WORCESTER POLYTECHNIC INSTITUTE

Tour Guide Robot Interactions

An Interactive Qualifying Project submitted to the Faculty of WORCESTER POLYTECHNIC INSTITUTE in partial fulfillment of the requirements for the degree of Bachelor of Science

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Abstract

The project focused on performing a feasibility study to evaluate the public's interest and comfort level with a tour guide robot, and on gaining information for guiding future development of the robot into a fully functioning and autonomous tour guide. This paper describes a series of experimental, robot guided tours performed on the WPI campus. Volunteers, who had already completed a normal, student-led campus tour, were guided on a limited, outdoor tour route by a robot. The robot was controlled remotely by a student in a "wizard of oz" type trial, without the knowledge of the tour participants. After the tours, the volunteers filled out questionnaires pertaining to their thoughts and feelings regarding their tour experiences. Overall, the participants were overwhelmingly pleased and enthusiastic about their robotic tour experiences leading to the conclusion that robot guided tours are a feasible practice for the WPI campus. Through analysis of the questionnaires, it was found that the participants mostly desired more interaction with the robot including dialog and interactive interfaces, and were most satisfied with the robot's ability to use gaze direction and body movements to indicate tour locations.

Acknowledgements

I would like to thank Professor Fischer for his advice and support during this project and especially for his assistance with authoring this report. I would also like to thank Jason Laperriere in Admissions and all of the student tour guides who helped me conduct the experimental tours. I'd like to offer a special thanks to the people at Segway for the use of a Segway Robotic Mobility Platform for the previous development of the tour guide robot, to the MQP group that performed the development, and to the members of the AIM lab at WPI for their assistance with the development and the use of the lab's resources. Finally, I would like to thank Erin Leger for her indispensable assistance during this project with constructing the robot body, conducting the experimental tours, and compiling the survey data.

Introduction

Development of a fully-autonomous, mobile robotic system is a challenging endeavor, and the task is made more challenging when the robot must interact with human users. The ways in which the robot interacts with humans must be useful and natural to the users and, often, the interactive behavior must be taken into consideration when developing the autonomous capabilities of the system. While autonomous behavior is a technical and therefore engineering issue, the preference of humans is not and is therefore inherently less predictable. As a result, the development time and cost of an autonomous system may be increased due to further design iterations required for adjusting the system's human-robot interaction characteristics.

Fortunately, increases in development cost and time can be minimized by studying the ways in which the system will interact with users before it becomes autonomous. This can be accomplished in several ways, one of which is commonly referred to as the "Wizard of Oz" experiment. In this type of experiment, human subjects interact with a system that appears to be autonomous but is in fact controlled by a human following a precisely prescribed script. The value in this type of study is twofold. First, a human operator can simulate a wide range of autonomous behaviors without the need to develop a system capable of producing the behaviors on its own. Secondly, the ways in which humans tend to communicate with other humans is different than the way in which they interact with machines, as has been found in studies pertaining to human-machine dialog [1]. As such, Wizard of Oz experiments have been used to develop robotic systems which interact with humans, such as a robotic doorman in Finland [2].

When a student team at WPI developed a mobile robot system, named GOAT (Guest Orientation, Assistance, and Telepresence Robot), capable of acting as a robotic tour guide, it was decided to use a Wizard of Oz experiment to study the way in which users would interact with the robot before in depth development of its behaviors and interfaces could proceed. To accomplish this, a method of controlling the robot remotely was used to conduct experimental tours with volunteers without their knowledge that the robot was controlled by a human. Their reactions were studied using video recordings, and their thoughts and feelings on the tour experience were obtained using questionnaire forms. The data gathered from the experiment will be used in the future development of the system from an autonomous capable platform to a fully-autonomous, tour guide robot for the WPI campus.

Background

The tour guide robot, as it existed at the beginning of the study, consisted of a mobile platform with various computers, sensors, and other components mounted on it. It was recognized that the appearance and behavior of the robot should be conducive to human interaction. To determine how best to modify the robot to achieve these goals, previous examples of tour guide robots were studied for clues as to which behaviors and aspects of robot appearance would be most effective.

There are several examples of tour guide robots available. These examples consist of indoor and outdoor tour guides which have significantly different design challenges in the way of autonomous navigation. However, the ways in which they interact with users is largely independent of whether they operate in an indoor or outdoor environment.

Minerva

Two examples were researched when deciding what behaviors and capabilities the robot should possess for interacting with campus visitors. The first was an indoor tour guide robot, named Minerva, developed by Carnegie Mellon University and deployed for a total period of 14 days, from August 24 through September 5, 1998, in the Smithsonian's National Museum of American History (Figure 1).

Figure 1: The Minerva tour guide robot

Minerva used three behaviors to interact with visitors to the museum: simple facial expressions, gaze direction, and voice [3].

NTU-1

A second tour guide robot studied was an outdoor example called NTU-1 which gives tours at the National Taiwan University (Figure 2).

Figure 2: The NTU-1 tour guide robot

This robot responds to users' inputs, given by way of a touch screen interface and voice commands, by using voice, displays on the screen, LED's, and motions of the body [4].

Due to limited resources for the project, the interactive capabilities that could be implemented for the study were limited to the existing platform and some low-cost modifications. Since both examples studied used voice to interact with their users, and since GOAT was equipped with a speaker system, it was decided that providing the robot with a voice was a must-have for the study. The robot was also equipped with a touch screen interface which could be utilized for user input and simulated facial expressions. However, upon testing, it was found that the screen was not easily visible in outdoor sunlight making these ideas impractical for the study. The final method of interaction considered was indicating to visitors which locations the robot was referring to through the use of head direction, as in the case of Minerva, and body motions as in the case of NTU-1. Since the purpose of a tour guide robot is to explain locations to people who are unfamiliar with them, it was decided that these methods of indicating what the robot was speaking about were necessary for the study.

GOAT Robot

The robot used for the study was a tour guide robot , known as the GOAT Robot (Guest Orientation, Assistance, and Telepresence Robot), developed by a three member, student team at WPI for their MQP. The robot as it existed at the beginning of the study is shown in Figure 3.

Figure 3: The GOAT tour guide robot used in the robotic tour study

GOAT was built using a Segway Robotic Mobility Platform (RMP) which is a type of mobile robotic platform intended for research and development. Added to the base platform were two Linux based computers linked by a local area network (LAN), one for control of the platform and a touch screen computer mounted on top to provide a user interface. While extensive effort had already taken place to bring the robot toward its final development goal as an autonomous tour guide, much work was left to be done until that goal was reached. Instead, additional, previously developed capabilities were used to conduct the tour study. These included the ability to manually control the robot using an Xbox 360 controller, the ability for other computers to connect to the robot's LAN via WIFI, cameras mounted on the robot as part of a computer vision system, and speakers mounted on the robot to interact with users through audio. The Xbox control, the WIFI connection, and the cameras were utilized to implement remote control of the robot using a laptop computer connected to the robot's LAN. This allowed a user to view images from the robot's camera and control it using the Xbox controller while remaining unseen by anyone interacting with the robot. The speakers were used to play audio information pertaining to the tour. Using the GOAT robot allowed for gathering information about how users interact with tour guide robots, information that will eventually be used to improve GOAT itself.

Project Goals

- Generate ideas for various robot guided tour scenarios and prepare the scripts
- Obtain Institutional Review Board approval for conducting the experimental tour study
- Provide robot guided tours to volunteers
- Conduct the tours in such a way that the volunteers perceive the robot to be autonomous
- Gauge the thoughts and feelings of the volunteers pertaining to their tour experience through the use of questionnaires and video recordings of their reactions
- Analyze the results of the questionnaires to draw conclusions about what was effective, what was not effective, and what may have been lacking from the robot guided tours
- Use the conclusions to make recommendations about what behaviors and capabilities should be added to the robot to make it an effective, autonomous tour guide
- Use the conclusions to gauge whether or not robot guided tours are a feasible and attractive feature for the WPI campus

Hypotheses

In order to frame the questions on the questionnaires provided to the volunteers, it was useful to first create hypotheses about how the robot's methods of interactions, or lack thereof, and people's perception of the robot would affect their tour experiences.

The primary hypotheses are as follows:

1. DIALOG: Lack of dialogue with the robot will make participants less engaged and will make them feel as though less information was gained.
2. GAZE: Having the robot turn toward the locations it is talking about will make people more interested in what it is saying.
3. SAFETY: The safer people feel around the robot, the more satisfied they will be with the tour experience.

Several questions were included on the questionnaire to address each of the hypotheses. In addition, questions were provided to determine how generally satisfied the volunteers were with the tour experience. This allowed the questions pertaining to each hypothesis to be compared with the general satisfaction questions in an attempt to find any correlations.

Methodology

Though the purpose of the study was to provide information about how to implement effective, robot guided tours, it required the creation of experimental tours along with a method of obtaining feedback from the tour participants to gain that information.

Experimental Tours

There were three main constraints that were adhered to when designing the experimental tours:

1. **Autonomous Appearance** - The volunteers must perceive the robot to be autonomous
2. **Safety Precautions** - The tours must be as safe as possible for the volunteers
3. **Tour Script** - The robot must provide pre-recorded voice information about each tour location and must appear to "look" at each location it is speaking about

Autonomous Appearance

To address the first requirement, a method of controlling the robot remotely was devised using an external computer connected to the robot's computer through a WIFI connection. Prior to the study, the robot was equipped with a Linux based computer running the Robot Operating System, or ROS [5]. ROS is a software framework designed for developing robot applications. The framework is graph based, meaning multiple nodes run simultaneously as separate applications which communicate using special ROS messages. Prior development included an RMP command node for sending commands to the RMP base, an Xbox RMP node for receiving input from an Xbox 360 controller and translating them into RMP commands, and a node for processing camera images and publishing them as ROS messages. However, the existing ROS configuration was local to the robot's computer which was not useful for remote control. Fortunately, ROS is designed to run on multiple computers linked by a network, with the network being transparent to each computer. The robot came equipped with a network router which allowed the control computer to communicate with the RMP base via an Ethernet connection. The router was also WIFI capable which allowed a computer running ROS to wirelessly connect to the network. As a result, it was a simple matter of running the Xbox RMP node on a laptop instead of the robot's computer, along with an existing ROS node, found in the open source ROS repository, which allowed the camera images to be viewed on the laptop. This allowed a user to connect the Xbox controller to a laptop, connect the laptop to the robot's wireless network, and control the robot by viewing camera images from a forward facing camera on the robot's body. Figure 4 shows an overview of the ROS network setup for remotely controlling the tour guide robot.

Figure 4: Network setup for remote control of robot

Safety Precautions

As described in the previous section, the robot was controlled remotely using an Xbox 360 controller shown in Figure 5.

Figure 5: Xbox 360 controller button mappings for remote control of robot

An analog joystick on the controller was mapped to the velocity and yaw rate of the RMP base, with the vertical axis of the stick controlling the linear velocity and the horizontal axis controlling the yaw rate. As a safety feature, the left analog trigger of the controller was programmed as a “deadman” switch. This meant the robot only responded to commands from the control stick if the deadman switch was depressed. If the deadman switch was released, the robot would be commanded to set the velocity and yaw rates to zero. This ensured that velocity and yaw commands would not be sent to the robot if the controller was dropped and the control stick was pressed off-center. In addition to the deadman safety feature, a “decel” button could be used to immediately command the velocity and yaw rates of the robot to be set to zero, after which the robot would power down. This allowed a remote operator of the robot to bring it to a controlled stop should any problems be detected when viewing remote images from the robot’s cameras.

Since all commands sent to the robot from the Xbox controller were relayed to the RMP via ROS software, safety features built into the RMP controller firmware were utilized as an additional layer of safety. Acceleration, velocity, and yaw rate limits were set in the firmware which constrained the rates to safe levels, i.e. no greater than average human walking speed for velocity, and acceleration and yaw rates that would not cause the robot to tip over. Also, the platform controller was equipped with an input for an emergency stop button. This input was wired to an emergency stop button on the robot body (Figure 6), and a relay that could be activated by pressing a button on a wireless fob (Figure 7).

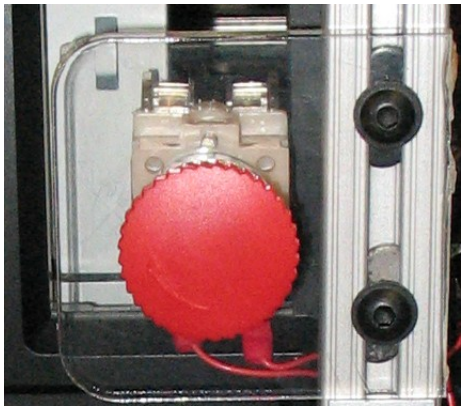


Figure 6: Emergency stop button on robot's body

Figure 7: Wireless relay fob for robot emergency stop system

The emergency stop system provided a means of stopping the robot if an error were to occur with the ROS software, the Linux computer, or the robot’s LAN. During the experimental tours, a study assistant joined the volunteer tour groups and followed the robot along its tour route. The assistant wore the

wireless relay fob at all times, monitored the robot's behavior, and was prepared to quickly activate the wireless fob or the emergency stop button on the robot body should any unexpected behavior or malfunctions occur with the robot.

Tour Script

The first step in creating the tours was to determine the route the robot would follow and the locations it would provide information about. In addition to locations, it was decided to have the robot provide information about itself while in transit between stops for purposes of engaging the tour participants and making them more familiar and comfortable with the robot. Since the tours were experimental and would require time from volunteers, the route was limited in scope to a subsection of the campus. The road encircling the quadrangle and the Bartlett Center was chosen for its relative simplicity, wide lanes of travel, numerous locations at which the robot could stop, and open area at its center to allow for the best possible reception of the robot's wireless network. Tests were performed to determine which possible tour locations in this area allowed for a strong remote connection with the robot. Based on the tests, it was determined that a tour route starting at Harrington Auditorium and ending behind the Bartlett Center would enable reliable control of the robot for a remote operator stationed at the center of the quadrangle. The design for the tour route is shown in Figure 8, with the tour route and locations shown in red, and topics for the robot to speak about while in transit labeled in yellow.

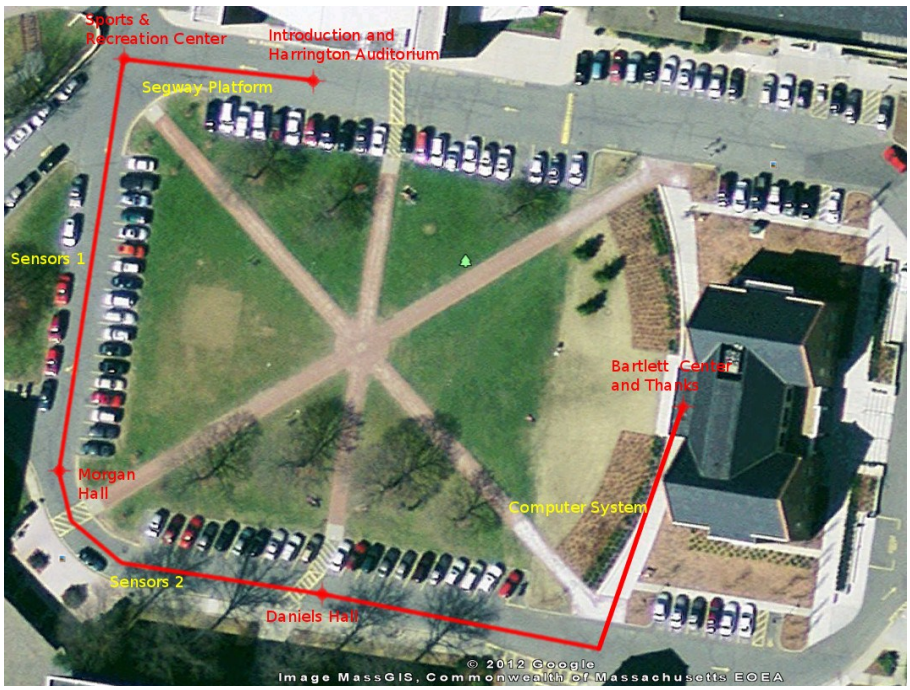


Figure 8: Robotic tour route indicated by red line. Tour locations are labeled in red text, in transit topics in yellow text.

Once the tour route was planned, and the locations and in transit topics the robot would talk about were chosen, a script (see Appendix E) was developed for what the robot would say during the tour. The text of the script was converted to synthesized speech using a free web-based program and the speech was saved to separate sound files and copied to the robot's computer and the laptop computer [6]. A ROS sound node was developed which would play each sound file successively in the order determined by the tour route when the up button on the Xbox controller's directional pad was pressed. By having the sound node run on the laptop as well as the robot's computer, the person controlling the robot would be able to hear, through the laptop's built in speakers, what the tour participants were hearing which allowed the robot controller to properly choreograph the tour. The tour participants heard the audio from the robot played through speakers attached to the robot's body (see Figure 9).

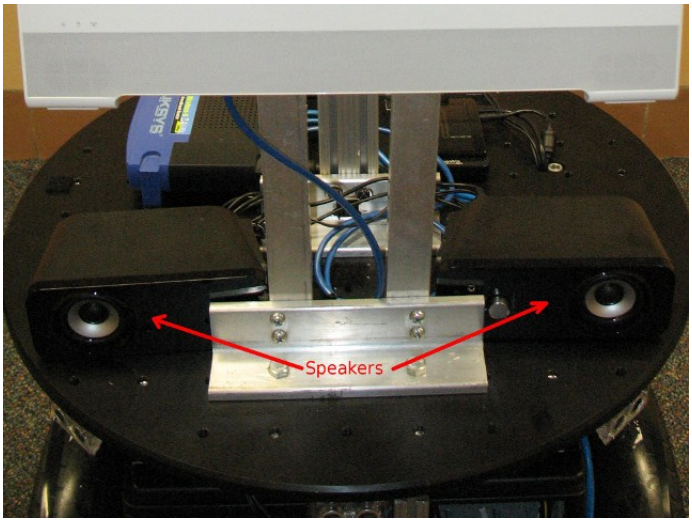


Figure 9: Speakers on robot for playing tour audio

To create the appearance that the robot was looking at each location it spoke about, the robot's frame was covered with a body and head (see Figure 10 and Figure 11). The body was constructed using disposable ponchos which offered some amount of protection should a rain shower occur during a tour. The head was a stuffed toy bought at a local toy store and attached to an existing sensor mast at the center of the robot's frame. The body and head served to personify the robot and indicate to the tour participants which location the robot was taking about.

Figure 10: Robot base before addition of body

Figure 11: Robot with body

Tour Videos

To supplement the feedback from the tour questionnaires, a webcam and microphone built into the robot's user interface computer were used to record videos of the tour participants' reactions to the robot (see Figure 12).

Figure 12: Webcam and microphone built into the robot's user interface computer

Tour Study Logistics

With the tour route mapped, the script written, technical and safety features developed, and the robot body constructed, the time came to work out the logistics of the tour procedure to ensure smooth operation of the tours for a successful study.

First, an expedited approval for the tour was received from the Institutional Review Board. This approval is necessary for any study performed by WPI students that involves human subjects. The expedited approval letter can be seen in Appendix B.

Next, Jason Laperriere, the Senior Assistant Director of Admissions was contacted to enlist the cooperation of the student tour guides. This was necessary since the tour volunteers would be recruited from the student led tour groups. With Jason's help, approval was gained from the Dean of Admissions and the student tour guides were notified of the upcoming study.

In addition to assistance from the Admissions staff, a study assistant, Erin Leger (see Figure 13), was recruited to assist with administering the tour study.

Figure 13: Volunteer tour study assistant, Erin, with the tour guide robot

Erin's assistance was critical since the study was performed with only one student investigator which was insufficient for coordinating the logistics of recruiting volunteers, performing the tours, and obtaining feedback.

Participant Feedback Questionnaire

To obtain feedback about the tour, a survey was designed which would be filled out by the tour participants at the conclusion of each tour (see Appendix C). The survey consisted of 19 statements, each with a corresponding Likert Scale which consisted of four choices: Strongly Disagree, Disagree, Agree, and Strongly Agree. The statements were separated into four categories, one for each of the three hypotheses and one for general tour satisfaction. With this format, the results pertaining to each hypothesis could be compared to the general satisfaction results in an attempt to prove or disprove each hypothesis by discovering how each of the tour factors addressed by the hypotheses affected people's satisfaction with the tour. In addition to the Likert scaled statements, three optional, open form questions were included with the surveys where participants could explain what they liked or disliked about the tours and offer suggestions for improvements.

Experimental Protocol

Once the admissions staff, the Institutional Review Board, and the study assistant were on board for the study, a procedure was created and rehearsed for recruiting the volunteers, performing the tours, and obtaining feedback.

The procedure was as follows:

1. Setup a remote operation station at the center of the quadrangle consisting of a chair, a table, and box to shade the remote operation laptop from the sun

2. Meet with the student tour guides at the Bartlett Center before they begin their tours to explain the study and ask for their assistance in introducing the student investigator to the tour groups

3. Bring the robot online inside of Higgins Laboratories and test the systems to ensure proper operation

4. Drive the robot to the start location of the tour route in front of Harrington Auditorium using the Xbox controller connected directly to the robot's computer

5. Switch the robot to tele-operation mode allowing for remote control with a laptop connected to the robot's wireless network

6. Walk to the front of the Bartlett center to meet the tour groups while the study assistant keeps watch over the robot

7. Meet the tour groups in front of Bartlett Center as they complete their tours, explain the study and its purpose, and ask for volunteers

8. Lead volunteers inside the Bartlett Center, handout consent forms, and collect them once completed

9. Lead the volunteers to the robot in front of Harrington Auditorium, introduce the study assistant, and explain precautions for maintaining a safe distance from the robot

10. Concurrent to step 9, the tour assistant starts recording from the webcam on the robot's user interface computer as the volunteers are being led to the robot

11. Leave the volunteers with the robot and setup remote operation laptop at remote operation station in the center of the quadrangle

12. Remotely operate the robot to follow the tour route while avoiding obstacles, stopping at tour locations, and playing tour audio as per the predetermined script

13. Concurrent to step 12, the study assistant follows the robot along the tour route to ensure the volunteers maintain a safe distance from the robot, and to monitor the robot and activate the emergency stop system should any errors occur with the robot's operation

14. Shutdown remote operation laptop and meet volunteers at the end of the tour route behind the Bartlett Center

15. Lead the volunteers inside the Bartlett Center, hand out the questionnaires, and collect when completed

16. Concurrently to step 15, the study assistant stops the recording from the robot webcam, returns the robot to local control with the Xbox controller connected to the robot's computer, drives the robot into Higgins Laboratories, powers down the robot, and begins charging the robot batteries

Results

Six experimental tours were successfully performed over three days with a total of 39 volunteer participants. Figure 14 shows some examples of volunteers participating in the robot guided tour experiment.

Figure 14: Volunteers participating in the robot guided tour experiments

The results of the study consisted of three components: the feedback from the Likert scaled survey statements, the feedback from the open answer questions included with the survey, and video recordings of tour participants' reactions to the tour guide robot taken from a camera mounted on the robot's user-interface computer.

Study Population

Though demographic statistics for the tour participants were not collected, the tour groups consisted predominantly of parents with their prospective student children and siblings of the prospective students. As such, the study population was split quite evenly between middle age and teenage, and between male and female participants.

Quantitative Analysis of Likert Scaled Statements

As part of the process of obtaining feedback from study participants, responses to the Likert scaled statements were encoded and analyzed in an attempt to find correlations between the key features of the tours addressed in the hypotheses and general tour satisfaction.

Data Entry and Coding

Once the experimental tours were complete, the data from the surveys was entered into a spread sheet for processing. Appendix F includes the raw Likert scale data as recorded directly from the surveys. The Likert scale answers to each statement were given values of one through four, with one being the Strongly Disagree option, two being the Disagree option, three being the Agree option, and four being the Strongly Agree option. The values of the statements were divided into four groups, three for each of the hypotheses pertaining to dialog with the robot (statements 1 through 6), the effect of gaze direction (statements 7 through 9), and perception of safety during the tour (statements 10 through 13), and a fourth group for the statements pertaining to general satisfaction (statements 14 through 19). However, the values for positive and negative statements were entered differently, i.e. a statement that would suggest the participant did not like an aspect of the tour by agreeing would be entered using the following formula:

$$\text{Value} = 5 - (\text{Likert value})$$

For the above formula, if a participant chose Strongly Agree for a negative statement such as “I was concerned the robot would malfunction”, their value would be: 5 – 4 = 1. The statements which were given inverted values are the following:

2. **I feel a human tour guide would provide more relevant information than a robot.**
3. **I wanted to ask the robot questions during the tour.**
5. **There was information I wanted which the robot did not provide.**
6. **I feel a human tour guide would provide more information than a robot.**
11. **I was concerned the robot would malfunction.**
12. **I was concerned the robot would collide with something.**
15. **I prefer human guided tours.**
19. **I will avoid robot guided tours in the future.**

For positive statements such as “I enjoy robot guided tours”, the value was entered directly meaning a choice of Strongly Agree would be equal to four. This allowed the numbers to be analyzed in a way that a higher value meant more satisfaction with the tour and a lower value meant less.

Next, the mean of each hypothesis category was found for each survey. An example result for one survey is shown in Table 1.

Table 1: Example mean and median category scores for one survey

	Dialog							Gaze				Safety					General Satisfaction						
Question Number	1	2	3	4	5	6	Mean	7	8	9	Mean	10	11	12	13	Mean	14	15	16	17	18	19	Mean
Score	4	2	1	3	2	2	2.33	3	4	3	3.33	4	3	3	3	3.25	3	2	3	3	3	3	2.83

Summary Statistics

The columns showing the mean score for each of the four question categories were used in the following analysis. From these mean category values for each survey response, the summary statistics including the mean, standard deviation, median, minimum, and maximum were calculated as shown in Table 2.

Table 2: Summary Statistics for each category across all surveys

	Dialog	Gaze	Safety	General Satisfaction
Mean	2.40	3.59	3.37	2.91
Standard Deviation	0.28	0.43	0.42	0.39
Median	2.33	3.67	3.25	2.38
Minimum	1.92	2.67	2.50	2.17
Maximum	3.17	4.00	4.00	3.83

* A score of 2.5 corresponds to neutral, where 4 is strongly positive and 1 is strongly negative

Correlation Analysis

A correlation analysis was performed to determine the relationship between the three factors associated with the hypotheses and the overall satisfaction. The analysis was performed using statistical analysis software to find the Pearson Correlation Coefficients for each hypothesis category with the general satisfaction category. The results are shown in Table 3. Although the results were not

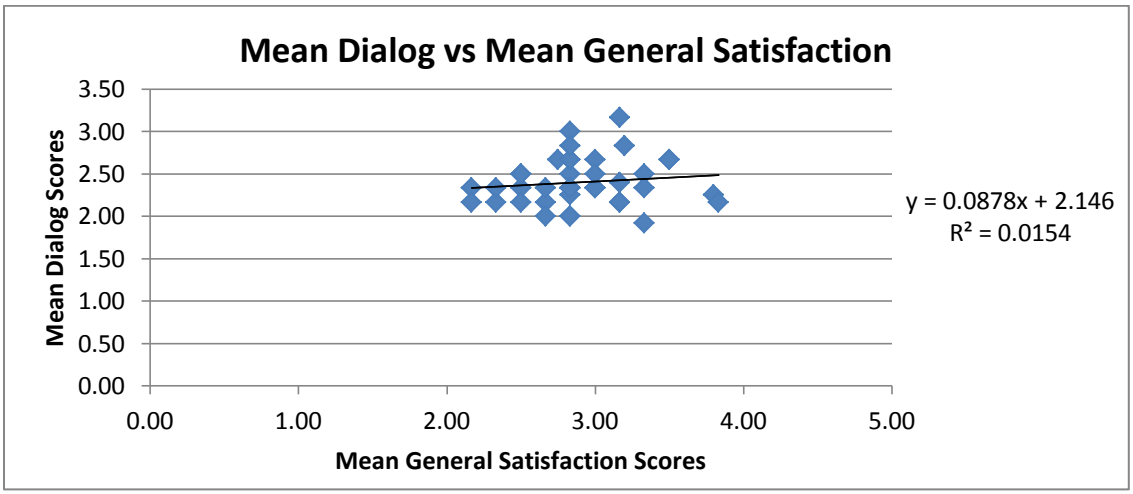
statistically significant due to the small sample size, the results suggest a positive correlation of all three hypotheses with overall satisfaction, which is encouraging. Further, it is clear that the factor associated with Gaze has the highest correlation, indicating that this factor showed the greatest effect on overall satisfaction.

Table 3: Pearson correlation coefficients relating each of the three hypotheses to general tour satisfaction

	Mean Dialog	Mean Gaze	Mean Safety
Correlation Coefficient	0.12417	0.23004	0.16712
P value	0.45137	0.15889	0.3092

Regression Analysis

A linear regression analysis was performed to further relate the factors associated with the hypotheses to the overall general satisfaction. The mean scores corresponding to the hypotheses were plotted against the mean of the general satisfaction scores. The results are shown in Figure 15. Note that all factors showed a positive slope as expected, with Gaze demonstrating the greatest slope. The low R^2 value is most likely due to compounding factors not accounted for in an individual linear regression.



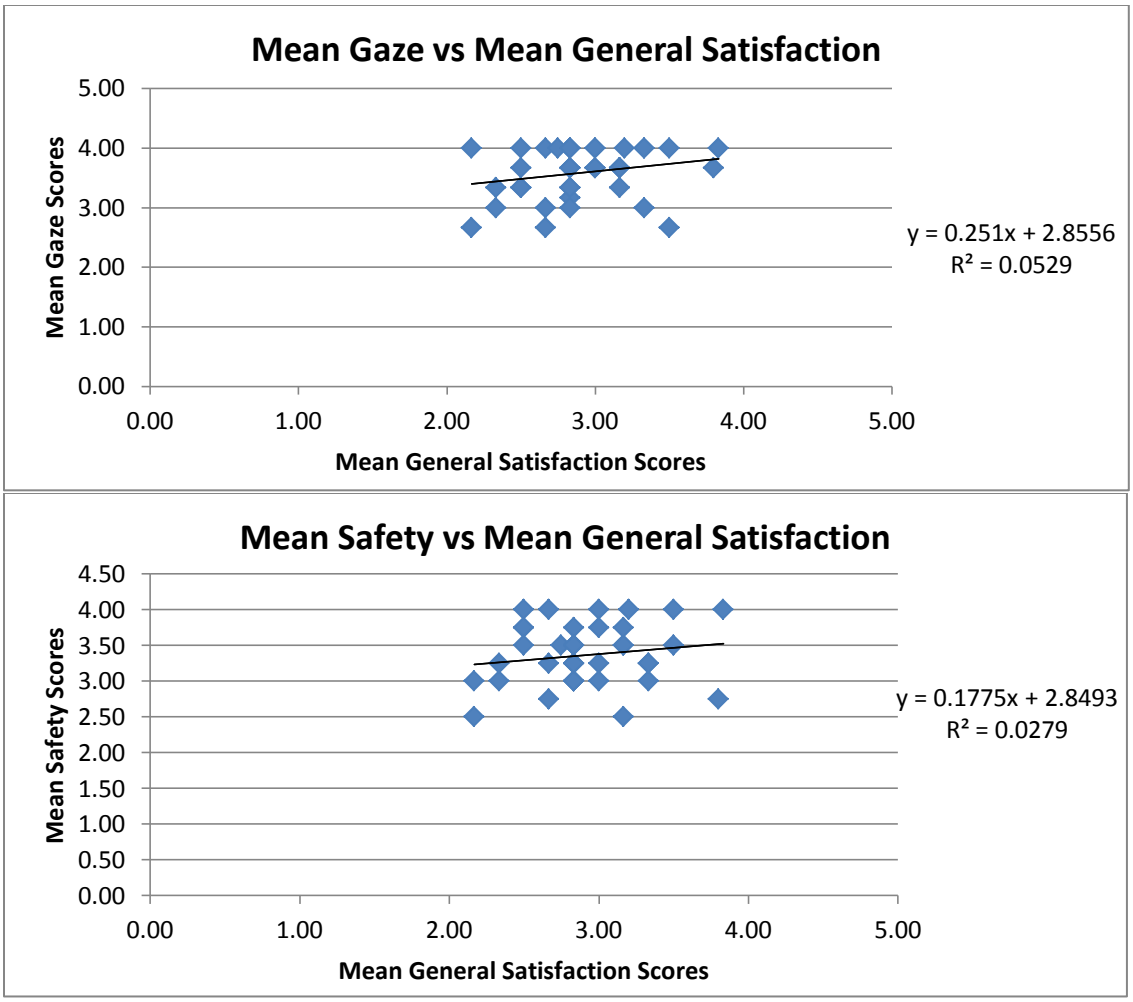


Figure 15: Mean scores of each hypothesis as a function of general tour satisfaction scores

To determine the multivariate effects based on the hypotheses, a multivariate regression was performed. The statistical software was used to find a multivariate linear regression model that attempts to predict overall satisfaction based on the three study factors. Further, it allows us to determine which of the three hypothesis factors had the greatest effect on general tour satisfaction. The results of the multivariate analysis are shown in Table 4. Note that the overall p value is 0.35 which is not statistically significant. This is most likely due to the small sample population in this preliminary feasibility study. However, the results are still promising and useful, suggesting that all three factors affect general satisfaction as predicted, and again that Gaze has the largest effect and greatest level of statistical significance.

Table 4: Coefficients and p-values from the multivariate analysis

	Coefficients	P-Level
Overall	N/A	0.35845
Intercept	1.44966	0.09236
Mean Dialog	0.08046	0.73785
Mean Gaze	0.21066	0.16714
Mean Safety	0.15153	0.34394

Further Analysis

Next, the survey responses for general satisfaction mean values were classified according to those less than the medians of each hypothesis category, and those greater than the medians of each hypothesis category. Also, the general satisfaction mean values were split according to how many mean values in each hypothesis were greater than or less than the middle possible score of 2.5 (i.e. the neutral score). The counts and means of all the splits are shown in Table 5. Note that for the gaze and safety categories, there were significantly more participants who provided positive responses than negative responses, with all responses related to gaze being positive. On the other end of the spectrum, the dialog split shows a significant number of negative responses. Adding support to the hypotheses, the means of the satisfaction scores split by the neutral score of 2.5 show a positive correlation between satisfaction in each category and general tour satisfaction, as do the general satisfaction scores split by the median in the gaze and safety categories.

Table 5: Counts and means of splits for general satisfaction scores

		Categories		
	Splits for Categories	**Dialog**	**Gaze**	**Safety**
Count	<= 2.5	29	0	2
	> 2.5	10	39	37
	<= Median	13	24	20
	> Median	26	15	19
Mean General Satisfaction	<= 2.5	2.861	N/A	2.667
	> 2.5	3.045	3.045	2.921
	<= Median	2.933	2.86667	2.857
	> Median	2.923	2.99444	2.962

Open Answer Questions

The survey filled out by tour participants included three open answer questions:

1. What did you like about the robot guided tour?
2. What did you dislike about the robot guided tour?
3. How could the robot guided tour be improved?

The answers to each of the questions were subdivided into categories which were determined by finding common themes in the feedback from the tour participants. The number of responses falling under each category was then tallied in an effort to determine which aspects of the tours had the greatest impact. The results of compiling the user comments are shown in Table 6. Note that the comments have been paraphrased. For quoted comments, refer to Appendix G.

Table 6: Paraphrased survey comments divided into categories

Question	Sub Category	Tally for Sub Category	Example Comments
What did you like about the robot guided tour?	Efficient and informative tours	21	1. Nothing gets forgotten, to the point, efficient 2. More information than current tours 3. Information about the robot
	Shows guests the possibilities of an education at WPI	19	1. Great innovation, exciting technology 2. Example of WPI as a University, shows student accomplishment
	A fun experience	15	1. Fun, cool 2. Different, novel
	Easy to understand	7	1. Easy to hear, good voice 2. Good personality
What did you dislike about the robot guided tour?	Lack of interactivity	21	1. Not interactive 2. Can't ask questions 3. No info on special interest areas
	Limited mobility	12	1. Can't go inside, limited tour area 2. Slow moving 3. Must stay behind the robot

	Difficult to identify with	10	1. No human element (stories, opinions, etc.) 2. Might replace student tour guides
	Too "robotic"	5	1. Monotone voice 2. Boring, pure information 3. Too much information about itself
	Safety Concerns	2	1. Almost went off course 2. Might be dangerous for small children
How could the robot guided tour be improved?	More interactivity	23	1. Human sidekick 2. Answer questions 3. UI for specific needs and interests, touch screen fully integrated 4. Different languages available 5. Smart phone connection for Q & A
	Movement improvements	12	1. Make it faster, more fluid/natural 2. Gesture toward buildings 3. Appear to walk backwards like a human tour guide 4. Indicate intended motion
	Expanded tour area	8	1. More campus coverage 2. Go inside buildings or show videos of the inside on touch screen 3. Include more info on a variety of topics
	Improve the personality (jokes, etc)	2	
	Add the robotic tour to the beginning of the human-guided tour	2	
	Let people know when the robot is coming their way	2	

Video of Tour Participants

Unfortunately, the video of the tour participants did not pick up any useful audio comments. However, there were two common reactions found throughout the footage. Perhaps most significant was the tendency for people to look at the robot and especially its rear facing computer monitor as it was speaking. Also, participants tended to look bored and listless when the robot was not speaking.

Discussion

In general, the successful execution of the robotic tours demonstrated their feasibility, and the enthusiasm and positive comments from the participants indicated their attractiveness as a permanent feature for the WPI campus. While these results suggest an intuitive sense of positive tour experiences, a more analytical approach of analyzing the survey results was utilized in an effort to find support for which features of the tours added to their success and which missing features decreased their attractiveness.

The results from the analysis of the Likert scaled statements suggest a correlation between the tour features addressed by each of the three hypotheses and the general satisfaction of tour participants as indicated by the upward trend in the graphs of the mean hypothesis scores with respect to overall satisfaction mean scores. The analysis also indicates which feature contributed most to the overall satisfaction, namely the ability of the robot to indicate which location it was speaking about using gaze direction and body movements with a mean score of 3.59. The correlation analysis also supports this finding, with the highest correlation value being 0.23004 for the mean score of the survey statements in the gaze category. Finally, the multivariate regression analysis also shows a significantly higher p-value for the mean gaze scores. However, it should be noted that the overall p-value of the multivariate analysis is 0.35845 which is much higher than the typical critical threshold of 0.05 for indicating statistical significance. This is not surprising considering the study was intended to be a limited feasibility study. Even so, the fact that the gaze factor appeared to have the greatest impact on general tour satisfaction in all three quantitative analyses is a strong indication that this is an important factor for the tour experience. Consequently, enabling the robot to indicate the locations it is referring to using gaze and other forms of “body language”, such as body movements and gestures, should be considered an important ability to develop for the robot.

Overwhelmingly, the comments found in the open answer survey questions appear to demonstrate enthusiasm for the robotic tours, not only in the answers to what people liked about the tours, but in their wide variety of creative suggestions for improvements. Commonly, people seemed to like the idea of robotic tours for their own sake, referring to them as a novel and creative idea and also as a good way to boost WPI’s reputation as a University and for demonstrating student accomplishment.

Interestingly, the comments found in the open answer questions add further support to the first hypothesis. The most commonly disliked aspect of the tour experience was the lack of interaction from the robot, including the inability to ask the robot questions. In addition, the most commonly suggested

improvement was for increased interaction including the ability to ask questions and an interactive and fully functioning user interface. While this result does not correspond with the quantitative analysis, which identified gaze and other gestures as the most significant factor for tour satisfaction, it is still significant in a qualitative sense and suggests that increased interaction with the robot should be a primary goal of future development.

Despite the reduced satisfaction associated with lack of interaction, people seemed to be satisfied with the information they gained from the robot. The most commonly liked features pertained to the amount of information gained, including information pertaining to the robot itself. While this demonstrates the robot's utility as a tour guide, it also further suggests that interaction is important for engaging participants since they generally felt a lack of interaction despite being satisfied with the informational content of the tours.

The fact that the second most common type of suggestions called for additional gestures, more natural movements, and additional methods for the robot to indicate its intent, adds additional support to the findings of the quantitative analysis, i.e. gaze, and possibly other types of gestures, were an important factor in how satisfied participants were with the tour. While the second hypothesis only covered gaze direction and body movements for indicating locations of interest as a result of the limited abilities of the robot, in general, the comments support the idea that natural interactions above and beyond simple verbal communication are necessary for making the experience natural, comfortable, and engaging for tour participants.

While the user comments do not shed further light on how the participants' perception concerning the safety of the robot affected their satisfaction with the tour, they do show that safety was not a primary concern for most individuals. There were a mere two comments showing concern for the robot appearing to go off course and also a concern for its safety around small children. The concern for the robot going off course can be attributed to technical difficulties which arose during the tours where the video feed from the robot became intermittent or was lost entirely, resulting in erratic control from the remote operator. In a sense, the lack of concern for the robot's reliability is a result of the remote operation which allowed human intelligence to be used for obstacle avoidance and path planning. The occasional incidents where it did appear to lose control show the robot must not only be reliable when it eventually becomes autonomous, but must also operate smoothly and efficiently so as not to detract from the tour experience by causing undo concern with erratic movements. Essentially, the sense of safety during the remotely controlled tours should be maintained for autonomous control.

The videos taken during the tours add further support to the idea that the robot should be as interactive as possible. The fact that people appeared disinterested when the robot was not speaking indicates the experience would be more engaging if the robot were able to have a dialog with participants during the gaps between the prerecorded audio segments. Also, participants often looked at the robot and especially at the user interface computer when it was speaking, indicating the need for more interaction and perhaps personification rather than simple prerecorded audio.

Future Work

The purpose of this study was to gain information about real users' experiences with the tour guide robot that could be used to help improve its function in the future. Based on the feedback, several key features appear to be important in helping the robot fulfill its proposed function:

1. The robot should be able to interact with users as much as possible, including dialogue capabilities, a functioning user interface, and further personification of the robot
2. The robot should have increased ability to use movements, gestures, and gaze direction to indicate what it is talking about and where it intends to move
3. Any future autonomous capability of the robot should not only be functional and reliable, but should be as smooth and efficient as possible to prevent concern over the safety of the robot

In general, the feedback gained from tour participants in this study could be analyzed in many ways and many conclusions could be drawn about what features and capabilities are important for a tour guide robot. However, it appears quite clear that people were enthusiastic about the idea of a tour guide robot, suggesting that robotic tours as a permanent feature of the WPI campus are indeed feasible.

Certainly, more studies can be done to draw more conclusions about what capabilities are most important for tour guide robots, and to further validate the feasibility of robotic tours. Furthermore, additional studies could experiment with additional tour scenarios such as the following:

- Robot conducting custom tours for individuals allowing the user to specify locations through the touchscreen interface computer.

- Robot working in conjunction with human tour guides to allow for more specific questions and personal stories. Perhaps have some scripted dialog between the robot and the tour guides as well.

- Have robotic tours as a supplement to human guided tours, either before or after a normal tour to cover information or locations not included in the human guided tours.

- Have the robot follow individual visitors and describe their surroundings, essentially a robot assisted, self-guided tour.

- Allow remote users to log into the robot and experience telepresence tours. These could be tours with predetermined routes, custom tours chosen by an individual, or custom tours chosen by popular vote of remote users.

There are many possibilities for robot guided tour studies and fully implemented robotic tours in the future. It is the author's hope that this report offers guidance to those who would make those possibilities a reality. Above all, this report, and the success of the study it describes, should serve as validation that robotic tours are not only feasible, but an exciting possible addition to the WPI campus.

Appendix A: References

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Appendix B: IRB Approval

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Worcester Polytechnic Institute IRB #1
IRB 00007374

9 August 2012
File: 12-103

Worcester Polytechnic Institute
100 Institute Road
Worcester, MA 01609

Re: IRB Expedited Review Approval: #12-103 "Tour Guide Robot Interactions"

Dear Prof. Fischer,

The WPI Institutional Review Committee (IRB) approves the above-referenced research activity, having conducted an expedited review according to the Code of Federal Regulations 45 (CFR46).

Consistent with 45 CFR 46.116 regarding the general requirements for informed consent, we remind you to only use the **attached stamped approved consent forms** and to give a copy of the signed consent form to your subjects. You are also required to store the signed consent forms in a secure location and retain them for a period of at least three years following the conclusion of your study. You may also convert the completed consent forms into electronic documents (.pdf format) and forward them to the IRB Secretary for electronic storage.

The period covered by this approval is 9 August 2012 until 8 August 2013, unless terminated sooner (in writing) by yourself or the WPI IRB. Amendments or changes to the research that might alter this specific approval must be submitted to the WPI IRB for review and may require a full IRB application in order for the research to continue.

Please contact the undersigned if you have any questions about the terms of this approval.

Sincerely,

Kent Rissmiller
WPI IRB Chair

Appendix C: Questionnaire

Robot Guided Tour Survey

Thank you for your participation in this study of robot guided tours. For each of the following statements, please circle the option that best describes how you feel. In addition, there are three optional questions on the last page that can be answered at your discretion.

1. **I found the information provided by the robot to be relevant.**

   [Strongly Disagree] [Disagree] [Agree] [Strongly Agree]

2. **I feel a human tour guide would provide more relevant information than a robot.**

   [Strongly Disagree] [Disagree] [Agree] [Strongly Agree]

3. **I wanted to ask the robot questions during the tour.**

   [Strongly Disagree] [Disagree] [Agree] [Strongly Agree]

4. **I was satisfied with the amount of information provided by the robot.**

   [Strongly Disagree] [Disagree] [Agree] [Strongly Agree]

5. **There was information I wanted which the robot did not provide.**

   [Strongly Disagree] [Disagree] [Agree] [Strongly Agree]

6. **I feel a human tour guide would provide more information than a robot.**

   [Strongly Disagree] [Disagree] [Agree] [Strongly Agree]

7. **I always knew which location the robot was referring to.**

   [Strongly Disagree] [Disagree] [Agree] [Strongly Agree]

8. **I felt I knew the locations the robot was looking at.**

   [Strongly Disagree] [Disagree] [Agree] [Strongly Agree]

9. **I focused my attention on the locations the robot was talking about.**

   [Strongly Disagree] [Disagree] [Agree] [Strongly Agree]

10. I felt safe around the robot.

[Strongly Disagree] [Disagree] [Agree] [Strongly Agree]

11. I was concerned the robot would malfunction.

[Strongly Disagree] [Disagree] [Agree] [Strongly Agree]

12. I was concerned the robot would collide with something.

[Strongly Disagree] [Disagree] [Agree] [Strongly Agree]

13. I felt the robot was under control at all times.

[Strongly Disagree] [Disagree] [Agree] [Strongly Agree]

14. I enjoy robot guided tours.

[Strongly Disagree] [Disagree] [Agree] [Strongly Agree]

15. I prefer human guided tours.

[Strongly Disagree] [Disagree] [Agree] [Strongly Agree]

16. I would recommend robot guided tours to others.

[Strongly Disagree] [Disagree] [Agree] [Strongly Agree]

17. I feel that robot guided tours are a good idea.

[Strongly Disagree] [Disagree] [Agree] [Strongly Agree]

18. I think robot guided tours should be a permanent feature at WPI.

[Strongly Disagree] [Disagree] [Agree] [Strongly Agree]

19. I will avoid robot guided tours in the future.

[Strongly Disagree] [Disagree] [Agree] [Strongly Agree]

Optional Questions

1. **What did you like about the robot guided tour?**

2. **What did you dislike about the robot guided tour?**

3. **How could the robot guided tour be improved?**

Appendix D: Consent Form

Informed Consent Agreement for Participation in a Research Study

Investigator: Gregory S. Fischer, Noah LeBlanc

Contact Information:

Professor Gregory S. Fischer
Mechanical Engineering Department
Worcester Polytechnic Institute
100 Institute Road
Worcester, MA 01609
Tel. 508-831-5680

Title of Research Study: Tour Guide Robot Interactions - IQP GSF - 1121

Introduction:
You are being asked to participate in a research study. Before you agree, however, you must be fully informed about the purpose of the study, the procedures to be followed, and any benefits, risks or discomfort that you may experience as a result of your participation. This form presents information about the study so that you may make a fully informed decision regarding your participation.

Purpose of the study: To compare and contrast human guided campus tours with robot guided campus tours.

Procedures to be followed: You will follow a robotic tour guide along a predetermined path. The robot will stop at several locations along the path and play prerecorded audio with information pertaining to each location. After completing the tour, you will fill out a questionnaire regarding your robotic tour experience. The tour and questionnaire should require no more than 30 minutes for completion.

Risks to study participants: The robotic platform has the potential to cause harm if it collides with you while it is in motion. Maintain a minimum distance of 6 feet (2 meters) from the robot at all times.

Benefits to research participants and others: This study is not intended to provide any benefits to the study participants.

Record keeping and confidentiality: Records of your participation in this study will be held confidential so far as permitted by law. However, the study investigators, the sponsor or it's designee and, under certain circumstances, the Worcester Polytechnic Institute Institutional Review Board (WPI IRB) will be able to inspect and have access to confidential data that identify you by name. Any publication or presentation of the data will not identify you. We will keep video recordings of your participation in the study, as well as your written answers to survey questions after completion of the study. These records will be kept in a secure office and never associated with you by name.

Compensation or treatment in the event of injury: In the unlikely event of physical injury resulting from participation in the research, you understand that medical treatment may be available from WPI, including first aid emergency care, and that your insurance carrier may be billed for the cost of such treatment. No compensation for medical care can be provided by WPI. You further understand that making such medical care available, or providing it, does not imply that such injury is the fault of the investigators. You do not give up any of your legal rights by signing this statement.

For more information about this research or about the rights of research participants, or in case of research-related injury, contact:

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Tel. 508-831-5680
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Professor Kent Rissmiller
IBR Chair
Tel. 508-831-5019
Email: kjr@wpi.edu

Michael J. Curley
University Compliance Officer
Tel. 508-831-6919
Email: mjcurley@wpi.edu

Your participation in this research is voluntary. Your refusal to participate will not result in any penalty to you or any loss of benefits to which you may otherwise be entitled. You may decide to stop participating in the research at any time without penalty or loss of other benefits. The project investigators retain the right to cancel or postpone the experimental procedures at any time they see fit.

By signing below, you acknowledge that you have been informed about and consent to be a participant in the study described above. Make sure that your questions are answered to your satisfaction before signing. You are entitled to retain a copy of this consent agreement.

_____ Date: _____
Study Participant Signature

Approved by WPI IRB
From: 8/9/12
To: 8/8/13

_____
Study Participant Name (Please print)

_____ Date: _____
Signature of Person who explained this study

Appendix E: Tour Script

Robot Tour Guide Script

Tour Locations

The following sections are the sound bites for each location the robot will stop at during the tour.

Introduction

Hello everybody. I would like to welcome you to the WPI robotic tor. I am the Guest Orientation, Assistance, and Tele-presence robot, created by a three member student team as part of their Major Qualifying Project here at WPI. You have already met one of those three students, Noah, who has put together this tour experience as part of his Interactive Qualifying Project. We appreciate your participation and without any further ado, let's begin our tour.

Harrington Auditorium

Next door to Alumni Gym is Harrington Auditorium, which has been called the finest indoor facility in New England Division III athletics. Brothers Charles and Frank Harrington were WPI athletes in the 1890s who had successful careers in the insurance industry. In the late 1960s, when WPI needed a modern athletic facility for its growing sports program, the brothers' philanthropic foundations provided the funds. The building houses a 2,800-seat gymnasium where the men's and women's basketball teams and the volleyball team play. The gym is often available for general student use and can serve as an auditorium for concerts and campus events. Also here are squash courts and the offices of the Military Science Department. In the lobby you'll find a long case filled with the many awards and trophies won by WPI athletes over the years.

Sports and Recreation Center

We are now standing before the WPI Sports and Recreation Center, recently opened for the first time on July 24, 2012. It is a 140,000 square foot recreational, educational, and environmentally friendly facility. It contains a pool, a fitness center, a four-court gymnasium, an indoor running track, rowing tanks, racquetball and squash courts, dance studios, and offices and meeting spaces for the coaches and staff of the Department of Physical Education, Recreation, and Athletics. The center also includes a connecting corridor to Harrington Auditorium, creating greater capacity for WPI to host conferences, robotics competitions, career fairs, admissions open houses, and alumni events.

Morgan Hall

At this corner of the quad is Morgan Hall, which is one of the most recently renovated residence halls on campus. Students often choose Morgan based on its central location on the Quad making trips to classrooms, labs, and the Campus Center quick and convenient.

The lively atmosphere is another reason the approximately 290 residents of Morgan call this hall home. With game rooms for spending time with friends, an on-site dining facility, called Morgan Commons, and laundry located right next door in Daniels, Morgan Hall is a great option for many students.

Daniels Hall

We are now at the entrance to Daniels Hall. Many students enjoy living in Daniels Hall due to its central location on the Quad. This coed hall is home to approximately 255 students, and was recently

renovated in the summer of 2011. There are common rooms for hanging out with friends, laundry facilities in the basement, and the closest dining facility, Morgan Commons, is located right next door. With a short walk to classrooms and labs, everything you need is in close proximity to Daniels Hall.

Bartlett Center and Tree

We begin the tour at the Bartlett Center. This is our recently constructed, main visitor's center. It is the second newest building on campus, and opened in April, 2006. This two-story, 16,589-square-foot building, is the new home for WPI's Office of Admissions and Office of Financial Aid. The building serves as a welcome center for campus visitors, particularly thousands of prospective students and their families. Bartlett Center is the first WPI building to be registered with the U.S. Green Building Council, and has been designed as a green building, using sustainable design principles under the Leadership in Energy and Environmental Design program.

In Transit Sound Bites

Segway Platform

As part of the tour, I'd like to tell you a bit about myself. First off, I am built using a Segway Robotic Mobility Platform, or RMP. These platforms are designed for use as prototype and research bases, of which I am the latter. The platform is built mainly from Segway Personal Transporter hardware and is both robust and powerful. Using the platform has allowed my creators to concentrate on my higher level functions, such as autonomous navigation, while taking advantage of the platform's existing mobile capabilities.

Sensors 1

As we travel to out next stop, I'd like to tell you more about myself. As a robot, I rely on various sensors to gather information about the world around me. One of the most important functions for an autonomous robot is localization, or the ability to determine my location in an environment. I achieve this using a GPS sensor to calculate my position on the campus, and a compass sensor to determine which direction I am facing. These sensors, which are both located on a mast at my highest point, allow me to find my location while stationary. While in motion, I utilize sensor information from the RMP base to update my position. The base contains wheel encoders to determine how far I have traveled and when I change direction.

Sensors 2

Well, enough about the campus for now, time for me to tell you more about my sensors. In addition to localization, my sensors also allow me to detect objects around myself so I can avoid them while in motion. I accomplish this using two types of sensors. The first is a ring of ultrasonic sensors around my mid-section. These send out sound pulses and use the resulting echoes to determine if any objects are present. I also have a stereo camera module at my front, which uses two cameras to create a three dimensional view of the area in front of me. I combine the data from these sensors to create a map of my environment, called an occupancy grid map, that marks areas as occupied or open. Using a path planning algorithm, I can then plan a route around the occupied areas to reach my destination.

Computer System

Before we reach our next destination, I'd like to tell you about my computer system. I actually have two

computers; one is a touch screen, which you can see facing behind me. This will eventually allow me to interact with people through a graphical user interface. Located in my base is a second computer which handles the bulk of my computing, including processing data from my sensors, determining where I will travel, and controlling the RMP base so that I reach my destinations.

Thank You

Now that the tour is complete, I would like to thank you for your participation. Before I say goodbye, I would appreciate if you could fill out a short survey based on your experience. The data from this survey will help me to become a better tour guide robot and hopefully become a permanent feature on the WPI campus. The purpose of a robot such as myself is to serve people like you, and therefore your opinion is invaluable to me and my developers. Once again, thank you for your time, and I hope you have a pleasant visit to the WPI campus.

Appendix F: Likert Scaled Statement Results

Dialog						Gaze			Safety				General Satisfaction					
Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19
4	3	4	3	3	3	3	4	3	4	2	2	3	3	3	3	3	3	2
3	3	4	3	3	3	4	4	4	3	2	3	3	2	3	3	3	3	2
3	3	3	4	2	3	4	4	4	4	2	2	3	3	3	3	3	4	2
4	3	4	3	3	3	4	4	3	4	2	3	3	3	3	3	4	3	2
3		4	3	3		4	4	3	3	2	2	2	4		3	4	4	1
3	3	3	2	3	3	4	4	3	3	3	3	3	4	2	3	3	3	2
2	1	4	3	3	1	4	1	3	4	1	1	4	4	4	4	4	4	1
3	3	3	2	3	2	4	4	2	4	1	2	4	3	3	3	2	2	2
3	3	3	2	3	3	4	4	3	4	1	2	3	4	3	3	3	3	1
3	2	4	3	3	2	3	3	3	4	2	2	3	4	2	3	3	4	2
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4	2.5	4	2	3	3	4	3	2.5	4	2	2.5	2.5	2.5	3	2.5	3	3	1
3	3	4	3	3	2	4	4	2	4	1	3	3	2	3	2	3	2	2
3	2	4	3	3	3	4	4	4	4	2	3	3	2	3	3	3	3	1
4	3	2	3	2	2	4	3	3	3	1	3		3	3	3	3	3	2
3	3	3	3	2	3	4	3	3	3	1	1	4	3	3	2	2	3	2
4	2	3	3	2	3	4	4	4	4	1	1	4	3		3	3	3	1
3	4	3	3	3	4	3	3	3	4	1	2	3	3	3	3	2	3	1
3	3	2	3	3	3	4	4	3	4	2	2	4	3	3	3	2	2	2
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3	3	4	4	2	3	4	3	4	4	1	2	4	3	3	3	3	3	1
3	3	4	2	3	3	3	3	3	4	1	1	4	3	4	3	3	3	2
4	2	2	3	2	2	4	3	3	3	1	1	4	3	2	3	3	3	1

Appendix G: Quoted Survey Comments

"I also enjoyed learning about the G.O.A.T. and how it works."

"I like to hear personal experiences, ask questions, and feel that it's important to see a student being enthusiastic about college."

"More interaction and being able to go inside buildings."

"The robot tour provides you an option of a tour of the campus when a human guide is not available."

"It represents very well the spirit of the University; definitely impressing upon us what a future at WPI would look like."

"Possibly different languages?"

"The technology aspect of the tour was really cool."

"The robot tour for a technology school like WPI is a very good idea."

"Need to supplement the robot tour with a human tour – both would be good!"

"[It] needs a moving gesture toward the building it is referring to."

"Showcased technology at WPI, which otherwise we did not have an opportunity to see."

"Do it before the human-being guided tour, without a release form – that would create an impression and distinguish WPI from its competitors. The short guided tour was the perfect fit."

"Rain ponchos are distracting, not finished looking."

"Travels well, but at one point I was worried the robot was going off-course."

"Offer as a supplement to live tours – part via robot, part with live person."

"Can't ask questions (yet), would need human back-up to hear unusual questions."

"It has the opportunity to be simple, concise and to the point without a lot of rambling."

"It stopped to talk about itself and the monotone voice leads to disinterest."

"It gave out pure information – something funny or witty would make it more interesting."

"The ability to ask questions, tell jokes and have a more interesting voice would make the robot much better."

"No ability to adjust presentation for situation or audience."

"Silly idea – human tour guides walk backwards – robot always faced front. Have robot head pivot (?) or pretend he is going backwards."

"A light could be added to indicate whether it was going to stop or start moving."

“Voice easy to hear and listen to.”

“[I disliked] having to stay behind and uncomfortable with some of the jerky movement. Would be concerned with small children in group.”

“Robot more fluid of motion so not worried about malfunction.”

“Robot stating where it’s going before it moves – i.e. to my right or left like a human would.”

“It was a little slow.”

“It might get rid of students giving tours.”

“It can’t have a personal opinion of the school.”

“It was so unique, and he had personality.”

“I wish his looks were more finalized.”

“The tour should be expanded to points which are of more interest to applicants.”

“Overall, really awesome idea, really good job with the robot!”

“It would be great if at some point the robot would be able to answer questions.”

“More talking during the walking. Maybe have it move a little bit faster.”

“Show video of inside facilities.”

“While providing visitors with information regarding WPI, the robot illustrates part of the capabilities of WPI students and the types of accomplishments the WPI programs allow.”

“If possible, reaction times and speech enunciation could be improved.”

“The robot gave substantial info about the area it was covering as well as itself.”

“I think it was a really cool way to present the information and show potential applicants about the cool projects they could be involved with.”

“I thought there could be a little more information about types of teams and options for sports at WPI.”

“I think you could just add a little more information but Really Really Cool.”

“It was a new experience.”

“Only covered part of the campus.”

“Talk about social aspects of the quad.”

“Not enough info, needs to be more interactive, would like the robot to be able to bring people into the locations.”

“Script can be thought out in advance, no need of notes or chance of items forgotten. Leaves less to chance.”

“Human assistant could answer questions but not need practice and script. Future interactive user interface could answer many FAQ’s individuals may have to tailor tour to specific needs.”

“It is a great novelty. It shows WPI’s commitment to solving problems with engineering.”

“More volume on sound.”

“Put a USB foam missile launcher to launch at bystanders who stand in front!”

“Allow people to ask questions via their smartphones.”

“Have the robot mention when it detects people standing in the way.”

“I enjoyed trying to figure out how the robot worked.”

“Interaction – could even use google voice recognition to turn questions into search strings.”

“I liked the fact that the robot represented the hard work of students who attended and are attending this college and demonstrated the potential that students can achieve during their time spent at WPI.”

“Very interesting. So cool to see what students are making but the robot actually provided great information.”

“Too slow. The robot was also a little stop and go.”

“Say ‘now we are moving on to…’ or something like it so it doesn’t seem like it was walking away.”

“Great innovation!”

“Build more interactive features – the touch screen is a good idea.”

“The novelty was interesting. If robot tour guides were to become commonplace I would have been less interested.”

“The robot had an interesting personality and character that makes it appealing and entertaining to observe.”

“It was uninteractive and impersonal.”

“It cannot answer questions about its student life.”

“Interactivity and surprises would greatly improve the experience. By surprises I’m referring to comedy or Disney-esque elements that make the tour distinct from a human tour. I think interspersing elements of entertainment would aid the tour’s overall appeal.”