces us to investigate how discourse referents are connected to the *common ground*.

It has become usual to identify the common ground with what is *mutually known* by the dialogue participants. The relation between the referential use of definite descriptions and mutual knowledge has been extensively studied in (Clark & Marshall 1981). For a *visual situation* use, it can be shown that the referential use of a definite description def $x.\varphi(x)$ is successful if the object referred to is the only one for which it is common knowledge that it has the property φ, see (Benz 1999).

The referent of a definite description is an object in the real source situation but this situation is normally not known to the discourse participants. That the anaphoric referential use of a definite is sensitive to the *common* discourse referents can be seen in examples like

(3) At 7:00 am Anna and Debra see how a Doberman bites the young girl Melanie. Anna must leave Debra with the girl. Therefore she can't see that the dog again attacks and bites another girl, Stefanie, some minutes later. Then (1) Anna meets Bob and Chris and tells them that she has seen how a Doberman attacked a young girl. The next day, (2) Debra meets Bob, and she tells him that the dog attacked also another young girl. Later, (3) she meets also Chris and tells him the same. Chris, who does not know that Bob knows already the whole story, (4) meets Bob again and says to him: "*The young girl* was not the only one who was attacked by the dangerous Doberman."



The use of *the young girl* by Chris is felicitous although both of them know that there have been two young girls who were attacked by the Doberman. Only one of them is available through a common discourse referent.

3. Dialogue as Multi–Agent System

For our presentation of multi–agent systems we follow (Fagin e.al. 1995). It consists of a set of *global states*, a set of possible *dialogue acts*, a *transition operation* τ, which models the effect of performing an action, and a function P which tells us, which actions can be performed in a given situation.

A global dialogue state consists of the *local* states of the participants $\mathrm{DP} = \{1, \ldots, m\}$, and the state of the environment. Essentially, our states will contain the same information as the pictures provided above. They are represented by tuples $\langle \mathcal{M}, \rightarrow, D_1, \ldots, D_m \rangle$. Here, $\mathcal{M}$ is a first order model which describes the situation talked about, D_a is a simple DRS extended with information (1) about the dialogue acts where the participant a was involved, and (2) about the real objects he has observed. $\rightarrow$ is a relation between objects and subjects, or subjects and subjects, where a subject is a pair $\langle a, u \rangle$ of a participant a and a discourse referent u. We write u^a for $\langle a, u \rangle$. If a new discourse referent is introduced into a DRS, then $\rightarrow$ will connect this referent to it's *source*. Now we are able to say what is a possible sequence of dialogues in our model. We identify them with sequences $G = \langle s_0, \mathtt{act}_0, \ldots, s_n \rangle$, where all s_i are global states, s_0 is a state where $\rightarrow^{s_0}$ and all $D_a^{s_0}$s are empty. Further, $\mathtt{act}_i \in P(s_i)$, i.e. it must be a *possible* dialogue act in situation s_i, and $s_{i+1} = \tau(\mathtt{act}_i, s_i)$ for all $i < n$. We denote the set of all such possible sequences of dialogues by $\mathcal{G}$.

We allow for three actions an agent can perform: $\mathtt{send}(a, H, D, l)$, $\mathtt{get}(a, H, D)$ and $\mathtt{observe}(H, D, l)$. $\mathtt{send}(a, H, D, l)$ is the actions which represents an assertion of speaker a with co–present addressees H. D is a DRS, which is the result of translating the speaker's utterance into a DRS by standard techniques known from (Kamp & Reyle 1993). l is a function which relates the discourse referents in $\mathcal{U}_D$ to the subjects in D_a. If the action $\mathtt{get}(a, H, D)$ is performed on the local state of an agent $b \in \mathrm{DP}$, then it means that he is an addressee $b \in H$ of an assertion with content D and speaker a. $\mathtt{observe}(H, D, l)$ means that he is a member of a (co–present) group H which observes some fact represented by a DRS D, where l is an injective function which relates the referents in $\mathcal{U}_D$ to real objects in the universe $|\mathcal{M}|$. These actions can be performed as parts of *joined* actions. They can be identified with sequences $(\mathtt{act}_a)_{a \in \mathrm{DP}}$, where $\mathtt{act}_a$ is one of the three (local) actions defined before. We allow for two sorts of joined actions: Either the sequence has the form $\mathtt{act}_a = \mathtt{observe}(H, D, l)$ with fixed H, D, l for $a \in H$, and $\mathtt{act}_a = \perp$ for $a \notin H$. Or, it has the form $\mathtt{act}_a = \mathtt{send}(b, D, H, l)$ for $a = b$, $\mathtt{act}_a = \mathtt{get}(H, D, l)$ for $a \in H$, and $\mathtt{act}_a = \perp$ for $a \notin H \cup \{b\}$, D, H fixed.

What are the effects of performing a joined action $(\mathtt{act}_a)_{a \in \mathrm{DP}}$? If it represents an assertion by a speaker b, then $\mathtt{send}(b, H, D, l)$ should not change the state of b except that he remembers that he has performed this action, i.e. we assume that D_b has a component Act_{D_b} such that for the new state D'_b we get $Act_{D'_b} =$

$Act_{D_b}{}^\wedge\langle \mathtt{send}(b,H,D,l)\rangle$. The act $\mathtt{get}(b,H,D)$ should result in a merge of D_a and D for $a \in H$, and in an extension of Act_{D_a} to $Act_{D_a}{}^\wedge\langle \mathtt{get}(b,H,D)\rangle$. There is some freedom in defining this merge. We may assume that it introduces for each referent in D a new referent into $\mathcal{U}_{D_b}$, and adds the conditions of Con_D to Con_{D_b} where the old variables are replaced accordingly. $\rightarrow$ belongs to the environment, and an assertion of the form $\mathtt{send}(b,H,D,l)$ has the effect that new chains are added to $\rightarrow$. In order to be able to start in our examples with *empty* representations, we consider also acts of joined observations. For $a \in H$, an observation $\mathtt{observe}(H,D,l)$ should have the effect that D is merged to his old information D_a in such a way that new discourse referents are introduced for objects which he has not jet observed. We assume that D_a has a fourth component Obs_{D_a} which is an injective function relating referents in $\mathcal{U}_{D_a}$ to objects in $|\mathcal{M}|$, i.e. a remembers which objects he has observed.

We don't go into further details here. Table 1 shows the relevant part of a global state for Example 3 which results after Ann's assertion (1). It translates into a DRS $D = \langle\{u_1,u_2\},\{\text{Doberman}(u_1), \text{young–girl}(u_2), \text{bit}(u_1,u_2)\}\rangle$. H_0 is the group $\{An, De\}$, H_1 the group $\{An, Bo, Ch\}$. l links u_1 to the Doberman (Dob), u_2 to Melanie (Mel). In addition, we assumed here that Chris has already some information represented in his DRS.

To get a full description of our system we have to say which joined actions can be performed in some global state s. We assume that an joined observation is always possible, if we have for $\mathtt{observe}(H,D,l)$ that $(\mathcal{M},l) \models D$. If the joined actions represents an assertion with $\mathtt{send}(b,H,D,l)$, then it should be a possible action in s, iff $D^s_b \trianglelefteq_l D$. $D \trianglelefteq_l D'$ holds between DRSes D, D', iff l is a function from $\mathcal{U}_{D'}$ to $\mathcal{U}_D$ such that for all condition $\varphi \in \mathrm{Con}_{D'}$ φ/l is an element of Con_D, where φ/l denotes the formula, where the free variables in φ are replaced by their l–values. This is essentially *Dekker's* condition for the licensing of first order formulas (Dekker 1997). It implies that the speaker can make only *true* assertions. For global states s we denote by $P(s)$ the set of joined actions which can be performed in this situation.

We denote by $\mathcal{S}(\mathcal{G})$ the set of all global states which may arise as a possible dialogue situation, i.e. all situations which belong to a $G \in \mathcal{G}$. For multi–agent systems it is usual to identify the *knowledge* of an agent a in a situation s relative to $\mathcal{S}(\mathcal{G})$ with the set of all situation which are *indiscernible* from s. Two situations are indiscernible for an agent a, iff his local states are identical for both situations. This allows us to include the information of agents about the global state, and their information about others into our model. We either may use *Kripke*–structures, see (Fagin e.al. 1995), or develop our theory along the lines of (Gerbrandy & Groeneveld 1997) as a *possibility* approach. Both descriptions provide us with (equivalent) representations $CG_w(H)$ of the *common ground* for a possibility w and a group H. It is as a set of accessible possible dialogue situations and contains all possibilities which are possible according to the knowledge of one participant, possible according to the knowledge a participant can have according to the knowledge of an other participants, etc.

Hence, the general apparatus for multi–agent system provides us with a natural representation of the mutual information of dialogue participants. But in view of our problem to explain the anaphoric referential use of a definite description we need a representation which provides us more directly with information about which subjects with which properties are common. For this reason we introduce the notion of a *common DRS*.

That a DRS is *joined* should mean that it can be embedded into all the DRSes representing the knowledge of the members of the group H in such a way that the images of one referent are all connected to each other via a common source. Hence, D is a joined DRS for a group H and possibility $w \in \mathcal{W}$, iff there is a family of functions $(l_a)_{a\in H}$ such that for all $a \in H$ $D^w_a \trianglelefteq_{l_a} D$, and for all $u \in \mathcal{U}_D$ $\exists x \forall a \in H\; x \rightarrow_r l_a(u)$, where $\rightarrow_r$ denotes the reflexive closure of $\rightarrow$. In order to restrict the possible size of a joined DRS we add the condition that for all $u, u' \in \mathcal{U}_D$, $u \neq u'$, there is at least one $a \in H$ such that $l_a(u) \neq l_a(u')$. Intuitively, a DRS is *mutual* joined if it is joined, everybody knows that it is joined, everybody knows that everybody knows that it is joined etc. This means that D must be a joined DRS relative to a family $(l_a)_{a\in H}$, and for all $b \in H$ and for all v which are possible for b there exists a family $(l^v_a)_{a\in H}$ such that D is joined in v relative $(l^v_a)_{a\in H}$ and $l^v_b = l_a$. By a simple iteration of this condition we get an intuitive definition of a *common* DRS, $C_w(D,H)$, for a group H in a possibility w. E.g. for the situation described in Table1 we find that the following DRS D is a maximal common DRS for the group $H_1 = \{An, Bo, Ch\}$.

u_1, u_2
Doberman(u_1)
young–girl(u_2)
bit(u_1, u_2)

A detailed examination of the examples introduced above would show that the uniqueness condition for the referential anaphoric use of a definite description is sensitive to the number of discourse referents in the maximal common DRSes.

4. The Representation Problem

The last section provided us with a reasonable description of a *common* DRS. But how can the participants have access to this DRS? The most intuitive way seems to be that they keep track of the discourse referents which have been introduced to each group, and about the properties of those referents. I.e. a participant will not only update his own DRS, if he gets some new information, but he will also update a DRS representing the knowledge of the group which *commonly* got this information. This leads to an extension of the local states. We add for each participant a and for each group $H \subseteq \mathrm{DP}$, where he is a member of this group, representing DRSes $D_{a,H}$. In the same way as in the last section we can describe the update operations connected to the possible local acts $\mathtt{send}(a,H,D,l)$, $\mathtt{get}(a,H,D)$ and $\mathtt{observe}(H,D,l)$ for global states with representations. Together with the function P, which specifies which actions are possible in a certain situation, this

$\rightarrow$	Anne An	Bob Bo	Chris Ch
$Dob \rightarrow u_1^{An}$ $Mel \rightarrow u_2^{An}$ $u_1^{An} \rightarrow u_1^{Bo}$ $u_2^{An} \rightarrow u_2^{Bo}$ $u_1^{An} \rightarrow u_{n+1}^{Ch}$ $u_2^{An} \rightarrow u_{n+2}^{Ch}$	u_1, u_2 Doberman(u_1) young–girl(u_2) bit(u_1, u_2) `observe`(H_0, D, l) `send`(H_1, D, id) l	u_1, u_2 Doberman(u_1) young–girl(u_2) bit(u_1, u_2) `get`(An, H_1, D) $\emptyset$	$u_1, \ldots, u_n,$ u_{n+1}, u_{n+2} Doberman(u_{n+1}) young–girl(u_{n+2}) bit(u_{n+1}, u_{n+2}) `get`(An, H_1, D) $\emptyset$

Table 1: (Part of) a global dialogue state for Example **(3)**.

will lead to a new set of possible dialogues $\mathcal{G}^+$ for the same sequences of actions.

The following figure describes the local state of Bob in Example 3 after his talk with Debra (2). The first column represents his total knowledge about the biting situation, the second his protocol for what he heard in common with Anne and Chris, and the third for what he has in common with Debra.

Bo	{ Bo,An,Ch }	{ Bo,De }
u_1, u_2, u_3 Dob(u_1) girl(u_2) bit(u_1, u_2) girl(u_3) bit(u_1, u_3) $u_3 \neq u_2$	u_1, u_2 Dob(u_1) girl(u_2) bit(u_1, u_2)	u_1, u_2, u_3 Dob(u_1) girl(u_2) bit(u_1, u_2) girl(u_3) bit(u_1, u_3) $u_3 \neq u_2$

If we compare this state with the parallel global state in $\mathcal{G}$, then we find that the DRS in the second column is a maximal common DRS. Hence, if Bob meets Chris, then he can apply the uniqueness condition which is connected to the definite *the girl* to this DRS. As Chris will have the same representation for the common DRS, they both will interpret the description as relating to a subject which is *chained* to Melanie.

We can show in general that the DRSes $D_{a,H}$, which are internal representations of agent a for the referents and conditions which are common, are identical for all $a, b \in H$. Furthermore, we can prove — with some effort — that they are always maximal common DRSes for the related dialogue situation in $\mathcal{G}$.

5. Conclusions

We are able to represent the chains that are defined by iterated specific uses of indefinite NPs. The theory of multi–agent systems, which builds the basis of for our model, provides us with natural descriptions of the common ground as an information state representing mutual information. But to be able to explain the referential anaphoric use of a definite description, and especially how to apply it's uniqueness condition, we found that, in fact, it is sensitive to common substructures of the local states of discourse participants. We characterised them as common DRSes and explained how the participants can represent these common DRSes. There are some points in our approach which should be emphasised:

- Specifically used indefinite NPs introduce *free* variables. The interpretation function, which is necessary to define the truth values for the conditions of a DRS, are provided by an external chain relation. They never get existentially bound.
- There are three distinct objects in our model which are possible representations for the linguistic *common ground*: (1) The information states representing common knowledge, (2) the common DRSes, and (3) the internal representations of the common DRSes. The theory about multi–agent systems allows us to describe exactly how common DRSes are related to common knowledge.
- The uniqueness condition connected to an anaphorically used definite description does not contribute anything to the *meaning* of a sentence where it occurs.

6. References

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