Preliminary Design Report

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Abstract

Traditional print ads are durable and distributable but can be too detailed and easily overlooked, not to mention a waste of paper. We propose a connected, innovative and affordable advertising solution which employs visually intriguing display techniques to draw attention. Usable by storefronts, restaurants and businesses it lends a modern approach to mountable signage with wireless and online content management.

1 Problem Statement

1.1 Need

Most people by now are familiar with billboards, which are actually screens that change spontaneously over time. This sort of interconnected marketability is certainly the future of advertising, since central control over displayed media is superior from a management aspect. These sorts of advertising modernizations are showing up in much simpler forms all over, from TVs being utilized as digital menus in restaurants to smaller screens implemented as less-ferquently changed promos in other establishments.

A reprogrammable sign for storefronts and restaurants engineered such that its ease of content management, versatility and price point made it comparable to ordinary storefront signs would have a definite marketability. Not only would its display be inexplicably more eye catching, but an Internet of Things (IoT) design approach would lead to a more easily connectable and scalable product.[1]

1.2 Objective

Our objective with this project is to design, build, test and implement a persistence of vision based advertising solution. This could then be mounted above the entrance to the Electrical and Computer Engineering Commons on the fourth floor of F.Paul Anderson Tower to display the time and a welcome message to students. To do this for less than $500 would make it more appealing to potential customers as the starting retail price of competition is $700. By requiring the device to support wireless communication, its functionality is expanded to provide a more versatile, valuable and useful product to the end user. Eliminating the need for physical interaction with the device also introduces more mounting opportunities: ceilings, unreachably high walls, et. al.

1.3 Background

Digital signage is being rapidly adopted in eateries, shops and stores as a lower long-term cost advertising solution.[2] Billboards are certainly the large scale picture of this advertising technique, with smaller scale versions for store fronts appearing as dedicated PC monitors or LED signs that scroll predetermined text. These are both eye catching means of advertising, though the key limiting factor of them is their lack of physical movement; animated lights can only draw so much attraction. However, by utilizing a trick of the eye known as persistence of vision (POV as it shall be referred to), moving modulated LEDs are capable of simulating an image. This physical movement of the lights makes the sign inherently more eye-catching to a passerby. An example of this 'simulated' image can be seen in Fig. 1.

Persistence of Vision (POV) signs are not new; there are a few solutions available to today's market. Although outdated, they are certainly attention grabbing, even if they do have limited functionality, size and color replication.

One such example of the existing POV sign technology is the SpaceWriter iBall [8] seen in Fig. 1. It is limited by 3 bit color (8 total colors) as well as an 8 inch vertical display height. This might be sufficient for simple graphics and ad animations, but there is only so much one can do with 8 colors. The interface for uploading new content to the iBall is a microSD card slot. The user must use archaic PC software to create 'frames' from provided images, or to create text. The instructional manual for this software can be found in one place [3], which is linked to by none of their advertising pages. The only available place to purchase such a device is eBay.

Figure 1: The basic SpaceWriter iBall [4], to give an idea of the concept.

By minimizing the energy consumption of the motor that spins the device, POV signs can be made to be more efficient than traditional scrolling text rectangular signs. Since the total number of LEDs required for a POV sign is a fraction of that required for a rectangle of LEDs with the same surface area, energy savings are possible. The reduction in LED usage in POV signs also helps cut production costs due to the fraction of LEDs required.

Sean Kelley, general manager of Buffalo Wild Wings on South Broadway, was consulted to see what sort of characteristics an advertising device would need in order to be noticed and thrive in already media-rich environments. According to Sean, certain TVs in the restaurant were set to run predetermined ads and logos several times per hour. When told about an ad display that would catch the customers eye more effectively, he agreed that there would certainly be a use for it. He also explained limitations; it would not be a table top device since room is already limited. Enclosing the device was also discussed, it was deemed dependent on size and height of mounting position.[5]

2 Requirements Specification

The device's functional goals were segmented into marketing requirements based on the importance put on specific qualities of operation. Mandating some details of design while still including lofty goals allows us to not only succeed, but to have technically gone above and beyond by creating these less-likely features.

2.1 Objective Tree

The objective tree found in Fig. 2 is based on the marketing requirements outlined in Fig. 3.

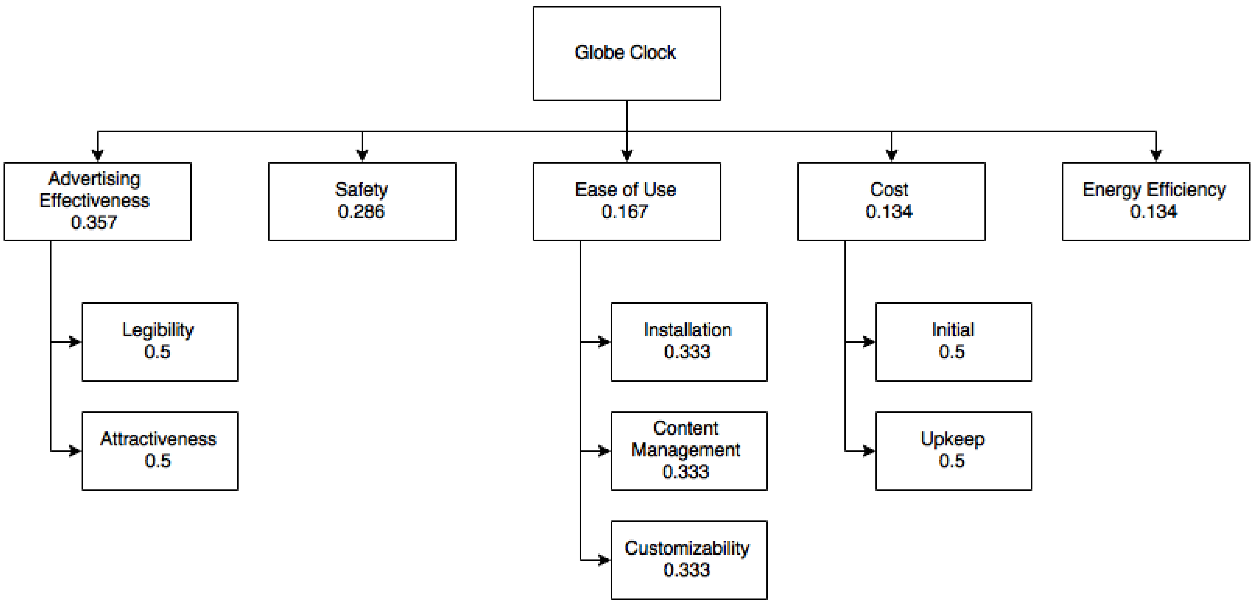


Figure 2: The objective tree with weights found using AHP[6]

2.2 Marketing Requirements

The concept of visualizing ad material on this emulated surface is quite scalable. Care was taken to design marketing requirements that do not specify a size, but rather a specific resolution for the device to achieve. Letting text and image refresh rate specifications imply the necessary windows in which a LED should pulse to generate a pixel allows for variously sized Globes to be feasible. The features which are definite are denoted by the italicized *shall.* Those that would deem us as having gone above and beyond, if they are to be completed, are denoted by *should.* The marketing requirements as we have formed them are shown in Fig. 3.

1. The device *shall* be able to display a 32 letter message (16 characters by 2 lines) around the circumference of the Globe (3360 bytes). This shall be known as the *standard configuration.*
2. The device *shall* be priced competitively (currently less than $500).
3. The device *shall* not be affected by people touching it or surrounding areas.
4. The device *shall* be reprogrammable without physical interaction with the device.
5. The device *shall* be easily mountable.
6. The device *shall* be powered from the socket with which it is mounted.
7. The device *shall* be more energy efficient than competition.
8. The device *should* be able to store 1 *standard configuration* of text.
9. The device *should* be able to be mounted on the ceiling with clearance for bystanders.
10. The device *should* be able to display 1 image.
11. The device *should* be able to display content clearly
12. The device *should* be able to operate outside in the elements.

Figure 3: Revised marketing requirements from the Requirements Report.

2.3 Engineering Requirements

Requirement	**Rel. Marketing Req.**
1. The device *shall* be able to connect to 2.4Ghz 802.11b/g networks.	4
1.1. The device *shall* be able to store 1 *standard configuration* of uploaded text.	8,4
1.2. The device *shall* be able to open a TCP or UDP connection to transfer the data to display.	4
1.3. The device *should* be able to broadcast its own 802.11b/g network with a preset SSID.	4
1.4. The device *should* be able to connect to 2.4Ghz 802.11n networks.	4
2. The device *shall* spin at a minimum of 900 RPM to achieve at least 15 fps.	1
2.1. The pixels *shall* be able to turn on and off within 833μs to achieve 15 fps. (to meet text display spec)	1
2.2. The resolution per character *shall* be greater than 5x7.	1
2.3. The pixel spacing must be close enough such that 14 pixels fit within the green and blue window sectioned off in Fig. 11	
3. The device *should* display a distinguishable image.	10
3.1. The strip of pixels *should* be able to turn on and off within 521μs to achieve 24fps (to meet image display spec).	7
3.2. Distortion along the edges of images *should* be minimized.	9
3.3. The image *should* be at least 14x80.	7,10
4. The device *shall* be able to replicate at least 256 colors.	1,7
5. The device shall consume less than 45W of power when displaying text.	7
6. Moving parts pertaining the creation of the POV image *shall* be enclosed.	
6.1. The enclosure *shall* provide a physical barrier with minimal visual degradation.	3,9

2.3.1 Justification and Testability

Table 1 shows the sub-specifications of Engineering Requirement 1.

Table 1: The device *shall* be able to connect to 802.11b/g networks, Ch. 1-11. (E.R. 1)

	Engineering Requirements	Justification	Testing	Mar. Req.
1.1	The device *shall* be able to store 1 *standard configuration* of uploaded text.	The displayed text will be an advertisement or other relevant information for the viewer	Look at the globe clock and see if it displays text correctly.	4,8
1.2	The device *shall* be able to open a TCP or UDP connection.	This allows for data transfer from a computer to the display so that text and images can be changed	Transfer known data over TCP connection; dump over serial from μController and verify similarity.	4
1.3	The device *should* be able to broadcast its own 802.11b/g network with a preset SSID.	This give the globe clock the ability to receive data from a computer.	Check and see if a 802.11b connected device shows the globe clock's broadcast.	4
1.4	The device *should* be able to connect to 802.11n networks.	This lets the globe clock connect to a computer	Successfully connect the globe clock to various other 802.11n enabled devices	4
1.5	The device *should* be able to store 2 *standard configurations* of uploaded images.	This will allow images to be changed periodically which will maximize ad revenue	Upload two images to the globe clock and switch them without re-uploading	4,10

Table 2 shows the sub-specifications of Engineering Requirement 2.

Table 2: The device *shall* spin at a minimum of 900 RPM to achieve at least 15 fps. (E.R. 2)

	Engineering Requirements	Justification	Testing	Mar. Req.
2.1	The pixels *shall* be able to turn on and off within 833μs to achieve 15 fps. (to meet text display spec)	These values are necessary for the transitions and movements to appear fluid to the human eye.	Monitor LED data lines with logic analyzer.	1
2.2	The resolution per character *shall* be greater than 5x7.	This ensures that letters won't appear grainy to the viewer.	Measure the number of pixels across characters and verify that its greater than 5x7.	1
2.3	The pixel spacing must be close enough such that 14 LEDs fit within the green and blue window sectioned off in Fig. 11	The pixel density needs to be high enough so that an image can be displayed clearly on the globe clock.	Count the number of pixels around the clock, divide by 4 and check to see if this number is 14 or greater.	1
2.4	The device *shall* be able to store 3360 bytes of uploaded data.	This is the required number of bytes to display 32 characters of text.	Ensure that program firmware leaves room for this.	8

Table 3 shows the sub-specifications of Engineering Requirement 3.

Table 3: The globe clock *should* display a distinguishable image. (E.R. 3).

	Engineering Requirements	Justification	Testing	Mar. Req.
3.1	The pixels *should* be able to turn on and off within 521μs ms to achieve 24fps.	Images would make the advertisements more attention-grabbing.	Monitor LED data line with logic analyzer	7
3.2	Distortion along the edges of images *should* be minimized.	The image should be displayed clearly on the surface of the sphere.	Display different test images onto the globe clock and ensure they are mapped clearly.	9
3.3	The image *should* be at least 14x80.	This ensures that an image won't appear grainy to the viewer.	Count the number of pixels displayed on the image displaying portion of the globe clock.	7,9

Table 4 shows the rest of the engineering requirements outlined in 2.3.

Table 4: Other Engineering Requirements as seen in 2.3.

	Engineering Requirements	Justification	Testing	Mar. Req.
4	The device *shall* be able to replicate at least 256 colors using RGB LEDs	To have greater color reproduction capabilities than the competition. [4]	Check LED spec sheet to verify PWM output is more than 7bits/color.	1,7
5	The device *shall* consume less than 45W of power when displaying text.	To be more efficient than the competition	Calculate and measure current consumed by circuitry and motor.	7
6	Moving parts pertaining the creation of the POV image *shall* be enclosed by a physical barrier with minimal visual degradation	To protect bystanders, consumers and the circuitry.	Subject the enclosed globe to jostling forces.	3,9

3 Impact

3.1 Economic

The globe clock is economically viable, because it allows the buyer to earn consistent ad revenue without spending much on capital or other reoccurring costs. The globe clock is built on energy efficient technologies such as LED lights so it will consume around 45 Watts of power which is less than a typical incandescent light bulb. Additionally, the globe clock will be sold for $600 which is a low start up cost compared with alternative means of advertising such as billboards or radio ads. The start up cost will be recouped quickly by the profits made from advertising thus making the globe clock economically viable.

3.2 Social

In order to meet the social need the globe clock will be more attractive, effective and impressionable. We should make the information displayed with rotating ring of LEDs become the great bright spot compared to the traditional print ads while benefiting the users by creating an advertising form that both attracts attention and stimulates customer response. In additional it should be widespread use in society by designing its ease of installation and use.

3.3 Safety

The globe clock it will be widely used in storefronts and businesses, so the customers safety is very important, and this device will take a very important role. It should avoid all the potential safety hazard and health dangers like the fire or rainwater in a special weather conditions while adhering the all safety code and standards. Safety is a significant factor for the device itself and during use because it will have a very close safety connection with users, customers and surrounding environment.

3.4 Manufacturability

Despite the flashing lights and mesmerizing nature of the globe clock, the underpinnings are built simply. The components are straightforward to assemble which will increase the scalability of mass manufacturing. Additionally, much of the underpinnings of the globe clock is software, which is exceptionally easy to mass produce, and furthers scalability.

3.5 Environmental

The globe clock is built to be environmentally sustainable as it encompasses technologies to keep energy consumption minimal. This not only keeps the operating costs of the globe clock down but also reduces the carbon footprint by not causing the power plants to burn as much fuel. The globe clock consumes only 45 watts of power which is substantially less than other advertising mediums such as billboards or television. Additionally, despite the advances of modern technology, many ads are still in print whether it be in the form of fliers, mail, or newspapers. If companies advertised on the globe clock instead of in print, less paper could be used and trees could be saved. Thus, advertising with the globe clock would be much more environmentally friendly than alternative advertising platforms.

4 Design

4.1 Design Plan

When designing something like this, inevitably it will involve a spinning ring of LEDs. The obvious roadblock is channeling the LED control signal from the processor to the rotating LEDs. This can be solved two ways: One is embedding the control circuitry onto the LED strip, so it rotates too. The other is commutating the control signal and bus power to the LEDs via a slip ring, seen in Fig. 8. The slip ring would still be necessary in both scenarios since the ring would still need power whether it had the control circuitry on it or not.

4.1.1 Connectivity

Working to achieve goals set under Engineering Requirement 1, the Espressif ™ESP8266 to be the most logical embedded WiFi solution. Since the WiFi solution was chosen first, choosing an application processor was then not necessary since the ESP8266 contains a reprogrammable application processor with 1Mb of program flash. The ESP8266 is suited for job due to the high weight put on reprogrammability as well as size constraints. Tables showing the AHP process for criteria and device selection can be seen in section 7.2.

Wide code base availability for this device (SDK from Espressif ™, Arduino IDE plugin, μPython port, NodeMCU interpreter and more) makes it an effective all-in-one controller solution. A simple breakout board for this IC is available from Sparkfun and other retailers, Sparkfun's board can be seen in Fig. 4, however it provides no voltage regulation or level shifting for UART pins. There are also only 3 GPIO pins available on the board once power and UART are utilized (reset takes one pin).

This configuration of the ESP8266 is more suited for acting as a slave WiFi device, where its only task would be to handle TCP/IP connections and transfer data over the UART to a host processor. It's ability to do this satisfies E.R. 1.2 GPIO operations would then be handled by the host processor eliminating the need for them on the ESP8266. The ESP8266 is also capable of connecting to 802.11b/g/n networks, satisfying E.R. 1.3 and 1.4.

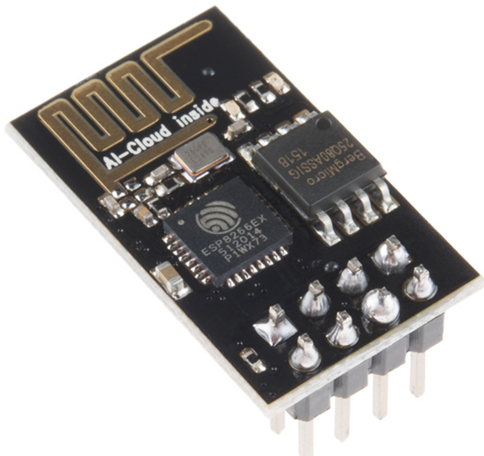


Figure 4: The baseline breakout board from Sparkfun of the ESP8266. [14]

The ESP8266 has many more GPIO than are exposed on the breakout board seen in Fig. 4. Adafruit [13] makes a breakout board that exposes these, as well as providing voltage regulation and level shifting for reset and UART pins, allowing the device to be reprogrammed from the Arduino IDE via a 5v or 3.3v USB to serial converter. This breakout board can be seen in Fig. 5.

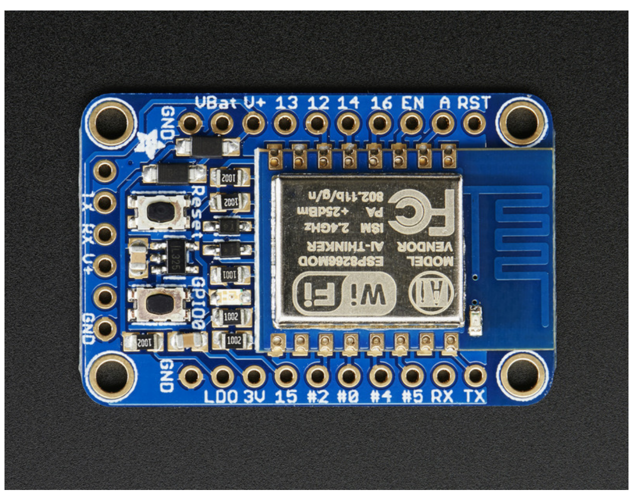


Figure 5: The ESP8266 breakout board available from Adafruit. [15]

Prototyping is then very straight forward utilizing this breakout board. The headers are separated by a breadboard friendly distance and the end pins match those of USB to serial converters available, one seen in Fig. 6

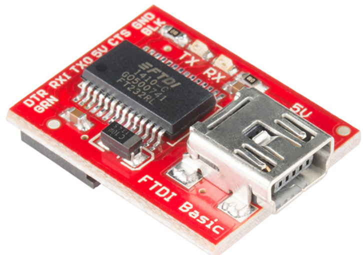


Figure 6: USB to serial converter from Sparkfun[16] with pin-out matching headers of ESP8266 breakout in Fig. 5

For long term solutions as well as a second revision prototype, module contained on the breakout board in Fig. 5 can be purchased directly from Adafruit as well.[17] This package can be seen in Fig. 7

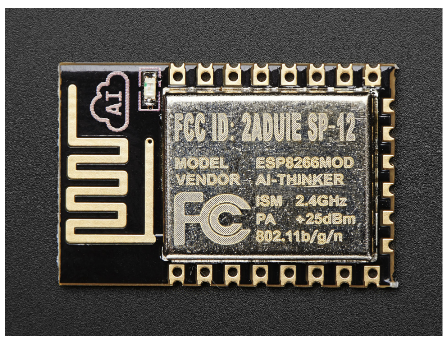


Figure 7: The ESP8266 standalone module from Adafruit.[17]

This embedded WiFi solution is minuscule, sized at only 24mm x16mm x 3mm.[17]. This is very conducive to an on-device circuitry solution, as opposed to a commutated connection to LEDs with WiFi and other circuitry stationary. This SMD module also is equipped with 4Mb of flash storage as opposed to the 1Mb that is shipped with the pre-soldered breakout board, both of these fulfilling E.R. 1.1.

4.1.2 Power

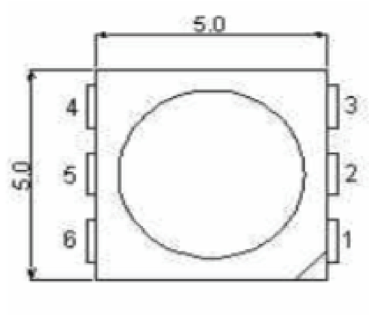
Seen in Fig. 8 is a slip ring which would work for us. It provides 6 rotationally independent signal paths from a stationary base to the rotating LEDs.

Figure 8: A 6 wire, 2A rated slip ring from Sparkfun. [9]

As you can see from Table 25 for a motor the safety criteria determined in order of importance are speed, heat dissipation and voltage/current. Heat dissipation and voltage/current are deemed to be equally important, while speed is seen as strongly more important than both of them. A highly rated motor with higher speed will increase the heat generation rate and power consumption. While a lower motor may not be appropriate for applications as well as the balance when the device is in spinning. Since the operating speed is always slower than the synchronous speed, a motor with around 1000 rpm will be considered to select [11]. The performance of heat dissipation and voltage/current design play the same role as these in LEDs for the clock safety (mentioned before). From [19], one can derive a maximum possible power usage for 14 LEDs to be 4.5W, Thus, motor selection can be deemed a lesser important decision as there is much power to spare and still be within E.R. 5.

4.1.3 LEDs

Commercially bought LEDs come in two forms. These are pre-made LED strips and individual LEDs. The properties of LEDs can be broken down into many categories. The ones that is important for this project is: size of led, the amount of colors, the ease of use, and the cost of the LEDs. Other important factors are brightness and power consumption, however for what we can buy there is extremely little variance between the available LEDs. Using the AHP table, seen in Fig. 24, we were able to find the importance of each property. The weights chosen were based on engineering requirements 2.2, 2.3, 3.1, 3.2, 4.



(a) Dimensional drawing of the WS2812 LED. [19]

(b) The WS2812 LED from Sparkfun. [20]

It is clear that the most important factors in selecting the right LED is size and the amount of colors. This makes it clear that we must use individual LEDs to get the best visibility. This can be accomplished by many different LEDs. We will want to go with the smallest LEDs available in order to have a better resolution. The smallest available for use is 5mm by 5mm. So if we stick each LED side by side we would get a total of 4 LEDs per inch. Having this metric enables us to compute minimum working radii for Globe Clocks since the desired resolution and feasible density are now defined.

This easily lets us satisfy E.R. 2.2 and 2.3 for a chosen ring diameter. The one wire interface on the WS2812 LEDs operates at 800kHz, each data bit taking 1.15μs. The baseline text requirement requires an overall vertical resolution of 14 pixels, equating to a strip of 14 LEDs. At 1.15μs per bit, 8 bits per color, 3 colors per LED, 14 LEDs per strip and the 50μs settle time required for a strip[19], this yields $t_{writeout} = 436.4\mu$s for a strip of 14. As you can see, this is less than both windows given in E.R. 2.1 and 3.1 for 15 and 24 FPS, respectively. The WS2812 is capable of reproducing 8 bit Pulse Width Modulation on all three color channels, yielding 256^3=16,777,216 total possible colors fulfilling E.R. 4. This also reinforces the importance of our most important node on the objective tree: Advertising Effectiveness.

4.1.4 Packaging

For the actual enclosure for the spinning LEDs, there were two thought processes; cover each individual LED bulb and let the strip of LEDs spin freely, or cover the entire unit inside of what can be thought of as a classic fish bowl type enclosure. After further research, it quickly became evident that simply protecting each individual LED would not aid in the protection of the overall structure at all. This solution is based on engineering requirements 6, 6.1.The strip of LED lights is placed atop a thin plastic ring and is very flimsy. Even if this strip was reinforced with a stronger material, it would add little to the overall integrity of the structure and the globe itself would still be vulnerable to damage. Covering just the LEDs would also do nothing for the overall product pertaining to the weather elements if it were mounted outside. Therefore, the best plan of action is to encapsulate the parts inside of a globe.

The next step of the research process pertains to what material must be used to act as our encapsulating globe. The following table shows possible globe materials and their characteristics. Note that these evaluations are based on known similarly sized samples of the individual materials [12]

Table 5: Different enclosure materials and their characteristics.

Material	Price	Durability	Visibility	Weight
Inj. Molded Plastic	Lowest	Weakest	Low visibility, severe discoloration	Lightest
Polycarbonate	Highest	Strongest	Good visibility, some discoloration	Light
Inj. Molded Acrylic	Medium	Moderate	Good visibility, slight discoloration	Light
Hand Crafted Acrylic	High	Moderate	No discoloration	Light
Glass	High	Strong	Slight discoloration	Heaviest

4.1.5 Safety

LED light bulbs play one of the most important roles in our project. As a marketing project, the safety of users and customers is the top one issue, as our objective tree shows with it having the second highest weight. The global clock needs a type of LED bulb which is both user-friendly and safe. During the whole process of display, the light generated by the LED bulb should be stable and visible. Also, the most important part is to protect customers eyes and be safe. Therefore, due to different parameters of different LED types, below are the most important factors of the LED lighting bulbs safety. First, voltage and current across the clock are in them. A good durability can make the clock to be used in a long term. Temperature of the bulbs during work determines the safety level as well.

As can be seen from table 19, for LED parameter the criteria determined in order of importance are heat dissipation, voltage/design current, durability and light angle safety. From the last row heat dissipation of a LED is seen as strongly more important than durability (factor of 5), moderately more important than light angle and voltage/current (factor of 3). It is the most important criteria because overheated LEDs can damage the device and even cause a fire to break out. A forced cooling system will be needed, if the temperature exceeds 60 degrees centigrade [10]. Durability can make the clock to be used in a long term, but it is not necessary. The hazard of using a limited durable bulb can be avoided by changing it according to its lifetime. LEDs are current-driven devices, exceeding the maximum current rating will cause excessive power dissipation which will increase the heat production and then endanger the safety of the device [10]. As an advertising sign people will not stare at it for a very long time, so eye safety determined by it angle is not as big consideration as others.

Because the clock is always put at somewhere closed to people and it rotates at a very fast speed, a shelter covering the whole clock is necessary to keep it safe for customers. A good shelter should not decrease the sharpness of the display and protect the customer from the high speed rotating clock. Shape of the shelter should also be considered and it must be suitable for the clock. Size and material are the parameters should be concerned and also the weight. On the other hand, shelter should be suitable to carry and the clock will be easy to remove from and place into it.

According to Table 20, for a shelter the criteria determined in order of importance are temperature resistance, transparency, solidity and weight. Temperature resistance of a shelter is seen as moderately more important than solidity transparency and weight (factor of 3). Because the clock will be placed indoor or outdoor, the shelter should be suitable for complex conditions of temperature. Additionally these factors cannot be changed. While the transparency of the shelter is moderately more important than both solidity and weight, it is mainly used to determine the attractiveness and effectiveness of the device. Since the shelter can be fixed in place, the weight of a shelter is not as important as any others. All of these criteria depend on the shelter material. Main material chooses for shelter can be acrylic sphere, plastic or metal cage. The metal cage is solid but it will disturb sight and heat dissipation. Plastic is available because it light and adiabatic but the cage affects aesthetic outcomes and effectivity. Improper speed will affect the stability and safety. So a mini motor with high quality is necessary to this project to keep customers safe. The rotating speed should not be too high or too low. The motor should operate at a stable condition and keep a low temperature. The material should be waterproof and make the motor durable. The mini motor should also be charged at a low voltage and current which makes it safer.

From table 21, for a motor the safety criteria determined in order of importance are speed, heat dissipation and voltage/current. Heat dissipation and voltage/current are deemed to be equally important, while speed is seen as strongly more important than both of them. A highly rated motor with higher speed will increase the heat generation rate and power consumption. While a lower motor may not be appropriate for applications as well as the balance when the device is in spinning. Since the operating speed is always slower than the synchronous speed, a motor with around 1000 rpm will be considered to select [11]. The performance of heat dissipation and voltage/current design play the same role as these in LEDs for the clock safety (mentioned before).

4.1.6 Display Area Optimization

One design decision that needed to be accounted for was what should be the vertical height of an image mapped onto the globe clock. It would be ideal to have a larger image height because this would make the image legible from farther away. However, the larger the image, the more it will be distorted along the top and bottom edges. To make referencing simple, we referred to the vertical height as an angle above center. The vertical heights considered were 30°, 45°, and 60° which would make the heights for the globe clock (with 6 inch radius) 6.28, 9.42, and 12.57 inches respectively. While a height of 12.57 inches would be ideal, there would be a lot of distortion on the image at the top and bottom edges. Therefore, the 45° angle (9.42 inches) would display the image at a large enough height while keeping distortion minimal.

Another design decision is the horizontal length of the image. Like vertical height, size and distortion are a factor in optimal horizontal height. Another factor to consider is that the globe clock will be spinning in a vertical direction. The vertical distance is chosen by the angle from the left edge to the right edge of the image and a 90° and 120° angles were compared with lengths of 9.42 and 12.57 inches respectively. The 90° angle was chosen because it would minimize distortion while allowing the image to remain visible to the viewer for a longer period of time. This is the optimal way to fulfill E.R. 3.2. This also makes the programming easier, because the image could be sketched from the x plane to the y plane. Thus, the ideal image mapping size would be 9.42 by 9.42 inches for a globe clock with a radius of 6 inches. The display area is shown in figures 10 and 11.

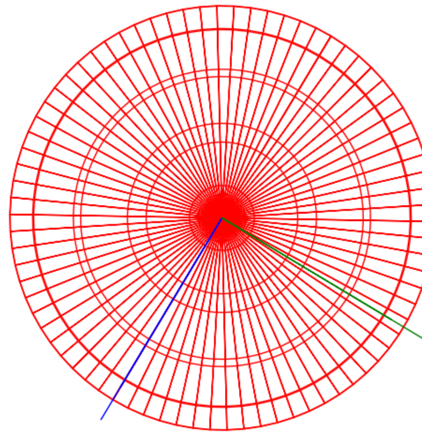


Figure 10: A top-down view of the globe with a 90° angle shown between the green and blue lines

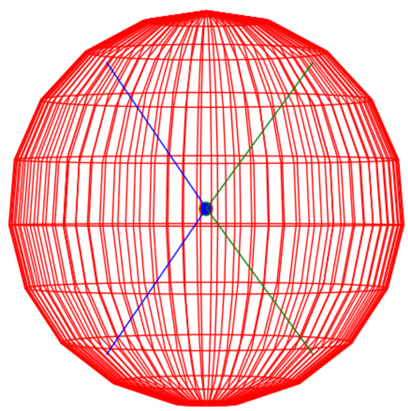


Figure 11: A side view of the globe with a 90° angle shown between the green and blue lines

4.2 Functional Decomposition

One required aspect of the Globe Clock is its ability to connect to 802.11/g networks. A hopeful goal of the project for the Globe to be able to provide (broadcast) its own access point. This would be useful in scenarios where an establishment wishing to use the product does not have WiFi connectivity. Due to the selection of ESP8266, this is possible.

This can be improved upon in implementation by commanding the device to search for all SSIDs (network names) and create its own such that it is unique to the surrounding network.

There are two ideas for end user interfaces, both possible if the device is on an Internet connected access point, only one if the device is providing its own network. Assuming the device is online and not just connected to the Local Area Network (LAN), a website can be created and hosted such that the Globe may be reprogrammed from multiple locations. Convenient for, say, if a store owner is home and wants the sign to say "Closed". If the user is on the Wireless LAN that the Globe is also on, an interface which is hosted by the device may be accessed, allowing a direct connection between the hand-held device and the Globe. The latter programming option would be the only on available if the customers network were not online, or, the Globe Clock was providing the access point.

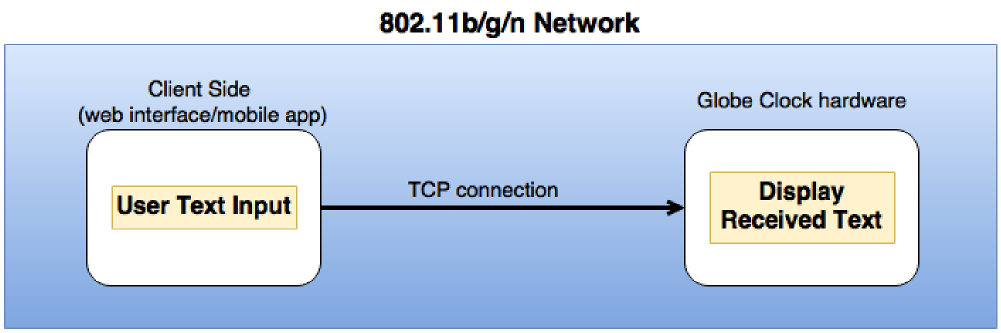


Figure 12: The most abstract of the functional diagrams, showing basic end user operation. Note the N type network possibility due to the choice of the ESP8266.

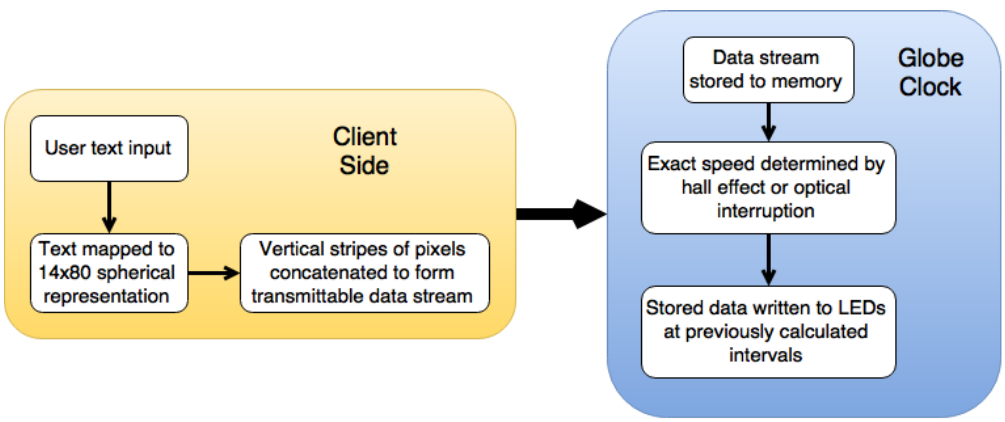


Figure 13: A diagram showing more specific functionality of the planned operations and interworkings.

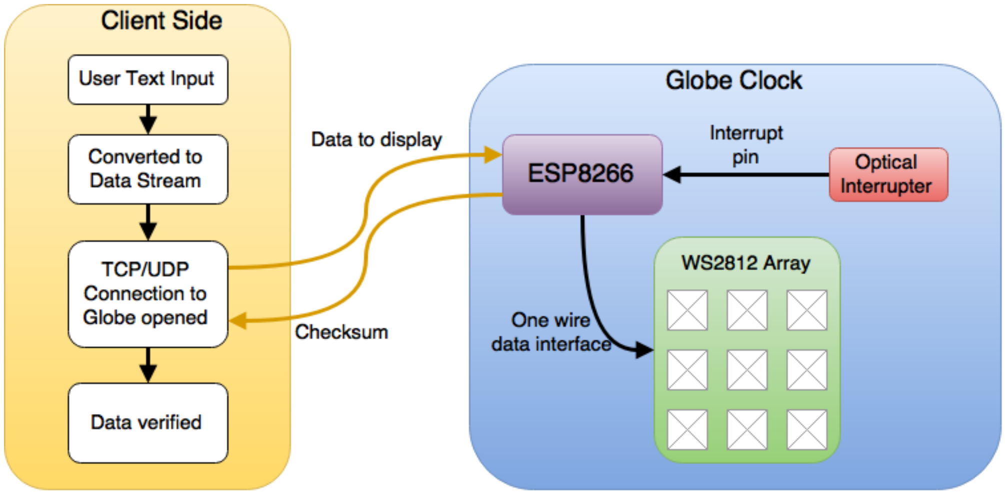


Figure 14: The most specific representation of device functionality.

4.3 Block Diagrams

In this section, major functional parts of project components are outlined via abstract grouping of duties and/or purpose. These diagrams are shown for selected electronic hardware components as well as the physical arrangement and construction of parts for a prototype.

4.3.1 WiFi and Processor

The Espressif ™ESP8266 WiFi stack was determined to be the best 802.11b/g network interface, the block diagram for this IC can be seen in Fig. 15. This exemplifies various interface components of the IC as well as visualize separation of wireless interface and command execution hardware.

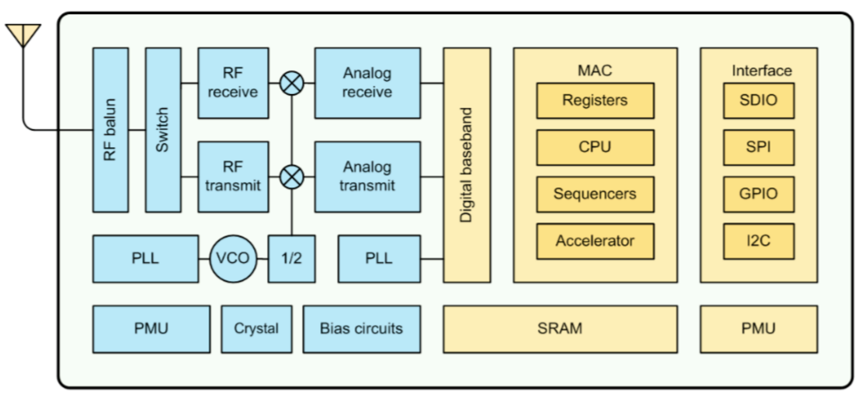


Figure 15: Block diagram for the ESP8266 WiFi stack and combined application processor. [18]

4.3.2 Packaging

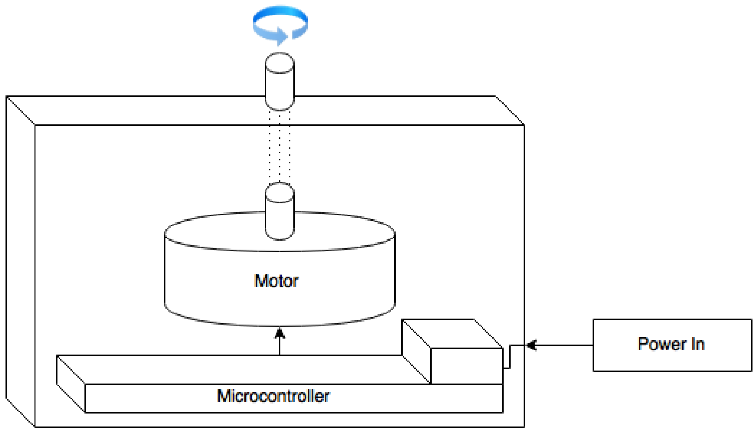


Figure 16: Preliminary assembly of the Globe Clock, showing circuitry stationary and a commutated LED data line.

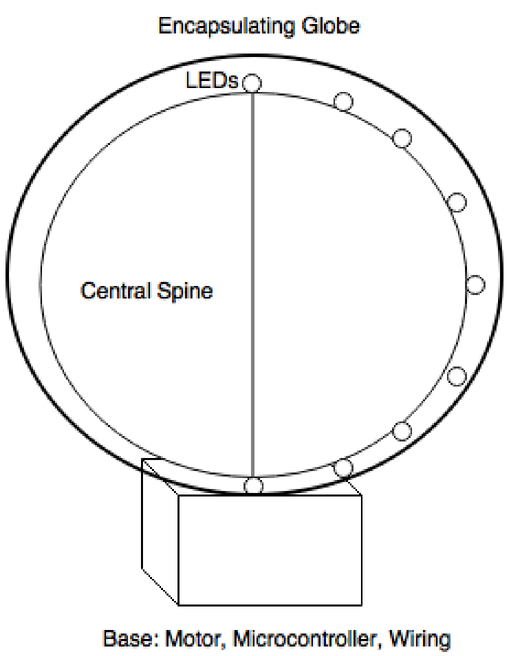


Figure 17: Visualization of enclosure relative to LED ring and base.

4.4 State Diagrams

In this section, program states are shown relative to the functional purposes of the device.

4.4.1 Initial Software Activity

The major routines necessary for operation can be seen in Fig. 18. Black arrows denote code execution progress, while green and red arrows represent the starting and stopping of the device spinning, respectively. This is the highest level description of operation.

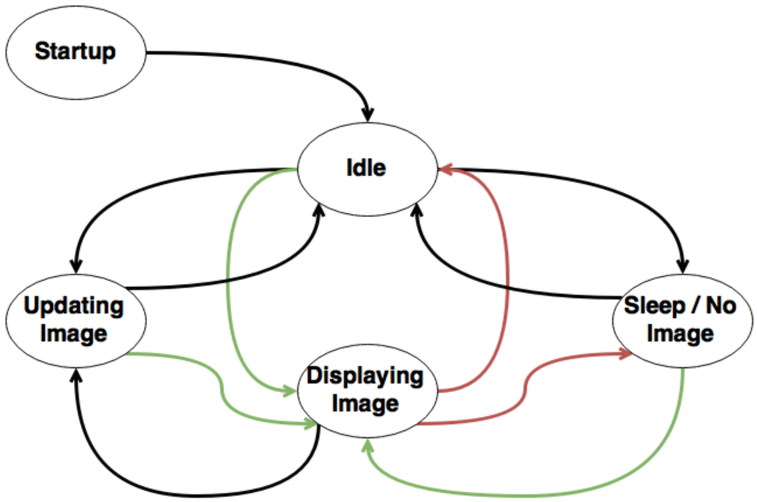


Figure 18: A preliminary state diagram for routines the Globe Clock will preform.

Software states relative to the displaying of information on LEDs is shown in Fig. 19. T_{rot} represents the period of a single rotation, in seconds. The time-stamp captured every rotation interrupt is continually compared with the previous one in order to maintain a running average of T_{rot}. By capturing the time-stamp after all the pixels have been written, this difference may be compared in real time with T_{rot}, if only during prototyping, to determine the accuracy of the the delay Equation. This can also be seen in Eq. 1, where N represents the horizontal resolution of the text/image to display. t_{write} represents the the time it takes to clock out M number of pixels worth of data. M is then the vertical resolution of the text/image to display.

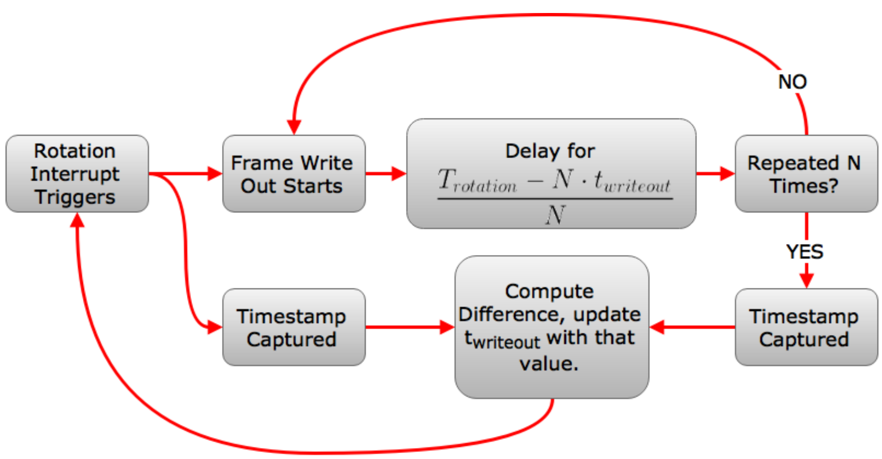


Figure 19: More detailed description of the process to display planned arrays of pixels on the device.

$$t_{delay} = \frac{T_{rot} - N \cdot t_{write}}{N} \tag{1}$$

5 Project Plan

The sponsor has already created a prototype based on proof of concept, this will be used to test text and image displaying algorithms while a more solid, scalable and sturdy frame and enclosure is built.

5.1 Breakdown Structure

The breakdown structure is sectioned into 3 tables, seen in Tables 6, 7 and 8. The tables are organized by parts acquired, with contingent sections referenced by ID in the far column. In the tables, μController is used for formatting sake.

Table 6: Breakdown Structure Part 1

Id	Activities	Description	Deliverables	Duration (days)	Member	Resources	Pred.
1.1	Order Parts	Order necessary parts	Working parts	7	Jessie		
1.2	Test indiv. parts	Connect to power	Testable connections	3	Jessie, Hao	multimeters	1.1, 2.1, 3.1, 4.1, 5.1
1.3	Testing power	Ensure proper voltages	Programmable system	3	Jessie, Hao	multi-meter	1.1, 2.1, 3.1, 4.1, 5.1
2.0	LEDs						
2.1	Schematic for LEDs	Design digital logic for LEDs	Testable schematic for LEDs	3	Matt, Bill	PC	1.0
2.2	Order LEDs	Order LEDs and related parts	Determin LED arrangement	7	Matt		2.1
2.3	Solder LEDs	Solder LEDs to the digital logic	Testable schematic of LED logic	5	Matt, Bill	PC	1.0
2.4	Test LEDs	Test LEDs with μController	Working LEDs	2	David, Hao	multimeter	2.2
2.5	Attach LEDs	Attach LEDs to Ring	Ring ready to spin	3	David	Solder Iron	2.3
3.0	Motor				Bill		
3.1	Order Motor	Research, order, and receive motor	Acquire physical motor	7	Matt	PC	
3.2	Connect motor to LED ring	Attach motor to aparatus	A ring that can spin	3	Hao	wiring, soldering iron	1.0, 2.4
3.3	Test motor	Test motor itself and connected devices	Working motor and spinning LED ring	2	Bill, Hao	Multimeter	1.0, 2.4, 3.2
4.0	Microcontroller						
4.1	Order Microcontroller	Order and receive μController	Acquire μController	7	Matt	PC	
4.2	Program the Microcontroller	Connect μController to parts	Have a testable microcontroller	2	Matt, Ben	Wiring, soldering iron	1.0, 4.2
4.3	Test Microcontroller	Test basic programs	Have a working μController	3	Matt, Ben	PC	4.2

Table 7: Breakdown Structure Part 2

Id	Activities	Description	Deliverables	Duration (days)	People Responsible	Resources	Pred.
5.0	Wifi Module						
5.1	Order Wifi Module	Research, order, and recieve wifi module	Acquire wifi module	7	Matt	PC	
5.2	Connect and Test Wifi Module	Connect the wifi module with microcontroller to test	Have a working wifi module	3	Hao	Wiring, soldering iron	1.0, 4.3, 5.1
6.0	Base and Enclosure				Bill		
6.1	Order plastic base and enclosure	Research, order, and receive base and enclosure	Have a base and enclosure	10	Matt, Bill	PC	
6.2	Test base and enclosure	Perform safety tests such as breakage or waterproofing	Have a safe enclosure for the original parts	4	Bill, Hao	Blunt object water	6.1
6.3	Enclosing individual parts	Combine all parts to create the globe clock	Have entire globe clock intact	5	Bill, Hao	Wiring	1.1, 2.1, 3.1, 4.1, 5.1, 6.2
7.0	Computer Interface						
7.1	Design computer interface	Design program that allows user to change text and images on globe clock	Have interface to change text and images on LEDs	20	Ben, Matt	PC	
7.2	Testing Computer Interface	Find and correct bugs in program	Have a stable program	13	Ben, Matt	PC	7.1
7.3	Manual for program	Write a manual for using program	Have a complete user manual	16	Ben, Hao	Word	7.2

Table 8: Breakdown Structure Part 3

Id	Activities	Description	Deliverables	Duration (days)	People Responsible	Resources	Pred.
8.0	EE 490 Tasks						
8.1	Reports						
8.1.1	CDR Report	Write CDR report	Complete assignment	9	All	Word	
8.1.2	Final Design report	Write Final Design report	Complete assignment	9	All	Word	
8.2	Presentations						
8.2.1	CDR Presentation	Present CDR findings	Completed Assignment	3	All	Word and Powerpoint	
8.2.2	PDR Presentation	Present PDR findings	Complete assignment	3	All	Word and Powerpoint	
8.2.3	Status Update Presentation	Present Status Updates	Complete assignment	3	All	Word and Powerpoint	
8.2.4	Final Design Presentation	Present Final Design	Complete assignment	3	All	Word and Powerpoint	
8.2.5	Fall Poster/ Senior Design Day	Make poster and present it	Complete assignment	6	All	Word and Powerpoint, Posterboard	
8.2.6	Spring Poster/Senior Design Day	Make poster and present it	Complete assignment	6	All	Word and Powerpoint, Posterboard	

5.2 Gantt Chart

Shown in Fig. 20 is the projected time line of progress. Each cell one day's worth of progress. This is tentative as no dates for class future class reports or presentations are known to us at this time.

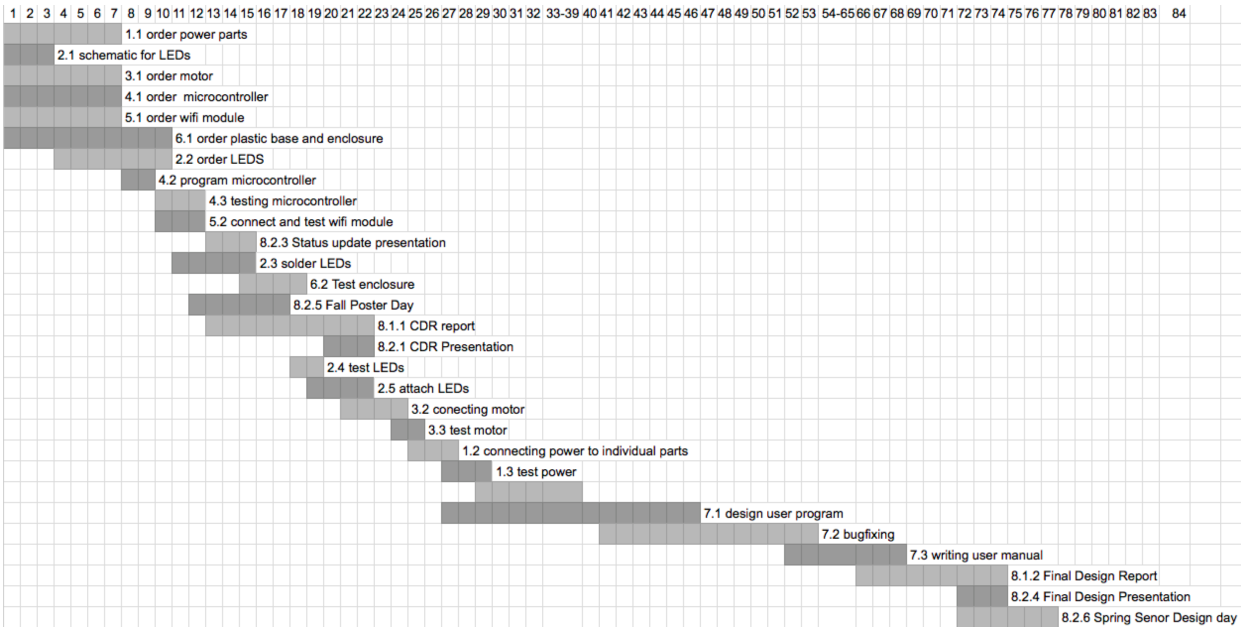


Figure 20: Projected time line where each cell represents 1 day.

5.3 Costs

The table below is the estimated cost of the project itemized. This cost is only estimated due to being the first prototype, if we are able we plan on trying to do more than just one iteration of the globe clock to continue to improve our design.

Part	Description	Supplier	Amount	Cost
ESP8266	WiFi Stack/Processor	Adafruit [15]	1	$10.95
Clear Globe	12 inch Clear Acrylic Globe	Amazon	1	$20.76
HD-45FMMT	HD Series Gasketed Polycarbonate Electronic Enclosure	Polycase	1	$12.65
Individually Addressable LED RGB Strip	1 meter, 60 LEDs/meter	Sparkfun [21]	1	$19.95
Total Cost				$64.31

Table 9: Cost of parts

5.4 Team Responsibilities

This project can be broken down into six major parts. These are power, LED's, motor, wifi and microcontroller chip, the outer enclosure and the user program. For each of these sections we will have one primary person for each section with multiple secondaries. For power the main person responsible will be Jessie. This is due to his main focus in his studies is power. He will have help from Hao as a secondary. For the LED section there will be three people working on this section due to its importance of the overall project. Matt, Bill and David will be focusing on this section. Hao will be primarily working on the motor with Bill and Matt as secondaries. For the wifi and microcontroller Matt will be the main person responsible, due to his vast knowledge of electronics. Bill will be mainly focused on the enclosure with Hao helping as a secondary. Lastly Ben will be main person responsible for writing the user program with Matt helping. This will take the most time by a decent amount. Thus the majority will lend a hand with the programming at one point during the process. For all of the group reports and presentation will be a complete group effect.

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7 Appendix A

7.1 Marketing Requirement Weight Calculation

Table 10 shows how the weights for the main leaves of the objective tree were found using the Analytical Hierarchy Process defined in *Design for Electrical and Computer Engineers*[6]

	Ad. Eff.	E.O.U.	Efficiency	Cost	Safety	Geo. Mean	**Weights**
Add. Eff.	1	3	5	3	1	2.141	0.357
E.O.U.	$\frac{1}{3}$	1	3	1	1	0.999	0.167
Efficiency	$\frac{1}{5}$	$\frac{1}{3}$	1	$\frac{1}{3}$	$\frac{1}{5}$	0.338	0.564
Cost	$\frac{1}{3}$	1	3	1	$\frac{1}{3}$	0.802	0.134
Safety	1	1	5	3	1	1.719	0.286

Table 10: The AHP process outlined for the main leaves of the objective tree seen in Fig. 2

Table 11 shows how the weights were found for the Advertising Effectiveness category of the objective tree.

	Legibility	Attractiveness	Geo. Mean	**Weight**
Legibility	1	1	1	.5
Attractiveness	1	1	1	.5

Table 11: Geometric weights for advertising

Table 12 shows how the weights were found for the Ease of Use category of the objective tree.

	Installation	Content Management	Customizability	Geo. Mean	**Weight**
Installation	1	1	1	1	0.333
Content Management	1	1	1	1	0.333
Customizability	1	1	1	1	0.333

Table 12: Geometric weights for ease of use

Table 13 shows how the weights were found for the Cost category of the objective tree.

	Initial	Upkeep	Geometric Mean	**Weight**
Initial	1	1	1	0.5
Upkeep	1	1	1	0.5

Table 13: Geometric weights for cost

7.2 WiFi/Processor Criteria and Module Selection

	Power	Size	Interfaces	Reprogramability	Geo. Mean	**Weight**
Power	1	1	$\frac{1}{3}$	$\frac{1}{3}$	0.577	0.161
Size	3	1	1	$\frac{1}{5}$	0.880	0.246
Interfaces	$\frac{1}{5}$	$\frac{1}{3}$	1	$\frac{1}{3}$	0.386	0.108
Reprogrammability	3	3	1	1	1.732	0.484

Table 14: The AHP criteria weight selection process for values regarded when choosing the best WiFi module for the project.

	CC3000	ESP8266	RN-131G	Geo. Mean	**Weight**
CC3000	1	3	3	2.080	0.510
ESP8266	$\frac{1}{3}$	1	3	1.000	0.245
RN-131G	3	$\frac{1}{3}$	1	1.000	0.245

Table 15: The AHP process for Power Consumption.

	CC3000	ESP8266	RN-131G	Geo. Mean	**Weight**
CC3000	1	1	$\frac{1}{3}$	0.693	0.221
ESP8266	1	1	3	1.442	0.460
RN-131G	3	$\frac{1}{3}$	1	1.000	0.319

Table 16: The AHP process for Physical Dimensions.

	CC3000	ESP8266	RN-131G	Geo. Mean	**Weight**
CC3000	1	$\frac{1}{3}$	$\frac{1}{3}$	0.480	0.143
ESP8266	3	1	1	1.442	0.429
RN-131G	3	1	1	1.246	0.429

Table 17: The AHP process for peripheral interfaces.

	CC3000	ESP8266	RN-131G	Geo. Mean	**Weight**
CC3000	1	$\frac{1}{5}$	$\frac{1}{3}$	0.405	0.094
ESP8266	5	1	3	2.467	0.572
RN-131G	3	1	1	1.442	0.334

Table 18: The AHP process for reprogrammability.

7.3 Safety

Table 19: LED Safety Parameters AHP

	Durability	I/V Traits	Light Angle	Heat Diss.	Geo. Mean	**Weight**
Durability	1	$\frac{1}{3}$	3	$\frac{1}{5}$	0.67	0.13
I/V Traits	3	1	3	$\frac{1}{3}$	1.32	0.26
Light Angle	$\frac{1}{3}$	$\frac{1}{3}$	1	$\frac{1}{3}$	0.44	0.09
Heat Diss.	5	3	3	1	2.59	0.52

Table 20: Shelter AHP

	Solidity	Transparency	Temp Resistance	Weight	Geo. Mean	**Weight**
Solidity	1	$\frac{1}{3}$	$\frac{1}{3}$	3	0.76	0.16
Transparency	3	1	$\frac{1}{3}$	3	1.32	0.27
Temp Resistance	3	3	1	3	2.28	0.48
Weight	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	1	0.44	0.09

Table 21: Motor Selection AHP

	Speed	Heat Dissipation	Voltage/Current	Geo. Mean	**Weight**
Speed	1	5	5	2.92	0.72
Heat Dissipation	$\frac{1}{5}$	1	1	0.58	0.14
Voltage/Current	$\frac{1}{5}$	1	1	0.58	0.14

7.4 Image Mapping

he AHP for the vertical angles is shown in table 22. The weights showed that the 45° angle got a weight 0.8436 which was the highest score.

Table 22: The AHP process for the vertical angle from the center

	30°	45°	60°	**Weight**
30°	1	$\frac{1}{5}$	3	0.2023
45°	5	1	5	0.7004
60°	$\frac{1}{3}$	$\frac{1}{5}$	1	0.0973

The AHP for the horizontal angles is shown in table 23. The 90° angle garnered the largest weight here at 0.8333.

Table 23: The AHP process for the horizontal angle from the left edge

	90°	120°	**Weight**
90°	1	5	0.8333
120°	$\frac{1}{5}$	1	0.1667

7.5 LEDs

Table 24: AHP process for LED criteria.

	Size	Ease of Use	# Colors	Cost	Geo. Mean	**Weight**
Size	1	9	3	6	2.77	0.52
Ease of Use	$\frac{1}{9}$	1	$\frac{1}{6}$	$\frac{1}{6}$	0.315	0.06
# Colors	$\frac{1}{3}$	6	1	3	1.43	0.27
Cost	$\frac{1}{6}$	6	$\frac{1}{3}$	1	0.80	

7.6 Power

Table 25: The AHP process for motor selection

	Speed	Heat Diss.	Op. Point	Geo. Mean	**Weight**
Speed	1	5	5	2.92	0.72
Heat Diss.	$\frac{1}{5}$	1	1	0.58	0.14
Op. Point	$\frac{1}{5}$	1	1	0.58	0.14