HoloMon : UCF Senior Design 1 Document

EEL4914 Group A, Lei Wei, Spring 2022

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1. Executive Summary

This project is tasked at ideally rendering a 3D hologram inside a display surface that will be placed onto an RV car that follows and can interact with a user. Through using several, interconnected subsystems, the team will attempt to build this project. The first is an autostereoscopic 3D display, which will not require any external interfaces like glasses to view, but act as a standalone device. The second is an RV car mounted with the 3D display and other components with a motion sensor similar to functionality as a RangeFinder and follows the user. The last hardware system is a webcam programmed with a trained ML program that recognizes hand gestures and will be combined with the previous two systems. The interconnecting software application will allow for user-hologram interactivity without necessarily putting too much strain on the actual 3D display itself.

The premise of these interconnected subsystems is to provide a user experience that is natural, defined as not needing extraneous devices like smart glasses, to interact with a virtual environment. The applications of this project will be focused in mainly entertainment and design, with some potential use cases being in accessibility.

Despite some features of the requirements already existing, the combination of these major subsystems is a novel idea we will call “HoloMon.” Therefore, our overarching team objective is to provide a proof-of-concept design and prototype that will fit within our current budget (see 6.1 Project Budget and Financing). Its exact market value will not be an influencing factor in project design, so our team can focus on research and quality of the device. Another important team objective is to exercise and demonstrate our individual and collective abilities to work in a team for a project that requires expertise in electrical engineering, computer engineering, and computer science skill sets. In section 7, we set a projected timeline for the lifespan of our project and in section 4.1 we list out constraints that will heavily influence the design of our project.

The influencing factors for HoloMon’s ultimate design and creation will be the research and limitations of our selected system software, software APIs, hardware systems, and hardware components. Some of the technologies we will be implementing include an ML model, mobile application,

2. Introduction

Project Background

Holograms have not been the most simplistic invention of all electronics. It was first sparked as an idea in science fiction. One of the most popular Holograms is known in movies such as Star Wars. Many futuristic films or tv shows have shown people using a phone that had holographic features that could be used for phone calls. Once this idea of creating a 3D like image using light and color came into light, engineers have been working to create an accurate Holographic image to depict images.

The first Hologram was created in the mid 1900's and was introduced through lasers. There are many ways to go about creating a realistic Hologram such as utilizing lasers, phones, and or oscillating LED's.

There are a couple disadvantages with Holographic images depending on which route is chosen. If the engineer decides to utilize 3-D goggles to create the Holographic effect, this route is very expensive. Not only is it expensive, but it is very difficult to project an image in 3-D with light. Another route when creating an image is using lasers. To do this, the engineer must have a record of interference patterns that occur from the laser meeting its own light when the object is lighting up. This route is less expensive than 3-D goggles, but the intricate details give the invention a very small door for succeeding. It takes a lot of time and has very little room for error. Oscillating LED's are less complicated to create and less expensive as well. This is what will be used when creating the HoloMon. The disadvantage of using the FlexLED is that once it is created, its image is not easily seen from every POV. The only way a FlexLED can be seen is if the user is standing directly in front of it and on the same level. However, even with this disadvantage, the advantages outweigh this one constraint.

There have not been many Holographic toys due to the fact that Holograms are not easy to create. There have not been many accurate Holographic merchandise in the field due to the complex designs. However, if one was done correctly, this would spark a large opportunity for the Holographic realm.

Motivation

The COVID-19 pandemic has significantly changed social interactions. From social distancing to quarantining, it has been a very confusing time for almost everyone. This is especially true for children between the ages of 4-7 years old, where they grew up without the regular social interactions we are accustomed to. HoloMon is a solution to this unforeseen collateral on part of the pandemic. We want to create an interactive robotic hologram that will provide a comfortable and cool way for children to acquire social interactions with their friends and peers. Additionally, playing Pokemon Shining Pearl during quarantine and watching a favorite Pokemon follow your character around in game and interacting with other NPCs was the inspiration that sparked the idea of this project.

3. Project Description

Project Goals and Objectives

To create an interactive robot to provide a surreal experience for kids. As a team, we want to have a good balance of software and hardware challenges.

Base Goals

-To create a robot that will follow a human hand and or body around:
This will be completed through sensors such as infrared and ultrasonic. The infrared sensor will detect an object in respect to an angle while the ultrasonic will detect an object through long distances. Together they will define an accurate distance detecting robot. The Arduino Uno will be the base of communication for the sensors and the motors.
-**The priority of this project is to create a hologram:**
This means that there will be a face attached to the robot. This hologram will be looking like a specific character from the HoloMon drawings. The amount of characters for the child to pick from has not been decided, but probably close to 4-6 different characters. But for simplicity and in regard for the basic goal, we will say there will be only 1 character. This character will be projected through the hologram once the user turns on the robot. To turn off the hologram will just mean the robot will need to be turned off.
-The hologram will only be visible at one spot:
The user will not be able to look at the HoloMon directly unless they are pointed facing directly towards the HoloMon.
-**The robot will have protective gear surrounding the robot/HoloMon.**
Doing so will ensure that any collisions will be mitigated upon impact.

Advanced Goals

- Allowing the user to choose 2 characters that will appear on the hologram:
The two characters will be designed by the team members and projected through the hologram. The HoloMan will have a very distinct and animal-like presentation.
- Ability to change hologram via phone application:
The user of the Holoman will be able to choose 1 out of 2 characters they would like to have follow them. The selected Holoman will be their buddy that they can interact with. If the user wants to select another buddy, they must select the character again using the mobile app.
-The HoloMon will be able to interact with its user via 1 or 2 hand gesture(via Hologram):
All gestures will be recognized through a webcam installed on the robot. The most basic feature for the robot is when the user waves to the HoloMon, the hologram will wave back. There is a whole realm of gesture recognition. One more idea is that when you clap the HoloMon will clap back.
- Robots will have collision detection due to sensors around the base of the robot:
This is an advanced feature because the robot will be following the human. If the human does so correctly, they can help their robot avoid obstacles such as rock

and or small bumps. However, the accuracy of the human helping the robot avoid all obstacles is most likely not good since the main target audience is children. When the robot detects something in its path it will stop until the user removes the object from its sight.

-The Hologram will be adjustable by the user utilizing mirrors that will be moved until the user can see the HoloMon:

As labeled in the constraints, the way the Hologram is being created, the user will be unable to see the Flexed since it is only facing one direction, straight. However, if one mirror is placed in front of the HoloMon and one behind, it will create a view for the user in front of the HoloMon.

Stretch Goals

-Have 3 gestures created by the HoloMon will be via Hologram (not robot):

Creating gestures using Flexed will be complex and difficult to communicate. However, not impossible. All gestures will be created through the visuals of the Hologram.

- User can choose between 4 HoloMon's via mobile device:

Four HoloMon will be selected by the user through a mobile app. The designs will all be created through drawings created by the team.

- Robots will have collision detection and will be able to go around the obstacle and continue to follow the user again:

This will be a little complex because the robot will not only have to distinguish the difference from a human and a random object, but will have to move around the object and then follow the human hand again.

Functions

1) User will be able to pick out which pokemon they want through an app. 2) get it to follow a person-code. 2) User will be able to interact with HoloMon (such as feeding, petting, and playing catch).

4. Requirements

The following is a list of criterias set forward to produce a high-quality and cost efficient product. This is a list of high level criterias that qualify the product as desirable as possible for the end user. This list will then be used to poblish the technical requirements and specifications of the final product.

4.1 Project Criteria

Criteria Number	Criteria Description
1.1	The user-HoloMon interaction will be based on the "rangefinder" motion sensor. I.e. if the range is <2m, the user is attempting to pet the hologram and it will respond accordingly.
1.2	The user-HoloMon interaction will also be based on a ML model and webcam for user-HoloMon interaction.
1.2	The user-HoloMon will create an account and choose the monster to be displayed as a hologram through a mobile application.
1.3	Users shall be able to update their data(credentials, settings, etc.) as needed through the mobile client.
1.4	User data shall be stored in our web server (Azure, AWS, etc.).
1.5	There shall be a variety of pixel art HoloMons to choose from (At least 3).
1.6	Each distinct HoloMon shall have at least 3 animation assets to give the user interactivity.
1.7	API shall be concurrent, allowing multiple users to interact with our database.

Table 1. *Criteria*

4.2 Technical Requirements

The following is a list of technical specifications determined to the product's criteria while establishing a high-quality design. These technical requirements will be used as a guide of development of the project.

Requirement Number	Requirement Description
1.1	The robot will fit the constraints of being 30” x 30” x 30”.
1.2	250 GB Azure SQL Database to hold enough user information.
1.3	HoloMon should be emitted in at least 12 frames per second to achieve the minum quality.
1.4	HoloMon device should stay at least one hour active without the need to recharge.
1.5	128 GB Azure Managed Disk to hold enough space for external libraries and frameworks.
1.6	HoloMon should have a maximum of one second delay to respond to the user’s gestures.
1.7	HoloMon should travel at least 2 inches per second.
1.8	Phone to HoloMon connection should not take more than 10 seconds.
1.9	Cost to be less than $400.

Table 2. *Requirements*

4.3 Constraints

Currently there are a few constraints with the design idea to prevent too much complexity in the project. The first is that the human-following robot will follow any human instead of a specific human. This is largely due to the fact that we would need to introduce some kind of device pairing service between the robot and most likely a phone, making HoloMon more difficult to create in the time frame given. Another constraint is that the hologram can only be changed by a single person at a time. Since we are creating a mobile application that can change the appearance of the HoloMon, it would be out of scope to introduce the ability for two separate instances of the mobile application to control the hologram simultaneously.

Currently, there are only 10 gestures picked up by the pre-trained, open-sourced machine learning application. Users would only have 10 ways to interact with the HoloMon by this method and collecting more data would be unfeasible due to the time constraint and budget.

Assets may also be troublesome since a variety would be needed to provide a decent user experience. The resolution would be minimal due to the number of assets to be created and due to the lacking technology to create holograms within our budget.

Another constraint considering the current project set up is that the chosen Holographic image is not 3-D. This means that the owner of the HoloMon will not be able to see the image of their character unless it is adjusted to the user's POV. Though this constraint does make the project a little less advanced, it is the cheapest and most efficient way to create the HoloMon. This constraint is easily fixed utilizing mirrors for the owner to adjust.

Continued research into our project focus also suggests that holograms, if using more available (and thereby cheaper methods) of displaying the animation, will be susceptible to vibrations and the amount of light in a given room.

5. House of Quality

We can analyze tradeoffs between various qualities in the technical specifications and constraints using the criteria and specifications presented in the preceding subsections. This can be arranged into a quality house to visualize and focus on the most critical components of the design that must be considered.

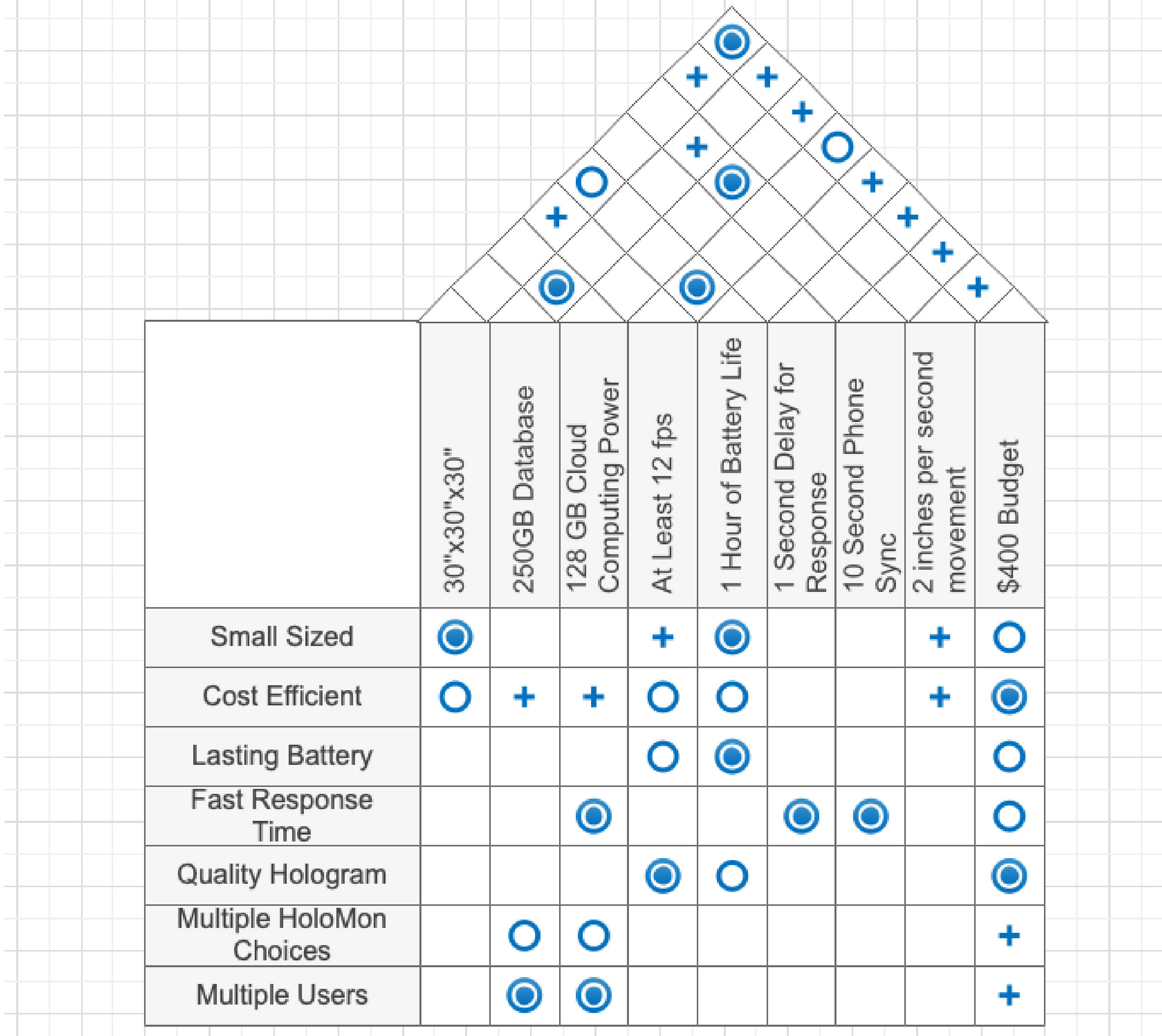


Figure 1. *House of Quality Diagram*

Legend	
◉	Strong
○	Fair
+	Weak

Figure 2. *House of Quality Diagram's Legend*

7. Project Block Diagrams

The following block diagrams are split between the project software and project hardware components. In each, the below color key represents the work distribution among the 4 team members.

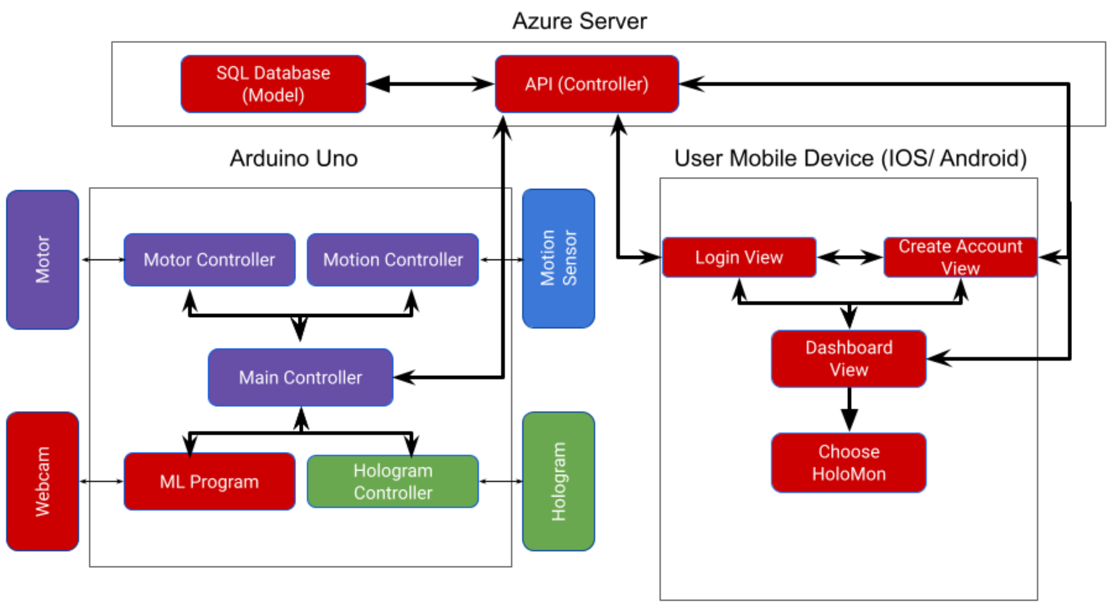


Figure 3. Project Software Block Diagram

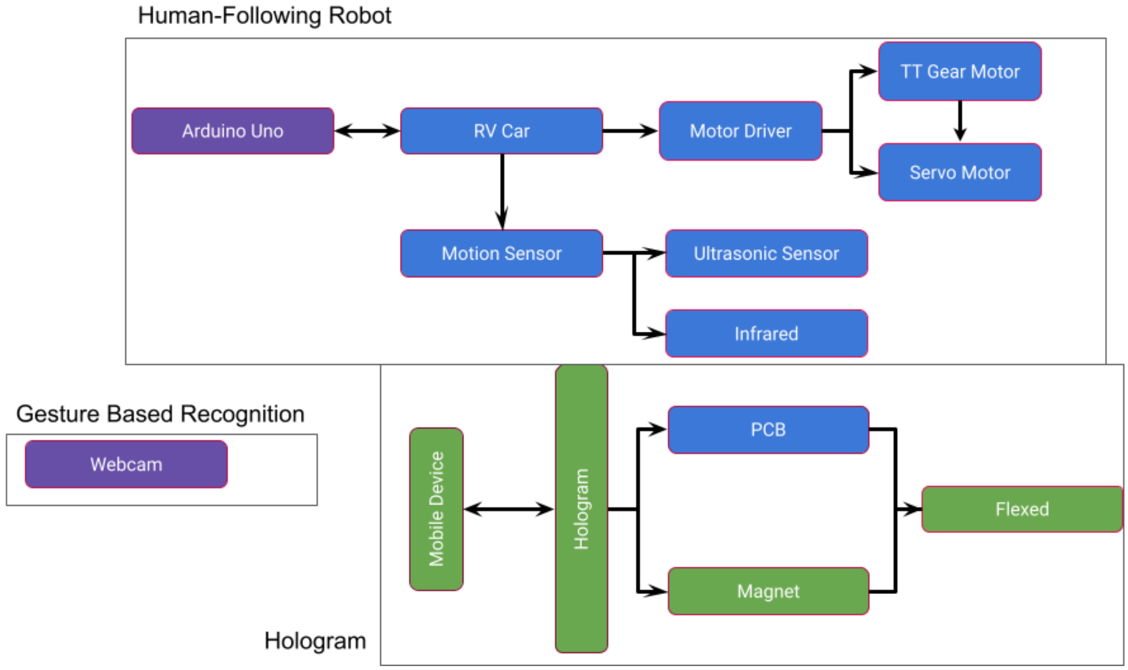
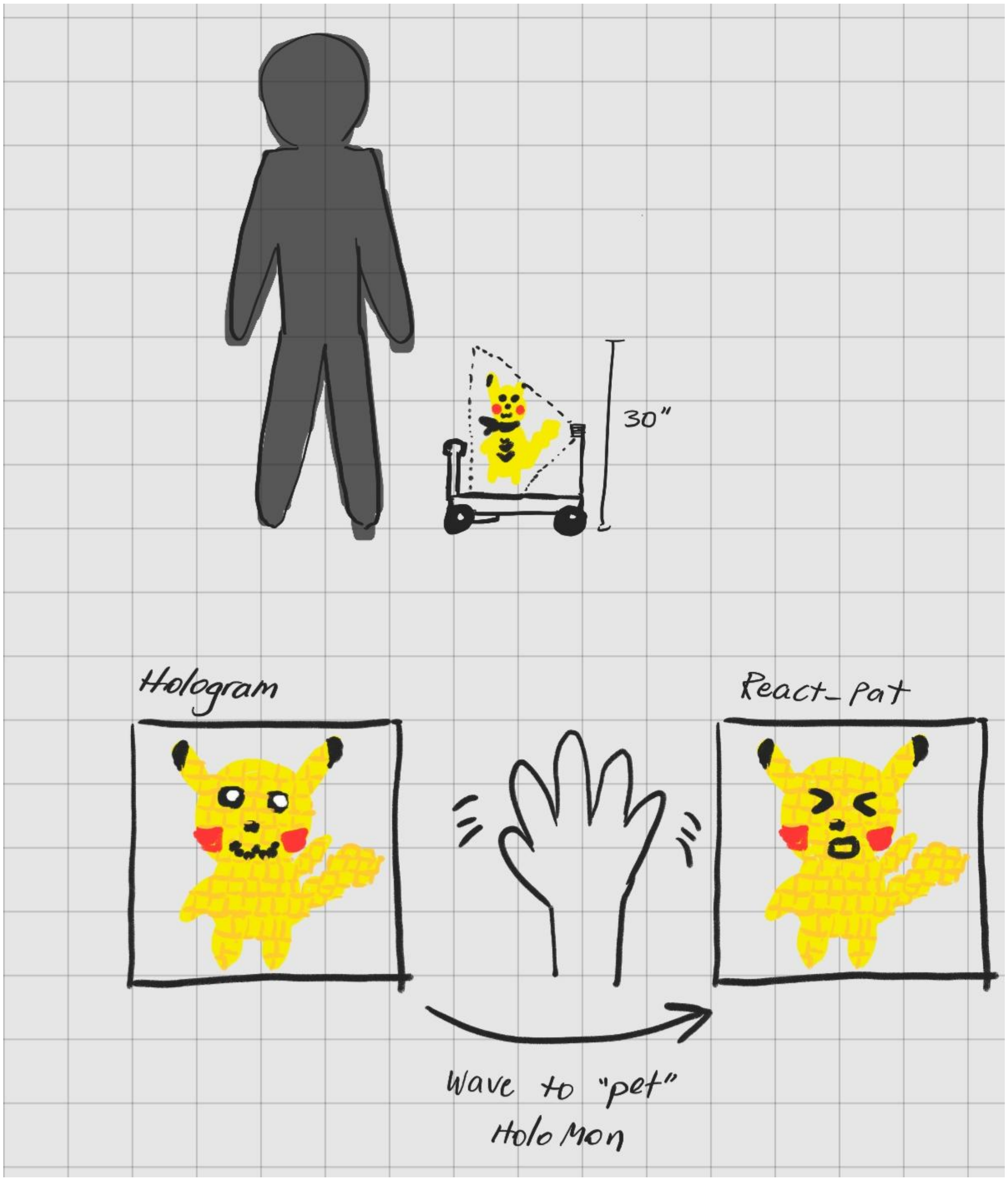
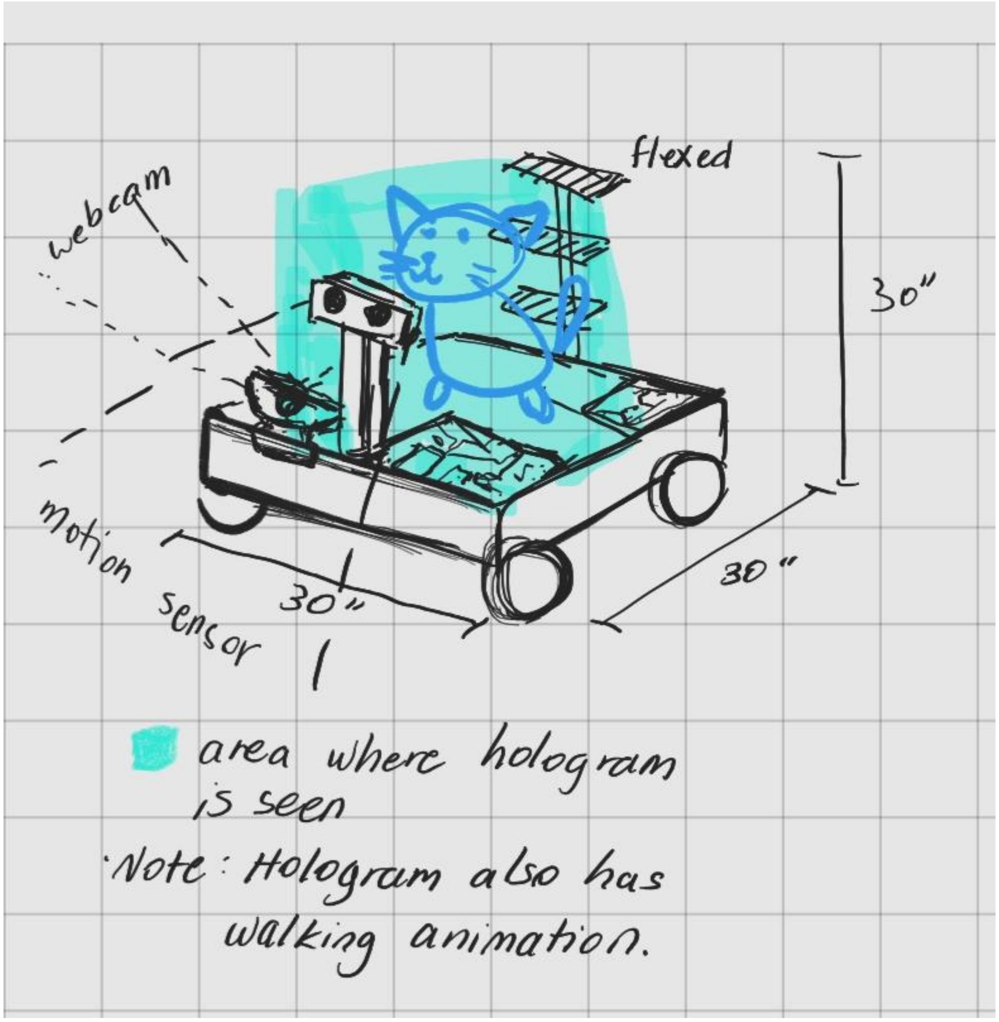


Figure 4. Project Hardware Block Diagram



Screenshot 1. *Project Design Perspective : the holograms will be pixelated animating characters that you can wave to. Requesting IP access from The Pokemon Company (International) in progress.*



Screenshot 2. *Project Design Close Up with Angled Perspective : the robot itself will be contained within 30" all around with an RC car carrying its parts*

7. Administrative Concerns

7.1 Budget and Financing

Our project will have a smaller or comparable budget to most senior design projects which heavily influences the type of display technology we can use to produce our prototype. The project will be both self-funded of $100 from each team member and are looking into receiving sponsorship from Niantic and/or sole proprietary sponsors. The minimum budget this project will have is therefore $400. We may also have a single-affiliated sponsor who is interested in donating another $100 for a total of $500 if Niantic declines to sponsor.
Below is Table 1 that visualizes the team's current budget and therefore the project's limitations based on the aforementioned budget. The next two tables, Table 2 and Table 3 outline the technological improvements of this project with potentially higher (mid-range and high-range) budgets respectively.

Item	Expected Quantity	Budget Per Allocated Item
Ultrasonic sensor	1	$0 (acquired)
Raspberry Pi 4 Module B	1	$35
Power Supply (9V battery)	2	$10
Infrared sensor	1	$10
Servo Motor	1	$35
Gear Motors	2	$30
Webcam	1	$50
PCB	1	$15
Magnets	2	$20
Plastic / Flexiglass	1	$100
RC Car	1	$40
Smart Tablet	1	$0 (acquired)
Current Estimated Total		$345
Budget Total		$400

Table 3. *Project Budget and Expenses (Current tier)*

The main difference between the current tier and mid tier for budgeting is that the mid tier would allow us to use an actual low-grade autostereoscopic 3D display. This would provide multi-angle viewing up to 360° rather than the current tier that only allows for a narrow range of angles to produce a 3D illusion.

Item	Expected Quantity	Budget Per Allocated Item
Ultrasonic sensor	1	$0 (acquired)
Raspberry Pi 4 Module B	1	$35
Power Supply (9V)	3	$10
Nvidia Jetson Nano	1	$218
Infrared sensor	1	$10
Servo Motor	1	$35
Gear Motors	2	$30
Webcam	1	$50
PCB	1	$15
Magnets	2	$20
Plastic / Flexiglass	1	$100
RC Car	1	$40
Autostereoscopic 3D Display	1	$900
Current Estimated Total		$1463
Budget Total		$1500

Table 4. *Project Budget and Expenses (Mid tier)*

The largest difference between the mid tier and high tier budgeting is that we would be able to use proprietary, state of the art technology from companies like Light Field Lab to provide high resolution animations in autostereoscopic 3D displays. Additionally, we could implement padding to the RC car chassis to prevent extraneous vibrations that may impact the quality of the hologram, as well as a better RC car. Having this high tier budget would produce sci-fi like quality of a HoloMon prototype following you around.

Item	Expected Quantity	Budget Per Allocated Item
Ultrasonic sensor	1	$0 (acquired)
Raspberry Pi 4 Module B	1	$35
Power Supply (9V)	5	$10
Nvidia Jetson Nano	1	$218
Infrared sensor	1	$10
Servo Motor	2	$70
Gear Motors	2	$30
Webcam	1	$50
PCB	1	$15
Magnets	2	$20
Plastic / Flexiglass	1	$100
RC Car	1	$60
Padding	4	$20
Autostereoscopic 3D display	1	$4000
Current Estimated Total		$4638
Budget Total		$5000

Table 5. *Project Budget and Expenses (High tier)*

8. Project Milestones

The initial project milestone for this semester is to understand what components and materials we will need to start our project as well as making sure we have all the necessary components. The initial project milestone for next semester is to have a working prototype of a human-following robot via motion sensor and/or mobile application. Table 4 below will show the project milestones for the first semester, while Table 5 will show the project milestones for the second semester of senior design.

#	Date	Description
1	February 4	Divide and Conquer Document (10 pages)
2	February 18	Updated Divide and Conquer (20-25 pages)
3	February 28	Have sponsorship and/or IP access
4	March 25	Draft Senior Design 1 Documentation (60 pages)
5	April 8	Draft Senior Design 1 Documentation (100 pages)
6	April 26	Submit final revision Senior Design 1 Documentation (120 pages)
7	April 26	Have completed project design
8	May 1	Order all necessary components
9	May 30	Start software development
10	May 31	Have all necessary components

Table 6. *Semester 1 Project Milestones*

11	August 15	Start second semester
12	August 15	Start hardware assembly
13	August 15	Have software application prototype complete
14	August 15	Start housing assembly for 3D Hologram
15	September 15	Complete Assembly of 8, 11, 12
16	September 24	Complete Unit Testing of 8, 11, 12
17	September 30	Complete Integration First Pass
18	October 8	Complete Integration Second Pass (if necessary)
19	October 11	Complete Integration Third Pass (if necessary)
20	October 16	Complete Integration Testing (end to end testing)
21	November 5	Project Completion
22	TBA	Committee Presentation
23	TBA	Senior Design Expo

Table 7. *Semester 2 Project Milestones*

Other Projects (Decision Matrix)

	Cost (Weight:3)	Motivation (weight:5)	Technological goals (Weight:4)	Difficulty/Time Constraint (weight:2)	Score
Project 1 (Holomon)	**1*3 = 3**	**3*5 = 15**	**3*4 = 12**	**1*2 = 2**	**32**
Project 2 (Ring Facial Security)	2*3 = 6	2*5 = 10	2*4 = 8	3*2 = 6	30
Project 3 (Smart Fridge)	2*3 = 6	2*5 = 10	1*4 = 4	2*2 = 4	24

9. Research,Technologies, and Components

In the following section we will discuss the research that took place as we strived to find the best overall design of our product.

VR:

The Covid-19 pandemic has dramatically changed many people's way of lives, and this is not going unnoticed by tech corporations looking to capitalize on future technological trends. The buzzword, "metaverse", has become a hot topic in 2021 and going into 2022 with many corporations investing heavily into it. Most notably to embrace this trend is Facebook, now rebranded as Meta. They have created what is currently the most popular VR headset series, with their newest version being the Oculus Quest 2. The Oculus features a VR headset that has a display split between the eyes allowing each eye to be shown a different feed creating a stereoscopic 3D effect. It also tracks your position in space and orients your point of view to mimic in the virtual world. The complimentary controllers use a visual tracking system called Oculus Insight that uses infrared LEDs in the controllers.

Figure ??, **Oculus Quest 2**

While VR is a hot topic right now, the difference between VR and holograms is that holograms can be seen with the naked eye as it portrays the image in the real-world. Using VR would incur high overhead costs such as a headset and would differentiate the user from the real-world which we don't want.

AR:

Augmented Reality (AR) differs from virtual reality because it overlays virtual features onto the real-world instead of completely reconstructing it. An AR system can be defined to consist of 3 features: real and virtual objects, real-time interaction, and accurate 3D registration of objects. Perhaps the most popular AR headset in recent times is Microsoft's HoloLens. Much like the Oculus, the HoloLens requires a bulky headset which doesn't match our needs. It is also important to note that the HoloLens have been discontinued by Microsoft as they explore other mixed reality options with Samsung.

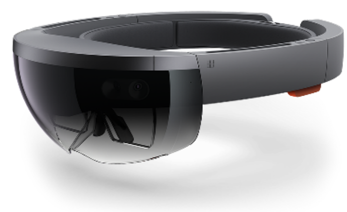


Figure ??, **Microsoft HoloLens**

Mobile AR has also made an emergence in past couple of years where the only requirement would be a smartphone. Unlike the HoloLens, the user would use a smartphone through which they would see the virtual objects. However, this would not be suitable for our product as we would want it to be seen with the naked eye without the need for any additional hardware.

Figure ??, **Mobile AR**

<u>LED-Based Hologram</u>

Recently a popular trend in the hologram field is to take an LED-based approach. This is because it is fast, simple, and relatively cheap to set up. It is being used in many areas from drone displays to advertisements and casual projects. It is important to note that drone holographic displays currently operate mainly on a large scale, so we will not consider that possibility. LED holograms come in many forms, but they operate through a similar principle. Probably the most common form is LED fans. They produce an illusion of a 3D object floating in space. The fan is spinning so fast that it becomes invisible to the naked eye and becomes see through. The LEDs are lit up in such a way while the fan is spinning that it tricks the human mind into thinking it is a full image.

Figure ??, **LED Holographic fan**

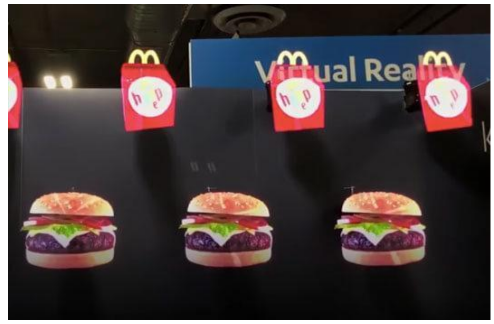


Figure ???, **Advertisement using holographic fan**

Some limitations of this technology are that it is not a true hologram in the sense that it does not produce a 3D volumetric image but just an illusion that can be seen from the front of the display. There are also safety concerns with this because it would need encapsulation due to the spinning fans or be placed out of reach. In addition, the fans produce noise and generate a significant amount of heat, so immersion and power management become significant issues.

<u>Pepper’s Ghost Illusion</u>

Appendix A - References

[1] Jason Geng, Three-dimensional display technologies." Adv Opt Photonics,vol. 5, no. 4, pp. 456–535, Dec. 2012, doi: undefined. https://www.ncbi.nlm.nih.gov /pmc/articles/PMC4269274/

Appendix B - Copyright Permissions

The Pokémon Company (International)

Currently, our team is in the process of receiving an internal response on our request for Pokemon IP access and sponsorship from Niantic as well. We have taken steps to ensure that our prototype will not be sold commercially and is simply for a senior capstone project.