Challenges to Grounding in Human-Robot Interaction

Sources of Errors & Miscommunications in Remote Exploration Robotics

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ABSTRACT

We report a study of a human-robot system composed of a science team (located in Pittsburgh), an engineering team (located in Chile), and a robot (located in Chile). We performed ethnographic observations simultaneously at both sites over two weeks as scientists collected data using the robot. Our data reveal problems in establishing and maintaining common ground between the science team and the robot due to missing contextual information about the robot. Our results have implications for the design of systems to support human-robot interaction.

Categories and Subject Descriptors

H.1.2 [**Models and Principles**]: User/Machine Systems; I.2.9 [**Computing Methodologies**]: Artificial Intelligence—*Robotics*

General Terms

Human Factors

Keywords

human-robot interaction, exploration robotics, ethnography, mutual knowledge, common ground

1. INTRODUCTION

The use of robots, especially autonomous mobile robots, to support work tasks is expected to rise significantly over the next few decades. However, there have been relatively few observational studies of people and robots working together in the unstructured "real world." Our goal in this research is to better understand how errors and misunderstandings occur in human-robot systems.

The setting we studied was the "Life in the Atacama" (LITA) project, a project intended to be analogous to planetary exploration but in which the exploration was done on Earth. There were two groups of people and one robot (Figure 1): a group of users commanding the robot remotely (the science team) and a second group collocated with, monitoring, and often issuing commands directly to the robot (the engineering team).

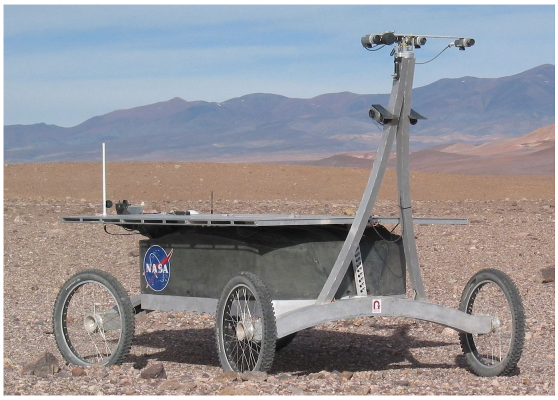

Figure 1: Zoë, the "robotic astrobiologist" used in the Life in the Atacama project.

2. RELATED WORK

Common ground refers to the knowledge, beliefs, goals, and attitudes that people share [1]. Clark and his colleagues [1] propose that common ground is required for successful collaboration - it helps collaborators to know what information is needed by their partners, how to present information so that it is understood, and whether or not the information has been interpreted correctly.Our observations suggest that grounding, the interactive process by which common ground is established, was problematic for the distributed human-robot teams in our study.

We are aware of several other studies that examine the grounding process as it might be applied to HRI. Jones and Hinds [3] observed SWAT teams and used their findings to inform the design of robot control architectures to coordinate multiple robots. More recently, Kiesler and her colleagues [4] have described experiments that report more effective communication between people and robots when common ground is greater. These early studies suggest that the grounding process provides a rich opportunity for understanding human-robot interaction.

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3. METHOD

The focus of this study was the Life in the Atacama (LITA) project, a multi-disciplinary collaboration primarily funded by NASA. Zoë, the robot in use during our study, is a four-wheeled, solar-powered rover equipped with a number of scientific instruments (see Figure 1). During 2004, a group of biologists, geologists, and instrument specialists spent two weeks in Pittsburgh commanding Zoë to collect data in order to search for life in the desert. During this period of remote science operations, observations were conducted simultaneously in Pittsburgh and in Chile. Field notes, combined with 63 artifact documents, formed the data set that was used in our analysis. In this paper, we focus on the problems created for the science team due to a lack of contextual information they received about the robot.

4. RESULTS: MISSING ROBOT CONTEXT

Missing contextual information about the state of the robot and the environment in which it was situated, especially information from the robot about the context in which data products were gathered, was a recurring problem for the LITA science team. In most cases, these failures in creating common ground resulted in errors in data collection or in uncertainty about how to interpret what was collected.

Without sufficient information about data and the context from which it is collected, making sound scientific judgments can be challenging. The science team received a number of bad data products from Zoë over the course of remote science operations. In one instance, the robot returned two pictures that were supposed to have been taken of its solar panels, but the two pictures were of entirely different parts of the robot. At first, one member of the team commented that "our targeting's off," but as the science team inspected the data more closely, it became apparent that the robot was reporting that the same camera angles had been used for both pictures, meaning that the images should have been essentially identical.

In another instance, the science team received a fluorescence image in which nearly half of the field of view appeared to be glowing, signaling the possible presence of life. This caused a great deal of excitement and confusion, as it was unclear whether the team had found a particularly fruitful patch of ground, whether the camera had malfunctioned, or whether something else was amiss. After nearly a day spent investigating the mysterious image, the team concluded that the image was taken later in the day than expected and sunlight had been shining underneath the robot, resulting in the strange glow they had observed. In both of these cases, a lack of information about the data and its context resulted in confusion and much time spent trying to deduce what could have gone wrong.This not only wasted valuable time and resources, but it also created frustration for team members.

5. IMPLICATIONS FOR HRI DESIGN

To help users to develop common ground with the robot and learn how to use the robot effectively, our observations suggest that more accurate and timely information about the state of the robot and its actions is needed. Our results suggest that the following information should be made accessible to users in language they can easily understand:

1. Technical information about the health of the robot and its instruments.
2. Status reports about the activities requested by the users, including any discrepancies between these requests and the location, time, or method used to collect the data.
3. When failures occur, specific information about exactly what failed and why.
4. Information relevant to the constraints under which the robot is operating, such as the exact amount of time and energy required to collect and transmit each data product.

6. DISCUSSION

Our use of common ground theory to explore the LITA project addresses issues that have not yet been raised in most other work in HRI. In contrast to previous work which has largely focused on the experience of a single user, the common ground framework provides insights into the social processes used to frame interpretations of the robot's activities and guide the development of users' mental models of the robot. Due to space constraints, our focus here has been on information needed by the science team for grounding, but a common ground framework also points to the information needed by the robot for the users and robot to have common ground.

Our results apply directly to several HRI scenarios, such as space exploration and urban search and rescue (USAR) [5]. Our analysis indicates that finding ways to create and maintain common ground between users and the robot will be crucial to users' ability to collaborate effectively with robots, achieve their goals with minimal frustration, and be confident in the conclusions they draw from data collected by robots on their behalf.

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