A LOGICAL FORMALISM FOR THE REPRESENTATION OF DETERMINERS

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ABSTRACT

Determiners play an important role in conveying the meaning of an utterance, but they have often been disregarded, perhaps because it seemed more important to devise methods to grasp the global meaning of a sentence, even if not in a precise way. Another problem with determiners is their inherent ambiguity.

In this paper we propose a logical formalism, which, among other things, is suitable for representing determiners without forcing a particular interpretation when their meaning is still not clear.

INTRODUCTION

Ambiguity of determiners is one of the most striking phenomena of natural language. What is strange is the ease with which humans use them: it seems that the multiplicity of interpretations of a noun phrase including a determiner is not explicitly perceived by human users of natural language [Hobbs 1986]. The approach we choose tries to model this behavior: each determiner has its characteristic semantic interpretation, which is different from that of other determiners and which can be furtherly specified on the basis of the information contents gathered from the overall context and from the remaining part of the sentence. If such an information content is not sufficient, then the meaning of the determiner remains ambiguous. What is of paramount importance is that any determiner has a "single" meaning, that can be furtherly specified by the context.

Of course, we need to express the semantics of determiners by means of a suitable representation. The one that we propose seems to be intuitively acceptable, formally precise and suitable for a compositional analysis of natural language that, even if questionable in some particular cases, is still one of the approaches that guarantee the most reasonable degree of generality in semantic interpretation.

It is obvious that the representation of a sentence in such a formalism may contain ambiguities; therefore a further step is needed in order to obtain an unambiguous specification of its meaning. Contrary to the intermediate formalism we are going to discuss, this final specification will not be given in declarative form, but in terms of operations on an underlying knowledge base.

REPRESENTATION FORMALISM

Our main goal in designing the representation formalism that will be used in the following sections were:

1) To maintain a close relationship between the pieces of information that are intuitively present in the input sentence and the predicates appearing in its interpretation.

2) To make explicit the distinction between surface objects and semantic entities: words on one side and concepts, individuals, classes etc. on the other.

3) To maintain a compositional analysis of language, where the starting point is provided by the dependency trees built by the rule-based syntactic component of the FIDO system [Lesmo, Torasso 84; Lesmo, Torasso 85a; Lesmo, Torasso 85b].

4) To devise a set of predicates allowing an easy translation between the obtained representation and the corresponding operations on a Knowledge Base.

A first example concerns a very simple sentence:

1) Bob loves Lucy.

The representation is (lower case strings refer to variables; upper case ones to constants or predicates):

\[ \text{REF} \left( S, x, \text{BOB} \right) \land \text{REF} \left( S, y, \text{LOVE} \right) \land \text{REF} \left( S, z, \text{LUCY} \right) \land \text{AGENT} \left( y, x \right) \land \text{OBJECT} \left( y, z \right) \]

This can be read as: there are three internal entities \((x, y, z)\); the speaker \((S)\) is referring to the first of them by using the word \(\text{BOB}\), to the second with \(\text{TO LOVE}\), to the third with \(\text{LUCY}\); the agent of \(y\) is \(x\), its object is \(z\). Fig. 1 depicts, in terms of nodes and arcs, the proposed representation. REF predicates are meant to indicate the mapping between words and internal nodes. Consider now ex.2:

2) The boy loves a girl

The representation reported below disregards the information contents gathered from the determiners:

\[ \text{REF} \left( S, x, \text{BOB} \right) \land \text{REF} \left( S, y, \text{LOVE} \right) \land \text{REF} \left( S, y, \text{GIRL} \right) \land \text{AGENT} \left( y, x \right) \land \text{OBJECT} \left( y, z \right) \]

The representation is analogous to the previous one. On the other hand, some problems arise in this case; they concern the communicative impact of ex.2, and which were not evident in the previous example. If we say "Bob loves Lucy", we assume that whoever hears this sentence knows both Bob and Lucy, so that he is able to reconstruct the right semantic interpretation, and to identify the specific individuals to whom the speaker is referring. But how can the hearer convey such kind of information when explicit names are not available? And, on the opposite side, how can the speaker tell the hearer that he is not referring to any specific individual, but he wants to mention a general property of the class? We believe that the discriminating information is carried by determiners. If we take them into account, we should state that ex.2 expresses something as: "BOB (this word should suffice for you to identify whom I'm talking about) LOVES GIRL (this word is not specific enough to allow you to identify the correct referent)" or, if we think of a knowledge base represented as a semantic network: "Dear hearer, you should find a node satisfying the 'BOY' constraint (and if you consider the context, this can be done unambiguously), then you should create a new node of type 'GIRL' and connect them via a node which is an 'ACT-OF 'LOVE' ".

\[ \text{REF} \left( S, x, \text{BOB} \right) \land \text{REF} \left( S, y, \text{LOVE} \right) \land \text{REF} \left( S, y, \text{GIRL} \right) \land \text{AGENT} \left( y, x \right) \land \text{OBJECT} \left( y, z \right) \]

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We can give now the complete representation of ex.2:

\[ 3rd) \text{REF}(S,x,BOY) \land \text{ENABLESAMEREF}(S,x) \land \text{IDENTIFIABLE}(S,x) \land \\
\text{not ENABLASSAMEREF}(S,H,MAN) \land \text{AGENT}(y,x) \land \text{OBJECT}(z,y) \]

that is: \(x\) is the speaker referring to entity \(y\) by means of the word \(BOY\), he assumes that \(y\) is identifiable to himself and that the expression used \((BOY)\) enables the hearer to refer to the same entity; there is also an act of loving \((y)\) and another entity \((z)\) whom he is referring to by means of the word \(MAN\); \(y\) is identifiable to himself, but the word \(MAN\) will not enable the hearer to refer to the same entity he is thinking about. Finally, \(x\) is the agent of \(y\) and \(z\) is the object of \(y\).

Actually, \(2r\) does not correspond exactly to sentence 2. In fact, \(x, z\) is ambiguous whilst \(2r\) is not. The source of ambiguity is the NP "a girl". In the previous discussions we assumed that the speaker knew the girl loved by "the boy", but this is not necessarily true. The "specific" reading is given in \(2r\) by the presence of the predicate \(\text{IDENTIFIABLE}(S,S,z)\). Now, how can we account for the inherent ambiguity of the indefinite determiner? Simply dropping from its semantics the "IDENTIFIABLE" predicate: it will be added in case some evidence about a "generic" simply dropping from its semantics the "IDENTIFIABLE" predicate:

The approach exemplified above will be described in the next section, covering the definite and indefinite determiners. The predicates used are listed below, together with an explanation of their intuitive meaning.

\[ \text{REF}(S,x,y,z): \text{Individual } x \text{ is able to refer to entity } y \text{ by means of expression } z, \]

\[ \text{ENABLESAMEREF}(S,y,TO EAT): \text{Individual } x \text{ assumes that individual } y \text{ is able to identify, by means of expression } x, \text{ the same entity which he refers to.} \]

\[ \text{IDENTIFIABLE}(S,y,z): \text{Individual } y \text{ assumes that individual } y \text{ is able to identify (or that } y \text{ knows) entity } z. \]

\[ \text{SEIZ}(x): \text{Entity } x \text{ is a set composed of at least two elements.} \]

\[ \text{ARBIRARY}(x): \text{Any member of the class } x \text{ identified by expression } z \text{ necessarily satisfies the property expressed by the proposition in which } z \text{ occurs.} \]

**Representation of Determiners**

We will describe the representations we have adopted for determiners, following the classification introduced in [Croft 85], which we report here (note, however, that the ARBITRARY predicate introduced above does not correspond to "arbitrary" in Croft's classification, only to its 'not defeasible' subclass):

- Perceptually available (this, that)
- Not perceptually available:
  - Identifiable (the, anaphoric pronouns)
  - Not identifiable:
    - Specific (specific, epistemic a)
    - Arbitrary:
      - Defeasible (generic / intentional a)
      - Not defeasible (any)

Table 1 lists the various representations we have adopted. Let us consider first the definite determiners (we are not going to discuss what Croft refers to as 'perceptually available'-referent determiners, i.e. demonstratives like 'this' and 'that').

The representation for "the" reported in table 1 can be paraphrased as: "There exists an entity that the speaker is able to refer to by means of the expression following the determiner; the speaker assumes that that expression will enable the hearer to refer to the same entity; the speaker is able to identify the referred entity." An example is provided by

\[ 3rd) \text{REPRFSN}_{EN}(S,x,BOY) \land \text{ENABLESAMEREF}(S,x) \land \text{IDENTIFIABLE}(S,x) \land \\
\text{not ENABLASSAMEREF}(S,H,MAN) \land \text{AGENT}(y,x) \land \text{OBJECT}(z,y) \]

It must be noted that it is not written anywhere that the entity \(x\) has to be an individual. In principle, it could be a generic entity (i.e., an 'intensional' mode of a semantic net), thus fulfilling the role of 'prototype individual' (Gross, Wood, Wehrstein 83).

A few words now to discuss plurals. For example:

4) I ragazzi mangiano (The boys are eating)

5) I ragazzi mangiano (The boys are eating)

6) Le ragazze mangiano (The girls are eating)

As regards indefinite determiners, the representations given in Table 1 can be paraphrased as: "There is an entity that the speaker is able to refer to by means of the expression following the determiner: the speaker cannot assume that that expression will enable the hearer to refer to the same entity". Let us consider first the 'specific' meaning of the determiner "a":

6) Un uomo entro adagio nella stanza (A man quietly entered the room)

7) Una donna entro adagio nella stanza (A woman quietly entered the room)

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8) Un uomo entro adagio nella stanza (A man quietly entered the room)

9) Una donna entro adagio nella stanza (A woman quietly entered the room)

Table 1: Semantic representation of the meaning of determiners. Note that the representation depends on the type of the expression which will be actually built up on the basis of the expression following the determiner. This has been done in order to provide a means of unifying the variable \(x\) occurring in the other predicates with the one appearing in the representation of the remaining NF.
The last determiner (in Croft's analysis) is "any". Its representation is reported in table 1, but lack of space prevents us from discussing it (moreover, not all students agree on its status of determiner vs. quantifier and no Italian lexeme has a meaning exactly equivalent to "any").

We list below the rules more strictly concerned with the operational interpretation of the predicates associated with determiners:

R1 (Definite): if REF(S,x,exp) & ENABLESAMEREF(S,H,x) & IDENTIFIABLE(S,S,x) then located=(exp,x)

R2 (Specific Indefinite): if REF(S,x,exp) & not ENABLESAMEREF(S,H,x) & IDENTIFIABLE(S,S,x) then created=(exp,x), mark(x,'INDIVIDUAL')

R3 (Plural definite): if REF(S,x,exp) & ENABLESAMEREF(S,H,x) & SET2(x) then located=(exp,x)

R4 (Generic Indefinite): if REF(S,x,exp) & not ENABLESAMEREF(S,H,x) & not IDENTIFIABLE(S,S,x) & not ARBITRARY(exp,x) then created=(exp,x), mark(x,'GENERIC-INDIFFERENT')

A few words on the functions used in the action part of the rules:

"located" locates first for individual referents; if none is available it considers generic nodes.

"created" builds a new instance of the most specific available concept identified by exp.

"locateset" works exactly as located, but the node that it locates must represent a set.

These rules are not complete, as they do not take into account Epistemic and Intensional Indefinite: In fact, both the representations of these interpretations must include the hypothetical knowledge of another individual and, as we said before, we did not treat belief contexts.

CONCLUDING REMARKS

Interpretation of determiners and quantifiers is usually over-simplified in many natural language interfaces. We think the formalism discussed in this paper constitutes a significant step in representing the meaning of the sentence at a more abstract level than many interfaces do: at the same time we can directly exploit the features of this representation to build the actual update command or query.

Other approaches use a direct translation of the sentence from its surface form (or from a purely syntactic tree) into a representation language which is actually a KB management or a DB query language. The formalism discussed in this paper does not make any assumption on the language used for actually accessing the KB (and for this reason the formalism does represent the meaning of a sentence in a natural or at least 'neutral' way [Hobbs 1985, Shubert & Pelletier 1982]).

On the other hand, the formalism is not too far from the way the domain knowledge is (or could be) represented inside a KB or DB, so that it is easy to develop translation rules stating what operations on the KB or DB should be done.

The constraints on the available space prevented us from discussing the problem of using the context to disambiguate among the different meanings of a given determiner (e.g. specific vs. unspecified "a"). Some efforts were made and the results are encouraging, though in many cases it is only very high-level information (e.g. actual knowledge and beliefs) can provide the basis for selecting the right interpretation.

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