MaRker: Attention Beacon for Mixed Reality Game Development

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***Abstract*—Over the course of the Fall and Winter Quarters, Lights and Action seeks to create hardware for mixed reality experiences. Using NeoPixel lights for wearable designs, we hope to develop a portable and flexible light system to highlight physical objects and augment such playful experiences. Development has involved designing interface and software to control the devices, with hardware considerations to meet specifications for intended use. Thus far, the hardware is functional, though further optimization is a goal. One design specification is to create an interface in Unity to help designers better customize the device's functionality. Future development includes customization of light patterns for multiple devices at once, coordinated through Bluetooth connections with a device running Unity. We also hope to design a housing for each device module with considerations on portability and wearability.**

***Index Terms*—Bluetooth, LEDs, lights, mixed reality (MR), NeoPixel, Unity, wearables.**

I. Introduction

IN THE CONTEXT of purely virtual playful spaces like video games, designers can highlight objects that are important. The ability to draw attention to significant points is essential to the flow of an experience, but that level of control is currently not available in mixed reality. MaRker intends to fill this space in designing mixed reality experiences with playful and entertaining uses in mind.

The primary goal of MaRker is to create a portable light-emitting device which meets several specifications. MaRker devices should be portable and easy to handle with the ability to attach to objects and surfaces. The device must be powered by a small battery, but the power supply must be able to sustain usage for a period of use with variable patterns and brightness. Much of the technology we use for these goals are related to that of wearables, such as NeoPixel lights. NeoPixels are programmable through values given to a controller, in this case an Arduino. MaRker should be intuitive for its intended users, so we hope to create an easy interface for game experiences in Unity. This interface should be flexible and capable of programming uses such as highlighting objects, directing towards a point of interest, or affecting the atmosphere of an experience.

Technology for mixed reality experiences do exist, but in many cases such augmentations are high specialized for a specific experience. For example, Professor Tess Tanenbaum's project Magia Transformo is a mixed reality experience which is based on a combination of physical motions and gestures of the players and the guidance of a tablet representing a spell book [1]. Other examples of technology for mixed reality and wearables include works by Professor Oğuz Buruk where a device is part of the experience but would not be as applicable in other cases. With MaRker, we hope to create a device that could be repurposed to support multiple different types of experiences. Such a device might not replace specialized devices but could augment mixed reality experiences and improve or expedite designs.

In the development of MaRker, the team has largely been working in a manner of prototyping and iteration. Many of the discrete parts of MaRker already exist but putting them together is the goal. For hardware, the team has been testing physical and mechanical constraints, planning ways to manage battery life and device effectiveness. Thus far, NeoPixel performance with rechargeable batteries has been very positive. For software, the team has been working to connect the Arduino to Unity in a way that will be efficient for our purposes. The connection between the two has been a challenge.

While testing the capabilities of the hardware and the software is central to designing MaRker, we will need to test and receive feedback on other marks as well. Because we intend to have MaRker be an effective tool for designers, we hope to run tests of a more qualitative manner. This may be player response times with and without MaRker lights, or feedback from designers on how they would use such a device.

II. MaRker Development

A. Primary Materials

The overall construction of the MaRker contains the following materials: an Arduino Nano, NeoPixel lights, a pressure-sensitive transistor, a low-energy Bluetooth module, a lithium-ion rechargeable battery, and passive components such as capacitors and resistors. Since the prototype is currently in development, the PCB was not manufactured yet; however, plans have been made to transition the MaRker from a breadboard to a custom casing and PCB. Fig. 1 shows the MaRker topology and indicates how the materials are connected.

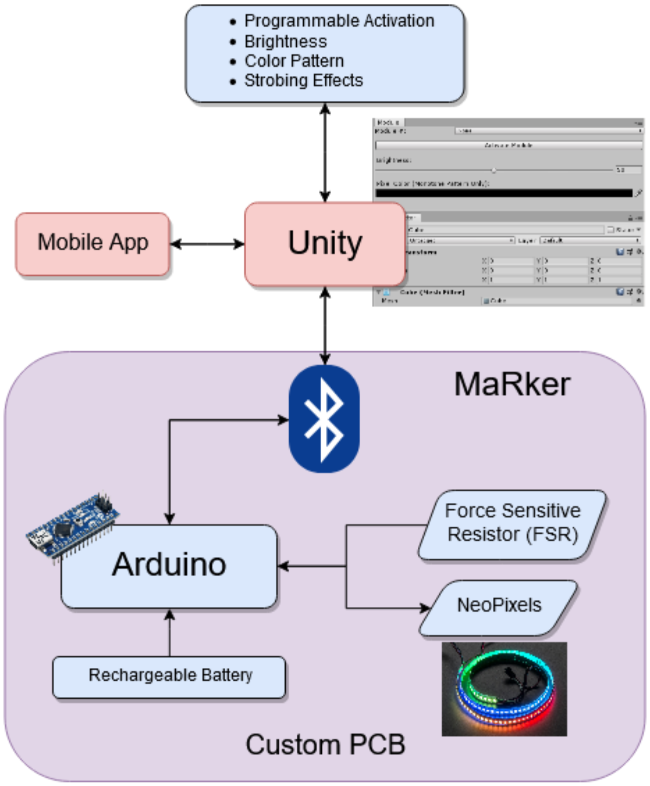

Fig. 1. MaRker Topology

During the early stages of development, Professor Tanenbaum, suggested Adafruit NeoPixels for this project since they were both affordable and addressable. Arduino was selected as the microcontroller for this project because it contains the most support with NeoPixels. In addition, the plan for this project was to have the deployable MaRkers, so Arduino Nanos were selected due to the 5V output and small size. The Arduinos were obtained from Amazon and the manufacturer that was selected was LAFVIN; they were selected over other manufacturers due to the low-cost. The pressure-sensitive transistor (FSR) was added to the project scope in order to allow feedback for the designers. The FSR allows users to interact with the MaRker by applying pressure on the transistor. Once pressed, MaRker could change the effects on the lights based on the designer's decision. The last module is the BLE module which has yet to be implemented in the current prototype. There are plans to use Bluetooth as the main way of communication between Unity and the Arduino. Rechargeable Lithium-Ion batteries were selected because the MaRkers are intended for long-term use and for user convenience. They are currently rechargeable by using a micro USB cable and able to power the MaRker prototype.

B. *High-Level Software*

As the primary microcontroller for each MaRker module, the Arduino Nano can hold 32KB of flash memory, plenty for moderately sized programs and their respective libraries in C++ (the programing language Arduinos utilize). Each Nano holds a driver program to interface the NeoPixels, Bluetooth Module, and Unity inputs. To do so, the driver imports libraries and hold them in memory, such as the Adafruit NeoPixel library and the Unity Uduino Library. The NeoPixels and Bluetooth module will have static pin assignments for this purpose.

On the workstation side, custom Unity assets are implemented to display a window within the Unity Editor GUI for Unity developers using Unity as a mixed reality tool, as shown in Fig. 2. Unity is a powerful tool to experiment with mixed reality and is the primary platform of not only our faculty mentor's project but also for the wider mixed reality development community at large [3]. The Unity GUI is constructed using two primary C# files, one to display the GUI and one for a data structure which will store and control each module's information, display pattern, etc. The GUI elements include but not limited to MaRker activation, brightness, loading and displaying NeoPixel patterns, setting pattern duration, choosing LED colors, etc. As the project progresses, the number of GUI functions will increase and/or decrease depending on the discretion of Professor Tanenbaum, feedback from our testers, and any last-minute hardware implementations; as such, Unity functionality will remain loosely planned and will mirror the hardware development. The data structure will also reflect the functionality of the Unity GUI; however, several core elements of the data structure will remain persistent. These core elements include MaRker communication elements like module names, Bluetooth communication elements, and pin assignments, and Unity object indexing, to save associations between the virtual world and the physical modules.

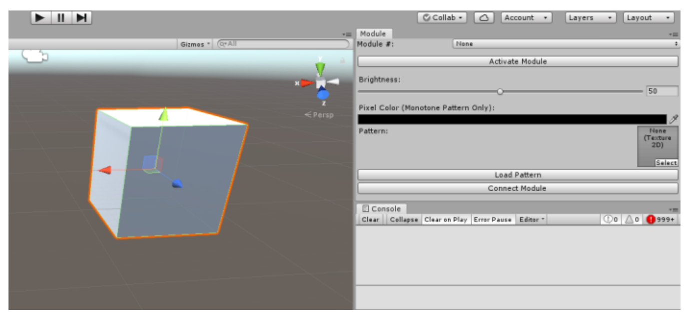

Fig. 2. MaRker Unity GUI mockup. Note that module selection is encapsulated as a function of the GUI for ease of use.

C. *Power and Energy*

The main power-consuming components are the NeoPixel LED strips, Arduino Nano microcontroller, and the Bluetooth module. The maximum power consumption for the Arduino Nano and Bluetooth module under 3.7 volts are 888 mW and 148 mW, respectively. NeoPixel strips consume major power as they operate under 5 volts power supply and each individual LED on the strip consumes up to 60 milliamps at maximum brightness white. For our prototype, we are driving a 2-meter-long strip containing 120 LEDs, which consumes 12 watts on average for our color needs. For future applications, we are planning to have 5 NeoPixels per unit and the battery needs to sustain the MaRker unit for at least 5 hours and thus 3.7 volts, 1100 mAh batteries would suffice.

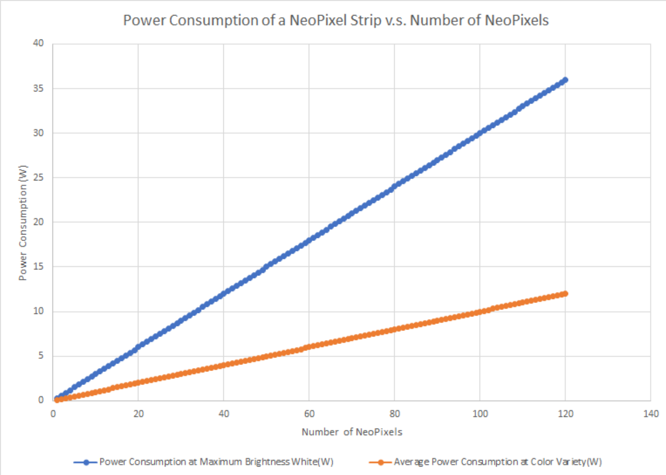

Fig. 3. Power Consumption of a NeoPixel Strip vs Number of NeoPixels

Powering the Arduino and Bluetooth are straightforward as they have built-in surge protections and operate well under 3.7 volts intrinsic supply from the battery. However, powering LED strips is more complicated. To prevent the initial onrush of current from damaging the pixels, we need to connect a large capacitor (1000 µF, 6.3V or higher) across the + and – terminals of NeoPixel strips. For future scaling down, it is possible to power the NeoPixel at 3.7 volts to conserve energy and save space by using smaller batteries depending on game designers' brightness requirements.

D. *Interfacing*

The current prototype only has one sensor, a force-sensitive sensor, to control the MaRker unit, which returns an analog signal to the Arduino microcontroller. On the Arduino IDE, we can associate behaviors of LEDs with the force applied. For example, in Fig. 4, the force sensor activates the programmed lighting sequence when the force applied is greater than our set threshold.

As the MaRker project aims to help mixed reality game designers to draw players' attention and Unity is one of the most common game designing platforms, integration of Unity and Arduino would greatly increase the accessibility for game designers [4]. As shown in Fig. 2, a Unity GUI could be used to program MaRker units, setting LED features including activation threshold, brightness, patterns, colors, etc.

To have wearable and deployable MaRker units, as the project proceeds, Bluetooth modules will be added to enable wireless control over each unit. The Bluetooth modules will wirelessly communicate with Unity and pass information to Arduinos on each unit.

E. *Results*

Current performance of MaRker prototypes show promise towards our established goals. Several prototype modules were created, each with varying NeoPixel LEDs, Bluetooth modules, and battery units. Three different NeoPixel configurations were tested, with an Arduino Nano for basic control: one with individual NeoPixels, one with a half-meter strip of NeoPixels, and a two-meter strip. Each configuration was powered and activated successfully, with an example shown in Fig. 4. where a half-meter strip was illuminated for demonstration purposes. The MaRkers were able to be lit and patterned in any color configuration that was chosen. Furthermore, several rechargeable battery units with varying capacities were also successfully tested with the configurations, with projected battery runtimes of at least 5 hours, depending on the battery capacity.

Fig. 4. MaRker Prototype demonstration using a two-meter long NeoPixel strip. The device held in the hands is the FSR to activate the module.

III. Conclusion

Overall, this project has achieved basic the construction of basic prototypes, functional software for both Arduino and Unity, and compensated for power consumption needs. Basic project constraints were also investigated during development to highlight future problems the project may encounter (See Appendix II). As such, the project is considered past the prototyping stage with moderate success.

With the success of our initial prototyping stage, forthcoming plans include a wearable/flexible 3D printed housing unit with built-in buttons, a custom PCB for all the components, running multiple modules simultaneously (ideally five), and fully programmable control of each MaRker module in the Unity environment. Tentative plans also include a mobile application for ease of use and audio functionality if time permits. Additionally, a testing phase is also planned for quantitative analysis, lacking in the initial development, to gain valuable feedback from players experiencing mixed reality with MaRkers. This testing phase will utilize Professor Tanenbaum's research, Magia Transformo, and measure metrics such as reaction, receptiveness, power performance, etc. for future iteration cycles [1][4].

Appendix I

Technical Standards

Since the MaRker deals with electronics, safety and radio standards were focused on. These two standards were necessary for this project because the MaRker is an electronic device, so it may be harmful if not manufactured properly. In addition, we had to make sure that the Bluetooth was up to date with the standards in order to ensure that the Bluetooth and its support will be reliable. Currently, the MaRker follows two technical standards, the IEEE 802.15.1 and NFPA 70.

IEEE 802.15.1 is relevant due to the usage of Bluetooth technology. According to the manufacturer Raytac, the Bluetooth module (Raytac MDBT42Q-512KV2) was certified by the FCC, IC, CE, Telec (MIC), KC, SRRC, NCC. In addition, the Bluetooth module has BT5.1 & BT5 & BT4.2 Bluetooth Specification certification. Meanwhile, the NFPA 70 standard ensures that the electronic that the installation of electronic components are secure. The MaRker now would pose as a threat to this standard because the components are exposed to direct contact, so a case with a custom PCB is planned to be made in order to mitigate this issue. We are also fortunate that the device currently requires only 5V of energy; however, we will continue to ensure that this standard is followed properly. The components themselves are reliable safe such as the Arduino Nanos, Force-Sensitive Resistor, and NeoPixels as they had been confirmed to be FCC and RoHS certified according to the vendor Adafruit.

Appendix II
Project Constraints

For a student project, securing funding is a common challenge that surfaces at the planning stage. The team has been granted funding from the EECS department of the University of California, the Henry Samueli School of Engineering for purchasing essential hardware components including LEDs, microcontrollers, Bluetooth modules, and sensors. With the help from our team mentor, Professor Tess Tanenbaum, the team has access to lab space and a variety of passive components. The team has also applied for funding from UCI's Undergraduate Research Opportunities Program for future needs.

The first challenge on the hardware side was the power supply. There are two main problems for powering any battery-driven circuits, initial inrush current that can potentially damage components and the variation of the battery output voltage. Fortunately, the microcontroller used, Arduino Nano, has built-in inrush protection that helps reduce the risk. For the LED strips, the way to mitigate large inrush current is to connect a large capacitor across the positive and negative terminals. The Nano also has a 5 volts output port that keeps the LEDs operating under the desired voltage.

Another major challenge is to integrate Unity with Arduino as there are few precedents available to learn from and Unity as a game development platform is not particularly familiar to the team composed of EECS students. With the help of Kat Witten, who has been helping with learning and utilizing Unity, the team has successfully developed a unity GUI and the Unity-Arduino integration is perpetually in progress.

Appendix III
Security Issues

Like any electronic device, MaRker has its own potential for security issues. Beyond physical or mechanical interference with the device, MaRker will connect with each other and with the user's computer through Bluetooth. While this connection should only interact with Unity within the user's computer, this is one possible security issue.

If an outside entity were to interfere with the Bluetooth connection with MaRker's Arduino controller, it would be possible for them to disrupt or alter the function of the light strips or possibly read information from Unity. While such a hypothetical breach would not have a high risk of personal damage, physical harm, or loss of personal information, it should still be a point of consideration in design. At worst, the outside entity could set the NeoPixels to maximum brightness, which shouldn't cause lasting harm, but should be considered.

One way that we hope to address such security concerns is to have the devices be capable of identifying which other device is being communicated with. Verification of device connections before use should help reduce some possibility of interference. In response to the risk of suddenly changing the settings on the NeoPixel lights, we could implement a smooth transition between patterns or limit the maximum brightness in standard use. One future design consideration is to diffuse the light from the NeoPixel as part of the housing for the device, which should also make it such that the device would not be bright enough to cause harm. These are some simple plans to address device security and will likely be part of future development.

Acknowledgment

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