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

## **(Team Section)**

| **Course Number and Title** | ECE 47700 *Digital Systems Senior Design Project* |
| --- | --- |
| **Semester / Year** | Fall 2023 |
| **Advisors** | Phil Walter |
| **Team Number** | 16 |
| **Project Title** | Autonomous Air Hockey Robot |

| Senior Design Students – Team Composition | | | |
| --- | --- | --- | --- |
| **Name** | **Major** | **Area(s) of Expertise Utilized in Project** | **Expected Graduation Date** |
| Abigale Haluska | CompE | Software, integration | Spring 2024 |
| Cameron McCutcheon | EE | Hardware, mechanical | Winter 2023 |
| Jonathon Morton | CompE | Hardware, software | Winter 2023 |
| Joseph Collins | CompE | Software, integration | Spring 2024 |

**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.

## The autonomous air hockey robot is a robot capable of playing against a human player in a classic game of air hockey. This project involves the use of a camera and computer vision to detect a puck and mallet in motion. The data received from the camera is offloaded to a PC, which analyzes the data to identify the puck’s trajectory and predicted location. The PC then determines which direction the mallet needs to move in to block and attack the puck, and sends that data to a microcontroller. Upon receiving data, the microcontroller controls PWM signals to move two stepper motors that are attached to an X-Y gantry system. The gantry system then moves a mallet to block and attack the moving puck. To keep score, two infrared laser beam sensors are used. When a puck is scored, the laser beam is broken, sending a signal to the microcontroller and incrementing the player’s score. Then, the score is sent over SPI to a 7-segment display scoreboard, which displays the updated score. The autonomous air hockey robot is to be used by air hockey hobbyists and enthusiasts, in which it provides individualized training opportunities.

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

## The autonomous air hockey robot is designed to offer air hockey hobbyists and enthusiasts an opportunity to train and play at their own desire. While classic air hockey typically involves two players, this product allows people to enjoy a game of air hockey without the dependence of another human player. Additionally, this game allows users to play at their own convenience which can increase training opportunities. This product is to be used by anyone between the ages of 5 - 80.

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 leveraged throughout the entire duration of this project cycle. The team behind this project began experiencing the process before the semester began, in which we spent a few weeks considering problems and potential ideas and solutions to accompany them. Upon deciding on the problem of air-hockey players needing company to train, the team began considering solutions and conducting patent searches to identify an approach. This was just the beginning of the engineering design process, as ideating opened the door to designing and testing.

While the team decided on the concept of an autonomous air hockey robot early on in the engineering design process, we spent a few weeks in the brainstorming phase as we considered all possibilities for assembling the mechanical robot and integrating that with both the PC and the microcontroller. Upon deciding on an XY gantry system, the team had to decide on a method of interfacing the motors used in controlling the gantry system, as well as the power supply and motor drivers needed to support the motors. We researched different motors along with their applications and ended up deciding on stepper motors given their high precision and torque capabilities. While this decision brought us closer to prototyping, we continued brainstorming methods of interfacing with the other on-board components. When deciding on a method of sending data from the PC to the microcontroller, the team leveraged our experience with serial communications to decide on using a USB - UART converter. Additionally, we considered our previous experiences with the C programming language and the STM microcontroller family to ultimately decide on using the STM32f091RCT6 microcontroller programmed in the C language. A more challenging decision to make was the camera to be used in the final product as none of the team members had experience in computer vision. With that said, we identified our selection criteria to include high frames per second, low latency, and low cost and were able to purchase a camera based on those criteria.

The team spent over a month in the “developing and prototyping” phase of the engineering design process, in which we embraced the process of iteration to eventually reach a prototype that we were comfortable testing. Throughout the developing and prototyping process, each team member took on a specific role and task and applied their area of expertise to their work. The roles distributed included team lead, software lead, hardware lead, and systems lead. The preliminary tasks to be worked on included PCB design, computer vision software development, embedded systems software development, and mechanical design. We decided to approach each task individually and gradually expand our work from the ground up before testing.

When working on the communication protocol to send data from the PC to the microcontroller, several experiments were used to confirm that data was being sent, received, and parsed as expected. While the motors were not delivered at this point in prototyping, we decided to use 4 debugging LEDs to correspond to the four characters of data received from the PC. We also used programs such as RealTerm and TeraTerm to observe the serial port of which data was being sent over.

To experiment with the computer vision, pre-recorded footage of a game of air hockey was used so that software could be developed while the physical robot itself was still being constructed. This allowed us to experiment with different methods of object detection, such as moving object detection versus color detection.

Following the construction of the gantry system and the robot itself, we began slowly integrating all of the components together and testing as we progressed. Throughout testing, the analysis and interpretation of data was critical to our success. To analyze data, we used an oscilloscope and probe different pins on the PCB to observe the signals being sent. This method of data analysis ended up being highly effective for debugging issues with the 7-segment display and SPI, in which we used data analysis to identify an issue of an ineffective data transmission line.

The team is now at a point where the product developed meets the initial expectations and requirements, in which demonstrating the product is the next and final stop of the engineering design process.

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

One major design constraint considered throughout this project is the product’s computer vision and its ability to function in dynamic environments. Air hockey is often played in fast-paced and fluctuating environments. For example, the end users can be expected to bump into the table, in which the overhead camera footage would be unstable. Additionally, it is common for air hockey enthusiasts to lean over the table when playing air hockey, in which their arms and upper body are moving along with the puck. When designing this product, it was imperative that the computer vision can isolate the moving puck even in such versatile conditions. Moving object detection was a considered method in identifying a moving puck, but we ended up deciding on color detection to detect the color of a puck as this was the most effective in differentiating between the puck and its fast-paced environment. Additionally, we added a color calibration feature to the code, in which the software can recognize the puck and mallet in varying light conditions.

An additional design constraint was the speed of the robot. Given that the robot would need to react to a moving puck in real time, this project requirement warranted the need for a high speed microcontroller with numerous timers. Given that the product would need to transmit and receive data as fast as possible in order to avoid any lag or inaccuracy in the robot’s movements, we ended up specifying a minimum clock frequency of 48 MHz, which was satisfied by the STM32f091RCT6.

The final major design constraint to be considered was the accuracy needed for a high-precision robot. In order to effectively block and attack a moving puck, the robot’s mallet would need to move to precise locations on the air hockey table. This led us to establish a product specification of high-precision motors with high-torque capabilities. Given these specifications, the team decided on NEMA23 stepper motors as they are known for supporting substantial loads with little sacrificing of precision.

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

## **Public Health, Safety, and Welfare:**

## Safety was a critical component of establishing our design specifications and constraints. Given the speed capabilities of the motors, the team warranted it necessary that we include limit switches at the ends of the gantry system to ensure that the robot stops moving once it reaches any edge of its half of the table. Additionally, public safety played a role in the inclusion of an emergency-stop button on the player’s side of the table. In the case the motors stall or interfere with the player’s safety, the emergency stop button can be pressed to instantly stop both motors.

## **Global Factors:**

## Global factors did not heavily influence the design specifications or constraints of this project, as air hockey is recognized as a world-wide game. When displaying digits on the scoreboard, the team was restricted to displaying digits in English, which constrains the product from being applicable globally. Additionally, the team only had access to certain cables in which the power cables used in this project are only compatible with US wall outlets, further limiting the product’s relevance globally.

## **Cultural Factors:**

## Athletic culture is often competitive and intense, in which players of all sports train with dedication to improve their performance. This cultural factor was considered when identifying the main design constraints of this product, as the competitive culture of athletes warrants the need for a high-speed and precise robot.

## **Social Factors:**

## Ease of use was the primary social factor that the team focused on when designing this product. In order to accomplish this goal, several systems were simplified for the user. Each of the subsystems in this product were designed to be powered by one central power cord, ensuring ease of use and maximum accessibility. In addition to this feature, the table automatically begins playing after being powered, eliminating any kind of setup requirements. Another large social factor that the team kept in mind while designing the product was maintaining the fun and enjoyable aspects of air hockey. This factor was implemented by including score-keeping functionality and the ability to score on the robot.

## **Environmental Factors:**

## Environmental factors posed significant design constraints for our project. Firstly, our project is approximately 5’ x 6’, yielding a design restriction in which our product can only be used in large spaces. Additionally, our robot uses computer vision to function. This implies that the product must only be used in well-lit spaces. Finally, the motors and camera of the robot had to be mounted upon the table for functionality purposes, meaning that the product is restricted from being used in outdoor spaces where heavy wind or rain might occur.

## **Economic Factors:**

## Economic factors heavily influenced the design constraints and specifications for our project. Given an initial project budget of less than $500, the team was constrained to choosing affordable components. The economic constraint of our budget mostly influenced our decision to choose our selected motor drivers and camera. While the motor drivers that we selected for our project are sufficient, there exist higher-cost motor drivers that would improve the speed and precision of our robot substantially. Additionally, our need for a high frame rate and low latency camera left us with few affordable options, as cameras with these specifications can cost several hundreds of dollars.

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

When prototyping our product, the user’s safety remained a priority in influencing the design and user interface of the robot. Firstly, we focused on developing verifiable software using free open source licenses such as Apache 2, BSD, and PSF. This focus was motivated by IEEE 1012, which is focused on software validation for supporting the safety and reliability of software embedded in microcontrollers. Additionally, the team considered IEEE 1872, which is a standard focused on ensuring safety when designing interactive robots. In order to incorporate this standard, the team implemented an emergency stop button as well as limit switches that prevent the robot from reaching beyond its intended field. Finally, the team considered IEEE 1920, a standard that encourages shared control between humans and robots, by giving the human player full control over the robot. The human player is able to turn the robot on and off by pressing a button or flipping a switch, ensuring that the interaction between human and robot is as controlled as possible.

1. Describe the final status of your product.

At this point in the design process, the team successfully prototyped an autonomous air hockey robot that can react to a puck in motion using computer vision. The entire mechanical system is fully prototyped and packaged. A gantry system composed of six pulleys, three linear guide rails, and two stepper motors was built and interacts with two motor drivers that are mounted to the bottom of a second-hand air hockey table. The motor drivers are connected to a 24V power supply, which is also mounted to the bottom of the air hockey table. Each goal has a puck shoot which houses IR sensors that are mounted and wired to a PCB that sits in the middle of the table. The PCB is mounted to a 3D printed container to ensure that all electronics are out of reach, and all wires are contained in plastic tubing to avoid electronic exposure. The PC that analyzes data is stored underneath the table on a shelf. Finally, the camera is attached to the preexisting scoreboard so that it looks down onto the surface of the table.

In addition to a complete mechanical build, all expected interfacing is complete except the housing of the 7-segment display/scoreboard. When a puck is pushed towards the robot’s side of the table, the robot is able to attack the puck by moving in its direction. Due to time constraints, the robot is not fast enough to beat an average human player at air hockey; however, it is capable of competing in a game of air hockey. The team plans to continue optimizing the speed following our demonstration.

When a puck is scored, the IR sensors successfully detect the score and relay that data to the microcontroller so that the player’s score is incremented. While the team can successfully interface with the 7-segment display to show the score, the scoreboard is not yet mounted as we discovered that long wires lead to poor data transmission. The scoreboard works as expected with short wires, but the team is currently working on overcoming the length constraint so that the scoreboard can be mounted above the table.

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.

## The team is composed of one electrical engineer and three computer engineers. The electrical engineer took the role of hardware lead, in which he focused on PCB design and mechanical design. This left the computer engineers to focus on embedded software and computer vision. One team member specifically focused on computer vision given the goals of the project, while the other two team members worked alongside the hardware lead to program the microcontroller on the PCB and interface with the components. To remain organized, the team used Microsoft Teams to communicate and used GitHub to share progress. Within our Github, each team member had a personal folder that contained their specific work. When establishing goals and planning tasks, the team communicated via Microsoft Teams chat. To ensure that the team met the objectives of this project, the team divided up the workload and created an initial project timeline to refer to.

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.

When working on this project, the team produced several documents related to the analysis of the robot’s design. In particular, we wrote a functional specification document which focused on the project’s functionality as a whole as well as the interaction between all components involved in the project. Additionally, the team wrote an electrical overview, software overview, and mechanical overview to solidify each of our designs. A component analysis was also written to support the decisions that were made when purchasing the components used in this project. Finally, a legal and regulatory analysis was written to analyze the project’s relation to any federal standards or published patents.

Outside of these documents, a reliability and safety analysis was conducted to verify that the project maintains a focus on the end user. An ethical and environmental analysis was also conducted to get a better understanding of how ethical and environmental constraints played a role in the development of this project. Finally, a user manual was written to ensure that the project is tailored towards the end user.

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.

## The final oral design review will occur in front of an audience composed of course faculty and other students in senior design. To prepare for this audience, the team is working on implementing the software needed to stop the robot if the limit switches are triggered. This will improve the safety of the robot. Additionally, the team focused on concealing all exposed wires and electronics to lower any risk to the end user.

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

## **(Individual Reflections Section)**

| **Course Number and Title** | ECE 47700 *Digital Systems Senior Design Project* |
| --- | --- |
| **Semester / Year** | Fall 2023 |
| **Advisors** | Phil Walter |
| **Team Number** | 16 |
| **Project Title** | Autonomous Air Hockey Robot |

| Senior Design Student Completing This Section | | | |
| --- | --- | --- | --- |
| **Name** | **Major** | **Area(s) of Expertise Utilized in Project** | **Expected Graduation Date** |
| Abigale Haluska | CompE | Embedded software, integration | Spring 2024 |

**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 took on the role of team lead for this project, which gave me the opportunity of working on several different parts of the project. As the team lead, I worked to ensure that all assignments were submitted and all deadlines were met. Additionally, I facilitated communication between the group and assigned tasks when warranted. Outside of organization, I supported the team in mechanical design as I have access to an on-campus lab that provided us with 3D printed and resin curing machines. With this access, I designed and printed several parts of the project’s packaging, including prototyped motor mounts, puck shoots, scoreboard extenders, and the PCB mount.

My interests are primarily in firmware and IoT, which led me to focus most of my time to developing the final software that was uploaded to the PCB for demonstration. In particular, I wrote code within an STM32Cube project to configure all necessary peripherals on the microcontroller. Within this project, I also wrote code that controls the PWM signals sent to the microcontroller depending on the data received over UART. This code involved modifying a UART/DMA callback function as well initializing two timers to trigger interrupts that allow the motors to accelerate and decelerate when moving. An additional timer was initialized to trigger an interrupt that multiplexes with the 7-segment display to display the players’ scores. The code also handles the interrupts triggered by both IR sensors. Finally, I wrote a small python script that sends serial data to the PC. The rest of my contributions focused on PCB assembly and soldering.

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

## This class has been my favorite course to take throughout college because of how much I was able to learn through hands-on experiences. I learn best through projects and labs, so this course was great for solidifying what I have learned in previous courses. In particular, my contributions in this class built upon what I had learned in ECE362 (a microcontrollers course) by offering me flexibility and freedom when interfacing with a microcontroller. I learned the fundamentals of SPI, UART, and DMA in ECE362, but this class allowed me to learn how to apply those fundamentals when designing a project. Additionally, I am currently in a software for embedded systems course, which covers topics similar to what I applied in senior design. Overall, senior design helped me gain confidence in understanding embedded systems and software development, and I feel more excited to be a full-time firmware engineer after taking this course.

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?

## Prior to this course, I had no experience in PCB design and assembly. While another team member managed the PCB design, I found this course to be super useful in supporting my understanding of PCB development. In this class, I learned how to solder small PCB components of varying packages using varying soldering techniques. While I had little soldering experience before this class, I ended up soldering all of the discrete components on the PCB as well as most of the connectors. I referenced the course material and online forums to improve my soldering techniques. Additionally, I acquired more knowledge in navigating STM32CubeIDE and debugging firmware. I mainly referenced online forums and manuals to improve my debugging skills.

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

## When considering my ethical responsibilities in the context of this engineering experience, I would describe my commitment to product safety to be the highest ethical responsibility that I had in this project. I have never worked with a project of such a large scale, so this experience emphasized the importance of safety standards in human-robot interaction. Additionally, I held the professional responsibility of communicating with my team and managing the team’s obligations.

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 team designed a neat project that can have an impact in several contexts. I would say that our product is the most relevant to societal and global contexts as it relates to entertainment and gameplay. Societal norms continue to integrate technology and engineering into human interaction, in which I would make an informed judgment that this project can encourage seamless interaction between humans and robots. Socially and societally, this product can also encourage people to challenge themselves by practicing a game to improve their performance. Globally, this product might be capable of inspiring students abroad to apply their knowledge and skills to create something interactive and engaging. When considering the economic impact of this product, I can assume that this product might impact the arcade and gameplay market in some way. While I am not confident in whether that impact would be in favor or against the arcade and gameplay market, I can make a judgment that it would influence the performance of existing air hockey tables. Finally, when considering this project in an environmental context, it can be assumed that the production and manufacturing of such a project would lead to extensive waste. Because of the power supplies and components used in this project, it would be important to consider the most environmentally efficient methods of manufacturing before initiating that process.

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

## **(Individual Reflections Section)**

| **Course Number and Title** | ECE 47700 *Digital Systems Senior Design Project* |
| --- | --- |
| **Semester / Year** | Fall 2023 |
| **Advisors** | Phil Walter |
| **Team Number** | 16 |
| **Project Title** | Autonomous Air Hockey Robot |

| Senior Design Student Completing This Section | | | |
| --- | --- | --- | --- |
| **Name** | **Major** | **Area(s) of Expertise Utilized in Project** | **Expected Graduation Date** |
| Cameron McCutcheon | EE | Mechanical Design  PCB Design  Motor Power Electronics | Winter 2023 |

**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 have had my hand in most elements of the project. The mechanical design, PCB, and motor power systems were all designed and mostly built by me. Specifically, I created the mechanical design from the ground up for the application, built and mounted 95% of it, and am continuing to oversee the powering of the system. I also did the entire design of the primary schematic and PCB for the project and soldered ~50% of the components. Finally but most importantly, I also designed and assembled the power distribution systems for the motors, PCB, and 7 segment display in each of their respective packages.

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

I’ve used nearly all of my prior professional and academic work in working on this project. For the mechanical and PCB design, I drew inspiration from an internship I had freshman year. For the motor power systems (and selection of the motors themselves), I’ve greatly built upon what I learned in ECE 321. As I found out today, the power systems for stepper motors in a high inertia context need to have significantly more overcurrent protection than I expected. The power electronics across the board (PCB power distribution, stepper motor drivers, LDO’s) have been a great addition to knowledge from ECE 20001 to 32100.

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?

This semester I have had to read more datasheets than ever. I’ve spoken to every one of my graduate student friends to get their opinion on a relevant facet of the project. I’ve always been of the opinion that doing something is the pinnacle of understanding it but this semester I unlearned that lesson. Rather, doing something with the guidance of an expert is the best way to truly understand a topic. From Chuck, Joe, and other professors I have learned countless lessons from metal fabrication to power electrons and then reinforced that knowledge by immediately applying it to our project.

I’ve also created what I call the table learning method. In the table learning method, you and an expert get under an air hockey table and, once they’ve had a chance to examine your system, they point out the dumb mistake you made. Then, as you sit embarrassed under the table with them, you reinforce your knowledge through embarrassment as they struggle to get out from under the table.

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

This project allowed me to truly understand the ethical ramifications of safety in an engineering context. The motors have enough torque to rip an arm off if allowed. Designing and implementing a safe system in this context has been a definite challenge given the time allowed. Time crunches, the safety of the team members, and other factors have forced me to recognize the importance of ethical design in the context of safety of the gantry system, and I believe this experience more than any class has taught me what it means to be an ethical engineer.

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?

Economic Impact:

I do not believe the autonomous air hockey table will have any large scale economic impact. As this system is designed for a small group of hobbyists, the only groups willing to buy this will be a small facet with expendable income. The materials, similarly, are not significant enough to warrant a large economic impact.

Environmental Impact:

Once again, there are relatively few environmental impacts as a result of this project. Materials are mostly recyclable and do not yield significant environmental impacts when created.

Societal Impact:

For the third time, there is relatively little societal impact for this project. Greater society has yet to widely play air hockey (namely being played at arcades and hobbyist settings). As such, the only societal impact will be limited in scope to hobbyist groups and the extremely small professional space.

That being said, the air hockey world champion has expressed interest in a training robot. The ramifications of this project in this scope could be larger.

Global Impact:

There is again, very little global impact to this project. While it may bring more players into the game if widely accepted, it is much more likely to have small scale impact on hobbyist groups.

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| Senior Design Student Completing This Section | | | |
| --- | --- | --- | --- |
| **Name** | **Major** | **Area(s) of Expertise Utilized in Project** | **Expected Graduation Date** |
| John Morton | CompE | Hardware and Software | Winter 2023 |

**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 contributions to the project were doing hardware, mechanical design, and software. I designed the puck retrieval system with the IR sensors, mounted limit switches and their housing, wired up a lot of the underside of the table, and contributed to the mechanical design of the table with Cameron. I contributed to the software on the microcontroller and helped out in many different ways on most aspects of the table. I did the initial testing with the motors and figured out how to interface with them.

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

## A lot of my prior knowledge came together on this project and connected. I was able to use knowledge from the microcontroller’s course in 362 for helping out with the programming on the microcontroller. SPI and UART were also great to have known from 40862 before coming into this project and helped with applying them to this project. I had done some 3D modeling in prior coursework which helped out greatly with the designs for the puck return system and the limit switch housing. Knowing how to debug circuits from 2K7 was also a great help when it came to things not working.

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 a lot of mechanical knowledge from working with Cameron and Chuck. I had some prior work with mechanical tools and know-how from other projects, but working with them in a design context for something much stronger and dynamic like this robot was a whole new level. I picked up on what they were saying and learned a lot from what they were doing. I also learned a lot about how motors work and what it takes to drive them. This came from both in class lectures and reading datasheets about them.

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

## First and foremost, the biggest responsibility of this project is safety. The motors can spin very fast and operate on a 24V power supply, so there’s a lot of powerful systems in place here. There are several safety features with limit switches, software tests and an e-stop on the side of the table to cut power. This can be especially important with a human player interacting with the robot, so it’s important to keep the player safe.

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?

## Overall, the air hockey robot is going to target air hockey enthusiasts and keep a limited market. Arcades and other venues would also have some interest in having an air hockey robot. The robot can cut into a market for these areas and dominate with little competition. Environmentally, there is a large upfront cost with the materials to build the table, gantry system, PCB, motors, and everything else that goes into making something like this. Once the table is in use, there will only be some electricity usage and noise pollution. The impact on the environment will remain minimal while in use. After the table is thrown out, parts of it can be recycled like electrical components and other materials, but the rest of it will end up in a landfill. Societally, the impact the table has depends on the group. Enthusiasts will have a great time playing and training against the robot and younger kids will also have fun against it. It can be a good introduction to robotics and STEM for kids at a young age to spark their curiosity and get them interested. Globally, a product like this could get people into robotics and provide them with a learning opportunity to make something themselves. Other hobbyist groups other than air hockey could also make a similar robot for their own groups as well. Overall, there is potential for some impact in all of these areas, but the market itself isn’t big enough to confidently say that this will reach a wide audience and make a big impact.

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| **Advisors** | Phil Walter |
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| Senior Design Student Completing This Section | | | |
| --- | --- | --- | --- |
| **Name** | **Major** | **Area(s) of Expertise Utilized in Project** | **Expected Graduation Date** |
| Joseph Collins | CompE | Software | Spring 2024 |

**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.

## As the software engineer for this team, the main contributions that I made to this project were in the software area. Specifically, most of my time was dedicated to the writing of code that focused on visual analysis. This included puck and mallet tracking, color calibration, puck location prediction, and instruction forwarding. Part of this process was also working with the team to establish the logic for the system. I also assisted in the writing of some of the code on the microcontroller.

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

## As a large portion of my work focused on software, I utilized the knowledge and skills I obtained from previous courses such as ECE 264 (Advanced C Programming) and ECE 368 (Data Structures). From these courses I gained the ability to write efficient and accurate code which was important as our project is one that is heavily time dependent. Although the visual analysis software was not written in C, I used the methods for effective code learned from those classes. The visual analysis software was however written in python, which I have had plenty of experience using in classes such as ECE 20875 (Python for Data Science), ECE 404 (Computer/Network Security), and ENGR 161/162 (FYE). I was also able to reference the subjects I learned in ECE 362 (Intro to Microcontrollers) and ECE 40862 (Embedded System Design) to understand the communication protocols utilized in this project such as UART and SPI. In addition to the technical skills obtained in my ECE classes, I was also able to pull from the soft skills that I learned. Communication and teamwork were large factors in this project, and I was lucky enough to have experience utilizing these traits in earlier classes.

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 beginning this project, I had little to no experience with many of the aspects present in the final product. For example, I had never attempted to learn anything about computer vision, which was a major component of this project. In order to address this lack of knowledge, I consulted many online resources. I read through plenty of documentation in order to ensure that I fully grasped the content and then wrote code to make use of this newly learned information. I made sure to apply new concepts independent of the actual project to ensure the functionality of individual components. Then, once I was confident in an individual component, I would integrate it into the project. The most important thing that I did to acquire and apply knew knowledge was give myself time to learn concepts fully.

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

## One of the major ethical responsibilities that I held throughout the course of this project was avoiding plagiarism and using authorized libraries. This is quite a prevalent factor to keep in mind when writing software, especially when using well known libraries, such as OpenCV. While writing the visual analysis software, I was very careful in making sure the solution was my own. I also read through OpenCV’s documentation regarding commercial use. OpenCV is under an open-source license that allows developers to use it in commercial products, meaning this project was able to make use of this external library.

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?

## From an economic perspective, the Autonomous Air Hockey Robot would not have a large global effect. This product is aimed towards hobbyists who want to play air hockey, which is not a huge demographic. From an environmental standpoint, this table will have quite a small effect. The majority of the effect will come from the manufacturing of the pieces used in the project, such as the printed circuit boards and electrical components. The actual use of the product will have an impact of even less magnitude. From a societal perspective, I believe this product will benefit air hockey hobbyists and enthusiasts. Although a small group of people, it is quite a resource for these individuals, as we have now enabled them to practice without the need for a second player. Even for people who are not air hockey enjoyers, it is still an interesting product for people who are interested in autonomous machines. Finally, from a global standpoint, the Autonomous Air Hockey Robot will not have a large global effect. This product is aimed towards a small demographic, which means it would be difficult to have an effect of that magnitude. However, this product can be used by anyone around the world meaning that we could have a wide, yet small group of users. I believe to obtain a more accurate judgement for each of these four contexts, it would be beneficial to consult professionals in each of these fields. For example, environmental engineers could be brought onto the team to audit our project with respect to how environmentally friendly our product is.