HoloMon: A Holographic Entertainment System

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Abstract — Holographic designs can be implemented in various ways. The implementation utilized for the following project is Peppers Ghost. Object recognition from AI has been around since 1956. Once penetrating the most basic form of recognition, the door to the AI world was opened to develop more complex algorithms. The ability for a machine to be able to learn and construct feedback to its user has proven itself to be one of the most useful inventions in the history of mankind. Mobile Application software has been implemented since the first phone. These Applications can be useful when interacting with other devices. For example, a Tv can be controlled by a phone application that acts like a TV remote. Similarly, this project will be utilizing an application to control their entertainment system via the BlueTooth module. This entertainment system will be developed by utilizing all of these three implementations listed: Mobile Application, Gesture Recognition, and Pepper's Ghost illusion.

Index Terms — holography, design automation, programming, object recognition, machine learning algorithm, printed circuits.

I. INTRODUCTION

Holograms have been the spotlight of entertainment since the mid 1900's. Many different industries have utilized this entertainment idea which was a magnet for customers. Pepper's Ghost illusion, utilized in this following project, is one of the most simple ways to implement this Holographic design. One industry to utilize this implementation is Disney, Magic Kingdom. The Haunted House ride incorporates this concept projecting ghosts into the air. Holographic designs almost bring out a curiosity and excitement from its users. Another concept that brings out nostalgia is the classic game Pokémon. This game, played by millions, brings out a child-like excitement in almost all ages. One of the attractive features of the project is allowing its user to choose which Pokémon they would like to interact with. This project is to incorporate both of these concepts while also making the game interactive with its user. The design would be considered a home entertainment system that could be easily accessed from the users phone through a mobile application. For future sections of the paper, whenever the term "HoloMon" is brought up, it refers to the holographic Pokémon that is interactable. Below is Figure 1 which visualizes an early concept art of HoloMon and acts as a size comparison of an average human compared to the project.

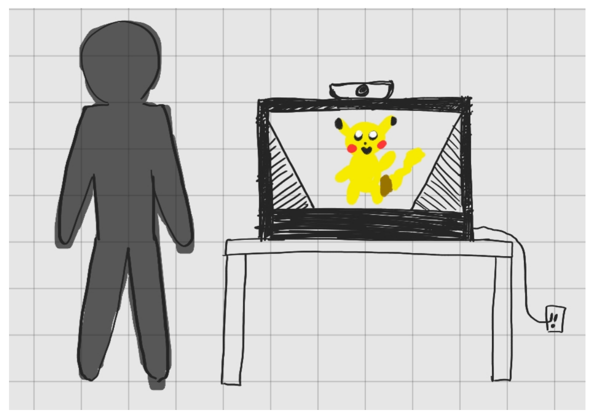

Figure 1. Early concept art of HoloMon.

II. SYSTEM COMPONENTS

A. Illustrations

The illustrations for the project were created through a tool called Sketchfab. 3D models can be created and used by any users who desire to create some form of 3-dimensional art. The models would be broken into skeletons and then by controlling the timing were able to adjust movements of the Pokémon. These movements would become vital to this project so that the Pokémon would be able to be seen as more realistic to the user. In doing so, this would unlock a more intentional interaction base with the HoloMon and its user. The four Pokémons being used are: Pikachu, Swinub, Arcanine, and Gengar. The hope is to have these four Pokémons interact with the user. Each one of these figures need to be broken down into their skeleton and given their movements to do according to the gesture done.

B. Gesture Recognition

In the project design, the team opted to use a camera-based gesture-recognition with a machine learning component with a usb webcam to interact with the HoloMon. This way, the process of interacting with the hologram would feel more natural and was more cost-effective than wearable-based gesture-recognition. Wearable-based gesture-recognition would require the user to be tethered and some kind of equipment to act as the interface between the user and the project. With camera-based gesture-recognition, it is possible to only use a usb webcam and machine learning to recognize the hand data. The Raspberry Pi 4 Model B is the primary controller of the gesture recognition sub-system, and more technical details of this implementation can be found in section 5. Below is figure 2, which visualizes the concept of the gesture-based interaction with the HoloMon.

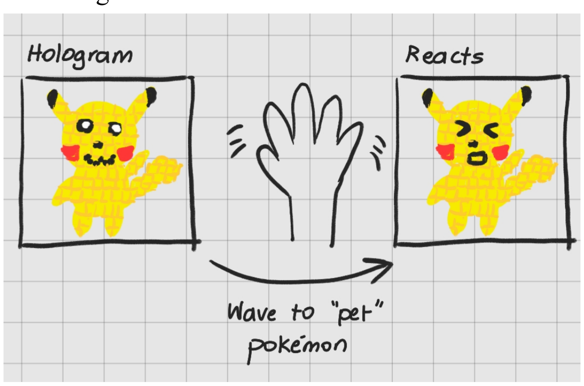

Figure 2. Concept of gesture-based interaction.

C. Mobile Phone Application

The mobile application is one of the first ways any user would interact with the HoloMon project. The user would login to our mobile application on their phone or create an account if they are a new user. After logging in, the user would see the Pokémon selection screen of up to 4 different Pokémon: pikachu, swinub, arcanine, and gengar. Once the user taps "GO" the mobile app sends data to the Raspberry Pi via a bluetooth connection and in the background there are more Python scripts running but what the user sees is their chosen Pokémon displayed as a HoloMon. The images below in Figure 3 describe the initial wireframes used to implement the UI/UX for the mobile application which was utilized in the final design for the mobile application implementation. The left image describes the register page with a few more fields in the final version. The right image represents the wireframe for the Pokémon selection screen.

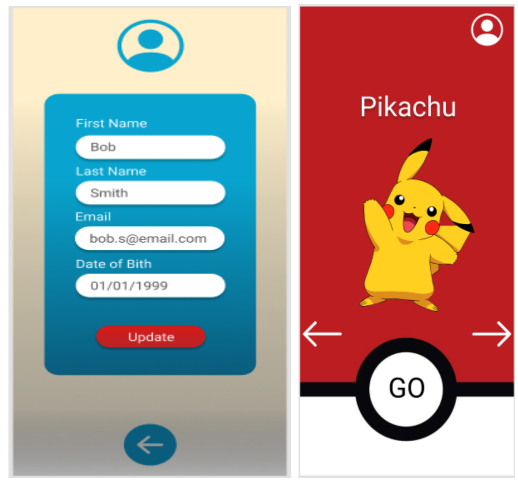

Figure 3. HoloMon Mobile App.

D. Power Efficiency

The main objective of the PCB is to optimize the efficiency of power usage for the project. With the Raspberry Pi doing a bunch of different iterations and controlling a majority of the programs. The battery aspect of the PCB has been decided as not useful in this specific project. This means, not only will the Raspberry Pi be in charge of itself and all the programs it will be running, it will also be powering the PCB. One restraint was the amount of power needed to keep the Raspberry running. It was concerned that the Pi may be overworked and then overheat, then destroying the component. In order to avoid this, it was thought that maybe the best option was to control something from the PCB to turn off one device when the user was not using it. The decision was to turn off the webcam when the user would not be using it. This would help the Raspberry Pi to not be overworked or overheat and create a more safe environment for it.

E. Housing Unit

To create an environment capable of making the HoloMon appear luminous, the interior portion of the housing unit will be spray painted black. This will create an ambiance and a more virtual setting for the Pokémon. The housing unit will be created to fit the TV monitor that will be inside. It must also be large enough to fit in the 4 sheets of plexiglass that will create the 3-D like image to the user. In order to ensure these dimension requirements are met, the housing unit is to be laid out and designed through CAD. Since this game will be most likely utilized inside, and will not be mobile, the housing unit will be composed of a wood structure. This will ensure durability and the texture is easily painted. The whole process of assembling the housing unit structure will be easily done so through a circular saw and screws. The only concern in doing everything with wood is the possibility of splitting wood. Other than this restraint, the wood is a perfect fit for the assembly.

Figure 4. Front CAD Model of Housing Unit.

III. SYSTEM CONCEPT

While explaining the subsystems in the previous section is important, understanding the entire concept is equally critical. The entire HoloMon project functions together as a holographic entertainment system that a user can interact with using gesture-based recognition and machine learning. The emphasis is on the interactions since the system constantly requires user input in order to function. The process starts from boot-up, where the system requires some time to initialize the Bluetooth functionality on the Raspberry Pi as well as running subprocesses for different Python scripts that have different specifications. The main logic controlled through the Raspberry Pi starts at a gateway script that opens operating systems subprocesses to run 3 main scripts: 1) connects the machine learning model to the local assets, 2) connects the bluetooth mobile application to the local assets, and 3) connects the motion sensor data to the usb webcam. Once these scripts are running, the rest is influenced by user input. Once the PCB and motion sensor detect motion within 3 meters of the sensor the usb webcam turns on. While the system is waiting for user input, it displays a looping video of a pokeball with the project name. Once the user has the mobile application on their phone, they select the Pokémon they want to see in the hologram. After the Pokémon is selected, the data is sent from the mobile application directly to the Raspberry Pi through the bluetooth and changes local assets. With the usb webcam active, the user can flash different approved gestures that will allow them to “interact” with the hologram. The system will change local assets based on the number of fingers they hold up to the webcam for approximately 5 seconds with a success rate of changing to the right asset about 30% of the time based on testing.

VII. EXISTING SIMILAR PROJECTS

There are similar products on the market that are within the realm of Pokémon and holograms. One example product is Pokémon GO, a free-to-play mobile app for Android and iOS devices that Niantic developed and released in 2016. The main similarities between this app and our project is the fact that it uses Pokémon but in a way such that its user interacts with its environment. There are also some features within Pokémon GO that allow them to have basic interactions with the Pokémon caught, such as petting and feeding [2]. A commercial product more similar to the holographic display that is part of the project is one called Olomagic. They are a company that produces holographic displays that generate 3D images in mid air. Their main functionality is to provide a new way of “marketing and communication” with a target audience of retail establishments, conferences, shopping centers, and events [3]. Another similar commercial product to Olomagic is SolidLight™ by Light Field Lab. Their product is not a hologram but more so a real hologram that accurately moves, refracts, and reflects in physical space by drawing images directly in mid-air instead of projecting a 2D image into a 3D space [4]. Ultimately this is the goal that the HoloMon team strives for, but the inherent costs were considerably out of budget for the proof of concept project. After doing much research, it is suggested that many products that are holographic lack the interactivity that the HoloMon project aims to realize through its novel combination of autostereoscopic display (a 3D display not requiring eyeglasses or extra equipment) and gesture-based interaction. Below is Figure 2 which visualizes the system data.

two different types of communication from the PCB to the

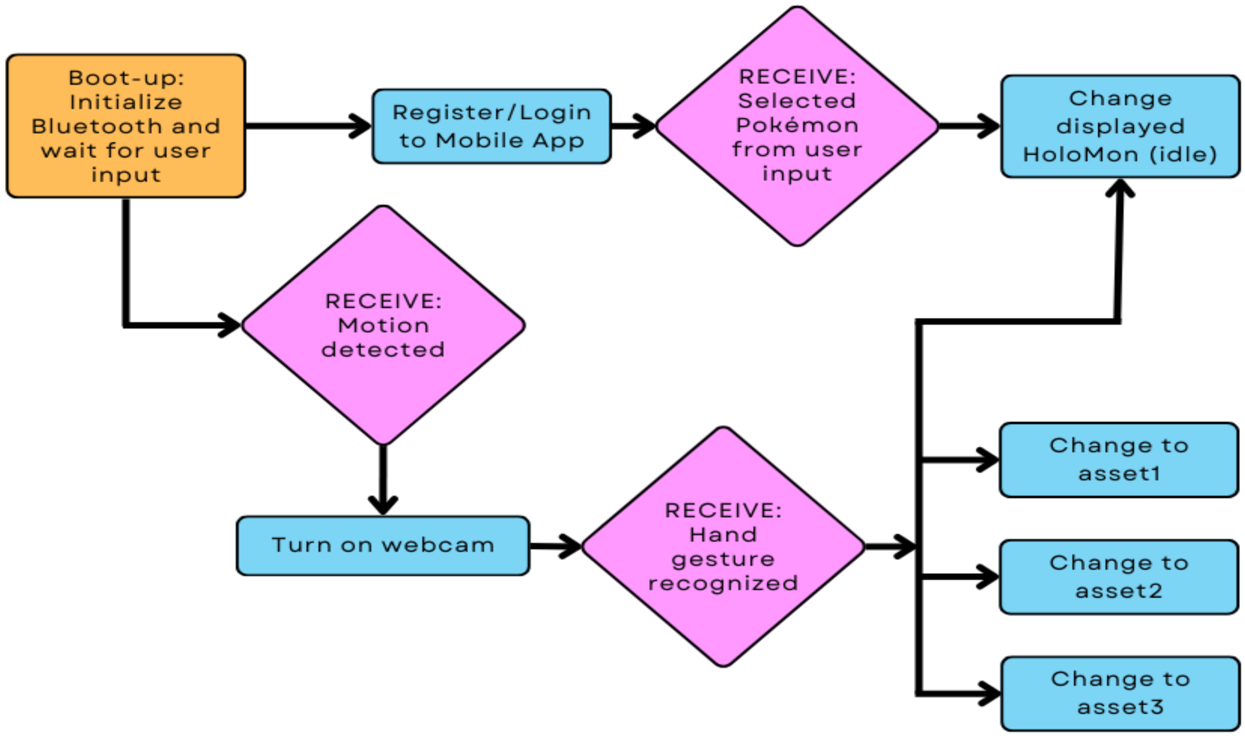

Figure 5. HoloMon data flow chart.

IV. HARDWARE DETAIL

The Hardware will be in charge of energy efficiency for the project. Since the project will not be utilizing any batteries and only be using wall outlets, the hope is to make the project as energy efficient as possible. Due to the amount of highly active programs utilized on the Raspberry Pi. One concern is that the Pi will be overworked due to the amount of high volume activity it is executing continuously while the user is using the entertainment program. The PCB will be programming the Webcam responsible for all of the gesture recognition. This major part of the project will be composed on EAGLE software and then ordered at a local PCB shop. The parts will be soldered individually by the team. The PCB is composed of three major parts: the power system, the MCU, and the jumpers. The power would be compromised by a 9V battery and a voltage regulator. The voltage regulator will be stepping down the 9 volts to 5 volts in order to make it compatible with the ATMEGA328 chip. There will be jumpers connected to each point of the MCU enabling the capabilities of an Arduino Uno. There will be two LED's responsible for will be responsible for the reset part of the PCB. The other LED will be on as long as the PCB has power running through it. This will also be the LED that can be programmed by the user . The PCB will contain an ATMEGA328 chip that will be taking data from the motion sensor and sending it to the Raspberry Pi. Then the Pi will be taking this information and through python it will turn off the webcam. There will be a USB-TTL converter responsible for being the gateway to the PCB. This USB-TTL converter is of model type CP2102 and required significant understanding of its internal mechanisms to properly convert the data sent through the Arduino to the Raspberry Pi on a UART bus since the motion sensor reads and writes on a digital pin. For example, one of the main components was the tiny switches on the converter itself, which sets the configuration for the type of data it will receive and the type of data it will output. There needs to be a way to essentially program the PCB through Raspberry Pi, which will contain the Arduino IDE on it. The Raspberry Pi will be programmed to incorporate gesture recognition which will ensure the interactions between the entertainment system and the user.

V. SOFTWARE DETAIL

The software components of the project are critical because the hardware enables the functionality but software creates the functionality. The different components of the software include the mobile application, the python scripts on the Raspberry Pi, the bluetooth connectivity, the machine learning model and gesture-recognition, and the PCB with the ATMEGA328p that essentially acts as an Arduino Uno.

A. Mobile Application

The mobile application uses the MERN technology stack. As aforementioned, the primary function of the app is to allow users to select what Pokémon they want to see in HoloMon. The MongoDB database stores the user account data including a user's first name, last name, username, email, date of birth, and password. The API is written in TypeScript using Node.ts and hosted on an Express server. The register API hashes the password with a salt that gets stored in the database. While there is no traditional frontend component using React, the mobile application uses React Native in JavaScript and has three main pages: Login page, Register page, and Pokémon Selection page. The bluetooth connectivity is also integrated into the mobile application, so the user can directly connect and disconnect to the Raspberry Pi for demoing. One limitation of the current mobile application is it only works with Android smartphones. The technical details for bluetooth will be explained in a later sub section.

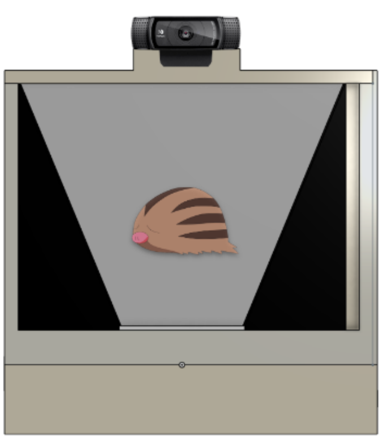

Figure 6. Front CAD Model of Housing Unit.

B. Python Scripts

With the Raspberry Pi being the main controller with its 4 python scripts, the team utilizes a hybrid method of operating systems subprocesses and turning the scripts into classes with object-oriented principles.

C. Bluetooth Connectivity

For the bluetooth connectivity, there are two sides to the protocol. The peripheral device in this project is the Raspberry Pi while the central device is the phone. The first step is to activate and initialize the peripheral device, and have it advertise its existence. The central device needs to find it and connect to it through the mobile application. In the mobile application code, there is a library called React Native BLE PLX that stands for Bluetooth Low Energy multi-platform library that allows the mobile app to recognize and use bluetooth protocol. Another component to the bluetooth is using the Nordic UART service, a proprietary bluetooth service which emulates a UART terminal to transfer data from the central device to the peripheral device in the project.

D. Machine Learning

Since the Raspberry Pi has a CPU with a Debian based Linux distribution, it is advanced and enables the main priorities of the project. Using its Operating Systems capabilities, the necessary packages were imported to run Python3 scripts. These include OpenCV, a popular open source computer vision and machine learning library, math library, OMXPlayer, pathlib, time, os, and subprocesses to realize this sub-system. Using a framework, the computer vision overlays 21 nodes onto an image of a hand. Through creating a machine learning model, it was possible to give it multiple hand images to train on, so when the usb webcam would be recording, any hand movements would be captured. Using this data, it was possible to make python scripts to change local assets on the Raspberry Pi based on the amount of fingers held up. For one finger it would change to a particular HoloMon reaction asset, two fingers to a different asset, and for three fingers it would change to a final 3rd reaction asset.

E. PCB with MCU chip

The PCB with the ATMEGA328p required a program to burn the bootloader onto, since the chip inherently comes from the manufacturer empty. The bootloader program allows the ATMEGA328p chip to be recognized as an Arduino Uno on the Arduino IDE. After the bootloader was burned onto it, the motion sensor was programmed using Arduino C code using the serial monitor with a baud rate of 9600. Through another python script, it was possible to connect the data sent from the motion sensor directly to the terminal on the Raspberry Pi.

VIII. BOARD DESIGN

The complete project is hosted primarily on the Raspberry Pi, with the PCB acting as a side device to optimize power efficiency through the HC-SR501 motion sensor. Since the PCB design and implementation was a critical requirement for this project, it went through rigorous breadboard testing in the first semester and beginning of the second semester once all components were delivered. This ensured that the individual parts were functional before soldering them onto the PCB. Once the one-layer PCB was soldered together with the components, it was possible to test the voltages running through the traces using a digital multimeter. The board was built by three major components:

1. Power
2. MCU
3. Jumpers

When creating this PCB, there was a lot of extensive research on what an ATMEGA328 chip needs in order to function. There needs to be some kind of clock system accompanied by capacitors. The battery needs to be stepped down in order to protect the MCU. Doing so requires a voltage regulator to step it down to 5.5V. The two LED's must be placed accordingly with a resistor or connected to a capacitor to ensure it does not get overloaded with current. When the team was testing the PCB with the multimeter the first time, one member accidentally touched an LED with another capacitor and the LED exploded. This led to the LED having to be desoldered and then resolder another LED on. One tricky part was ensuring that every component had its voltage needs met and that none of the components were in danger of being fried. This just meant more research when it came to selecting the components. Another thing that was not exactly taken into account was the spacing of the PCB. When placing the components on EAGLE, there was an overlook on how close the powerjack and the voltage regulator were together. When soldering came around, these two components collided with each other. Luckily, the team was able to solder the voltage regulator upside down and it still correctly stepped down the voltage (note that this was tested before attaching the MCU on). But in the future this is a lesson learned to check the insides and outs before ordering. This would not have been the biggest issue with this design if the PCB had to be reordered due to the cheapness of the PCB. However, if working with something that costs thousands of dollars, this could be a great mistake. Another problem that occurred were the mounting holes. The scale was set to micrometers instead of millimeters, and the holes came out microscopic. Again, luckily this was not proven to be a deal breaker, since the PCB had the ability to be taken with care and precaution. If the environment had not been like this, the PCB would have been rendered useless.

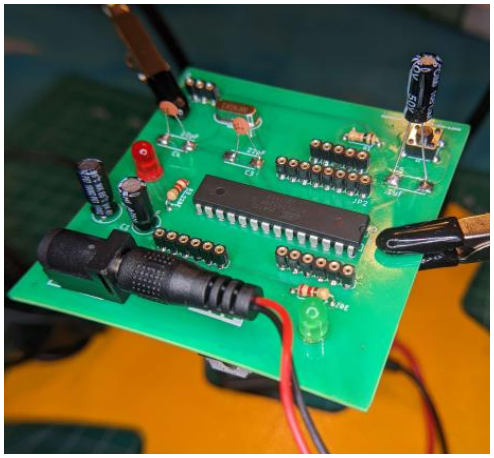

Figure 7. Soldered PCB.

Once everything was on, the next step was to take the PCB and try to execute a code. This part was the rigorous and most stressful part of the PCB design. When trying to program the PCB on Arduino IDE, it kept showing ten errors and was not being read properly. This issue took about a week to solve. The extended research led to many different solutions. The first thing to do was to make sure the ATMEGA was properly boot loaded. This could be done by switching out the Atmega with an Atmega from an arduino and seeing if it would run. When bootloading, the Atmega was placed onto a breadboard and then compiled, then it was connected to an arduino. When doing this, everything ran perfectly. Which created worry when it wasn't first compiling on the PCB. One issue that was discovered was actually pertaining to the UART converter. The UART had to be specifically set up in a mode based on which switch was flipped. Another thing discovered was that the PCB had to be reset before uploading the code. This was done and the PCB was working perfectly. There was a major concern that the PCB would not be able to work, since something so small could disrupt the whole mechanics of the PCB. However, with the use of research and persistence, the PCB ran perfectly.

IX. LIMITATIONS AND CHALLENGES

Since this project serves mainly to be a proof of concept while also taking an interesting and niche area in bringing video games into a hybrid mode of reality, there is plenty left to be desired.

A. Limitations

The main concerns that influenced this project's limitation are primarily time and financial constraints. For this reason, we went with Pepper's Ghost Illusion instead of a real hologram or 3D volumetric display, which commercial products cost upwards of $4000. Another limitation of the project is the ability for gestures to be recognized and have the Raspberry Pi switch the local assets more accurately. Additionally, there is slightly higher delay than desired since the gesture assets take about 5 seconds each to play through before the other video assets could play.

B. Challenges

There were many challenges the team faced. The first biggest hurdle was figuring out how to program the ATMEGA328p chip on the PCB. Using a laptop with Arduino IDE installed, the team found difficulties with uploading a sketch file onto the PCB directly. The next challenge was trying to figure out how to program the ATMEGA328p chip on the PCB from the Raspberry Pi through the CP2102 converter. Cannot use mediapipe for 32-bit Raspberry Pi. One other challenge was trying to preserve the wood when putting the housing unit together. There were a couple times when putting the screws in that the wood started to splinter and we would have to go about it another way. When putting the wood together, one of the pieces was placed adjacent instead of directly onto which ended up making the whole unit too short for the plexiglass to fit on top. So there had to be extra wood added on top and stapled so that the plexiglass could fit. Another challenge was trying to get the PCB to send data to the raspberry pi to turn off the webcam. This consisted of creating a lot of files and trying to get Arduino IDE to respond to the Pi. This took hours to figure out and was very tedious. We ended up figuring out this two way communication to get the Pi and the PCB to work.

C. Successes

There were many things conducted that flowed together very smoothly and made the senior design project be conducted more efficiently. One thing that went smoothly was getting the illustration movements for the Pokémon. This is not to say that gesture recognition came easy, but getting Pikachu on the screen itself was not difficult. One thing that the team did well was meeting up weekly when the second semester started. This is advice the team would give to any other team starting their second semester. This enabled the team to learn objectives and set goals and get the ball rolling. Another thing that helped the team was being able to have some team bonding activities. That made the team a little closer and able to be beyond classmates and create friendships as well while upholding the professional standards.

X. CONCLUSION

The past year has been a great example of what it would be like to work with an actual team. The first semester was a dive into research and preparation. It showed what it would be like to create actual Specs. This part became tedious at points but was vital in teaching students the criteria of what goes into components selection and the mechanics of things fitting together. The second semester involved taking everything that was learned and putting it to work. The toughest part of this was the integration of all the components together. However, with the help of teammates, the difficulty became a lot easier. One thing that was acknowledged this semester was the flawless communication between teammates. Communication is probably the most important criteria when it comes to conducting a project. Luckily, the team was able to communicate needs and wants at the very beginning of the semester. There was not much of a learning curb when it came to that. There was also flawless communication between the software and the hardware teammates. There was one teammate who was able to communicate between the student doing hardware and the other student doing software. It seemed like all four students held up a very important role in the project and were able to use their strengths in a very different and unique way. Another thing that worked very well was the workload. The load was distributed almost perfectly to each individual. There was not one student who was left with an unbearable amount of work. Each student upheld their responsibilities and promises which made everything integrate simply and efficiently. All these lessons learned made going into the work industry a little less intimidating. Due to the high amount of resilience the team has shown, it is exciting to think that what was once an idea, became fully functional. The skills and lessons learned will be used in the workforce for the rest of the students' lives. Another thing learned was the actuality of how an idea can be transformed into an actual invention. There can be a separation between learning and actually creating ideas. Engineers are to always question and come up with ideas. It is what makes an engineer successful. The total combination of the hardware can be seen in the image below.

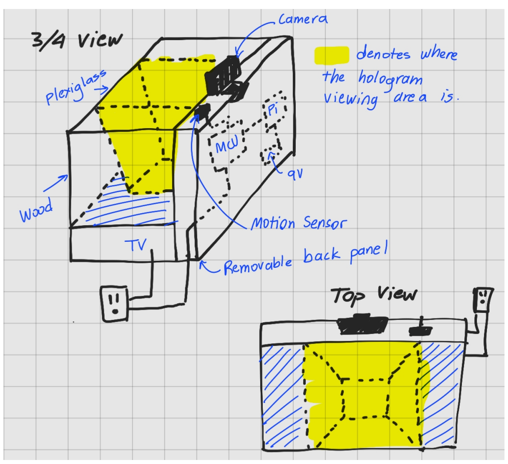

Figure 8. Initial concept art of the complete project.

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