Project Proposal

Team 17 - Globetrotters

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Introduction

Problem:

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 [1]. 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 from both the educational goals and the entertainment value that are central to the LabEscape experience.

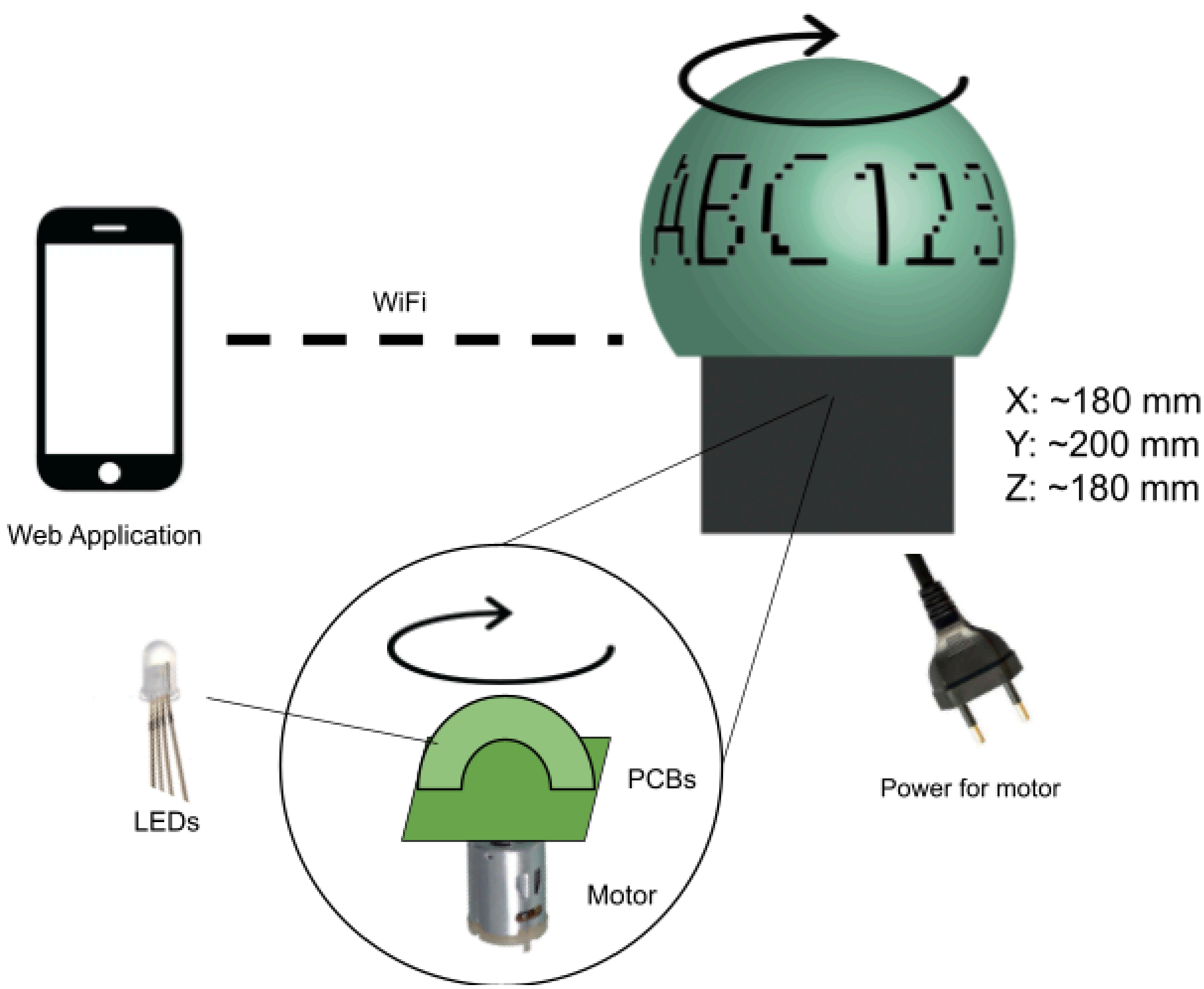
Recently, the team attempted to create an LED globe that uses Persistence of Vision (POV) to display text, images, and animations. The project has run into several problems. The LEDs are not syncing with the motor's rotational speed, the motor seems to run faster than needed and even generates lift which 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.

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.

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 RP2040 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, while an ESP01S module will 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 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.

Visual Aid:



High-level requirements list:

1. LED Control

   a. Imagery imprints on the human for roughly 1/16th of a second. We can utilize this to achieve persistence of vision when spinning a light very quickly so that it revolves in 1/16th of a second. Our design has two sides so that time is cut in half to fully rotating every 1/8th of a second. This would require an RPM of 480. However 480 RPM is the bare minimum and would result in a flicker effect as your eye is stimulated and then resolves the stimuli only to be immediately stimulated again. To maintain a higher level of stimulation and avoid flickering we aim to be able to maintain the eyes stimulation at between 10 and 100 percent. This would require us to spin our LED's at 10 rotations per second or 600 RPM.

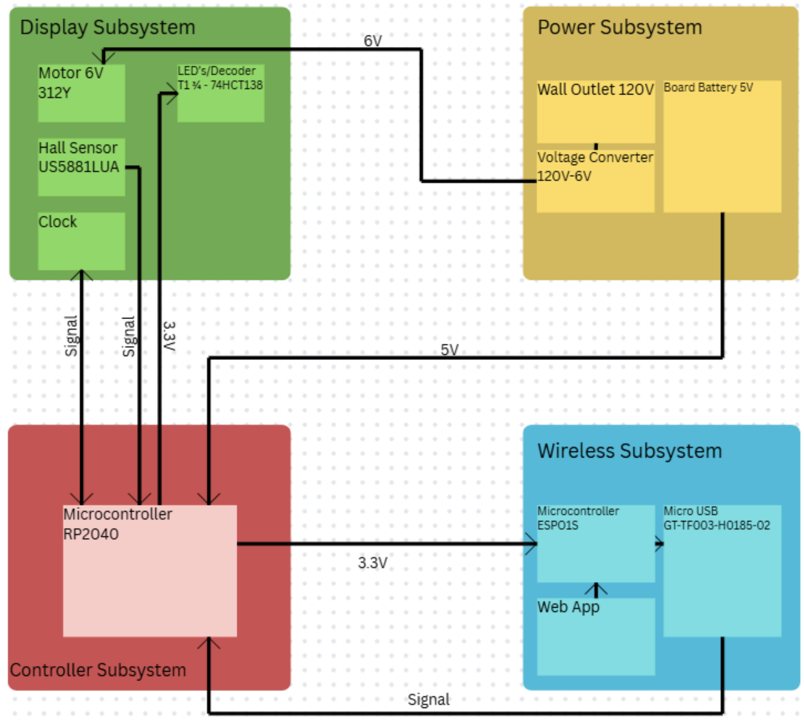
      Although spinning the sphere faster would allow for clearer and brighter images we would eventually run into issues of our Microcontroller not being able to address our LED's fast enough. This is due to the fact that our microcontroller, in tandem, with our decoder may run into problems of being able to run onboard programming and send out signals fast enough to keep up with our spin speed relative to the previously written LED's in the sequence.

      In other words our high level requirement is that the time to execute our LED control code shall be fast enough not to interfere with our minimum required spin speed of 600RPM.

2. Resolution
   a. Since our design has the LEDS interlaced we aim to have a vertical color resolution of a color every 2.75 mm. Resolution on the horizontal axis is negligible as the LEDS turn on and off in 10's of nanoseconds and the clocks speed is even more negligible.
3. Color
   a. The way that the RGB LEDS work is that by playing with the voltages of the LEDs we can get the full spectrum of colors. For the purposes of this project we aim to be able to design our LED control to achieve 256 (for the retro feel) color variations. This will be accomplished by utilizing a 4HCT138 3-to-8 decoder to provide desired voltages between .33V to 3.84V. Additionally, we settled on 256 as that allows for a sufficient gap in between voltage levels to ensure accuracy of color. We can also utilize the fact that we are interlacing our LED's to provide additional colors.

Design

Block Diagram:



- **Subsystem Overview:**
  1. Display Subsystem
     a. This system consists of of motor, sensor, LEDs, 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 micro-controller.
  2. Controller Subsystem
     a. This subsystem consists of our main microcontroller which will hold the logic and do all calculations necessary to display items on our LED display.
  3. Wireless Subsystem
     a. Our wireless subsystem will consist of a web hosted app that is able to interface with a dedicated microcontroller. This dedicated microcontroller is able to interact with our storage medium (the Micro SD). Our micro SD that interfaces with our microcontroller to transfer information.
  4. Power Subsystem
     a. Our power subsystem includes our batteries that power both our main functional board and a separate power source for our motor and rest of board if possible.

- **Subsystem Requirements:**
    1. Display Subsystem
        a. 64 5mm 4 Pin LEDs make up the display. LEDs are in 8 groups of 8 attached to our 3-to-8 decoder. Each group of 8 has their anodes connected to a MOSFET which is connected to the decoder and +5V. The LED driver pulses 8 LEDs at a time using 24 pins, 3 per LED.
        b. 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. Controller Subsystem
        a. The RP2040 has to have external flash memory and have connections to SD card storage, LED driver, 3-to-8 decoder, USB(micro/C?) for programming and all sensors. Pin allocation isn't a concern given how many the RP2040 has.
    3. Wireless Subsystem
        a. Our wireless subsystem will have to communicate with a web app and also properly "talk" to the program on board our device.
    4. Power Subsystem
        a. Our power subsystem requires 5V DC, provided by wall supply from the barrel jack. The first iteration of this globe may have been broken by overvoltage because these types of power supplies come in a variety of voltages. To avoid this problem we should implement a load switch and voltage regulator so our PCBs don't get fried if the end user plugs in the wrong cable again.
        b. To get power to the upper board we will require a transformer circuit and two copper coils for induction. Qi Standard coils for wireless charging can do 25W at 5V, which is more than enough for what we need. If there are serious issues we can have batteries mounted on the top board, but that would add to the load on the motor and be inconvienient for the end user.

Tolerance Analysis

To get an even display, we probably want 128-256 horizontal pixels, depending on how the LEDs are aligned so the "pixel" size is relatively square. The globe rotates every 100 ms, which means in the worst case we are lighting up each pixel once 391 us. We can only pulse one group of 8 at a time, so that's 49 us/pixel or 21 kHz. The led driver can handle PWM of up to 1 MHz which means there isn't an issue there and the RP2040 is certified to clock up to 200MHz. If our programs aren't super inefficient, 21 kHz is able to be done and we should be able to pulse more frequently and get full spectrum color. For PWM to appear as solid color to the human eye it generally has to be 80Hz or greater which is much less than the 21 kHz we just calculated.

Ethics and Safety

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.

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.

References

1. ACM. ACM Code of Ethics and Professional Conduct. Association for Computing Machinery, 2018, https://www.acm.org/code-of-ethics. Accessed 19 Sept. 2025.
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