CONTROL OF INFERENCE: ROLE OF SOME ASPECTS OF DISCOURSE STRUCTURE - CENTERING+

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(Dedicated to the memory of William A. Martin)

ABSTRACT

The purpose of this communication is to examine one particular aspect of discourse structure, namely, a discourse construct called center of a sentence (utterance) in discourse and its relation to the larger issue of control of inference. We have described very briefly the notion of center(s) of a sentence in discourse and discussed how the centering phenomenon might be incorporated in a formal model of inference and its relation to the intrinsic complexity of certain inferences.

1. INTRODUCTION

Although there is considerable research in the development of suitable representations for different pieces of knowledge so that the necessary inferences can be drawn (e.g., for comprehending a discourse), very little is known about how the inferential processes are controlled (some exceptions are [1], [2], and [4], for example) i.e., how the more appropriate inferences are drawn and how the irrelevant (yet valid) inferences are prevented from being drawn, or at least drawn with greater difficulty; alternatively, how the various pieces of knowledge and their organization impose ordering on the set of inferences so that this ordering reflects the relative ease (or difficulty) associated with these inferences.

The purpose of this communication is to examine one particular aspect of discourse structure, namely, a discourse construct called center of a sentence in discourse and its relation to the larger issue of control of inference. First we will describe very briefly the notion of center(s) of a sentence in discourse and then discuss (again very briefly) how the centering phenomenon might be incorporated in a formal model of inference and whether such a model might shed light on the intrinsic complexity of certain inferences.

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In a natural language sentence in discourse (in sharp contrast to sentences of a formal language) one or more entities (arguments of the main predicate) are singled out. We call these the centers*. Centered entitles may be syntactically marked but this need not be the case.

Let S_i be the current utterance (sentence) and let D_{i-1} be the preceding discourse (at times only the preceding sentence S_{i-1}). We assume that as the discourse is unfolding a discourse "model" is being created. By "model", for the purpose of our present discussion, we mean simply a data structure in terms of a set of entities and relations among them. We are not claiming here that this is all there is to a discourse "model", however, for our immediate purpose this representation would be adequate. In addition to constructing the discourse model, we will assume that we keep track of those entities which are centered so far. Our main goal is that in terms of the discourse model together with the associated set of centers, and the center(s) of the current sentence, we should be able to give some account of the appropriateness (or inappropriateness) of the current sentence *Si* in the discourse context D_{i-1}. The notion of center is relevant to the determination of how the current utterance is integrated in the discourse "model" constructed so far and how the succeeding discourse is to be integrated in the preceding discourse of which the current utterance is now a part.

For each utterance (sentence), S_i, in discourse, we will associate two centers, $C_b(S_i)$: the backward looking center, and $C_f(S_i)$: the forward looking center(s)**. $C_b S_i)$ determines how S_i is going to be incorporated in the preceding discourse D_{i-1} and thus incrementally augment the current discourse model. $C_f(S_i)$ determines how S_i will get linked up to the succeeding discourse. We will assume that $C_b(S_i)$ is always a singleton, i.e. each sentence has only one backward looking center; however, $Cf(S_t)$ could be a set. Further, it is

This notion is related to the AI notion of (local) focus [3] and the notions of topic and focus in linguistics, but it is not identical to any of these.

We are not concerned here about the determination of centers. Syntactic structure, stress, and discourse context are some of the determining factors. For our present purpose it is enough to assume that a sentence in discourse has centers.

not necessary that $C_b(Si)$ and $Cf(S_i)$ are disjoint. In an obvious way we can define $C_f(D_{i-1})$ which would be the set of all forward looking centers associated with the preceding discourse D_{i-1}. (We have defined $Cf(D_{i-1})$ as a set without any further structure on it. This is clearly not adequate. Some structure on this set is necessary to account for the relative ease (or difficulty) of accessing elements of this set. See examples in Section 2. Stack organization by itself is not adequate. We will not discuss this issue here due to restriction on allowed space for the paper.)

We will now define "appropriateness" of S_i in the discourse context D_{i-1}. S_i is "appropriate" in the discourse context D_{i-1} if $C_b(S_i)$ E $Cf(D_{i-1})$, i.e. the backward looking center is identical to one of the forward looking centers, or $C_b(S^i)$ is a proword for some element in Cf(Di-i), or C^S^) is functionally dependent on some element of Cf(Di-1). Cf(Dj.) the set of forward looking centers for D_i cannot be represented by just the union of Cf(Di-1) and Cf(Si). (See the remark at the end of the previous paragraph.) We do not drop centers but allow for some of them to be temporarily placed in the background.

The intuitive notion of appropriateness is that if the condition is satisfied the resultant discourse Di = Di-1 S_i will be judged to be more coherent, better "well-formed," less awkward than the case when the condition is not satisfied. Thus it is not the case that if the condition is not satisfied, S_i cannot follow D_{i-1} but rather if it does, the resultant discourse $D_i = D_{i-1}$ S_i will be more difficult to comprehend i.e., there would be more processing involved in integrating S_i into the discourse model constructed so far (more as compared to the case when the condition is fulfilled). Our mathematical treatment so far has attempted to characterize this increased processing in terms of some complexity measures associated with certain inference schemes.

2. EXAMPLES

(1) S_1: John hit Bill. $C_b(S_1)$ = John; $C_f(S_1)$ = (John, Bill).

This example shows that $C_b(S_1)$ corresponds roughly to the notion of topic of a sentence. $C_f(S_1)$ corresponds roughly to the linguistic notion of focus or the AI notion of (local) focus [3]. $C_b(S_1)$ and $C_f(S_1)$ are not necessarily disjoint.

(2) S_1: Bill was hit by John. $C_b(S_1)$ = Bill; $C_f(S_1)$ = (John, Bill)

(3) S_1: It was John who hit Bill. $C_b(S_1)$ = Bill; $C_f(S_1)$ = John

John is the focus; hence it is $Cf(S_i)$. Bill is the $C_b(S_i)$ which corresponds to the topic. Note that Bill is not in Cf(Si). In this respect (3) above is different from (2). The it-cleft construction has the effect of temporarily putting Bill in the background thereby making it difficult to access Bill from the set of previously centered entitles, i.e., Bill can be made the center in the succeeding discourse only by explicitly reintroducing it. For this reason, discourse (3a 3b) is less awkward than discourse (3a' 3b').

3a S_1: Bill was hit by John.

3b S_{i+1}: He (=Bill) was taken to the hospital.

3a' S_1: It was John who hit Bill.

3b' S_{i+1}: He (= Bill) was taken to the hospital.

$C_b(S_1)$ can be a pro-word for some element in $C_f(S_{1-1})$, or $C_b(S_1)$ can be functionally dependent on some element in $C_f(S_{i-1})$. For example,

1a S_1: John walked up to the house.
$C_f(S_1)$ = {John, house}

1b S_{i+1}: The door was locked. $C_b(S_{i+1})$ = {door}

$C_b(S_{i-1})$ * door is not in $Cf(S_i)$, however, it is functionally dependent on house (i.e. the door of the house), hence (la lb) is appropriate. Such dependencies could be nested. It is important to note that whenever we have such functional dependencies, we have an effect which is similar to that in it-cleft sentences, i.e., in 1_b S_{i+1}: the door was locked, $Cb(S_{i+1})$ = door; house in $Cf(S_i)$ is temporarily put in the background, i.e., it can be brought into the succeeding discourse only by explicit reintroduction. Hence (2a2b2c2d) is more awkward than (2a'2b'2c'2d'). (The contrast can be made sharper by allowing for further nested functional dependencies.)

2a John walked up to the house.
2b The door was locked.
2c But the handle was broken.
2d It (= the house) looked unoccupied for a long time.

2a' John walked up to the house.
2b' The door was locked.
2c' But the handle was broken.
2d' The house looked unoccupied for a long time.

3. COMPLEXITY OF INFERENCING

We will now briefly describe our formal investigations in complexity of inferencing with respect to the notion of centering. Centering contributes to the difficulty of inferencing (i.e. of incorporating S_i into the discourse model constructed up to D_{i-1}), in various ways: 1) violation of centering constraints, 2) size of the forward looking centers of D_{i-1} the larger this set the more difficulty in incorporating S_i 3) the total number of entities centered in the discourse. In a formal model of inference incorporating the notion of center, each of these aspects of discourses relevant to their ease of comprehension may be naturally translated into measures of complexity on the deductions which can be formalized in the

model. Thus each of these measures would impose a complexity ordering on the formal deductions of the model. An inference (i.e. pair of premises and conclusion) which could be derived in the model might then be assigned as its intrinsic complexity along one of these measures the minimum complexity of the deductions which derive that inference. By combining the different measures we might arrive at a useful partial ordering of the complexity of inferences. It would be particularly interesting to show that the inferences which fell below a given level of complexity in such an ordering are simpler than those falling above that level in a computational sense. Thus a first question to consider would be: are the collections of inferences which fall below a given level of complexity along each of the measures considered above decidable sets. If so, are the decision procedures for the collections at higher levels more complex (computationally) than the decision procedures for lower levels.

In order to investigate these questions in any detail we must choose a formal model of inference and a means of incorporating the notion of center into that model. In the studies we have completed thus far, the model of inference we have chosen is the system of natural deduction as formulated by Prawitz and our means of introducing the notion of center has been to require the centering of parameters which are used as the proper parameters of quantifier introduction and elimination rules. By using Prawitz's normalization theorem, we have been able to answer the decidability question broached above for the third measure of complexity indicated above (that in terms of total number of centered entities). In particular, if "TT is a deduction in Prawitz*s system C' let c(TT) * the number of distinct parameters which occur in formulas in TT. Let T_n ■ { A | A is a parameter free formula of C^f and 3TT (TT is a deduction of A from the empty set of assumptions and c(TT) = n}.

Proposition; 1) For every n, T_n is primitive recursive.
2) For every n, $T_{n+1} - T_n = 0$

At present we are studying other formal models of inference in order to determine whether a more natural introduction of the notion of center can be achieved than in the case of natural deduction. In particular, it seems that centering, if it plays a genuine role in inferential complexity at all, ought to be relevant to the complexity of inferences In the propositional as well as in the full predicate calculus. Our natural deduction model does not exhibit this feature. Indeed, it is easy to see that all the purely propositional inferences comprehended in the model described above occur in T_0. Hence, our model does not discriminate at all among propositional inferences of differing complexity. We are currently studying ways in which the propositional complexity of inferences might be accommodated within our model, a study which seems essential if the centering phenomenon is to have bearing on the computational complexity of inferenclng procedures.

In addition, it may be that measures of complexity based on the notion of centering provide a nice structure only on a proper subcollection of all valid inferences in the propositional or predicate calculus. This seems particularly plausible in view of the fact that such measures were derived from phenomena which arise in natural discourse and the consideration that not all valid inferences may be derivable by deductions which constitute natural discourses. The question whether there are proper fragments of the predicate calculus to which the complexity measures considered here more naturally apply is currently under study.

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