Mixed Reality Human-Robot Interaction for Reduction of Workplace Repetitive Strain Injury

ECSE498 - Honors Thesis 1

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Abstract

This research is focused on leveraging technology to reduce the risk of repetitive strain injury, specifically in the labor force with workers who directly interact with power tools on a day-to-day basis. Repetitive strain injury is a debilitating condition caused mainly through repeated actions for long periods of time. This condition can cause severe pain and impede body movements. The thesis explores the risks that repetitive strain injuries pose and its impact on the labor force from health to financial, and seeks to address this issue through a solution using technology. The thesis discusses the implementation of an augmented reality solution that allows the users of power tools to be separated from the tool through robotic mediation, as well as training users through an interactive interface. Currently, "the augmented reality display of the power tool onto a replica tool in the user's hands" component of this project has been completed. The user is able to receive visual feedback from the virtual display through the various motions associated with the power tool's operations. The milestones achieved thus far include the integration of the software and hardware components, as well as a functioning augmented reality display onto the replica tool. The next step would be to implement an augmented reality display directly from the external work environment onto the user's environment. This thesis also highlights the potential impacts it has on society, which includes improving the quality of life through risk mitigation, and pushing bounds in various scientific applications.

Acknowledgements

Guofan Yin: Graduate Electrical Engineering Student | McGill University

Guofan was a crucial member of this project, especially in mentoring me and guiding me in the right direction. I met with Guofan on a weekly basis to update him on my progress. He would keep me informed with the latest information regarding the project, and we would discuss the tasks to pursue moving forward. Furthermore, Guofan was a crucial member of this project in integration of the systems and setting up the hardware; this will be further detailed in *Section 8*. It was a great learning experience and pleasure to work with Guofan.

Scott Park: Honors Mechanical Engineering Student | McGill University

Scott Park guided me in the right direction for utilizing Blender and gave me advice on how to use it. Scott Park also exposed me to *GrabCAD.com*, a repository for pre-made CAD models, which helped make the design process more efficient.

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1. List of Abbreviations

RSI – Repetition Strain Injury
AR – Augmented Reality
VR – Virtual Reality
ROS – Robot Operating System
Slave Site – Work Environment of the Real Workplace
Master Site – Work Environment of User

2. Introduction, Motivation, and Objectives

Section 2 addresses the key issues that are being tackled in this thesis as well as the main project objectives.

2.1 Theme of Project

The overarching theme of this project is to leverage technology to empower the blue-collar working class by reducing the risk for RSI. A blue collar worker is generally defined as someone who has a career in a manual labour related function. The work of a blue collar worker can include manufacturing, mining, construction, mechanical maintenance, and warehousing [9]. This project empowers the blue collar working class specifically because there hasn't been an abundance of technology to assist in the ergonomics and safety of their work environment. The white collar working classes on the other hand, have a myriad of various technology solutions to improve ergonomics in the work place, many being RSI focused. These technologies include break reminder tools, activity mitigation tools, training tools as well as tracking tools that record data on day-to-day activities [10].

2.2 Description of Problem

RSI is a potentially debilitating condition that results from the over use of hands or repeated motion over a long period of time [6]. It involves injuries affecting tendons, tendon sheaths, muscles, nerves and joints. RSI injuries can be crippling as they may leave the worker in permanent pain. In severe cases, RSI can even result in immobility. RSI is a very common condition, but its symptoms are extreme in labor workers who work repetitively with different types of tools that generate potent vibrations and exert forces. Below are statistics that illustrate the amount of people affected by RSI and some associated costs:

- 1 in 10 adults in Canada have had RSI serious enough to limit their normal activities [11]

- RSI is the USA's most common and costly occupational health problem, affecting hundreds of thousands of American workers, and costing more than *$20 billion* a year in workers compensation [8].

- In 2005/06 an estimated 374 000 people in Great Britain suffered from an RSI caused or made worse by their work [12].

As illustrated through statistics, RSI not only affects people's lives on a daily basis, but also has an extremely high treatment cost. Thus, the impact of RSI on society is highly significant. Some typical causes of RSI include:

- Overuse of Muscles
- Poor Training
- Vibrating Equipment
- Forceful Activities
- Direct Pressure to Body
- Prolonged Periods of working Without Break
- Poor Posture and Poorly Organized Work Environment

These causes are mainly prevalent in the work environment of blue-collar workers. The individuals who work with power tools on a day-to-day basis are especially at risk of this condition.

2.3 Project Objectives and Impact

The goal of this project is to develop a solution to reduce RSI and risk in the work environment. The overview is to utilize an augmented reality tool that is capable of training power tool users more efficiently and interactively, and use robotic mediation techniques to eliminate the need of workers' presence at work sites. Essentially, the workers operating the power tool will be separated from the real tool and real work environment. Furthermore, the real work environment will be projected to the user environment through an augmented reality view. As discussed in *Section 2*.2, the effects of RSI are detrimental to a large population of people. Thus, the scope of this project is highly impactful on a massive scale.

2.4 Target Tool

The tool that this project is targeting is the *Campbell Hausfeld TL050201AV – Air Impact Wrench* as shown in *figure 1*. This is the first tool that this project will focus on implementing using AR. The long-term goal is to tackle a wide range of power tools. This specific tool has a torque of 250 feet-lbs., weight of 5 lbs., and operation speed of 6000 revolutions per minute (rpm). It is typically used for tightening and loosening nuts and bolts, and sometimes for light drilling. This is a very commonplace tool for a blue collar worker, and can cause significant strain to the users' body. Therefore, this tool makes a well-fitting initial target for this project [5].

Figure 1: The Campbell Hausfeld TL050201AV Air Impact Wrench

3. Background

Section 3 reviews some of the technical theories and terminology that applies to this thesis project and will be essential to understanding its purpose.

3.1 Augmented Reality

Augmented reality is a live feed of a user's real-world environment in which specific elements of this environment are overlaid by computer generated digital information. This digital information can include sensory inputs such as sound, video or graphic. It is a technology that mixes reality with the virtual components. Users of augmented reality can expect to see both their real surrounding as well as additional information that overlays the components in their surroundings. This view is specific to a single user of the augmented reality tool; others who are not using the tool will not be able to see what the user is seeing. The technique of augmented reality is used to enhance the perception of reality. With the help of this technology, the components of the surrounding world of the user become highly interactive and easily manipulated digitally [1]. Augmented reality is commonly projected through tools such as mobile devices and smart glasses.

Augmented Reality is often misinterpreted with *Virtual Reality*. Virtual Reality, also known as computer-simulated reality, replaces a user's entire view of the real world with a virtual simulation. In virtual reality, the user has no perception of his or her actual environment as everything is digital. The tools used to project VR are very similar to that of AR, as VR uses displays through a computer screen or a special headset.

3.2 Telemanipulation

Telemanipulation is a technique that enables an individual directly controlling a particular tool to perform the operations through a robot in the site of work. The device used in this thesis will be a type of mechanical robot or robotic arm that can operate the real tool in the actual site of work. This is known as telemanipulation through a robotic source. Telemanipulation of a robot contains 3 key components [3], as illustrated in *figure 2*:

Human Operator or Master: the individual performing the observation and control of the task. The site in which the operator is in will be called *master site.*

Communication Channel or Network: a device or machine that extends the sensory and manipulation capabilities of the human operator. This essentially acts as the mediation between the human operator and the robot

Tele-Operator or Slave: a mechanical or electro-mechanical device that is supervised by the human operator through control systems to perform the task in the real environment. The site in which the tele-operator is in will be called *slave site.*

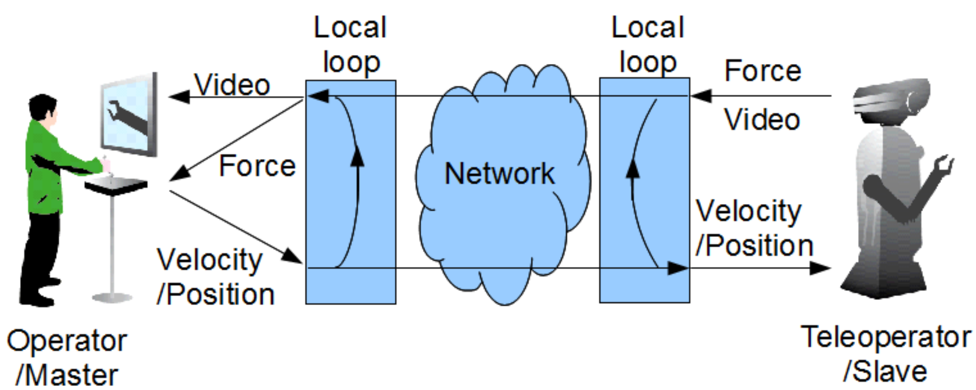

Figure 2: An illustration of the fundamental concepts of telecommunication

3.3 Haptic Feedback

Haptic feedback refers to emulating the sense of touch by applying forces, vibrations or motions to a user. This technique is used in electronic devices to provide more information to users and create a more interactive user experience. Haptic feedback is crucial in facilitating control of virtual objects.

3.4 Triangulation

Triangulation is used to describe the calibration process of the motion tracking sensors. It is the process in determining the location of a transmitter through measuring the radial distance or the direction of the received signal from 2 or 3 different points [14].

4. Problem Approach and Requirements

Section 4 reviews the methods in tackling the issue described in *Section 2*, as well as the tools utilized. This project began with a minimal scope and the end goal was vague. As the semester progressed, the project goals became clearer and better defined. The overall problem approach is divided into 2 sections: the initial overview and the refined overview.

4.1 Problem Approach: Initial Overview

The initial approach to this problem was to resolve RSI through a more interactive training tool. Typically, power tool training is very limited since it is usually through instruction manuals. The initial goal was to utilize an augmented reality environment to provide comprehensive and interactive training for the users before being exposed to the actual tool in the field. Features included visual, haptic, and auditory feedback that gave the user a detailed understanding of how to properly interact with the tool. The main constraint of this approach is that it only addresses the poor training but doesn't have the caliber to reduce RSI significantly, thus, the project approach was refined.

4.2 Problem Approach: Refined Overview

The refined approach brought this project to the next level. As outlined briefly in *Section 2*, it will allow a worker to operate externally from the master site without having to touch the real tool.

<u>Short Term Goal</u>

The short term goal is to overlay the AR display on a simple tool replica. This replica will be a similar to the real tool, and will be 3D printed. The users will hold the replica in their hands, and through the AR glasses, they will see a virtual wrench in place of the replica as shown in *figures 4 and 5*. The replica tool will be coupled with various sensors and speakers to provide haptic and auditory feedback generated from the actual tool; more detail regarding feedback will be outlined in *Section 5*. Furthermore, the view of the task at the slave site is to be projected into the master environment so that the users can interact with it as if they were at the site.

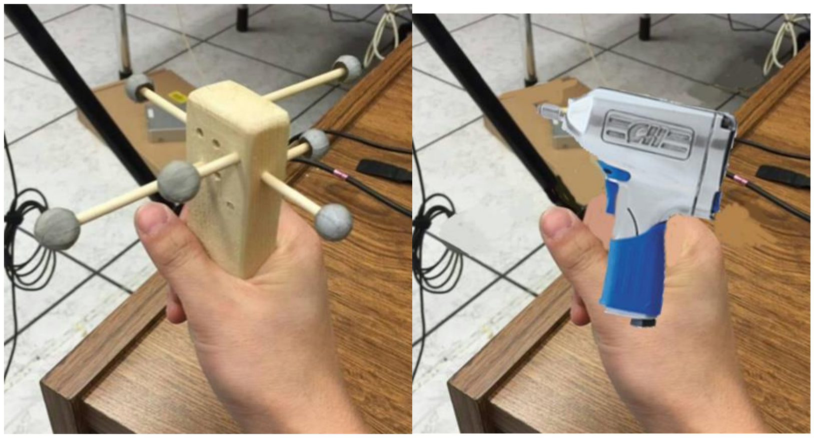

Figure 4 & 5: Figure 4 shows a replica tool with motion sensors integrated while Figure 5 shows what the user sees through Augment Reality Glasses (Moverio BT-200)

Long Term Goal

The long term goal is to tie the short term project, which focuses on the AR display on the user side, to the actual environment of work where the robot is located. The main focus is on the robotic mediation side. Control systems methodologies will be used as the mediation between the user and the robot and signal processing tools will be used to transmit information from the real site to the user and outputted through motors and speakers. Essentially, the long term scope of the project allows the robot to emulate the user while providing feedback of its slave site, so it is as if the user was immersed in the real site of work.

The thesis is still in the middle of the short term goal and will not be able to move forward to the long term within the next semester

Constraints

There are 2 major constraints to this project:

1. *Accuracy*: it will be difficult to emulate the real work environment to an external user with high accuracy. There will need to be a large amount of testing and calibration to achieve precision. This is especially crucial in fields with tasks that require high levels of precision. This will be discussed further in *Section 5*.
2. *Time Delay*: in transmitting the signals between the slave site and the master site, whether it's through radio connections or cables, it may experience a delay. A real-time feed of the slave site to the master is crucial in this project. Transmission delays can be detrimental to the speed and accuracy of the users' work.

4.3 Project Requirements

This project requires the use of various hardware and software tools. *Figure 6* shows the integration of these tools:

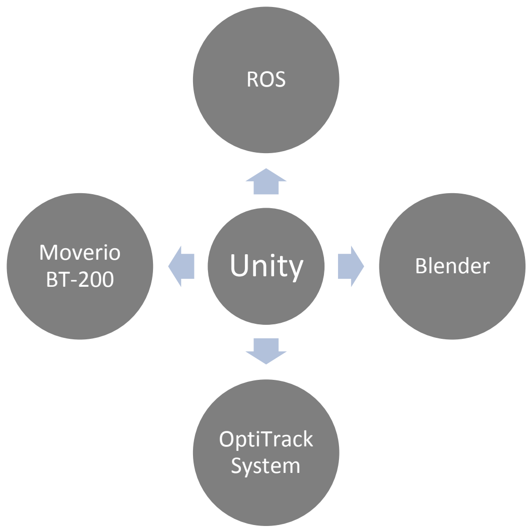

Figure 6: This figure illustrates how each of the tools integrates together. As seen below, Unity is the center of this project, acting as the medium of integration.

<u>Moverio BT-200</u>

The Moverio BT-200 is a pair of smart glasses that is used to project the augmented reality display to the user. It is compatible through Bluetooth, Android, and other technologies. It can deliver large 2D or 3D images in a 360° scope to the user.

<u>OptiTrack System</u>

The OptiTrack System is mainly used for precise motion capture. Motion sensing technologies are used heavily in this project. Motion sensing technologies involve a device that detects moving objects. The moving objects are attached with motion detectors that facilitate the device in capturing the position of the moving objects. In this project, OptiTrack's motion capture system is implemented. This system involves a motion detection camera and motion capture sensors which reflect infrared light back to the detection cameras for location updates.

Moverio BT-200 and the tool replica are attached with the motion capture markers. The user needs to be sitting in front of the motion capture cameras, shown in *figure 7*, to allow for movement to be captured. This data is directly streamed to Unity, which then sends the display through Moverio BT-200 for the user to see. The data stream and calibration software used in OptiTrack is called Motive API.

Blender

Blender is an open source 3D graphics software. Due to the fact that Unity cannot render complex shapes, 3D designs of the designated tool are done in Blender, which directly transfers to Unity.

ROS

ROS, also known as Robot Operating System, is a library of software framework for robotic software development. It provides functionalities similar to that of an operating system. In this specific project, ROS is mainly used to program the functionality of the robot in the work environment. The ROS component of this project is mainly handled by the research team at an affiliated University.

Unity

Unity is a game engine mainly used to develop video games. This software tool is the center of the project as it integrates with all other components. Unity is used to develop the animation of the 3D objects in the AR display. Models from *Blender* are imported into Unity and C# scripts are written to animate those models. The *OptiTrack* Motion Tracking system directly integrates with Unity and streams data to update the position of the real object, which is then updated in the AR display. *Figure 7* illustrates the tools used in practice:

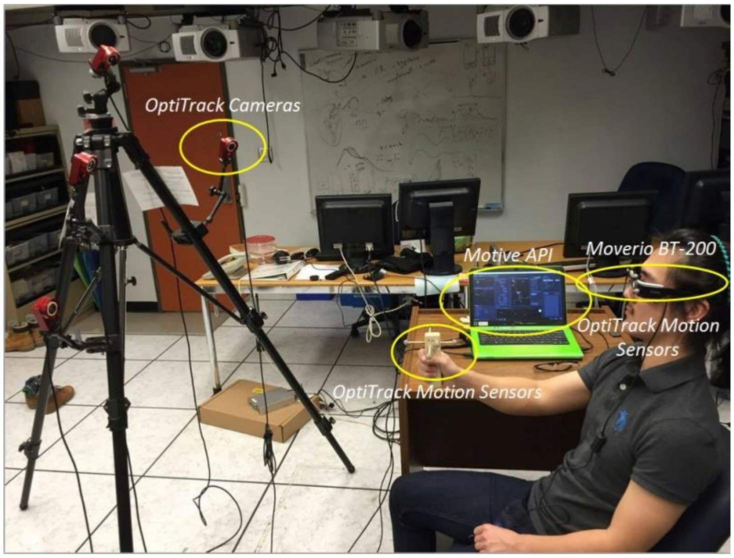

Figure 7: This figure is taken from the laboratory and displays the actual environment set up with each component labeled

5. Design and Results

Section 5 will highlight what has been accomplished this semester as well as the plan to tackle components that are not completed. The design process of this project is divided into 4 key components: the model, control logic, feedback, and integration.

5.1 Model

As noted earlier in the *Section 4*, the model of this project is designed in Blender with a base design taken from the open source repository *GrabCAD*, and then modified. The model is split into separate *moveable* components that make up the tool (as shown in *figure 8*). This is because each part that has its unique movement, so it needs to be its own entity when imported into Unity. In Unity, a C# script can be attached to each individual part of the whole component to allow for movement. This will be highlighted in *Section 5.2*.

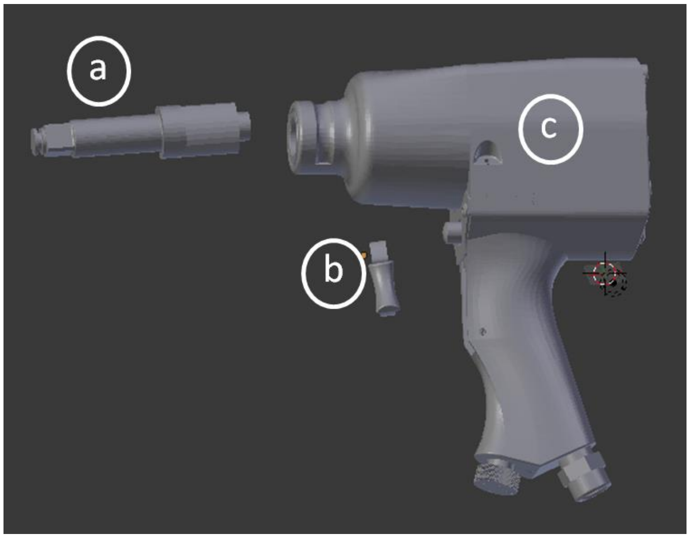

Figure 8: The current 3D CAD model modified in Blender
a) the wrench head, b) the wrench trigger switch and c) the wrench body

A challenge with this design is that its complexity and size makes the rendering in Unity quite slow. A simpler design would be both integrate more easily and render faster. The only tradeoff is potentially the user experience.

5.2 Control Logic

The control logic is divided into 2 sub-components: motion or visual feedback of 3D model and the view of the model through a 360° lens.

The control logic is written inside Unity with C#. Unity has a documentations page that provides detailed instructions on each class. In terms of the motion of the tool or visual feedback on the 3D models, C# scripts were written to animate the components of the 3D model, for instance: the spinning of the wrench head, the clicking of a button, the movement of the wrench body or the triggering of the button to spin the wrench head. The code written for the 360° view focuses allowing the user to view the augmented reality environment while keeping the precision of the positioning of the virtual display overlaying the replica tool. *Figure 9* illustrates the software architecture involved in the C# scripts.

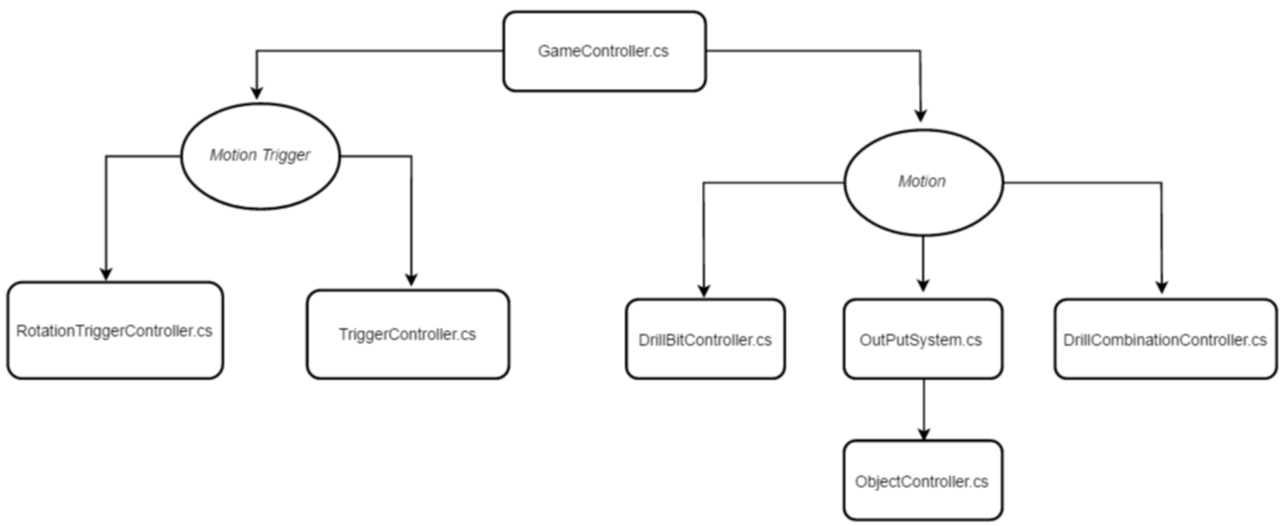

Figure 9: UML diagram for component motion in Unity.

5.3 Feedback

The feedback section focuses on enhancing the user experience through auditory and haptic feedback. The feedback section is incomplete as of this semester. The following is the plan to implement the feedback.

<u>Auditory Feedback</u>

The plan to implement auditory feedback is to acquire the real wrench and record all the sounds associated with its movements, for example the spinning of the wrench head. The recorded sounds can be directly imported into Unity with the associated motion that triggers each sound. The difficulty comes in using speakers to voice the sound effects. Moverio BT-200 doesn’t have auditory output functions, so external mini speakers need to be added to the replica object. This will be challenging due to the fact that the replica object is very small, which makes adding speakers more difficult due to space constraints. An alternate solution could be to place the mini speakers onto the Moverio BT-200 or around the operating environment of the user.

Haptic Feedback

Haptic feedback includes the vibrations associated with the spinning of the wrench head and other parts of the wrench. To implement this, a range of vibrations that directly correlate to the real spin speed of the wrench head needs to be calibrated. Vibration motors can be implemented to achieve this effect. A vibrating disk motor should be implemented as it is programmable and very light weight so it can achieve the effects we are trying to emulate [13]. The challenge lays in configuring the vibration motors to vibrate at different intensities to cater to the experience of the real wrench; this will be discussed further in *Section 5.5*.

A closed loop control system model as shown in *Figure 10* should be implemented. This allows users to adjust their movements based on the feedback generated from the slave site.

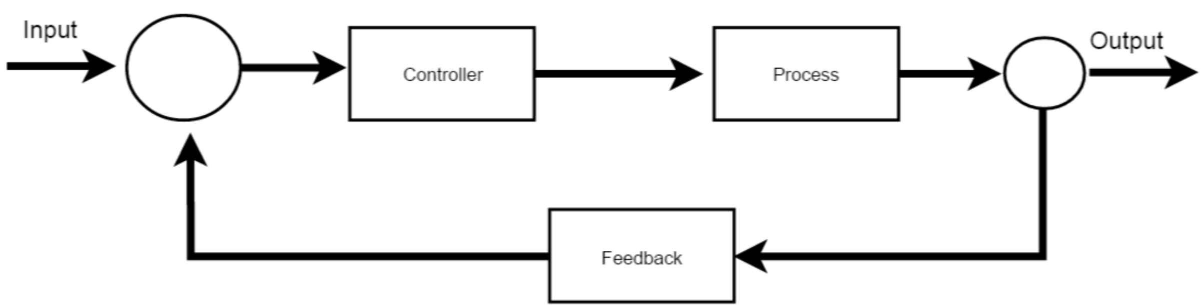

Figure 10: A typical closed loop control system

5.4 Integration

This project involves various tools from hardware to software, which need to be integrated for the project to run. The integration part is fairly straight forward with pre-written Github code that assisted with some components. The integration also includes initial project setup and hardware calibration.

Blender to Unity - Direct Transfer

Moverio BT-200 to Unity – Moverio Unity Plugin

OptiTrack to Unity -Data stream: Unity-OptiTrack Github

OptiTrack Calibration:

The initial calibration of the OptiTrack motion capture system is essential. In the calibration process, the system calculates the position and orientation of each of the motion sensor cameras, as well as the amount of distortions in captured images. With the calibration data, Motive creates a 3D capture volume through capturing data in 2D images from multiple synchronized cameras and associating the position of each known calibration markers from each camera through *triangulation* [4].

If the positioning of the motion capture camera system is shifted at all, then the entire system needs to be recalibrated. Furthermore, this system needs to be calibrated periodically to prevent the deterioration of accuracy from factors such as fluctuation in temperature or other ambient factors.

The steps in the calibration include [4]:

1. Prepare and optimize the capture setup.
2. Mask extraneous reflections that cannot be removed from capture volume.
3. Collect calibration samples: wave a calibration wand stuck with motion tracking markers in front of the cameras.
4. Calculate and review the calibration results.

5.5 Further Design Features to Implement and Research

The features highlighted below are include some tasks that will be conducted next semester as well as some features that need to be considered and further researched.

<u>Signal Processing in Slave Device</u>

Sensory capabilities are definitely required for the slave device. This device should be equipped with sensory devices such as video cameras, force sensors, proximity sensors and tactile sensors (site) that can be fed back to the user. This is not the focus of McGill's team, but definitely needs to be considered.

<u>Scalability to Range of Motion</u>

It would be very interesting to implement a feature in which the ratio of the range of motion from the user's end to that of the real work environment can be adjusted. In some cases, for work that requires high detail, it would be effective to implement a feature in which large ranges of motion on the user's side is scaled down to smaller ranges of motion in the real environment, and vice versa for work requiring larger ranges of motion. Techniques utilizing tele-functioning can be implemented. Tele-functioning is a robotic manipulation method in which the dynamic functions of the master and slave are related through a function [5]. The factor as seen in a theoretical model in *Figure 11* can be adjusted to scale up or down the values of forces on the slave side. Additionally, this can be directly integrated with the haptic feedback on the user side, except scaled down significantly. The variables that are associated with this scaling include position, velocity, and force. The scaling effect can be used to further improve precision of the tool to understand how the slave is interacting with its environment and projecting that information through a ratio to the operator. Control architecture needs to be developed to determine the variables that dictate the dynamic behaviors of the system [5]. Further research needs to be done on the practical implementation.

$$\dot{\mathbf{x}}_s \;=\; \lambda_v \, \dot{\mathbf{x}}_m$$

Figure 11: The factor λ correlating the relationship between master and slave

Data Feedback from Slave Site

Data feedback from the slave site may be in the form of forces applied, relevant positions of slave, graphical data, or the environment's auditory information. As discussed earlier, the goal is to have the view of the tele-operator in the slave site overlaid into the user's environment in the master site. Depending on the type of the task in the slave site, the feedback provided to the user will be in different forms. In the case of an air wrench, the user will need to know the exact distance from the wrench head to the target bolt and the amount of rotation that needs to be applied.

In order to tackle this, the proposal is broken into the following components:

- Display virtual feed of slave site through Moverio BT-200 *while* overlaying the tool onto the replica in the user's hands
    - *Proposed Solution:* Create a new component in Unity that allows the import of live video or graphics and directly project it in the same environment as the current tool (the live video or graphic will be streamed from the slave site through cameras on the robot)
- Provide feedback necessary for user to understand how to accurately approach bolt and apply the accurate amount of rotations
    - *Proposed Solution:* For the former issue, the propose solution would be the technique of tele-functioning, which was discussed in the previous subsection. For the latter issue, using haptic feedback would allow us to determine when the bolt has been tightened as the wrench's rotation would slow down, as would the vibration. Sensors on the tele-operator's tool will process the signals generated by the real wrench and feed the information to the vibration motors in the master's replica tool to emulate this haptic feedback.

Communication Channel between Master and Slave

The communication line between the master and slave is crucial. To even begin to tackle this issue, we need to determine various factors such as the distance between the 2 sites and the medium (ex: water or air). We can start by assuming that the user is operating on land, thus, the medium is air. If that was the case, there are 3 possible approaches that we can take: radio wave control, Wi-Fi control, or Bluetooth control. Each of the cases, excluding Wi-Fi, has a different range for distance coverage. Now another factor comes into play: the work environment. For instance, in work environments that are hazardous and remote, control and communications must take place in the form of high frequency digital and analog radios for control. The Moverio BT-200 is compatible with Bluetooth, so that is the most feasible communication channel as of now for testing purposes. Bluetooth has a max range of approximately 100 meters [2], so the use case jere may be operating power tools at a construction site. There will need to be a Bluetooth adaptor connected to microprocessors and motor controllers on the slave side. On the master side, there needs to be a way to send these signals through the operator's motion in operating the tool. It's possible to consider these signals through the computer that Unity is operating on. When the data is received from OptiTrack Motion sensors, it will be relayed through the computer to the Augmented Reality display and also to the slave site which will receive this signal and replicate this movement seen through Unity. The form of communication also allows us to dictate what type of robot needs to be implemented as it needs to be capable of implementing the communication technology. Further research needs to be conducted to fully understand this process as this is a hypothesis at a potential solution.

5.6 Design Decisions

Blender was chosen as the 3D CAD tool because it’s open source software that integrates directly with Unity. It was chosen because it was the most cost efficient solution. When entering the project, all other hardware and software tools had already been chosen, so there was no room for decision there from me.

In terms of software development, there were some decisions made regarding how to move forward with the class design and system architecture. The decision was made on what type of integration can be easily debugged in Unity. A component based C# class structure was taken.

5.7 Key Results

The key results from this semester include:

Model Design

- Completed 3D model in Blender
- Acquired wrench tool environment for real simulations

Software Design

- Completed animiation of wrench components in Unity
- Completed 360° view of object in Unity

Integration

- Completed integration between Unity and OptiTrack
- Completed OptiTrack motion sensing system integration
- Competed Moverio BT-200 integration

6. Plan for Next Semester

Section 6 discusses the tasks to accomplish for next semester, the timeline for key milestones, and the plan for testing.

6.1 Goals

The goal for the next semester is to have a completed version of the augmented reality display from the user's environment. Furthermore, research can be done on the linkage between the robotic component and the AR from the user's environment. The robot component of the project is being conducted by another University, so seeking ways to integrate the 2 pieces of the project would definitely be facilitate progress. The table below shows the list of tasks to be accomplished for the upcoming semester in components.

Augmented Reality	• Create an AR display of the slave site seen on the robotic site that interacts with the current AR display of the tools that the user can completely engage in the work environment • Calibrate the precision of the positioning of the tool in the user's hands • Integrate haptic and auditory feedback in the current design
3D Model	• Further enhance current 3D model • 3D print the finalized version of model and integrate it with motion sensors
Research	• Research on signal processing methods to connect robot feedback to user end • Research on control systems strategies for robotic control by user

Table 1: A breakdown of the tasks for next semester by category

6.2 Timeline

Completion Date	Task
Mid-September 2016	Enhanced 3D model
Mid-September 2016	3D printed tool with sensor integration
End-October 2016	Calibration for precision of tool
End-November 2016	AR display of real work environment
Ongoing	Haptic and auditory feedback
Ongoing	Research on signal processing
Ongoing	Research on control systems

6.3 Design Testing Plan and Decisions

Functionality Testing – Focus on technical features

- *Unit Testing:* This is to test each component involved with this project to ensure that they can operate individually. This includes the OptiTrack System (cameras, motion sensors, Motive API), Unity environment and Moverio BT-200
- *Integration Testing:* This is to test the components working together to ensure that the right information is being outputted

User Testing – Focus on user experience

- *User Friendliness*: this test will evaluate how the user will interact with the tool, in terms of the ability to adapt, receive feedback, and intuitiveness of design. Repeated simulations will be run on a range of different users (potentially some with power tool experience and some without). The testers can provide criticism on the effectiveness of the visual, haptic, and auditory feedback in conveying the real tool, and their overall experience in using the tool.
- *Precision*: this test includes the precision in overlaying of the virtual model onto the replica model, and the interaction with the virtual feed from the slave site. The former part can be tested through re-runs of simulations and then recording the data on differences in distance between the virtual component and the real component; this can then be adjusted through either recalibrating the motion detector cameras, replacing the motion sensors, or modifying the C# script on Unity. Since the robot or slave side of the project will not have been integrated by the end of this semester, the latter component of precision testing will mostly consist of the scaling between the slave environment and the master environment. Determining an accurate scaling factor allows the user to achieve higher precision in task performance.

7. Impact on Society and Environment

This section analyses some of the costs, benefits, and potential risks in the implementation of this project as well as the societal impact that it imposes.

7.1 Mass Production and Target User

The initial cost of this project is quite high, with the requirement of hardware pieces including the Augmented Reality Glasses, various sensors and speakers, OptiTrack Motion Sensor System, 3D printed replica, and the a potential robot or robotic arm depending on the environment and function of the job. If mass production of this product occurs, economies of scale can be achieved and the costs would be significantly reduced, especially if a robotic arm is implemented over an actual robot.

Additionally, other costs associated include system setup, maintenance, and employee training. To apply this project to every blue collar worker in risk of RSI is not realistic. However, this projected is not expected to target every blue collar worker. Until further advancements in technology that will reduce the costs associated with this project, the target user group is mainly workers who are in a role that is extremely susceptible to RSI, or in hazardous conditions which impose high risks. From a corporate perspective, it would be far more advantageous to incur a cost to implement this product to improve employee safety, rather than compromising cost for safety.

7.2 User End

Blue collar workers are not typically exposed to the latest technology, and can generally be considered to have less tech savvy roles at the workplace. The challenge presented in this case, is for the users to adapt to the learning curve associated with using this AR tool and adjust to the new methods of working that replaces traditional methods which have been commonplace for the past decades. If the users don't adapt to these methods, the initial output of the workers can be very limited and can be negative to efficiency.

The benefits of this project for its users are vast. The blue collar class workers are able to conduct their roles in safer environments that are less susceptible to conditions like RSI; this prevents work from affecting their lives negatively. The risk of operating in a hazardous environment is completely eliminated and workers can come to their jobs everyday with full assurance, which can lead to boosted employee morale.

7.3 Safety and Risk

The goal of this thesis is to leverage technology to address the issue of safety and risk imposed on the blue collar working class. Through this augmented reality tool, a worker will be separated from the work environment, improving safety, and will be separated from power tools, which significantly reduces the risk of getting RSI. Improvement in safety and mitigation of risk are the key results of this project.

7.4 Benefits to Society

This project benefits society in 2 key ways: improvement to quality of life and encouragement of a wide span of new solutions in which this technology can be used.

Through using this tool, the blue collar working class will not only feel empowered as employees, but also safe. As mentioned in the *Section 2*, RSI is a debilitating condition that can constrain regular movements and in severe cases cause immobility. RSI is detrimental to the quality of life, and eliminating the serious cases is a significant impact to the people of society. Reduction of RSI and other risks of working in hazardous environments also reduce the costs incurred with rehabilitation associated with RSI and other medical expenses. As highlighted in *Section 2*, RSI is the USA's most common and costly occupational health problem, and can cost up to $2 billion annually. Taking away risks reduces a huge financial burden on workers as well as their respective companies.

The goal of this thesis was to empower the blue collar working class through technology, however, this tool can be powerful in so many other different areas of application; it can serve as a solution to a much wider range of contemporary issues that could not have been tackled in the past without AR or telemanipulation. Some of the fields in which telemanipulation through AR can be applied include: space, underwater, medicine, and hazardous environments.

<u>Space</u>

- It’s highly costly to have human operators in space
- Space is a highly hostile environment for humans

<u>Underwater</u>

- In the oil and gas industry, underwater pipes and cables require maintenance and routine operations
- The Science community can use this technology for marine and archaeological explorations

<u>Medicine</u>

- In geographic locations without as much medical expertise
- In microsurgery scenarios where fine details and small precise movements are required, the movement of a doctor can be scaled down through robotic mediation so that more fine operations can be conducted

<u>Hazardous Environment</u>

- In environment where radioactive waste needs to be handled
- In environment where nuclear waste or toxic waste requires disposal

8. Report on Teamwork

Section 8 will outline the division of task and some difficulties faced between the team. The honors thesis is intended for 1 student, however, this semester I worked with a graduate electrical engineering student, Guofan on this project.

8.1 Task Division

Richard

- Building and updating 3D Graphic
- Writing C# classes in Unity for the visual display of object motion
- Creating weekly updates on Wiki
- Updating Software Repository
- Implementing auditory feedback in Unity
- Research on tools
- Research on RSI

Guofan

- Communicating with other teams on project progress
- Writing C# classes in Unity for the visual display of object motion
- Implementing data transfer connection between OptiTrack and Unity
- Setting up OptiTrack physical environment
- Moverio BT-200 Integration

8.2 Difficulties Faced

The difficulties faced this semester during meetings were mainly involved with the direction of the project. As outlined in *Section 4,* the project was refined throughout this term and the direction was shifted. This was difficult in terms of defining future tasks and allocating time to each task. For the upcoming semester, this shouldn't be as big of an issue because the project goal is much more refined and finalized, although it is susceptible to change. To address difficulties in the shifting of project direction, frequent communication with the professor will be crucial in terms of defining and confirming next steps.

9. Conclusion

The work accomplished in the winter 2016 semester consists of the initial set up of the system environment, and integration of project tools. The preliminary 3D model and its associated visual feedback have been built in Unity as well as the 360° view. The next step would be to further enhance the current model by improving the accuracy of the augmented reality display. An additional feature that allows users to fully engage in their task through a feed of the slave site displayed with AR glasses also needs to be implemented. Furthermore, haptic and auditory feedback can be implemented through the use of sensors and mini-speakers.

The project thus far has been eye-opening, as augmented reality is one of the hottest current trends in the world of technology. To be able to engage in so many different types of tools and be exposed to a diverse set of tasks ranging from software development, to 3D design, to RSI research, to motion sensing technologies, is definitely a fantastic learning experience for me. This semester involved constantly learning, especially in operating the Unity software, or designing a model in Blender. I learned that even though the project scope seems monumental and difficult to achieve, as long as it is divided into small components, we are able to complete it a small step at a time. There are a myriad number of tasks remaining until the completing of this project, but I definitely look forward to taking the next steps, because as the old saying goes, “Rome wasn’t built in a day”.

10. References

[1] “Augmented Reality,” Mashable. [Online]. Available at: http://mashable.com/category/augmented-reality/. [Accessed: 14-Apr-2016]

[2] “Bluetooth Range: 100m, 1km, or 10km?,” Bluetooth Range: 100m, 1km, or 10km? [Online]. Available at: http://www.bluair.pl/bluetooth-range. [Accessed: 14-Apr-2016]

[3] C. M., “RoboticTelemanipulation:General AspectsandControlAspects,” tech. [Online]. Available at: http://www-lar.deis.unibo.it/euron-geoplex-sumsch/files/lectures_1/melchiorri/melchiorri_01_teleman.pdf. [Accessed: 09-Apr-2016]

[4] “Calibration,” *OptiTrack*. [Online]. Available at: http://wiki.optitrack.com/index.php?title=calibration. [Accessed: 10-Apr-2016]

[5] “Campbell Hausfeld TL050201AV 1/2 in. Air Impact Wrench,” *www.cpocampbellhausfeld.com*. [Online]. Available at: http://www.cpocampbellhausfeld.com/campbell-hausfeld-tl050201av-1-2-in--air-impact-wrench/cbhntl050201av,default,pd.html?cgid=campbell-hausfeld-impact-wrenches. [Accessed: 10-Apr-2016]

[6] H. K., T. I. T., and C. L. M., “Telefunctioning: An Approach to Telerobotic Manipulations,” IEEE Xplore. [Online]. Available at: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=4791228. [Accessed: 14-Apr-2016]

[7] P. B., “HealthDay,” *Repetitive Stress Injury (RSI)*. [Online]. Available at: http://consumer.healthday.com/encyclopedia/pain-management-30/pain-health-news-520/repetitive-stress-injury-rsi-646236.html. [Accessed: 10-Apr-2016]

[8] “Repetitive Strain Injury Statistics,” *Repetitive Strain Injury Statistics*. [Online]. Available at: http://www.rsi-therapy.com/statistics.htm. [Accessed: 10-Apr-2016]

[9] S. S., “What Is a Blue-Collar Worker and a White-Collar Worker?,” *What Is a Blue-Collar Worker and a White-Collar Worker?* [Online]. Available at: http://smallbusiness.chron.com/bluecollar-worker-whitecollar-worker-11074.html. [Accessed: 10-Apr-2016]

[10] T. B., “5 Free Software Tools To Help Prevent RSI And Make You More Productive | Timbo on Tech,” 5 Free Software Tools To Help Prevent RSI And Make You More Productive | Timbo on Tech, 13-Jan-2008. [Online]. Available at: http://timboontech.blogspot.ca/2013/01/5-free-software-tools-to-help-prevent.html. [Accessed: 09-Apr-2016].

[11] “The Daily, Tuesday, August 12, 2003. Repetitive strain injury,” *The Daily, Tuesday, August 12, 2003. Repetitive strain injury*, Dec-2003. [Online]. Available at: http://www.statcan.gc.ca/daily-quotidien/030812/dq030812b-eng.htm. [Accessed: 10-Apr-2016]

[12] “Upper limb disorders,” *Upper limb disorders*. [Online]. Available at: http://www.hse.gov.uk/msd/uld/index.htm. [Accessed: 10-Apr-2016]

[13] “VPM2 Vibrating Disk Motor,” RobotShop. [Online]. Available at: http://www.robotshop.com/ca/en/solarbotics-vpm2-vibrating-motor.html. [Accessed: 12-Apr-2016]

[14] “What is triangulation? - Definition from WhatIs.com,” SearchNetworking. [Online]. Available at: http://searchnetworking.techtarget.com/definition/triangulation. [Accessed: 10-Apr-2016]