ATHABASCA UNIVERSITY

TELEPRESENCE ROBOT ENABLE REMOTE LAB IN DISTANCE EDUCATION

BY

MARC DENOJEAN-MAIRET

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE

DEGREE OF MASTER OF SCIENCE IN INFORMATION SYSTEMS

SCHOOL OF COMPUTING AND INFORMATION SYSTEMS

ATHABASCA, ALBERTA

MARCH 2016

Athabasca University
FACULTY OF GRADUATE STUDIES

The future of learning.

Approval of Thesis

The undersigned certify that they have read the thesis entitled

"Telepresence Robot Enable Remote Lab in Distance Education"

Submitted by

Marc Denojean-Mairet

In partial fulfillment of the requirements for the degree of

Master of Science in Information Systems

The thesis examination committee certifies that the thesis
and the oral examination is approved

Supervisor:

Dr. Qing Tan

Athabasca University

Committee members:

Dr. Xiaokun Zhang

Athabasca University

Dr. Robert McFadden

Mobile Detect Inc.

March 10, 2016

1 University Drive, Athabasca, AB, T9S 3A3 Canada
P: 780.509.7536 | Toll-free (CAN/U.S.) 1.800.561-4650 x 7536
fgs@athabascau.ca | fgs.athabascau.ca | athabascau.ca

DEDICATION

To my wife Hyung Rae and my daughter Diane.

ACKNOWLEDGEMENTS

First of all, I would like to express my sincere gratitude to my thesis supervisor Dr. Tan for the continuous support of my study and related research, for his respect of my ideas, for his patience, and knowledge. His trust in my abilities provided me with the motivation to research this challenging topic. I could not have imagined having a better advisor and mentor for my MSc IS.

Furthermore, I would like to thank the rest of my thesis committee: Dr. Zhang for his insightful comments and encouragement which incented me to widen my research. Likewise, my sincere thanks to Dr. El Bendary for her perceptive comments and encouragement. Furthermore, I want to thank Dr. McFadden for agreeing to be my external committee member

ABSTRACT

How to conduct lab work in distance education creates a new paradigm shift for online universities. This thesis proposes the use of telepresence robots for remote lab work. There are three main contributions in this thesis. The first contribution is the development of a telepresence robot that is the main component of the telepresence robot based ubiquitous computing platform. The one developed gives an example of affordability, scalability, compatibility, and customizable for the applications. The second contribution is the design and implementation of the telepresence robot system architecture. This telepresence robot system architecture provides an implementable framework for the research, particularly focusing on the telepresence robot implementation for remote lab in distance learning. The third contribution is the validation process of the developed telepresence robot based ubiquitous computing platform under the distance educational scenarios. This contribution tests the feasibility of using such a telepresence robot in a remote lab environment.

TABLE OF CONTENTS

Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF GRAPHS

LIST OF EQUATIONS

Chapter I

Introduction

1.1 Research Background

Online learning is becoming very popular among students. As a result, online universities are growing and must continuously integrate new technologies to provide remote students with ubiquitous learning (Stein, 2014). Now, remote students are using their mobile devices to access online learning at anytime and from anywhere. For many online students, the attraction of earning a degree online is that it will be less expensive than going to a "brick and mortar" university. For many of these students, it means that they can work and at the same time earn a university degree or that they can attend to the needs of their families. Even, for a full-time student, the reduction in travel time and living arrangement can be significant especially for out of country students. In addition, learning at your own pace is very important for all these students. Most course subjects can easily be delivered online. However, some course subjects are more challenging especially, science courses that require a lab component in order to earn the full course credit. For instance, chemistry, biology, and some network courses require students to take a lab component to get full credit. To do so, the students must travel to the actual university laboratories or travel to nearest located laboratories. This is not a perfect solution since the cost to the students and to the universities can be very high. It is difficult for some students to pay for a week travel abroad for lab works. In addition, it is expensive for an online university to have actual laboratories in different places. Besides, it is difficult if not impossible to send expensive or sensitive lab instruments to the students' homes. This creates a new paradigm shift for online universities that must provide ubiquitous learning and laboratory work experience to their students and at the same time, control costs. Online Universities have started answering this problem by implementing new technologies such as virtual labs and remote labs. However, these new technologies do not completely solve the problem. Especially when learning outcome must be increased as many students see science courses and laboratory work experiences as boring. A new paradigm also exists in higher education: Today students are experts in mobile technologies, and are learning best when playing games and by interacting with their peers on social media. This means that traditional education where one remembers facts and applies then is becoming costly and inefficient since new knowledge is increasing exponentially. Luckily, Information and Communications Technology (ICT) in learning and especially in distance learning is greatly advancing. ***As a result, there is a need for an alternative solution that would fully engage remotely located students and increase the learning outcome when doing remote lab activities.*** A novel application of telepresence robot systems in higher education would provide a solution to this issue, which would be to use telepresence robots in remote labs indoor and outdoor for online universities. Students that cannot attend laboratory work at the university because of travel costs or other reasons could use a telepresence robot as their avatars to conduct lab works within a remote lab system. According to (M. K. Lee & Takayama, 2011) found that "[Mobile Remote Presence] allowed remote pilots to work with local coworkers almost as if they were there in person." Furthermore, some studies show that a

Telepresence robot in a class room setting help in learning activities (Fumihide, T., Toshimitsu, T., Shizuko, M., Nao, T., & Masahiko, 2014; Tanaka, Takahashi, & Morita, 2013). As per (M. K. Lee & Takayama, 2011):

> … results also confirmed that MRP can enable more casual and social interaction, and provide greater opportunity for remote pilots to get to know local coworkers and vice versa.

1.2 Research Issues

There are three major issues that were encountered when this research started to be investigated. The first issue is that commercial telepresence robots are expensive. Commercial telepresence robots range in price from $899 USD to over $60,000 USD. Price point is a major factor in accepting new technologies especially in education where budgets have shrunk over the years.

The second issue is that these commercial telepresence robots are not suitable for remote lab work unless being heavily modified. Also, many of them are missing features that are necessary for a telepresence robot enable remote lab such as open software and hardware. Furthermore, most commercial telepresence robot companies do not allow access to their software or hardware to be modified. As a result, these telepresence robots cannot be easily used in remote labs.

The third and final issue is that there are little to no studies related to the use of telepresence robots in remote lab for lab work in distance education. Information such as what feature the telepresence robot should have or what

User Interface (UI) work best is not available. Or, how to integrate telepresence robot systems within learning management systems such a Moodle do not exist as well. As a result, we have little data regarding the benefits of using telepresence robot systems in laboratory and especially in remote lab environments. Moreover, we do not know if an untrained person would be able to drive and use a telepresence robot in such environment where the user might have to move objects remotely to perform experiments in chemistry, physics, or biology lab. We know little about the user experience when driving a telepresence robot in a lab setting.

These three main questions emerge out of these research issues:

1. Can an affordable telepresence robot for remote lab work research be built within a small budget?

2. What could be the system architecture of a telepresence robot system for lab work?

3. How can the proposed research solution be validated? Is the way of validity correct (effective) for this type of research? Analyze, evaluate, and validate the research.

1.3 Research Objectives

To answer these three questions, three research objectives are accomplished in this thesis.

The first research objective studies the various telepresence robot systems available today and study their best features. This research objective results in the design of an affordable telepresence robot that provides a ubiquitous computing platform for remote lab work in distance education. The ubiquitous computing platform could also be used for research and other educational projects.

The second research objective investigate what architecture a telepresence robot system for remote lab can be. The study focuses on reviewing remote lab setups, wireless sensors network, virtual lab software, and Learning Management Systems (LMS) such as Moodle. This second research objective analyses and defines the telepresence robot system architecture within a remote lab environment (indoor and outdoor). It outlines the major components of the system and its dependencies from the LMS.

The third and final research objective investigates how to validate the research study. For this final research objective, the affordable ubiquitous computing platform is used to get feedback from students and other people to prove the usability and practicality of telepresence robot systems in remote labs.

1.4 Research Methodology

As we have very little data on telepresence robots enable remote lab, this research is an exploratory research. This research main focus is not to provide conclusive findings but to help better understand the problems of using ubiquitous computing platforms in remote lab and explore in what type of ecosystem such a platform could be used in distance education. The topic of telepresence robot enable remote lab has been explored at different level of complexity in this thesis. One important idea during this research was that telepresence robots were maybe not suitable for remote labs. This was expressed by the believed that driving an affordable telepresence robot without extensive training was too difficult for the average person. The research methodology used qualitative and quantitative approaches to answer the research questions.

The Athabasca University Online Library has been extensively used during the research for gathering peer review journal papers and conference papers on telepresence robotics, remote labs, and wireless sensors network (WSN). These papers have been used for the literature review. Also, the World Wide Web (WWW) was used to find information on commercial telepresence robots, remote labs, embedded computing, open-source software, and WSN. I looked at websites of companies that offers commercial products in those areas of interest. Google search engine was used to find relevant links and Google Scholar was used to find relevant articles. YouTube was also used to watch video of commercial and experimental telepresence robots and other pertinent information.

For research objective number one, the WWW was searched for relevant links to telepresence robots, open-source software, and embedded computing device used by educators for teaching programming, computing, and robotics. Also, the Athabasca University (AU) library was searched for papers, articles, and books about telepresence robotics. After reading and analyzing the information gathered, a 3D model of the planned telepresence robot was designed. The software used for this was Google SketchUp. Subsequently, a full size foam mock-up of the robot was made to have a feel of the general dimensions. Finally, a working prototype was built. For the software of the telepresence robot, the WWW was searched for open-source software that can be used for this project. The goal of this research objective was to find open-source software and hardware that could be used to build a telepresence robot within a small budget and to identify important features of telepresence robots.

For research objective two, the AU library was searched for papers, articles, and books relevant to telepresence robots, mobile robotics, teleoperation, laboratory, remote laboratory, and WSN. The WWW via Google and Google Scholar was explored for these topics as well. The information collected was analyzed and based on these findings; a proposed architecture design for telepresence robot systems for laboratory and remote lab was created.

For research objective three, an internal validity and an external validity of the research was done. For the internal validity, my supervisors, and me have tested the telepresence robot and we have reported our observations. For the external validity, a test and a survey was done with 40 participants. The participants drove the telepresence robot within a mock-up lab environment and answered a questionnaire about their driving experience. The survey is shown in appendix A.

1.5 Research Contributions

There are three main contributions in this thesis:

The first contribution is the development of a telepresence robot that is the main component of the telepresence robot based ubiquitous computing platform. The one developed gives an example of affordability, scalability, compatibility, and customizable for the applications. This is the key component of this exploratory research telepresence robot enabling remote lab for distance learning. This affordable telepresence robot made this research possible since no commercial alternative was available to meet the solution criteria of the research. There are three main reasons why this telepresence robot needed to be developed. The first reason is that no other commercially available telepresence robots have all the features that was required for this study: Openness of software and hardware, an arm with a gripper, pan and tilt head, Wi-Fi, Bluetooth, HD cameras, ability to interface sensors, the ability to run Linux OS, and low cost (within $1,000 Canadian dollars). The second reason is cost. The research solution has a target to provide affordable telepresence robot within cost of $1,000 Canadian dollars. Therefore, the budget for this study was only $1,000 CAD. For this budget, there are no commercial telepresence robots that have all the features needed. The third reason is facility of replication. The researcher believes that a low cost and easily duplicated ubiquitous computing platform will permit other researchers to further explore this topic and add to the knowledge base. High cost and complexity can prevent new researches to be started and the solution to be adoptable. This telepresence robot based ubiquitous computing platform achieves theses goals by designing a simplified and effective system architecture. This is done by using reliable and inexpensive hardware components and open-source applications.

The second contribution is the design and implementation of the telepresence robot system architecture in coping with the overall system architecture of the telepresence robot enabled remote lab for distance education. This telepresence robot system architecture provides an implementable framework for the research, particularly focusing on the telepresence robot implementation for remote lab in distance learning. The researcher designed a potential overall system architecture including remote lab, virtual lab, and the 5R adaptive learning management system under the proposed indoor remote lab scenarios. This ecosystem of the research solution includes the student, the telepresence robot, the remote lab wireless sensor network, the hardware interface, the virtual lab server, the web server, and the learning management system as well as the instructors (lab assistants or professors). In this proposed ecosystem, the telepresence robot based ubiquitous computing platform is the main component of the proposed solution.

The third contribution is the validation implementation of the developed telepresence robot based ubiquitous computing platform under the distance educational scenarios. This contribution tests the feasibility of using such a telepresence robot in a remote lab environment. Importantly, the validation of the process could be applied to other similar future studies. A major concern of this exploratory research was to know if untrained students at a distance could use a telepresence robot to do lab work. Usability is a major factor in accepting new technologies. To test the solution a mock-up remote lab and a simple experiment was designed. It would not have been possible within the scope of this thesis to implement the full indoor lab scenarios. As a result, a simpler version of the indoor remote lab was implemented to test this solution. The focus of this validation implementation was on the usability of the telepresence robot in distance education by inviting geographically dispersed students and other participants to drive the telepresence robot to conduct some lab activities. A dexterity test was designed and a questionnaire was provided for the participants to answer. This validation including the implementation of the telepresence robot, processing and analyzing the answers of the questionnaire survey gives an effective way to identify a wide range of issues and to verify system functions in related to the telepresence robot enabled remote lab in distance education, which provides a solid foundation for the entire research. The validation process was found to be effective in validating this type of research.

1.6 Research Scope

The scope of this thesis mainly focused on developing an affordable telepresence robot for the ubiquitous computing platform that could be used in remote lab work. The emphasis was on affordability, flexibility, simplicity of the design, and the easiness of duplication within an open-source community. Also, compatibility and customization were other important factors in the design. It is to be noted that this telepresence robot based ubiquitous computing platform is a prototype and that some features are not implemented because of time and resources constraints. The proposed telepresence robot architecture deals with the theoretical design of such a system for remote lab in distance education. No specific implementation of the full system was planned since it would be out of scope for this thesis. To validate the implementation of the developed telepresence robot, a simpler version of the indoor remote lab architecture was instigated. A simple mock-up lab was built and a dexterity test was designed.

1.7 Thesis Organization

Chapter II offers a comprehensive literature review of telepresence robot, remote laboratory, virtual laboratory, wireless sensor networks, and pedagogy. Chapter III discusses the design of the telepresence robot with sections on the CPUs, head, body, arm, software, and pilot interface and controls. Chapter IV discusses the system architecture and implementation. A concept for indoor remote lab is proposed followed by a possible system architecture of such a system. As well, the implementation of the telepresence robot is discussed and another concept for outdoor remote lab is offered. Chapter V talks about the implementation validation. It describes the experiment and questionnaire design. Furthermore, it goes in details over the analysis of the data collected during the survey. Findings are discussed at the end of this chapter.

Chapter II

Literature Review

2.1 Telepresence Robot

Telepresence robots are becoming more and more common in businesses, healthcare and education. Some companies such as VGo, Double Robotics, Anybots, and iRobot are offering commercial Telepresence robots that can be used in these environments (“Anybots,” 2014, “Double Robotics,” 2014, “iRobot,” 2014, “VGO,” 2014). According to (Desai, Tsui, Yanco, & Uhlik, 2011) “Contemporary telepresence robots can be described as embodied video conferencing on wheels.” When compared to Telepresence video conferencing systems such as Skype, Telepresence robots offer the added benefit of being able to move around within the remote location environment. This gives the pilots of the TR a greater sense of being at the remote location and promotes social interactions between individuals (Kristoffersson, Coradeschi, & Loutfi, 2013). When using telepresence robots in an environment a complex interaction between remote users and local users is created. The remote user (pilot) interacts with the local people and at the same time controls the robot. Local users are interacting with another human via video conferencing but; also, interact with a robot (Human-Robot Interaction). The remote pilot is interacting with a computer (used to control the robot) and, at the same time, interacts with another human (Kristoffersson, Severinson Eklundh, & Loutfi, 2012). As a result, the acceptance of this technology by local and remote users is very important. The unified theory of acceptance and use of technology model (UTAUT) defines four factors that influence the use of technology; performance expectancy, effort expectancy, social influence, and facilitation conditions (Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, 2003). Moreover, new social norms emerge out of using telepresence robots. There is ambivalence about what a telepresence robot represents for the local user. Sometime, it is a person and other time, it is an object (M. K. Lee & Takayama, 2011).

2.2 Telepresence Robot Hardware

A standard commercial telepresence robot is usually composed of a mobile robot base that has two motorized wheels and one or two trailing casters ("Giraff," 2014, "iRobot," 2014, "VGO," 2014). Some mobile robots bases are self-balancing bases and do not have the trailing casters ("Anybots," 2014, "Double Robotics," 2014). Telepresence robots are also composed of a LCD display, one or two webcams, one or many microphones, a main computer board, motor control boards, and some sensors. Some telepresence robots have pan and tilt cameras that can be controlled by the pilot. Not all telepresence robots offer this feature. For instance, Double robotics robot does not have the pan and tilt feature ("Double Robotics," 2014). The telepresence robot is basically a remotely operated video conferencing system on a mobile robot base. The telepresence robot is controlled via WI-FI through the Internet. Most telepresence robots are "human height" since there are designed for social interactions. Their heights can be between 119 cm to 152 cm ("Double Robotics," 2014). Some of the telepresence robots have the possibility of changing their heights based on the situations by lowering or rising their bodies

(“Anybots,” 2014, “Double Robotics,” 2014, “iRobot,” 2014). This can be done remotely by the pilot or manually by a local user as in the case of the Anybots’ QB Telepresence robot. For instance, in a meeting room, the remote user can lower the height of robot and be at “sitting height”. The ability of changing the height of the robot remotely is much more attractive than asking someone to do locally. Many telepresence robots like Giraff and iRobot Ava 500 use single board computers as their main control unit. For example, the Giraff has a mini-ATX board with an Intel i7-3610QM (quad core) processor, 4 GB of ram and 60 GB solid state hard drive (“Giraff,” 2014). However, some telepresence robots such as Double Robotics use tablets and smartphones instead (“Double Robotics,” 2014).

2.3 Telepresence Robot Software

Telepresence robots use open-source or proprietary video conferencing software (VC). These VCs software are very much like Skype and permit the pilot to interact with local users. The Operating Systems used by Telepresence robots are Microsoft Windows Embedded, Linux, and Robot Operating System (ROS). Other operation systems are also used. Double Robotics uses Apple’s iOS (“Double Robotics,” 2014). In this case, the tablet will use Bluetooth to communicate with the base and control the motors. Giraff uses Microsoft Windows Embedded and iRobot Ava 500 is a Linux-based robot. Assisted driving, semi-autonomous, and autonomous Telepresence robots have extra software layers that handle object avoidance, navigation, and environment mapping. ROS is an open-source robot operating system used by researchers and commercial companies to power their robots (“ROS,” 2014). The core concepts of ROS are nodes, messages, topics, and services (Quigley et al., 2009). ROS is not exactly an OS but more an add-on of software libraries to an OS such as Linux OS. Open-source software programs such as ROS can be used by Telepresence robots since it is a framework that provides common robotics functions such as motion planning, object recognition, and physical manipulation (Greenwald, 2010). Another open-source software used for robotics and video processing is OpenCV (Open Source Computer Vision Library). OpenCV library has more than 2500 algorithms optimised for computer vision and machine learning. These algorithms can be used to detect face, recognize objects, track moving objects, and extra 3D model of objects (“OpenCV,” 2014).

2.4 Telepresence Robot Control

Telepresence robot systems are usually controlled via a web interface and/or an application running on the remote pilot’s computer (“Anybots,” 2014, “Double Robotics,” 2014, “iRobot,” 2014, “VGO,” 2014). The keyboard, mouse, or track pad can be used to move around the robot and pan/tilt the camera. Also, on mobile devices such as smartphones or tablets, the user will use the touch screen to control the telepresence robot. Many of the commercial telepresence robots are just remote controlled robots. However, some telepresence robots are autonomous. The pilot just pick a destination and the robot will navigate to it automatically (“iRobot,” 2014). Tele-operated robots are simply controlled by a pilot remotely usually using an interface that has four directional buttons. The operator can control and move the robot in all directions by pressing one of these buttons (Katherine M. Tsui et al., 2014). Assisted driving telepresence robots are an improvement over simple remote controlled robots since it helps the pilot avoiding collisions or falling down the stairs (MacHaret & Florencio, 2012). Distance sensors and mechanical sensors are mounted in the base of the robot and detect immediate collisions with objects or people while the robot is being driven in the remote environment. The sensors automatically stop the robot without the remote pilot input. Semi-autonomous goal is to share the control of the robot between the pilot and the computer, which translate in “safe” short-range navigation. The pilot can, for instance, issue low-level commands and it will be translated to “safe” low-level commands. For instance, the robot will be asked to move within a room and the semi-autonomous mode will prevent collisions with people or objects (MacHaret & Florencio, 2012). As per (Wei & Dolan, 2009), a human pilot can collaborate with a vehicle artificial intelligence to achieve better driving performance, robustness, and safety. In autonomous mode telepresence robots can navigate the local remote environment without the help of the remote pilot therefore freeing the remote pilot from the boring and difficult work of driving the robot from and to different locations within the remote environment (MacHaret & Florencio, 2012). The pilot can choose a destination on a map and the robot will navigate to that destination by itself and at the same time avoid any collisions with objects or people (Coltin, Biswas, Pomerleau, & Veloso, 2012). These autonomous telepresence robots are the most sophisticated of all telepresence robots available today. They use laser rangefinders to scan and map their environments (Katherine M. Tsui et al., 2014). Augmented Reality (AR) and Augmented Virtuality (AV) can be used to improve control of the Telepresence robot and improve the remote user present in the environment. AR adds information to the video feed of the robot and, as a result, helps help the pilot in making decisions by reducing the pilot workload. In contrast, AV uses real time video images and virtual images to increase the pilot's awareness of the robot environment (Sanguino, Márquez, Carlson, & R. Millán, 2014).

2.5 Telepresence Robot Cost Analysis

Commercial Telepresence robots are expensive. Their prices start at $899 USD to over $60,000 USD. In addition, most of the commercial Telepresence robot companies require their customer to pay for network services that start at $1,200 per year ("Anybots," 2014). Double Robotics do not have yearly network or licensing fees ("Double Robotics," 2014). The lowest prices are for base models targeted to the general public or small companies market. When options are added, the units are much more expensive. For instance, QB from Anybots is a very nice telepresence robot but it can cost up to $12,359 USD with options plus $1,908 USD (SMB Connection Services) per year for up to 12 users ("Anybots," 2014). Furthermore, most of these robots are not upgradable and it is difficult to add new hardware to them. Therefore, these Telepresence robots are not very well suited for academia research. For research purposes, a university department can easily spend in excess of $10,000 in a Telepresence robot that will not exactly match the needs of the department, researchers and students. Below is a table with the prices of commercially available Telepresence robots.

Table 1 – Telepresence robot price analysis

Robot	Company	Price	Service Fee/Year	Source
QB	Anybots	$10,149 USD	$1,908 USD	www.anybots.com
VGo	VGo	$5,995 USD	$1,200 USD	www.vgocom.com
Double	Double Robotics	$3,165 USD	N/A	www.doublerobotics.com
Ava 500	iRobot	$69,500* USD	N/A	www.engadget.com**
Beam+	Suitabletech	$1,995 USD	N/A	www.suitabletech.com
BeamPro	Suitabletech	$2,369 USD + $574 USD per month (lease)	N/A	www.suitabletech.com
Origibot	Origin Robotics	$899 USD	N/A	www.originrobotics.com

*no price available on the company's website. **Engadget.com is not the official company website.

In the recent months, some companies and crowd funded projects have offered telepresence robots under $2,000 USD. “Beam+” from Suitable Technologies is a telepresence robot priced just under $2,000 USD. The “Beam+” is targeted to the home and small business market. “BeamPro” Telepresence robot is also available from the same company for $2,369 USD down payment and $574 USD per month (lease term) (“Suitable Technologies,” 2014). Origibot is a crowed funded project priced at $899 USD. It is targeted to the hacker market. Both of these telepresence robots are interesting. However, they have their own limitations. Beam+ does not have an arm and cannot be easily modified. In contrary, Origibot has an arm and gripper. But, it does not have any on-board computer which limits its possibilities.

2.6 Telepresence Robot in HealthCare

In healthcare, telepresence robots are used from Intensive Care Units (ICU) to elderly care at home for remotely visiting patients (Kristoffersson et al., 2013). According to (Kristoffersson et al., 2013) in Intensive Care Units (ICU), a study shows that the use of telepresence robots can increase response time during “off-hours”. Patients can be seen within 5 min after a request for consultation is made. Travel time to and from the hospital for the physician has been eliminated. Another project with telepresence robots is to monitor at home young children that have been discharge early from the hospital. As a result, instead of bring the children back to the hospital; the doctors can visit the children at home by using a telepresence robot (Kristoffersson et al., 2013). Telepresence robots can be used in dementia care to reduce the patient social isolation and help families reduce traveling time to interact with patients in care facilities. In this study, a European telepresence robot named “Giraff” tested by the ExCITE team received positive feedback by participants and showed that patients had positive reactions when connecting with their families via Giraff (Moyle et al., 2014). One more promising project for telepresence robots in healthcare is for elderly patients that want to stay at their home but need to be supervised. Isolation for seniors is a problem when they cannot participate to family activities. Isolation, for this senior people can lead to health issues such as depression. The use of Telepresence robots can reduce isolation for this group of people and mitigate depression by promoting social engagement (Katherine M Tsui, Norton, Brooks, Yanco, & Kontak, n.d.). Western countries and Japan have an increasing older population that will need more and more healthcare as they become older. As a result, it can potential stress the healthcare systems of these countries (Michaud, Boissy, & Labont, 2004). It is noted by (Orha & Oniga, 2012) that assistive technologies and especially robots, in the future, will play a greater role in eldercare in providing services that are beyond human staff capabilities. These Telepresence robot systems can server many different purposes such as health monitoring, monitoring, and social interactions. The ExCITE team has been doing this with Giraff. From this study and after getting feedback from users of Giraff, the ExCITE team improved Giraff by adding automatic docking to the charging station, obstacle detection, and self-localization (Gonzalez-Jimenez, Galindo, & Ruiz-Sarmiento, 2012).

2.7 Telepresence Robot in Businesses

Some businesses are starting to adopt Telepresence robots within their offices or factories environments. Since, nowadays, business is conducted internationally with geographical dispersed teams (Kristoffersson et al., 2013)(Kristoffersson et al., 2012). Good collaboration and cooperation within teams are essential for the success of these businesses (Kristoffersson et al., 2013). Consequently, extensive travel is needed in order to meet these dispersed teams all over the world. Telepresence robot can help reduce travel for the users and reduce travel cost for the companies. Users of telepresence robot systems can interact with coworkers during meetings. What is more, telepresence robot systems permit these users to interact with coworkers informally during short and not plan conversations in hallways and outside meeting rooms. These types of random meetings with coworkers promote collaboration within teams and across teams. In addition, telepresence robot systems add interactivity during conversations since users of telepresence robot systems can follow coworkers or employees to different locations within the business environments (Kristoffersson et al., 2013). In addition, as per (Guizzo, 2010):

> Participating as a robot, I think, makes a huge difference, mainly because when you speak, people look at the robot and you feel you have their attention. Even rolling into the room and choosing your place around the table gives you a better sense of "being there."

2.8 Telepresence Robot in Education

Some Telepresence robot projects involve ill children attending school via telepresence robot systems while staying at home or in hospitals. For these children physically attending school is often not possible. Schools try to help these students by providing them with home-tutors, online courses, and special transportation arrangements. VGo a Telepresence robotics company has helped ill children attend school from their homes by using a Telepresence robot. Three ill students used VGo successfully. Lyndon Baty from Knox City in Texas is a high school student that cannot go to school because of an illness that require him to have limited physical contacts with people. Every morning Lyndon go to his computer instead of getting in the bus and connect to VGo at school. There, he can navigate the school and interact with other children and teachers as if he was physically actually there (Special & Needs, 2013). Another example of how VGo is used in school involves Aidan Bailey a second grader at Edgewood-Colesburg, Iowa. Aiden received a double lung transplant that prevent him from going to school and socialize with his classmates. Before using VGo, Aidan used Skype. However, with Skype, Aiden was stationary and was bounded to a desk. This changed with VGo and now Aidan can move around whenever he wants (Special & Needs, 2013). VGo is not the only Telepresence robot company that demonstrated that Telepresence robots are useful in education environments. With the help of Double Robotics, the Kodiak Island Borough School District, Alaska uses Double a Telepresence robot to connect with the remote schools and their students ("Double Robotics," 2014). Another example from Double Robotics is Kolton Kincaid a 16 year olds high school student who was paralyzed in a farm accident. He is now able to go to his school and roam the halls of Haven High School, Kansas and interact with his friends as if he was actually there. Kolton controls the robot from Denver via an iPad. These studies have shown that sick children could do the same tasks than other children in the same environment (Kristoffersson et al., 2013).

A study in remote education involves the teaching of a foreign language, in this case English, using a Telepresence robot located in South Korea (Kwon, Koo, Kim, & Kwon, 2010). The lack of native English speaking teachers in South Korea was the motivation for this study. This study received positive feedbacks from the teachers. Using TR systems over video conferencing systems such as Skype have some advantages. A study done by (Fumihide, T., Toshimitsu, T., Shizuko, M., Nao, T., & Masahiko, 2014) involving an English learning school and four public elementary schools in Tsukuba City, Japan showed that young children responded better when a Telepresence system was used than when Skype alone was used by foreign teachers. It was found that children interacting with foreign speaking teachers via Skype only would freeze early on during the interaction. On the contrary, when Skype-robot was used, children responded better and did not freeze as much. Children who could not respond to the foreign teacher during the Skype-only interaction were still able to communicate their intentions during the Skype-robot interaction. Moreover, the study suggested that child-operated Telepresence robots were useful for remote education such as teaching foreign languages.

2.9 Telepresence Robot Issues and Researches

Telepresence robots have to overcome many issues when used in real life environments such as in schools, hospitals, or factories. Good network communication and low latency is of upmost importance for safety and controllability of Telepresence robots (Kwon et al., 2010). Since Telepresence robots use Wi-Fi and not wire to connect to networks, the risk of having poor communication or even losing communication is very real. If the remote user loses communication, he or she will not be able to see or hear the local environment and will not know what the robot is doing at this point in time. High quality video with low latency is very important in Telepresence robots. Therefore, the best video compression algorithms and hardware must be used. Another problem when operating a Telepresence robot in a crowded environment is collision avoidance. It is difficult for the remote pilot to have full situational awareness of the environment since the camera field of view is usually narrow. A wide field of view lens can be used to mitigate the "tunnelling" effect when driving Telepresence robots. A similar problem is location awareness; this happen when a pilot is driving the robot in an unfamiliar environment. As a result, the pilot does not know in which room the robot is and does not know how to go to the next location. It has been reported during studies that it was difficult to follow people and, at the same time, participate to a conversation. Adding a level of autonomy to Telepresence robots would enhance the driving experience and would help in focusing better on the conversation and interaction with local people (Alers et al., 2013). Maastricht Intelligent Telepresence RObot (MITRO) was specifically build and designed to do research on Augmented Telepresence and assisted control ("MITRO," 2013). Driving the robot requires a lot of concentration from the pilot and multitasking become difficult. Researchers are developing Telepresence robots that are able to navigate an environment autonomously and, therefore, making the experience of driving a Telepresence robot more enjoyable. For instance, CoBot-2 control is symbiotic with a variable level of autonomy from the pilot control. This semi-autonomous control scheme permits an easy and safe control of the robot (Coltin et al., 2012). Another issue reported during the studies is that it is difficult to find the person who is talking within a group of people. Sound localization is not very good for most Telepresence robots. An Attention-Directed Telepresence robot was develop by (Yan, Tee, Chua, Huang, & Li, 2013). The robot uses 8 microphones for 3D sound localization.

Also, reported during studies is the lack of being able to pick-up objects when using Telepresence robots. With most of the commercial robot, the pilot can see and hear the local environment but he or she cannot interact with it physically by, for instance, grabbing an object and bring it up to the camera to examine it in details (K. M. Tsui & Yanco, 2013).

2.10 Remote Laboratory

A Remote Lab are computer-mediated laboratories that permits students to carry experiments remotely through the Internet (Odeh, Shanab, Anabtawi, & Hodrob, 2013). Students controlled real instruments such as oscilloscopes, Geiger counters and mass spectrometers (Sauter, Uttal, Rapp, Downing, & Jona, 2013). A typical Remote Lab setup consists of scientific instruments connected to local computers. Specialist electronic boards such as data acquisition boards make the connections. Also, audio and video feedback is provided for observing the experiments (Benmohamed, Leleve, Prevot, & Lyon, 2004) (Odeh et al., 2013). (Sauter et al., 2013) noted after their studies that students that used Remote Labs felt that they conducted real experiments and those students that watched videos felt more engaged with the activity involved in the experiments. However, some students do not consider Remote Labs realistic and that students might become distracted and impatient with computers (Ma & Nickerson, 2006). The usability of Remote Labs greatly depend of the bandwidth and the quality of the network connection between the students and the Remote Labs; poor network connections will affect the outcome of the laboratory experience (Ayodele, Kehinde, & Komolafe, 2012).

2.11 Virtual Laboratory

A Virtual Lab is a computer simulated environment which recreates the real world to promote Discovery Learning (Subramanian & Marsic, 2001). These virtual environments can be used to simulate a classroom laboratory experience (Diwakar et al., 2014). Further, (Diwakar et al., 2014) state that these virtual environments provide a learning experience equivalent to a real classroom laboratory experience for distance learners. Within this virtual environment, students are permitted to make errors and correct them to increase their engagement and interest (Subramanian & Marsic, 2001). A typical example of a Virtual Lab can be found at the University of Delaware, USA. An interactive animation helps students learn how to use a compound microscope ("UD Virtual Compound Microscope," 2011). The virtual instrument fidelity represents a real compound microscope with turning knobs, iris, and light switches. The students must operate the knobs and switches of the virtual microscope correctly to bring the specimen of the slides into focus. As a result, students with no experience in using a compound microscope learn the basic on how to operate such a device. However, Virtual Labs are not without problems. Creating a realistic simulation of a classroom lab or of a scientific instrument can be very difficult. It is expensive and time consuming to program Virtual Labs (Subramanian & Marsic, 2001). In addition, Virtual Labs are being seen as secondary in value when compared with real laboratories (Hallyburton, Lunsford, College, Drive, & Nc, 2010). In non-military environments, WSNs applications are diverse. WSNs are used in science, healthcare, education, and robotics. For instance, WSNs nodes can be used underwater to monitor water parameters and pollution (Lloret, 2013).

2.12 Wireless Sensor Networks

Wireless Sensor Networks (WSN) are made of many nodes and each autonomous sensor node can communicate with another node or a gateway (Uthra & Raja, 2012). Within this sensing field, nodes relay the sensed information to a central based station where the data are analysed (Troubleyn, Moerman, & Demeester, 2013). Each node is made of sensor (s), a CPU, memory, short-range radio transceiver, and a power source (Krishnamachari & Networks, 2005). A WSN node can have a lot of different type of sensors. These sensors can be gyroscope, accelerometer, magnetometer, pressure sensor, acoustic sensor, pyroelectric effect sensors, humidity sensor, temperature sensor, light sensor, and chemical composition sensor (Labs, 2013). A large amount of sensors permit the monitoring of a large geographical area with creates accuracy (Uthra & Raja, 2012). Wireless Sensor Networks can be organized as a Star networks or Mesh networks. In a Star network, each node communicate with a central gateway and in a Mesh network, each node communicate to the nearest node (Lewis, 2004). Also, other network organizations are possible such as Ring, Tree, bus, and fully connected networks. WSNs can be used for military or civilian projects. The military has been interested in WSNs and funded through DARPA the SensIT program. The project had two main goals. The first goal was to develop a new type of software for nodes. The second goal was to be able to extra timely and right information from the WSNs (Kumar, Ph, & Shepherd, n.d.). The military primary goal during battlefield monitoring is target tracking. Research on target tracking in Wireless Sensor Networks is becoming more and more popular (Li, Qin, Shan, Zhang, & Yang, 2014). In non-military programs, WSNs are used in science, healthcare, education, and robotics. In education, WSNs are used in online labs to support learning. Wireless Sensor and Actuator Networks (WSAN) are an accurate and flexible way to remotely interact with a laboratory (Cardoso & Gil, 2013). WSNs can be used for robot navigation and mapping. (W.-Y. Lee, Hur, Hwang, Eom, & Kim, 2010) propose an algorithm for navigating a mobile robot through Wireless Sensor Networks. The mobile robot can navigate without a map, compass, or gps just by interacting close sensor nodes.

2.13 Pedagogy

Online universities must stay relevant to students in order to manage growth and retain their appeal within higher educational institutions. Remote labs and telepresence robotics can provide added flexibility to online learning by permitting remote students to do lab works at anytime. Studies suggest that students view remote labs and telepresence robots positively. In the case of remote labs, the activities must provide real learning and be well integrated within the other learning materials (Kist, Gibbings, Maxwell, & Jolly, 2013). A study by (Tatli & Ayas, 2013) suggests that virtual laboratory software were as effective as real chemistry laboratories. Moreover, remote and virtual labs can be as effective as traditional labs when it comes to teach specific course concepts (Corter et al., 2007). It is also noted that students using remote labs and virtual labs do more solo work and, under constructivist perspective might increase they learning since they do not take a passive role in recording and organizing data (Corter et al., 2007).

According to (Lang, 2012):

A pilot study was done comparing the performance of two groups of students conducting a typical first year university level physics lab using a traditional face-to-face lab format and the remote web-based science lab technology. No significant differences in the work the students produced were found. Student experiences with respect to a set of learning objectives derived from a meta-analysis of the literature were also investigated and no significant differences were found.

Remote labs, virtual labs, and augmented remote labs might create new difficulties in learning. These difficulties might arise from authenticity, fidelity, and credibility issues (Wang et al., 2014). All these issues might affect the learning outcome. Does the actual presence of the students in the laboratory influence their learning outcome? The possibility to be “there” via telepresence robotics can help in learning outcomes and, might, increase involvements when compared with traditional video-conferencing systems.

According to (Tanaka et al., 2013), “Children uncomfortable with English could participate in various educational activity conducted in English if granted physical access to educational toys via the control of a robot prototype.” A field pilot study by (Yun, Kim, & Choi, 2013) suggested that Teleoperated robots can be effectively used to teach English to South Korean elementary students.

Chapter III

Design of the Ubiquitous Computing Platform

I was awarded $1,000 from the Athabasca University Graduate Student Mission Critical Research Fund (GSMCRF) to build an affordable telepresence robot that could be used in my research. A first prototype named Mark I was build for less than $400 CAD. A second prototype the Mark II quickly followed the Mark I. The main two improvements of the Mark II over the Mark I are the addition of the HD head web camera and the simplification of the electronic hardware. Now, only three main electronic modules are used: A Raspberry Pi 2, an Arduino UNO, and a motor controller board. The new Raspberry Pi 2 is more powerful than the original Raspberry Pi and permits to do visual processing of the video feeds. For example, color or shape recognition can be done. Also face recognition could be implemented and data about the recognized face could be displayed to the pilot of the telepresence robot. This can be accomplished with open-source applications such as OpenCV. Furthermore, OpenCV or similar applications could be used to provide an automation layer to the telepresence robot's software architecture. Computer vision could be used for guiding and tracking. For instance, the robot could recognize an object on the lab table and know that the user is pressing the forward key on the keyboard. As a result, the robot could autonomously drive itself to the object. The pilot would not be aware that the robot is moving autonomously. The design of this telepresence robots are not based on a specific existing telepresence robot but, instead, is based on the requirements outlined in the next section. It is a fully working prototype that has been remotely driven by people in Canada, Taiwan, Egypt, and France. A paper for the 13th IEEE

International Conference on Ubiquitous Computing and Communications (IUCC2014) was submitted for this project.

The telepresence robot is build with common and widely affordable components that can be found practically anywhere or that can be easily ordered online at very reasonable prices. In addition, the telepresence robot needed to be easy to build, modify, and program since non-engineers could use it for research and educational purposes. As much as possible I use open-source components and applications that would have a large community of users and few licensing restrictions. Also, these components and applications should currently be well known to educators and used for educational purposes.

3.1 Robot Requirements

The telepresence robot for remote lab should have the following characteristics:

- Ability to do video conferencing
- Ability to grab objects
- Video display screen of 4” minimum
- HD head video camera
- Ability to pan and tilt the head 180 degrees
- Compact base
- Be stable with a minimum of front and back rocking when moving
- Small turning radius
- Wi-Fi communication

- Bluetooth communication
- Easy sensors integration
- Total weight of less than 5 kg
- Total height of at least 4 feet
- 4 degree of freedom
- Possibility to add sensors
- Ability to communicate with lab servers

3.2 Base Design

The base is rectangular with sides of 26 cm by 37 cm. The dimensions are not critical but this size gives good stability and a small footprint to the robot. The drive train is composed of two 12 volts geared motors paired with 12.7 cm wheels (5 inches) and a rear caster wheel. As a result, the robot works like a tank and uses differential steering to turn. A simple H-bridge motor controller drives these two motors. The battery used is a 3 cells Lipo pack 11.1 volts 4000 mAh. The DC geared motors, wheels, H-bridge, and battery were all bought

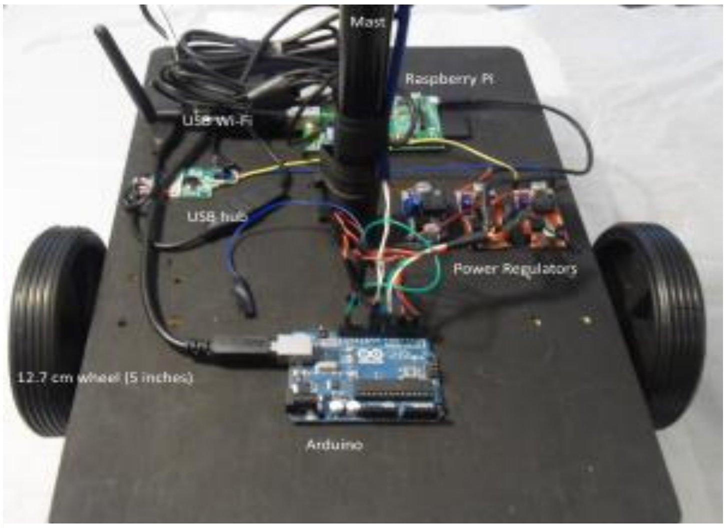


Figure 1 - Mark I base

online from different vendors. Power regulators are used to independently power the USB hub, the servos, and the Raspberry Pi. The Mark I ‘s base is shown in figure 1 and 2.

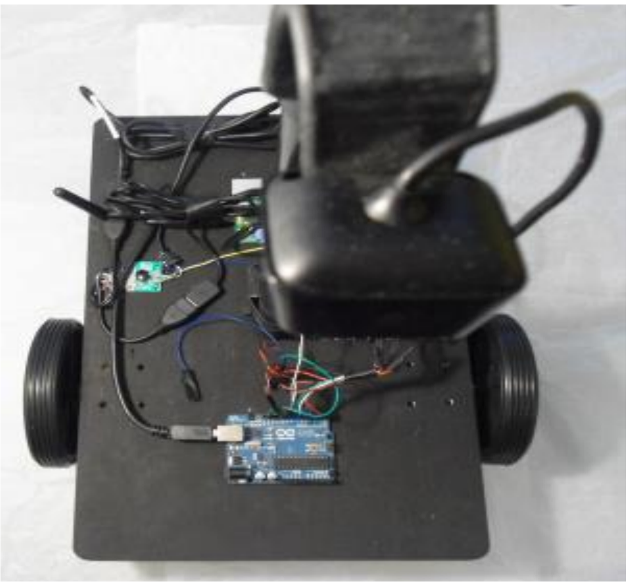


Figure 2 – Mark I front camera

3.3 The CPUs

For video conferencing, the robot uses a dedicated android phone/tablet. Android mobile devices offer a wide choice of screen sizes, computing power, camera resolutions, and memory sizes. For everything else, the robot uses a Raspberry Pi 2. The Raspberry Pi 2 is an inexpensive credit card size computer running Linux OS (“Raspberry Pi Foundation,” 2014). This permits to program the robot with any popular programming language such as Python. In addition, the Raspberry Pi 2 can run most of the Linux applications. To control the motor controller, servos, and sensors, an Arduino Uno board is used (“Arduino,” 2014). The Arduino talks to the Raspberry Pi 2 via a serial connection. A similar process is described by (Shodiq, Nugraheni, Lim, & Wicaksono, 2010) to control the drive motors. Wi-Fi is used by the Raspberry Pi 2 to connect to the network. The front navigation camera, the Arduino, and the Wi-Fi USB dongle are all connected to the Raspberry Pi 2 via a powered USB hub. A Bluetooth module can be added to the Raspberry Pi or the Arduino. However, Bluetooth is already available on the Android mobile device and can be used to communicate if needed. In addition, most Android mobile devices incorporate sensor such as GPS, Magnetometer, Accelerometer, Light, Temperature, and Gyroscope that can be used by the telepresence robot with little programming.

3.4 The Head

The robot needed to be able to pan and tilt its head. Two standard hobby servos are used for this function. Each servo can move 180 degrees. The Android mobile device is attached to the top of the mast and a HD web camera is mounted to the pan-tilt mechanism of the head. The pan-tilt mechanism was easily made of two metal straps bent in a U-shape. The head also carries a HD web camera to enhance the pilot view. It was found that a dedicated HD video camera gave a better immersion experience than the “stock” tablet from video camera. The reason is that most tablet front cameras have low resolutions. The HD web camera greatly helps in navigating the telepresence robot and in the ability of grabbing objects with the arm. The head is shown in figure 3.

Figure 3 - Head

3.5 The Body

The head of the robot is mount on the top of a 4-foot tall mast. The mast is attached to the base just behind the wheels to prevent the robot from tilting forward. As the center of gravity is kept low with most of the weight of robot on the base and the mast mounted behind the pivot point of the base, the robot is pretty stable when moving. The front navigation camera is mounted to the mast looking down at the base. This gives a good view of the base and wheels of the robot, which greatly help in spatial awareness when piloting the robot. The Mark I robot is shown in figure 4. The Mark II version is shown in figure 5.

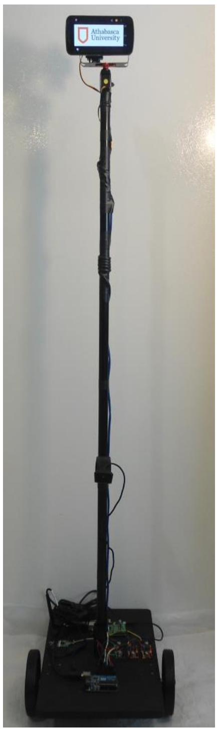


Figure 4 - Mark I

Figure 5 - Mark II

3.6 The Arm

A two degree of freedom arm was attached to the telepresence robot. The arm is controlled by two servos. One servo is used to move the arm up and down at the shoulder joint. The second servo is used to open and close the gripper. The arm is balance with some counterweights. From the pivot point to the wrist, the arm is 30 cm in length. The gripper is 15 cm in length. The total length of the arm from the pivot point to the end of the gripper fingers is 45 cm. From the pivot point to the opposite end of the arm, the length is 30 cm. The gripper servo is mounted on this section of the arm and is acting as counterweight. Counterweights were necessary because the servos used are small servos with a limited power. By using the counterweights, the weight of the gripper is cancelled. The arm is shown in figure 6.

Figure 6 - Arm

3.7 The Software

The robot uses webRTC (Web Real-Time Communication) technology for video conferencing. webRTC is implemented in browsers such as Chrome and Firefox. Firefox Hello is an example of the implementation of webRTC API. As a result, no special development was done in order to use webRTC with this telepresence robot. webRTC enables peer-to-peer multiple clients video conferencing within a web browser. The client does not need to install plugins or applications to connect to the robot. The client just uses a URL to connect to the telepresence robot. One main advantage of using WebRTC is that it can handle multi-party calls. As a result, users could share the experience of driving the telepresence robot alternatively or one user control the arm and gripper and the other user control the movement of the robot. Each user sees the same video feeds from the telepresence robot. webRTC needs to coordinate communication between peers. To do that, webRTC uses a signaling process. For this telepresence robot, the signaling mechanism uses Socket.io running on a Node.js server. Three types of information are exchanged between browsers. The first one is a session control message to start or close communication. The second one is the network information such as IP addresses and ports. The third information is the type of medias being exchanged. For instance, the type of codecs used and the video resolution. A success full exchange must be performed in order to start a peer-to-peer session. The client just uses a URL to connect to the telepresence robot. After entering the web address of the telepresence robot, the user just need to accept to share her/his audio and video devices and click on the telepresence robot id to start driving. When the user is connected to the telepresence robot a female voice will announce it and the head camera video feed will be displayed. Figure 7 and figure 8 show the connection process.

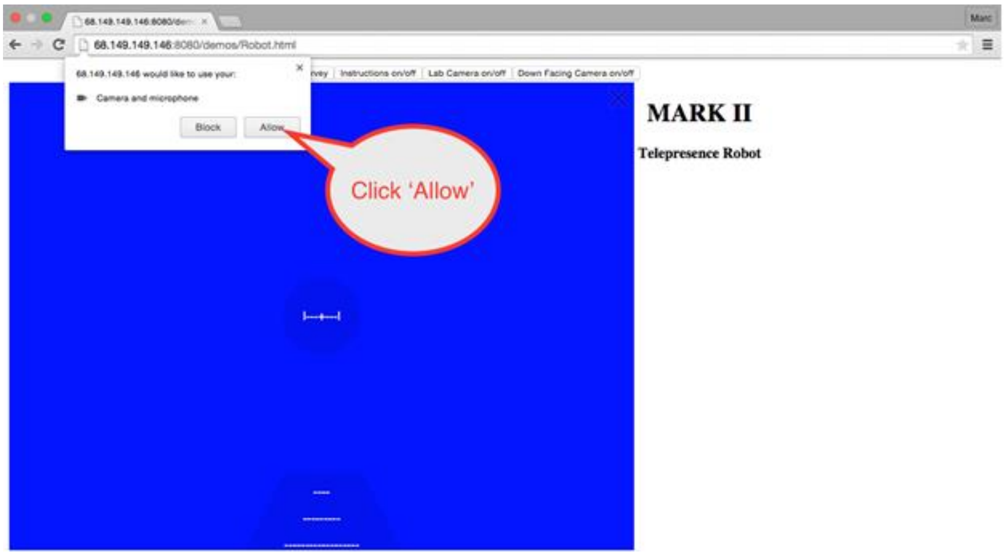


Figure 7 - Share media

Figure 8 - Connection

Node.js and Socket.io are used for the main application of the telepresence robot. The application which includes a signaling service is running on the on-board Raspberry Pi. The complete application is written in JavaScript and HTML 5. Node.js is a JavaScript runtime built on Chrome's V8 JavaScript engine and it permits the creation of HTTP servers. Socket.io establishes a bidirectional events channel between two peers. In this implementation, Socket.io is used to carry signaling information. This works very well when there are no NATs (Network Address Translation) or firewalls. When NATs and firewalls are present, A STUN server and a TURN server are used. The STUN server is used to get an external network address and the TURN server is used to relay traffic when peer to peer connection fails. These servers run on a separate server and not on the on-board Raspberry Pi. An Arduino is connected to the Raspberry Pi via a USB cable. An Arduino sketch read the incoming serial data and controls the motor controller and the servos by using its out pins. Figure 9 shows the software architecture.

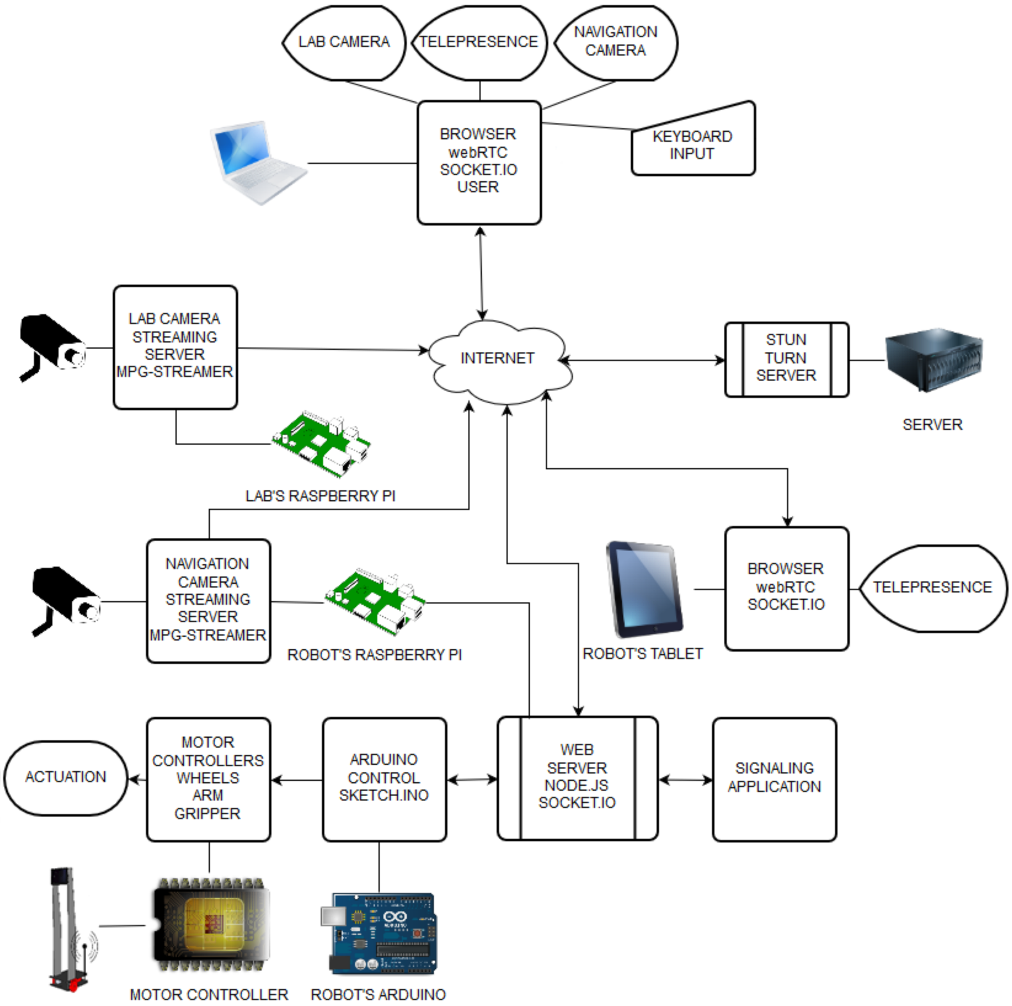


Figure 9 - Software Architecture

3.8 WebRTC

WebRTC is a free, open source technology that provide browsers with Real-Time Communication (RTC) capabilities. This technology enable media streaming (video/audio) and data sharing between browsers (Peer-To-Peer). WebRTC is implemented via JavaScript APIs (Application Program Interface). As a result, no plugins are necessary in order to use WebRTC. However, webRTC is a technology and not a solution. In order to use it as a solution, other components must be added to it. Currently, WebRTC is well supported in Chrome, Firefox and Opera. Figure 10 shows how WebRTC works.

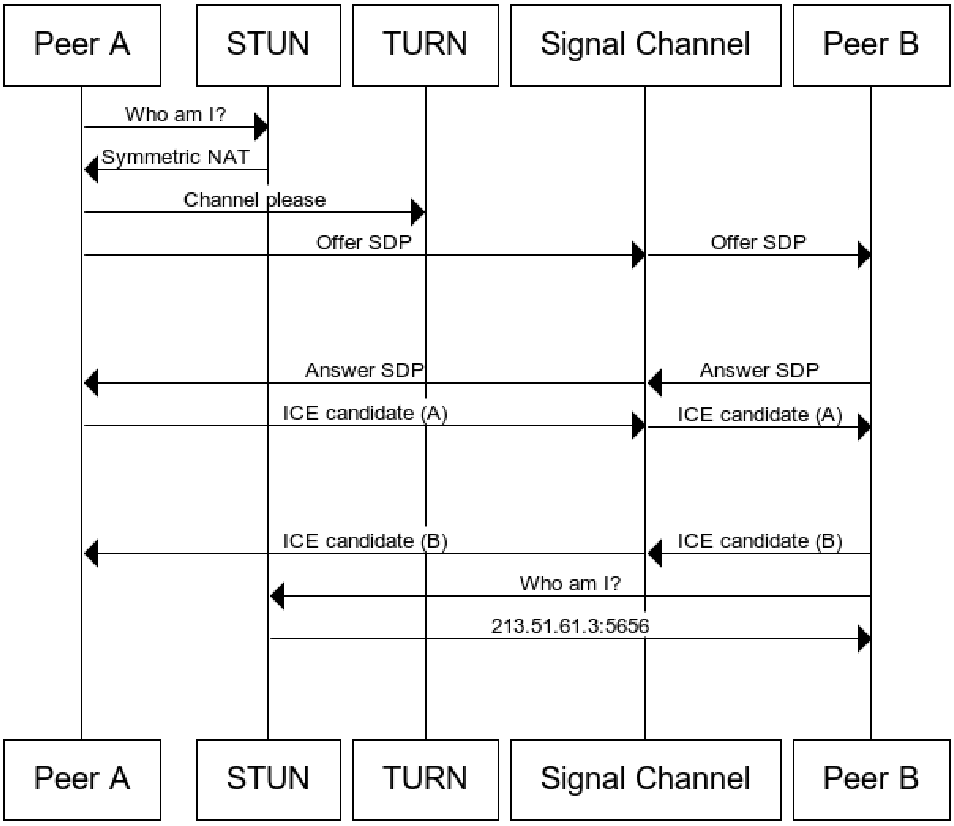


Figure 10 - WebRTC Exchange

Reprinted from https://developer.mozilla.org/en-US/docs/Web/API/WebRTC_API/Connectivity

3.8.1 APIs

WebRTC implements three main APIs.

- GetUserMedia
- PeerConnection
- DataChannel

GetUserMedia is used to gain access to the media devices such as web cameras, and microphones. PeerConnection handles all the connections between the two peers. It encodes and decodes media and handle NAT traversal (Network Address Translation). DataChannel is used to send data between two browsers such as text.

3.8.2 Signaling

In order to initiate a P2P (Peer-To-Peer) call with WebRTC, a signaling process must be implemented. WebRTC does not define signaling and this is left to the developers to implement the solution that works best for them. To implement signaling, a solution uses Socket.io and Node.js. In this case, Socket.io runs on top of Node.js and it is used for signaling. Socket.io works well since it has “rooms” concept. These are channels that Socket.io can joint or leave. However, many other mechanisms can be implemented. One very common mechanism is to use SIP (Session Initiation Protocol). SIP is extensively used in Internet telephony for Voice over IP (VoIP). Consequently, a server is needed. Signaling is used to exchange SDP (Session Description

Protocol) to describe streaming media initial parameters and to exchange media capabilities of each browser. Figure 11 shows how calls are made when using WebRTC. 1 and 2 are user A initiating a call to user B. 3 and 4 are the answer from user B to user A. After this initial handshake, user A and user B can directly stream media from browser to browser without going through the server (5).

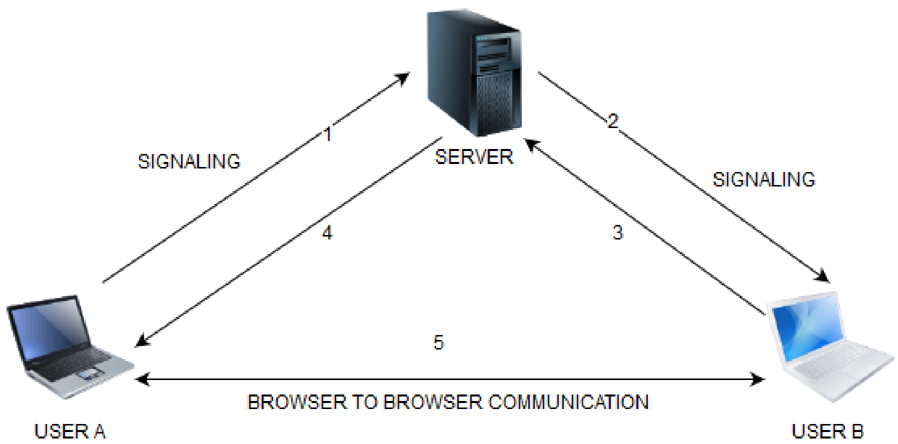


Figure 11 - Signaling

No other servers are necessary if both browsers are on the same private network or not behind NATs and firewalls. However, to traverse NATs and firewalls, WebRTC uses ICE (Interactive Connectivity Establishment). As part of this process, WebRTC might use STUN (Session Traversal Utilities for NAT) and TURN (Traversal Using Relays around NAT) servers.

3.8.3 STUN

A STUN server is used when a computer is behind a NAT. The NAT assigns a private IP and a port to the computer. Also, NAT translates the private IP to a public IP for the outside world to see via mapping tables. Thus, the computer behind the NAT does not know its public IP. It must ask the STUN server for this information. After, receiving its public IP and port, the computer can send this information to other computers to start P2P media streaming. The other computers can do the same by contacting the STUN server and sending their public IPs to peers. STUN servers do not need much computing power to fulfill their functions. So, they are inexpensive to build and maintain. Figure 12 shows communication between peer and STUN server.

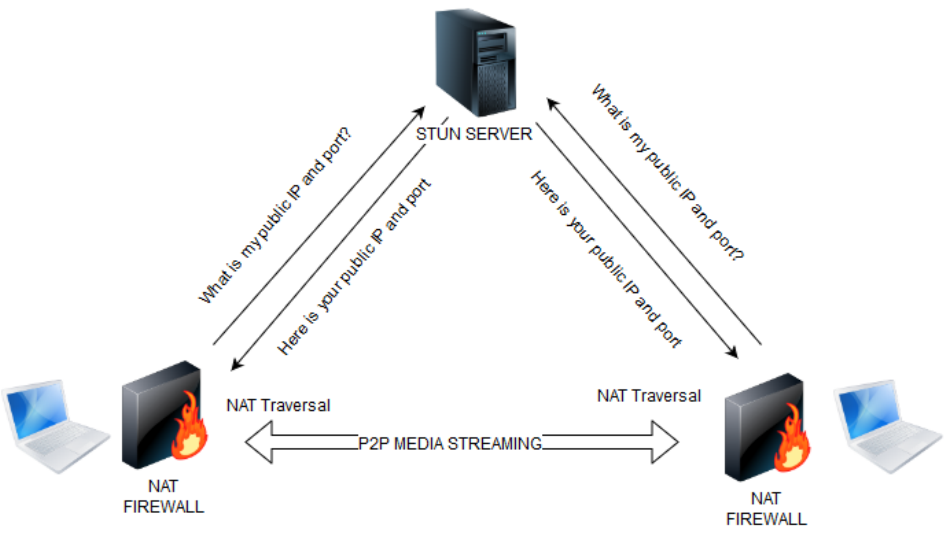


Figure 12 - STUN Server

3.8.4 TURN

In some cases, P2P media connections cannot be made even if a STUN server is used. In these cases, a TURN (Traversal Using Relays around NAT) server can be used to relay the media streams. A TURN server is acting like a proxy server for the peers. TURN servers are outside of NAT and have a public IP. Therefore, they can be reached by the peers and they guarantee communication between hosts unless a specific firewall rule is implemented. Usually a WebRTC solution will try to first establish the P2P connection by contacting a STUN server. If it fails, a TURN server is then used. This situation usually happens when a peer is behind a symmetric NAT or when ports are restricted. To accomplish this, TURN uses, most commonly, UDP (User Datagram Protocol) and port 443 or port 80. These two ports are usually left open even in most restrictive firewalls. Since, TURN servers are used to relay media between two clients, they use a lot of bandwidth. Thus, they are more

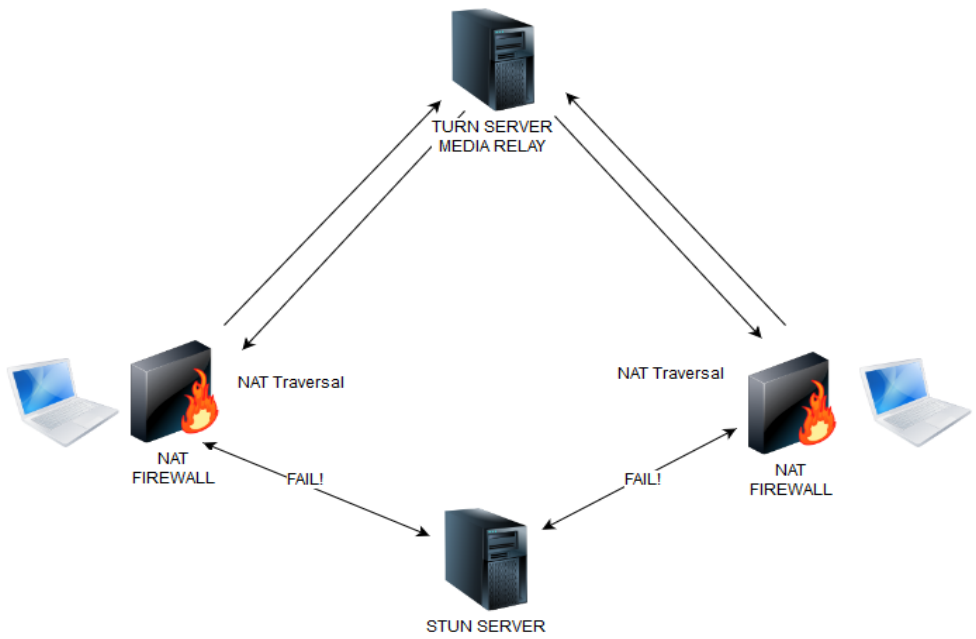


Figure 13 - TURN Server

expensive then STUN servers to maintain and operate. Moreover, they increase overall latency since packets must travel through an extra node. Figure 13 shows connection from the peers to the TURN server.

3.9 Pilot Interface and Controls

The pilot interface is composed of three main views. The head camera view is the central view on the interface. Some simple graphics are used to provide an augmented reality of the scene. The graphics are a ruler and a line scale which help the pilot in judging the size of the objects and the distance from these objects. More information could be displayed on this view such as temperature, humidity, lighting conditions, etc. The other two views are secondary views and are used to provide additional spatial references to the pilot. The secondary view on the top right of the interface is the lab camera view. A vide-angle lens is used to provide over 180 degrees of view. This give a “bird-view” of the room and it is very easy for the pilot to see where the robot is in relation to the lab table for instance. The other secondary view is the down facing camera view. The field of view of this camera is closer to the body of the robot and can help in judging distances between the robot body and an obstacle. These two secondary views can be turn off by the pilot if there are too distractive.

The robot is controlled via the keyboard. The arrow keys are used to move the telepresence robot forward, backward, left and right. Since, the telepresence robot uses differential steering, pressing the right or left arrow key will make the telepresence robot turn on itself clockwise and counterclockwise.

The W, A, S, and Z keys are used to pan and tilt the head camera. The N and M keys are used to close and open the gripper. The < and > keys are used to move the arm up and down. The telepresence robot has two speed. The normal speed is used to drive the telepresence robot around the environment and it matches the average slow walking speed of a person. The slow speed is used to move the telepresence very precisely and it is best suited when grabbing and moving objects on the lab table. To toggle the speeds, the pilot can just press the 1 or 2 keys at anytime. The user interface is shown in figure 14.

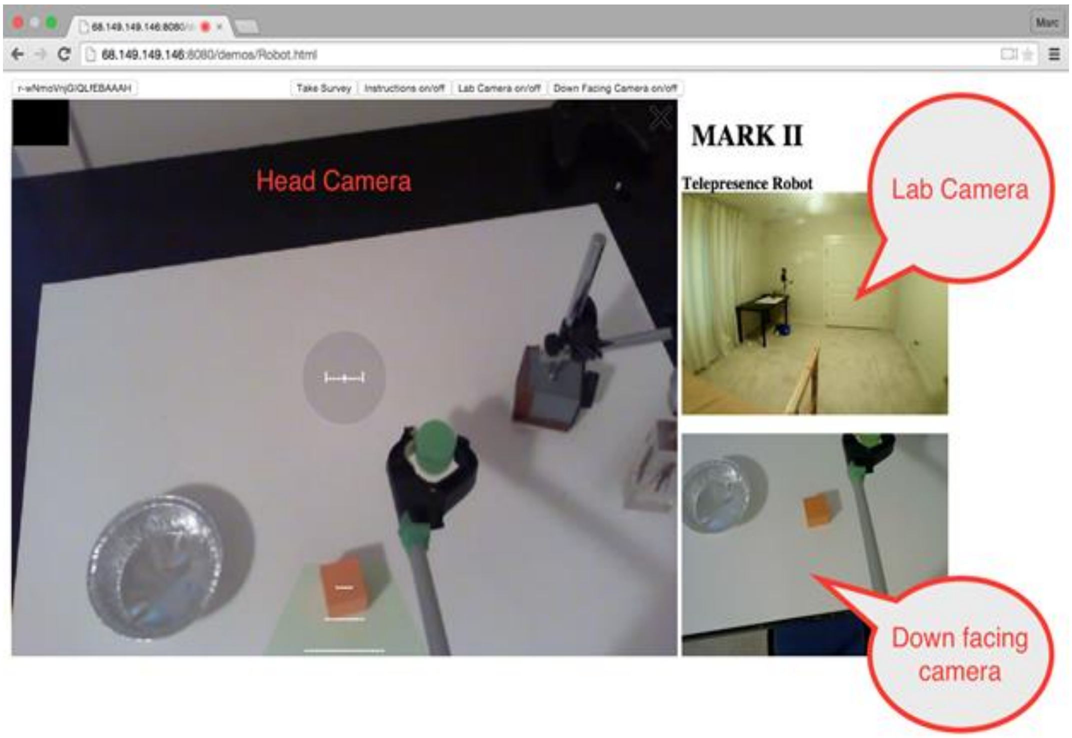


Figure 14 - Pilot interface

Chapter IV

System Architecture and Implementation

In this chapter, a concept for indoor remote lab is proposed followed by a possible system architecture of such a system. Moreover, the implementation of the telepresence robot is discussed and another concept for outdoor remote lab is offered.

4.1 Concept for Indoor Remote Lab

A simple concept on how telepresence robot can be used in remote lab environment is shown in figure 15. A remote student needs to do lab works for the course, Chemistry 210. The student would remotely login via the Internet to the remote lab server and use a telepresence robot placed in the lab as avatar. The student would be able to move the telepresence robot within the lab and go to any lab stations to start learning. The telepresence robot would be able to interact with the lab's equipment via wireless sensors network (WSN) to control and get data from the instruments. For instance, the pH of a solution could be read from a pH meter. Or, two chemical solutions could be made to react by remotely activating electro-magnetic valves, which would let each solution flow to a flask. In addition, a 5R adaptation learning management system would deliver the correct lab instructions and other learning materials to the student ensuring that the right content is provided to the right learner based on the student's learning profile, current location of the robot avatar at the lab, and device that the student uses for display (Tan, Zhang, & Mcgreal, 2011).

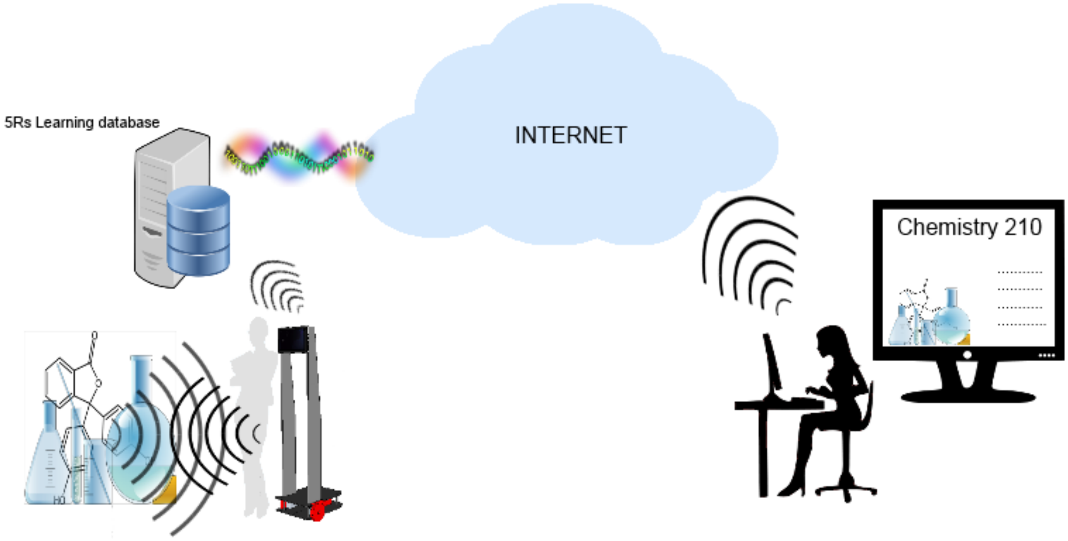


Figure 15 - Lab concept

4.2 Architecture Indoor Remote Lab

Based on the above concept, a possible architecture for telepresence robot system is shown in figure 16.

In this system architecture, a user login to the main webserver is given access to the lab server and the telepresence robot. The telepresence robot is independent of the lab server. As a result, it can be driven to another lab if desired. This will enhance the feeling of "being there" and might increase learning since the experience feel more real. On the contrary, in a common remote lab setup, the camera video is fixed and is controlled by the lab server.

The virtual lab application server and the 5R Adaptation Learning System talk to the lab server. The 5R Adaptation Learning System provides the correct lesson to the user based on the 5R algorithm. The lab server handles the hardware resources and the telepresence robot can communicate with these resources via wireless sensors network. For instance, the telepresence robot would communicate via near field communication (NFC) when approaching a workstation. As a result, the lab server would be aware of which experiment the user want to perform and could communicate this information to the virtual lab application server and the 5R server. This telepresence robot is an adaptive system that can be reconfigure to add custom features and behaviors based on the students' profiles and the lab environments.

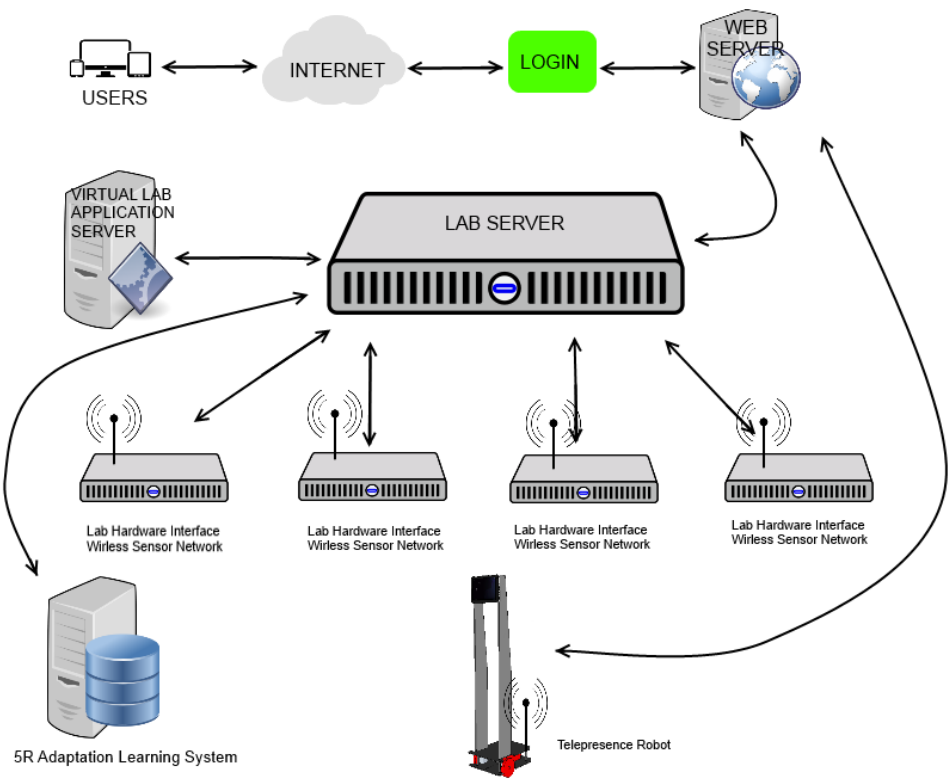


Figure 16 – System architecture

4.3 Telepresence Robot Implementation

To test the solution a mock-up remote lab and a simple experiment was designed. It would not have been possible within the scope of this thesis to implement the full indoor lab scenarios described in section 4.1. For this implementation, a telepresence robot was setup in a mock-up remote lab. The focus was on the use of the telepresence robot by participants geographically dispersed and connecting to the telepresence robot via Internet. The main components of this implementation were the telepresence robot, a lab camera and a STUN/TURN server. The lab camera system is composed of a HD webcam and a raspberry pi computer running a video steaming server. It permits to support smart lab environments. The raspberry pi could be used to read the remote sensors in the lab and stream these data to the user. With a Bluetooth dongle, the raspberry pi could connect to any Bluetooth sensors. Figure 17 shows this implementation architecture.

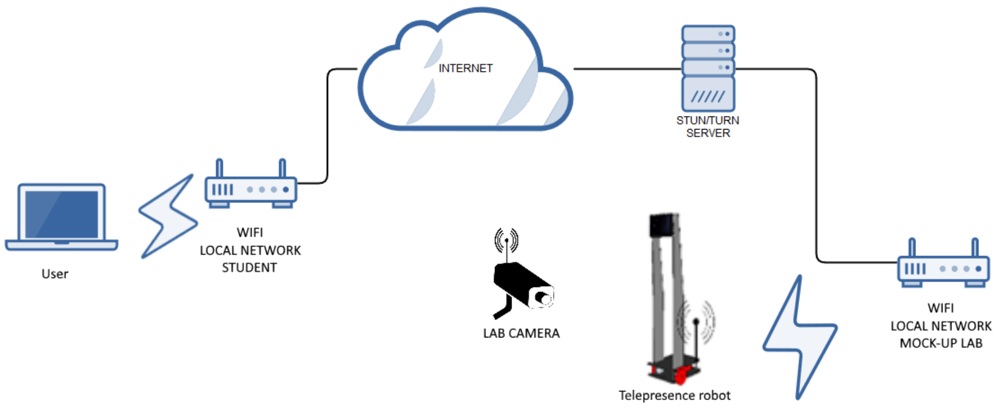


Figure 17 - Implementation Architecture

The robot is controlled via a closed-loop system. The human operator sends commands to the robot through a control and communication process and receives feedbacks from cameras. The feedback is from 3 cameras. An independent lab camera and two cameras onboard the telepresence robot. With this feedback system, the pilot can adjust the telepresence robot movements in real-time. Figure 18 shows the closed-loop control system.

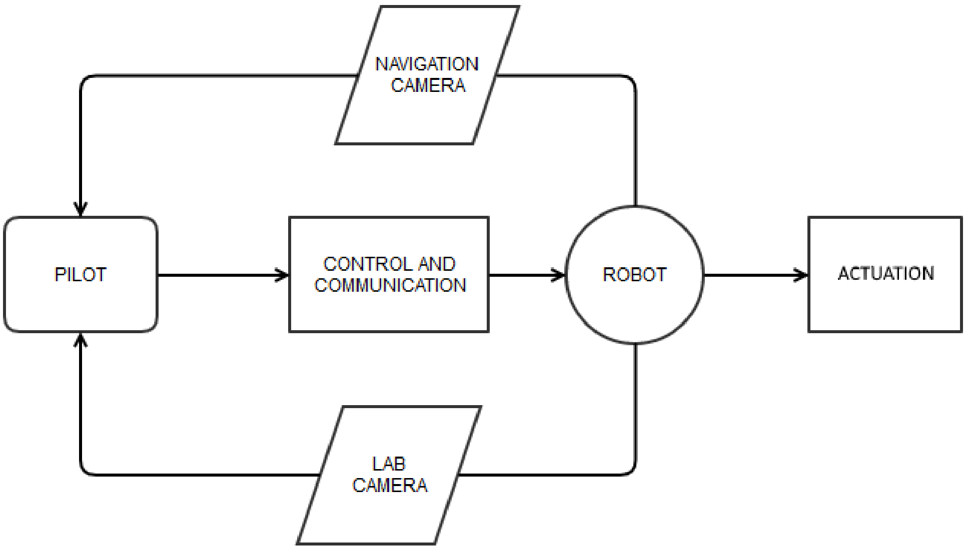


Figure 18 - Closed-loop Control

4.4 Concept for Outdoor Remote Lab

For outdoor remote lab work, an educator could bring a telepresence robot with a different platform but with the same hardware to a specific location of interest. For instance, the telepresence would have a four wheels drive platform instead of the two wheels drive drivetrain, which would permit it to navigate within the specific area and collect data with its sensors. The sensors could be gas sensors or more sophisticated instruments such as ground-penetrating radar or IR camera. The data collected would be transmitted to the students' computers in real-time. For disable students, the possibility of joining fieldtrips and doing real-time research would be invaluable. To use their avatar, the students would only need to have an Internet connection and logging in the telepresence robot. The telepresence robot can function without the need to be connected to a lab server and only needs a network connection such as 3G, 4G, and WiMAX. Figure 19 show the outdoor concept.

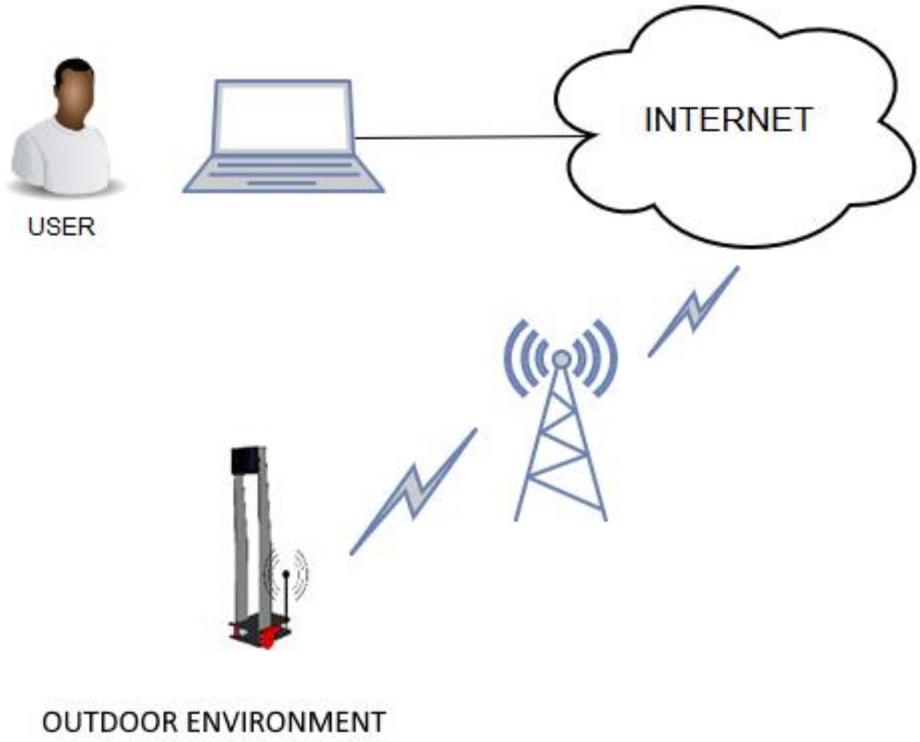


Figure 19 - Outdoor Concept

Chapter V

Research Validation

5.1 Introduction

To validate this research, a test drive of the telepresence robot and an exploratory survey were used. The test drive entailed driving the telepresence robot in a mock-up remote lab environment. Forty participants were asked to drive the robot to a lab table and use the robot's arm and gripper to move two small objects into a container. The two small objects were place on the table close to the container and the participants task was to pick-up these objects and deposit them in the container. Please see appendix B for the instructions that were sent to the participants. After this test, and directly from the pilot interface, participants were able to take the exploratory survey by clicking on a button and be redirected to the survey webpage generated by LimeSurvey. Forty participants took the driving test and thirty-three participants selected to take the survey.

After analysing the survey and observing the driving test, we found that a simple affordable telepresence robot can be driven and used to manipulate objects by people who did not receive prior training. Most of the participants to the driving test were able to successfully finish the test by moving the two object into the container. Overall, this survey showed that most of participants had a positive experience when driving the telepresence robot and performing the dexterity task. Very few participants rated their experience negatively.

5.2 Experiment Design

5.2.1 Participants

The Forty participants of this studies were students and faculties from Canada, Egypt, Taiwan, China and France. Additionally, any other interested people were asked to participate. The participation in this study was only voluntary. No names were collected during the experiment and answer to the questions in the survey cannot be match with a person. Therefore, the survey was anonymous. Participants could choose to take the driving test and not take the survey. Many of these participants were geographically dispersed. People connected to the telepresence robot from Canada, Egypt, Taiwan and France.

5.2.2 Driving and Dexterity Test Setup

For the driving and dexterity test, the Telepresence Robot was alone in a room which measured 12 feet by 12 feet. In this room, a lab table was positioned against a wall and on the table; two small geometric objects made of foam were positioned close to a 10 cm in diameter recipient. The small objects were:

- A cylinder with a diameter of 3.5 cm and height of 3.5 cm
- A square measuring 3.5 cm by 3.5 cm by 3.5 cm

Figure 20 shows the two objects on the lab table.

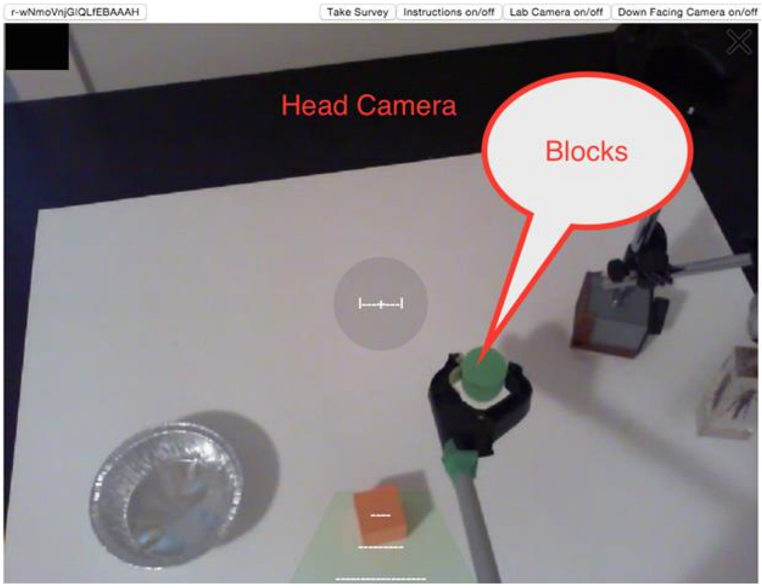


Figure 20 - Objects

The Telepresence Robot was placed 2 meters away from the table facing it. No obstacles were placed in the path to the table. In addition, we added a straight line on the floor going from the robot to the table as seen in figure 21.

Figure 21 - Line

A lab camera with a wide angle lens was setup in such a way that it gave a bird eye view of the room. As seen on figure 22, the lab camera helps in locating the telepresence robot in the lab. Without the lab camera, the pilot can be disoriented in not knowing the exact position of the telepresence robot relative to lab environment. This camera greatly helps in unfamiliar environment by giving a 3d person view of the remote scene.

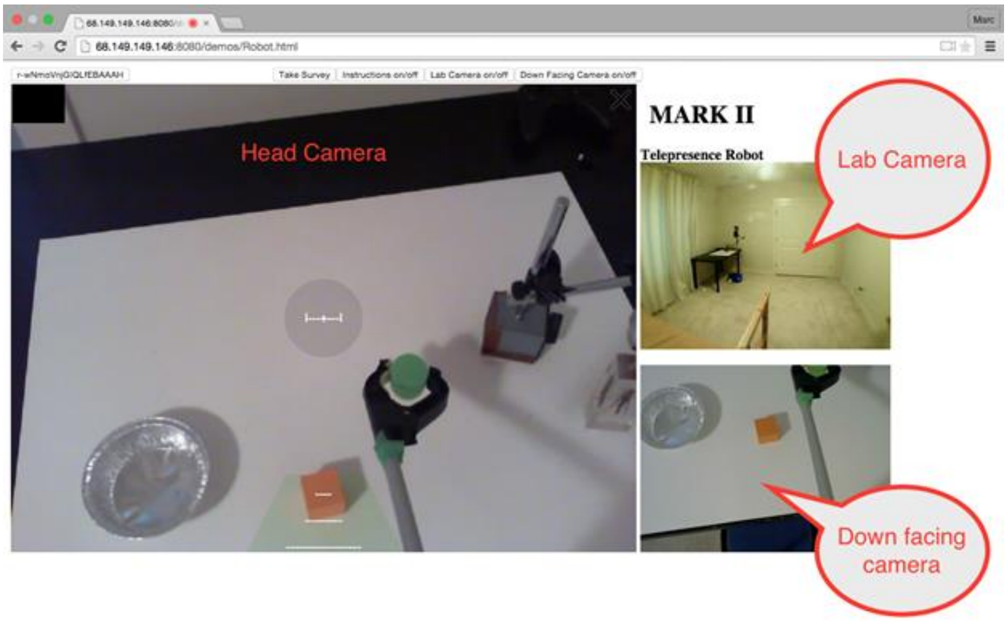


Figure 22 - Lab camera

No investigators were present in the room to help the participants. Investigators were able to observe the robot via the lab camera only but were not in the same room. It took 7 days to complete this survey with the forty participants.

5.3 Questionnaire Design and Analysis Methodology

The questionnaire is composed of twenty-two questions. And it was created with LimeSurvey. LimeSurvey is a free and open-source survey application. This web application was hosted on one of Athabasca University server. Nominal and ordinal scales are used in the questionnaire. Nominal scale is used to collect descriptive information about the participants such as gender and age group. The gender question is a dichotomous variable with only two categories. Ordinal scale is used to know the attitudes or opinions of the participants toward the use of telepresence robots. Questions such as “How easy was it to navigate the robot within the remote lab?” are asked in this scale. In this ordinal scale, the ranking of the value is important but the difference between values are not known. For instance, we can tell that “strongly agree” is better than “agree” but we don’t know of how much. As a result, no mean is calculating on these ordinal scale questions. Instead, the Median and Mode is used to describe the central tendency. The arithmetic mean is equal to the sum of all the values in the data set divided by the number of values in the data set.

Sample Population Mean:

$$\bar{x} = \frac{\Sigma x}{n}$$

Equation 1 - Sample Population Mean

Given a frequency distribution:

$$\bar{x} = \frac{\Sigma(x.f)}{\Sigma f}$$

Equation 2 - Frequency Distribution

One issue in statistics when using the mean to report the central tendency is that it is greatly influenced by outliners. Especially, if the data set is skewed. In statistics, an outliner is an observation that is distant from the other observed values. In the contrary, the Median is not strongly influenced by outliners. The median is the middle value of an arranged data set from lowest value to highest value. The median value indicates that 50% of the values are below the median and 50% of the values are above the median. To calculate the median, the data must be sorted in ascending order from lowest to highest value. Here are the formulas for calculating the median of an ungrouped data set score:

Odd set score:

$$median = \left(\frac{n+1}{2}\right)^{th}$$

Equation 3 - Odd Set Score

Even set score:

$$median = \left(\frac{n}{2}\right)^{th} + \left(\frac{n}{2}+1\right)^{th}$$

Equation 4 - Even Set Score

The mode is the value is the value that most frequently occurs in a data set. The mode is simply the value with the highest frequency. Figure 23 shows the different locations of the mean, median, and mode for a normal distribution and a skewed distribution.

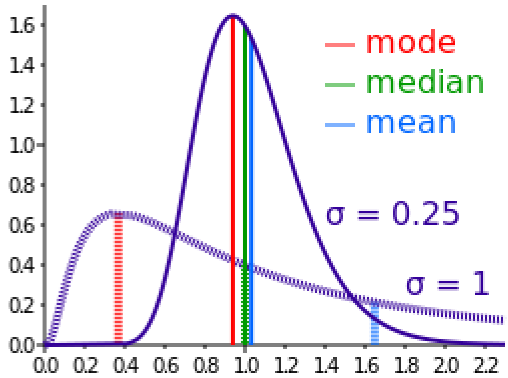


Figure 23 - σ is the standard deviation

Reprinted from https://commons.wikimedia.org/wiki/File%3AComparison_mean_median_mode.svg, by By Cmglee (Own work) [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0) or GFDL (http://www.gnu.org/copyleft/fdl.html)], via Wikimedia Commons.

In this questionnaire, some questions are very similar but worded differently. This was done to see if the answers were reliable. For instance, question #6 "*How easy was it to navigate the robot within the remote lab?*" has a median of 4 and a mode of 4. Question # 8 "*Was the robot easily driven within the remote lab?*" is very similar to question #6 and it has a median of 4 and a mode 4. This suggest that the attitude toward how easy the robot was to drive is reliable and consistent. For the analysis, the middle or neutral answer in the scale was discarded to prevent central tendency bias. The scale for the ordinal questions is from 1 to 5 with 1 being the worst and 5 being the best. In this five-point scale, 3 is the neutral variable. In addition, for analysis categories were aggregated. For instance, "agree" and "strongly agree" were collapsed under "agree". The same is done with "strongly disagree" and "disagree" changed to "disagree". The aggregation is done to provide a simpler picture of the participants' attitude toward a specific question. For example, for question #4 "*How competent do you feel about driving the robot within the remote lab?*" 39.39% or the participants chose 4 in the rating scale and 21.21% chose 5 in the rating scale. We know that 5 is better than 4 but we don't know the magnitude of it. Therefore, it does not really add much more information to our analysis. As a result, it is simpler to say that 60.60% of the participants felt competent in driving the telepresence robot in the lab. A wide range of questions is used, in this questionnaire, to explore this topic. Furthermore, comment boxes are provided with each question to get any feedback from the participants. The full questionnaire is shown in appendix A.

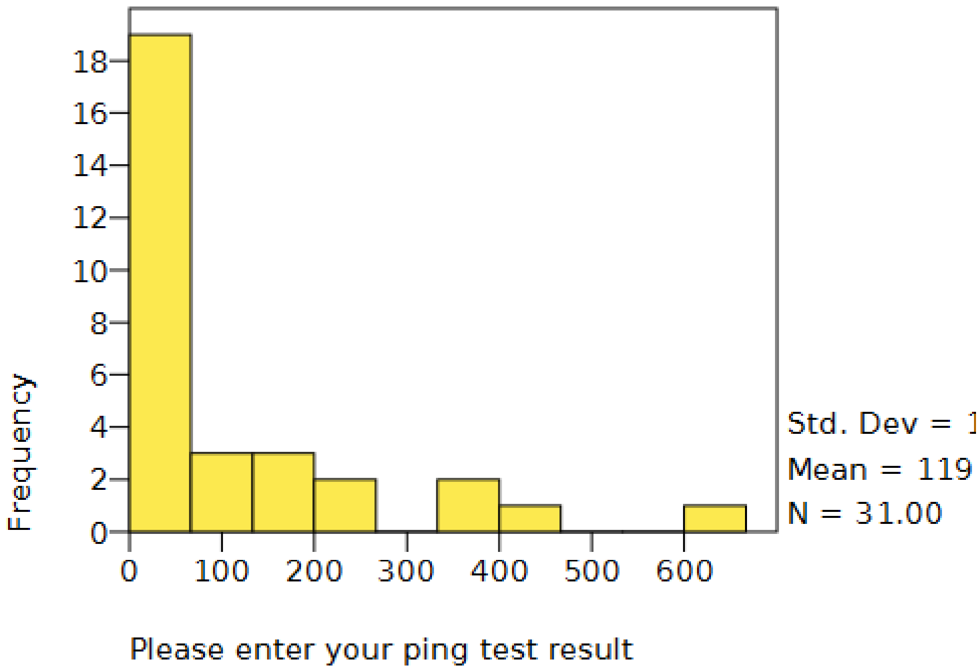
For this statistical analysis, the survey data were exported directly from LimeSurvey to PSPP. PSPP is the free and open-source equivalent of the commercially available statistical application SPSS. PSPP can do descriptive statistics, T-tests, non-parametric tests and many more. For further analysis, cross-tab analysis is used to test for independence using chi-square test for independence.

5.4 Analysis

This is the analysis of the questions asked in the survey:

Question #1: *Please enter your ping test result*

The Mean is 119.14ms which is not too much for general web activities. However, it is slow for online games. Especially, games such as First Person Shooter. The Telepresence robot was connected to Shaw cable Internet with a 30 Mbps download and 2.50 Mbps upload. A speed test performed on the same network of the Telepresence robot showed that the network speed was within the above perimeters. Pings to the Telepresence robot within the same network but 1000 kilometer away showed results as low as 40ms. It is important to note that most of the participants where geographical dispersed nationally and internationally. The curve is a skewed distribution to the left.

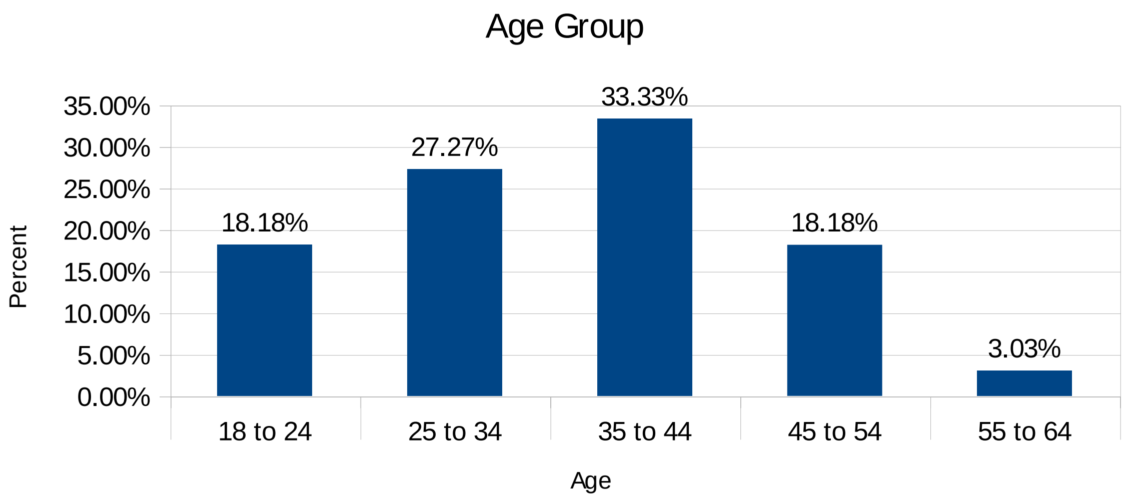


Graph 1 - Ping Test Results

Question #2: *How old are you?*

Age Group:

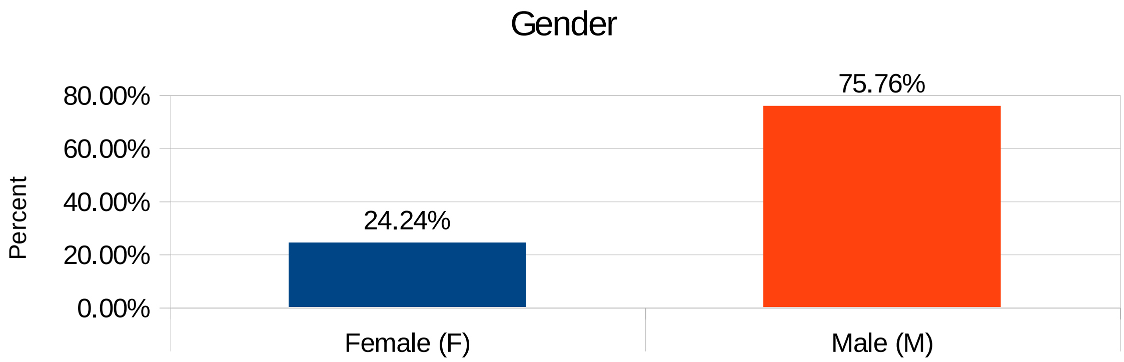
27.27% of the participants are between 25 to 34 years old and 33.33% of the participants are between 35 to 44 years old. These two age groups are indicative of distance education students. This is an acceptable target group for this study since it focuses on remote lab in distance education.



Graph 2 – Age group

Question #3: *What is your gender?*

And 75.76 of the participants were males. It would have been better if we had more female participants in this study. However, I don't think that it would have change the overall result of the survey.



Graph 3 - Gender

Question #20: *Have you driven a Telepresence robot before?*

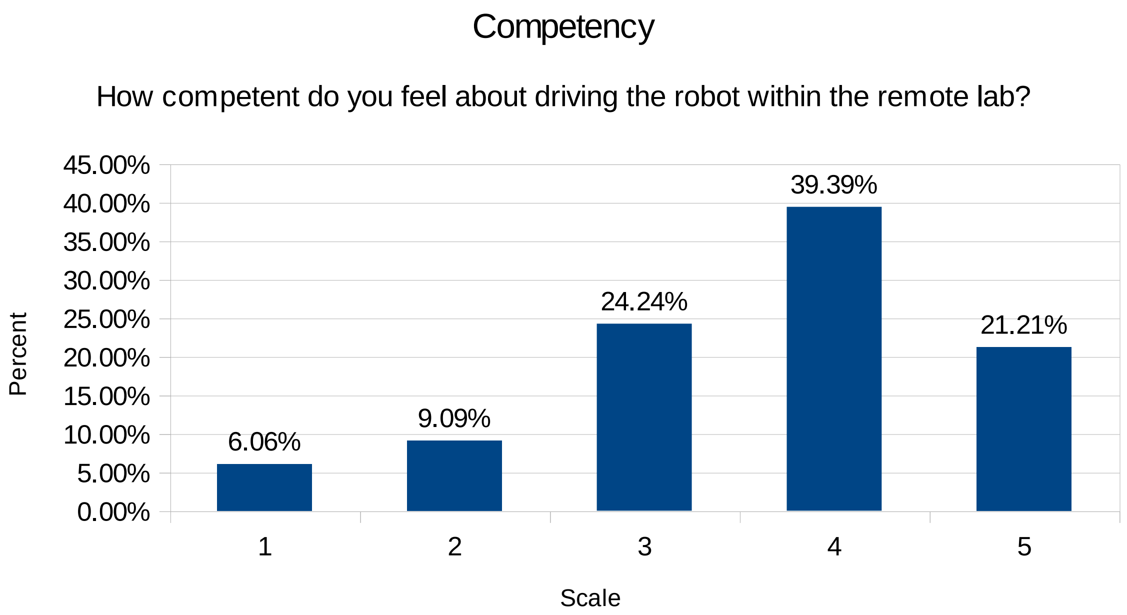
And only 2 participants had driven a Telepresence robot before taking the dexterity test.

Table 2 - Driving experience

Have you driven a Telepresence robot before?

Answer	Count
Yes (Y)	2
No (N)	31

Question #4: *How competent do you feel about driving the robot within the remote lab?*



Graph 4 - Competency

Table 3 - Competency

N	*Valid*	33
	Missing	0
Mode		4
Range		4
Percentiles	50 (Median)	4

Participants' comments for question #4:

- “The question is unclear. Are you asking if I feel confident that I could drive the robot in general (considering how smart and agile I normally am ;-))... or if I drove the robot well or badly during that experiment?”
- “il faut aller doucement et maîtrisé le roboy”

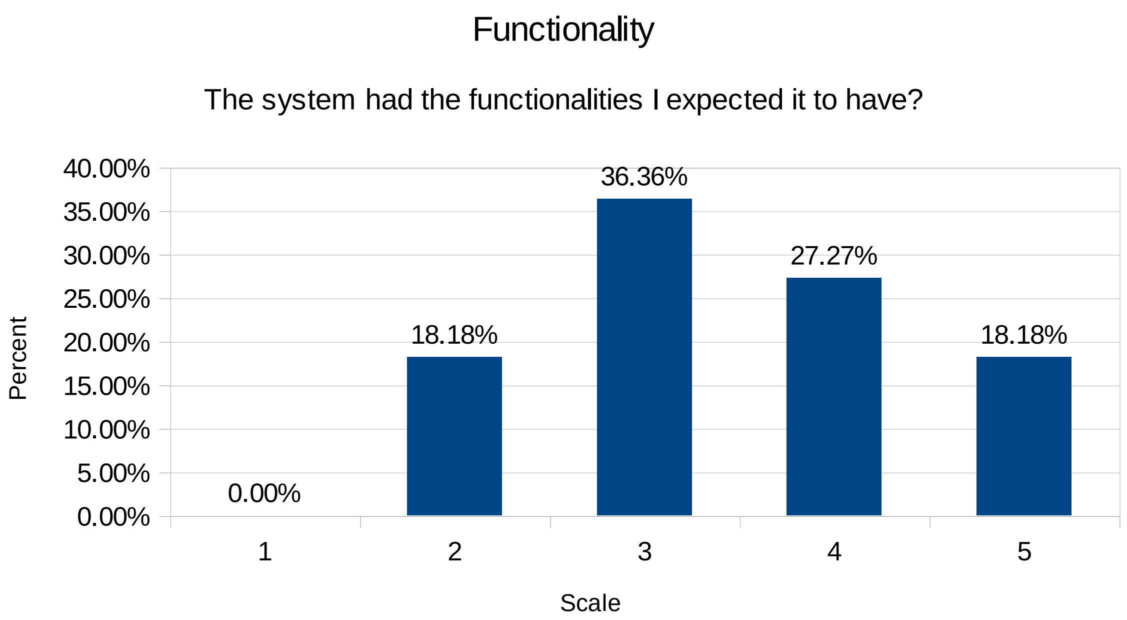
- “It needs some training to get familiar with the speeds and angels of rotation .. then it goes well”
- “The instruction is perfect and easy!”
- “I was able to control robot functions easily.”
- “At first, it seems difficult. But after a few tries, it gets easy to control the robot.”
- “I could not touch and move those two objects to the can.”
- “took a while to get the hang of driving the robot. Got used to it after a number of minutes”
- “Once you understand the controls navigation becomes easier.”
- “Once I got the hang of the controls and the reaction time of my keys to the movement of the robot, I felt very confident.”
- “There was some getting used to the depth perception, but it only took two minutes to figure it out.”
- “I am sure with more practice it would become easier to control the robot. Otherwise it is an easy operation.”
- “It took a lot of getting used to.”
- “While the robot had some quirky behaviour I found that with a few minuets of practice I was quite comfortable controlling it and could easily perform the required tasks.”

42.42% of participants entered a comment for this question.

Synthesis question #4:

Most respondents indicated that they felt competent driving the robot in the lab (N=20, 60.60%). The Median is 4 and the Mode is 4. From the participants' comments, practice is the main factor on how much a participant feels competent in driving the robot. Since, participants did not have any training before performing the driving test, we can infer that we could dramatically increase the number of participants that feel competent in driving the robot by providing training before the driving test. I was surprise to see that most of participants had positive feelings toward their abilities to drive the telepresence robot. I was expecting that the majority of participants would find driving the robot very difficult and that it would take a lot of training before they could drive the telepresence robot confidently. This result supports the idea that affordable telepresence robot can be used in remote lab environment.

Question #5: *The system had the functionalities I expected it to have?*



Graph 5 - Functionality

Table 4 - Functionality

N	*Valid*	33
	Missing	0
Mode		3
Range		3
Percentiles	50 (Median)	3

Participants' comments for question #5:

- “Just to drive and complete the lab works.”
- “I want to be able to navigate either 1) with keyboard (forward backward motion) and mouse (direction over 360 degrees) or 2) using a gamepad.”
- “c'est un robot qui est fonctionnel”

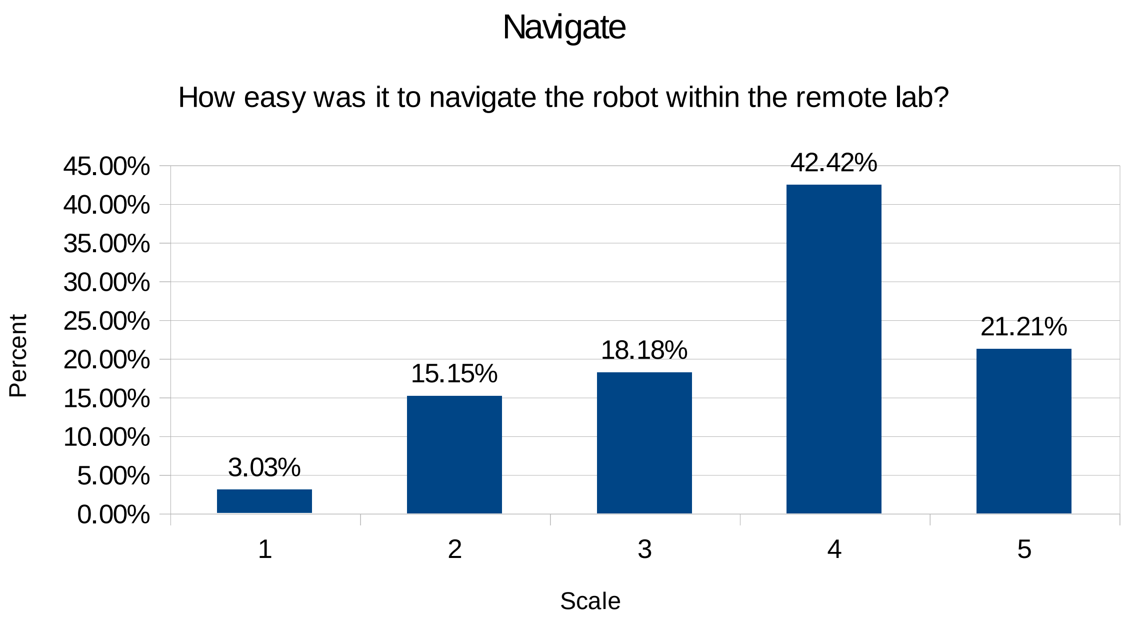
- “May be if the arm could be moved without moving the whole body of the robot it will be more convinient”
- “I aware about the grabbing strength, that if the robot pressure so hard on glasses, it may be broken. So, I think the grabbing strength should be set within the instructions and considered within the final version.”
- “Had no idea what to expect.”
- “Robot functionalities worked as per instructions.“
- “For the experiment, I think the functionalities are enough.”
- “I had expected arrow keys and only a couple of other keys to operate.”
- “It would be nice for the robot to be able to strafe side to side.”
- “The robot had all the necessary motions required to accomplished the set task”
- “For a minimum viable product it is very functional”
- “I didn't think the hand mechanism would be able to hold on to the objects that well, but it worked really well.”
- “Having sound was great as I was able to hear when the robot bumped the table.”
- “I can't think of any additional functions or features that would have made the tasks significantly easier.”

45.45% of participants entered a comment for this question.

Synthesis question #5:

Most respondents did not have a clear idea of what functionality the robot should have (Median=3, Mode =3). However, 45.45% (N=15) of respondents agreed that the robot had enough functionality to perform the lab task. From the comments, some participants requested to have functionality such as game-pad, and force feedback added to the robot. This result is inline with what I was expecting since it is very difficult to know what functionality is needed when one is unfamiliar with the technology. However, it seems that the current functionality of the telepresence robot was enough to perform the task successfully.

Question #6: *How easy was it to navigate the robot within the remote lab?*



Graph 6 - Navigate

Table 5 - Navigate

N	*Valid*	33
	Missing	0
Mode		4
Range		4
Percentiles	50 (Median)	4

Participants' comments for question #6:

- “Navigation is laborious. Response time between action on the keyboard and reaction (robot moving) can be quite large. Ping was good, so not a latency issue.”
- “Several times, I pressed the forward or left right key a couple of times and nothing happened, even 10 seconds after. Then suddenly the robot made a 360 degree spin or raced against the table!”
- “lag au niveau de la caméra principale, difficulté avec le clavier français.”
- “The switching from different movement (e.g. from right to left) takes a noticeable times “
- “The green line helped, and once I new to move the head up, it was easy to move forwards and get to the table.”
- “It was fairly easy to navigate based on lab and face down camera.”
- “According to the instructions, it is easy to navigate the robot.”
- “I could not touch and move those two objects to the can.”
- “The controls were very intuitive for moving, I would recommend using the [s] key instead of [z] for down and remapping [<] [>] to [Page Up]

[Page Down] so I can both hands stationary the keyboard."

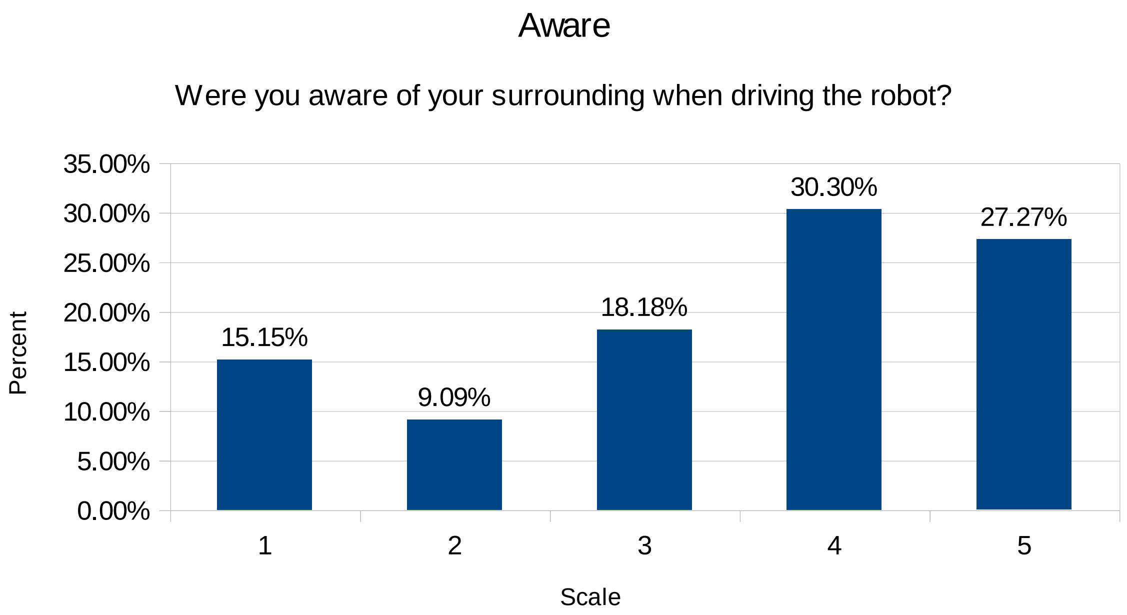
- "It is quite easy to navigate but it takes some getting used to for people who are new to navigating robots"
- "Lots of coordination needed in terms of visual and understanding the controls layout on the keyboard"
- "Very easy once you get confident in the controls. The only thing that would have made it easier to drive was a larger camera perspective to know where to drive it in the distance."
- "If the latency was lower then it would have been very easy."
- "After some practice, it became very easy."
- "With a little bit of practice I found it easy to navigate. The control latency would make it difficult to perform very precise navigation but was more than adequate for the required tasks."

42.42% of the participants entered comments for this question.

Synthesis question #6:

Most respondents agree that it was easy to navigate the robot within the lab (Median=4, Mode=4, N=21, 63.63%). Only 18.18% (N=6) of the respondents found it difficult to navigate the robot within the lab. Furthermore, only 6 respondents selected 3 (neutral) for their answers (18.18%). From the comments, we see that lag from the main video feed is a major problem. The lag was probably due to the fact that three HD camera were streaming real-time videos on a 2.5 Mbps upload bandwidth. For this question, I was expecting a negative attitude since I thought that participants did not have previous training with the telepresence robot. This result supports the idea that telepresence robots are not too difficult to drive.

Question #7: *Were you aware of your surrounding when driving the robot?*



Graph 7 - Aware

Table 6 - Aware

N	*Valid*	33
	Missing	0
Mode		4
Range		4
Percentiles	50 (Median)	4

Participants' comments for question #7:

- "Better than last time. Appreciation of depth remains an issue though."
- "caméra des pieds devrait être sur le bras"

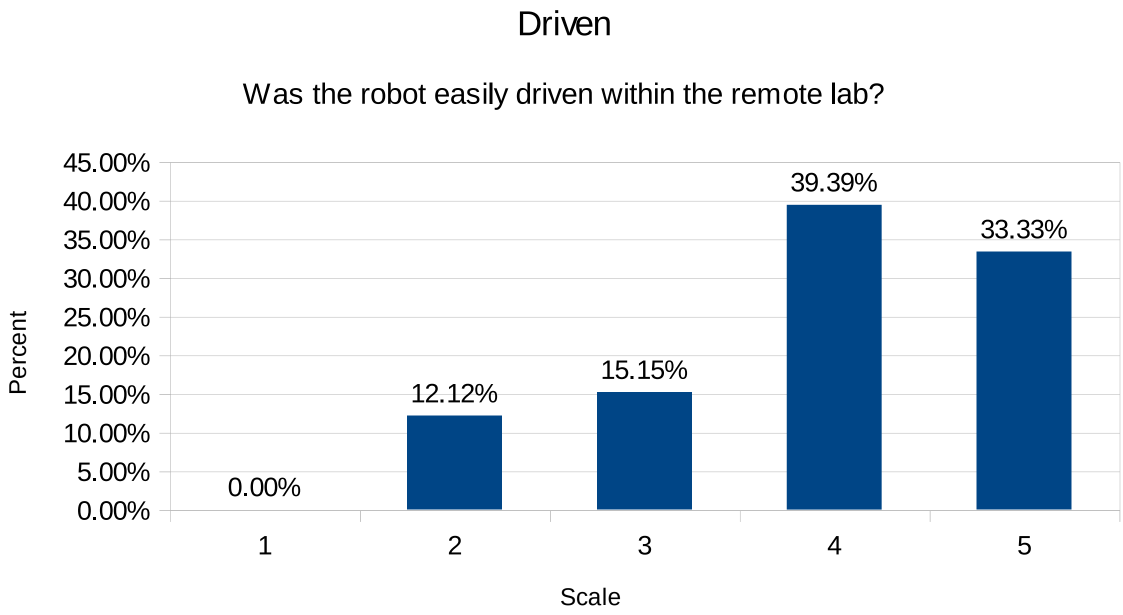
- "j'étais trop concentré sur la conduite"
- "Was good to have other cameras to be able to see. Also interesting to hear the noises being made as it helped bring awareness."
- "I was aware based on lab camera."
- "A fourth camera showing the front of the robot would have been helpful too"
- "Only focus on the stuff on the table."
- "Both the lab and downward facing camera helped with awareness of the robot in the lab"
- "The two camera perspectives were helpful. The close range one would have been easier to view through I think if it was raised up a little bit more."
- "The two additional cameras helped quite a bit, and having sound was great."
- "The depth perception of the arm took a bit to get used to. The arm seemed to be higher than I first expected. There was no shadow of the arm to give a sense of height."
- "I felt like I was in the lab and not in my house."
- "While the field of view of the on-board cameras is quite narrow, having the "Lab Camera" made it relatively easy to understand the surroundings."

39.39% of the participants entered comments for this question.

Synthesis question #7:

Most respondents said that they were aware of their surroundings when driving the robot (Median=4, Mode=4, N=19, 57.57%). On the other hand, 24.24% of the respondents said that they were not aware of their surroundings when driving the robot. From the comments, we can note that the lab camera and the down camera helped in awareness of the environment. Also, some participants commented that sound was helpful in bringing awareness. Some comments mention that the lack of depth perception was an issue when using the arm to grab objects. This result match my expectation since particular attention was made to have two HD cameras on the robot and a lab camera for the lab.

Question #8: *Was the robot easily driven within the remote lab?*



Graph 8 - Driven

Table 7 - Driven

N	*Valid*	33
	Missing	0
Mode		4
Range		3
Percentiles	50 (Median)	4

Participants' comments for question #8:

- "What's the difference between this question and second question above?"
- "The robot move not flexible."
- "le robot est facilement conductible"
- "Sometimes the robot delays to react to the command and sometimes

sudden unexpected movements happen"

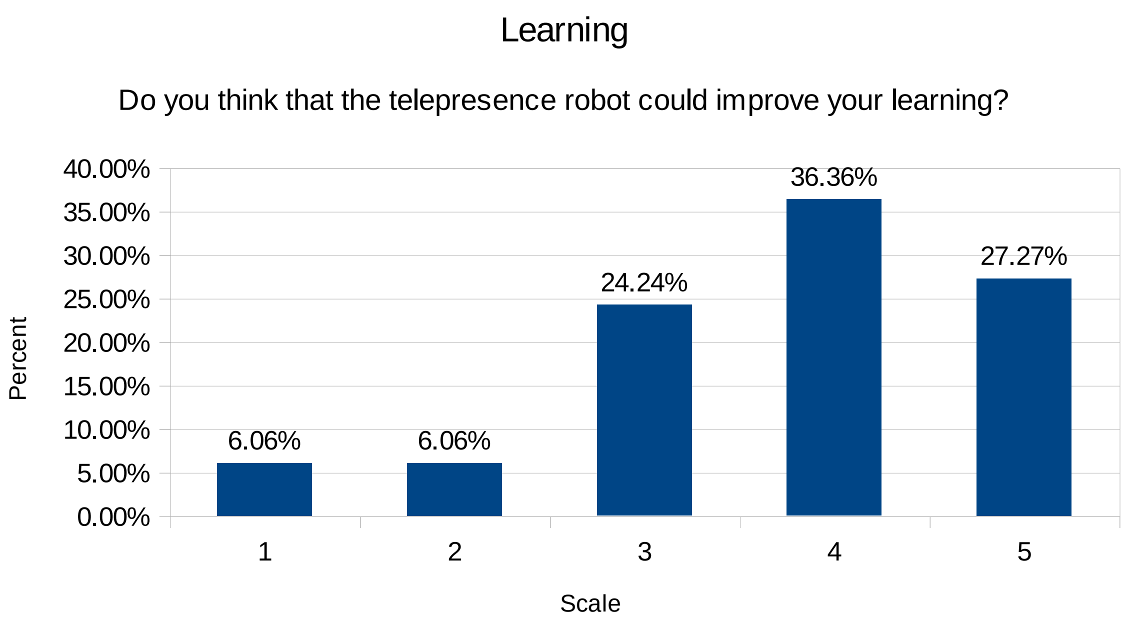
- "Aside from the controls, the robot did as I expected"
- "I just had to move the robot arm close to the table to determine the height of the robot arm from the table top."
- "With keyboards, it is easy to control it."
- "The Robot moved easily within the room however in cases where more precision is needed it may be difficult to position the Robot precisely."
- "Very easy. Speeding up and slowing down helps a great deal."
- "There was a bit of a delay in the video feed, otherwise it was easy to drive."
- "While it took practice, the robot actually seemed very efficient once I got used to the controls."
- "The lack of obstacles in the lab made the driving pretty easy."

36.36% of the participants entered comments for this question.

Synthesis question #8:

Most respondents agree that the robot was easily driven within the remote lab (Median=4, Mode=4, N=24, 72.72%). Only 12.12% chose to disagree (N=4). This support the result from question #5 which was similar in meaning. There is no major difference between the result of question #5 and question #7. The comments do not offer new insights. Lag and training are mentioned as factors that affected driving the robot within the lab. This result shows that a simple telepresence robot is easy to drive even for people with no previous experience.

Question #9: *Do you think that the telepresence robot could improve your learning?*



Graph 9 - Learning

Table 8 - Learning

N	*Valid*	*33*
	Missing	*0*
Mode		*4*
Range		*4*
Percentiles	*50 (Median)*	*4*

Participants' comments for question #9:

- "I don't know at this stage. N/A"
- "Definitely not now."
- "en améliorant la fluidité ce serait parfait."

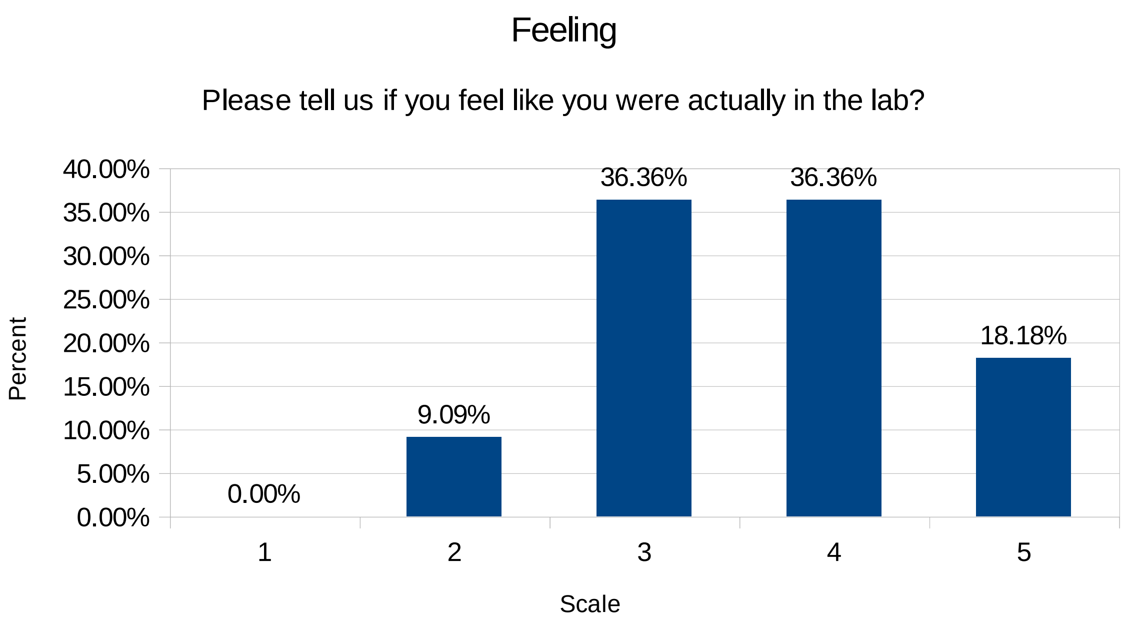
- "le robot est bon pour apprendre à distance"
- "If it could mean that I could interact with an environment remotely, where I otherwise could not have this interaction, then definitely, a telepresence robot could definitely help."
- "Yes with good camera resolution."
- "It might be helpful in doing remote functions associated with learning."
- "I think so. It almost like playing a video game without the slight delay in response to commands"
- "I think it depends on what kind of learning."
- "I could not even touch and move those two objects to the can."
- "This really depends on the context of the learning and the material it is used with."
- "Depends. What types of learning applications is it going to support? With more functionality, and maybe sensors, I can see the robot being useful as a learning aid in a physics lab."
- "It depends on what it's application is. I think it provides a great tool for interacting with another surrounding over the internet."
- "It would depend on the subject, I can't think of an example where the robot would be an improvement over a video camera."
- "It was a fascinating experience for me given that I am studying networking"

45.45% of the participants entered comments for this question.

Synthesis question #9:

Most respondents agree that the robot could improve their learning (Median=4, Mode=4, N=21, 63.63%). And, 12.12% disagree that the robot could improve their learning (N=4). Some comments mention the type of learning as factor to decide if the robot could improve their learning. The result shows that participants would accept to learn via telepresence robots if the robot would make the learning more interactive.

Question #10: *Please tell us if you feel like you were actually in the lab?*



Graph 10 - Feeling

Table 9 - Feeling

N	*Valid*	*33*
	Missing	*0*
Mode		*.*
Range		*3*
Percentiles	*50 (Median)*	*4*

Participants' comments for question #10:

- "No because I was focusing too much on the navigation and completing the task."
- "le virtuel ne remplace pas le réel."
- "difficulté d'appréhension des distances"
- "The distribution of cameras was successfully."
- "It feels really real."
- "I need to focus on every angle of the camera which makes me aware that I am using a remote robot. I think it can be improved by using a single wide range of camera."
- "Yes. There was some sense of reality with robotic motor sound"
- "Yes, the ability to look around and pick up objects gave the sense of being physically present"
- "In a sense yes. With a couple more camera views it would add more awareness to the surroundings."
- "Somewhat."

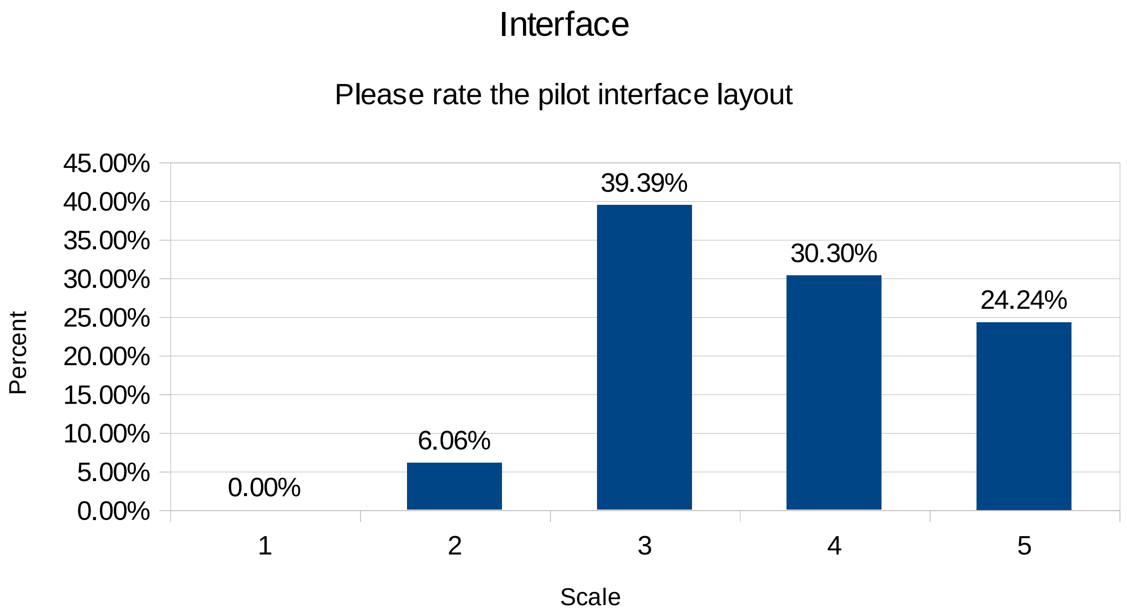
- "I felt like I was in the lab and could affect what was going on in there."
- "Yes I felt quite connected to the environment."

36.36% of the participants entered comments for this question.

Synthesis question #10:

54.45% of the respondents agree that they feel they were actually in the lab (Median=4, Mode=None, N=18). However, 36.36% of respondents chose neutral as their answers (N=12). And, 9.09% of participants disagree. Many comments mentioned that there was a sense of “being there”. However, some respondents commented that the need to focus on video feeds from the cameras made them aware that they were driving a robot remotely. This result somewhat supports what can be found in the literature. It seems that there is a feeling of “being there” but the feeling is not strong enough for many of the participants.

Question #11: *Please rate the pilot interface layout*



Graph 11 - Interface

Table 10 - Interface

N	*Valid*	*33*
	Missing	*0*
Mode		*3*
Range		*3*
Percentiles	*50 (Median)*	*4*

Participants' comments for question #11:

"ATh un peu inutile"

"très net"

"needs some enhancements regarding the synchronization of the 3 screens (robot head/room/ arm)"

"Didn't really like the controls very much. The arrows worked well, but <> n,m and cwzas didn't work well for me."

"With the control descriptions open beside me it was Ok. Having information up front to show the controls would help."

"layout was easy to understand"

"More cameras and angleswill improve the driver's experience"

"There are too many keys to control."

"Did not really care too much about the pilot interface. I used the cameras and the room layout to navigate to the blocks"

"I liked the easy to use controls. They made sense between the left handed hot keys and the arrow keys on the right hand."

"It was user friendly but keyboard controls seem unnatural in controlling the robot."

"I think that the interface is fine, being able to map the control keys to a users preference may be a good upgrade."

"The layout was useful for figuring out how to complete the assigned task."

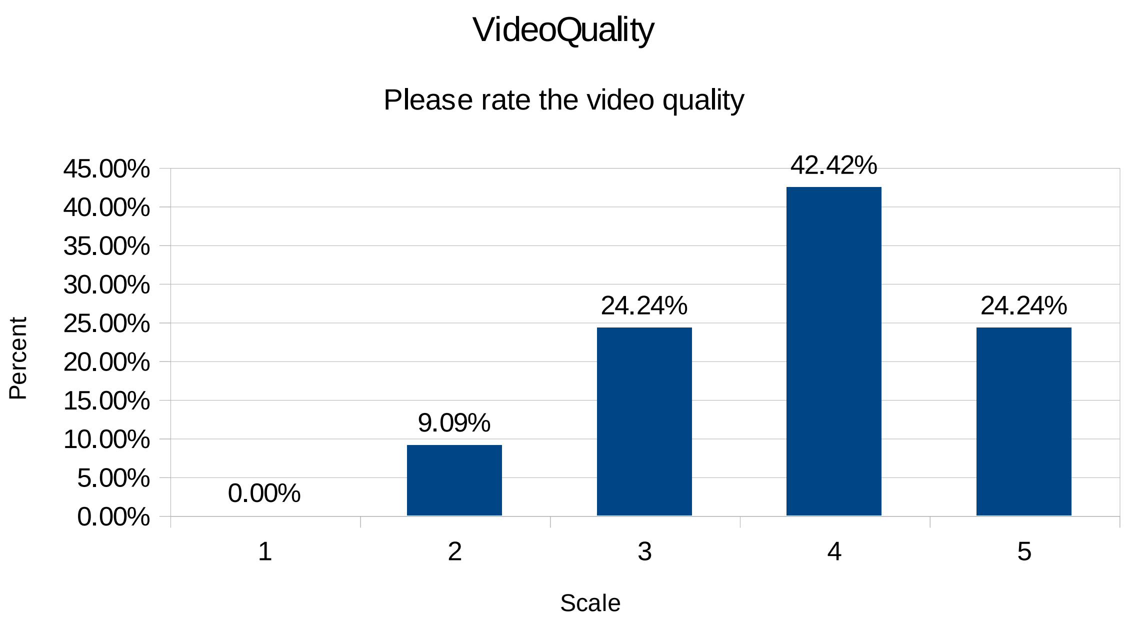
"Once I learned the controls it was quite easy to control the robot. I did spend some time initially referring to the documentation which may not have been necessary if there was an overly on the video, or keymap on the webpage."

39.39% of the participants entered comments for this question.

Synthesis question #11:

39.39% of respondents selected neutral as their answers (N=13). Only 54.54% of respondents rated the pilot interface favorably (Median=4, Mode=3, N=18). Some of the comments mention that controlling the robot with the keyboard keys was not very intuitive. The result is close to what I was expecting since I new that the keyboard was not the best way to control the telepresence robot. The use of a mouse or gamepad would have been better.

Question #12: *Please rate the video quality*



Graph 12 - Video quality

Table 11 - Video quality

N	*Valid*	*33*
	Missing	*0*
Mode		*4*
Range		*3*
Percentiles	*50 (Median)*	*4*

Participants' comments for question #12:

- "the head camera was a little lag when i use it."
- "caméra principale plus lente que les autres"
- "très bonne qualité"
- "Good, except there was a moment where I remember things got blurry as I was about to place something in the tin plate."
- "The resolution was very low and looking from some angles it was hard to tell what the writing or object was."
- "Video quality was good"
- "The video showing the arm was not very clear. I believe this should be more high definition since it shows th point at which you pick up the objetcs"
- "The main view seems very vague."
- "The robot head camera was a bit blurry at times. But the down facing camera had excellent resolution."
- "There was some issue with the primary camera, the two supporting cameras has a very good quality."
- "The resolution quality of the video was fine, I had a bit of a delay between the head camera and down facing camera for a period."
- "I could see very clearly in the room. The video was very helpful."

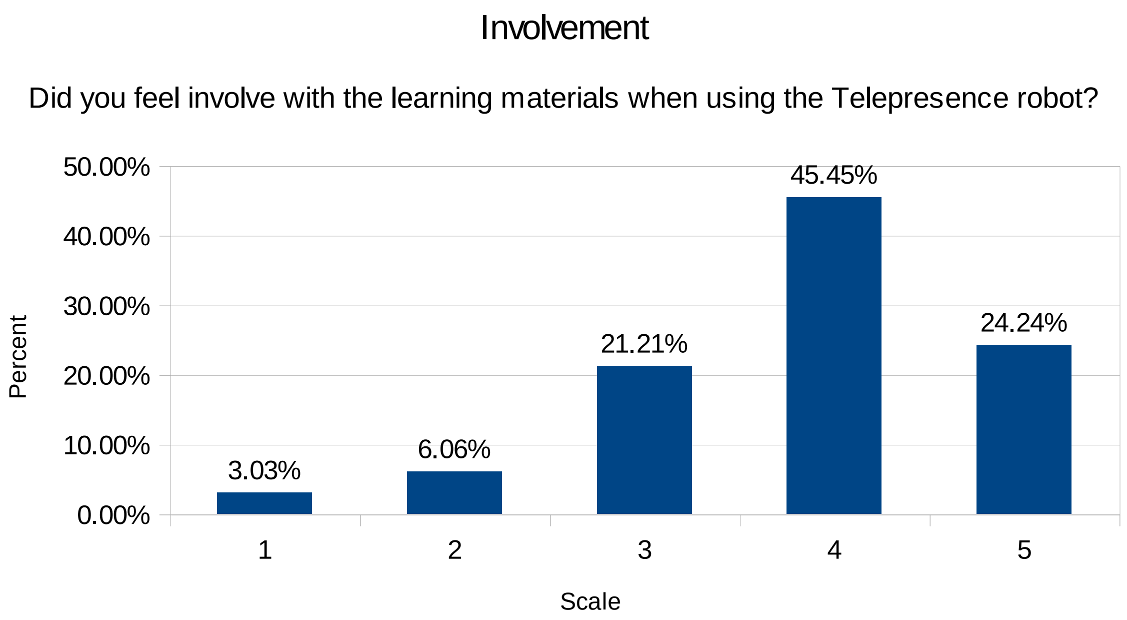
- "The video quality of the Lab cam and the "Down View" were excellent however the "Head Cam" video was poor sometimes, while excellent at other times."

39.39% of the participants entered comments for this question.

Synthesis question #12:

Most respondents agree that the video quality was good (Median=4, Mode=4, N=22, 66.66%). Some comments judge the front and lab camera video streams as being good in general. However, it is noted that the head camera (principal camera) video stream was not always good and was noticeably of lower quality than the other cameras. The video quality can be improved by having a better upload bandwidth.

Question #13: *Did you feel involve with the learning materials when using the Telepresence robot?*



Graph 13 - Involvement

Table 12 - Involvement

N	*Valid*	*33*
	Missing	*0*
Mode		*4*
Range		*4*
Percentiles	*50 (Median)*	*4*

Participants' comments for question #13:

- "N/A"
- "N/A"

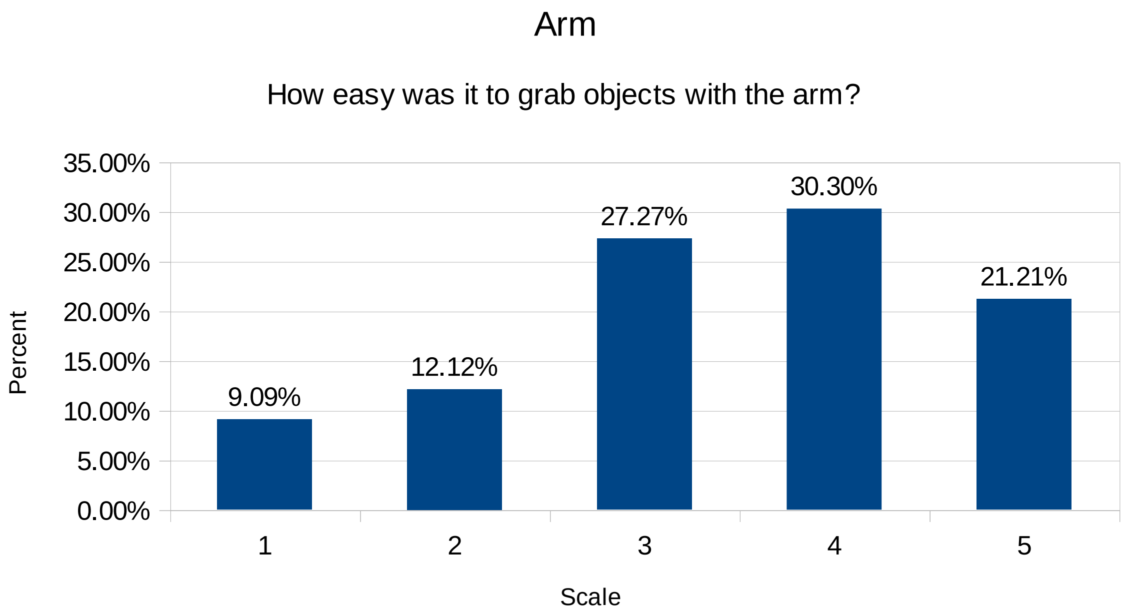
- "j'étais très concentré"
- "cela demandé beaucoup de concentration"
- "N/A? Not sure what the learning materials were? The instructions?"
- "Yes its engaging."
- "Does not suit my learning style"
- "yes completed moving both objects"
- "Yes i did. I was testing my ability to navigate and have a sense of the blocks positioning."
- "Yes, it was easy to recognize the objects and understand the tasks required."

30.30% of the participants entered comments for this question.

Synthesis question #13:

Most participants agree that they felt involved with the learning material when using the telepresence robot (Median=4, Mode=4, N=23, 69.69%) and 9.09% disagree. Some comments mention that the participant was very focused on the task at hand.

Question #14: *How easy was it to grab objects with the arm?*



Graph 14 - Arm

Table 13 - Arm

N	*Valid*	*33*
	Missing	*0*
Mode		*4*
Range		*4*
Percentiles	*50 (Median)*	*4*

Participants' comments for question #14:

- "in video it is hard to know the distance between arm and object."
- "Grabbing itself is easy. But getting to the position were you can grab something is difficult."

- "The robot hand have problem.I press ">" but the arm is open."
- "les lags ne facilitent pas la tache mais en les appréhendant cela devrait rentrer"
- "les objets était difficilement perceptible spatialement"
- "Also, some solutions need to be provided if some objects are dropped on the floor to grab them"
- "The round one I had some troubles, had to take a second try at it."
- "It was fairly easy once I get robot hand on the object"
- "It it easy when I get used to controlling."
- "I could not even touch and move those two objects to the can."
- "I was expecting the hands to open from both sides but only the right side of the claw was opening up. The grip was surprisingly stronger then I expected."
- "Not that difficult. The camera views, especially the down facing camera helped with reaching for them."
- "It seemed to have a very a firm grip which made it easy to pick up the two items."
- "I was able to grab both objects on first attempts."
- "Knowing the height of the arm took a bit to figure out, and there was a bit of a delay between pressing the control keys and the actual movement."

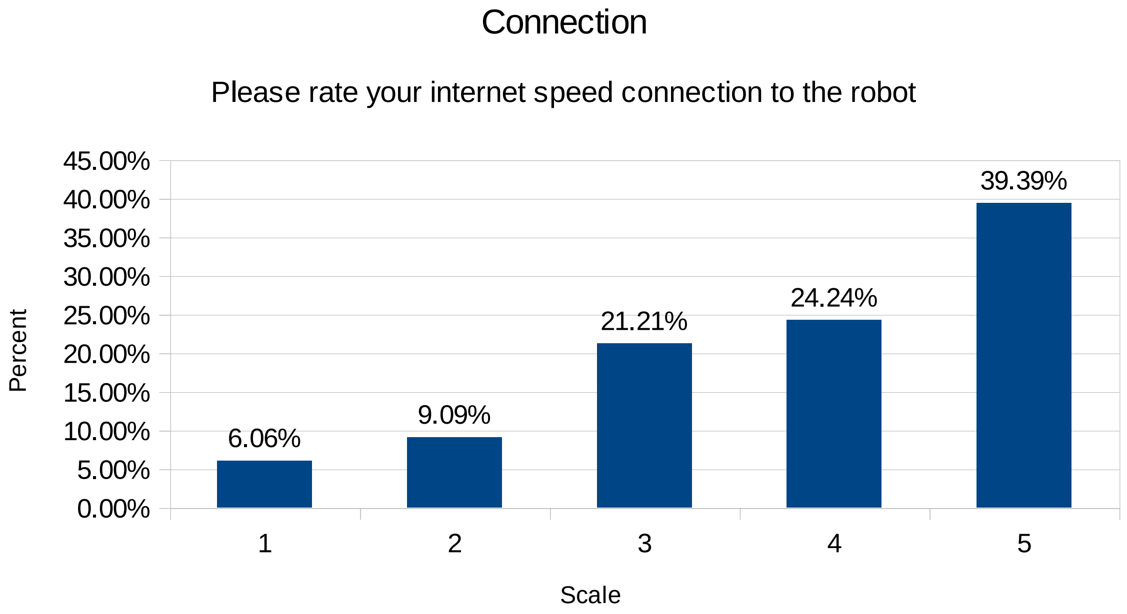
- "Once I was familiar with the controls, it was very easy."
- "While it was not "easy", once I had some practice with the robot I was able to confidently use the arm to pick up and move the objects. The quality of the movements was "just good enough" for the tasks required."

51.52% of the participants entered comments for this question.

Synthesis question #14:

51.51% of respondents agree that it was easy to grab the objects with the arm (Median=4, Mode=4, N=17). However, 21.21% of participants disagree (N=7) and 27.27% chose neutral as their answers. This question was one of the most commented question in the survey suggesting that the task of using the arm to move objects was the most interesting for the participants. Some comments mention lag and depth perception as factor as affect how easy is to grab the objects. I was not expecting that most of the participants would succeed to grab and move the two objects. From my observations and the comments, participants quickly adapted to the telepresence robot behaviors and used other indicators to compensate for the lack of depth perception.

Question #15: *Please rate your internet speed connection to the robot*



Graph 15 - Connection

Table 14 - Connection

N	*Valid*	*33*
	Missing	*0*
Mode		*5*
Range		*4*
Percentiles	*50 (Median)*	*4*

Participants' comments for question #15:

- "I felt it like if the internet speed was atrocious, yet latency was good. So, what's the problem?"

- "196 ms de ping c'est beaucoup mais dans un cadre plus professionnel les connexions seraient surement meilleur"
- "I have a 100Mbs Bandwidth."
- "Seemed fine, didn't feel like there was any delay."
- "It was synchronized for the most part but it froze thrice."
- "I noticed some latency when pressing keyboard keys and robot responding to keys but that may be due to my internet connection."
- "The network seems not very smooth so that I can not control the robot easily."
- "I was connected at 100 Mbps LAN connection to the ISP router 10 MBbs"
- "Shaw Internet Connection (~50Mbps)"
- "There was delay but it did not affect the experiment, it was noticeable that the 3 cameras did not sync at the same time."
- "expected some lagging but that wasn't the case. Robot responded promptly without lags"
- "Real time. Had no latency issues with the connection through the web browser."
- "There was a bit more delay for controlling the arm up and down instance in comparison to the forward, back, and side movements. But overall really good."

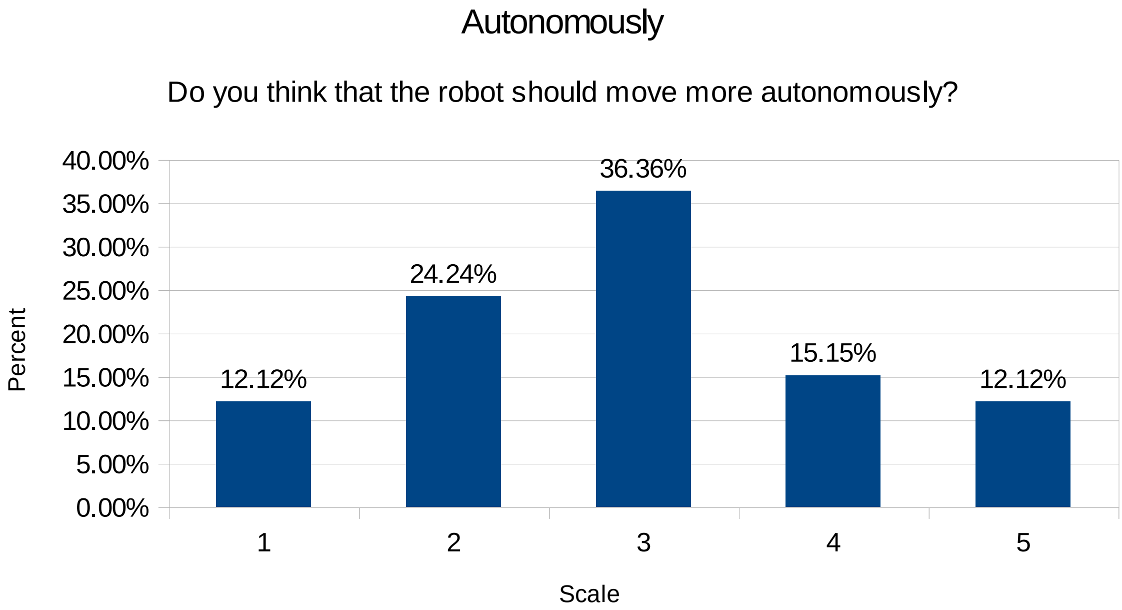
- "The connection seemed to vary, for parts of the test the delay between pressing the control key and the actual movement was near instantly and for parts I needed to let the connection catch up."
- "I was very pleased with my internet connection's speed."
- "I have Shaw 50mbps business service in Calgary (50mbps down/3mbps up)"

48.48% of the participants entered comments for this question.

Synthesis question #15:

Most respondents rated their connections as good (Median=4, Mode=5, N=21, 63.63%) and 15.15% as bad (N=5). From the comments, we note that most of the respondents had good Internet bandwidths with their providers.

Question #16: *Do you think that the robot should move more autonomously?*



Graph 16 - Autonomously

Table 15 - Autonomously

N	*Valid*	*33*
	Missing	*0*
Mode		*3*
Range		*4*
Percentiles	*50 (Median)*	*3*

Participants' comments for question #16:

- "Yes, adding some autonomous navigation would be awesome and remove some of the frustration we get trying to navigate manually. For example, we could have a map view of the room/lab and click on the map to move the robot from one waypoint to another. Then we could regain manual control to complete any given task, when required."

- "je préfère le conduire"
- "Also, the functionality of the buttons (1 & 2) that speed up and slow the motion should be enhanced"
- "Yes I think it should move more freely and with a better surrounding awareness."
- "Not sure, I think it depends on the objective."
- "It depends. Building those intelligence will also require control. I will prefer the current level"
- "If so, then the user can not be part of the experiment."
- "Not sure"
- "i think the robot should be directed based on the users preference"
- "This is a iffie question. This functionality would depend on the purposing of the robot. For more autonomous movement sensors would have to be introduced."
- "I think the more control and exact movement linking between the user controls and the robot the better. Which I think it had."
- "I would be unsure how to control the robot if it was partially autonomous."
- "It would depend on the situation, for this exercise autonomous

movement wouldn't help much."

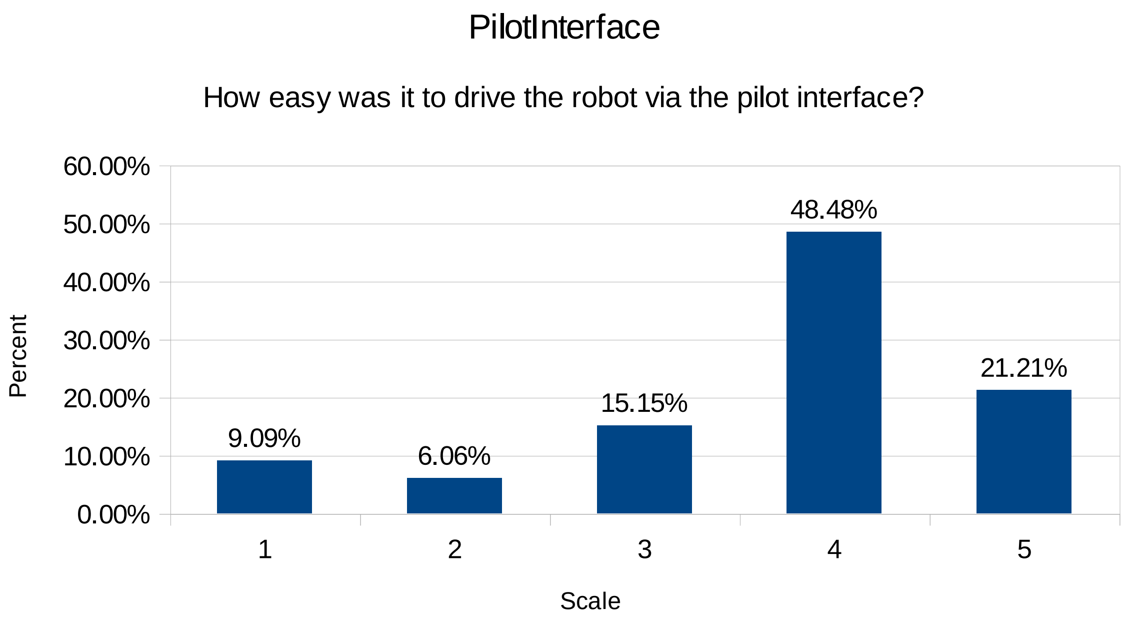
- "It might be worth experimenting with a little bit of autonomy. Click on the screen to move to that location sort of thing."

42.42% of the participants entered comments for this question.

Synthesis question #16:

Many respondents (N=12, 36.36%) disagree but a roughly equal number (N=9, 27.27) agree. Moreover, 36.36% of the participants chose neutral as their answers (Median=3, Mode=3, N=12). These results are reflected in the comment section with respondents saying that some automation could be nice and some other saying that automation would take away from the whole experience. This is an interesting question that would need more exploratory research since the result do not provide much insights.

Question #17: *How easy was it to drive the robot via the pilot interface?*



Graph 17 - Pilot interface

Table 16 - Pilot interface

N	*Valid*	*33*
	Missing	*0*
Mode		*4*
Range		*4*
Percentiles	*50 (Median)*	*4*

Participants' comments for question #17:

- "I did not see navigation keys on the pilot interface, so I am not sure what you are talking about."

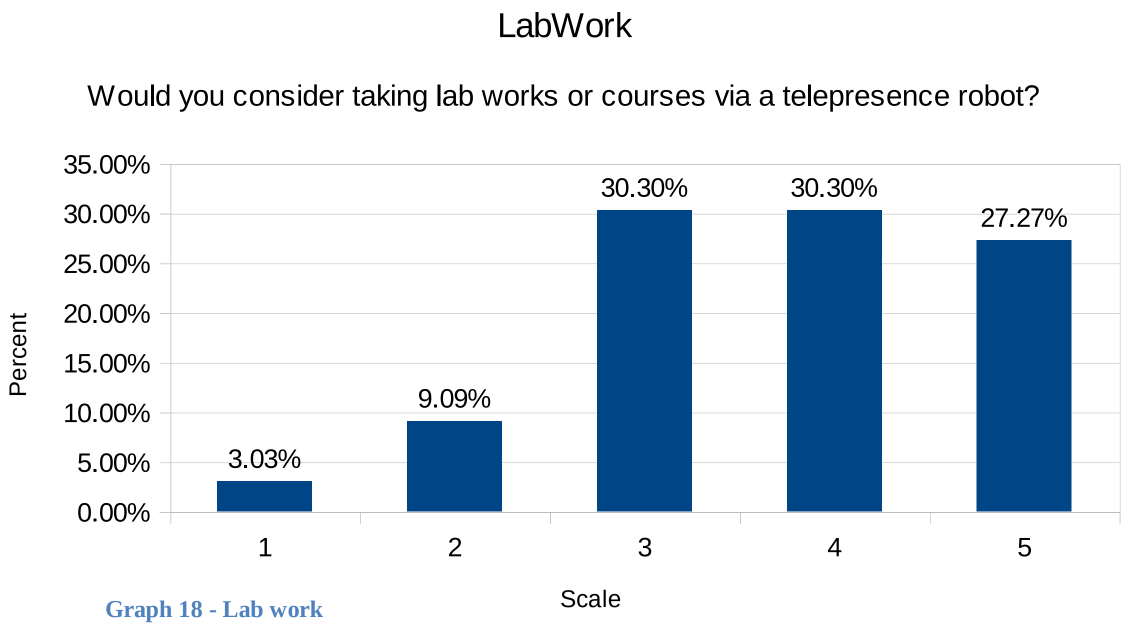
- "The robot move not Smooth."
- "oui quand on va doucement"
- "There is a small deviation between the Lab cam and the down facing cam."
- "Note at beginning it was a bit difficult but once I understand how to control works, it was very easy."
- "As long as I remembered what buttons, it was easy to drive it."
- "The moving is not difficult at all but the camera's resolution offers a limited peripheral view which kind of force you to drive the robot aimlessly."
- "Only when I get used to it."
- "I could not even touch and move those two objects to the can."
- "Easy enough. All cameras helped with moving the robot around."
- "The only improvement as I mentioned above would be a larger viewing ability for the close range camera."
- "The pilot interface was very helpful and easy to understand."
- "As with the arm, the controllability is "just good enough" for the required task. If the environment had more obstructions it would have been frustrating."

39.39% of the participants entered comments for this question.

Synthesis question #17:

69.69% of the respondents agree that it was easy to drive the robot via the pilot interface (Median=4, Mode=4, N=23) and 15.15% disagree (N=5). Only 15.15% of the respondents chose neutral as their answers. From the comments, video lag and control issues are mentioned as negative factor affecting the driving experience. This question is similar with question #10 and the results are very similar: 69.69% agree in this question and 54.54% agree in question #10.

Question #18: *Would you consider taking lab works or courses via a telepresence robot?*



Graph 18 - Lab work

Table 17 - Lab work

N	*Valid*	33
	Missing	0
Mode		.
Range		4
Percentiles	50 (Median)	4

Participants' comments for question #18:

- "Yes and no. Definitely if it were an outdoor telepresence robot ;-)"
- "peut être bientôt en France :D"
- "oui surtout à cause de mon handicap qui m'incapacite."
- "Sure, however after considering some enhancements to overcome disadvantages"
- "Why not? It saves me travel time and money. It is also safe to work remotely."
- "No idea - would have to depend on what it was."
- "With a high resolution camera, it might have some compelling reasons."
- "In some kind of cases, for example, the risky work, I would use a telepresence robot."
- "Does not suit my learning style"
- "Depends on the nature of the course. Some additional trianing may be needed to familiarize with the motions of the robot"
- "It really depends on what the course is about but I think it can be used effectively in learning the right context."
- "Yes I would. Maybe for physics, astronomy and physical sciences. Chemistry I would be a bit worried if the user does not have good dexterity. I can see this robot working well with children, who are autistic, but function at a very high level"

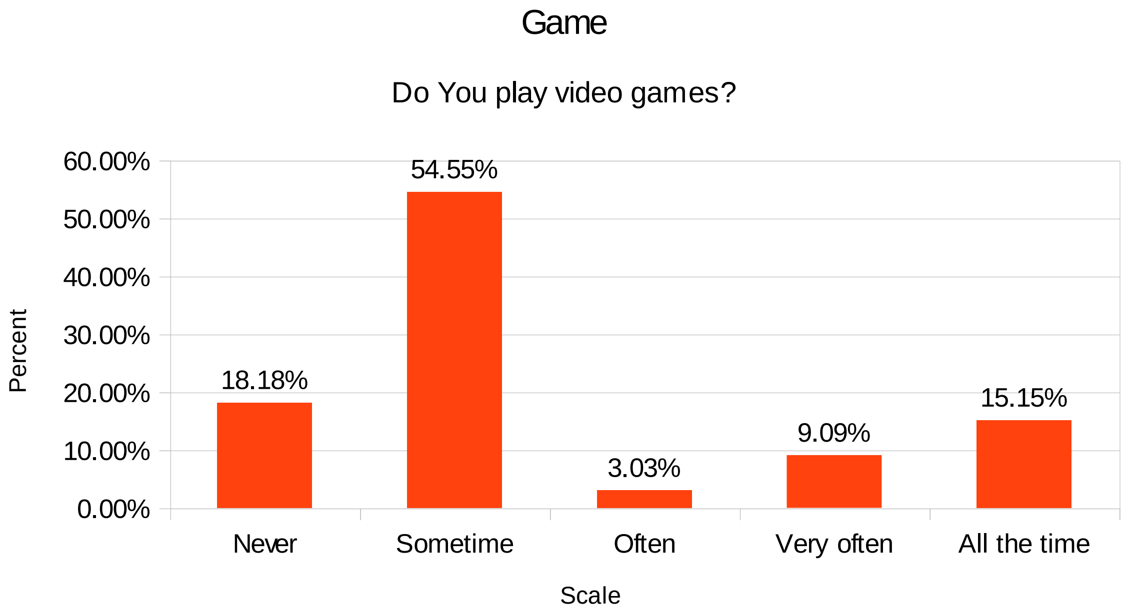
- "Very cool!"
- "This would be exciting. It would make a very interesting learning experience."

42.42% of the participants entered comments for this question.

Synthesis question #18:

57.57% of respondents would consider taking lab works or courses via a telepresence robot (Median=4, Mode=None, N=19). 30.30% of respondents are undecided (N=10) and 12.12% (N=4) would not take lab works or courses via a telepresence robot. From the comments, we learn that participants would consider taking courses via a telepresence robot depending on what the course is about. Also, some comments mention that some enhancements should be made to the robot before they consider taking courses via it.

Question #19: *Do you play video games?*



Graph 19 - Game

Participants' comments for question #19:

- "Yes; I love it, and I'm a badass at it :)"
- "Beaucoup"
- "When I have time - which is never now. I think last time was Christmas"
- "Never played video games"
- "Been a while. I play mainly PC strategy games requiring both keyboard and mouse dexterity"
- "Yes! Actually the keys felt very much laid out like video game

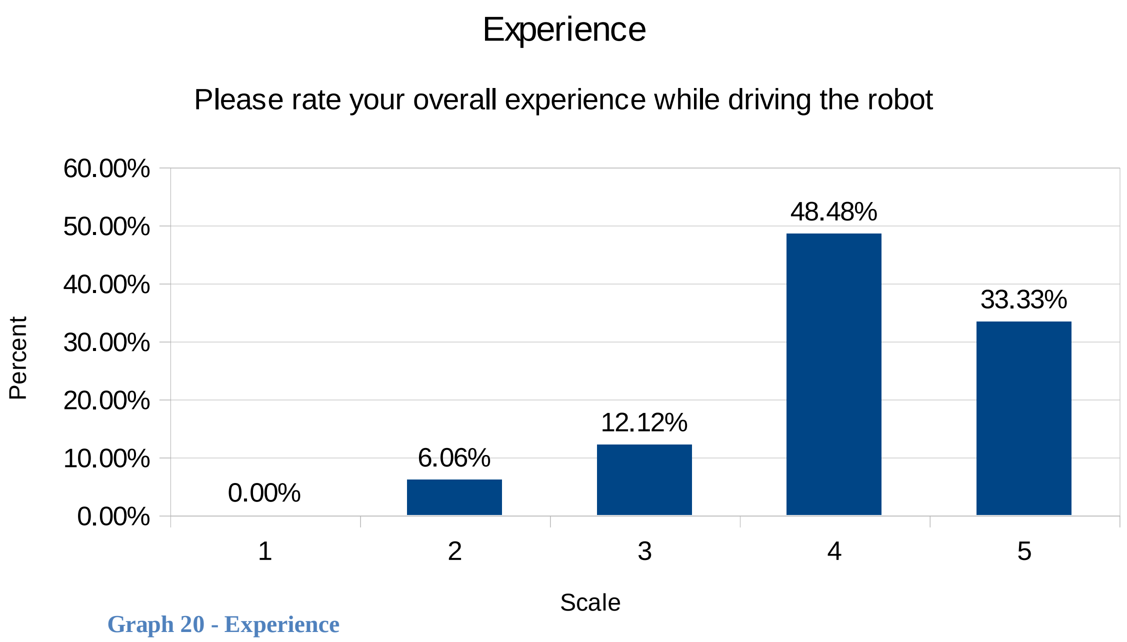
controls."

18.18% of the participants entered comments for this question.

Synthesis question #19:

Most respondents play video games “Sometime” (N=18, 54.55%). Moreover, 18.18% (N=6) of respondents “Never” play video games versus 15.15% (N=5) of respondents who play video games “All the time”. I was expecting that more participants would play video games on a regular basis since I thought that the ability of driving the robot would increase with the amount of games played. This was assuming that most of the games played would be games such as First Person Shooter or simulation games such as car racing games.

Question #21: *Please rate your overall experience while driving the robot*



Graph 20 - Experience

Table 18 - Experience

N	*Valid*	*33*
	Missing	*0*
Mode		*4*
Range		*3*
Percentiles	*50 (Median)*	*4*

Participants' comments for question #21:

- "Globalement bonne pour un prototype"
- "très bonne expérience et enrichissante"
- "It is fun and I like it so much!"
- "Was fun, but a bit hard to get started"
- "Improved after a few tries."
- "It was a good experience due to clear instructions and easy to navigate robot."
- "Maybe this is my person inadequancy"
- "It was pretty fun! I took my time because I didn't want to break the robot and wanted to pass the test."
- "It was educational."
- "It was a lot of fun."

30.30% of the participants entered comments for this question.

Synthesis question #21:

Most of the respondents said that they had a positive experience while driving the robot (Median=4, Mode=4, N=27, 81.81%). Most of the comments express a positive experience while driving the robot. However, the result should be considerate carefully since Acquiescence bias might be present in the result.

Participants' finale Comments:

Graph 21 - Final comments

Table 19 - Final comments

Please enter any comments you might have		
Answer	18	54.55%
No answer	15	45.45%

- ":)"
- "Impressive. VERY POTENTIAL FOR MANY WAY."
- "Améliorer la connexion entre les utilisateurs en adaptant l'interface par rapport a la connexion (par exemple faire une interface légère, basse résolution pour les mauvaises connexions et une interface HD pour les connexions fibrés.)"
- "Expérience à renouveler."
- "I would like to thanks all for this great work, I may recommend to consider the pressure rate for different objects."
- "I think this work is very good for those students who might not able to join lab physically. It is easy, cheap, and safe to use the robot. It might be good idea to give 5-10 minutes practice for a student who might not be comfortable with the use of technologies. To sum, it is very good work and keep up refining it."
- "1. The camera resolution needs improvement. 2. Surrounding awareness is a bit limited."
- "It was a well designed lab with clear instructions and easy to navigate options. Lab test was coordinated well and Marc helped proactively during the test. Good work."
- "I think this is a great creation. It will sure be useful not just in learning but also in industry like auto-dispensing of medications in community pharmacy."

- "At first, the robot is hard to control. After a few tries, when I get used to controlling the robot, it's getting interesting."
- "I am sure this is own inadequacy (change management + skills update opportunity) when it comes to video games, consoles, virtual reality, robotics ... since I am from the very traditional "old school" methodology."
- "Maybe there are too many keys to remember and apply in unison for me."
- "Again, I may be the "isolated incidence" (statistical outlier?) of being unable to touch and move those two objects to the can."
- "Nice work! It's a good concept!"
- "Very impressed with the overall performance of the robot"
- "I think this Robot was very easily accessible and easy to use and as long as it is used in a suitable context it can be beneficial in learning."
- "The lab is a very controlled environment. But thinking a bit, I can see this robot in the open field. This would require wireless connection and a distributed system that can support this pervasive device. The robot would need to have telescopic arms and head to make it viable in the open environment."
- "Otherwise, it fits the need within the lab environment."
- "Great work on your Telepresence robot! I hope to see it in future teaching applications :)."

- "It is an interesting area of research; I would be interested in seeing the applications in learning that you had in mind."
- "It was a fascinating experience. It makes me feel like taking Athabasca University's undergraduate course on robotic programming. I am curious about what sort of courses could be taken with the robot. I had a lot of trouble at first, but I am confident I could use the robot now that I am familiar with the controls. The biggest challenge was finding out the exact way the robot responded to commands. It what I wanted, but not exactly the way I expected it to. Once I was familiar with the outcomes of the controls, it became much easier. I was an interesting experience."

Synthesis question "Final Comments":

54.55% of the participants left a comments (N=18). Some comments mention that connection between the user and the robot should be improved. Other comments mention that awareness is limited because of the camera resolution. More training is mentioned as something that would improve the user experience. A respondent commented that this telepresence robot would be good for students that cannot be physically present in the lab.

5.5 Additional Analysis

For this additional analysis, Chi-Square test for independence is used. The chi square test for independence of two variables is a test which uses a contingency table. A contingency table is a table in a matrix format. The test is done to understand the type of relationship between two variables. The test tells if two variables are dependent on each other or not. The test can be done on ordinal scale. One limitation of this test is to have a somewhat large sample size. The assumption for this test is that the two variable are independent. Thus, the alternative hypothesis is that some dependence between the two variables exist (Gingrich, 2004).

Chi-Square:

$$x^2 = \sum_i (O_i - E_i)^2 / E_i$$

Equation 5 - Chi-Square

Question #1:

Is there a relationship between playing video games and question #4: *How competent do you feel about driving the robot within the remote lab?*

Hypothesis:

H_0: Games and Question #4 are independent.

H_a: Games and Question #4 are not independent.

Significance level: 0.05

Test Method: Chi-Square for Independence.

Result:

Table 20 - Result Analysis Question #1

Chi-square tests. Statistic	*Value*	*df*	*Asymp. Sig. (2-tailed)*
Pearson Chi-Square	19.48	16	0.245
Likelihood Ratio	22.8	16	0.119
N of Valid Cases	33		

Since $p > 0.05$ ***we accept*** $\boldsymbol{H_0}$

This is an interesting result since I was expecting that participants would feel more competent when driving the telepresence robot if they played video games on a regular basis. Video games such as First Person Shooter have similar controls of the characters via the keyboard. Also, the players should be more familiar with virtual environments.

Question #2:

Is there a relationship between playing video games and question #14: *How easy was it to grab objects with the arm?*

Hypothesis:

H_0: Games and Question #14 are independent.

H_a: Games and Question #14 are not independent.

Significance level: 0.05

Test Method: Chi-Square for Independence.

Result:

Table 21 - Result Analysis Question #2

Chi-square tests. Statistic	*Value*	*df*	*Asymp. Sig. (2-tailed)*
Pearson Chi-Square	9.22	16	0.904
Likelihood Ratio	10.79	16	0.822
N of Valid Cases	33		

Since $p > 0.05$ ***we accept H_0***

The result is counter intuitive since we would expect that gamers would be able to do better than non-gamers when it comes to use the telepresence robot's arm and gripper to grab objects.

Question #3:

Is there a relationship between gender and question #4: *How competent do you feel about driving the robot within the remote lab?*

Hypothesis:

H_0: Genders and Question #4 are independent.

H_a: Genders and Question #4 are not independent.

Significance level: 0.05

Test Method: Chi-Square for Independence.

Result:

Table 22 - Result Analysis Question #3

Chi-square tests. Statistic	*Value*	*df*	*Asymp. Sig. (2-tailed)*
Pearson Chi-Square	4.21	4	0.378
Likelihood Ratio	4.2	4	0.38
N of Valid Cases	33		

Since $p > 0.05$ ***we accept H_0***

The result is what I was expecting to see. I did not think that a relationship would exist.

Question #4:

Is there a relationship between gender and question #14: *How easy was it to grab objects with the arm?*

Hypothesis:

H_0: Genders and Question #14 are independent.

H_a: Genders and Question #14 are not independent.

Significance level: 0.05

Test Method: Chi-Square for Independence.

Result:

Table 23 - Result Analysis Question #4

Chi-square tests. Statistic	*Value*	*df*	*Asymp. Sig. (2-tailed)*
Pearson Chi-Square	8.37	4	0.079
Likelihood Ratio	9.99	4	0.041
N of Valid Cases	33		

Since $p > 0.05$ ***we accept H_0***

Same as the previous question, I did not expect to see a relationship but since the participants were multicultural, the question was asked.

Question #5:

Is there a relationship between q*uestion #6: How easy was it to navigate the robot within the remote lab?* and question #9: *Do you think that the telepresence robot could improve your learning?*

Hypothesis:

H_0: Question #6 and Question #9 are independent.

H_a: Question #6 and Question #9 are not independent.

Significance level: 0.05

Test Method: Chi-Square for Independence.

Result:

Table 24 - Result Analysis Question #5

Chi-square tests. Statistic	***Value***	***df***	***Asymp. Sig. (2-tailed)***
Pearson Chi-Square	35.89	16	0.003
Likelihood Ratio	22.19	16	0.137
Linear-by-Linear Association	8.16	1	0.004
N of Valid Cases	33		

Since $p < 0.05$ ***we reject H_0 and accept H_a***

This result would imply that participants that had a positive attitude toward driving the telepresence robot in the lab also had a positive attitude toward learning via the telepresence robot. Making the telepresence robot easy to drive would increase the acceptance of the technology by participants.

5.6 Findings and Discussion

This research found that 36 out of 40 participants succeed in completing the driving and dexterity test. As a result, only 4 participants failed the driving and dexterity test and were not able to move the two blocks into the container. This is most interesting since only 2 out of 33 respondents had driven a telepresence robot before taking the test. One of the researcher expectation was that most of the participants would fail the dexterity test. Moreover, none of the participants had received any training on the robot before the test. The only information that was given to them was a simple instruction pdf file describing what the test was about and how to control the robot. In addition, in average, each participant took approximately 20 minutes to finish the driving and dexterity test. Some participants finish the test within 5 minutes while some other took over 45 minutes to finish the test. This result demonstrates that telepresence robots can easily be used by students with little or no training in an unfamiliar environment to do simple tasks.

Another interesting finding is that it appears that there is no direct relationship between playing video games and question #3: *How competent do you feel about driving the robot within the remote lab?* Moreover, it appears that there is no relationship between genders and question #3 as well. The same result exists for question #13: *How easy was it to grab objects with the arm?*

Also, we find that q*uestion #5: How easy was it to navigate the robot within the remote lab?* and question #8: *Do you think that the telepresence robot could improve your learning?* are dependent. The relationship is positive since the correlation seems to indicate that participants who agreed that it was easy to navigate the robot within the remote lab can be expected to agree that the telepresence robot could improve their learning. Increasing how well telepresence robots move around will have a positive impact on how well the technology will be accepted by students.

5.6.1 Other findings and Possible Solutions

Video:

One of the main issue with the telepresence robot was the lag from the main video feed. Since the telepresence robot would be used as a teleconference system on wheels, it uses WebRTC (Web Real-Time Communication) has its main video chat application. A generic implementation of WebRTC was used in the Mark II (present telepresence robot) with no attempt to optimize it. More research should be done at this level to improve the implementation of WebRTC in a telepresence robot. The main focus should be on the STUN, TURN, and Signaling applications of WebRTC and the real-time optimization of the camera resolution to prevent lose of frames or a too grainy video when the user's bandwidth changes.

Control:

At this point in time, pilots use the keyboard to control the robot. The keys used to control the telepresence robot are similar with the keys used in games such as RPG or FPS. This worked pretty well. However, some users have mentioned that remembering all the keys was difficult. In addition, other participants have expressed the desire to use other devices to control the robot such as joystick, game-pad, and computer mice. Some development would be needed here to implement the use of these devices to control the robot. Another interesting implementation could be to use “Speech Recognition” to control some of the feature of the robot such as speed or the robot hand. “Speech Recognition” would be useful for people with physical disabilities. “Text-to-Speech” could be used to give feedback on the state of the robot. “Text-to-Speech” has been implemented in this version of the robot application using HTLM5. However, it is limited to just advising the user that the robot is ready.

Autonomous:

When asked if the robot should move more autonomously, a roughly equal amount of respondents disagree, agree, and were uncertain. However, from observation of the driving and dexterity test, we can deduce that some automation would improve the user experience. Here, it is important to note that the “setting” of this test was free of obstacles and was limited to only one room. If the telepresence robot was actually used in a real lab environment with many areas and obstacles, automation would enhance the driving experience. Moreover, some respondents mentioned that they had to be focused while driving the robot and that it negatively affected there feeling of “being there”. Having to strongly focus on driving while doing lab work over a long period of time could quickly degrade the user experience. In addition, it would be exhausting and could interfere with the learning material at hand. On the other hand, some participants mentioned that they like to be in control of the robot. As a result, more research and development could be started to investigate the possibility to have autonomous feature based on the user preference. Levels of automation could be implemented from no automation to full automation. A useful automation feature for users that were disoriented while driving the robot would have been the display of a map of the lab or the building where the robot was currently located. The pilot could click on the map and the robot would move to that location autonomously. Also, autonomous obstacle avoidance features would have been welcome by pilots who collided numerous time with walls and the lab table.

Course Integration:

When ask if the respondents would consider taking a lab course via a telepresence robot 57.57% of the participants agreed. However, some respondents mentioned that it would depend of the course and the context. Therefore, to promote and maximize the use of this telepresence robot in a remote lab, it should be part of a framework such as the 5R Adaptation Framework. As a result, more research and development should be started to investigate this integration.

Chapter VI

Conclusion and Future Study

6.1 Contribution

This thesis introduces a novel application for telepresence robots in distance education. It proposes the use of telepresence robots to do lab work indoor and outdoor. Studies about the use of telepresence robots in business and education exist but no studies were found in the literatures regarding the use of telepresence robots for remote labs in distance learning. As a result, this is an uncharted research area that this thesis has started to investigate. Additionally, this thesis presented the use of an affordable telepresence robot equipped with a robotic arm to do lab work at a distance and it has been published in a conference proceeding in December 2014 (Appendix C). Next academic and technical contributions made in this thesis research will be further presented in detail.

6.1.1 Academic Contributions

A complete literature review was conducted in chapter II focusing on telepresence robot hardware, software, control, and cost. Likewise, this literature review explored the use of telepresence robots in healthcare, business, and education. Additional literature reviews were done on remote laboratory, virtual laboratory, wireless sensor networks, and pedagogy. An analysis of the literature review is done in section 2.9. This analysis highlights the issues encountered in real world environments when using telepresence robots. For instance, it is mentioned that good network bandwidth and low latency are essential in order to control the telepresence robot safely. The use of a wide angle lens is cited to reduce the "tunnelling" effect experienced by user when driving telepresence robots. Location awareness is discussed and resulted in the implementation of the "lab" camera. This independent camera offers a bird's-eye view of the lab and helps the pilot of the telepresence robot know his or her location within the lab. Chapter III talks about the requirements of the telepresence robot solution based on the literature review analysis. It also introduces the software architecture of the implemented solution for this research. This software architecture for the implemented telepresence robot solution is unique because the telepresence part of the robot is independent of the robot itself. Thus, the telepresence is just an add-on to the robot and can be implemented with any tablet, smartphone, or laptop, which makes robot and telepresence become modular in the software architecture. As a result, the robot can easily be reconfigured to be used without telepresence if necessary. As well, the use of a Raspberry Pi computer to run a web server makes this telepresence robot independent from a lab located web server. Therefore, this telepresence robot become standalone and can be used outside of the lab if needed. Moreover, the raspberry pi adds flexibility and computing power to this telepresence robot. Chapter IV introduces a concept and architecture for the indoor remote lab. This concept is unique in distance education since it combines a telepresence robot, a virtual lab, and the 5R Adaptation Learning System for lab work in a remote lab. As well, in this chapter, the implementation of the solution is presented and a concept for outdoor remote lab is discussed. The implementation of the solution gives a template that can be used in future studies. Finally, chapter V describes the validation of the implemented solution. This study is distinctive because no other similar studies exist in literature. To investigate how students could use a telepresence robot in a remote lab, a test and a survey were designed. Forty participants, geographically dispersed, were asked to perform a dexterity test using the telepresence robot. They were asked to move to small objects into a container by using the telepresence robot's arm. This test allowed them to remotely drive the telepresence robot in a mock-up lab. After the test, the participants were asked to take a survey online. The earlier believe that most of the participants would not be able to successfully move the two objects into the container without prior training was dismissed. Only four participants out of forty failed to move the two objects into the container. This survey shows that most of participants had a positive experience when driving the telepresence robot and performing the dexterity task. The results also indicate that an affordable telepresence robot can be used to perform simple tasks by students that did not receive prior training.

6.1.2 Technical Contribution

For this research, an affordable telepresence robot was developed and built. This telepresence robot uses open-source software and inexpensive hardware to keep the total cost of the solution low. The total cost of building the telepresence robot was $400 CAD. The telepresence robot is built with common and widely affordable components that can be found practically anywhere or that can be easily ordered online at very reasonable prices. The telepresence robot uses a Raspberry Pi and an Arduino as main processing units. These components are well known to educators and are used for educational purposes. This telepresence robot gives an example of affordability, scalability, compatibility, and customizable for the applications. A pilot interface was developed and implemented as well as the application that processes the commands issued by the pilot. And, WebRTC was implemented for the telepresence part of the robot. WebRTC was chosen because of its security, rich communication, and cost.

6.2 Conclusion

There are three main contributions in this research. The first contribution is the development of a telepresence robot that is the main component of the telepresence robot based ubiquitous computing platform. The one developed gives an example of affordability, scalability, compatibility, and customizable for the applications. The second contribution is the design and implementation of the telepresence robot system architecture in coping with the overall system architecture of the telepresence robot enabled remote lab for distance education. This telepresence robot system architecture provides an implementable framework for the research, particularly focusing on the telepresence robot implementation for remote lab in distance learning. The third contribution is the validation implementation of the developed telepresence robot based ubiquitous computing platform under the distance educational scenarios. The validation process was found to be effective in validating this type of research. As a result, this validation process could be used by similar studies. This contribution tests the feasibility of using such a telepresence robot in a remote lab environment.

This research has demonstrated that an affordable telepresence robot can be used in a remote lab environment by untrained users. Moreover, most of participants had a positive experience when driving the telepresence robot and performing the dexterity task. One assumption made by the researcher was that participants that play video games would do better than participants that do not play video games during the dexterity test and driving test. The analysis showed that this assumption was not true. Moreover, participants who agreed that it was easy to navigate the robot within the remote lab can be expected to agree that the telepresence robot could improve their learning. Increasing how easy telepresence robots move around will have a positive impact on how well the technology will be accepted by students.

6.3 Future Study

Further research should be done to investigate how telepresence robots could improve learning in distance education. One potential research could be to investigate how the feeling of "being there" could increase learning and how it relates to "Extending to There".

"Being There" is a psychological feeling that the pilot of a telepresence robot experience when driving the robot in a remote location. The pilot start to feel like she or he is actually at the remote location. The feeling is increase by the fact that the telepresence robot occupies space and can interact with the remote environment. For instance, people in the remote location must mind the telepresence robot when they move around in order not to collide with it. Moreover, the telepresence robot can run into obstacles. This exploratory research shows that a majority of the participants felt like they were in the remote lab. One important advantage of “being there” is that the distance learner feels more connected with the people at the remote location. The distance learner can move the telepresence robot toward a colleague or an instructor and start an informal conversation. The distance learner’s knowledge could increase as she or he can acquire new knowledge by observing others in social interactions. As a result, social learning is present. With a telepresence robot equipped with an arm and a gripper, the distance learner can reproduce what was just learned in the remote lab. For instance, the distance learner in a remote chemistry lab could manipulate two chemicals to create a chemical reaction in real-time. This is done in a safe and comfortable environment for the distance learner. Furthermore, driving the telepresence robot can be factor of motivation when learning since it can be thought as a game. This type of social observational learning is not possible with other types of remote lab video conference technologies because the video feeds are static and are directed only on the experiment at hand. There is no possibility for the distance learner to interact independently with the remote physical environment or with other people located there. The feeling of “being there” requires an immersive technology that permit the distance learn to interact with the remote environment at a social and physical level.

“Extending to There” means that the distance learner senses are extended to the remote location via the telepresence robot. The pilot receives real-time data from the telepresence robot video and sensor devices. Furthermore, the distance learner is able to interact mechanically with the remote environment. For instance, the pilot can grab an object in the remote lab or push a button. The distance learner's sensory systems are being extended and even enhanced to the remote environment. For instance, the video cameras extend the pilot's eye. The camera's microphone extends the pilot hearing system. Somatic sensation can be extended and adequate feedback mechanism can be implemented. For example, touch and pressure sensors can be added to the gripper giving a real-time feedback to the telepresence robot user when grabbing objects. Sensory systems can also be enhanced. An Infrared camera can be installed on the telepresence robot and give a complete new view and perspective of the remote environment to the pilot. New and enhanced data is now sent to the distance learner which can convert these data to information to learn new thing about an object. To "extending to there", a telepresence robot must be able to transmit data in real-time and have the possibility to connect to on-board or local sensors. Furthermore, it must be able to interact physically with the remote environment. The telepresence robot could be part of the Internet of things (IoT) and exchange information with other devices or physical objects embedded with sensors.

"Being There" and "Extending to There" could help in providing a pedagogical approach that contains discovery learning, learning by doing and blended learning. The telepresence robot could help in creating an educational process that will help in knowledge transfer to student in distance learning by providing a blended approach of social interaction, digital media, and hands-on activities. The telepresence robot can be preprogrammed with specific instructions that will deliver the learning content in a definite sequence. This sequence is based on the pedagogical approach of the instructor. Moreover, the telepresence robot can be reconfigured to match the student needs, abilities and learning style. For instance, the telepresence robot could be reconfigured to meet the needs of a disable student. This would be done “on the fly” by changing parameters in the telepresence robot software and by enabling or disabling some of the telepresence robot hardware.

The scope of this thesis did not permit the investigation of two potentially important variables in this research validation. The first one is the skill sets of the participants. It would be interesting to know what is the skill set of each participants and see which skill help a participant in driving the telepresence robot. A future study could explore the technical skills of the participants and see how these skills relates to the new technology. For instance, does being technological knowledgeable make the participant’s attitude toward the technology more positive? The second variable is gender. Not enough participants were female in this study. To have more accurate results, a future survey with an equal or greater amount of female participants should be done.

Additionally, future studies should investigate accuracy of the telepresence robot’s movements. If the robot will be used in lab environments where dissections, for instance, need to be performed, accuracy when moving the arm and the robot should be discussed and investigate the limitations imposed by, for example, network bandwidths and video lags.

Other very interesting study would be to investigate how disable students that cannot attend lab courses could use this technology. For instance, they could log on to their “avatars” and experience the lab environment as if they were there physically. Another interesting use of telepresence robots would be for departments such as Nursing. Future Nurses could remotely connect to telepresence robots located in hospitals and walk along doctors and other nurses.

REFERENCES

Alers, S., Bloembergen, D., Claes, D., Fossel, J., Hennes, D., & Tuyls, K. (2013). Telepresence Robots as a Research Platform for AI, 2–3.

Anybots. (2014). Retrieved June 5, 2014, from www.anybots.com

Arduino. (2014). Retrieved June 5, 2014, from http://arduino.cc

Ayodele, K. P., Kehinde, L. O., & Komolafe, O. a. (2012). Hybrid Online Labs: Making Remote Laboratories Usable Under Unfavorable Bandwidth Conditions. *International Journal of Online Engineering (iJOE)*, *8*(4), 14–21. http://doi.org/10.3991/ijoe.v8i4.2158

Benmohamed, H., Leleve, A., Prevot, P., & Lyon, I. (2004). Remote Laboratories : New Technology and Standard Based Architecture.

Cardoso, A., & Gil, P. (2013). Online Learning in Engineering Courses Using Wireless Sensor and Actuator Networks. *International Journal of Engineering Pedagogy (iJEP)*, *3*(S1), pp. 76–80. Retrieved from http://online-journals.org/index.php/i-jep/article/view/2457

Coltin, B., Biswas, J., Pomerleau, D., & Veloso, M. (2012). Effective semi-autonomous telepresence. *Lecture Notes in Computer Science (including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, *7416 LNCS*, 365–376.

Corter, J. E., Nickerson, J. V., Esche, S. K., Chassapis, C., Im, S., & Ma, J. (2007). Constructing reality: A study of Remote, Hands-On, and Simulated Laboratories. *ACM Transactions on Computer-Human Interaction*, *14*(2), 7–es. http://doi.org/10.1145/1275511.1275513

Desai, M., Tsui, K. M., Yanco, H. a., & Uhlik, C. (2011). Essential features of telepresence robots. *2011 IEEE Conference on Technologies for Practical Robot Applications*, 15–20. http://doi.org/10.1109/TEPRA.2011.5753474

Diwakar, S., Parasuram, H., Medini, C., Raman, R., Nedungadi, P., Wiertelak, E., … Nair, B. (2014). Complementing Neurophysiology Education for Developing Countries via Cost-Effective Virtual Labs: Case Studies and Classroom Scenarios. *Journal of Undergraduate Neuroscience Education : JUNE : A Publication of FUN, Faculty for Undergraduate Neuroscience*, *12*(2), A130–9. Retrieved from http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3970995&tool=pmcentrez&rendertype=abstract

Double Robotics. (2014). Retrieved June 5, 2014, from http://www.doublerobotics.com/

Fumihide, T., Toshimitsu, T., Shizuko, M., Nao, T., & Masahiko, M. (2014). Telepresence Robot Helps Children in Communicating with Teachers who Speak a Different Language. In *ACM/IEEE International Conference On Human-Robot Interaction* (pp. 399–406).

Gingrich, P. (2004). Chi Square Tests. *Introductory Statistics for the Social Sciences*, 735–742.

Giraff. (2014). Retrieved June 5, 2014, from http://www.giraff.org

Gonzalez-Jimenez, J., Galindo, C., & Ruiz-Sarmiento, J. R. (2012). Technical improvements of the Giraff telepresence robot based on users' evaluation. *Proceedings - IEEE International Workshop on Robot and Human Interactive Communication*, 827–832.

Greenwald, T. (2010). Open- source software is making it neariy as easy to program a robot as it is to write. *Technology Review*, *116*(5), 30–33.

Guizzo, E. (2010). When My Avatar Went to Work. *EEE Spectrum*, *47*(9), 26–31.

Hallyburton, C. L., Lunsford, E., College, S. C., Drive, C., & Nc, S. (2010). Challenges and Opportunities for Learning Biology in Distance-Based Settings Corresponding Author : elunsford@southwesterncc.edu, 27–34.

iRobot. (2014). Retrieved June 5, 2014, from http://www.irobot.com

Kist, A. a., Gibbings, P., Maxwell, A. D., & Jolly, H. (2013). Supporting Remote Laboratory Activities at an Institutional Level. *International Journal of Online Engineering (iJOE)*, *9*(S5), 38. http://doi.org/10.3991/ijoe.v9iS5.2772

Krishnamachari, B., & Networks, A. (2005). An Introduction to, (January), 1–101.

Kristoffersson, A., Coradeschi, S., & Loutfi, A. (2013). A review of mobile robotic telepresence. *Advances in Human-Computer Interaction*, *2013*.

Kristoffersson, A., Severinson Eklundh, K., & Loutfi, A. (2012). Measuring the Quality of Interaction in Mobile Robotic Telepresence: A Pilot's Perspective. *International Journal of Social Robotics*, *5*(1), 89–101. http://doi.org/10.1007/s12369-012-0166-7

Kumar, S., Ph, D., & Shepherd, D. (n.d.). SensIT : Sensor Information Technology For the Warfighter, 1–7.

Kwon, O., Koo, S., Kim, Y., & Kwon, D. (2010). Telepresence robot system for English tutoring. *2010 IEEE Workshop on Advanced Robotics and Its Social Impacts*, 152–155. http://doi.org/10.1109/ARSO.2010.5679999

Labs, S. (2013). The Evolution of Wireless Sensor Networks, 1–5. Retrieved from http://www.silabs.com/pages/Silabs-Search.aspx?q=wsn

Lang, J. (2012). Comparative Study of Hands-on and Remote Physics Labs for First Year University Level Physics Students. *Transformative Dialogues: Teaching & Learning Journal*, *6*(1), 1–26.

Lee, M. K., & Takayama, L. (2011). " Now , I Have a Body ": Uses and Social Norms for Mobile Remote Presence in the Workplace, 33–42.

Lee, W.-Y., Hur, K., Hwang, K., Eom, D.-S., & Kim, J.-O. (2010). Mobile Robot Navigation Using Wireless Sensor Networks Without Localization Procedure. *Wireless Personal Communications*, *62*(2), 257–275. http://doi.org/10.1007/s11277-010-0052-2

Lewis, F. L. (2004). Wireless Sensor Networks, 1–18. http://doi.org/10.1007/b117506

Li, S., Qin, Z., Shan, L., Zhang, R., & Yang, X. (2014). A Survey on Target Tracking in Well-deployed Wireless Sensor Networks. *Journal of*

Software, *9*(5), 1255–1263. http://doi.org/10.4304/jsw.9.5.1255-1262

Lloret, J. (2013). Underwater sensor nodes and networks. *Sensors (Basel, Switzerland)*, *13*(9), 11782–96. http://doi.org/10.3390/s130911782

Ma, J., & Nickerson, J. V. (2006). Hands-on, simulated, and remote laboratories. *ACM Computing Surveys*, *38*(3), 7–es. http://doi.org/10.1145/1132960.1132961

MacHaret, D. G., & Florencio, D. a. (2012). A collaborative control system for telepresence robots. *IEEE International Conference on Intelligent Robots and Systems*, 5105–5111.

Michaud, F., Boissy, P., & Labont, D. (2004). Telepresence Robot for Home Care Assistance.

MITRO. (2013). Retrieved from http://swarmlab.unimaas.nl/mitro/

Moyle, W., Jones, C., Cooke, M., O'Dwyer, S., Sung, B., & Drummond, S. (2014). Connecting the person with dementia and family: a feasibility study of a telepresence robot. *BMC Geriatrics*, *14*(1), 7. Retrieved from http://www.biomedcentral.com/1471-2318/14/7

Odeh, S., Shanab, S. A., Anabtawi, M., & Hodrob, R. (2013). A R EMOTE E NGINEERING L AB B ASED ON A UGMENTED R EALITY FOR T EACHING E LECTRONICS A Remote Engineering Lab Based on Augmented Reality for Teaching Electronics, *9*(5), 61–68.

OpenCV. (2014). Retrieved June 5, 2014, from http://opencv.org

Orha, I., & Oniga, S. (2012). Assistance and telepresence robots : a solution for elderly people, *5*, 87–90.

Petelin, J. B., Nelson, M. E., & Goodman, J. (2007). Deployment and early experience with remote-presence patient care in a community hospital. *Surgical Endoscopy*, *21*(1), 53–6. http://doi.org/10.1007/s00464-005-0261-z

Quigley, M., Gerkey, B., Conley, K., Faust, J., Foote, T., Leibs, J., … Ng, A. (2009). ROS : an open-source Robot Operating System. *ICRA Workshop on Open Source Software*, *3*(3.2), 5.

Raspberry Pi Foundation. (2014). Retrieved June 5, 2014, from www.raspberrypi.org

ROS. (2014). Retrieved June 5, 2014, from http://www.ros.org

Sanguino, T. J. M., Márquez, J. M. A., Carlson, T., & R. Millán, J. D. (2014). Improving Skills and Perception in Robot Navigation by an Augmented Virtuality Assistance System. *Journal of Intelligent & Robotic Systems*. http://doi.org/10.1007/s10846-014-0038-5

Sauter, M., Uttal, D. H., Rapp, D. N., Downing, M., & Jona, K. (2013). Getting real : The authenticity of remote labs and simulations for science learning. *Distance Education*, *34*(1), 37–47.

Shodiq, M., Nugraheni, C., Lim, R., & Wicaksono, H. (2010). OBSTACLES AVOIDANCE FOR INTELLIGENT TELEPRESENCE, *4*(5), 3–9.

Special, W., & Needs, H. (2013). School ' s Now in Session – For Everyone. VGo Communications. Retrieved from http://www.vgocom.com/educators

Stein, S. K. (2014). Lessons Learned Building the Online History Program at the University of Memphis. *History Teacher*, *47*(3), 373–386.

Subramanian, R., & Marsic, I. (2001). ViBE : Virtual Biology Experiments, 316–325.

Suitable Technologies. (2014). Retrieved June 5, 2014, from https://www.suitabletech.com/lease/

Tan, Q., Zhang, X., & Mcgreal, R. (2011). The 5R Adaptation Framework for Location-Based Mobile Learning Systems. In *10th World Conference on Mobile and Contextual Learning* (pp. 18–21).

Tanaka, F., Takahashi, T., & Morita, M. (2013). Tricycle-style operation interface for children to control a telepresence robot. *Advanced Robotics, 27*(17), 1375–1384. http://doi.org/10.1080/01691864.2013.826782

Tatli, Z., & Ayas, A. (2013). Effect of a Virtual Chemistry Laboratory on Students ' Achievement, *16*, 159–170.

Troubleyn, E., Moerman, I., & Demeester, P. (2013). QoS Challenges in Wireless Sensor Networked Robotics. *Wireless Personal Communications*, *70*(3), 1059–1075. http://doi.org/10.1007/s11277-013-1103-2

Tsui, K. M., Norton, A., Brooks, D. J., McCann, E., Medvedev, M. S., Allspaw, J., … Yanco, H. a. (2014). Iterative design of a semi-autonomous social telepresence robot research platform: a chronology. *Intelligent Service Robotics*, *7*(2), 103–119. http://doi.org/10.1007/s11370-014-0148-8

Tsui, K. M., Norton, A., Brooks, D., Yanco, H. A., & Kontak, D. (n.d.). Designing Telepresence Robot Systems for Use by People with Special Needs.

Tsui, K. M., & Yanco, H. a. (2013). Design Challenges and Guidelines for Social Interaction Using Mobile Telepresence Robots. *Reviews of Human Factors and Ergonomics*, *9*(1), 227–301. http://doi.org/10.1177/1557234X13502462

UD Virtual Compound Microscope. (2011). Retrieved June 14, 2014, from http://www.udel.edu/biology/ketcham/microscope/scope.html

Uthra, R. A., & Raja, S. V. K. (2012). QoS routing in wireless sensor networks—a survey. *ACM Computing Surveys*, *45*(1), 1–12. http://doi.org/10.1145/2379776.2379785

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: toward a unified view^, *27*(3), 425–478.

VGO. (2014). Retrieved June 5, 2014, from http://www.vgocom.com

Wang, C., Wu, H., Lee, S. W., Hwang, F., Chang, H., Wu, Y., … Lin, J. (2014). A Review of Research on Technology-Assisted School Science Laboratories, *17*, 307–320.

Wei, J., & Dolan, J. M. (2009). A multi-level collaborative driving framework for autonomous vehicles. *RO-MAN 2009 - The 18th IEEE International Symposium on Robot and Human Interactive Communication*, 40–45. http://doi.org/10.1109/ROMAN.2009.5326205

Yan, R., Tee, K. P., Chua, Y., Huang, Z., & Li, H. (2013). An Attention-Directed Robot for Social Telepresence Attention-Directed.

Yun, S.-S., Kim, M., & Choi, M.-T. (2013). Easy Interface and Control of Tele-education Robots. *International Journal of Social Robotics*, *5*(3), 335–343. http://doi.org/10.1007/s12369-013-0192-0

APPENDIX A

Questionnaire

TELEPRESENCE ROBOT ENABLED REMOTE LAB

A telepresence robot is a remote-controlled robot equipped with a camera and a screen. It permits the remote user to navigate freely within the remote environment as if the remote user was actually 'there'.

You have completed 0% of this survey

0%

100%

Survey Questions

Please give us your feedback about your experience using the Telepresence robot during a learning activity.

Please enter your ping test result

Only numbers may be entered in this field.

Answer

How old are you?
Choose one of the following answers

- 18 to 24
- 25 to 34
- 35 to 44
- 45 to 54
- 55 to 64

Please select your age group.

What is your gender?

- Female
- Male
- No answer

How competent do you feel about driving the robot within the remote lab?
Choose one of the following answers

- 1 Not at all competent
- 2
- 3
- 4
- 5 Very competent

Please enter your comment here:

The system had the functionalities I expected it to have?
Choose one of the following answers

- 1 None of the functionalities I expected
- 2 Some of the functionalities I expected
- 3 Most of the functionalities I expected
- 4 All functionalities I expected
- 5 All possible functionalities I expected

Please enter your comment here:

How easy was it to navigate the robot within the remote lab?
Choose one of the following answers

- 1 Very difficult
- 2
- 3
- 4
- 5 Very easy

Please enter your comment here:

Were you aware of your surrounding when driving the robot?
Choose one of the following answers

- 1 Not aware
- 2
- 3
- 4
- 5 Very aware

Please enter your comment here:

Was the robot easily driven within the remote lab?
Choose one of the following answers

- 1 Very difficult
- 2
- 3
- 4
- 5 Very easy

Please enter your comment here:

Do you think that the telepresence robot could improve your learning?
Choose one of the following answers

- 1 Not at all
- 2
- 3
- 4
- 5 Very much

Please enter your comment here:

Please tell us if you feel like you were actually in the lab?
Choose one of the following answers

- 1 Not at all
- 2
- 3
- 4
- 5 Very much

Please enter your comment here:

Please rate the pilot interface layout

Choose one of the following answers

- 1 Very bad
- 2
- 3
- 4
- 5 Very good

Please enter your comment here:

Please rate the video quality
Choose one of the following answers

- 1 Very bad
- 2
- 3
- 4
- 5 Very good

Please enter your comment here:

Did you feel involve with the learning materials when using the Telepresence robot?

Choose one of the following answers

- 1 Not at all
- 2
- 3
- 4
- 5 Very much

Please enter your comment here:

How easy was it to grab objects with the arm?
Choose one of the following answers

- 1 Very difficult
- 2
- 3
- 4
- 5 Very easy

Please enter your comment here:

Please rate your internet speed connection to the robot

Choose one of the following answers

- 1 Very bad
- 2
- 3
- 4
- 5 Very good

Please enter your comment here:

Do you think that the robot should move more autonomously?
Choose one of the following answers

- 1 Not at all
- 2
- 3
- 4
- 5 Very much

Please enter your comment here:

How easy was it to drive the robot via the pilot interface?

Choose one of the following answers

- 1 Very difficult
- 2
- 3
- 4
- 5 Very easy

Please enter your comment here:

Would you consider taking lab works or courses via a telepresence robot?
Choose one of the following answers

- 1 Not at all
- 2
- 3
- 4
- 5 Very much

Please enter your comment here:

Do you play video games?
Choose one of the following answers

- 1 Never
- 2 Sometime
- 3 Often
- 4 Very often
- 5 All the time

Please enter your comment here:

Have you driven a Telepresence robot before?

- Yes
- No

Please rate your overall experience while driving the robot
Choose one of the following answers

- 1 Very bad
- 2
- 3
- 4
- 5 Very good

Please enter your comment here:

Please enter any comments you might have

Answer

	Submit	Exit and clear survey ☐ Are you sure you want to clear all your responses?

APPENDIX B

Instructions

Telepresence Robot Enabled Remote Lab

Thank you for being a participant in our survey project. Below are the instructions on how to drive and use the Telepresence robot.

Requirements

To do the test drive of the Telepresence robot, you will need the following:

1) A high speed Internet connection.
2) A computer with a keyboard.
3) A computer with a webcam.
4) A computer with a microphone if you want to communicate with the lab assistant.
5) You **MUST use Google Chrome browser** to connect to the Telepresence robot.
6) Any OS will work until you use **Google Chrome** as browser.

Ping Test

First, we need you to do a simple latency test of your network. Here are the instructions for Windows OS and Mac OS.

For Windows OS please go to this URL:

https://community.shaw.ca/docs/DOC-1051#Solution1

For Mac OS please go to this URL:

https://community.shaw.ca/docs/DOC-1131#solution1

Please ping the following IP address: 68.149.149.146

Step#1

Copy this command:

ping 68.149.149.146

Step#2

Please record the first five (5) pings entries (time=xxx ms) and average them.

If an average is automatically given, please record this value instead.

Step#3

You will have the opportunity to enter this average value in the survey.

Connecting

To connect to the Telepresence robot simple copy this URL and past it in your **Google Chrome** browser:

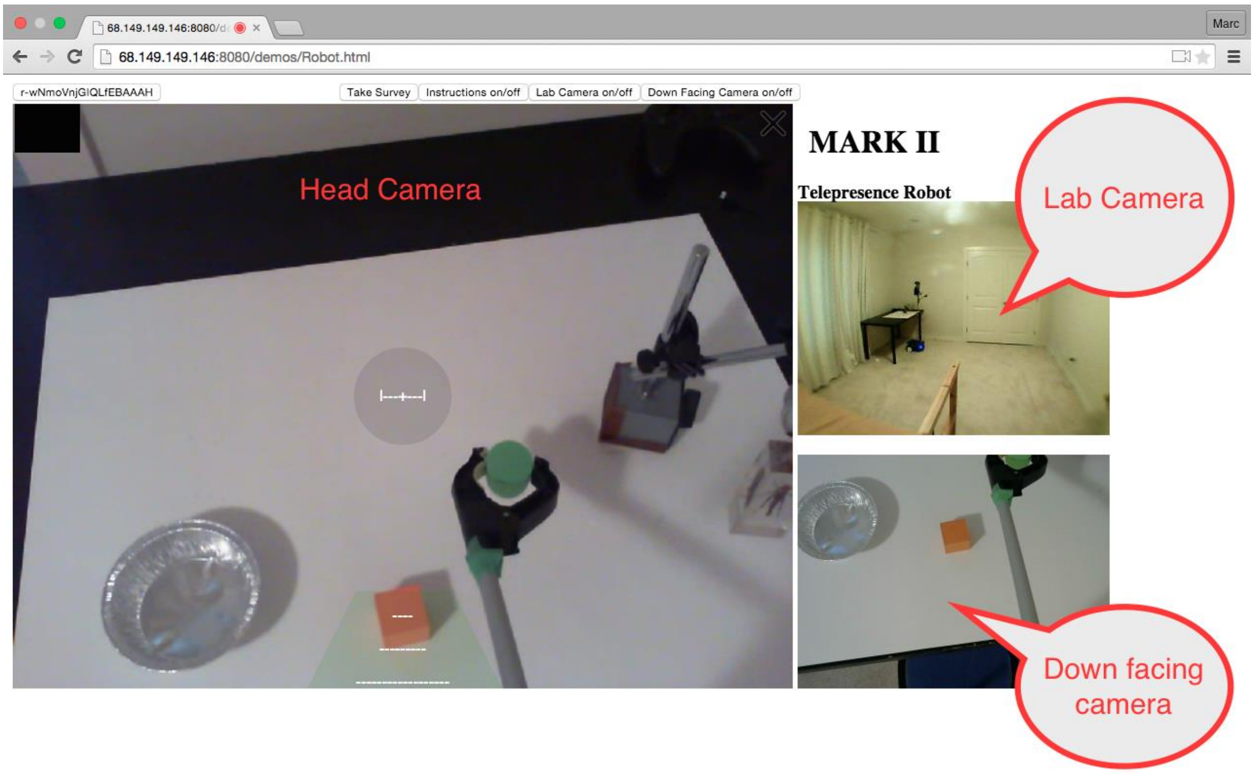
68.149.149.146:8080/demos/Robot.html

Upon connection, the pilot interface will be displayed and you will be asked to agree to share your mic and webcam. Please agree to it in order to start the session.

Pilot Interface

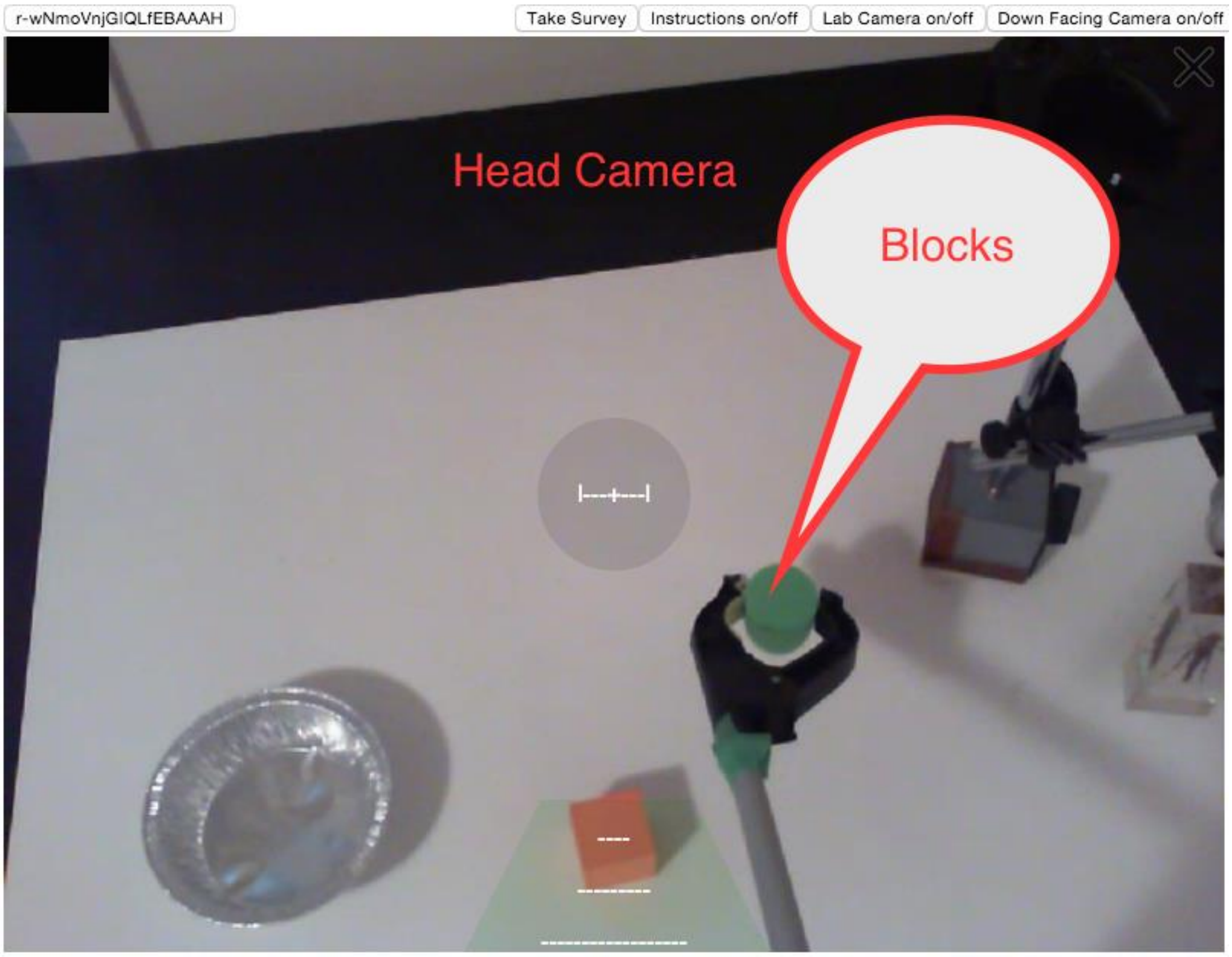
To connect to the Telepresence robot, click on the upper left corner button. The video from the robot head will be displayed and a voice will announce that you are now connected.

Click on the ‘Lab Camera’ button to display the lab camera view and click on the ‘Down Facing Camera’ button to display the down facing view.



Lab Task

As a lab task, you will have to grab these two blocks and move then into the aluminum cup.



Driving the Telepresence Robot

- The **up arrow** □ key will move the robot forward.
- The **down arrow** □key will move the robot backward.
- The **right arrow** □ will rotate the robot to the right (clockwise).
- The **left arrow** □key will rotate the robot to the left (counterclockwise).

Speed: The Telepresence robot has two speeds (slow and fast). Slow is the default speed and it is better for fine control of the Telepresence robot. In 'fast' mode, the Telepresence robot will move quickly. You can switch speed at any time by pressing the '1' or '2' keys.

- '**1**' is for slow speed
- '**2**' is for fast speed.

Controlling the Head Movements

The ‘w’, ‘a’, ‘s’, ‘z’ keys are used to move the head of the Telepresence robot.

- ‘**c**’ will center the head.
- ‘**w**’ will move the head up.
- ‘**z**’ will move the head down.
- ‘**a**’ will move the head to the left.
- ‘**s’** will move the head to the right.

Controlling the Arm and the Hand

- To move the arm down press the ‘<’ key.
- To move the arm up press the ‘>’ key.
- To open the hand: press the ‘**n**’ key.
- To close the hand: press the ‘**m**’ key.

Following the Line

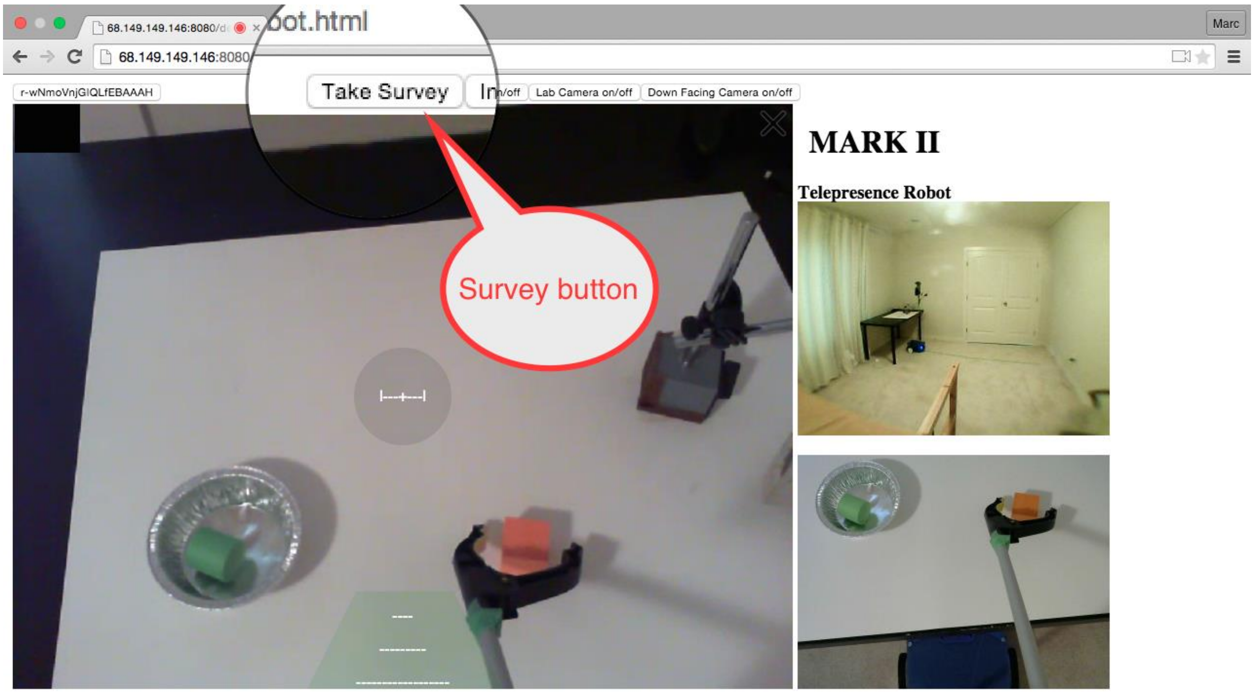
You can follow the green line to go to the lab table.

Taking the Survey

To take the survey please click on the survey button (pilot interface) or copy and paste this URL in your browser:

https://telepresencerobotsurvey.athabascau.ca/

Or you can click on the survey button from the pilot interface.



Log Out

To log out of the Telepresence robot simple close your browser.

APPENDIX C

Conference Paper

IEEE computer society

The Community for Technology Leaders

CSDL Institutions and Libraries About Resources

CSDL Home » C » CSE » 2014 » 2014 IEEE 17th International Conference on Computational Science and Engineering (CSE)

A Ubiquitous Computing Platform - Affordable Telepresence Robot Design and Applications

(Abstract)

to
ISBN:
pp: 793-798

Marc Denojean-Mairet

Qing Tan

Frederique Pivot

Mohamed Ally

DOI Bookmark: http://doi.ieeecomputersociety.org/10.1109/CSE.2014.162

ABSTRACT

Online universities are growing and they have to continuously integrate new technologies to provide remote students with ubiquitous learning. How to conduct lab work becomes a great challenge in distance education. Existing methods to deal with lab work in distance education institutions usually require students to travel to the actual university laboratory or the nearest located laboratories or be lent lab kits by the university. This is not perfect and can be costly to the universities and students. One possible novel solution would be to use telepresence robots as avatars for remote lab work. To investigate this novel application of telepresence robots, we built an affordable robot and we provide an application scenario, the affordable telepresence robot for remote lab as a case study. This paper will mainly focus on the design and applications of affordable telepresence robot that provides a ubiquitous computing platform for the remote lab solution in distance education.

A Ubiquitous Computing Platform – Affordable Telepresence Robot Design and Applications

Marc Denojean-Mairet[1], Qing Tan[1], Frederique Pivot[2], Mohamed Ally[3]
School of Computing and Information Systems[1], Centre for Science[2], Centre for Distance Education[3]
Athabasca University
Athabasca, Canada
Marc.denojean-mairet@hotmail.com, qingt@athabascau.ca, fpivot@athabascau.ca, mohameda@athabascau.ca

***bstract*—Online universities are growing and they have to continuously integrate new technologies to provide remote students with ubiquitous learning. How to conduct lab work becomes a great challenge in distance education. Existing methods to deal with lab work in distance education institutions usually require students to travel to the actual university laboratory or the nearest located laboratories or be lent lab kits by the university. This is not perfect and can be costly to the universities and students. One possible novel solution would be to use telepresence robots as avatars for remote lab work. To investigate this novel application of telepresence robots, we built an affordable robot and we provide an application scenario, the affordable telepresence robot for remote lab as a case study. This paper will mainly focus on the design and applications of affordable telepresence robot that provides a ubiquitous computing platform for the remote lab solution in distance education.**

Keywords—Telepresence Robot; Ubiquitous Computing; Remote Lab; Online Education Technology

Introduction

Online universities are growing [1]. And, they must continuously integrate new technologies to provide remote students with ubiquitous learning. Since, Information and Communications Technology (ICT) in learning and especially in distance learning is greatly advancing, online universities have access to new technologies such as remote lab and telepresence robotics to enhance their offerings. As a result, there are opportunities for research in these areas to find novel solutions that increase distance students satisfaction and lower costs for universities and students. One such research is the integration and use of telepresence robots within remote lab environments to facilitate distance learning of science courses. Interested in investigating this research, we started to look for telepresence robots. Telepresence robots are becoming more and more common in businesses, healthcare and education [2]. Some companies such as VGo, Double Robotics, Anybots, and iRobot are offering commercial Telepresence robots that can be used in these environments. These Telepresence robots are mobile robot platforms that provide two-way audio and video communication [3]. However, we quickly discovered that as good as these robots are, they would not meet our needs. The main reasons are that they are not easily upgradable and that they are expensive. For instance, QB from Anybots is a very nice telepresence robot but it can cost up to $12,359 USD with options plus $1,908 USD (SMB Connection Services) per year for up to 12 users [4]. Anybots offers a rental option that costs $675 USD per month. Although it seems to make the robot much more affordable, none of the companies that we surveyed, including Anybots, had telepresence robots easily upgradable and modified for customer's personal use.

A standard commercial telepresence robot is usually composed of a mobile robot base that has two motorized wheels and one or two trailing casters [5]. Some mobile robots bases are self-balancing bases and do not have the trailing casters [6][7]. Telepresence robot systems are also composed of a LCD display, one or two webcams, one or many microphones, a main computer board, motor control boards, and some sensors. Some telepresence robots have pan and tilt cameras that can be controlled by the pilot. Not all telepresence robots offer this feature.

As we needed a telepresence robot that would be tailored to our own research and application needs, we decided to build our own. We realized that many students, researchers, organizations might be interested in exploring telepresence robotics but that financing was an issue. So; we challenged ourselves to build our own affordable telepresence robot within a small budget of $400 Canadian dollars.

In this paper, we mainly focus on the design and applications of affordable telepresence robots. Following this section, we will describe our design of the telepresence robot. In section 3, we will present the implementation of our prototype telepresence robot and the findings from the implementation. Then we investigate possible applications of this ubiquitous computing platform and use remote lab as a case study through a online learning scenario. Finally we will concluded this paper.

Design of The Telepresence robot

Background and Requirements

Our challenge was to build a telepresence robot with common and widely affordable components that could be found practically anywhere or that could be easily ordered online at very reasonable prices. In addition, the telepresence robot needed to be easy to build, modify, and program since non-engineers would use it for research and educational purposes. As much as possible we wanted to use open-source components that would have a large community of users and few licensing restrictions. Also, these components should currently be well known to educators and used for educational purposes.

A telepresence robot is also a ubiquitous computing platform on which various computation will take place, including robot control, wireless sensors network, context-aware computing, human computer interaction, and artificial intelligence. Particularly for telepresence robot in an educational remote lab environment, the robot should have the following characteristics:

- Ability to do video conferencing
- Video display screen of 4 inches minimum
- Head video camera
- Ability to pan and tilt the head 180 degrees
- Compact base
- Be stable with a minimum of front and back rocking when moving

- Have a driving front camera for spatial awareness
- Small turning radius
- Wi-Fi communication
- Bluetooth communication
- Easy sensors integration
- Total weight of less than 5 kg
- Total height of at least 4 feet

Our robot needed to meet all these criteria but also, needed to work and perform as well as an available commercial unit. Based on all the above requirements, we built our first prototype of a 4 degrees of freedom telepresence robot with great success staying within a very reasonable price tag of less than $400 Canadian dollars. The design of the telepresence robot can be easily modified to meet different application needs. However, its mainframe, electronic circuits, control, and interface will remain the same.

The Base Design

The base is rectangular with sides of 26 cm by 37 cm. The dimensions are not critical but this size gives good stability and a small footprint to the robot. The drive train is composed of two 12 volts geared motors paired with 12.7 cm wheels (5 inches) and a rear caster wheel. As a result, the robot works like a tank and uses differential steering to turn. A simple H-bridge motor controller drives these two motors. The battery used is a 3 cells Lipo pack 11.1 volts 4000 mAh. The DC geared motors, wheels, H-bridge, and battery were all bought online from different vendors. Power regulators are used to independently power the USB hub, the servos, and the Raspberry Pi. Pictures of the base including the front camera are shown in Fig. 1.

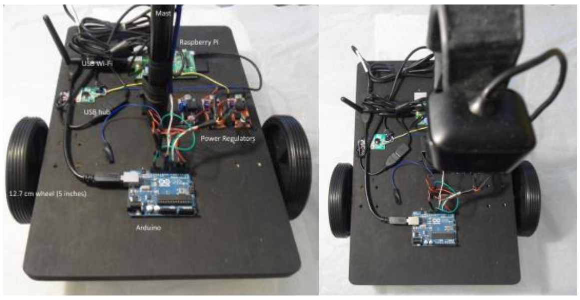


Fig. 1. Pictures of the telepresence robot base

The CPUs

For video conferencing, the robot uses a dedicated android phone/tablet. Android mobile devices offer a wide choice of screen sizes, computing power, camera resolutions, and memory sizes. For everything else, the robot uses a Raspberry Pi. The Raspberry Pi is an inexpensive credit card size computer running Linux OS [14]. This permits to program the robot with any popular programming language such as Python.

To control the motor controller, servos, and sensors, an Arduino Uno board is used. The Arduino talks to the Raspberry Pi via a serial connection. Wi-Fi is used by the Raspberry Pi to connect to the network. The front navigation camera, the Arduino, and the Wi-Fi USB dongle are all connected to the Raspberry Pi via a powered USB hub. A Bluetooth module can be added to the Raspberry Pi or the Arduino. However, Bluetooth is already available on the Android mobile device and can be used to communicate if needed.

In addition, most Android mobile devices incorporate sensor such as GPS, Magnetometer, Accelerometer, Light, Temperature, and Gyroscope that can be used by the telepresence robot with little programming.

The Head

The robot needed to be able to pan and tilt its head. Two standard hobby servos are used for this function. Each servo can move 180 degrees. The Android mobile device is attached to the pan-tilt camera mount. The pan-tilt mount was easily made of two metal straps bent in a U-shape. A picture of the head is shown in Fig. 2.

Fig. 2. A picture of the telepresence robot head

The Body

The head of the robot is mount on the top of a 4-foot tall mast. This pole can be made of metal or wood. The mast is attached to the base just behind the wheels to prevent the robot from tilting forward. As the center of gravity is kept low with most of the weight of robot on the base and the mast mounted behind the pivot point of the base, the robot is pretty stable when moving. The front navigation camera is mounted to the mast looking down at the base. This gives a good view of the base and wheels of the robot, which greatly help in spatial awareness when piloting the robot. A picture of the telepresence robot is shown in Fig. 3.

Fig. 3. A picture of the telepresence robot

The Software

A Python script is used to control the robot. The pilot can move the robot by pressing the arrow keys. Other keys are used to control the pan and tilt of the head. An Arduino script controls the motor controller and the servo. Mjpg-streamer is used to stream the front navigation video to local host port 8080. Skype is used on the Android mobile device for video conferencing and video streaming. Right now, the user needs to SSH into the robot to drive it. A better solution being implemented is to use WebSocket that is supported by most web browsers. Since, WebSocket utilizes port 80 there is no need to worry about opening ports on the user side when connecting to the telepresence robot.

The Implementation and Findings

The Primary Test of the Telepresence Robot

The prototype telepresence robot was tested in different ways. The robot was tested on a 2.5 Mbps upload speed network with less than 40 milliseconds latency with good performances. The robot was driven on the same local area network, on the Internet within city of Vancouver, between cities of Vancouver and Edmonton in Canada, and between cities of Vancouver in Canada and Paris in France. The test drives was conducted on MacBook Pro laptop computers and Windows 8 Microsoft workstation. The users' experiences are very much the same in terms of how easier to drive and how well the robot performed. A picture of a test driving the telepresence robot is shown in Fig. 4.

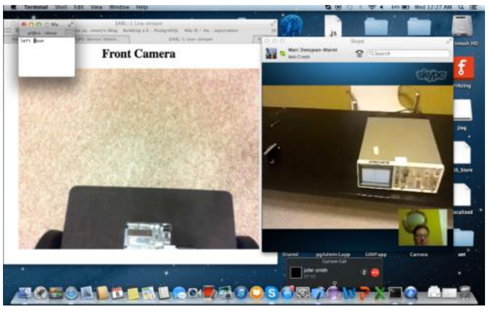


Fig. 4. A picture of a test drive of the telepresence robot

Findings

It was easier than expected to build this robot within a reasonable budget. This is due to the fact that most of the components where bought online at very reasonable prices. No attempts were done to test this robot durability but the components are of good quality and will provide good long-term resilience. Moreover, the components are cheap enough to just change them if they break.

After driving the robot for a while, we found that speed and spatial awareness is important. Slow is better than fast when it comes to speed. Driving the robot within a confined space can add to the pilot's workload and create stress for the pilot. Driving a telepresence robot is easy but at the same time, requires concentration. The best way to lower the pilot workload is to drive slow and have good spatial awareness. For spatial awareness the front navigation camera is very useful. Just seeing the front of the robot base and its wheels gives a really good sense of the robot footprint within a space and when combined with the front head camera greatly augment spatial awareness. However, sometime, the pilot can lose the sense of direction and not know in which direction the robot is actually pointing. This happen if the head camera is completely tilted down looking at the floor. At this point, the pilot does not have any reference points to tell in which direction the robot is facing. A good possible solution to this would be to have a virtual representation of the robot on the driving console displaying its direction. Also, in an unfamiliar environment, a map displaying the robot position in space in real time would help the pilot to navigate. Markers on the floor such as lines or words could also help in navigating since the pilot could just follow lines to navigate to lab stations.

The pan and tilt feature is useful when the robot is not movin and the user wants to look at an object nearby. However, the pan is not as necessary as the tilt feature. Most of the time, it is more practical and natural to just use the arrow key to look around instead of using the pan keys. The pan function can add complexity to the robot and confuses the pilot about the spatial orientation of the robot. It was noted that if the base of the robot were round instead of rectangular, the turning radius of the robot would be tighter when pivoting to look around and would give a more natural experience when looking around using the arrow keys. In this case, two caster wheels would be needed or the robot should be self-balancing.

Latency in the network is the main problem when driving a telepresence robot. If the information is not displayed quickly enough to the pilot or if the robot does not execute right away the pilot's commands, doubts about the robot position can occur. Also, the pilot can get frustrated about delays in the video feed and be distracted from the learning tasks. Having a good network upload speed and low latency can mitigate delays in video streams. The robot was tested on a 2.5 Mbps upload speed network with less than 40 milliseconds latency with good performances. Using robust video conferencing applications such as Skype can help performances as well. Since our goal was to use such a telepresence robot in a remote lab environment, we simulated a lab table with an oscilloscope and we were able to drive the robot to the table and examine the oscilloscope screen as if we were actually there.

During this test, we noted that it would be nice if we could lower the height of the telepresence robot to have the head at the same level than the oscilloscope's screen. This would have given us a better view of the screen and the impression that we would have been sitting at the table instead of just standing in front of it. Looking at electronic lab equipment on a table from a standing position does not feel very natural. The possibility of zooming in the oscilloscope screen would also be a nice feature to have.

Other interesting findings, which now appear obvious, are that lighting and color reproduction are important when using a telepresence robot. Good lighting produces sharp and clear pictures. The head camera should reproduce colors very well since correct color vision makes the experience more real and can become an issue if looking at chemicals or color-coded wires in a lab setting.

After successfully driving and using the telepresence robot remotely, we wanted to extend its ability to interact with objects within the remote lab environment for doing lab work. As a result, we added a simple two degrees of freedom arm to the robot. Now, we could grab and move objects and perform experiments remotely. The arm added only $23 to the total cost of the telepresence robot.

Applications of Telepresence Robot

Telepresence robots can be used in many different environments. Some are used in hospitals, schools, and businesses. In this section, we breifly review the existing applications, then we provide an application scenario, the affordable telepresence robot for remote lab as a case study.

Telepresence Robot Applications

In healthcare, telepresence robots are used for remotely visiting patients. According to [8] in Intensive Care Units (ICU), a study shows that the use of telepresence robots can increase response time during “off-hours”. Patients can be seen within 5 min after a request for consultation is made. Travel time to and from the hospital for the physician has been eliminated.

In schools, ill children use telepresence robots to remotely go to school and visit their peers. One such example from [9] is Kolton Kincaid a 16 year olds high school student who was paralyzed in a farm accident. He is now able to go to his school and roam the halls of Haven High School, Kansas and interact with his friends as if he was actually there. Kolton controls the robot from Denver via an iPad. A study in remote education involves the teaching of a foreign language, in this case English, using a Telepresence robot located in South Korea [10]. The lack of native English speaking teachers in South Korea was the motivation for this study. This study received positive feedbacks from the teachers.

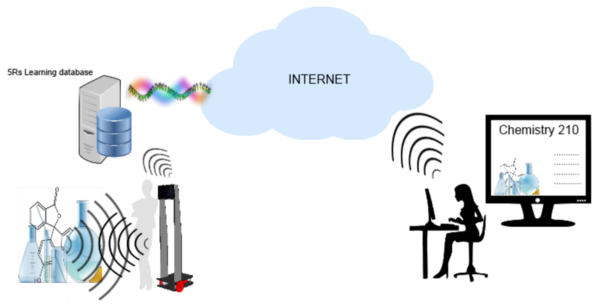
In business, telepresence robots are used to participate in meetings and meet colleagues in their offices. According to [11] telepresence robots permit remote workers to visit their local coworkers and participate in formal and informal meetings. It decreases the amount of travelling for the remote workers and reduces travelling costs for companies.

Telepresence Robot for Remote Lab

How to conduct lab work becomes a great challenge in distance education. Existing methods to deal with lab work in distance education institutions usually require students to travel to the actual university laboratory or the nearest located laboratories or be lent lab kits by the university. The solutions are not perfect, as the cost to the students and universities can be very high, the time constraints can be very tight, and the performance and evaluation of lab work can be compromised when no supervision or tracking record is present. This creates a new paradigm shift for online universities that must provide a ubiquitous learning and laboratory work experience to their students and at the same time control cost. A novel application of telepresence robot in higher education would provide a solution to this issue, which would be to use telepresence robots in remote labs indoors and outdoors for online universities. Students that cannot attend laboratory work at the university because of travel costs or other reasons could use a telepresence robot as their avatars to conduct lab works within a remote lab system.

In our educational scenario, the concept for such a system is shown in Fig. 5. A remote student needs to do lab works for the course, Chemistry 210. The student would remotely login via the Internet to the remote lab server and use a telepresence robot placed in the lab as avatar. The student would be able to move the telepresence robot within the lab and go to any lab stations to start learning. The telepresence robot would be able to interact with the lab's equipment via wireless sensors network (WSN) to control and get data from the instruments. In addition, a 5R adaptation learning management system would deliver the correct lab instruction and other learning materials to the student ensuring that the right content is provided to the right learner based on the student's learning profile, current location of the robot avatar at the lab, and device that the student uses for display [12].

Fig. 5. The Teleprersence Robot Enabled Remote Lab



For outdoor remote lab activities, an educator could bring a telepresence robot to a specific location of interest and a student could log into the telepresence robot. To be able to use the telepresence robot, only a network connection would be needed since the robot can work independently from a local server. The student would then be able to gather data from sensors mounted on the robot. For instance, environmental sensors could display temperature, light, and humidity data. A gas sensor module connected to one of the CPUs could read concentration of gases such as methane in the immediate environment of the robot. Also, students could use more sophisticated devices such as IR cameras or even ground-penetrating radars that would be on the robot. Real-time data and images from these devices would be displayed on the student's computer screen.

Remote labs and telepresence robotics can provide added flexibility to online learning by permitting remote students to do lab works at any time. Studies suggest that students view remote labs and telepresence robots positively. According to [8], "remote access laboratories (RAL) activities can have a great impact on student learning. However, it is important that the activities are well embedded within the other learning materials."

Other important application in education is to use the telepresence robot to enable the disable students to remotely be present in classroom, participate in class activities, and join fieldtrips. A disable student just needs to logging in the telepresence robot, then the student can experience the learning activities in real-time through the robot avatar.

Telepresence Robot's Arm Experiment

After installing the arm to the robot, we were able to conduct a very simple experiment. We decided to do a chemical reaction by using sodium bicarbonate and acetic acid. We set up a lab table with an open glass container full of acetic acid at one end and a small paper pack full of sodium bicarbonate at the other end of the table. Remotely, using the telepresence robot, we picked up the small paper bag full of sodium bicarbonate and dropped it into the jar containing the acetic acid. Within seconds, we were able to observe the chemical reaction between these two chemicals. We clearly saw the bubbles of carbon dioxide forming at the surface of the liquid. This experiment demonstrated that it was possible to do chemistry work remotely with a telepresence robot. The experiment is shown in Fig. 6 and the arm is shown in Fig. 7.

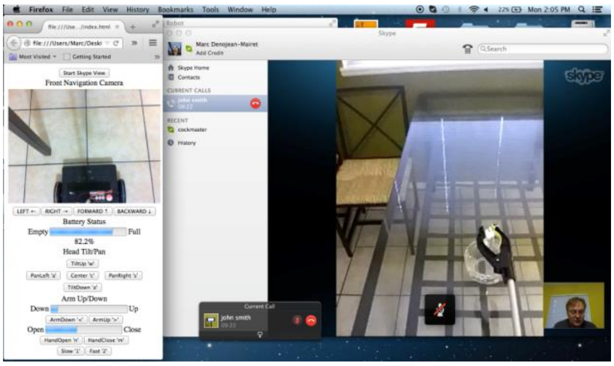


Fig. 6. Experiment

Fig. 7. Arm

Conclusions

We were able to build our telepresence robot prototype within our assigned budget. The robot performs well and is easy to drive. The addition of the two degrees of freedom arm permitted us to do actual lab work remotely as if we were actually at the lab doing the work. The flexible design concept permits us to try different configurations of the robot as needed. Of course, the robot can be improved on what already has been done. We believe that telepresence robots will have a place in distance education and particularly in remote lab environments. Our affordable telepresence robot for remote lab case study demonstrates the possible applications of telepresence robots in remote labs and their integration within an adaptation learning system.

References

[1] S. K. Stein, “Lessons Learned Building the Online History Program at the University of Memphis,” *Hist. Teacher*, vol. 47, no. 3, pp. 373–386, 2014.

[2] M. Fumihide, T., Toshimitsu, T., Shizuko, M., Nao, T., and Masahiko, “Telepresence Robot Helps Children in Communicating with Teachers who Speak a Different Language,” in ACM/IEEE International Conference On Human-Robot Interaction, 2014, pp. 399–407.

[3] M. Desai, K.M. Tsui, H.A.Yanco, and C. Uhlik, "Essential features of telepresence robots", *2011 IEEE Conference on Technologies for Practical Robot Applications*, pp. 15–20.

[4] “Anybots,” 2014. [Online]. Available: www.anybots.com. [Accessed: 05-Jun-2014].

[5] Giraff. 2014 *Giraff*. Retrieved June 05, 2014, from http://www.giraff.org

[6] Anybots. Retrieved June 05, 2014, from www.anybots.com

[7] Double Robotics, *Inc. Retrieved June 05, 2014, from http://www.doublerobotics.com/*

[8] J. B. Petelin, M. E. Nelson, and J. Goodman, “Deployment and early experience with remote-presence patient care in a community hospital.,” *Surg. Endosc.*, vol. 21, no. 1, pp. 53–6, Jan. 2007.

[9] “Double Robotics,” *Double Robotics, Inc.*, 2014. [Online]. Available: http://www.doublerobotics.com/. [Accessed: 05-Jun-2014].

[10] O. Kwon, S. Koo, Y. Kim, and D. Kwon, “Telepresence robot system for English tutoring,” *2010 IEEE Work. Adv. Robot. its Soc. Impacts*, pp. 152–155, Oct. 2010.

[11] A. Kristoffersson, S. Coradeschi, and A. Loutfi, “A review of mobile robotic telepresence,” *Adv. Human-Computer Interact.*, vol. 2013, 2013.

[12] Q. Tan, X. Zhang, and R. Mcgreal, “The 5R Adaptation Framework for Location-Based Mobile Learning Systems,” in *10th World Conference on Mobile and*

Contextual Learning, 2011, pp. 18–21.

[13] A. a. Kist, P. Gibbings, A. D. Maxwell, and H. Jolly, “Supporting Remote Laboratory Activities at an Institutional Level,” *Int. J. Online Eng.*, vol. 9, no. S5, p. 38, May 2013.

[14] “Raspberry Pi Foundation.” [Online]. Available: www.raspberrypi.org. [Accessed: 05-Jun-2014].

APPENDIX D

Survey Ethic Approval

General Info

FileNo: 21699

Title: TELEPRESENCE ROBOT ENABLED REMOTE LAB IN DISTANCE EDUCATION (Thesis)

Start Date: 09/03/2015

End Date: 31/08/2015

Keywords:

Project Members

Principal Investigator

Prefix: Mr.

Last Name: Denojean-Mairet

First Name: Marc

Affiliation: Faculty of Science & Technology\School of Computing & Information Systems

Rank: Graduate Student

Gender: Male

Email: marc.denojeanmairet@gmail.com

Phone1: (780) 802-7642

Phone2:

Fax:

Mailing Address: 1268 Rutherford Rd Edmonton, AB T6W 1H7

Institution: Athabasca University

Country: Canada

Comments:

Others

Rank	Last Name	First Name	Affiliation	Role In Project
Associate Professor	Tan	Qing	Faculty of Science & Technology\School of Computing & Information Systems	Supervisor

Common Questions

1. 1. Project Description

#	Question	Answer
1.1	Provide a clear statement of the purpose and objectives of the project.	This research will help in determining if a telepresence robot can be used in a remote lab environment. The survey will help in understanding the usability of such a system and what new study areas need to be further investigated.
1.2	Comment on the significance of this research project in light of the existing body of knowledge.	No significant research have been done on telepresence robot enabled remote lab. This research has the potential to advance the available knowledge on this topic.
1.3	Describe how research results will be disseminated.	Final research report to be provided to AU|Article(s) to be submitted to academic and professional journals|Presentation(s) at academic/professional conferences
1.4	If 'other', please explain.	
1.5	State the research question(s) and/or any associated hypothesis or proposition.	1. Can an affordable telepresence robot for remote lab work research be built within a small budget? 2. What could be the system architecture of a telepresence robot system for lab work? 3. Is the validity of the research study correct?

1.6	Provide a brief summary of the mode of inquiry for the research. Note the research design/methods and the procedures to be followed.	This ethics application is a part of my MScIS thesis research. It is to validate the design and development of the telepresence robot. The telepresence robot will be placed in a mock up lab, and I will invite up to 40 participants to drive the telepresence robot to complete tasks in the mock up lab. Then the participants will answer a questionnaires. Then I will process and analyze the questionnaires, eventually disseminate the research results through my MScIS thesis and other publications.
1.7	List of references cited and sources for all quotes in this application is appended.	Yes

2. 2. Data Collection

#	Question	Answer
2.1	Will the researcher or project team be able to identify any of the participants at any stage of the project?	Yes
2.2	Will participants be recruited or their data be collected from Alberta Health Services or Covenant Health or a data custodian as defined in the Alberta Health Information Act?	No
2.3	The primary/raw data collected will (check all that apply):	Be anonymous - the information NEVER had identifiers associated with it (eg anonymous surveys) and risk of identification of individuals is low or very low
2.4	If this project involves secondary use of data, list all original	N/A

	sources. If not, please enter N/A.	
2.5	In research where total anonymity and confidentiality is sought but cannot be guaranteed (e.g., where participants talk in a group) how will confidentiality be achieved? If not applicable, please enter N/A.	N/A

3. 3. Data Identifiers

#	Question	Answer
3.1	Personal Identifiers: Will you be collecting - at any time during the project, including recruitment - any of the following (check all that apply):	Email Address
3.2	If other, please describe.	
3.3	Will you be collecting - at any time of the project, including recruitment of participants - any of the following (check all that apply):	None
3.4	If other, please describe.	
3.5	If you are collecting any of the above, provide a comprehensive rationale to explain why it is necessary to collect this information. If you are not, please enter N/A.	N/A
3.6	If identifying information will be removed at some point, when and how will this be done? If this is not applicable, please enter N/A.	N/A
3.7	Specify what identifiable information will be RETAINED once data collection is complete, and explain why retention is necessary. Include the retention of	N/A

	master lists that link participant identifiers with de-identified data.	
3.8	Describe your plans to link the data in this project with data associated with other studies (e.g., within a data repository) or with data belonging to another organization. If not applicable, please enter N/A.	N/A

4. 4. Data Confidentiality and Privacy

#	Question	Answer
4.1	How will confidentiality of the data be maintained? Describe how the identity of participants will be protected both during and after research.	A web form with the survey questions will be hosted on an AU server. The link to the web form will be provided to the participants. The survey should not take more than 10 to 15 minutes to complete. The survey is anonymous and no personal information is collected.
4.2	How will the principal investigator ensure that all project personnel are aware of their responsibilities concerning participants' privacy and the confidentiality of their information?	The principal investigator and his supervisor are the only persons involved in this project.
4.3	Will identifiable data be transferred or made available to persons or agencies outside the research team?	No
4.4	If YES, describe in detail what identifiable information will be released, to whom, why they need access, and under what conditions. What safeguards will be used to protect the identity of participants and the privacy of their data? If NO, please enter N/A.	N/A

4.5	Provide details if identifiable data will be leaving the institution, province, or country (eg. member of research team is located in another institution or country, etc.). If not applicable, please enter N/A	N/A

5. 5. Data Storage, Retention and Disposal

#	Question	Answer
5.1	Describe how research data will be stored (e.g., digital files, hard copies, audio recordings, other). Specify the physical location and how it will be secured to protect confidentiality and privacy. (For example, study documents will be kept in a locked filing cabinet and computer files will be encrypted, etc.). If not applicable, please enter N/A.	All the data will be kept on a AU server. The server is password protected and only me will be able to access the data.
5.2	University policy requires that you keep your data for a minimum of 5 years following completion of the project but there is no limit on data retention. Specify any plans for future use of the data. If the data will become part of a data repository or if this project involves the creation of a research database or registry for future research use, please provide details. If not applicable, please enter N/A	N/A
5.3	If you plan to destroy your data, describe when and how this will be done. Indicate your plans for the destruction of the identifiers at the earliest opportunity consistent with the conduct of the research. If	N/A

	not applicable, please enter N/A.	

6. 6. Participant Information

#	Question	Answer
6.1	Who are you studying? Describe the population that will be included in this project.	AU community This is a voluntary participation and we cannot specify who or which group will take the survey. We will ask GSF and GS association to help us reach a wider range of people.
6.2	Describe the inclusion criteria for participants (e.g., age range, health status, gender, etc.). Justify the inclusion criteria (e.g. safety, uniformity, research methodology, statistical requirement, etc.).	Age is between 18 to 64 year old. This is appropriate for this type of study. We don't need younger or old people for this study. Both genders are needed to represent the online university students.
6.3	Describe and justify the exclusion criteria for participants.	N/A
6.4	Will you be interacting with human participants, (i.e., will there be direct contact with human participants, for this study)? Note: NO means there will be no direct contact with participants, chart reviews, secondary data, interaction, etc.	No
6.5	How many participants do you hope to recruit (including controls, if applicable)?	Around 40 people maximum.
6.6	Of these recruits, how many are controls? (Possible answer: None, Half, Random, Unknown, or an estimate in numbers, etc.)	N/A
6.7	If this is a multi-site project, how many participants (including controls, if applicable) are expected to be enrolled by all	N/A

	investigators at all sites in the entire project? If not applicable, please enter N/A.	
6.8	Provide a justification of sample size.	For our survey, a sample size of 40 is enough to make statistical inferences about our project.
6.9	Does the research specifically target aboriginal groups or communities?	No

7. 7. Recruitment

#	Question	Answer
7.1	Describe how you will identify potential participants (please be specific as to how you will find potentially eligible participants).	My supervisor and I will invite participants within AU community; The participants might be fellow students or fellow colleagues.
7.2	Once you have identified a list of potentially eligible participants, indicate how the potential participants' names will be passed on to the researchers (if applicable) AND how the potential participants will be approached about the research.	An email will be sent to the participants.
7.3	How will people obtain details about the research in order to make a decision about participating? Select all that apply:	Potential participants will contact researcher(s)|Researcher(s) will contact potential participants
7.4	Provide the locations where recruitment will occur (e.g., schools, shopping malls, clinics, etc.).	AU Community
7.5	Will potential participants be recruited through pre-existing relationships with researchers (e.g., Will an instructor recruit students from his/her classes, or a	Yes

	physician recruit patients from his/her practice? Other examples may be employees, acquaintances, own children or family members, etc.)?	
7.6	If YES, identify the relationship between the researchers and participants that could compromise the freedom to decline participation (e.g. professor-student). How will you ensure that there is no undue pressure on the potential participants to agree to the study? If NO, please enter N/A.	Participation will be voluntary. I have no influence over them.
7.7	Outline any other means by which participants could be identified, should additional participants be needed (e.g., response to advertising such as flyers, posters, ads in newspapers, websites, email, listserves; pre-existing records or existing registries; physician or community organization referrals; longitudinal study, etc.).	N/A

8. 8. Informed Consent Determination

#	Question	Answer
8.1	Describe who will provide informed consent for this project. Select all that apply. Additional information on the informed consent process is available at: http://www.pre.ethics.gc.ca/eng/policy-politique/initiatives/tcps2-eptc2/chapter3-chapitre3/#toc03-intro	All participants have capacity to give free and informed consent
8.2	If applicable, provide justification for requesting a Waiver of Consent (Minimal risk only, additional	N/A

	guidance available at: http://www.pre.ethics.gc.ca/eng/policy-politique/initiatives/tcps2-eptc2/chapter3-chapitre3/#toc03-1b). If not applicable, please enter N/A.	
8.3	How is participant consent to be indicated and documented? Select all that apply:	Implied by overt action (i.e. completion of questionnaire)
8.4	Except for "Signed consent form" use only, explain how the project information will be communicated and participant consent will be documented. Provide details for EACH of the options selected above.	The project information will be communicated by email.
8.5	Authorized Representative, Third Party Consent, Assent: Explain why participants lack capacity to give informed consent (e.g., age, mental or physical condition, etc.). If not applicable, please enter N/A.	N/A
8.6	Will participants who lack capacity to give full informed consent be asked to give assent?	No
8.7	Provide details. If applicable, attach a copy of assent form(s) in the Attachments Tab. If not applicable, please enter N/A.	N/A
8.8	In cases where participants (re)gain capacity to give informed consent during the project, how will they be asked to provide consent on their own behalf? If not applicable, please enter N/A.	N/A
8.9	What assistance will be provided to participants, or those consenting on their behalf, who have special needs (e.g., non-English speakers, visually	N/A

	impaired, etc.)?	
8.10	If at any time a participant wishes to withdraw, end, or modify their participation in the research or certain aspects of the research, describe how their participation will be ended or changed.	Simply by choosing not to answer the survey questions.
8.11	Describe the circumstances and limitations of data withdrawal from the study, including the last point at which it can be done.	This can be done at anytime before clicking the 'submit' button on the survey form.
8.12	Will this project involve any group(s) where non-participants are present? For example, classroom research might involve groups that include participants and non-participants.	No

9. 9. Group Research Dissemination

#	Question	Answer
9.1	How will you ensure that non-participants are not included in the project? How will you ensure that data from non-participants are not used in the project?	Only participants that choose to answer the survey questions are included in the project.
9.2	During the recruitment process, how will you guard against peer pressure influencing an individual's decision to participate or not?	The participation is voluntary.
9.3	How will you provide appropriate activities for non-participants?	N/A

10. 10. Risk Assessment and Benefit Analysis

#	Question	Answer
10.1	Provide your assessment of the risks that may be associated with	Minimal Risk - research in which the probability and magnitude of possible harms implied by participation is no

	this research.	greater than those encountered by participants in those aspects of their everyday life that relate to the research (TCPS2)
10.2	Provide a description of potential physical risks and discomforts.	- The physical risks will NOT be greater than those encountered by the participants in everyday life
10.3	Provide details of the risks and discomforts associated with the research, for instance, health, cognitive or emotional factors, socio-economic status or physiological or health conditions. If there are none, please state.	None
10.4	Describe how you will manage and minimize risks and discomforts, as well as mitigate.	N/A
10.5	If your project has the potential to identify individuals that are upset, distressed, or disturbed, or individuals warranting medical attention, describe the arrangements made to try to assist these individuals. Explain if no arrangements have been made.	N/A
10.6	Other, please list and describe.	N/A
10.7	Describe any potential benefits of the proposed research to the participants. If there are no benefits, state this explicitly.	No benefits
10.8	Describe the scientific and/or scholarly benefits of the proposed research.	No significant research has been done on telepresence robot enabled remote labs. This research has the potential to advance the available knowledge on this topic
10.9	Benefits/Risks Analysis: Describe the relationship of benefits to risk	The risks are extremely low.

	of participation in the research.	

11. 11. Interviews, Focus Groups, Surveys and Question ...

#	Question	Answer
11.1	Are any of the questions potentially of a sensitive nature? If yes, please enter details below. If no, please enter N/A.	N/A
11.2	If any data were released, could it reasonably place participants at risk of criminal or civil law suits? If yes, provide justification for including such information in the project. If no, please enter N/A.	N/A
11.3	Will you be using audio/video recording equipment and/or other capture of sound or images for the project? If yes, provide details. If no, please enter N/A.	N/A
11.4	Internet-based research: Will your interaction with humans occur in private spaces (e.g., members only chat rooms, social networking sites, email discussions, etc.)?	Not applicable
11.5	Will these interactions occur in public space(s) where you will post questions initiating and/or maintaining interaction with participants?	Not applicable
11.6	Describe how permission to use the site(s) will be obtained. If not applicable, please enter N/A.	N/A
11.7	If you are using a third party research tool, website survey software, transaction log tools, screen capturing software, or masked survey sites, how will you	N/A

	ensure the security of data gathered at that site? If not applicable, please enter N/A.	
11.8	If you do not plan to identify yourself and your position as a researcher to the participants from the onset of the research project, explain why you are not doing so, at what point you will disclose that you are a researcher, provide details of debriefing procedures, if any, and if participants will be given a way to opt out. If not applicable, please enter N/A.	N/A
11.9	How will you protect the privacy and confidentiality of participants who may be identified by email addresses, IP addresses, and/or other identifying information that may be captured by the system during your interactions with these participants? If not applicable, please enter N/A.	Any data collected will be destroy.

12. 12. Use of Deception or Partial Disclosure

#	**Question**		**Answer**
12.1	Describe the information that will be withheld from, or the misinformation that will be provided to, the participants. If not applicable, please enter N/A.		N/A
12.2	Provide rationale for withholding information.		N/A
12.3	Indicate how and when participants will be informed of the		N/A

	concealment and/or deception. Describe the plans for debriefing the participants. Indicate when the participants will be debriefed, and describe the nature and extent of debriefing		

13. 13. Conflict of Interest

#	Question	Answer
13.1	Have you read the "Conflict of Interest in Research Policy" and related Procedures found in the Research section of the policy manual? Available at http://ous.athabascau.ca/policy/humanresources/150_002.htm	Yes
13.2	How will you ensure that all research team members will be apprised of the above-noted policy and procedures?	If a conflict of interest is identified before or during the research, the activity raising this conflict will be stopped immediately.

14. 14. Study Objectives and Design

#	Question	Answer
14.1	Provide a lay summary of your proposed research suitable for the general public (restricted to 300 words).	How to conduct lab work becomes a great challenge in distance education. This creates a new paradigm shift for online universities that must provide a ubiquitous learning and laboratory work experience to their students and at the same time control cost. A novel application of telepresence robots in distance education would be to use

		telepresence robots for lab work indoors and outdoors. A very interesting use of such a telepresence robot system would be for disabled students who cannot attend lab courses. They could log on to their "avatars" and experience the lab environment as if they were there physically. The main advantage of using telepresence robots for lab work is the feeling of "being there" experienced by the remote user. The main disadvantage of using telepresence robots is that they are expensive and not easily adaptable to laboratory environments. Out of this study, three questions emerge. The first question is can an affordable telepresence robot for lab work research be built? The second question is what could be the system architecture of a telepresence robot system for lab work? The third and final question is the validity of the research correct? As a result, three research objectives are described in this thesis proposal. To answer these research questions, qualitative and quantitative research methodology will be used.
14.2	Provide a description of your research proposal including project objectives, background, scope, methods, procedures, etc. (restricted to 1000 words). Footnotes and references must be uploaded in the Attachments Tab.	This ethics application is a part of my MScIS thesis research. It is to validate the design and development of the telepresence robot. The telepresence robot will be placed in a mock up lab, and I will invite up to 40 participants to drive the telepresence robot to complete tasks in the mock up lab. Then the participants will answer a questionnaires. Then I will process and analyze the questionnaires, eventually disseminate the research results

		through my MScIS thesis and other publications.
14.3	Describe procedures, treatment, or activities that are above or in addition to standard practices in this project area (e.g., health-related procedures, curriculum enhancements, extra follow-up, etc.).	N/A
14.4	If the proposed research is above minimal risk and is not funded via a competitive peer review grant or industry-sponsored clinical trial, the REB will require evidence of scientific review. Provide information about the review process and its results if appropriate. If not applicable, please enter N/A.	N/A
14.5	If applicable, please append the body of literature, along with references.	Not applicable

15. 15. Research Methods and Procedures

#	Question	Answer
15.1	Some research methods prompt specific ethical issues. The methods listed below have additional questions associated with them in this application. This project will involve the following: Select all that Apply.	Surveys and Questionnaires (including internet surveys)
15.2	If other, describe.	N/A
15.3	Is this project a Clinical trial? (i.e., any investigation involving participants that evaluates the effects of one or more health-related interventions on health	No

	outcomes)?	
15.4	If you are using any tests in this project diagnostically, indicate the member(s) of the project team who will administer the measures/instruments. If not, please enter N/A.	N/A
15.5	If any test results could be interpreted diagnostically, how will these be reported back to the participants? If not applicable, please enter N/A.	N/A

16. 16. Research Locations and Other Approval

#	Question	Answer
16.1	List the locations of the proposed research, including recruitment activities. Provide name of institution or organization, town, or province as applicable	AU Community
16.2	Are you using AU Resources? If yes, please list below. If no, please enter N/A.	Server

17. 17. Multi-Institution Review

#	Question	Answer
17.1	Has this project already received approval from another REB (or equivalent)?	No
17.2	If yes, please list the institution and attach the approval memo in the Attachments Tab. If not applicable, please enter N/A.	N/A

18. 18. Funding

#	Question	Answer

18.1	Will some organization or person other than the researcher be providing cash funding or in-kind support to this research project?	Yes
18.2	If funding approved, specify source(s).	AU
18.3	If funding pending, specify source(s).	
18.4	Describe any expectations, expressed or implicit, that arise from the funder-researcher relationship.	Final report on the research will be due to GSRF. I was awarded $1,000 from the Critical Research Fund (GSMCRF)for this research project to build the telepresence robot.

19. 19. Reimbursements and Incentives

#	Question	Answer
19.1	If you are providing expense reimbursements, describe in detail the expenses for which participants will be reimbursed, the value of the reimbursements and the process (e.g. participants will receive a cash reimbursement for parking, at the rate of $x per visit for up to # of visits for a total value of $x). If not applicable, please enter N/A.	N/A
19.2	If you will be collecting personal information to reimburse or pay participants, describe the information to be collected and how privacy will be maintained. If not applicable, please enter N/A.	N/A
19.3	Will participants receive any incentives for participating in this research? Select all that apply:	No
19.4	Provide details of the value,	N/A

	including the likelihood (odds) of winning for prize draws and lotteries. If not applicable, please enter N/A.	
19.5	Excluding prize draws, what is the maximum value of the incentives offered to an individual throughout the research?	$0
19.6	If incentives are offered to participants, they should not be so large or attractive as to constitute coercion. Justify the value of the incentives you are offering relative to your study population. If not applicable, please enter N/A.	N/A

20. 20. Aboriginal Peoples

#	Question	Answer
20.1	If your research involves aboriginal peoples, please complete this section. If your research does not involve aboriginal peoples, move on to the next tab.	No, my research does not involve aboriginal peoples
20.2	If you will be obtaining consent from Elders, leaders, or other community representatives, provide details. If not applicable, please enter N/A.	N/A
20.3	If leaders of the group will be involved in the identification of potential participants, provide details. If not applicable, please enter N/A.	N/A
20.4	Provide details if: • property or private information belonging to the group as a whole is studied or used; • the research is designed to	N/A

	analyze or describe characteristics of the group, or • individuals are selected to speak on behalf of, or otherwise represent the group. If not applicable, please enter N/A.	
20.5	Provide information regarding consent, agreements regarding access, ownership and sharing of research data with communities.	N/A
20.6	Provide information about how final results of the study will be shared with the participating community (e.g., via band office, special presentation, deposit in community school, etc). If not applicable, please enter N/A.	N/A
20.7	Is there a research agreement with the community?	Not applicable
20.8	Provide details about the agreement or why an agreement is not in place, not required, etc. If not applicable, please enter N/A.	N/A

21. 21. Sound or Image

#	Question	Answer
21.1	If your research involves sound or images, please complete this section. If your research does not involve sound or images, please move on to the next tab.	No, my research does not involve sound or images
21.2	Explain if consent obtained at the beginning of the project will be sufficient to cover the use of sound or image data collected during the course of the project, or if it will be necessary to obtain consent at different times, for different stages of the project, or for different	

	types of data. If not applicable, please enter N/A.	
21.3	At what stage, if any, can a participant withdraw his/her material? If not applicable, please enter N/A.	
21.4	If you or your participants' audio- or video-records, photographs, or other materials artistically represent participants or others, what steps will you take to protect the dignity of those that may be represented or identified?	
21.5	Who will have access to this data? For example, in cases where you will be sharing sounds, images, or materials for verification or feedback, what steps will you take to protect the dignity of those who may be represented or identified?	
21.6	When publicly reporting data or disseminating results of your project (e.g., presentation, reports, articles, books, curriculum material, performances, etc) that include the sounds, images, or materials you have collected by participants, what steps will you take to protect the dignity of those who may be represented or identified?	
21.7	What opportunities are provided to participants to choose to be identified as the author/creator of the materials created in situations where it makes sense to do so?	
21.8	If necessary, what arrangements will you make to return original	

	materials to participants?	

22. 22. Registries and Databases (including Biobanks)

#	Question	Answer
22.1	If your research involves registries and databases, please complete this section. If your research does not involve registries and databases please move on to the next tab.	No, my research does not involve registries and databases
22.2	Where will the databases be located? Specify if the database will be under Canadian or foreign jurisdiction. Note that data housed on US servers fall under the US Patriot Act. At a minimum, participants should be informed of this potential breach in confidentiality.	
22.3	Who will have access to the databases? How is that access determined?	
22.4	Specify if the biobank(s) will be located under Canadian or foreign jurisdiction	
22.5	If other, please provide details:	
22.6	Will identifying information be stored within the database?	
22.7	Will identifying information be forwarded to non-local registries?	
22.8	If the database is to be maintained locally, what steps have been taken to ensure the privacy and security of the database are upheld?	

22.9	Who is responsible for the database?	
22.10	Please explain standard operating procedures for the database management, use and access. Please append any documentation in the Attachments Tab.	

23. 23. Hazard Safety

#	Question	Answer
23.1	Does the proposed research involve biohazards? If yes, consult the Public Health Agency of Canada Laboratory Biosafety Guidelines and contact the Research Ethics Office at rebsec@athabascau.ca.	No
23.2	Does the proposed research involve radiation? If yes, please contact the Research Ethics Office at rebsec@athabascau.ca.	No

24. 24. Clinical Trials

#	Question	Answer
24.1	If your research involves Clinical Trials, please complete the questions in this section. If your research does not involve Clinical Trials, please move on to the next tab.	No, my research does not involve clinical trials
24.2	Protocol number if applicable. If not applicable, please enter N/A	
24.3	Protocol Date if applicable. If not applicable, please enter N/A	
24.4	Clinical trials must be registered before participant recruitment can begin. Provide registry and	

	registration number (e.g., clinicaltrials.gov) if applicable. If not applicable, please enter N/A.	
24.5	Is this an investigator-initiated clinical trial?	
24.6	Does the project involve any of the following?	
24.7	If other, please describe.	
24.8	Trial Phase: Check all that apply.	
24.9	If applicable, describe the provisions made to break the code of a double-blind study in an emergency situation, and indicate who has the code. If not applicable, please enter N/A.	
24.10	If applicable, provide justification for using placebo or no-treatment arm. If not applicable, please enter N/A.	
24.11	If applicable, describe the clinical criteria for withdrawing an individual participant from the project due to safety or toxicity concerns. If not applicable, please enter N/A.	

25. 25. Data Safety and Monitoring for Clinical Trials

#	Question	Answer
25.1	If your research involves clinical trials, please complete this section. If your research does not involve clinical trials, please move on to the next tab.	No, my research does not involve clinical trials
25.2	Check the one that most accurately reflects the plan for data safety and	

	monitoring for this project:	
25.3	Describe data monitoring procedures while research is going on. Include details of planned interim analysis, Data Safety Monitoring Board, or other monitoring systems. If not applicable, please enter N/A.	
25.4	Summarize any pre-specified criteria for stopping or changing the project protocol due to safety concerns. If not applicable, please enter N/A.	

26. 26. Health and Biological Specimen Collection

#	Question	Answer
26.1	If your research involves health and biological specimen collection, please complete this section. If your research does not involve health and biological specimen collection, please move on to the next tab.	No, my research does not involve health and biological specimen collection
26.2	Indicate health or biological specimen(s) that will be collected (for example, body tissues or fluids, be specific). If none, please enter N/A.	
26.3	This project will involve the following (select all that apply):	
26.4	If other, please provide details:	
26.5	Explain how the specimen will be collected. If not applicable, please enter N/A	
26.6	Explain how the specimen will be stored and how long the specimens will be stored and where the	

	specimen will be stored. If not applicable, please enter N/A.	
26.7	Specify all intended uses of collected specimen(s). If not applicable, please enter N/A.	

27. 27. Checklist

#	Question	Answer
27.1	In the Attachments Tab, please ensure that you have appended all of the applicable documents. Ensure your supervisor has been added as a project team member (in the Project Team Info tab) and has reviewed and approved your application prior to 'Submitting' the application.	All Recruitment Materials|Letter of Initial Contact|Questionnaires, Cover Letters, Surveys, Tests, Interview Scripts etc
27.2	If other, please list:	N/A

28. 28. MANDATORY: SUPERVISOR'S SUPPORT

#	Question	Answer
28.1	Supervisor's Acknowledgement of Support for Ethics Application/Project (please indicate your support in the text box)	A research aims at using telepresence robots to enable online students to conduct their laboratory tasks remotely. Students could remotely engage with the telepresence robots placed in the lab through the Internet. The associated telepresence robots will become the avatars of the students. Students will be able to remotely present themselves within the lab through their avatars. The telepresence robots will be equipped with sensors to be integrated into the wireless sensor network of the remote laboratories. The online students will be able to interact with their lab works by connecting to the wireless-sensor-networked lab environment.

		The research has developed an affordable telepresence robot that is going to use as the ubiquitous computing platform for a mock-up remote lab. LAter on, Marc will focus on studying the research issues through running the telepresence robot and collecting feedback of users. Therefore the user survey is necessary and important for Marc to continue the research.
28.2	NOTE FOR SUPERVISOR: Please advise your student once you have indicated your support for the ethics application so that the student may proceed to SUBMIT the application for review.	

Attachments

Description	**File Name**	**Version Date**
Survey questionnaire HTML format.	surveyPage (2).html	09/02/2015
Consent form	consent.txt	12/02/2015
Volunteer Request Email	Email.txt	12/02/2015
References	References.txt	12/02/2015
email recruitment letter	Volunteer Request Email.docx	26/02/2015
revised consent form	Informed Consent.docx	26/02/2015
email response to request for clarifications from VPA	response to VPA request for clarifications feb 26_15.pdf	25/02/2015

APPENDIX E

Software List

HTML:

- Index.html
- Robot.html

JavaScript:

- myLogic.js
- robotServer.js
- Node.js

Other:

- Socket.io
- MPG-Streamer
- Johnny-Five
- Motion
- EasyRTC
- webRTC
- rfc5766-turn-server