

The Role of Negotiation in Collaborative Activity

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In problem solving, people often recognize that they have goals in common. To achieve their common goals, they plan and act jointly. Collaboration sustains these activities, which is to say, that working together and working to achieve shared goals defines collaboration. People are agents in collaboration, that is, actors who have goals and can have effects in the world.

To collaborate, agents *negotiate*; they interactively come to agreement on actions and beliefs that comprise the planning and acting decisions leading to the common goal. Negotiation is fundamental to all collaboration because agents need to agree in order to act together. Collaborators accomplish negotiation through *discourses*, which are extended forms of linguistic communication, spoken or written. The most common type of discourse for collaboration is conversation. These conversations are not large scale transfers of information; rather they constitute the process of reaching agreement on beliefs and intentions that make it possible for the collaborators to act individually or collectively. These conversations are well-structured. Structure is critical to the negotiation process because it helps the collaborators determine the role individual utterances play in the negotiation.

A sample conversation is presented in Figure 1. This conversation between two people in the course of a bi-weekly meeting concerns the task of automating one person's (K's) job. While K is willing to collaborate in attaining this goal, she does not know what will make that possible. M and K's conversation negotiates the details of what is to be done. A later portion of this same conversation (not shown) concerns who will do the task and when.

M and K's conversation demonstrates a fundamental fact about collaboration: collaboration is based on the establishment of beliefs among collaborators. The conversation displays several properties of the "Shared-Plan" model of collaboration (c.f. [GS90, GK93]). M and K establish beliefs about the *recipe*, that is, the actions that will result in their goal when M and K eventually undertake them. As the SharedPlan model indicates, M and K seek to make their privately held beliefs *mutual beliefs*, that is, beliefs that they each

M: Throughput, error meeting, European congestion. We started talking at the error meeting about figuring out a good tool to deal withI mean we've seen the same kind of problem come up over and over again. And there may be some way to automate what you do a little bit.

K: One thing I've got to do [M: what?] is I've got to talk to John about his graphics stuff. Evidently people have been telling me he has a thing that makes nodes, circles and draws lines. Mean that would help even just as a start.

M: OK

K: But I have, I need to do that, and see what he he's got written. All right?

M: I'm not sure it's worth using fancy graphics on the LISP machine or stuff for this kind of thing.

K: I'm not even thinking about fancy. I mean I would just, like I said, if I had a little Xerox template that showed the nodes and I could fill in my own allergism [sic], just quickly draw it, that would be a help. [M: mm] You know.

M: Well, you'd also want.... Typically what we draw is something like this [K: yeh], right?[K: yeh] And I mean ideally I think what you'd like is a map, and then if you mark the lines that have [K: yeh] retransmissions, and then you also process the outage report and you mark the lines[K: right] that have outages[K: yup], during the same time that these ones had [K: yep] retransmissions. [K: that's] right?

Figure 1: Collaborating on Automation

come to believe and know that the other believes as well (and know that the other knows ad infinitum). In another portion of M and K's conversation not shown, they establish mutual beliefs about who can perform the actions. Collaborators must determine this agent *executability*, so that they can be sure that there is someone to do the actions of the recipe. M and K must also determine the *intentionality* of agents who perform actions. While an agent may be able to perform an action, having the intention to do so commits the agent to act in a very concrete way. Agents must have such intentions before they act. Because intentions are part of one's own mental state, agents share mutual beliefs about their own intentions, so that other agents can be assured that someone is committed to do the actions of the recipe.

M and K are clearly collaborators in the activity of creating a system that will "automate K's job a little." They do share mutual beliefs, but this portion of their conversation indicates, they do something more—they negotiate the beliefs that will be accepted as mutual between them.

Why do collaborators negotiate?

Everyone has the same intuitive answer to this question: agents negotiate because they disagree on how to reach their goals. To resolve their disagreements, they must confer together. This answer is in fact a secondary reason for negotiation in collaborative activity. The first concerns the limitations of human information about the everyday world.

Each agent comes to a collaboration with limited information, and is seeking to gain as much information as possible about how to get things done. Information is limited because agents simply do not know everything they need to in every situation. They lack information about the conditions that hold in the world and about the means to get things done. When an agent recognizes that he has a goal to achieve, he may not know which other agents, if any, want to share that goal, which agents can execute actions that will achieve the goal, and which actions are needed to achieve the goal. The information that an agent is willing to pass onto others are *beliefs*, because they are bits of information that individual agents believe themselves.

Establishing mutual beliefs distinguishes collaborative negotiation from negotiations with opposing goals among agents (such as labor disputes). Agents in collaborative negotiation benefit from mutual beliefs. When every agent believes that the others believe what he believes, he has assurance that all the parties to the collaboration believe the same critical beliefs that he does. In particular, an agent has the minimal assurance that the goal is attainable when all the agents believe individually and as a group that certain actions will achieve the goal and that specific agents can perform the actions. With any less information about everyone's beliefs, an agent must act on faith that each

agent is able and intends to do the actions that he contributes to the common goal. In non-collaborative situations, agents may wish to share only some of what they believe is the case.

Just communicating one's beliefs does not constitute a negotiation. The heart of negotiation is bringing about the acceptance of beliefs as mutually believed by other agents. Accepting another's belief as one's own assures the agent holding the belief that all the agents agree on the beliefs relevant to the goal. Mutual acceptance of one agent's beliefs is, of course, not guaranteed. The greatest complexity in negotiation arises when another agent is unwilling to believe the first agent's proposed beliefs. Everyone's intuition about collaboration thus plays a role—when agents need to agree on the beliefs that they will mutually share, they often end up in disputes about them. Negotiation includes the process of resolving such disputes.

The format for a collaborative negotiation

How do agents come to agree on the mutual beliefs? How do they signal that these beliefs are relevant to their common goal? How do they discount beliefs as irrelevant or misguided? To address these questions, I have been studying the collaborations of people attempting to achieve a variety of common goals. I have focused on their linguistic communication in conversations with one another, and to a lesser extent, their non-verbal, gestural communication. Linguistic behavior provides a great deal of data through which one can observe collaborations in action.

The conversation shown in figure 1 exhibits two paramount features of negotiation: the agreement on a common goal, and the proposal-rejection-reproposal exchange between the participants. It is M who proposes the common goal with "and there may be some way to automate what you do a little bit," while K accepts this proposal implicitly with her response in which she proposes an action that will contribute to the goal. It is also M who rejects K's proposal and re-proposal to act, and establishes the common ground of describing the means by which K's job is currently done.

This sample illustrates that (1) each person has limited information about his circumstances: M wants to automate K's job in part and wants to involve K in the process; she does not know how K will respond to her desires. As is evident from the transcript, she also has rather detailed beliefs about how to accomplish the task. K, on the other hand, does not know about M's desires to accomplish the task nor about how M wishes to go about it. K also has some beliefs of her own, rather different than M's, about accomplishing the goal. This sample also indicates that (2) agents are not just transferring information between themselves. M proposes the task, and K offers her beliefs about what activities would contribute to their goal: talking to John about graphics software and cre-

ating a “template” of the network. M also reviews the current means by which K does her job.

To capture the process of coming to mutual belief in conversations such as M and K’s, I have constructed an artificial language of negotiation ([Sid92]). This language does not capture the attentional state or linguistic structure of discourse structure ([GS86]); it does provide a detailed level of representation of intentional structure by means of the negotiation cycle process. Figure 2 contains a description of the automation conversation using the messages of the negotiation language. It must be noted that much of what is proposed in this example is not in the utterances themselves but can be inferred from them. Hence plan recognition [AP80, Kau90] is still necessary for negotiation. Recent work by Lochbaum [Loc93] presents a plan recognition model suitable for collaborative activities.

A brief review of the language will help the reader to interpret this figure. Messages containing PFA allow the receiver to conclude that the sender believes the propositional content of the message, and intends to bring about receiver’s believing the propositional content. For AR messages, the receiver can conclude that both sender and receiver believe that the receiver believes the propositional content and that both believe the receiver intends for the sender to believe the propositional content. For RJ messages, the receiver believes that the sender does not believe the propositional content, while for AP messages, the receiver can conclude that there is mutual belief in the propositional content of the message.

The negotiation language makes beliefs held between the conversational partners more evident. For example, when K receives the message labeled P1 in Figure 2, she can conclude that M believes that there is a way to automate K’s job, and that M intends for K to come to hold that belief as well. All PFA messages are labelled in the figure.

The negotiation language does not commit agents to action upon accepting beliefs. Commitment to action [Win86, Sho90] must be captured by additional rules of action and intention either agreed to by the collaborators or assumed by default. A understanding of the nature of commitment rests in part on a clear picture of what agents believe and mutually believe. For example, what conclusions about commitment follow when an agent A receives a PFA message from agent B with a propositional contents of (Should-do A some-action), and A sends back a message (AP A (Should-do A some-action) B)? A and B mutually believe that A should-do some-action, but does that mean that A committed to do it? Suppose instead the contents of message were: (Want/Intend/Demand B (Do A some-action)). Is commitment clearly forthcoming? It is not always sensible to conclude that A is automatically committed to the action on the basis of mutual belief that A should perform some-action or that B wants or intends that A do the action as the familiar circum-

- P1: (PFA M “There may be some way to automate what you do a little bit” K)
- P2: (PFA M (Undertake M&K (Automate K’s job)) K)
- P3: (PFA K “I must talk to John about his graphics stuff” M)
 - (AR K P1 M)
 - (AR K P2 M) [conveyed by P3]
 - (AP K P1 M)
 - (AP K P2 M)
- P4: (PFA K “People been telling me about his program” M)
- P5: (PFA K “People say John’s program makes nodes, circles and draws lines” M)
- P6: (PFA K (Using John’s program will contribute to our goal) M)
 - (AR M P3, P4, P5, P6 K) [from M: OK]
- P7: (PA K (K evaluate John’s program) M)
- P8: (PFA K (Should-do M (AP M P3,P7 K)) M)
 - [from K: All right?]
- P9: (PFA M (Not worth using fancy LISP machine graphics to accomplish our goal) K)
 - (RJ M P8 K)
- P10: (PFA K (I am not thinking of fancy graphics) M)
 - (AR K P9 M)
 - (RJ K P9 M)
- P11: (PFA K (I need a template to show nodes, ...) M)
- P12: (PFA K (The template program will contribute to our goal) M)
- P13: (PFA M “What we typically draw is something like this” K)
 - (AR M P10 &P11 &P12 K)
 - (RJ M P10 &P11 &P12 K)
- P14: (PFA M (Should-do K (AP M P13 K)) K)
 - [from M: right?]
- P15: (PFA M “(What you’d like is a map)” K)

Figure 2: A translation of the M and K conversation

stance D1 below illustrates. Rather commitment may be specified on the basis of beliefs about the action to be performed, the relevance of the action to common goals, and the acceptability of that action to the agent in the social context.

D1: Parent: You should take out the garbage.

Teenaged kid: Ok, okay. (No action follows)

The translation of M and K’s actual conversation also displays several rounds of proposals and acknowledgements. Significant differences between the natural conversation and the simulated one emerge as well. First, people rely on their conversational partners to infer what they are doing. While people sometimes explicitly accept and reject proposals, often they just extend new proposals and expect that their partners can infer that some previous proposal is either accepted or rejected. M and K’s (actual) conversation contains no explicit language for the acceptance of the initial proposal about automating K’s job, or for the rejection of K’s proposals concerning the evaluation and use of John’s program. K signals her agreement with the initial proposal by proposing actions that she thinks will contribute to the goal. M’s signals her rejection of K’s

proposed actions through from her negative comments about fancy graphics and her long remarks about what is typical to draw. M's initial proposal to automate K's job is the most complex form of inference in this example. She expresses a belief, and K's acceptance of it allows M to assume that K will infer that M means for them to undertake a collaboration on the basis of this acceptance!

A second difference in human communication for negotiation concerns the lack of certain actions. People understand the lack of an acceptance of a proposal to be evidence that their conversational partner rejects it. When M only acknowledges the receipt of K's proposals about John's program, K concludes they are not accepted, and re-proposes some of her proposals. In fact it is never completely clear what M has believed of K's proposed beliefs. While M clearly rejects P8, it is not clear whether M believes P4 and P5, which are could be believed even if P8 is rejected.

Finally, it becomes clear that "OK" is a highly loaded word in English; it seems to mean a variety of things. Intonation appears to be a factor in disambiguating meaning. The tune of "OK" in M and K's conversation is low and reduced in volume. While these features alone do not signal any particular negotiation action, their use, together with the absence of any speech that supports accepting the previous proposal, indicates only acknowledgement of the message, not acceptance.

Necessary Features of Man-Machine Collaboration

The automation dialogue illustrates the role of belief and mutual belief in human collaboration. I am now exploring the design of a user interface in which collaboration and negotiation are the underlying models of communication. That the user and machine are collaborating means that they may need to establish beliefs about recipes, agency and intention for actions that lead to the goal. If they already hold such beliefs and are engaged in the actions of the activity, then they must share beliefs about the success or failure of their actions and about alternative recipes in the case of failure.

To establish beliefs and mutual beliefs, the person and machine use a language of negotiation. One choice would be to require that people adapt to an artificial language, such as the one discussed here, suitably doctored with predicates such as "propose, acknowledge, accept, reject, counter," and the like rather than terms such as PFA, AK, AP, etc. This choice burdens a user with yet more special terms to use when conversing, a option that is less than ideal. As an alternative, I am exploring a small sub-language for a particular domain (airline travel reservations) in which the type of negotiation is determined in part by utterance type (e.g. "no" is taken as rejection) and part by the context of what has been previously negotiated.

In summary, the nature of human-machine collab-

oration can draw greatly on the features of human-human collaboration. Most especially human to human collaboration involves negotiation of what is to be believed among the collaborators. Extending this form of interaction to human-machine collaboration will provide each agent with a better understanding of the dynamic state of each's beliefs.

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