

LED PERSISTENCE OF VISION GLOBE

By

Melvin Alpizar Arrieta

Gavi Campbell

Owen Bowers

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TA: Gayatri Chandran

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Abstract

The human visual system retains an image for a brief interval—approximately one-tenth of a second—after the stimulus is removed. This phenomenon, known as persistence of vision, arises from the delayed response of retinal photoreceptors and sensory neural circuits. For centuries, this property has been used to create motion illusions, from early optical toys to modern cinema. In this project, developed for ECE 445, we exploit the same principle to create a dynamic two-dimensional display using a single array of LEDs rotating on a spherical path, producing the illusion of a globe-shaped floating display. The final product's intended use is for UIUC's LabEscape, to display various graphics including clock time and clues through wireless communication in real time.

Contents

1. Introduction	5
1.1 Problem statement	5
1.2 Solution	5
1.3 High level requirements	6
2 Design.....	7
2.1 Display Subsystem	7
2.1.3 Motor	8
2.1.4 LEDs/Drivers.....	8
2.2 Control Subsystem	8
2.2.1 Microcontroller ESP32	8
2.3 Wireless Subsystem	8
2.3.1 Web App	9
2.3.2 MicroSD.....	9
2.4 Power Subsystem.....	10
3. Design Verification	11
3.1 Display Subsystem	11
3.2 Controller Subsystem.....	11
3.3 Wireless Subsystem	11
3.4 Power Subsystem.....	12
4. Costs.....	13
4.1 Parts	13
4.2 Labor	14
4.3 Schedule.....	15
5. Conclusion.....	15
5.1 Accomplishments.....	15
5.2 Uncertainties.....	15
5.3 Ethical Considerations	15
5.3.1 Ethics.....	15
5.3.2 Safety	15

5.4 Future work.....	16
References	18
Appendix A Requirement and Verification Table	Error! Bookmark not defined.

1. Introduction

LabEscape at UIUC is a science outreach escape room with the mission of providing rewarding and thrilling experiences that show how science can be amazing, useful, beautiful, and fun. Their puzzles are built around real physical phenomena, giving visitors the chance to see science in action. When an exhibit does not work as intended, it can take away both the educational goals and the entertainment value that are central to the LabEscape experience.

1.1 Problem statement

Recently, the team attempted to create an LED globe that uses Persistence of Vision (**POV**) to display text, images, and animations. The project has run into several problems. The LEDs are not syncing with the motor's rotational speed, the motor seems to run faster than needed, even generating lift which makes the system unstable, and there is uncertainty about whether the correct voltage is being applied. With little documentation to reference, troubleshooting has proven difficult. On top of these issues, the team hopes to add more functionality, including the ability to display images and animations as well as control the globe remotely through WiFi. Solving these problems is important not only for the success of the project but also for maintaining LabEscape's mission of delivering science that both excites and educates.

1.2 Solution

Our solution is to design and build a stable, WiFi-enabled LED globe that reliably displays text, images, and animations using Persistence of Vision. At a high level, the system will synchronize LED patterns with the rotation of the globe to create clear visuals, while providing a user-friendly interface for uploading and managing content remotely. This approach directly addresses the synchronization, stability, and usability issues that have limited earlier attempts at the project [1] .

To implement this, the globe will use a 6V motor with a maximum output of 4000 rpm, paired with a hall effect sensor to track rotational position. The ESP32 microcontroller will use this feedback to precisely time LED updates, eliminating flicker and distortion. A microSD card will store image and animation files, allowing for more complex displays. The ESP32 will additionally provide WiFi connectivity for a web-based control app. Through this app, users will be able to upload content, adjust settings, and trigger animations in real time. The motor will draw power directly from an outlet, while the control electronics and LEDs will run from wireless regulated power to ensure stable performance. Together, these components create a system that not only solves the technical problems of synchronization and instability but also adds new functionality that makes the globe more interactive, engaging, and easy to maintain. By delivering a reliable and visually impressive exhibit, this solution will help LabEscape achieve its mission of creating unforgettable experiences that demonstrate the fun and wonder of science.

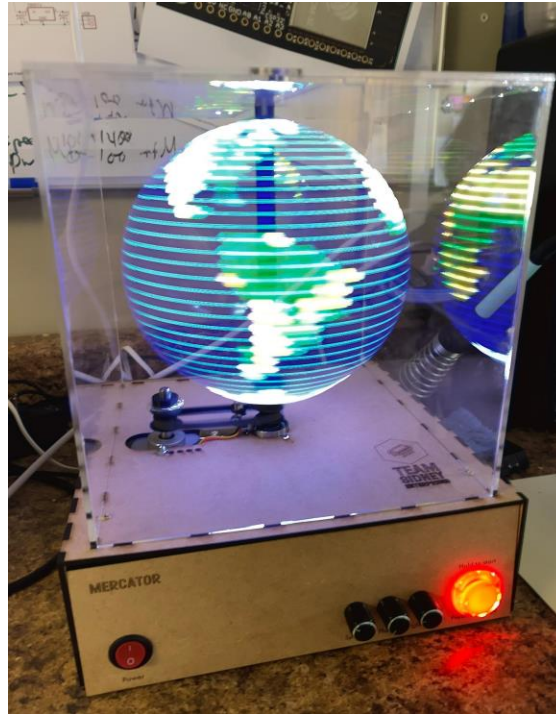


Figure 1. An example of persistence-of-vision globe developed by a hobbyist. Credit: Matt Walsh, [Medium](#)

1.3 High level requirements

Our POV Globe will satisfy the following high-level requirements:

1. **Resolution & Color:** The POV globe should display RGB images with 64x256 pixels resolution and 8-bit color. The images should remain stationary and clear to the viewer as the globe rotates continuously.
2. **Power:** The globe will be powered via a 12V, 3A power adaptor. The rotating segment containing the LEDs and circuit board will draw 25W through a slip-ring transformer – i.e. without an on-board battery.
3. **Data Transfer:** The rotating circuit board should wirelessly receive data and store it onto an onboard SD card. The system shall then read and display this data on the LED array in under 10 seconds.

2 Design

The design for the POV glob includes four subsystems, for power delivery, [list all]

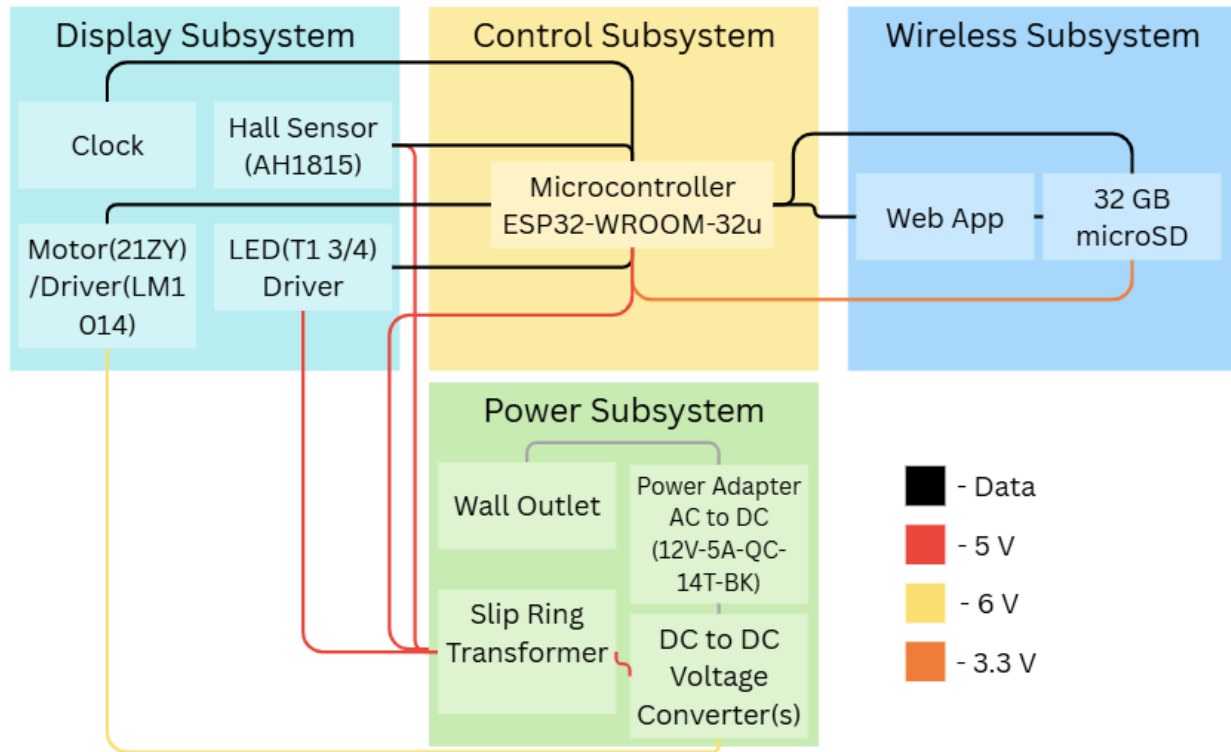


Figure 2: A block diagram indicating connections between components and subcomponents.

2.1 Display Subsystem

This system consists of a motor¹, hall sensor², LEDs³, and clock. All of which are necessary to provide the logistical and mechanical needs to allow for a readable display. This subsystem interacts heavily with our microcontroller. 64 5mm 4 Pin LEDs make up the display. LEDs are in groups of 12 attached to LED drivers. Each group of 12 has their anodes connected to each of the 12 different pins. The LED driver⁴

¹ LEDs must achieve 256 distinct color levels

² Sparkfun Electornics. "Hall-Effect Sensor - AH1815 (Non-Latching)." *Sparkfun Electornics*, <https://www.sparkfun.com/hall-effect-sensor-ah1815-non-latching.html>.

³ Envistia Mall. "5MM T1-3/4 4 Pin Common Anode / Common Cathode Clear / Diffused RGB LED." *Envistia Mall*, <https://support.envistiamall.com/kb/5mm-t1-3-4-4-pin-common-anode-common-cathode-clear-diffused-rgb-led/>.

⁴ Kinetic Technologies, "KTD2061/58/59/60 – 36-Channel RGB LED Drivers with I2C Control (Rev. 04e, Mar. 2022)," *Kinetic Technologies*, 2022, <https://www.kinet-ic.com/uploads/KTD2061-58-59-60-04e.pdf>. Accessed 15 Oct. 2025

pulses 12 LEDs at a time using 36 pins, 3 per LED. The motor has to spin at 600 RPM and will have to have solid mounting to the base as well as the LED board.

2.1.3 Motor

The motor must spin the globe at a rate of 600 ± 15 RPM.

2.1.4 LEDs/Drivers

LEDs must achieve 256 distinct color levels. Utilizing our LED drivers we will be able to assure proper addressability of each LED and its color.

2.2 Control Subsystem

This subsystem consists of our ESP32⁵ microcontroller which will hold the logic and do all calculations necessary to display items on our LED display.

2.2.1 Microcontroller ESP32

The ESP32 being used has 21 GPIO pins and 2 cores. The two cores are utilized to run synchronization software and LED pattern logic simultaneously. The 21 GPIO pins are for interfacing and power. Each GPIO has PWM capabilities as well allowing for customization on LED colors.

2.3 Wireless Subsystem

The wireless subsystem will consist of a web hosted app that is able to interface with the ESP 32. A micro-SD that interfaces with our microcontroller to transfer information.

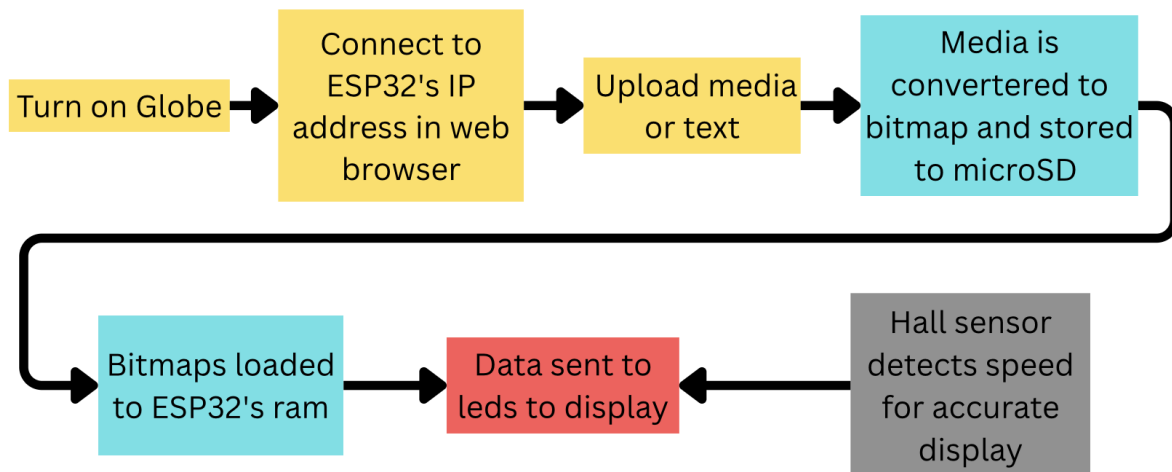


Figure 3: Flow Chart indicating the path our user's would take to display media on the globe

⁵ ESPRESSIF. "ESP32-WROOM-32U." *Espressif Systems*, https://www.espressif.com/sites/default/files/documentation/esp32-wroom-32d_esp32-wroom-32u_datasheet_en.pdf. Accessed 12 October 2025.

2.3.1 Web App

The Web App will allow for users to connect to the onboard microcontroller and transfer data through the microcontroller to be stored on the connected SD card. The libraries that are used to achieve this are the C WiFi and WebServer libraries. The WiFi library aids in connecting to WiFi and the WebServer library allows for the ESP32 to host it's own web server using simple HTML.

```
// ----- SETUP -----  
void setup() {  
    Serial.begin(115200);  
  
    // --- Access Point Mode ---  
    WiFi.softAP("ESP32_SD_Server", "12345678");  
    Serial.println("Access Point started");  
    Serial.print("IP Address: ");  
    Serial.println(WiFi.softAPIP());  
  
    // --- SD Card ---  
    if (!SD.begin(SD_CS)) {  
        Serial.println("SD init failed");  
        while (1);  
    }  
  
    // --- Server routes ---  
    server.on("/", HTTP_GET, handleRoot);  
    server.on("/list", HTTP_GET, handleList);  
    server.on("/upload", HTTP_POST, handleUpload);  
    server.on("/download/", HTTP_GET, handleDownload);  
    server.on("/delete/", HTTP_GET, handleDelete);  
  
    server.begin();  
    Serial.println("Server started");  
}
```

Figure 5: Code snippet of setup for ESP32. Starts the server once the microSD card is initialized correctly

2.3.2 MicroSD

The MicroSD will store our images to be displayed on the LED globe. Data transfer from this item is sufficient to make live updates to the display or to load the data into our ESP32's memory for it to be displayed at a faster rate.

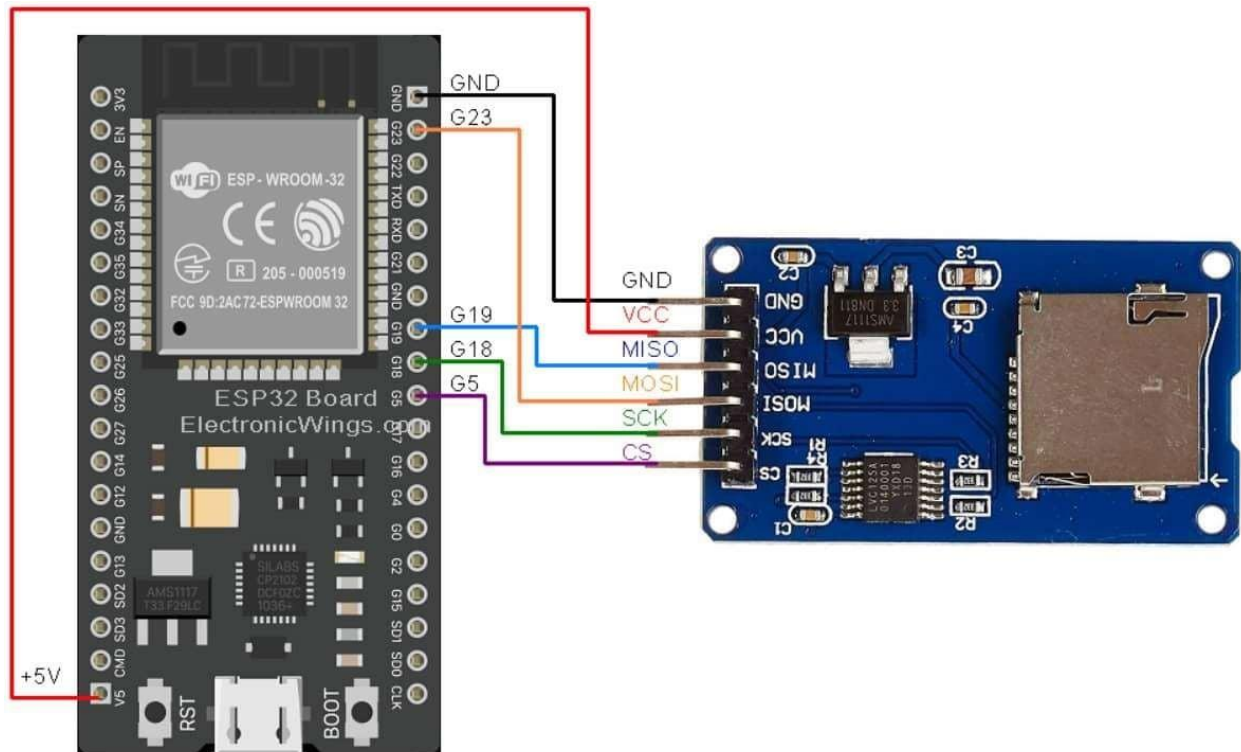


Figure 4: MicroSD module hooked up to ESP32. Credit: [ElectronicWings](#)

2.4 Power Subsystem

The power subsystem consists of a 12 V DC external power adapter, which serves as the primary input source. This voltage is stepped down using two dedicated converters: one provides 6 V for the motor, and the other delivers 5 V to power the remaining electronic components.

3. Design Verification

If all systems are working properly we will test whether we are able to upload a set of images wirelessly and display those images properly onto our LED display. Properly implies the proper positioning of pixels from our respective images onto our rotating sphere of LED's. Verification for each subcomponent is as follows:

3.1 Display Subsystem

Requirements	Verifications
The motor must spin the globe at a rate of 600 ± 15 RPM	Using the system's hall sensor and magnet, the speed of the motor is polled every 10 seconds for a 5-minute continuous run to make sure it remains in the acceptable range.
The display must render frames with a less than 5% flicker	Using an oscilloscope, we will sample the LED PWM signals and compare them to the timing
LEDs must achieve 256 distinct color levels	Verify with an oscilloscope that the PWM voltage levels is between 0.33-3.84 V

Table 1: Requirements and verification for the display subsystem.

3.2 Controller Subsystem

Requirements	Verifications
LED control loop must complete in less than 1 ms per iteration	Using the ESP32's built in microsecond counter, we can wrap the LED update logic with timestamp reads and view them in the serial terminal
SD card must support a read rate greater than 1 MB/s	Run a transfer test with different sized files (5, 50 and 500 KB) to see how fast a file is read.

Table 2: Requirements and verification for the Controller Subsystem.

3.3 Wireless Subsystem

Requirements	Verifications
The time from a WiFi command (e.g., image change) being sent until the first pixel is updated must be ≤ 3 seconds.	Timing the web app input up until the globe changes to what the input indicated.
Microcontroller must hold a steady connection for at least 2 hours	Run a script that periodically sends and receives data from the web app for a couple of hours, logging it in a serial terminal.

Table 3: Requirements and verification for the wireless subsystem.

3.4 Power Subsystem

Requirements	Verifications
Voltage for LED PCB and main PCB must be $5V \pm 0.2 V$	Using a multimeter, we'll measure the PCB's output voltage under load
PCB must draw less than 6 A as the total current	Using a multimeter, we'll measure the current being supplied to the PCB while in operation

Table 4: Requirements and verification for the power subsystem.

4. Costs

The cost of our project includes the many components we will have to purchase as well as the cost of PCB orders and labor costs.

4.1 Parts

Table 5 Parts Costs

Part	Manufacturer	Retail Cost (\$)	Amount	Actual Cost (\$)
Hall-Effect Sensor - AH1815 (Non-Latching)	Sparkfun	\$1.05	1	\$1.05
Led Driver KTD2061	Kinetic Technologies	\$1.66	6	\$9.96
Neodymium Magnet Disk Sensor N35 D6mm(A) x 3mm	Radial Magnet	\$1.00	1	\$1.00
31ZY Permanent Magnet Motor, 6V/12V/24V 3500-8000RPM Permanent Magnet DC Motor Electric Brushed Motor CW/CCW (12V 8000RPM)	Robot Shop	\$16.91	1	\$16.91
5MM T1-3/4 4 Pin Common Anode / Common Cathode Clear / Diffused RGB LED	Chanzon	\$0.09	100	\$9.00
LM1014 Motor Speed Controller	National Semiconductor	\$5.72	1	\$5.72
ESP32-WROOM-32U	Digikey	\$4.84	1	\$4.84
12 V, 5 A AC-DC Power Jack	Gilivier	\$9.98	1	\$9.98
SanDisk Ultra PLUS 32GB	SanDisk	\$14.99	1	\$14.99

microSD Memory Card ⁶				
Slip Ring with Flange - 22mm diameter, 6 wires, max 240V @ 2A ⁷	Adafruit	\$14.95	1	14.95
Total				\$88.40

4.2 Labor

According to the Grainger College of Engineering⁸ graduates with a computer engineering degree earn on average \$57.09/hr. Assuming that we spend a maximum of 70 hours working on this project we get a total cost of labor of:

$$70 \times \$57.09 = \$3996.30$$

⁶

Target. "SanDisk Ultra PLUS 32GB microSD Memory Card." *Target*, <https://www.target.com/p/sandisk-ultra-plus-32gb-microsd-memory-card/-/A-14413251>. Accessed 2 November 2025.

⁷ Adafruit. "Slip Ring with Flange - 22mm diameter, 6 wires, max 240V @ 2A." *Adafruit*, <https://www.adafruit.com/product/736>. Accessed 2 November 2025.

⁸ Grainger College of Engineering. "Computer Engineering." *The Grainger College of Engineering, University of Illinois Urbana-Champaign*, <https://grainger.illinois.edu/academics/undergraduate/majors-and-minors/computer-engineering>. Accessed 13 October 2025

5. Conclusion

5.1 Accomplishments

We have accomplished quite few exciting feats so far in our testing. Namely we have accomplished proper persistence of vision, multicore control via the ESP32 allowing for proper image synchronization, algorithm to translate pixels from an image onto our spherical design, and remote storage of images.

5.2 Uncertainties

We have a couple of uncertainties as to the writing of this document, particularly regarding the design of a power conversion system for our motor. In practice we ran our motor at about .42 amps which was sufficient for our breadboard prototypes. However, for our final design this number will likely be different. Therefore, we are uncertain as to when we will be designing this circuit that will regulate the power into our system. This will likely happen once we have finalized our design, but if that proves to be unrealistic, we will likely design a power conversion system that will supply a satisfactory result. As our system is designed to adjust to different speeds within reason, this is an acceptable option.

5.3 Ethical Considerations

5.3.1 Ethics

The development of our LED globe project involves several ethical considerations. We prioritize the safety, health, and welfare of the public by ensuring that the device is electrically safe, mechanically stable, and responsibly designed. The purpose of the globe is to serve as an engaging and educational demonstration of Persistence of Vision, which supports LabEscape's mission of using science to inspire curiosity and learning.

A key ethical concern is privacy and security, since the device can be controlled remotely over WiFi. Without safeguards, unauthorized individuals could connect to the globe and display inappropriate or misleading messages during public demonstrations. To prevent this, we will implement password protection and restrict control access so that only LabEscape staff can update the display. By being transparent about how the system works, documenting our security measures, and providing clear guidelines for responsible use, we will reduce the risk of intentional misuse.

5.3.2 Safety

- **Electrical Safety**

The globe relies on a high-speed 6V motor powered from an outlet, a microcontroller, LEDs, and a WiFi module. To minimize electrical risks such as overheating, short circuits, or accidental shock, the system will use proper voltage regulation, fuses, and insulation. All wiring and connections will be securely enclosed, and the power supply will be housed in a protective casing to prevent accidental contact. During development, we

will follow standard lab safety practices, including the use of insulated tools and protective eyewear when soldering.

- **Mechanical Safety:**

Because the motor could spin at hundreds or even thousands of revolutions per minute, mechanical stability is a priority. The globe will be securely mounted and balanced to avoid vibrations that could damage components or cause parts to detach. A protective housing will be added around the rotating assembly to reduce the risk of accidental contact during operation. The mounting system will also be tested to ensure it remains stable even during extended demonstrations.

- **End-User Safety:**

Since the project is intended for public demonstrations, the device will always be operated under supervision. Users will not have direct access to the motor or electronics, and clear instructions and warnings will be provided to minimize risks. Security measures such as password protection on the WiFi interface will ensure that only authorized staff can change the display. Additionally, flashing lights and animations can trigger seizures in individuals with photosensitive epilepsy, so visible warnings will be posted near the exhibit to alert visitors before use. Together, these precautions ensure the globe remains both safe and reliable in an educational setting.

5.4 Future work

Week	Task	Responsibility
Oct 27 th – Nov 3 rd	Receive and Begin work on PCB order. Build power converter from wall socket to device.	Melvin
Oct 27 th – Nov 3 rd	Compile all code snippets including Wifi Connectivity, Image Display, and Spin Synchronization into one full program. Complete logic for mapping pixels onto 64 LEDS.	Gavi
Nov 3 rd – Nov 10 th	Finish assembly of initial PCB order and test initial system.	Gavi
Nov 3 rd – Nov 10 th	3D print supporting structures for device. Deadline to complete compiling errors and fixes for next PCB order.	Melvin
Nov 10 th – Nov 17 th	Complete web app, making sure it functions as intended, Finish assembly of second PCB order and test remaining systems.	Melvin, Gavi

Nov 17 th – Nov 24 th	Mock Demo. Extra time for improvements	Everyone
Nov 24 th – Dec 1 st	Thanksgiving Break	Noone
Dec 1 st – Dec 8 th	Final Demo	Everyone
Dec 8 th – Dec 15 th	Final Presentations	Everyone

Table 6: A table describing our schedule for the upcoming weeks.

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