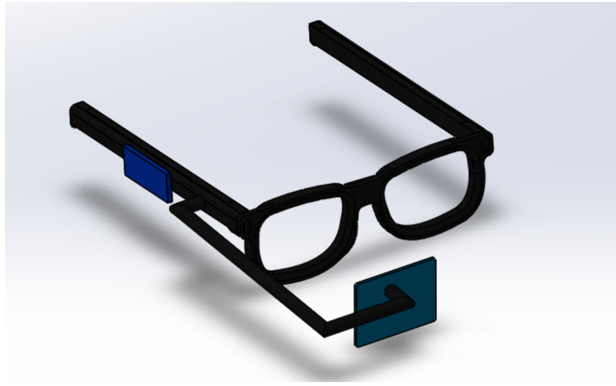

“Arduino Surveillance Eyewear”

April 30th, 2021

MEM-Team 10
MEM491, Spring Quarter

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Abstract

Modern security systems have become an integral part of our society. The most common form of security systems is constant video surveillance of a target area. Security systems have become more prevalent in personal use for home security and baby monitoring. This is due to the advancement of technology, where smart devices have become more integrated in everyday use.

Home security products require a monitor to see the live video feed or require the user to use their own smart device and the product's app to access the live video feed. This limits the mobility of the user as well as limits the freedom of the user's hands and smart devices. This project aims to develop surveillance eyewear that users can wear to see live video feed from a wireless camera without limiting the user's mobility.

This project will demonstrate the use of Arduino technology to transmit images via Wi-Fi communication within a compact system. The system will be light enough and ergonomic such that a user can adorn their own eyewear. By utilizing 3D CAD software, the Arduino IDE, analyzing material properties, and researching the limitations of human sight, the feasibility of this project can be verified through force and moment calculations as well as utilizing Solidworks' built in modeling simulation programs. The development of this form of surveillance eyewear will be one of the initial steps towards mobilizing the home security market for the public sector.

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1. Executive Summary

1.1. Quad Chart

Objective	**Stakeholders**
- Develop a practical form of surveillance technology that allows freedom of the user's hands and smart devices. - The product must be compact, lightweight, comfortable, and low cost.	- Academic researchers and educators - Surveillance technology companies, such as home security - Parents and caretakers
Approach	**Key Milestones**
- Develop an eyewear attachment that can display live video feed via wireless communication - Utilize low cost Arduino modules and 3D CAD software to develop a realistic product - Conduct biomedical research for eye limitations and head movement	- Component Research: 3/6/2020 - System Testing: 3/23/2021 - 3D CAD Modeling: 3/23/2021 - Final Product: 3/30/2021 - Poster Presentation: 5/10/2021 - Spring Term Technical Report:5/28/2021

2. Introduction

2.1. Motivation

In our current day, security systems have become an integral part of our society with around 21 million houses throughout the nation having one built into their houses [1]. The most common form of security systems is home security and baby monitoring. Security systems have become more prevalent in use for home security and babysitting as technology has advanced and smart devices have become more integrated in everyday use for the cost of about $400 per year [2]. As such, home security devices have become a new market where consumers can purchase a set of cameras that enables the user to see what the camera is observing with their smart device.

2.2. Problem Statement

While surveillance technology advances as camera technology is enhanced. However, one key trait that all surveillance systems share is the lack of mobility for the user while observing the video feed. In large office buildings, there are dozens of cameras set up with 24 hour activity, and all the cameras are reporting to one area. As such, there is generally a central monitoring room within the building with the monitors displaying several feeds at once. For home security, users are able to connect to the video feed on a smart device, but these products limit the user's mobility in having to move their smart device around with them. While it is not the biggest issue, it can be considered a burden in having to move the smart device every time they move to a new area as well as being physically draining to constantly turn their head to see the monitor if they had set it aside too far from their working area.

2.3. Stakeholder Needs

The stakeholders that are most interested in developing new surveillance technology are academic researchers and educators, surveillance technology companies, and the general public people. Academic researchers in the engineering field and educators are indirect stakeholders, these include colleges and universities in developing new forms of technology. Surveillance

Technology companies will be a direct stakeholder as any new form of surveillance technology has a direct impact on their market. Home security companies will be the ones most impacted as developing a portable personalized monitor for home security can be the most applicable and marketable product. Parents and caretakers will be directly affected from being potential consumers and users of the product.

The specific needs of these stakeholders vary from user to user, but in general needs to meet all of the following criteria: affordability and availability, system compactness, ergonomic design, and ease of use. The product cost must be a relatively low cost for consumers willing to purchase the product, as well as for the companies to manufacture and sell to a large audience range. The surveillance technology developed must be a compact and lightweight system in order to be as mobile as possible while enabling freedom in CAD design for a practical physical framework to house the system. The product will be designed for the user to be used up to a few hours at a time. As such, the product must be ergonomic and comfortable for the user to wear to minimize obstruction in the user's performance in tasks.

2.4. State of the Art

In the current market for areas such as home security and baby monitors, there are no existing products that offer a hands-free and smart device-free access to live video feed. Additionally, these existing products come at a relatively high price, for the services they offer. This project uses Arduino technology and 3D CAD design to develop an affordable product to serve this niche. Current design ideas are developing a single unit that enables the user to attach an adjustable display to a pair of eyewear and a separate camera unit that communicates exclusively to the display attachment. The adjustable display's position will be adjustable to enable visibility of the screen, such that the user can see the screen at all times.

2.5. Approach

The final product aims towards making a simple, affordable, and comfortable design for the surveillance eyewear. Utilizing Arduino based microcontrollers and modules, this enables access to flexible programming for low cost components. These low cost components are small and lightweight, which allows for a housing unit design and display appendage specifically for eyewear. Due to the limitations of the human eyes, a display appendage will be freely adjustable to change to a comfortable and readable distance from the user's eyes. With these design details taken into consideration, this design was chosen to maintain simplicity while achieving the needs required.

3. Materials and Methods

3.1. Software

This project has two different sections of development: a CAD portion to develop a physical model, and a coding portion to develop the live video feed system. The software that was utilized for the 3D CAD portion is called "Solidworks". The software was utilized as a visual aid for the product as well as the main method for prototyping. Succinctly, individual components of the overall design were also created in Solidworks as part files. Each component was then mated to the overall structure so that the structure became fully defined. This process took place in an assembly file. Examples of the individual files used in the assembly file include an adjustable arm, a battery unit, clamps, a counterweight, the LED module and frame, and supporting rods. A current exhaustive list of the components is shown in Section 4.3.2.1 of this report.

The software that was utilized for the coding portion is called "The Arduino IDE". This open source software was used to write code and upload it to our "works-like" prototype. The codes uploaded to both circuits include the "WiFi" library and the "Arduino Web Sockets" library. Another library used for the display is the "TJpg_Decoder" library. This library decompresses the images transmitted from the camera to save memory space. SSID and Password required to establish a WiFi connection have been predefined in the code. The web socket opens a two-way communication between the client and the server. The TTGO Display microcontroller acts as a server and waits for the camera, which operates as a client, to initialize communication. Once the communication channel is established between the two microcontrollers, the decompressed images get transmitted to the display in binary format. The display uses a function from the "TFT_eSPI" library to display the array of bytes as images.

3.2. Hardware

The hardware requirements consist of ESP32 microcontrollers and compatible modules. The final system includes two circuits, wirelessly connected to one another. The first circuit consists of an ESP-32 camera that is connected to FTDI shield with female-to-female jumper wires. While the camera itself is a microcontroller and has WiFi integrated in it, it still needs an FTDI programmer to upload the code to its serial pins: UOR and UOT. The second circuit contains a TTGO T-Display, which has a dual-core microcontroller and WiFi Module integrated in it. An external shield is not required for this circuit, because the code can be directly uploaded to the display. The 1.14inch display was selected to make our final system compact and efficient. Finally, both circuits were powered via a rechargeable 3.7V LiPo Battery.

4. Results

4.1. Specifications, Constraints, and Standards

This project focuses on developing eyewear intended for the user to wear, and as such there were certain specifications, constraints, and standards that needed to be considered. The human eye is composed of 5 different parts to give the sense of sight. These parts are the cornea, iris/pupil, lens, retina and optic nerve. Together they regulate and amend the incoming light into signals that the brain can translate into the images of our environment. Light is measured on a wavelength spectrum and the eye is able to see that in between 380 to 780 nanometers which is the range between ultraviolet and infrared light [3]. Therefore, the light produced from the display would have to fall within that range in order to make our product usable for the average consumer. Intensity will also need to be considered for safety purposes. With the screen being a minimum of 3 inches away from the eye, a mid level brightness similar to that on a smartphone would be proficient to provide a visible image while preventing short or long term eye damage [4]. The design of the eyewear must be lighter than 3.52oz to prevent any discomfort from the user's head [5].

4.2. Concepts

The general design concept of this project is to develop a live video display system that can be attached to a user's own form of eyewear while maintaining the freedom of the user's hands and smart devices. In order to achieve this, the general design of the product involves developing a lightweight display system that communicates directly with a mobile camera system. The camera system will communicate to the display system via WiFi, as seen in Figure 1, where the display system will receive the feed and operate at a minimum of 10FPS. The display will be lightweight and attached to an adjustable arm, such that a user can orientate the display to their own comfortable placement.

4.3. Detailed Design

4.3.1. Model 1: Arduino Design

4.3.1.1. Description

Model 1 consists of a "works-like" prototype that demonstrates the desired functionality of the product. The hardware used is described in Section 3.1. The schematics of the hardware connections and WiFi communication between the components are shown below in Figure 1. Please note that each circuit is powered through a 1000mAh 3.7V LiPo Battery.

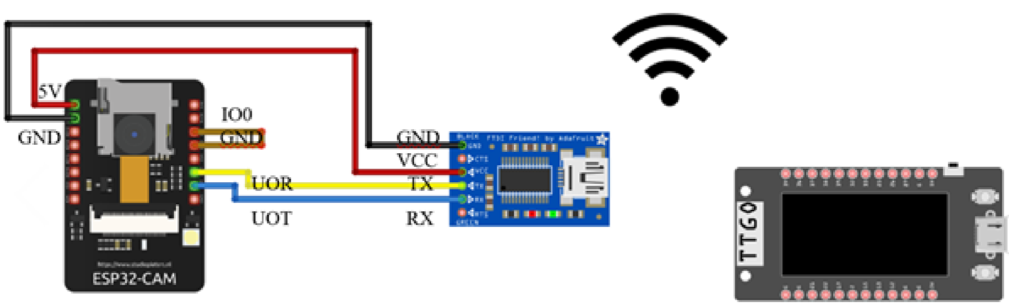

Figure 1: Schematic of hardware connections

4.3.1.2. Results

After physically connecting the hardware, both circuits were tested individually. Successful physical connections are displayed in Figure 2. *(Please note power source not included).* The ESP32 camera operates in Wifi Station mode and acts as a Web Socket client. The TTGO Display operates in Access Point Mode and acts as a Web Socket Server. The display opens the server and waits for the camera to connect. Once the connection is established, the images are sent in binary format via the Websocket.

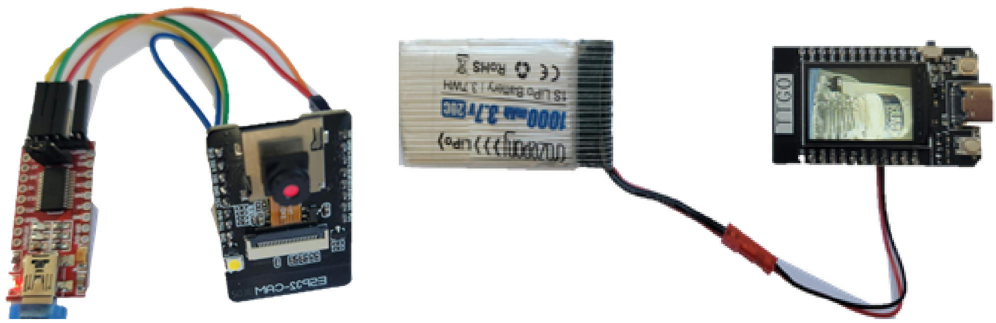

Figure 2: Physical connections of components

4.3.1.3. Lessons Learned

The working prototype came after multiple failed attempts through iterative testing. The original plan was to use Arduino MEGA and NANO microcontrollers with Bluetooth communication. However, further research indicated that these microcontrollers were unable to process images via Bluetooth communication. After discovering this limitation, more time was invested into researching other microcontrollers, cameras, and wireless communications. As a result, the new system operates using an ESP32-CAM and compatible modules. Additionally, by switching to these new components, it came with the benefit of producing a more compact and efficient system compared to the original microcontrollers.

4.3.2. Model 2: CAD Design

4.3.2.1. Description

A 3D CAD model of the current design was created through iterative testing. All 3D CAD models were created in Solidworks, where individual components of the product were created as Solidworks part files and the final product was assembled in a Solidworks assembly file. A list of components used in the final assembly are as follows: an adjustable arm, battery unit, clamps with rubber grips, a counterweight, TTGO T-Display, and a pair of standard glasses for simulation, as seen in Appendix D. The separate camera system with the ESP32-CAM is still being optimized as the physical design is still being improved and the wiring is not yet finalized.

4.3.2.2. Results

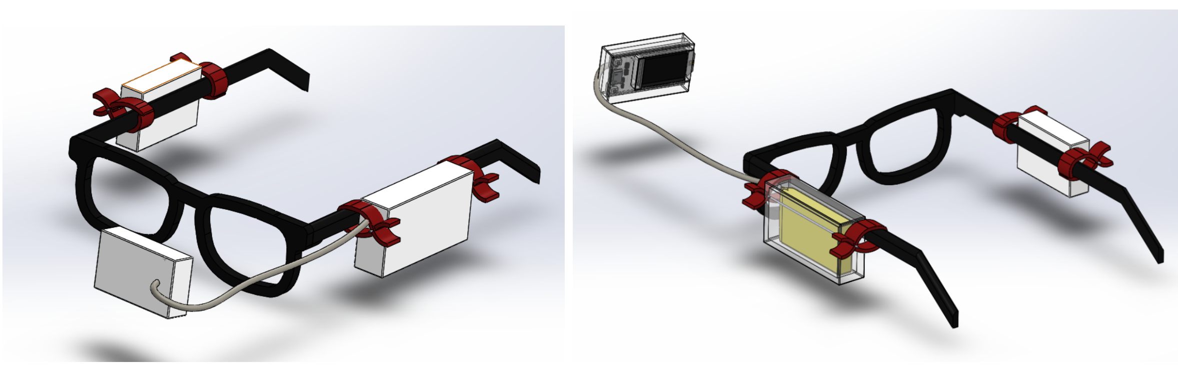

Figure 3: Front and transparent images of the current 3D model design

The housing unit is located on the left-hand side of the glasses as seen in the rear version of the product in Figure 3. It is located in between the clamps and houses the battery unit of the design. The wires of the battery then run through a hole in the housing unit which then travels to the rear part of the TTGO T-Display. The wires are then covered by a freely adjustable arm like those seen in microphones. The opposite side of the glasses contain a counterweight indicated by the lack of an adjustable arm. It serves to balance the forces exerted by the display and battery exerted on the user's head.

4.3.2.3. Lessons Learned

The creation and refinement of the CAD model was originally intended to house the Arduino MEGA and NANO microcontrollers. However, after the discovery that those microcontrollers were not powerful enough, the CAD model needed to be adjusted to fit the new hardware specifications of the ESP32 TTGO Display module and related components. After the new Arduino system was established, the CAD modeling for the eyewear was able to be set into motion. The 3D models were updated to fit the new component size parameters, with the current model as seen in Figure 3. Continuous updating of the design will take place until such a time a physical prototype is created.

One major question that came up during the process of creating a model was figuring out how to dimension certain components to make sure that they all fit within the predefined parameters. For example, due to research conducted at the beginning stages of the project, it was determined that a good distance from the eye to the LED device is around 3-4 inches. From this, the size of the adjustable arm was to be determined. Factors of this were not immediately obvious but after careful consideration and the visual aid of a 3D model, the right size of the adjustable arm was determined.

Moving forward there are areas of the 3D model which will be refined. Continuous improvement of the model will help to minimize error during manufacturing. The clamp needs slight improvements in design to resemble real life conditions more closely. 3D blueprints will also be created for the purposes of a final project report and for use in manufacturing.

4.4. Additional Analyses

When designing technology to be worn by a user it is important to consider all forces and moments experienced by the user. By analyzing the masses of the components and any resulting moments, weight limitations can be determined to maintain a comfortable experience. Additional analysis to be conducted in the future include material properties, such as determining the optimal type of rubber padding for the clamps, cost effective materials for manufacturing the models, etc.

4.4.1. Mass Analysis

The overall mass of the unit is necessary to determine comfort for the wearer. Currently, there is an international standard for the contact area of nose-pads which dictates a larger area of minimum $0.4\ in^2$ if the glasses weigh 0.88 oz or more. Due to this, the final product needs to weigh as little as possible so as to not require the wearer to need custom glasses instead of their own eyewear. As the model develops, it is planned to further reduce the weight by sourcing smaller batteries to reduce the highest weight point, the battery unit, as seen in the chart below.

Table 1: Product mass breakdown

Component	Mass	Overall Mass Contribution
Battery	1.77 oz	71.28%
TTGO T-Display and Covering	0.67 oz	27.08%
Clamps (weighted as a pair)	0.038 oz	1.54%
Adjustable Arm	0.0007 oz	0.03%
TOTAL	**2.4787 oz**	**100%**

The addition of a counterweight on the opposing side of the glasses would add approximately an extra 2.4787oz to balance the eyewear. However, by further reducing the weight of the battery unit, the counterweight will be reduced equivalently.

4.4.2. Moment Analysis

The final design currently places over 70% of the total mass between the front of the glasses and the ear rests. Since the remaining mass is suspended beyond the frames in front of the user by means of a virtually weightless arm, the entirety of the remaining mass will be used to determine any moments applied to the glasses. The moment of the combined masses from the TTGO T-Display and covering (0.67 oz) is applied 3.5 inches from the front of the glasses, it culminates to be roughly $0.0126\, lb \cdot ft/s$. This moment would feel like a mass of 2.5 oz was added to the frames pulling them forward and off of the user's face.

The combined mass of all the other components distributed evenly behind the rotation point, the front of the glasses, is more than enough to counteract the moment being applied. The additional mass of the user's glasses will make for a stable seating on the user's head. However, reducing the overall weight is necessary as well to maximize the comfort. Additionally, the counterweight will prevent any moments that would cause the glasses to rotate sideways off of the user's head.

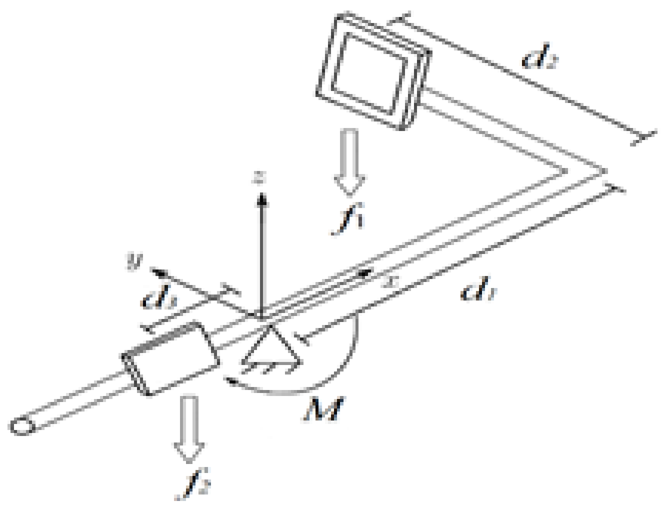

Figure 4: Force and moment mathematical modeling

5. Discussion

After several months of designing this project, the development has proceeded at a relatively constant pace. Design efforts on both the hardware and software portions have achieved developmental milestones, leading to more opportunities for refinement of the glasses. The original plan has not changed nor has the big picture view of how to accomplish it, however changes to hardware were necessary. After learning that the original Arduino microcontrollers could not accomplish the task of video transmission via bluetooth, the shift to the ESP32 for WiFi communication was needed. This seemed like it would be a setback but instead proved to be a simplification of the development. With a simpler hardware setup and an easily adaptable coding framework, a new working model was created and the CAD for the hardware was quickly designed to push for a fully modeled proof of concept.

The focus can now move towards optimizing comfort and ergonomics of the product. By developing a CAD model with accurate force and moment calculations, the importance of refining and minimizing weight has become ever more apparent. To ensure that the product will be comfortable and stable, these details are what makes the product stand out as a mobile surveillance system.

6. Budget Update

Table 2: Spring Term Expenses Projection			
ID	Quantity	Description	Cost
1	1	Freely Adjustable Arm	$0.65
2	2	Crazepony 3.7V 1000mAh Lipo Battery and Battery Charger	$5.99
3	1	ESP32-CAM WiFi Bluetooth Camera Module Development Board	$9.49
4	4	Clamps with Rubber Grips	$0.32
5	1	Counterweight Material	$0.60
6	4	HiLetgo ESP32 LCD WiFi Kit ESP-32 1.14 Inch LCD TTGO T-Display	$14.99

7	1	HiLetgo FT232RL FTDI Mini USB to TTL Serial Converter Adapter Module	$6.99
8	1	3D Printing Material, TTGO Cover, Housing Unit Shell and Connective Rod	$0.40
9	1	Wiring	$1.00
Total Cost			$40.43

7. Project Management Update

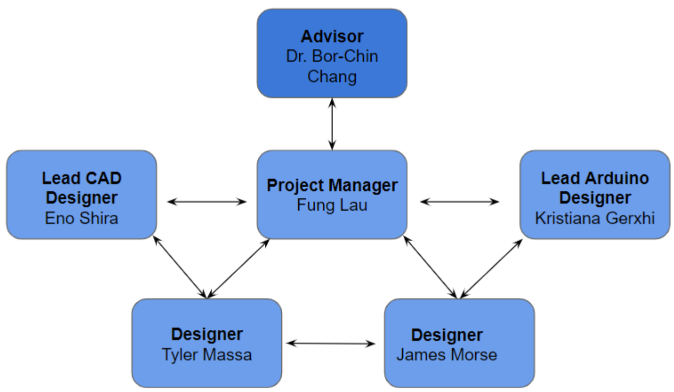

Figure 5: Team member roles diagram

The role of the Project Manager oversees and focuses the work of the group in order to reach milestones and deadlines of project development as well making sure work is being produced, delivering weekly to bi-weekly progress reports to the advisor, and assisting all other group members when needed. The Lead Arduino Designer is in charge of the Arduino development of the project. They are to ensure that all group members are developing Arduino code, able to provide insight into Arduino systems, and managing the most updated version of the Arduino files. The Lead CAD Designer is in charge of the physical eyewear framework of the project. They are to ensure that all group members are able to provide feedback on the physical eyewear framework, updating the framework according to the Arduino system size, and managing the most updated and shared CAD files. The Designers are team members who are able to work flexibly between the Arduino and CAD portion of the project.

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9. Appendices

Appendix A. Gantt Chart

Table 3: Schedule and Milestones	
Milestone	Date
Component Research	11/1/2020-3/6/2020
CAD Model Creation and Updating	11/1/2020-3/23/2021
Changes and Iterative Testing	11/1/2020-3/23/2021
Arduino Testing	11/15/2020-3/23/2021
Final Product	3/30/2021
Poster Development	4/20/2021-5/10/2021
Written Proposal	4/20/2021-5/27/2021

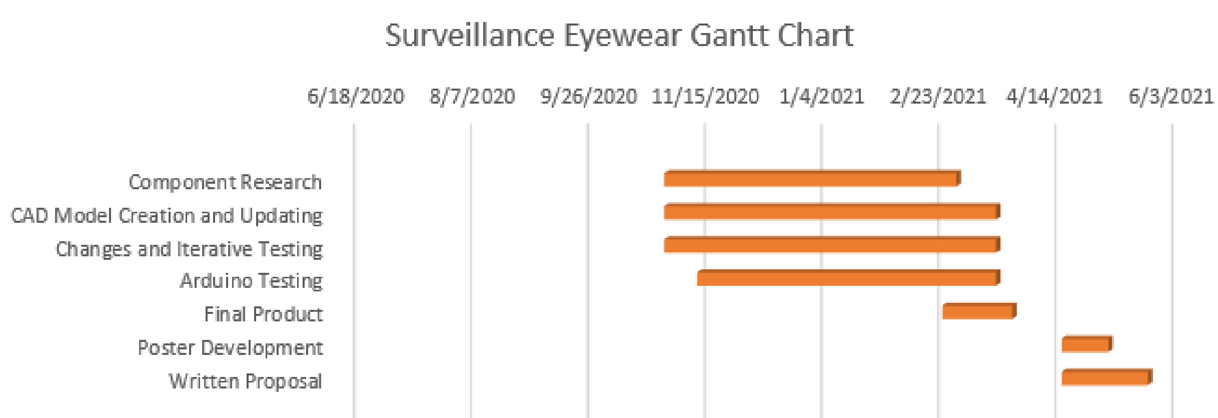


Figure 6: Surveillance Eyewear Gantt Chart

Appendix B. Arduino Connection Schematics

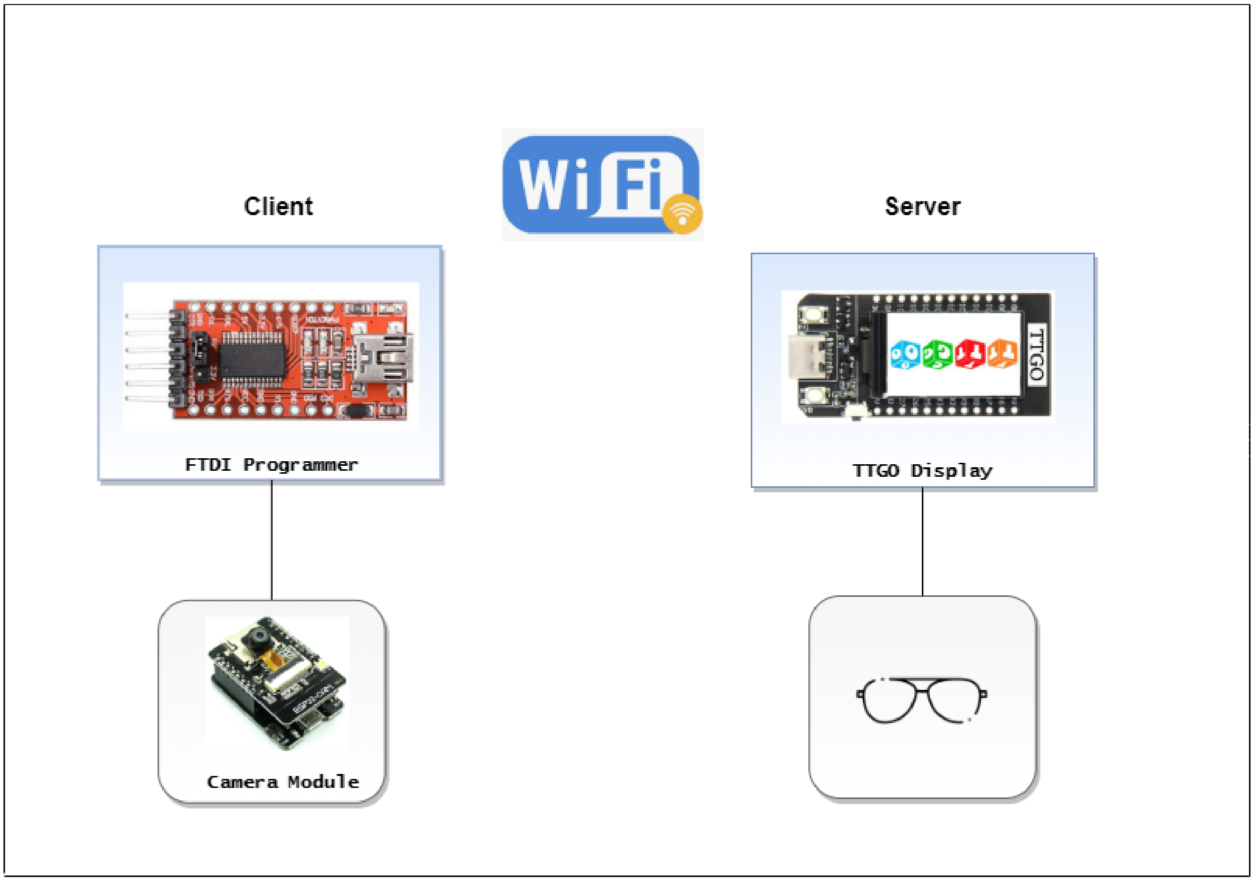


Figure 7: Overall system mapping

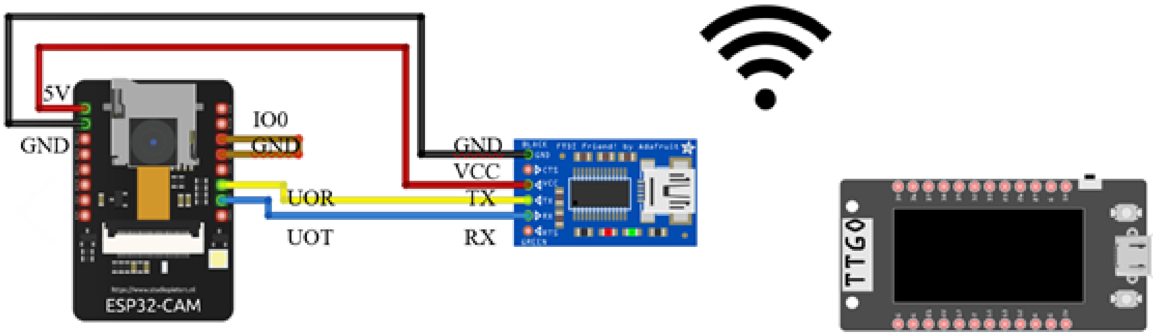


Figure 8: Portable Camera Connections

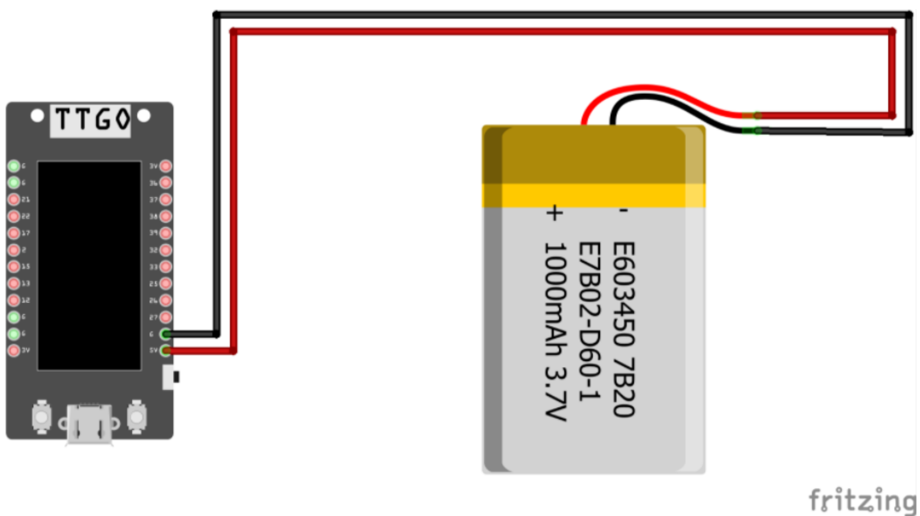
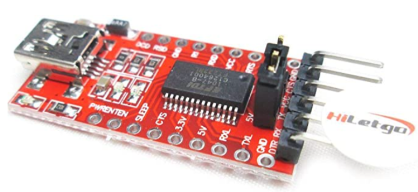


Figure 9: Display Module to Power Connections

Appendix C. Hardware Specifications

Table 4: Hardware Specifications	
HiLetgo ESP32 LCD WiFi Kit ESP-32 1.14 Inch LCD TTGO T-Display 	Manufacturer: HiLetgo Chipset: ESPRESSIF-ESP32 240MHz Xtensa single-/dual-core 32-bit LX6 Microprocessor FLASH: QSPI flash 4MB SRAM: 520 kB SRAM USB to TTL: CP2104 USB: Type-C
HiLetgo FT232RL FTDI Mini USB to TTL Serial Converter Adapter Module 	Manufacturer: HiLetgo Chipset: FT232RL, not genuine FTDI chip, Working Voltage: 3.3V/5.5V RXD/TXD transceiver communication indicator, with 500MA self-restore Fuse Pin Definition: DTR,RXD,TX,VCC,CTS,GND Support Win95/98/98se/ME/2000/XP/win7 32bit 64bit /Vsita/, do not Support Win8
ESP32-CAM WiFi Bluetooth Camera Module Development Board 	Manufacturer: Xiuxin Ultra-small 802.11b/g/n Wi-Fi BT/BLE SoC module Low-power dual-core 32-bit CPU for application processors Up to 240MHz, up to 600 DMIPS Built-in 520 KB SRAM, external 4M PSRAM Supports interfaces such as UART/SPI/I2C/PWM/ADC/DAC Support OV2640 and OV7670 cameras with built-in flash Support for images WiFI upload Support TF card Support multiple sleep modes Embedded Lwip and FreeRTOS Support STA/AP/STA AP working mode Support Smart Config/AirKiss One-click distribution network Support for serial local upgrade and remote firmware upgrade (FOTA) Support secondary development

Appendix D. 3D Model of Eyewear and Components

List of Eyewear Components

1. Freely Adjustable Arm
2. Housing Unit
3. 3.7V 1000 mAh Lipo Battery
4. Connective Rod
5. Clamps with Rubber Grips
6. Counterweight
7. TTGO T-Display
8. TTGO Cover
9. Glasses (Used for modeling purposes)