Human-Agent Collaboration in Meetings

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Abstract
Both virtual and embodied intelligent agents are being designed and deployed in multi-user situations, and we join this research effort by proposing a series of research projects that aim to design and build a meeting facilitation agent. The agent should be able to facilitate the *right activities*, in the *right way*, and at the *right moment*. Our designs are informed by human-human group meeting theories and meeting facilitation frameworks. Moreover, we are interested in exploring the differences between human-human collaboration and human-agent collaboration, and how such uniqueness of an agent can expend human teams' capabilities in the meeting context.

Author Keywords
Human-agent collaboration; meeting facilitator; intelligent agent; robot; teamwork.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction
Artificial agents that talk and interact like humans have been a long-time interest of researchers. Naturally, many researchers have been inspired by human-human interaction. Some have gone so far as to build computational models that operationalize theoretical models from communications and sociolinguistics [2; 4]. Most of this work has focused on the case where an artificial agent is interacting with a single human.

Our interest is in designing agents that interact with groups and teams. In this, we join an emerging trend in designing and deploying both virtual agents (e.g., chat-bots) and embodied agents (e.g., robots) to function in multi-user situations [7; 9; 10; 15]. This, in turn, requires that we look beyond interaction among pairs of individuals, and broaden our scope to include interaction within groups. Fortunately, there are a variety of theories of group (e.g., [13; 14]) and organizational behavior to draw on (e.g., [6]).

The focus of our design work is to explore the use of artificial agents to facilitate meetings. This leads directly to two intertwined research questions:

RQ1: a) What aspects of meetings require facilitation? And b) how should any facilitation be carried out?

For example, one might identify facilitation targets such as introducing two people in the meeting to each other, or intervening when one person is talking too much. Either of the facilitation attempts could be carried out publicly — for example, by a robot taking the floor and speaking to the group — or privately, by a chat-bot that appears only to the person or people directly involved. And, of course, each of these courses of action contains a lot of subtleties: when and how a robot should 'take the floor' in a group interaction.

RQ2: To what extent is the interaction between an artificial agent and a group similar to the interaction between a human agent (playing the same role) and the group?

In addition to the research question of what needs to be facilitated and how it is carried out, we are also interested in a second research question that bears on our methodology. Does human behavior dictate the design of how agents ought to behave? We are not convinced, as an artificial facilitator's interaction with a group might necessarily be different from a human facilitator's interaction. Human's might have different interpretations and expectations of an artificial agent than they would a human. For example, it is plausible that an artificial agent that intervenes to suggest that a person is talking too much will be assumed to have simply based the suggestion on tracking individual speaking times, whereas the same statement made by a human facilitator might be assumed to be based on boredom or judgements of the importance of the speaker, either of which could be grounds for offense.

Our proposed work presents a unique opportunity to conduct comparative studies as we are developing an agent that will replace a human who has an equivalent role in the group. Specifically, we propose to study the differences in two ways: 1) conducting empirical studies to compare group interactions with artificial agents and that of human agents, under the theoretical framework of group meeting behaviors; 2) studying the fitness of computational models developed from human-human interaction when applied to human-agent interaction, thus allowing us to using a data-driven approach to identify differences between human-human and human-agent interaction. By developing these two complimentary methods, we hope to make both empirical and methodological contributions to the research community.

Related Work

Our goal is to design intelligent agents to support group meetings. Researchers from social science, human computer interaction (HCI), and business schools have a long history of studying group meetings, and there are many theories proposed to describe meetings and meeting facilitation. Two areas of work particularly relevant to our study are: McGrath who found that group activity may have one or more mode of operation: inception, problem-solving, conflict resolution, and execution [13; 14] and Bostrom et al. who proposed a framework of Group Facilitation [1].

Researchers have also spent decades designing, studying, and improving meeting-support systems, in particular video-conferencing systems, to support remote meetings [20; 16; 3]. Among these works, the most relevant one to our study is that researchers have explored different ways of representing the remote participants in a meeting (e.g., a cartoon icon, a full-size avatar on screen, or the face), and how the avatar design can significantly influence people's perceptions and experience of the meeting [11].

History shows us that mechanically applying existing theories of human-human interaction to the design of human-agent collaboration is ill-advised. The failure of Microsoft's paperclip is a classic example of mechanically applying the Computers-Are-Social-Actors (CASA) theory [17] to design an intelligent agent in early days [18]. There should be differences between human meeting facilitators and agent meeting facilitators and the goal should not be designing an agent to mimic human. Take the distributed collaboration studies as an analogy, at the beginning many researchers tried to mimic the collocated collaboration aspects; then Jim Holland argued that replicating collocation is not the goal of supporting distributed collaboration, rather, it should be "beyond being there" [8]. Therefore, in our effort of designing meeting facilitator agents, we are exploring the unique advantages of agent facilitators compared to human facilitators.

Human-agent collaboration is not a new research topic though, as early as the 1960s people were considering interaction with intelligent agents [12]. Then, in the 1990s, researchers found that people tend to perceive computers as teammates when they collaborate with these machines [17]. Only recently are there studies about the effects of human-agent collaboration on task efficiency [5], human relationships, and perceptions [7] in real-world teamwork scenarios, such as in search and rescue missions [9]. But search and rescue missions are less common collaboration scenarios than workplace collaboration scenarios in people's daily life. Thus, in our work, we follow the trend of studying human-agent collaboration in real-world scenarios, but focus our research interest on a teamwork scenario—that millions of people participate in everyday—workplace meetings.

Research Agenda

To answer RQ1, we will start by studying human meeting facilitator behaviors (Phase 1). We will then conduct wizard-of-oz studies to empirically identify effective facilitating behavior designs for artificial agents (Phase 2). The results, by comparing to human facilitator behaviors, will provide some insights to answer RQ2. At the functional system development stage (Phase 3), we will learn further about RQ2 by testing and tuning computational models learned from human-human interactions.

Phase 1: Building up a baseline of human meeting facilitator behaviors

We plan to record and study the weekly meetings of multiple workplace groups to build up a baseline of how a human agent facilitates meetings. We will collect video data, sensor data and conversation scripts, and focus on behavioral and text analysis.

In the first step, researchers will annotate and extract excerpts of meetings based on the taxonomy proposed by Group Facilitation framework [1]. For instance, one excerpt may be labeled as "group engaging in conflict resolution". We will then focus on analyzing facilitators' behaviors within this excerpt. A grounded-theory based approach will be used to identify a taxonomy of facilitating strategies for mediating group conflicts across multiple excerpts with the same label. Statistically, we will also be able to identify the most common and the most effective set of strategies (e.g., by labeling the outcome and conducting predictive analysis).

Phase 2: Wizard-of-Oz study testing various designs of an agent meeting facilitator intervention

Facilitation strategies adopted by human facilitators are a useful resource to inspire agent facilitator designs, but the question remains as to their transferability. We learn the lesson from numerous previous studies that human-agent interaction and human-human interaction typically differ in many aspects. From an information-processing perspective, the differences may fall on the stage of 1) sensing/attention. For instance, the same communication strategy may be more or less likely to be sensed when it is coming from a robot, sometimes due to the physical form;2) interpretation/ comprehension. Although the classic computer-as-social-actor (CASA) paradigm suggests that people tend to apply the same set of social rules to artificial objects, many studies have also provided counterevidence, sometimes due to the novelty effect of new technologies; 3) response/interaction. Because we do not expect people to interact with an agent facilitator in the same way they interact with human facilitator, we see an exciting opportunity to introduce designs that illicit novel interactions with agents that outperform human facilitation.

Plenty of research opportunities exist for inquiring about these potential differences. We plan to conduct wizard-of-oz experiments to study the transfer effects of facilitation strategies we identified from human facilitators to agent facilitators. Beyond identifying a set of effective strategies for agent facilitator design, we hope to deepen our understanding of the differences between human-human and human-agent interaction in collaborative contexts. For example, by looking at the set of transferrable strategies and the set of non-transferrable ones, we may be able to identify general mechanisms that mediate how people sense, comprehend and interact with artificial agents.

Phase 3: Building functional intelligent agents in various representations to facilitate a meeting

While the previous two phases aim to answer the "how to facilitate" question, this will be the phase we attempt to answer "when to facilitate". We hope to create methodologies that allow for iterative development of computation models that automate agent facilitation.

In the first step, we will build machine learning models for the set of effective strategies of agent facilitators we identified in phase 2. We will build the model based on the human facilitator data we collected and labeled in phase 1. These models should be predictive, as our fundamental question is to answer "what signals in the group in time T-1 predict facilitators to engage in the particular intervention (as we labeled) in time T". Multiple candidate modeling approaches (e.g., classification, transient models) can be experimented with by using both textual features from the conversation logs and behavioral data from video and sensors. We will also resort to behavioral and social theories to aid the feature selection.

At this step, we will pay attention to the top predictive features for different facilitating strategies. By seeking associations (and disassociation) with behavioral theories, we may further refine our models and potentially discover new knowledge about meeting facilitation.

We then transfer these models to agent algorithms and conduct evaluative studies. We expect mismatch in transferring these models learned from human agent behaviors to agent behaviors. By tuning these models through iterative user research, there is opportunity to gain further knowledge of the differences between human-human interaction and human-agent interaction. For example, we may compare the top predictive features between human facilitator models and our final models of agents.

Conclusion

In this work, we propose a series of studies to develop a meeting facilitation agent that is able to facilitate the *right activities*, in the *right way*, at the *right moment* in a meeting. We build up our work based on existing group meeting and meeting facilitation theories, while paying close attention to their limitations as these may shed light on the differences between human-human and human-agent interaction. Such differences have been given increasing consideration recently, as they are not only important from a design perspective, but are also critical for developing AI technologies that are primarily using data-driven methods (e.g., [21]).

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