Conflict resolution in collaborative planning dialogs

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In a collaborative planning environment in which the agents are autonomous and heterogeneous, it is inevitable that discrepancies in the agents' beliefs result in conflicts during the planning process. In such cases, it is important that the agents engage in collaborative negotiation to resolve the detected conflicts in order to determine what should constitute their shared plan of actions and shared beliefs. This paper presents a plan-based model for conflict detection and resolution in collaborative planning dialogs. Our model specifies how a collaborative system should detect conflicts that arise between the system and its user during the planning process. If the detected conflicts warrant resolution, our model initiates collaborative negotiation in an attempt to resolve the conflicts in the agent's beliefs. In addition, when multiple conflicts arise, our model identifies and addresses the most effective aspect in its pursuit of conflict resolution. Furthermore, by capturing the collaborative planning process in a recursive *Propose–Evaluate–Modify* cycle of actions, our model is capable of handling embedded negotiation during conflict resolution.

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1. Introduction

In collaborative planning, the participants are often autonomous and heterogeneous; thus, it is inevitable that conflicts arise among them. For example, some agents may have more extensive and accurate domain knowledge than other agents, and knowledge about the circumstances of a particular planning task may be more readily available to some agents than to others. Thus, there are discrepancies in the agents' beliefs that may result in conflicts among the agents as they collaborate on constructing a plan. In order for the collaborative planning process to proceed as smoothly as possible, the agents must be able to detect these conflicts as soon as they become evident, and attempt to resolve them in the most efficient and effective manner. As a result, the agents will engage in *collaborative negotiation subdialogs* to resolve the discrepancies in their beliefs. We follow Sidner (1994) in referring to these subdialogs as *collaborative negotiation subdialogs* because the agents are working cooperatively to reach an agreement regarding the issue in dispute. In particular, collaborative negotiation subdialogs have the following features: (1) the agents are open and honest with one another, (2) the agents do not insist on winning an argument and may change their beliefs if convincing evidence is presented to

them, and (3) the agents are interested in sharing beliefs with one another to determine whether their own beliefs should be revised. Such negotiation differs from argumentation (Birnbaum, Flowers & McGuire, 1980; Reichman, 1981; Cohen, 1987; Quilici, 1992; Maybury, 1993) and other kinds of negotiation, such as labor negotiation (Sycara, 1989), in that the participants are not trying to enforce their views on one another or to maximize their own benefits, but rather are trying to share their individual knowledge and beliefs in order to determine what *really* is best for the agents as a group (Chu-Carroll & Carberry, 1995*c*).

The following dialog segment, taken from a transcript of naturally occurring dialogs between travel agents and customers (SRI Transcripts, 1992), illustrates a collaborative negotiation subdialog to resolve a conflict between two agents:

(1) C: *I talked to C.D. again, about going from Hong Kong to Moscow.*
(2)   *He made me feel like there had to be some other options besides going through Heathrow.*
(3) T: *Ok.*
(4) C: *There had to be several different cities you can go through like Beijing, to Helsinki, there has to be some options.*
(5) T: *Ok well, what I do is ask for connections available and that's what I'm getting is through Heathrow.*
(6) C: *Ok, so if somebody was in some other city and wanted to go to Moscow there has to be other options doesn't there?*
(7) T: *Oh I see what you mean, departing from a different city rather than Hong Kong.*
(8) C: *Yeah.*
(9) T: *Oh sure.*

In this dialog, T and C share a common goal—to construct the best plan for C to travel from Hong Kong to Moscow. T and C have previously constructed a plan in which C will travel from Hong Kong to Moscow by way of Heathrow Airport in London. However, in utterance (2), C expresses his belief that an alternative plan to traveling by way of London must exist, and in (4), provides his reasons for holding this belief. In utterance (5), T justifies her conflicting belief that going through London is the only available plan by explaining to C how this plan was obtained. In (6), C again insists on his original belief that other options exist and provides a different reason to support it. Finally in utterance (7), T confirms C's reason provided in (6) and in utterance (9) accepts C's belief that an alternative plan must exist. Thus, utterances (5)–(9) in this dialog constitute a collaborative negotiation subdialog for the purpose of squaring away the agents' conflict about whether or not an alternative to their original plan exists.

Although many researchers have developed systems that respond to user queries (McKeown, 1985; Paris, 1988; Seneff, Hirschman & Zue, 1991; Maybury, 1992; Moore & Paris, 1993; Cawsey, 1993; van Beek, Cohen & Schmidt, 1993, Logan, Reece, Cawsey, Galliers & Jones, 1994; Raskutti & Zukerman, 1994), with the exception of Logan *et al.* (1994), they either do not consider possible disagreements between the system and the user, or assume that the user will always accept the system's point of view when conflicts arise. However, our analysis of collaborative planning dialogs shows that conflicts