## **Purdue ECE Senior Design Semester Report**

## **(Team Section)**

| **Course Number and Title** | ECE 47700 *Digital Systems Senior Design Project* |
| --- | --- |
| **Semester / Year** | Spring 2022 |
| **Advisors** | Phil Walter |
| **Team Number** | 2 |
| **Project Title** | VRm |

| Senior Design Students – Team Composition | | | |
| --- | --- | --- | --- |
| **Name** | **Major** | **Area(s) of Expertise Utilized in Project** | **Expected Graduation Date** |
| Brian Latimer | CompE | Unity | Spring 2022 |
| Matthew Wen | CompE | Raspberry Pi, Google Cloud | Spring 2022 |
| Emma Clary | CompE | Microcontrollers | Spring 2022 |
| James Donnelly | CompE | PCB Design | Spring 2022 |

**Project Description:** Provide a brief (2-3 page) technical description of the design project, as outlined below:

1. Provide a general description of the product to be delivered by this design project.

## VRm is a Virtual Reality project that allows a user to control a physical robot arm via a VR simulation. The VR user will control the movement of the robot arm by manipulating a target with the controller, and the simulated arm will try to reach that target's position and orientation. Our solution allows for greater control of the robot arm compared to similar projects due to the increased range of motion from the extra joints and VR controllers. VRm allows users to complete tasks naturally in an environment that is unsafe and unsuitable for direct human interaction.

1. What is the purpose of this product? For whom is it intended?

## The purpose of this project is to allow a user to be able to remotely control a robotic arm, in a way that is natural to the user. The robot is intended to be used for professional use, as it is meant to be used in potentially unsafe or unsuitable locations for humans.

1. Describe how the engineering design process used to create your product was utilized in this project. Include how you were able to develop and conduct appropriate experiments, analyze and interpret data, and use engineering judgment to draw conclusions related to the development of your product.

## The engineering design process was followed throughout the duration of the project, starting from its conception during our brainstorming phase and ending with our final implementation. We did extensive research into what problems exist that could be solved with a robotic arm and what current solutions exist, as well as how our idea of a VR controllable robot arm could be used to better solve these problems. Once we agreed on our final idea, we began to plan the things we needed to buy, the steps we would need to take during assembly, as well as assigning tasks to team members. With this detailed plan in place, we were now ready to begin the development and prototyping process. We began with limited functionality, starting with the controller app that came with the arm, and using a VR simulation. Over time, we began to increase functionality through adding a working server, controlling the arm through a development board, and finally hooking everything up to our PCB for our final implementation. Throughout this testing process, we were constantly looking for ways to improve our project until we saw fit to officially test its functionality in front of course staff.

1. Describe the design constraints, and resulting specifications, incorporated into your product (list a minimum of 3).

## One design constraint established that it must be able to work from any distance via Wi-Fi, which influenced some of the resources that we used. Adding off of that, the second design constraint we had was to minimize the amount of data that we can transfer per second, so the data we were transferring always worked, even when Wi-Fi speeds were slower than normal. The third constraint we incorporated was that the mobility of the robot arm had to match the mobility of a human arm, which meant we had to add an extra joint to the robotic arm. As a result of these specifications, we used Google Cloud to handle Wi-Fi, since the VR simulation and Raspberry Pi can both send and receive data wirelessly using it. For the limiting of data being sent, we settled on 10 packets per second, with around 500 bytes per packet. As for the third constraint, we successfully added an extra joint to allow for that mobility we wanted to achieve.

1. Describe how each of the following factors influenced your design specifications and constraints.

## **Public Health, Safety, and Welfare:** We placed a buzzer to notify people around if there is an error that occurred. Also, when there is a loss in connection, the arm doesn't move to an original position just to prevent surprises or for it to cause further damage.

## **Global Factors:** We wanted to ensure that our project could be used anywhere around the world right out of the box, with the possibility that its remote user could be anywhere else in the world. Our design requires that the product be placed in a location with electricity and wifi availability. This is due to the fact that we need a wall outlet as of now. Since we need a connection to the unity data server, we need a wifi connection. Regardless of where you are in the world, electricity and wifi would all work the same.

## **Cultural Factors:** Regarding the cosmetics of our project, we made sure to keep everything simple and robust. As this is a product intended for a professional environment, we wanted to make sure that it looked professional as well, without anything that may be deemed offensive that would discourage its use in a professional setting.

## **Social Factors:** The biggest social factor we considered was the access to wifi and a VR controller to go with this project. Since our main client would be a company, we feel that this limitation is not that big of a consideration.

## **Environmental Factors:** We kept the manufacturing price, particular for this PCB board design simple. The reason is that the fewer resources we use to do our task, the better it is for the environment. We also used different accessories and took the time to understand how it works and how to embed it into our arm so the accessories could be reused or recycled for different projects. For example, if not a lot of cloud resources are needed, Google Cloud will automatically scale up or scale down based on usage. Or, we used the VR headset from Meta so you can use the VR headset to use for Meta related applications, or for our arm.

## **Economic Factors:** Our design process took into account the absurdly high prices of regular robotic arms. We designed our robotic arm to be a cost-effective solution to the problems robotic arms solve. This would allow for smaller companies and consumers to be able to afford this robotic arm.

1. Describe the appropriate engineering standards incorporated into the creation of your product.

Our device is quite simple in terms of the parts we put to use. We made sure that all of the parts of our project, like the microcontroller, robotic arm, Raspberry Pi, and VR headset all passed the required safety standards. In terms of safety, nothing in our project poses any danger if malfunctioning. One could say that the VR headset might pose the greatest risk due to the onboard battery, but that is unlikely to happen due to the standard the headset needs to meet to be sold. Specifically, we kept in mind that our project would need to comply with FCC and UL standards. The FCC certification is necessary as the remote communication aspect of our project renders it as an unintentional radiator. The UL certification comes into play as our product may be used in the workplace, so it must follow OSHA regulations. We believe that having these certifications will be enough to justify putting our product into our intended market.

1. Describe the final status of your product.

The robotic arm fully works while being controlled by the simulation, and beeps whenever the control by the simulation is lost. We also have a camera mounted on the robotic arm that allows the user to see what the robot arm can interact with. Overall, the arm and arm simulation program worked how we envisioned it to work.

1. Describe the makeup of your project team and how you were organized to establish goals, plan tasks, and meet the objectives of this project.

## For our team, we had Brian Latimer working on the Unity VR application, Matthew Wen working on the Raspberry Pi and Google Cloud, Emma Clary working on the microcontroller and servo drivers, and James Donnelly working on the PCB design. We used a website called Notion to plan out the work we would have to do each week of the semester to get the project done. This allowed us to gauge how much work we were to do each week, so we weren’t left with nothing to do some weeks and too much work other weeks. Whenever something unexpected came up, we would communicate to see who should work on it based on what skills were needed to solve any problems. This organization allowed us to work on the project in an effective way.

1. Did your project require the production of any written documentation other than this document (i.e., manuals, educational materials, etc.)? If so, describe the types, composition, and nature of the audiences for whom these materials were intended.

## Our product has an optional user manual, but all they must do to use the arm is run the VR application. If needed, the instruction manual can be used. The user manual is designed for an audience of those who are not well versed with VR applications, as well as users that encounter problems. The instructional manual describes how to launch the application, turn on the robot, and what is to do if the arm stops working.

1. Describe the types, composition, and nature of the audiences in attendance for the final oral design review. Discuss how you prepared for this audience.

## Our audience will be composed of our peers and professors teaching this class. To prepare for this final presentation, we have made many changes to streamline the demo process. We made the process as simple as possible, and developed alternative demos in case we run into any problems with connectivity during the demo. We did as much as we could with the resources we were able to get our hands on, such as implementing as much as the midterm presentation comments as we saw helped the project. We are sure that we will be able to tackle and extra comments this way.

## **Purdue ECE Senior Design Semester Report**

## **(Individual Reflections Section)**

| **Course Number and Title** | ECE 47700 *Digital Systems Senior Design Project* |
| --- | --- |
| **Semester / Year** | Spring 2022 |
| **Advisors** | Phil Walter |
| **Team Number** | 2 |
| **Project Title** | VRm |

| Senior Design Student Completing This Section | | | |
| --- | --- | --- | --- |
| **Name** | **Major** | **Area(s) of Expertise Utilized in Project** | **Expected Graduation Date** |
| Brian Latimer | CompE | Unity | Spring 2022 |

**Individual Reflection:** Provide a brief (1-2 page) individual reflection of the design project, as outlined below:

1. Describe your personal contributions to the project.

## I designed the VR simulation that computes the arm joint data and sends it to the Google Cloud server. I used Unity, C# scripting, and various Unity packages to build the simulation.

1. Describe how your contributions to this project built on the knowledge and skills you acquired in earlier course work.

## Working with Unity and the C# language was made much easier with previous C experience, like ECE 39595, CS159, ECE 270, and ECE 368. With all of these classes taken, C# was a very natural language to work with.

1. Describe how you acquired and applied new knowledge as needed to contribute to this project. What learning strategies did you employ to do so?

## Before starting this project, I had no experience with Unity. To gain the experience needed to complete this project, I did a lot of tutorials for Unity, both before building the arm simulation and during building the arm simulation. Doing these tutorials, while not directly useful towards building the arm simulation, greatly helped me understand the tools Unity had to then build that arm simulation.

1. Discuss your ethical and professional responsibilities as they relate to this engineering design experience.

## Building this robotic arm simulation required me to think ethically and responsibly about designing the simulation in an accessible format. This included giving the simulation a variety of ways to tweak the simulation to one's liking. This also included not making anything in the simulation too intense (forced moving for instance can cause motion sickness) for those who may not be used to VR.

1. Consider what the impact of the product of this engineering design experience could have in economic, environmental, societal, and global contexts. Discuss how you would make (or did make) an informed judgment as to your product’s impact in each of these four contexts?

## Economically, this product was designed to be as low cost as possible, which it achieves since most other robotic arms go for thousands of dollars. As for an environmental context, there really isn’t any detriment, potentially, the robot could even be used for environmental purposes such as cleaning up dangerous areas if strapped on a mobility robot. Societally this product doesn’t make much of a difference due to its use cases favoring specialized use. Globally, this product could reduce the danger people all over the world are in when faced with potentially dangerous situations. This could also improve the productivity of factories.

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| **Name** | **Major** | **Area(s) of Expertise Utilized in Project** | **Expected Graduation Date** |
| Matthew Wen | CompE | Raspberry Pi, Google Cloud | Spring 2022 |

**Individual Reflection:** Provide a brief (1-2 page) individual reflection of the design project, as outlined below:

1. Describe your personal contributions to the project.

## I was in charge of connecting all components of the project; from the VR headset to the raspberry pi. Brian did additional customization of the software of the VR headset while Emma continued the connection from the raspberry pi to the STM and PCB. In terms of the connection from the VR headset to the server, I ensured that it can send arm data from the headset to the arm, in addition retrieve video streaming data from the server to the VR headset. For the Raspberry Pi, I worked on the data structures and class structure of the class, but not the direct data structures that triggered all the hardware of the arm.

1. Describe how your contributions to this project built on the knowledge and skills you acquired in earlier course work.

## My experience at Morey Corp taught me about message brokers, specifically the MQTT protocol. In addition, there were multiple side projects that I was involved in that helped me learn a little bit more about the tools we used here. Lastly, courses like ECE 264 and ECE 368 help me understand data structures, and writing efficient code. Other courses like ECE 39595J helped me understand object oriented programming. ECE 404 helped me understand security in terms of hosting a server, TCP and UDP handshake, and encryption that we set up for the Project. Compilers or ECE 468 helped me understand docker and more understanding of object oriented programming.

1. Describe how you acquired and applied new knowledge as needed to contribute to this project. What learning strategies did you employ to do so?

## I acquired new knowledge by basically writing small snippets of python and nodejs, and then fully integrating into the project. This technique I used in all my projects when trying to learn how something works; it was previously recommended to me by ECE 264 Professor, Professor Quinn. This snippet technique helped us establish a websocket connection the the VR headset, set up MQTT and ZeroMq with our raspberry pi, and help us set up UDP with our Google Cloud Server.

1. Discuss your ethical and professional responsibilities as they relate to this engineering design experience.

## Some of my experience in ECESS helped me work better as a team. As an ECESS member who has to deal with multiple people who are hard to work with, I took notes on what these ECESS members were doing wrong, and ensured that I didn't act the same way when I'm dealing with this team. I think that's why this senior design went smoothly, because all my members were great team members, it was up to me to improve and act as a good member. In addition, Emma and Brian worked with me before, and they don't have a problem with me talking to them if I have an issue and vice versa; we put in the work to work out any issues if we do run into problems.

1. Consider what the impact of the product of this engineering design experience could have in economic, environmental, societal, and global contexts. Discuss how you would make (or did make) an informed judgment as to your product’s impact in each of these four contexts?

## Our project has multiple applications in terms of doing certain tasks. It allowed people to do remote work, or do work where instead of sacrificing a human life or their arm, we can use a robotic arm to do the same thing and sacrifice the machinery. That helps people economically and socially. In terms of the environment, we made it into a unity application so we reuse other people's hardware. In a global context, we use the resources we have like Google Cloud etc because the goal is to work as remotely as possible.

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| **Advisors** | Phil Walter |
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| Senior Design Student Completing This Section | | | |
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| **Name** | **Major** | **Area(s) of Expertise Utilized in Project** | **Expected Graduation Date** |
| Emma Clary | CompE | Microcontrollers | Spring 2022 |

**Individual Reflection:** Provide a brief (1-2 page) individual reflection of the design project, as outlined below:

1. Describe your personal contributions to the project.

## I was the hardware lead for this project. This means I was in charge of controlling the motors through the use of UART, the buzzer with PWM, and communicating with the Pi using UART. I also modified the robot arm to include an extra 2 degrees of freedom, and added a counterbalance spring to go onto the back of the robot so we could hit the +/- 5 degrees requirement for the PSSC. I was also in charge of the schematic, and debugged the pcb once it came. I found and ordered all of the components for the PCB, and I was also in charge of installing the arm into the final packaging.

1. Describe how your contributions to this project built on the knowledge and skills you acquired in earlier course work.

## I was mostly working in C and Python, which I gained in depth experience in from ECE 39595, ECE 264, and ECE 368. As for the embedded side of the project, ECE 270, ECE 362, and ECE 40862 were invaluable for learning PWM, UART, Timers, interrupts, and many other concepts I used for the project.

1. Describe how you acquired and applied new knowledge as needed to contribute to this project. What learning strategies did you employ to do so?

## My learning strategies for this class mostly included researching online course materials or using open source content online. For example, whenever I ran into issues with the UART for the Raspberry Pi, I found a couple sources that outlined the same issue and I was able to use those sources to figure out what my issue was. I also used a lot of the online documentation through LeArm and Raspberry Pi to debug the servo motor and the Pi. They have great documentation that outlines almost every protocol and possible issue you could have, so that was a fantastic resource. Our course staff was also a fantastic resource whenever I ran into issues with our project, especially our PCB.

1. Discuss your ethical and professional responsibilities as they relate to this engineering design experience.

## Considering our project is meant to be used in a situation that is unsafe for humans, it puts our project at the center of potentially harmful situations if it were to fail. For example, we outlined a potential job as a crane operator or traffic director. In both of these situations, if our project were to fail, it could potentially be fatal to other people or extremely costly to replace damaged equipment. Therefore it places a great responsibility to be professionally and ethically responsible while designing this project. During the design process we had to consider a lot of edge cases and make sure our design minimized the amount of damage it could cause. It was important to design these ideas early so that we could implement it further down the design process.

1. Consider what the impact of the product of this engineering design experience could have in economic, environmental, societal, and global contexts. Discuss how you would make (or did make) an informed judgment as to your product’s impact in each of these four contexts?

## As I mentioned above, our project is meant to be used in a situation that is unsafe for humans. I think the biggest impact of our project will be societal since it will hopefully reduce the number of occupational deaths in the world. We decided that that would be our target impact from the start since it fit so well into our project. We also considered the economical and environmental impact since you would not need to transport workers from site to site every single day. Instead the job could be done remotely, which could reduce emissions and the transportation costs (time/money) for the company.

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## **(Individual Reflections Section)**

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| **Advisors** | Phil Walter |
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| Senior Design Student Completing This Section | | | |
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| **Name** | **Major** | **Area(s) of Expertise Utilized in Project** | **Expected Graduation Date** |
| James Donnelly | CompE | PCB Design | Spring 2022 |

**Individual Reflection:** Provide a brief (1-2 page) individual reflection of the design project, as outlined below:

1. Describe your personal contributions to the project.

## My biggest contribution to this project was the PCB design, fabrication, and assembly. In addition to everything related to the PCB, I assisted with camera debugging with the Pi as well as other minor areas when Matthew, Emma, and Brian needed assistance.

1. Describe how your contributions to this project built on the knowledge and skills you acquired in earlier course work.

## While KiCad and PCB design, along with soldering, were all completely new topics from me, the biggest skill that I used for this project was knowing how to learn. With all of these things that were so new to me, I needed to be able to learn these new skills quickly and efficiently, I had to be able to retain the knowledge so that I could keep building off what I was learning. I did this with KiCad, soldering, as well as understanding the Pi and how it interfaced with the cameras.

1. Describe how you acquired and applied new knowledge as needed to contribute to this project. What learning strategies did you employ to do so?

## Extending from what I said above, a lot of it was about doing my homework before I started, so I wasn’t just blindly trying. This was especially helpful with soldering. Another thing I did was to practice before I tried the real thing. This helped me with KiCad and soldering, where I was able to mess around a bit until I was confident enough to try to start working on the actual project.

1. Discuss your ethical and professional responsibilities as they relate to this engineering design experience.

## One thing we focused on heavily during the research process was researching other existing projects and patents to make sure that we weren’t crossing any legal boundaries. Obviously, violating existing patents would be a serious ethical offense, one that would be enough to completely nullify the integrity and usefulness of our project. This type of research was something that I had never had to do before during an actual design process.

1. Consider what the impact of the product of this engineering design experience could have in economic, environmental, societal, and global contexts. Discuss how you would make (or did make) an informed judgement as to your product’s impact in each of these four contexts?

## One thing that immediately stands out is the possibility that our product could put people out of employment. Instead of requiring a bunch of workers to be on site, we could instead have multiple arms controlled remotely by a single person in a control room. At first glance, this would appear to have a negative effect in economic and global contexts. However, seeing that our product is intended to take people out of dangerous work environments and create an opportunity for them to do physical work remotely, I believe that the benefits of these contexts will outweigh its negative effects. I think the global contexts could see benefits, as it would allow more people to work together across the world in a remote setting. Finally, I think there would also be an environmental gain as the increased possibility of remote work would allow for people to travel less, thus lowering emissions due to travel.