

# Enabling Human-Robot Collaboration via Argumentation

## (Extended Abstract)

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### ABSTRACT

A case is made for *logical argumentation* as a means for enabling true collaboration between human and robot partners. The majority of human-robot systems involve interactions in which the robot is subordinate, and all high-level decision making is performed by the human. However, in order to enable human-robot partnerships, both parties must be able to participate in constructive dialogue where each party can present ideas, these are discussed, and a shared conclusion is agreed upon. Argumentation is a method that can support such needs, as outlined in this short paper.

### Categories and Subject Descriptors

I.2.11 [Artificial Intelligence]: Distributed Artificial Intelligence—*Coherence & co-ordination; languages & structures; multiagent systems.*

### General Terms

Languages, Theory

### Keywords

Human-Robot Interaction, Argumentation

## 1. INTRODUCTION

Humans interact with each other in a range of relationships, some of which are subordinate while others are collaborative, where the skills of one complement those of the other. Each of these relationships, to be successful and productive, relies on some amount of communication, *dialogue*, in which each party presents ideas, which are discussed together, and a shared conclusion is agreed upon by both. In contrast, the vast majority of human-robot relationships are ones in which the human is master and tells the robot what to do. This puts many limitations on human-robot interaction: if a robot fails at its assigned task, it can only report failure and cannot discuss the reasons for that failure; a robot cannot recognize new opportunities and interrupt its task to suggest alternate actions. Dialogue that is founded on unscripted and opportunistic exchange of ideas

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does not exist in current human-robot interaction (HRI) systems, where the focus is largely on natural language architectures [5] or delivery methods [3], rather than dynamic content selection. For HRI systems to be truly collaborative, participants need to be able to engage in constructive dialogue that can adjust dynamically as the dialogue and situation unfolds. *Argumentation* [10] is a well-founded theoretical method that can support such needs. *Argumentation-based dialogue* [6] can be used to handle situations such as recovering from failure, pre-empting failure, and revising plans. In this short paper, we make a case for argumentation to enable true human-robot collaboration.

## 2. APPROACH

Our approach combines theoretical models of logical argumentation-based dialogue for implementation in a dynamic human-robot setting. Traditional autonomous robot control architectures involve steps in which a human is not consulted: first, the robot senses its environment; second, the robot formulates an intended plan for what to do in order to achieve its goal and selects actions accordingly; then, the robot performs the selected actions; and the process repeats. Although modern architectures employ less sequential strategies, these fundamental ideas are widely utilized. We are concerned with situations in which a robot and human seek agreement about the goal that they are trying to achieve and the plan they will attempt in order to achieve their goal. Our approach engages human and robot in an argumentation-based *dialogue game* [6], where they exchange locutions according to a protocol in order to reach agreement about goals and plans. Argumentation-based dialogue protocols include: *information-seeking* [11], where one agent asks another agent a question that it believes the other can answer; *inquiry* [4], where two agents collaboratively answer a question that neither knew the answer to beforehand; *persuasion* [8], where an agent tries to alter the beliefs of another agent; *negotiation* [9], where two agents attempt to reach agreement about allocation of a scarce resource; and *deliberation* [7], where agents collaboratively decide what action to take.

We model *human-robot dialogues* between a robot,  $R$ , and a human,  $H$ , using the following notation:  $\Delta_R$  is the set of beliefs that the robot has about its environment and the world;  $\Gamma_R(H)$  is the set of beliefs that the robot has about the human, i.e., what the robot believes the human believes;  $CS_R$  is the robot's *commitment store*, the set of propositions that have been put forth in the dialogue by the robot;  $CS_H$  is the human's commitment store;  $\mathcal{G}oals_R$  is the set of robot's

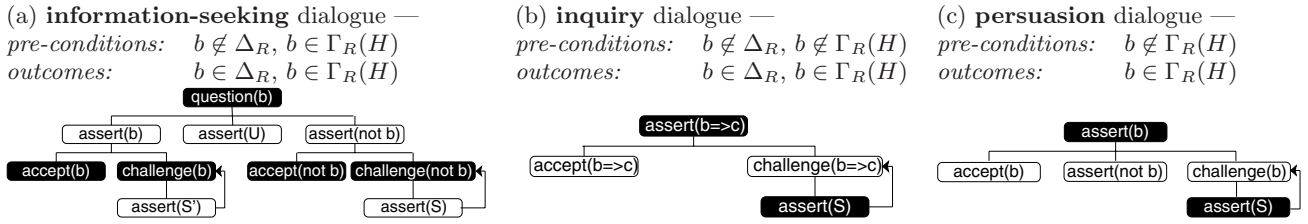


Figure 1: Protocols for discussing beliefs

goals;  $Plans_R$  is the set of robot’s plans; and  $\Sigma_R$  is the information the robot can use in the dialogue, where:  $\Sigma_R = \Delta_R \cup \Gamma_R(H) \cup CS_R \cup CS_H \cup Goals_R \cup Plans_R$ . The robot is only allowed to utter locutions that make use of information from  $\Sigma_R$  [6]. A dialogue may affect the robot’s beliefs ( $b \in \Delta_R \cup \Gamma_R(H)$ ) or actions ( $a \in Actions$ ).

Figures 1 and 2 show our human-robot dialogue protocols. The *pre-conditions* must be true in order for the dialogue to apply; and the *outcomes* come true when a dialogue terminates. The trees outline locution sequences, where the top level (root) is uttered by the participant who initiates the dialogue (white text on black). The next level contains the possible responses by the other participant (black text on white), and so on. Some locutions cause the dialogue to terminate, such as *accept(b)*. Other locutions cause the dialogue to loop back, such as *assert(S)*. For example, if a participant’s assertion,  $A$ , is challenged, then she presents  $A = (S, b)$ , where  $S$  is the support for  $b$ . If the challenger agrees with the support, then the conclusion is accepted. Otherwise, the dialogue reaches an impasse (because a participant would be forced to repeat herself).

Three types of dialogue allow the human and robot to discuss *beliefs*: **information-seeking** is used when the robot asks a question of the human, or vice versa; **inquiry** is used when the robot and human work together to answer a question; and **persuasion** is used when the robot wants to alter the human’s beliefs. This type of dialogue is helpful for error prevention: e.g., when the human asks the robot to execute a plan which the robot believes will fail. Two types of dialogue allow the human and robot to discuss *plans* and *goals*: **negotiation** is typically used when two agents need to reach an agreement about allocating resources; and a **deliberation** dialogue can be used when the human and robot need to decide on a plan. Negotiation is used to discuss a task,  $k$ , and makes use of a special type of connective:  $k \rightsquigarrow j$ , which can be read as: *if k then j*, i.e., *if you do k, then I will do j* [1]. Deliberation is used for one agent to propose that an action,  $a$ , be undertaken, to which the second agent can either *accept(a)* the proposal, agreeing to execute the specified action, or voice a preference for a different action,  $z$ : *propose(z>a)*.

### 3. SUMMARY

We have presented a model for human-robot interaction that supports flexible and dynamic argumentation-based dialogue. Our methodology applies theoretical models in a real-time setting and contributes to both HRI and argumentation. Current work includes a user study to assess an implementation of the methodology outlined here and evaluate the effectiveness of our approach with human subjects [2].

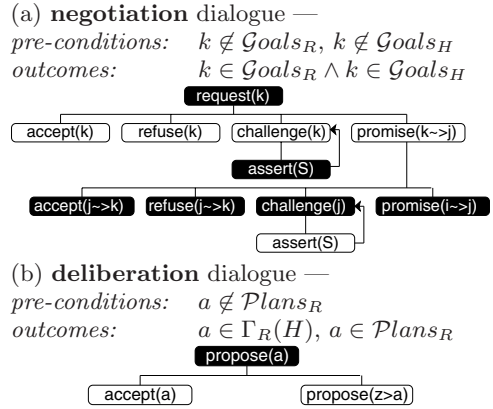


Figure 2: Protocols for discussing plans and goals

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