# ELEC 490 Proposal Report

Group #33
Adel Abdel-Hamid 13aah16@queensu.ca (10142673)
Eric Chau 13ec50@queensu.ca (10141119)
Monica Rao 13mrr6@queensu.ca (10133414)

Faculty supervisor: Dr Saeed Gazor
Department of Electrical and Computer Engineering
Queen's University at Kingston
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# Contents

# 1 Executive Summary

The purpose of this project is to build a Kinect-type device, named the Konect, and connect it to a VR system in order to simulate a surgical procedure. The Konect must be as small and precise as possible in order for it to be easily transported and for the simulation to be as realistic as possible respectively. The scope of this project will consists of a fully functional Konect, a fully functional virtual world, a bill of materials, a user manual and a list of the codes.

This project was chosen to improve training possibilities for surgeons before working on a patient and without the need for surgical materials that are limited and can be expensive to acquire. By using the Konect, surgeons in training can experience what it seems like to perform a real surgery without the risk of injuring their patient, and without wasting precious resources. The overall goal of this project is to build a working prototype Konect, paired with a working VR simulation. The hardware will mainly consist of designing and building various circuit schematics and getting them printed on PC boards in order to assemble all components together. The virtual reality environment is planned to be programmed in Unity using C#.

A gantt chart and summary table have been made to keep the team on track for deadlines, as well as keep the team organized to schedule meetings with the project adviser. Testing and evaluating the overall project will be done multiple times throughout the course of building the Konect. The hardware will be tested by checking the voltage and current values of the circuit and simulating the desired results to avoid any potential complications. The software component of the project will be tested in real-time while simulating the virtual reality environment in Unity. A form of testing known as ”functionality test” will also be used, which includes testing certain mmore functionalities such as proper physics for simulation-object collisions, and operational code.

The overall budget for this project is planned for 400 dollars, but the team already expects to exceed that amount due to the other components that are needed to be purchased for the hardware component of the project.

## 2 Introduction

This proposal summarizes the ELEC490 project undertaken by Group 33 - the Konect VR group. This report has been prepared for Departmental approval. The intended audience for this report are Dr. Saeed Gazor, Dr Peng Fang and any other interested members of the faculty.

With the growing improvements in technology also comes improvements in medicine. For the past 30 years, technology and medicine have been getting closer and closer to developing the best technology.(1) Although doctors are now capable of operating minimally invasive surgeries (MIS) and use the help of robots for more complicated procedures, fewer new technologies have been used to maximise the training and learning capabilities of future medical staff members.

The use of a VR (virtual reality) set is to simulate a surgical situation allows for new surgeons to learn vital skills before taking a patient under surgery by using a computer generated environment to improve their efficiency at performing certain procedures such as MIS.(2) The use of VR training was shown to improve performance by resident doctors. In one study, residents trained with the VR simulation for a gallbladder surgery were 29% faster than their classically trained counterparts and were five times less likely to cause injury the gallbladder.(3)

In order to follow the users movements in the simulation, a motion sensor system would be used to detect the precise movements. Motion sensors such as the Microsoft kinect have been used by surgeons before, to manipulate key medical images during surgery.(4) However, the project will connect a motion sensor built from scratch, known as the ”Konect”, that will be pair with a VR set to simulate surgery for training purposes.

## 3 Objective

The main objective of this project is to create a virtual reality environment for doctors and surgeons alike to train and practise without the need for surgical materials. This would ultimately save resources and finances yet provide a safe and interactive way to gain experience.

With the high expense of medical equipment and with the best equipment reserved only for real surgeries, most medical students are very limited in terms of their available practise resources. Many medical students require a high number of simulation hours of practise prior to real experience, and for a good reason. Surgery is very intensive and normally life altering for clients. However, due to the limited amount of equipment universities have available, students are required to take turns and may only use the equipment while a certified professional is present since universities cannot put themselves at a potential financial risk by having students break the equipment. With virtual reality, universities do not need certified professionals to be present as they are not risking any equipment whatsoever. The professionals would then only be required to teach then the students may practise in their own time. This would make it substantially easier for practising medical students to acquire their required number of hours while also avoiding a significant amount of potential financial risk for the university.

Apart from saving a substantial amount of time, it also bridges the gap between practising on synthetic material and real life surgery. Currently, many medical students use everything other than flesh to simulate and practise surgery on. To some students, it is no surprise that it comes as a shock when they jump from simply shadowing surgeons by watching and practising on synthetic material to applying their practices on real living flesh. By using the Konect, students are able to experience what appears to be a real surgery without the risk of injuring anyone. This is vital in terms of allowing students to feel more comfortable with surgeries prior to actually doing them.

Ultimately, the Konect will save cost and time for many in the field of science and medicine along with opening up the possibility for many to experience surgeries in an immerse yet safe and budget friendly environment. Although there is no deadline which would make this implementation particularly successful, the sooner it is out in the market the better for students and practising doctors alike. Ideally, a fully operating design would be completed by the end of the Winter academic semester of 2018.

## 4 Design Approach

In order to fully implement the Konect system, the Konect hardware would first need to be built prior to designing the virtual reality environment. The design of the actual Konect system would depend on the circuitry that the team would have to design and build. The team researched that we will need a few different types of circuits to build the system, one will be for the servo motor to control the shifting of the Konect. The other circuit will be for the various sensors required. The team made a design schematic of the two important circuits needed, these can be seen in Appendix (please refer to

Appendix). The rest of the hardware will be assembled together to a full model of the Konect system once all the circuitry is made and tested.

The system as an entirety will have very simple inputs and outputs. The input being the user them-self, by using motions to interact with the Konect. The output would simply be the entire virtual reality environment. Specifically, the user's movements are taken as inputs for the Konect C# code and move the Konect's motor to the required position. Similarly, the user's movements are taken as inputs for the VR Unity code which in turn will affect both the new position of the character in the VR world and affect the users future inputs. The Flow chart in figure 1 below shows the summary of how the user, Kinect, and VR will interact.

By having a structured approach, we can ensure all the components required are completed. It also aids in terms of organization by ensuring all dependent components are scheduled to be completed after the independent components which they depend on. For example, the virtual reality environment cannot be interacted without the functioning hardware of the Konect system.

After completing the system, it can be analyzed by determining the precision of the Konect's measuring accuracy. In order to quantitatively compare to the industry's standard, it is possible to compare with Microsoft's Kinect in order to determine the Konect's full capabilities and limitations.

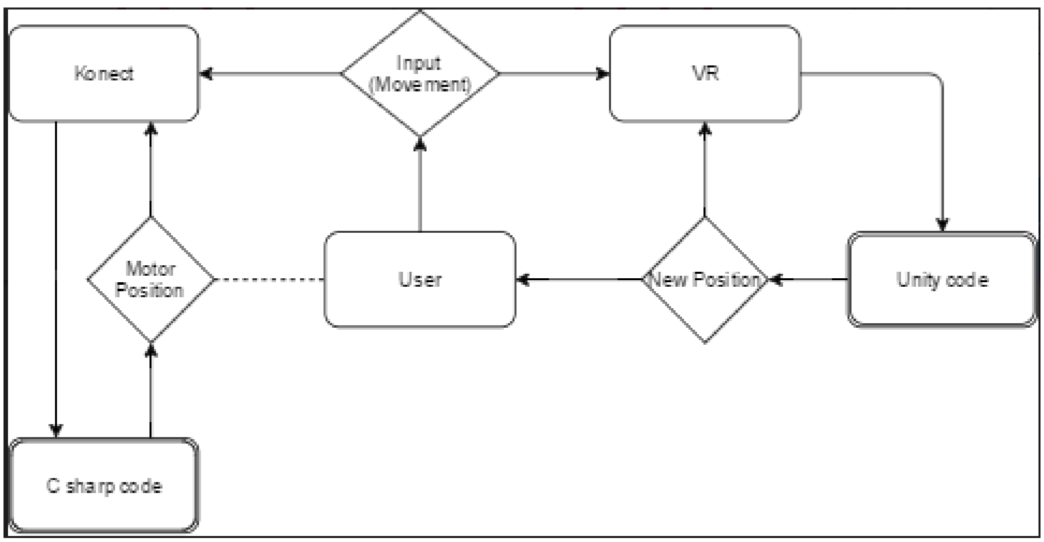



Figure 1: Flow Chart for Proposed Project

Ideally, the group would like to build the complete hardware for the Konect. This would allow full customization for the group in case modifications are required. However, as a backup solution, it is definitely possible to use Microsoft's Kinect as a hardware substitute. Microsoft Kinect's SDK is very flexible in the sense that it supports C++, C#, and VB.NET. With the virtual reality environment tentatively planned to be programmed in Unity using C#, Microsoft's Kinect makes and ideal candidate as backup hardware solution in the unfortunate situation where the group's Konect hardware fails.

# 5 Work Plan

In order to keep the team on track the work must be distributed among the members equally. The work plan for the team will be divided upon the skills mentioned earlier. The team will divide the responsibilities and duties of each group member by the qualifications and interests. The two electrical students on the team will take care of the hardware aspect of the project. They will mainly focus their attention to building and coding the Konect. The computer engineer on the team will focus on the software side of the project. They will spend most of the time developing a code for the virtual reality simulation using unity and C# for the Konect. The gantt chart was also created to display the overall milestones the teams hopes to achieve and to help better plan out when scheduling meetings with the faculty supervisor. The major milestones and summary of work deadlines can be seen in the gantt chart below, please refer to Figure 2 below. The overview for the time line of the project is summarized in the table below. Please refer to table 1 below:

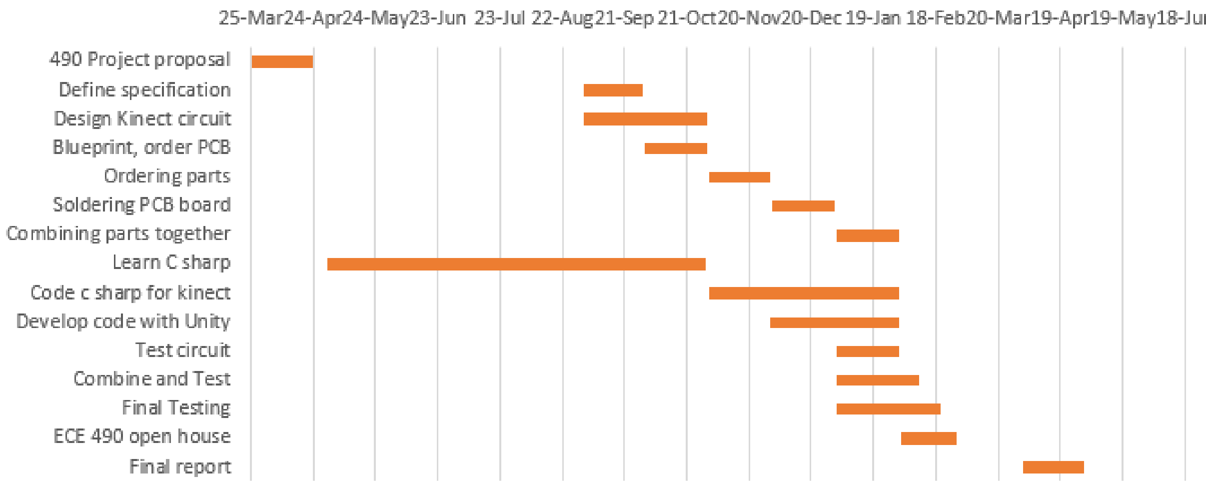



Figure 2: Gantt Chart for the Work Plan

Table 1: Project Schedule Table

| Milestones | Detail Actions | Starting and End Date |
|---|---|---|
| 490 project proposal | write a proposal report that outlines the plan for 490 | April 2017 |
| Define Specification | Define the size, cost and performance with adviser | Sept 1, 2017- Sept 30, 2017 |
| Design Kinect circuit | Design schematic, layout, and prototyping | Sept 1, 2017 - Oct 31, 2017 |
| Blueprint, order parts | Place order for PCB boards | Oct 2017 |
| Ordering Parts for Kinect,and VR head set | Ordering off parts on-line | Nov 1, 2017 - Nov 30, 2017 |
| Soldering PCB board | Soldering | Dec 1, 2017 - Dec 31, 2017 |
| Combining all parts together | Design the combined schematic | Jan 1, 2018 - Jan 31, 2018 |
| Learning C sharp | Learn the new language | Sept 1, 2017 - Nov 30, 2017 |
| Code c sharp for Kinect | Develop code in c-sharp for our kinect | Dec 1, 2017 - Jan 31, 2018 |
| Develop code with unity software | Develop code to work with VR | Nov 30, 2017 - Jan 31, 2018 |
| Testing of the Circuit | Testing voltage, current,and signal outputs | Jan 1, 2018 - Jan 31, 2018 |
| Combining and Testing | Combining testing of working kinetic,code | Jan 1, 2018 - Feb 10, 2018 |
| Final Testing | Testing Kinetic and VR working together | Jan 1, 2018 - Feb 20, 2018 |
| ECE 490 open house | ECE demo their complete 490 projects | Feb 2018 |
| Final Report | Must write the final report of completed project | April 2018 |

# 6 Deliverables

Upon completion of our Konect system, a complete design document will be compiled and delivered. It will contain initial plans such as hardware materials needed, assembly, and testing. Along with hardware, the software plans would also be elaborated on. This would include things such as development of the virtual reality environment, interaction of the virtual reality environment with the user, and also the interaction of the virtual reality environment with the hardware (namely the Konect system itself). Android APK development and implementation would be explained, including the development of the APK in Android Studio.

The Konect should be able to simulate independently without the aid or intervention of a third party. Along with independence, it should successfully simulate at a high accuracy rate and precision. This will be dependent on how well the Konect reads the user's attempted movements. The system will be analyzed based on its success to independently operate, along with the relative success of the replication of the user's attempted movements in the virtual reality environment. The user should be able to consistently be able to complete desired tasks and movements at a high success rate.

In general, the evaluation will be based on the user's experience of the system's sensing precision and virtual reality simulation along with the system's ability to run completely independently. Depending on the level of intervention required from the team during system use, the level of success will be determined accordingly. If the system is unable to operate independently in the absence of third party, the system would likely be considered unsuccessful in that aspect. If the system is able to operate completely independently without any intervention, it would be considered a success in that aspect. Anything in between would depend on the consistency at which the system requires aid, and the duration at which the aid is required. Another evaluation would be the system's sensing precision. The evaluation of that outcome would also be dependent on the virtual reality's ability to simulate the user's action. This evaluation will be dependent upon the completion of the system, since it is impossible to determine the precision in the virtual reality environment when the virtual reality environment doesn't exist yet.

Along with the previously mentioned deliverables, a section will be dedicated towards the experimental results of the Konect System. This would initially include the successfullness of the system's ability to run on Android along with the Konect hardware, along with a list of successful or unsuccessful attempts by the user to complete certain tasks using the system. These tasks would range from simple gestures such as hand movements to complicated tasks such as completing a programmed objective requiring a number of precise hand and/or body movements. Depending on the outcome and success of the user, the results would be explained in detail describing the level of success the user was able to achieve along with the ease of use.

A user manual explaining how to operate the Konect and VR. This will include labeling for all possible inputs (ie Reset button, on/off button), explaining how to replace broken parts (ie list of parts, how to recharge batteries) and explaining how to connect the VR and Konect with each other. Calibration along with user interface guidance will initially be provided upon first use, however the user manual will also provide guidance.

A list of all the codes for both the Konect and the VR system will be included, annotated with comments explaining the main functions of the code. Since Unity and Android Studio use different languages, they will be separated into different appendices upon creation of the final design deliverables. A list of API's used for hardware compatibility will also be included in a separate appendix. All major classes and methods will be annotated and will explain their purpose. The Java code in Android Studio will mostly consist of explanations of the user interface along with implementation of linkers with the Unity virtual reality environment. The code in Unity will likely be the bulk of the code listing, explaining everything ranging from simple object instantiation to user interaction with the virtual reality environment. Any excess resources such as API's will be explained in terms of their purpose, the type of data being used (an API in this case), and how it implemented in our system.

# 7 Testing and Evaluation

The testing of the voltage and current of the circuit will done with the multi-meter. There will be multiple test done in order to make sure that the circuit will continue to work as more components are added to this integrated project. The oscilloscope will be used to test the signal output when we assemble the Konect and test if we get the correct wave function.

There will be multiple tests done for the course of this project. This is because to avoid any potential disasters. Tests that would have to be done will include: voltage, current, motors, camera focusing, sensor testing, as well as make sure it works properly with our code in C# language. The simulation testing can be done with Matlab, whenever we will have to recalibrate the Konect system. This will also prevent any unwanted consequences.

For the virtual reality environment, much of the testing will be real-time while simulating the virtual reality environment in Unity. Unity is convenient in the sense that game objects are live upon instantiation and code is live upon rendering. There is no need to recompile for each test, thus testing will likely occur during the design process of the virtual reality environment. This includes testing sections of game objects and "units" of code into what is known as AUTs (Application Under Test). This will ensure that bugs and errors will be fixed as early as possible in the development process and software lifecycle. By doing so, overall system implementation will be more efficient. Bad designs will be avoided, since a bad design choice will be identified upon implementation and testing, more suitable design choices will be implemented, and ensures there is sufficient computing power available for each AUT being rendered.

Since this is a user based system, the performance desired varies from user to user. However, there are basic system functionalities which will have certain performance expectations. This is known as "functionality test", which includes functionalities such as proper physics for simulation-object collisions, and operational code. Scalability as the user progresses through the simulation should be constant through most processes. Matrix testing will also be used, where as many different possible aspects of the simulation will be tested as possible. An example of this would be if the user of a surgery simulation was meant to cut through the abdomen of the patient, however accidentally cuts through the thigh. The virtual reality simulation should simulate a failed surgery, allowing the user to cut through the thigh. However a failed matrix test may simulate the user cutting through the abdomen, even though the user actually accidentally cut into the thigh. These matrix tests would be prioritized in terms of most important scenarios to least important. By doing so, it ensures proper functionality of the core of the simulation.

Checkpoint and final software tests will include actual generation of APK files to be tested for real application. This means rendering and generating the APK file to be tested on an android device, outside of the Unity emulator. By doing so, this ensures that expectations are met in terms of the hands-on real life experience. A Unity render-preview may not always come out the exact way as a generated APK file on an actual Android device would.

The major standard for this project would be to try to create a working prototype of the Konect surgical simulation system. Performance standard would include to be: to have a positioning error of +/- 2 cm, to have a minimum lag response in the feedback system, to have accurate calibration, in other words to be able to accurately analyze and check the users movements every second. An example of feedback system can be seen in the figure below (please refer to figure 3).

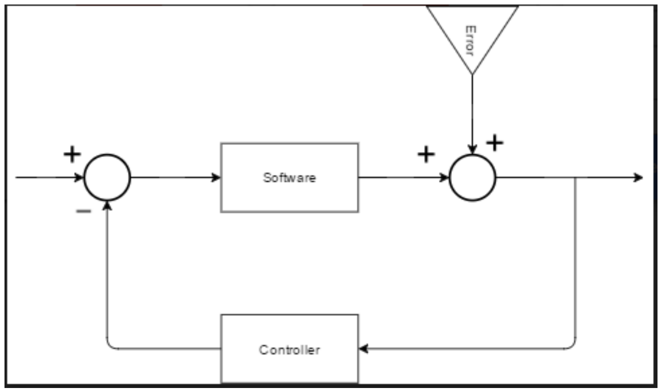



Figure 3: Example Feedback loop for system lag

## 8 Resource Requirement (Budget estimation)

The parts that need to be purchased will need to be accelerator, laser sensor, motion sensors, few high power cameras, resistors, capacitors, inductors, one 7 pin op amp, 3 16-pin op-amps, approximately 3 external batteries, three small Ardunino boards, LCD monitor, a motor (for the leaning forward and back movements) etc. The team will need to put in a order for a custom PC boards to be made. A virtual relativity head set will also need to be purchased.

The team is planning on using the prototype shop to use the soldering iron in order to solder the circuit components to the PCB board for the Konect. The Lab space may be needed to test out the circuit components and measuring with an oscilloscope the wave output, voltage, and current values. This is to ensure that correct circuit layout works before placing an order to avoid any potential disasters.

The equipment needed for this project will be: a soldering iron from the prototype workshop, a multimeter, screw driver, various wires and probes from the common electrical kit, a LCD screen, motor, three small Ardunio boards etc.

The software needed for this project would include: Eagle in order to design the layout, schematic and custom PCB board designs, Android studio, Unity and C#/Ardunio will be used to code the software components of the project for the VR headset as well as the custom kinetic. Matlab, may be used to test simulations of the system. Or to help with recalibration of the system.

The budget for this project should be around approximately 400 dollars but the team expects to go over a bit over since the parts that need to be purchased plus a good quality virtual reality head set are needed and could add some added costs. This is also factoring in any other potential failures in the custom PCB, when soldering and replacement parts. In order to avoid potential failure the team has planned that the testing of the circuits and PCBs will be looked over by a supervisor or Ta in order to make sure that the board and circuits function properly. Also, extra parts will be planned to be ordered to make sure if a part goes missing or when soldering the board needs to be replaced. By following this budget plan/ estimation the team hopes to avoid any complications and to successfully complete the project at hand.

## 9 Qualification

Group 33 consists of two electrical engineering and one computer engineering majors. The members of this group share knowledge in computer programming, software performance analysis, signals systems, sensors actuators, robotics, electric circuits and electronics and analog systems, all of which are necessary to build and test the Konect motion sensor system. To generate the simulation, Java and C# will be used for Android Studio and Unity Engine respectively. Furthermore, Matlab will be used to run simulations, as such our knowledge in Control systems and Numerical methods will be necessary for correct calibration.

The Konect system will be built using our knowledge in electric circuits and electronics to build its circuits. Knowledge in sensors and actuators to follow the users movements and robotics to rotate the Konect as required is required as well.

The virtual reality environment will be built in Unity3D and implemented on an Android device with Android Studio. Knowledge from computer programming and software performance analysis will aid in the overall process, while previous small projects with Unity3D and Android Studio will aid in the implementation of simulation objects and user interface. Anything new will be self-taught, such as the exposure to virtual reality programming. A simple game using unity was made and knowledge gained from that will help with familiarity with the Unity interface and game-object creation. Previous Android Studio knowledge will also aid in familiarity, except with the Android Studio interface along with interactions via Android OS.

Previous projects done using sensors and actuators include building a pinball machine from scratch, using two Arduino boards. Another project using an Arduino was, robot that can pick up a ball, follow a black line and place it at a target. IR and Bluetooth were also used to send a command from the computer straight to the robot. The previously mentioned robot also used basic robotics concepts for movement and to manipulate the ball picking arm. A visual aid app and a game app for blind children were also created using android studio by members of the team. The visual aid app was built using navigation and API. Using Indigo API's in a hackathon, one team member was able to make two computer application systems that would be able to detect emotions with analyzing the blink rate with the web camera on your computer. The other application was a posture detection application that detects when a person is slouching too much while working on their computer, this was done using Matlab software and signal analysis.

## 10 Conclusion

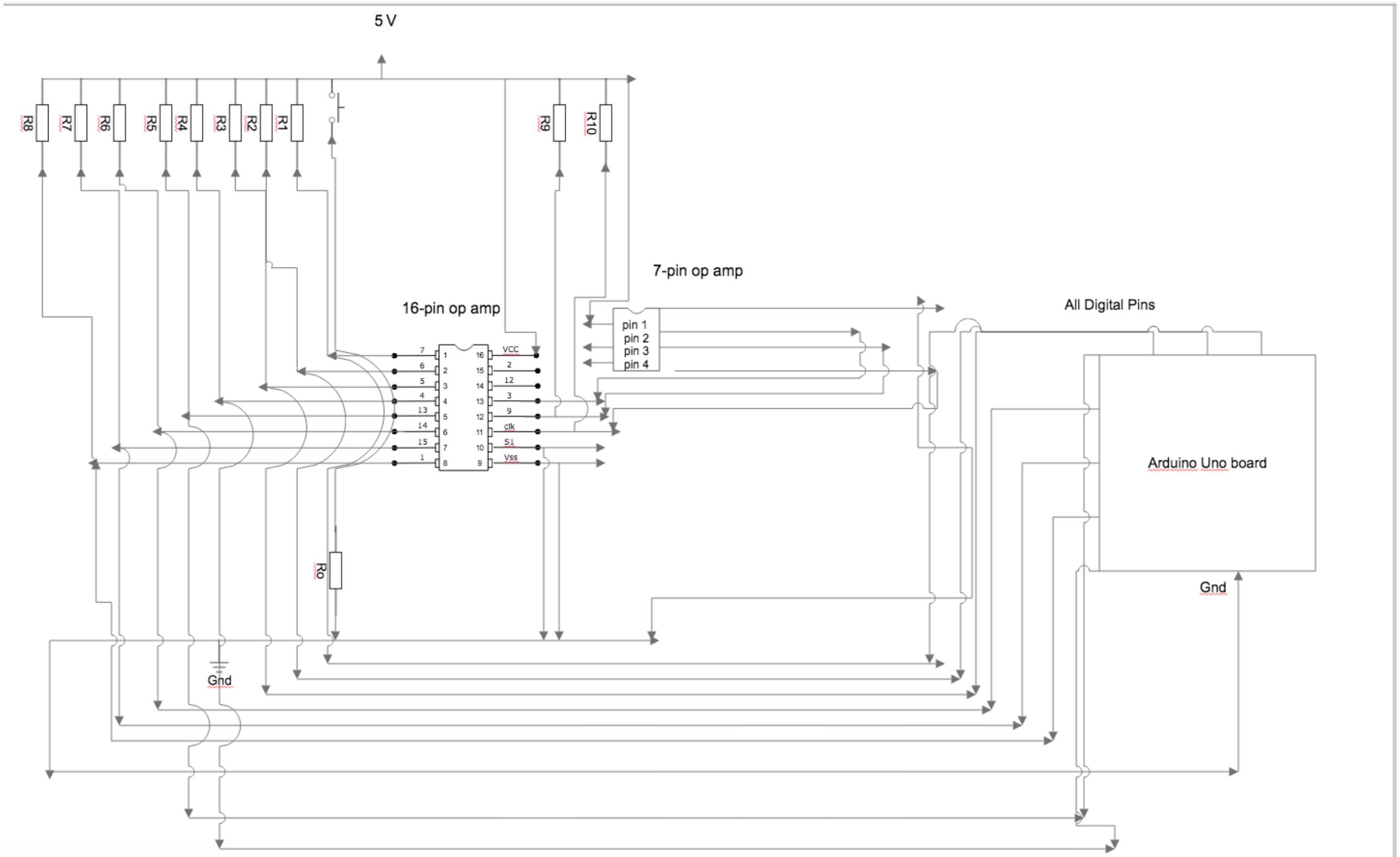
The purpose of this project is to create a simulation for surgeons in training to use for practice. To that end, a Kinect type system will be built and paired with a VR system to simulate the operation room in the point of view of the user. The functional requirements of this project are for the Konect to have a positioning error of +/- 2 cm, to have a minimum lag response in the feedback system and to have accurate calibration. Additional requirements are for the Konect and VR to be easily movable and easy to operate.

The design of the project consists of two circuit schematics for the hardware section. The first represents the circuitry for the Konect sensors. The second represents the circuitry for the Konect servo motor, which rotates the Konect to follow the user's movement more precisely. A flow chart representing the software side of the project. Microsoft Kinect's SDK is very flexible in the sense that it supports C++, C#, and VB.NET. With the virtual reality environment tentatively planned to be programmed in Unity using C#, Microsoft's Kinect makes and ideal candidate as backup hardware solution in the unfortunate situation where the group's Konect hardware fails.

A gantt chart and summary table have been made to keep the team on track for deadlines, as well as keep the team organized to schedule meetings with project adviser. Testing and evaluating the overall project will be done multiple times throughout the course of building it. The hardware will be tested by checking the voltage and current values of the circuit and simulating the desired results, using Matlab, to avoid any potential failures. The projects code will be tested in real-time while simulating the virtual reality environment in Unity software. This is also known as the "functionality test", which includes functions such as proper physics for simulation-object collisions, and operational code. This will help the team to make sure that the accuracy of the movement inputs are valid.

With the proper planning and organization, the team is looking forward to researching and developing this Konect system with VR capabilities next year.

# 11 Appendix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R3
R2
R1
R9
R10
7-pin op amp
16-pin op amp
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pin 2
pin 3
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All Digital Pins
VCC
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S1
Vss
Arduino Uno board
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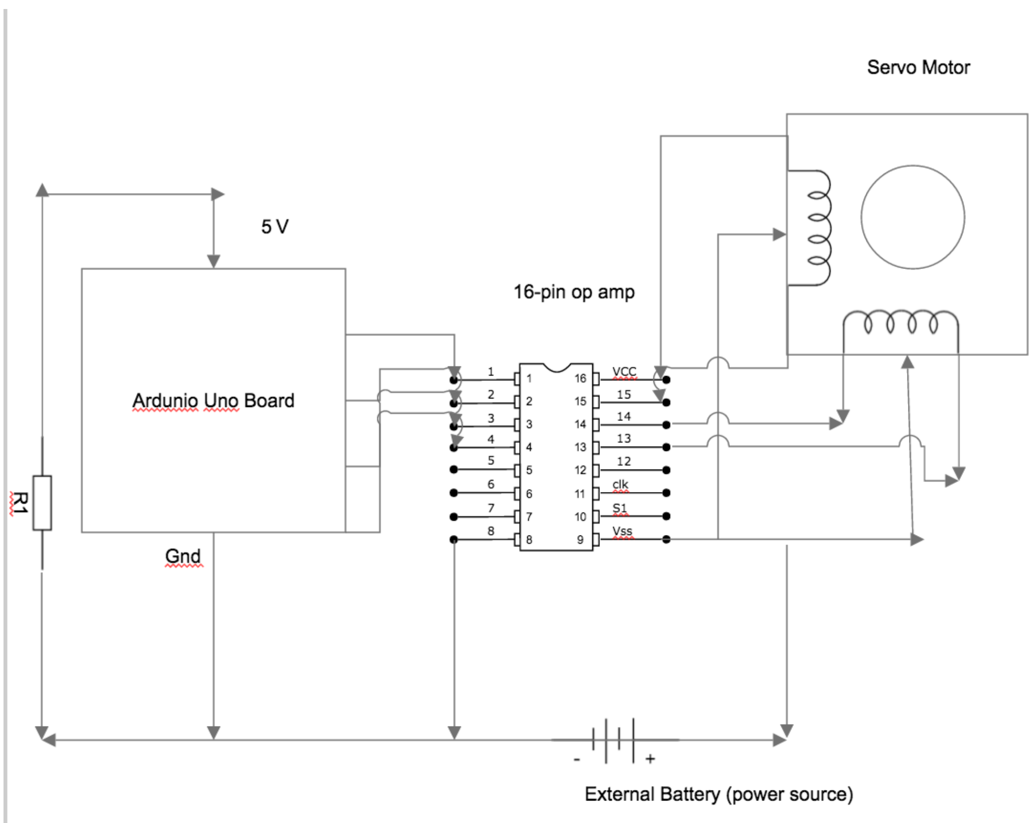
Gnd
Gnd


Servo Motor
5 V
16-pin op amp
Ardunio Uno Board
VCC
clk
S1
Vss
R1
Gnd
External Battery (power source)

# 12 Bibliography

## References


[1] "The future of surgery: Less cutting, more robots."

[2] "The future of surgery is robotic, data-driven, and artificially intelligent."

[3] "Surgical simulation training: Is virtual reality the future of surgical training?"

[4] "Microsoft kinect-based technology for vascular surgery now being extended to neurosurgery."