Evaluating Mobile Remote Presence (MRP) Robots

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ABSTRACT

Video teleconferencing systems (VTCs) have enhanced remote meetings because their ability to convey nonverbal or social cues can make them simulate in-person interaction more closely than telephone conversations. Yet many people feel that something is still lacking, most likely because VTCs require all interaction to take place in a pre-defined set of rooms and/or from a single viewpoint. In contrast, mobile remote presence (MRP) robots, sometimes called telepresence robots, enable participants to move their focus from their colleagues' faces to a screen at the front of the room, to artifacts on a table, to posters or sticky notes on the room's walls, etc. Consumers now have a choice of several commercially available MRP systems, but there are few evaluation methods tailored for this type of system. In this paper we present a proposed set of heuristics for evaluating the user experience of a MRP robot. Further, we describe the process we used to develop these heuristics.

Categories and Subject Descriptors

H.5.3 [**Group and Organization Interfaces**]: Computer-supported cooperative work

General Terms

Human Factors, Experimentation

Keywords

Human Robot Interaction, Heuristics, MRP, Telepresence, Robotics, Usability, Robot.

1. INTRODUCTION

VTCs can be thought of as telepresence (stationary remote presence) systems. Sheridan described telepresence as a remote human operator receiving "sufficient information about the teleoperator and the task environment, displayed in a sufficiently natural way, that the operator feels physically present at the remote site." [10, pg. 6] Rosenberg defined telepresence as "a human-computer interface which allows a user to take advantage of natural human abilities when interacting with an environment other than the direct surroundings" [8]: in other words, a system that can enable users to interact naturally with a remote environment. Steuer defined telepresence as "the experience of presence in an environment by means of a communication medium" [9, pg. 74] the feeling of "being there." [9, pg. 76]

Mobile telepresence robots (that is, mobile remote presence, or MRP, robots) can provide a more flexible telepresence experience than VTCs by allowing participants to have some degree of mobility in the remote environment. MRP robots are typically a mobile platform with some form of audio/video system installed on them. The increased mobility allows remote participants a greater degree of agency, as opposed to a fixed-place video camera and screen.

Due to a number of technical achievements in the past ten years, there has been an increase in the number and variety of MRP robotic products available. Often they are specialized to a specific environment such as elder care (e.g., Giraff, manufactured by Giraff Technologies AB), health care (e.g., RP-7 by InTouch Health), or as an office product (e.g., the MantaroBot TeleMe by Mantaro). Currently there are robots with a wide variety of capabilities and price ranges on the market [4]. There has been an increased interest in the use of MRP robots by geographically diverse companies as a way to facilitate remote employees' collaboration, as well as to reduce travel expenses. With the increasing cost of travel, it often does not take long to recoup the investment in a MRP system.

Our company owns several VGo robots, which we have been using to study the social aspects of MRPs in office settings. Over the course of several years of using this robot, we have established an understanding of the capabilities and challenges associated with this particular model. We also developed a base of users who are familiar with its operation.

Thanks to iRobot's generosity in lending us their new MRP robot, the iRobot AVA 500, recently we had a chance to evaluate this robot in our corporate environment. The AVA is a very different robot from the VGo, as can be seen by comparing their characteristics in Table 1. It is pictured in Figure 1.

We wished to learn as much as possible about the AVA, but did not have the luxury of evaluating the system in multiple ways over a period of years as we had done with the VGo. In fact, we only had two days with the AVA, and the first day needed to be devoted to the technical integration of the system into our VTC network. Thus we were faced with the challenge of performing an evaluation very quickly that would yield insights into how well the robot would be likely to fit our collaboration needs and work environment.

2. METHODOLOGY

When usability engineers need to evaluate a system quickly, they often turn to heuristic evaluation [6] because this method has been shown to uncover a large fraction of the system's potential interaction problems within a short period of time [7]. While we know of a specialized heuristic evaluation method for assistive robotics, which encompasses some forms of MRP robots [11], we have not seen a heuristic evaluation technique aimed specifically at MRP robots. We thought it would be useful to create such a set of heuristics for MRP robots. Since a number of different types of

MRP robots are becoming more widely available, we felt that others may also find such a method to be useful.

Table 1. Characteristics of Two MRP Systems

Characteristic	VGo	AVA 500
Manufacturer	VGo Communications, Inc.	iRobot
Cost	$6000	$70,000
Integration with existing Video teleconferencing systems	No	Yes
Obstacle detection	Yes, but limited to a range of inches	Yes, with a range of several feet
Obstacle avoidance	No	Yes
Weight	19 lbs	170 lbs
Camera resolution	640x480	1080p
Screen size	6”	21.5”
Screen resolution	640x480	1080p
Height	48”	Adjustable from 52.5” to 64.5”
Adjustable camera angle	Yes	Yes
Autonomous navigation	No	Yes
Requires mapping of area before use	No	Yes
Self docking	Yes, within feet	Yes, from anywhere

Coincidentally, some of our research group members have been investigating the state-of-the-art of specialized heuristics: those

Figure 1. AVA 500 robot is preparing to connect to a remote operator. It is shown in the lower height position.

heuristics that are aimed at a class of systems or interfaces instead of being a general-purpose set that can be used to evaluate almost any type of computer-based application (such as Nielsen’s heuristics [7]). As part of our investigations, we have been examining best practices for developing these sets of heuristics. We saw an opportunity to exercise these best practices to create a set of heuristics suitable for evaluating MRP robot systems.

After examining 60 specialized heuristic sets, we saw some commonalities in how they were developed. Some developers relied heavily upon Nielsen’s heuristics [7], some incorporated theoretical- or empirical-based literature, and some used empirical evaluation methods such as field observation or previously submitted usability issue reports to create categories of usability problems which were then turned into heuristics. Because there are strengths associated with each approach, we believe it is a best practice to combine all three.

Accordingly, we examined the literature for principles that, if followed, could lead to MRP designs that avoid problems observed in empirical investigations. For example, Lee and Takayama used a combination of critical incident interviews, surveys, and observations to identify problems with MRP systems and develop principles to avoid them [5].

To begin gathering empirical data, we reached out to our MRP user community to solicit comments on their experiences. We asked them questions aimed at eliciting both the positive and negative aspects of using an MRP in an office environment. These operators often used the VGo in meetings that emphasized information sharing and information building. We also gathered observations based on seeing VGo robots used for department meetings and corporate-sponsored social events.

Ideally, we wished to have a set of heuristics prior to the period in which we could use the AVA robot, so that we could use them to evaluate the AVA. This approach would imply that the empirical information used to develop the heuristics would be confined to VGo-related data. Yet we knew we would have a richer set of data if we could gather at least some from using the AVA. Consequently we decided to use our brief time with the AVA to gather empirical data that could inform heuristic development.

During the loan period, we had a chance to use the AVA for a large meeting with breakout sessions in the main conference room and several remote participants. This was a “real” meeting in the sense that it was not a contrived event whose purpose was to evaluate the AVA. The primary purposes of this meeting were to share information and brainstorm ideas. We recruited one of the remote participants to use the AVA. We arranged to interview that participant after the event using a set of questions developed based on our knowledge of the VGo.

We used the grounded theory qualitative analysis method [3] to analyze the observation data from both robots to surface positive and negative experiences. When analyzing the data, we remained alert for issues that are especially pertinent to MRP robotics in contrast with general-purpose software or computer-supported cooperative systems hosted on conventional (that is, non-mobile) computer systems. For example, we envisioned that collaborators’ and bystanders’ safety would be a concern in MRP robotics

Grounded theory results in groupings of data based on similarities of the data within a group in a relevant dimension. We compiled a list of comments and impressions from our MRP users, both AVA and VGo. We then looked for common themes in these comments. Comments with similar themes were grouped together. These groupings evolved into heuristics.

3. HEURISTICS AND SUPPORTING OBSERVATIONS

3.1 Minimize driving costs

We have seen two approaches for navigating a MRP to a specific location. These two options depend on the level of autonomy of the particular MRP. The first is for the MRP to be driven directly to specific location by the operator. This can be a tedious task, often requiring several minutes of navigating down long hallways. The VGo robot is an example of this type of MRP. The second option requires a much higher degree of autonomy. The operator selects a location, and the MRP autonomously navigates to the location. Once there, it alerts the operator of its location and availability. The AVA is an example of this type of MRP.

The remote user of the VGo presses the arrow keys on the preconfigured laptop in the direction they want the robot to travel. Alternatively, operators can use a mouse on a half circle on the UI. This half circle represents the amount of forward translation and rotation commands that could be issued to the robot. The robot will not move without these commands being issued by a user.

Prior to normal use, the AVA requires a pre-mapped area of operations to show it the physical limitations of the room. Additionally, the AVA has multiple sensors that fuse information for advanced obstacle detection and avoidance capacities. This approach allows the AVA to autonomously navigate to a given location without any input from the user other than the initial command to move to a specific point. Once the robot has autonomously reached its location, it alerts the user and establishes a video teleconference between the two end points. Essentially it is possible for operators to point on a map to where they want the robot to be located and the robot will autonomously drive to that location.

This autonomous approach resolves an issue noted by Lee and Takayama, who found "The most frequently mentioned downside was the burden of driving. Pilots reported that the hassle of driving the MRP to go to a meeting room made the MRP system less useful and efficient" [5, pg 38]. Long stretches of driving without useful interaction are clearly burdensome to the operator.

3.2 Allow flexible use

The "M" (mobility) in MRP allows for certain freedoms and benefits on top of those offered by traditional VTC telepresence. Benefits include being able to travel to a remote individual's office, participating in side conversations, moving between break-out sessions, dynamically switching viewpoints between different areas and artifacts, and taking part in group discussions while being able to make greater use of body language. We saw these benefits manifested in the AVA's travels among breakout tables, which couldn't occur using a traditional VTC.

A similar heuristic is included in Nielsen's heuristic set [7] and is also discussed in Lee and Takayama [5].

3.3 Design the MRP to elicit the appropriate amount of interaction from humans collocated with the robot

One common thread among the users was the lack of courtesy of other people regarding the robot as a stand-in for another person. Often they found that people would walk in front of the robot and block it in seemingly unintentional ways. We observed one person interject themselves into a conversation between the AVA and another person. This interjecting person then maneuvered his body to block the view of the robot. We believe that people did not always see the robot as a full avatar for its remote user, since the robot was not accorded the same spatial considerations as another person. The AVA operator explicitly commented about it being difficult to start a conversation with remote colleagues because of this effect.

3.4 Ensure safety

One comment received from the co-present meeting participants is that the AVA robot moves at a fast pace when it is autonomously navigating. While the sensors prevent it form running into objects or people, the robot startled several meeting participants, who feared it might run into them. This heuristic is also included in Tsui [11].

Safety is obviously an important feature; it would be unfortunate to have the robot cause injuries to other meeting participants. One study showed that if the robot operator is engaged in a secondary task as cognitively simple as pushing a correct button, their ability to safely operate the robot drastically reduced [2]. A task with a higher cognitive load, such as having a technical discussion, could obviously distract the operator more, thus increasing the risk of creating damage due to a driving error. It is for these reasons we included safety as a key design focus.

3.5 Provide operators with awareness of the rationale for the robot's autonomy-influenced behaviors

When using the AVA, the operator was frustrated because its autonomous algorithms were preventing the robot from getting as close to the table as the operator desired. (Note that the operator had not had a chance to be trained on the "push" mode that would have enabled him to place the robot in contact with the table.) In this case, the operator did not know that the autonomy "safety" algorithm was keeping the robot from driving very close to the table.

This same safety algorithm caused the robot to drive around obstacles the operator could not see, thus surprising the operator when the robot did not travel in a straight line.

3.6 Provide feedback regarding system state

The system state includes the status of the MRP, the operator endpoint, and their connection to each other.

Often VGo users encountered problems with obstacles, which stopped the VGo from moving. The operator was not alerted that MRP was unable to move. This left the operator unsure if the commands were received, the motor was not working, or if the MRP was in an unmovable state.

The AVA operator also commented about the controls for operating the robot being overlaid on the map, so he was unable to use both the controls and the map at the same time. This design decision may have been a tradeoff due the limited screen size of the user interaction device, an iPad mini.

Note that this heuristic is similar to one in Nielsen's heuristic set [7].

3.7 Provide for an immersive operator experience

The robot represents its operator, and thus through the robot the operator should be able to experience as many sights and sounds as they would if they were co-located with other participants. This sense of immersion is based on having sufficient sensory experiences to enable the operator to feel as though he or she is "being there." Lee and Takayama [5] describe the importance of achieving a feeling of immersion.

In the case of our observations, operators of both the VGo and AVA robots wished that they had a zoom feature to view artifacts as though they were physically picking them up and examining them closely. We also found that users of both robots experienced difficulty with visual light balance problems. Whenever a user looked at a screen or a projection they were effectively blinded: the light from a projector or screen was too bright and users could neither see what was being presented, nor the rest of the meeting participants—effectively ruining any feeling of immersion.

One common comment of the VGo users was that the field of view was not wide enough to see two other people sitting at a medium sized table, again eliminating a feeling of immersion. Further, VGo users commented that the camera did not have a high enough resolution to read what was written on the white board in the room. In contrast, the AVA user appreciated the full HD video and thought it contributed very positively to his interactions.

4. FUTURE WORK

MRP robots in a corporate work environment have seen a lot of growth and development in the past few years. It is an area that we expect to see both technological advancement and new social mores develop in the future. Based on the AVA and VGo observations, many employees are not used to seeing a robot in the work place, which means that there is the opportunity to study the social interactions as they evolve with increased familiarity.

Future work will focus on validating these heuristics. We plan to use these heuristics to assess additional MRP systems in the workplace, and compare the results to those obtained by performing both an evaluation using Nielsen's heuristics and a formal usability test.

In addition, it may be fruitful to investigate the potential relationship between the heuristics proposed here and the heuristics that have been proposed specifically for collaborative systems, such as Baker et al.'s [1] heuristics for groupware based on the mechanics of collaboration.

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