

Modifying Beliefs in a Plan-Based Dialogue Model

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1 Introduction

Previous models of discourse have inadequately accounted for how beliefs change during a conversation. This paper outlines a model of dialogue which maintains and updates a user's multi-level belief model as the discourse proceeds. This belief model is used in a plan-recognition framework to identify communicative goals such as expressing surprise.

2 Plans, Beliefs, and Processing

My plan-based model of dialogue incrementally builds a structure of the discourse (a Dialogue Model, or DM) using a multi-level belief model updated after each utterance. The belief model contains the beliefs ascribed to the user during the course of the conversation and how strongly each belief is held.

Researchers [1, 3, 5] have noted that discourse understanding can be enhanced by recognizing a user's goals, and that this recognition process requires reasoning about the agent's beliefs [7]. For example, in order to recognize from utterance IS₂ in the following dialogue that the speaker has the communicative goal of expressing surprise at the proposition that Dr. Smith is teaching CIS360 and not just asking if Dr. Smith is teaching CIS420, it is necessary for the system to be able to plausibly ascribe to IS the beliefs that 1) Dr. Smith is teaching CIS420; 2) that this somehow implies that Dr. Smith is not teaching CIS360; and 3) that IP believes that Dr. Smith is teaching CIS360.

IS₁: Who is teaching CIS 360?

IP₁: Dr. Smith.

IS₂: Dr. Smith is teaching CIS 420, isn't she?

IP₂: Yes, she is. Dr. Smith is teaching two courses.

IS₃: What time is CIS 360?

My model ascribes these beliefs to IS as the discourse proceeds, and uses the ascribed beliefs for recognizing utterances that involve negotiation dialogues. Without the ability to modify a belief model as a dialogue progresses, it would not be possible to plausibly ascribe 1) or 3), so it is unclear how recognizing expressions of surprise would be accomplished in systems such as Litman's [5] that recognize discourse goals but do not maintain belief models. IS₂ also exemplifies how people may have levels of belief and indicate those levels in the

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surface form of utterances. Here, IS uses a tag question to indicate that he thinks that Dr. Smith is teaching CIS420, but is not certain of it. My belief model maintains three levels of belief, three levels of disbelief, and one level indicating no belief about a proposition.

My process model begins with the semantic representation of an utterance. The effects of the surface speech act, such as a tag question, are used to suggest augmentations to the belief model. Plan inference rules are used to infer actions that might motivate the utterance; the belief ascription process during constraint satisfaction determines whether it is reasonable to ascribe the requisite beliefs to the agent of the action and, if not, the inference is rejected. Focusing heuristics allow expectations derived from the existing dialogue context to guide the recognition process by preferring those inferences that lead to the most coherent expansions of the existing dialogue model.

The resultant DM contains a structure of the dialogue at every point in the discourse, including three different kinds of goals, each modeled on a separate level: the *domain level* models domain goals such as *traveling by train*; the *problem-solving level*, plan-construction goals such as *instantiating a variable in a plan*; and the *discourse level*, communicative goals such as *expressing surprise*. Within each of these levels, actions may contribute to other actions on the same level; for example, on the discourse level, providing background data, asking a question, and answering a question all can be part of obtaining information.² So, actions at each level form a tree structure in which each node represents an action that a participant is performing and the children of a node represent actions pursued in order to perform the parent action. This tree structure allows my model to capture the relationship among several utterances that are all part of the same higher-level discourse plan, which is not possible in Litman's model [5]. In addition, an action on one level may contribute to, or link to, an action on an immediately higher level. For example, discourse actions may be executed to attain the knowledge needed for problem-solving actions at the middle level.

This tripartite, plan-based model of discourse fa-

²The DM is really a mental model of intentions [7] which implicitly captures a number of intentions that are attributed to the participants, such as the intention that the participants follow through with the subactions that are part of plans for actions in the DM.

cilitates recognition of changing beliefs as the dialogue progresses. Allen's representation of an Inform speech act [1] assumed that a listener adopted the communicated proposition. Clearly, listeners do not adopt everything they are told (e.g., IS₂ indicates that IS does not immediately accept that Dr. Smith is teaching CIS360). Perrault [6] assumed that a listener adopted the communicated proposition unless the listener had conflicting beliefs, as in IS₂. Unfortunately, Perrault assumes that people's beliefs persist so it would not be possible for Perrault to model IS adopting IP's explanation in IP₂. I am assuming that the participants are involved in a cooperative dialogue, so try to square away their beliefs [4]. Thus, after every *Inform* action, a speaker expects the listener either to accept any claims that the speaker made or to initiate a negotiation dialogue.³ Acceptance can be communicated in two ways. Either the listener can explicitly indicate acceptance (e.g., "oh, alright"), or the listener can implicitly convey acceptance [2] by making an utterance which cannot be interpreted as initiating a negotiation dialogue. Since both parties are engaged in a cooperative dialogue in which beliefs are squared away, this failure to initiate a negotiation dialogue by default indicates (implicit) acceptance of any claims not disputed. This corresponds with a restricted form of Perrault's default reasoning about the effects of Inform acts [6]. An example of implicit acceptance is considered in the next section.

3 Example

Consider the dialogue model given in Section 2. The process model infers from the first utterance that IS is executing a high level discourse action of *Obtain-Info-Ref* to determine who is teaching CIS360 and problem-solving actions of *Instantiate-Var* and *Build-Plan* in order to build a plan to take CIS360 so that IS may eventually execute a domain action, *Take-Course*, to take CIS360. IS₂ is recognized as an expression of surprise at IP's answer since acceptance or negotiation of the answer is expected and since the following beliefs can be ascribed to IS: 1) as a default rule, that teachers generally teach only one course; 2) that Dr. Smith is already teaching CIS420 (from the tag question form); and 3) that the combination of 1) and 2) implies that Dr. Smith is not teaching CIS360. IP responds by trying to make her answer believable and to resolve the conflict. This is done by informing IS that his belief about Dr. Smith teaching CIS420 is correct, but that Dr. Smith is an exception to the default rule.

Focusing heuristics suggest explicit acceptance of or objection to IP₂ as ways to continue the current discourse plan. However utterance IS₃, instead, pursues a

³ A third possibility exists: that the participants agree to disagree about a particular point, and continue the dialogue. My model will handle this also, but it is not preferred, and for space reasons will not be considered further here.

completely new discourse action, *Obtain-Info-Ref*, unrelated to the original Obtain-Info-Ref, though still related to the problem-solving action of *Instantiate-Var* in order to build a plan to take CIS360. Since a new discourse plan is being pursued, the process model infers by default that IP₂ has been accepted because otherwise IS would have initiated a negotiation dialogue. Since the inform action is accepted (implicitly), this action, and the higher level actions that it contributes to, are considered to be successfully completed, so the goals and effects of these plans are considered to hold. Some of the goals of these plans are that 1) IS believes that Dr. Smith teaches both CIS360 and CIS420, and thus is an exception to the default rule that teachers only teach one course and 2) IS knows that Dr. Smith is the faculty member that teaches CIS360, the answer to the original question that IS asked. Once the process model recognizes IS₃ as pursuing this new *Obtain-Info-Ref* action, the belief model is updated accordingly.

4 Conclusion

Previous models of dialogue have inadequately accounted for changing beliefs of the participants. This paper has outlined a plan-based model of dialogue that makes use of beliefs currently ascribed to the user, expectations derived from the focus of attention in the dialogue, and implicit or explicit cues from the user both to identify communicative goals and to recognize altered user beliefs.

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