

An Argumentation-based Dialogue System for Human-Robot Collaboration

(Demonstration)

Mohammad Q. Azhar^{1,2}, Simon Parsons^{2,3}, and Elizabeth Sklar^{2,3}

¹Borough of Manhattan Community College,

²The Graduate Center and ³Brooklyn College

The City University of New York, New York, USA

mazhar@bmcc.cuny.edu, parsons@sci.brooklyn.cuny.edu, sklar@sci.brooklyn.cuny.edu

ABSTRACT

Human-robot collaboration may fail due to conflicts in beliefs or plans between cooperating partners, or due to robot errors. Dialogue is an intuitive way to resolve such conflicts due to miscommunication. The research demonstrated here explores the notion of using argumentation-based dialogue for human-robot interaction. The demonstration presents a proof-of-concept prototype of a logic-based dialogue framework grounded in argumentation theory that addresses the “what to say” problem in human-robot communication during a collaborative task. A simulated human-robot *treasure hunt game* is shown, where a robot searches for objects of interest in a region that is not accessible to a human and interacts with the human in order to interpret its sensor data and complete the task effectively.

Categories and Subject Descriptors

I.2.9 [Robotics]: Miscellaneous; H.1.2 [Models and Principles]: User/Machine Systems—*Human factors*

Keywords

Dialogue Modeling, Argumentation, Human-Robot Collaboration, Human Robot Interaction

1. INTRODUCTION

Generating effective robot dialogue during human-robot interaction (HRI) is difficult. Our research involves designing and implementing an *argumentation-based HRI dialogue framework (ArgHRI)* that can provide an effective mechanism of support for generating dialogues to resolve conflicts (i.e., conflicting beliefs, plans and goals) and diagnose robot errors during human-robot collaboration. The research approach centers around generating the content of effective dialogue based on reasoning using logical argumentation [1]. In our framework, a robot maintains beliefs about its world and its human dialogue partner, which are updated in real time. Using these beliefs, the robot reasons about the world

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and generates plausible task-based dialogue that aids toward fluent and meaningful human-robot communication, with the goals of resolving conflicting beliefs and explaining robot errors.

In our demonstration, a human and a robot collaborate using dialogue to find treasures—objects of interest—in a simulated *treasure hunt game*. The system places multiple “treasures” dynamically in a simulated arena, which is divided into seven regions: six rooms and a hallway. Our ArgHRI framework provides dialogue support for *one* robot collaborating with *one* human. The system does not interpret or process natural language. Dialogues are supported through labels and icons on the human collaborator’s interface. The human participant needs to provide an abstract action plan (e.g., go to room 1, 2 and 3) to the robot in order to achieve their mutual goal (e.g., find all treasures). The robot uses a classical planning algorithm to execute the plan. Our framework allows the human and robot to engage in a dialogue in which they share premises and can exchange the reasons for the beliefs that they hold to resolve conflicts or diagnose errors.

2. BACKGROUND

Argumentation is a reasoning mechanism modeled after human argumentation, deriving reasoning semantics by analyzing the supports and defeats. *Argumentation dialogue* is based on argumentation theory [5] and can be used to evaluate the acceptability of an argument for resolving conflicts and making collaborative decisions. In a human-robot environment, both participants have to constantly deal with uncertain and conflicting information while collaborating in the dynamic physical world, which can lead to *conflicting beliefs*. *Information-seeking*, *inquiry* and *persuasion* dialogues are human communication techniques for conflict resolution during collaboration.

Robot errors may occur due to conflicting information, miscommunication or simply lack of communication. Inquiry and information-seeking dialogues could be employed to resolve robot errors due to miscommunication [3].

Current research on human-robot dialogue primarily addresses the “how to say it” and “when to say it” problems. The “how to say it” problem addresses the best way for a robot to *deliver* (e.g., using text, speech or different modality) dialogue content [4]. The “when to say it” problem considers the timing of dialogue delivery. Many existing HRI systems use scripted dialogue management modules (e.g.,

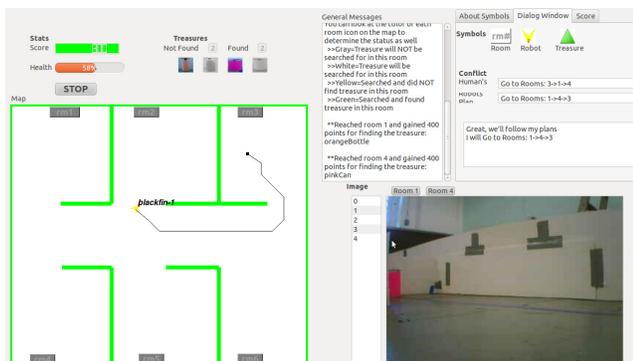


Figure 1: ArgHRI Dialogue Manager

robot receptionist [2]). However, a scripted dialogue model is insufficient for robots that operate in a highly dynamic and changing environment where human and robot work together, such as search and rescue.

3. OUR APPROACH

In contrast, our work contains several innovations that contribute to both the human-robot interaction and the argumentation communities by providing a structured HRI method for a robot to maintain its beliefs, to reason using those beliefs, and to interact with a human via dialogue to resolve conflicts and diagnose errors; a dialogue framework that is integrated into planning and decision-making for a human-robot collaborative task; and a practical, real-time dynamic implementation in which argumentation is successfully applied.

Our argumentation-based human-robot collaboration system, *ArgHRI*, consists of four major components: an **ontology** that describes the robot’s environment and capabilities; a **memory system** for the robot to maintain its beliefs; an **argumentation engine**, *ArgTrust*, adopted from [7], that supports the robot’s internal decision-making; and a **dialogue system** for interacting with a human. An argumentation-based dialogue manager for human-robot collaboration has been implemented (see Figure 1) and integrated into the *HRTeam* framework [6], which supports both *simulated* and *physical* experimentation with mixed-initiative human/multi-robot teams.

The ArgHRI interface has two modes for experimentation: **minimum dialogue mode**, where the user is given a choice to select a plan and the robot executes the plan; and **full dialogue mode** where the user steps through several panels:

1. *belief dialogue panel*: the user enters her beliefs about possible locations of treasures;
2. *plan dialogue panel*: the user chooses the sequence in she wants the robot to traverse locations;
3. *conflict dialogue panel*: the system checks if there is a conflict between the robot’s and human’s plans. The robot’s plan is based on the robot’s location and its battery power. A “health bar” (e.g., battery power) on the upper left side of the interface is meant to remind the participant about the robot’s limited amount of

energy. The robot can not traverse all the rooms since there are limits on robot’s battery which runs out as the robot travels. The human participant needs to decide on his/her beliefs about the locations of treasure considering the robot’s battery power and the number of treasures on the map. The system displays the number of treasures as “not found” in the beginning of each run. If the robot’s plan is different from the human’s plan, an explanation will be given. In this simple demonstration, the conflict arises when the cost of the human participant’s proposed plan is higher than the robot’s plan. The human can “agree” or “disagree” with the robot’s plan. If the human agrees, then it will execute its plan, otherwise the robot will execute the human’s plan.

4. CONCLUSION

We recently conducted an informal user study and a more formal pilot study with human subjects using a physical robot. The survey results of our pilot study suggested that the full dialogue mode, implemented in our argumentation-based framework provides meaningful communication as compared to minimal dialogue mode. This demonstration is an initial proof-of-concept for our argumentation-based dialogue framework to support human-robot collaboration. Our long term goal is to extend the ArgHRI framework to provide extensive dialogue support for more than one robot during human-robot collaboration in a dynamic search and rescue domain.

Acknowledgments

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