Interactive Donor Wall Illumination

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1 Introduction

1.1 Objective:

The donor wall is located on the southwest side on the first floor in ECEB. It celebrates and appreciates everyone who helped and donated for the building and the department. The problem with the hallway with the donor wall is two-fold. Because of poor lighting, the donor names are not noticed as much as they should, especially after the sunset. Also, because of the lack of chairs and tables for people to study on or socialize, the hallway is just a "highway" for people to walk through. To bring more attention to the donor names and to liven up that hallway, we are going to design and implement an interactive, highly responsive, and maintenance-free illumination system for the donor wall. Firstly, LEDs will be placed behind the names to always softly illuminate each name. Secondly, LEDs will fill in the translucent gaps (non-copper areas) in the "circuit board" with interactive illumination. Thirdly, Sensors will be embedded throughout the design to implement interactive and highly responsive system. According to various signals received by the sensors, a microcontroller will be used to control LEDs to control interactive patterns. As a result, our design will allow the donor wall to bring more attention to the donors and to liven up the hallway.

1.2 Background:

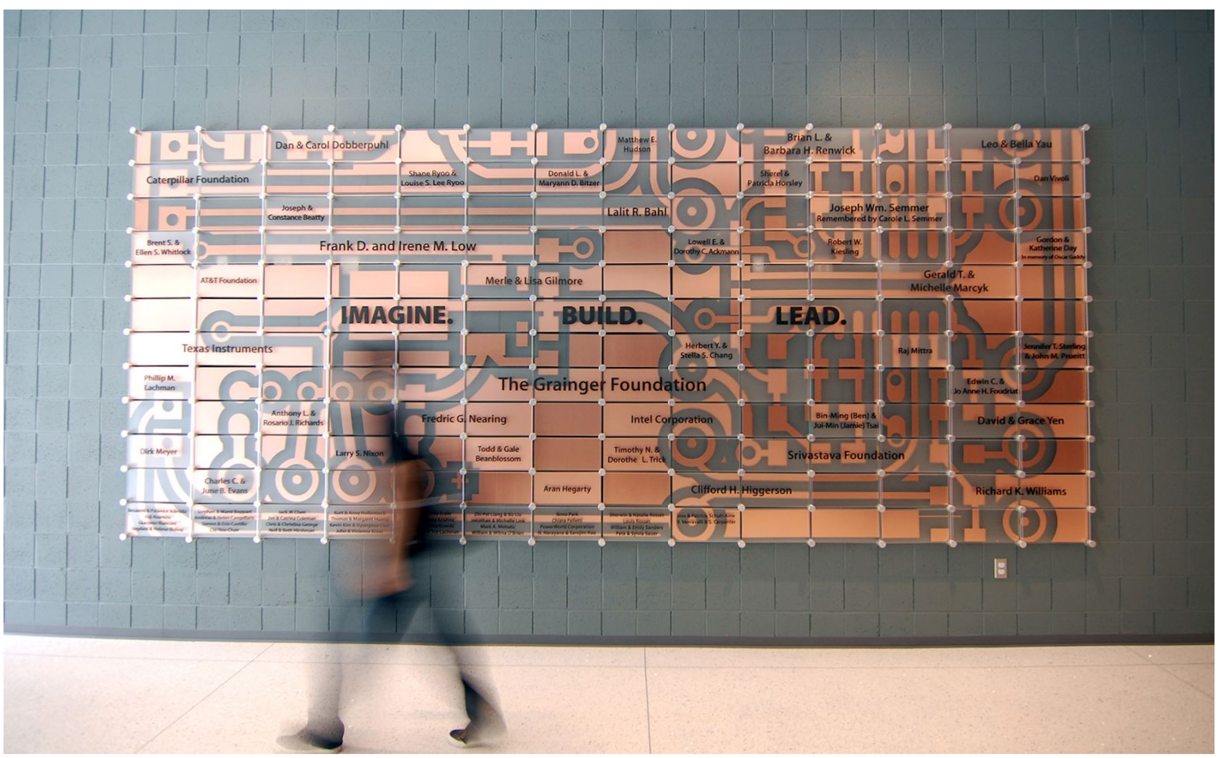

Figure 1: Image of Donor Wall (touched up by Kurt Bielema)[1]

Our team have been in touch with Skot Wiedmann, Todd Sweet, Catherine Somers and Timothy Newman to discuss any potential limitations of our project, the purpose and the background of the donor wall, and any concerns that they may have about the project. The most important takeaways from the meetings is that the original purpose of the donor wall is to celebrate and highlight the donor names. As long as the project is able to bring more attention to the donor names or not disrupt or destroy the original purpose of the donor wall, they would not have any particular concerns (if this project were to be installed on the actual donor wall). Also, Skott Wiedmann is the one who designed the copper layout on the donor wall as well as have experience with interactive art projects similar to ours. Thus, he will generally be a valuable person to talk to about this project.

Viewing the donor wall from the front, it's made up of 14×12 acrylic glass panels where each are connected by wall screw mount sign standoffs. Viewing from the left side into the donor wall, there are 3 layers of acrylic glass panels. The acrylic glass layer closest to the wall is a frosted acrylic panel with thin copper sheet (coated with some chemical to prevent copper erosion) adhered on top. The second layer is a blank frosted acrylic panel with a little space from the first layer. The final layer is separated from the two layers with a standoff. For the final layer, the acrylic panels with names are frosted while all the other panels are transparent.

1.3 High-level Requirements:

There are three main modes to our donor wall illumination project. They are listed below in the order of how much a person is engaged in the interaction with the donor wall. Note that for all three modes, the name blocks on the donor wall are always softly illuminated from the back center of the acrylic glass. Also, note that for all three modes, the varying parameters between each modes are the number of pulses, consistent or inconsistent time interval, and short and long time intervals.

- **Default Mode (No engagement)**:
  - When there is no obstacle near and in front of the donor wall, the name blocks are always softly illuminated from the back center of the acrylic glass. Also, seemingly random quick pulses of "currents" flows throughout the board at a relatively slow inconsistent interval (~2 pulses every 1-2 second). In this mode, the initial pulses starts from the outer edges of the donor wall. Whenever a pulse ends up at or goes through a name block(s), the already soft illuminated name block(s) is slowly and smoothly illuminated with a stronger intensity. After 1 or 2 seconds of strong intensity, the name block is slowly and smoothly returned back to the soft glow. The aesthetics should be calming and smooth. In other words, there are a few quick pulses starting at the edges of the donor wall at inconsistent time intervals to have a relatively infrequent "highlights" of the name blocks.

- **"Human is Present or Moving" Mode (Some or potentially no engagement):**
  - When an obstacle such as human(s) passes by or is present in front of the donor wall within about 3 or 4 meters, multiple motion sensors (Passive Infrared Sensor, PIR) will be used to detect human(s). Once detected, the LEDs will animate about 4 or 5 smooth but quick pulses of "currents" flowing through the circuit at a regular interval (about every 1 second). At every interval, the starting points of each pulse are the (un)varying position of the detected person. If possible, it's desired to have each pulse to be in the same direction as the direction of a walking person. If not, some pulses may diverge out from the detected position of a person. Then, as each pulse arrives to the name blocks, the already soft illuminated name block(s) is slowly and smoothly illuminated with a stronger intensity. After 1 or 2 seconds of strong intensity, the name block is slowly and smoothly returned back to the soft glow. In other words, there are quick and multiple pulses starting at consistent time intervals at the detected locations of a person to have relatively more "highlights" of the name blocks than that of the default mode. This mode will require quite complex sensor and control units.

- **All-Mode-Override Mode (Complete engagement):**
  - When a person's hand is present in front of a name block within about 10 *cm* (this distance may change depending on the sensor's parameters), the LEDs will display about 20 or 30 exploding, diverging, and quick pulses starting from that particular name block. Each pulse will travel out from the particular name block to every other name block. Then, as each pulse arrives to the name blocks, the already soft illuminated name block(s) is slowly and smoothly illuminated with a stronger intensity. After 1 or 2 seconds of strong intensity, the name block is slowly and smoothly returned back to the soft glow. Once every name block has been "highlighted," the illumination system goes back to the default mode. This mode overrides any previous modes. Proximity sensor will be used and will allow the users to interact with the donor wall without physically touching.
  - Another option is to have the pulses "explodes" but fades out gradually. This effect is easily described by a water drop dropping into water. The "waves" starts where the drop fell and it dies out as it travels outward. We will physically experiment which effect (either gradual decrease of pulse intensity or constant pulse intensity to illuminate all the rest of name blocks) is the best to choose.
- Our original idea includes a time dependent feature where the system turns on or off at specific times set by the user. However, with relatively high complexity for all three modes above, a switch to manually turn the system on and off will be implemented. The original idea was to have the system to refresh and cool down regularly. For example, it can be turned off at around 4AM when there's almost nobody in ECEB and turned back on at around 7AM before class starts for a total of 3 hours of cool down time.

2 Design

2.1 Block Diagram & Physical Design:

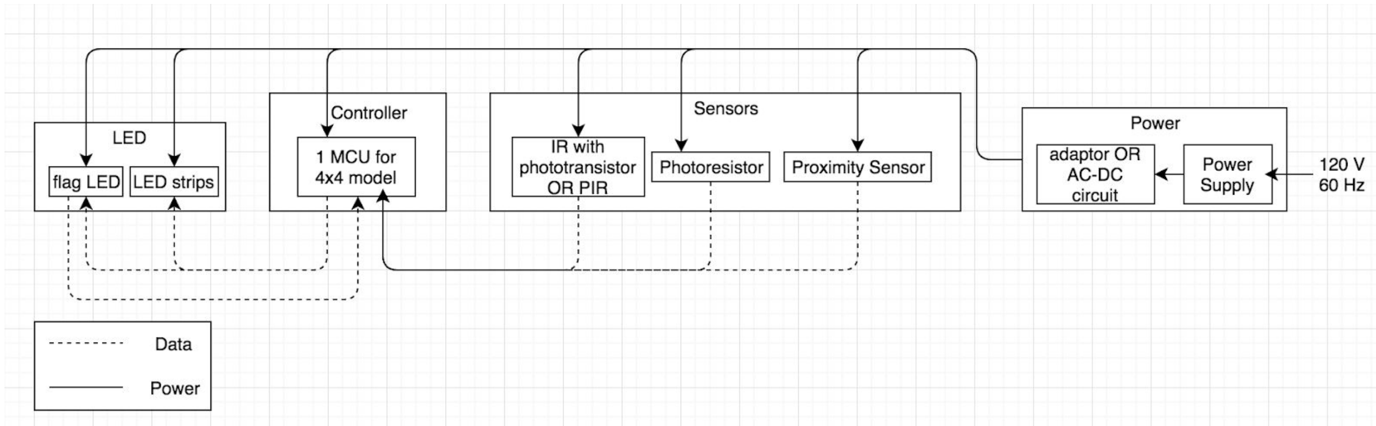

Figure 2: Donor Wall Illumination Block Diagram

Our design contains 4 main blocks: Sensors block, power block, control block and LED block. Power block is used to supply power to other blocks. Sensors are used to get information from the outside world. The relevant function of each type of sensors are explained in **Section 2.2.1**. The signals from the sensors are sent to and handled by the control block. Based on a program, the control block will control the LED block to display different animation effects.

2.2 Functional Overview:

2.2.1 Sensors block: This block is used to get signals from the outside world and to send these signals into the control block to process. This sensors block contains three different types of sensors: photoresistor, IR LED with phototransistor or PIR sensor, and proximity sensors. Photoresistor sensors are used to continue the flow of the "current" animation from one block to the adjacent block(s). They detect if a nearby LED (flag LED) is turned on which in turn signals the LEDs on the adjacent block(s) to continue the current animation. IR LED with phototransistor or PIR sensors are used to detect if any human(s) is passing by or is present nearby or in front of the wall (within 3 or 4 meters). In other words, they are used to trigger the "Human is Present or Moving" Mode. Proximity sensors are used to detect if someone is trying to interact with a name block with an object such as their hands (within 10cm). In other words, proximity sensors are used to trigger the "All-Mode-Override" Mode. Overall, this sensor block allows our system to "see" and respond to the outside world.

Requirement:
The photoresistor used to communicate to the adjacent block(s) for continuation of the light flow must be smooth. In other words, there cannot be significant latency.

2.2.2 Controlling block: The central part of the system is the control unit. We plan to use the microcontroller on Arduino to process the signal from those sensors and send signal to LEDs to achieve different animations. Handling the IO signals and implementing the algorithm to control the whole system is the essential work of controlling block. With this controlling block, our system can "think" and "make decisions" by itself. In default mode, the controlling block controls LEDs to mimic 2-3 pulses flowing through the Donor Wall. In "Human is Present or Moving" mode, the controller gets updated position of the user through IR sensors, and tells relative LEDs to be turned on. In "All-Mode-Override Mode", the controller needs to know which block is being approached by the user and tells the LEDs to mimic exploding current flow.

Requirement:
Systematically handle IO signals and accurately control LEDs in different position. Correctly decide signal priority to switch between different modes. And the runtime of the programme must be short enough to handle large number of IOs with low latency.

2.2.3 LED block: This block is important to display the light animation. It will be controlled by the controlling block. Our first option is to implement our idea using programmable LED strips for the gaps between the copper to mimic current flow. The LED strips will have to be bidirectional, meaning that the light has to flow forward and backwards in order to implement all three of our system modes. If the option of using LED strips do not achieve our expectation due to low light resolution or programming limits of the strips, we will use individual LEDs instead when there are no other alternatives. In order to continue the "current flow" from one block to the next adjacent block, we will use flag LED and photoresistors to instigate the continuation of the light flow on the adjacent block.

Requirement:
The LED strips has to have enough LED to have high resolution animation. The strips will also have to be bidirectional. The flag LED cannot interfere with the overall light animation. Thus the intensity and size of the flag LED will have to be considered.

2.2.4 Power block: The whole system is running from the power block, and a switch will be implemented in the system to allow a person to manually turn the whole system on and off. The system will draw power from the wall outlet (120V, 60Hz). We are looking at options to buy adapters or to build the AC to DC conversion circuit to convert the AC source to be used to power up all of our block systems. DC to DC conversion circuit and voltage regulators may be built or bought depending on the LEDs' and sensors' power parameters and sensitivity.

Requirement:
Must provide stable power to each other blocks. The switch must be reliable and durable.

2.3 Risk Analysis:

As stated above, the central part of our project is the controlling block mainly because of so many IOs necessary for our project. With so many IOs, a relatively high computing power may be necessary. The greatest risk to successful completion of the project is the algorithm and control programme implementation. We need to consider the running time of the program and prioritize different signals from different sensors when switching between different modes. Another risk is to find appropriate LED strips that are easily programmable and controlled, and it must be of high quality to meet the animation resolution expectation. If the LED strips do not satisfy our design goals, we will have to look at other options such as using individual LEDs instead which could change the design of our whole system. Resorting to individual LED can possibly limit the ability to implement all three of our system modes as listed in the High-level Requirements.

3 Ethics & Safety

3.1 Ethics:

Based on the *IEEE Code of Ethics* [2], we understand that we must comply with ethical design and sustainable development practices. And we must disclose promptly factors that might endanger the public or the environment.

3.2 Safety:

There are several potential safety hazards in our project. Because our power supply may draw very high currents with so many LEDs. There must be no exposed wires. Potentially hazardous components must be kept hidden from the typical user in order to prevent accidental electric shock.

And after being turned on for a long time, LEDs may produce large amount of heat and the glasses and copper blocks may have relatively high temperature. So, the whole circuit should be designed to sustain heat damage.

4 Reference

[1] Jonathan Damery, "**Donor wall celebrates leadership donors to the Building Campaign for ECE ILLINOIS**", 2014. [Online] Source: http://buildingcampaign.ece.illinois.edu/donor-wall-celebrates-leadership-donors-to-the-building-campaign-for-ece-illinois/. [Retrieved: 19. Sept. 2018]

[2] IEEE, "**7.8 IEEE Code of Ethics**" [Online] Source: https://www.ieee.org/about/corporate/governance/p7-8.html. [Retrieved: 19. Sept. 2018]