OPTICAL SYNTHESIZER

Project Proposal

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Introduction

With the advent of modern Virtual Reality (VR) systems such as the Oculus Rift and HTC Vive, there is a need to explore ways to control these systems. The current solutions rely primarily on tracking the headset and handheld controllers.[1] While they do encourage considerable movement and interaction, they leave the user to lunge around in open air, interacting with imaginary surfaces that offer no physical response. A real physical object could provide the grounding needed in a VR experience that further immerses the user while allowing them to remain connected to the physical world. In order to experiment with this connection, an instrument will be developed using a traditional piano key bed; however, to take advantage of the VR system instead of an audio signal the instrument will generate an optical signal as its output.

Motivation

Artists have long sought after ways to apply the abstract nature of music to break free from representation – according to The Art Story, Wassily Kandinsky viewed music as the most transcendent form of art, and thus endeavoured to create paintings that emulated music, helping to create the Abstract Expressionism movement.[2] While Kandinsky was seeking to capture music in his paintings, inventors were busy trying to create instruments that could create so called colour-music. Alexander Wallace Rimington developed one of the first colour-organs, and coined the term colour-music in his book by the same name in 1912.[3] He even proposed a scale for the conventional piano keyboard that started with middle C at 395 THz (deep red) and followed the frequency doubling scale of music so that all of the visible colours were covered in a single octave.[4] In 1922, Thomas Wilfred began performing his new invention, the Clavilux[5] – a complex instrument that produced equally complex colour-music by bending light through controllable lenses and filters in order to produce abstract projections.[6]

These nearly forgotten technologies were at some point superseded by visualization devices which took sound as their input, and produced some visual output. With the proliferation of computers, software based visualization became the de facto method of translating sound into visuals, available for virtually any music player; however, this sort of forced synesthesia rarely has much impact on the sober user compared to the music itself. Further, it misses the original goal artists like Kandinsky had in mind – to make art which moved the viewer in the same way that music does, not to literally translate music to visuals.

With the recent explosion in virtual reality technology, perhaps we can return to the concepts of Rimington and Wilfred, and create visuals directly by playing an instrument. VR's ability to display three-dimensional visual information directly into the eyes makes it the ideal output. The instrument developed will seek to solve the problem of creating visuals in a way that emulates the nature of music while breaking free from a direct relationship to sound. At the same time, it will test a new system of physical control that enables the user to become more immersed in the virtual world.

Project Summary

This project will focus on creating a hardware instrument, referred to as an optical synthesizer that operates as a peripheral for a virtual reality experience. The hardware will be based on an analog synthesizer with a conventional keyboard, but will not be related to sound in any other way. It will generate an output to a Unity based experience and may receive inputs from that system as well. The scope will be limited to the hardware interface itself, and will not involve the creation of the virtual artwork as that will be simultaneously completed for another project. The success of this project will be determined by the functionality of the device itself and its ability to generate light data.

Project Details

Architecture and Environment

The hardware for the optical synthesizer will center around an Arduino microcontroller, likely an Arduino Due or Mega to satisfy the high number of inputs required by the key bed and other physical manipulators. All code will be written in C using the Arduino IDE. While a Raspberry Pi Zero might be suitable and incredibly economical for this project, its capabilities far exceed the requirements of this project and much of it would be left unused. As such it will only be used if methods involving a microcontroller fall short.

The key bed will either interface directly with the microcontroller or will use its own microcontroller to communicate through midi if the demands on the core microcontroller become too high. This module will include any other physical controls such as potentiometers to affect synthesis parameters. The core microcontroller will consolidate the inputs and send them to the synthesis module, the analog component, which will produce an analog signal that the microcontroller finally reads. The analog signal will be processed using a Fast Fourier Transform or Fast Hartley Transform as described by Open Music Labs and Arduinoos.[7] The key positions and this processed light signal will then be sent to the computer via USB. The light signal will also be used to produce direct feedback via an LED strip attached to the keyboard. Software based controls may also be returned to the device. The process diagram of the optical synthesizer can be seen in figure 1.

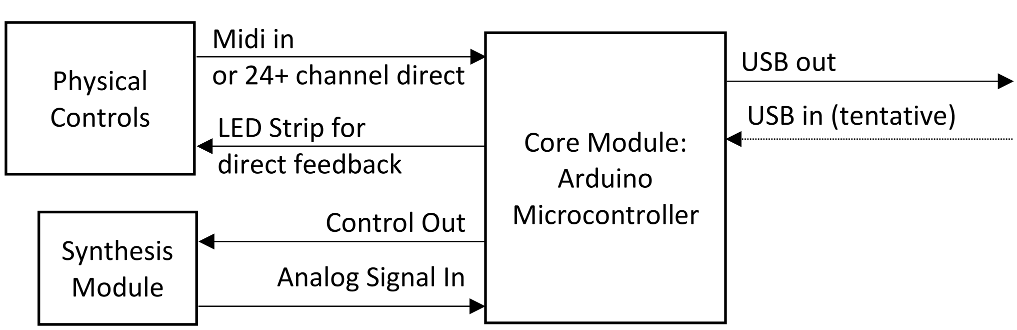

Figure 1 – Schematic of the optical synthesizer

This hardware device will work in parallel with the HTC Vive virtual reality headset and a Leap Motion tracker. The headset will display the imagery while the Leap Motion tracker will be used to synchronize the hand positions with the keyboard. The devices will require a powerful computer and interface with each other through a program developed using the Unity game engine. This program will be written in C#, but will remain outside the scope of this project. The overall interface can be seen in figure 2 with this project highlighted in red.

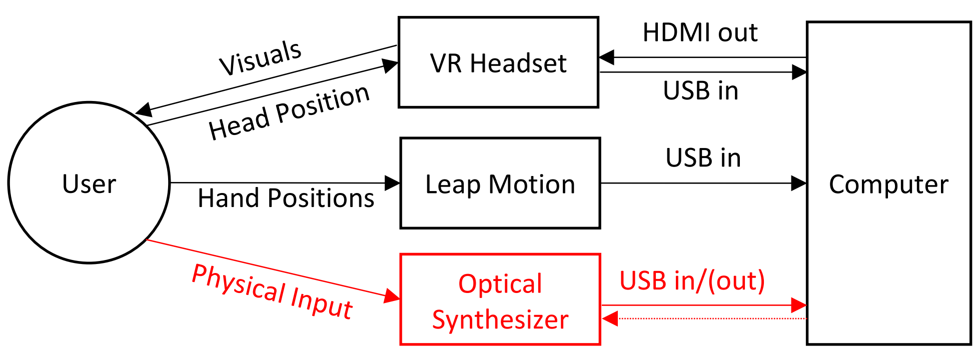

Figure 2 – Schematic of the complete interface, items in red are in the scope of this project

Implementation Issues and Challenges

This project is unique in its goals of avoiding associations with sound and in physically interfacing with a virtual reality device. While it is unique, it also combines many existing concepts. Analog synthesizers, visualization, and keyboards are all well explored areas; however, combining them into a new instrument that works only with light is a new challenge. While there is considerable documentation on building midi interfaces, analog synthesizers and even visualizers, applying this to a device which only works with light means entering uncharted territory. The most challenging aspects to the implementation will be optimizing the use of the microcontroller, designing the analog components, and coming up with a logical way to map the keys to the colours.

Optimizing the microcontroller will be challenging as it is being asked to multitask between several operations. It will simultaneously be receiving and processing commands from the keyboard, sending controls to the synthesizer module, and analyzing the resulting analog signal as well as sending a serial output to USB and activating lights on the keyboard. The code must be very efficient to accomplish all of these tasks without noticeable delays, a requirement made more important due to the involvement of virtual reality.

Designing the analog portion will be challenging as the signal will not be in the audible range, and thus the components must be reconfigured to suit the frequencies characteristic of the device. In addition, the visible spectrum ends less than double the frequency at which it begins, so no frequency of visible light will have a corresponding harmonic perceptible. As such the analog component will either have to be mapped logarithmically or devised in an entirely new way that creates a rich signal without simply relying on conventional square, triangular and saw tooth waves.

Finally, the mapping of the keyboard will be challenging due to its arbitrary nature. There are many possibilities, including the simplistic model proposed by Rimington;[8] however, most correlate to some root in music rather than being oriented around the functionality of the eye itself. Music is structured around the anatomy of the ear and how our brain processes that information. While we want to create an instrument that evokes emotion as music does, it makes little sense to adhere to this model when processing visual information. Instead a mapping which is based around the physiology of the eye and psychology of optic processing will be needed.

Deliverables

The optical synthesizer project will result in a functional hardware prototype and subsequent report of findings from this experimental prototype. Due to the complex nature of this project it will be separated into 4 phases: 1. Core, 2. Controller 3. Synthesizer, 4. Extended development.

Phase 1 – Core: In this phase the software and interfaces for the core module will be developed. During this phase the core module will interface with a MicroKorg synthesizer via midi and an analog signal allowing for a focus on the software functionality and optimization. At this stage an Arduino Uno will be used and the electronics required to obtain a midi and analog signal developed. The software implemented will first be capable of passing midi information over USB, then a Fast Fourier Transform (FFT) of the incoming signal will be tested to determine the limits of the device. The result of the FFT will be passed via USB to a very basic testing and debugging interface. The layout can be seen below in figure 3.

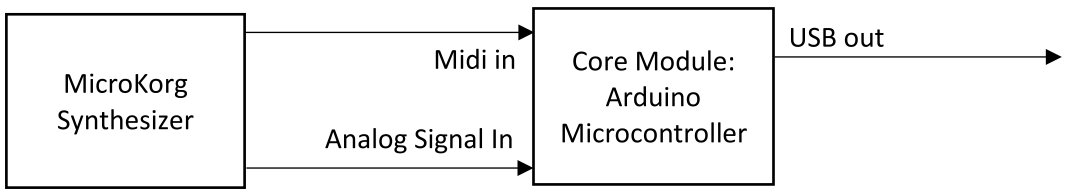

Figure 3 – Schematic of the optical synthesizer during phase 1

Phase 2 – Control Module: This phase will involve developing the control module of the system. A keybed and any other control surfaces required for the synthesizer will be rigged and tested. It will be determined whether the control module requires its own microcontroller or will interface directly with the core microcontroller. An LED strip to visually indicate the keys pressed and the result of the FFT will also be implemented so that the keyboard can be used independently of the virtual reality device. The MicroKorg will remain as the analog input for testing purposes.

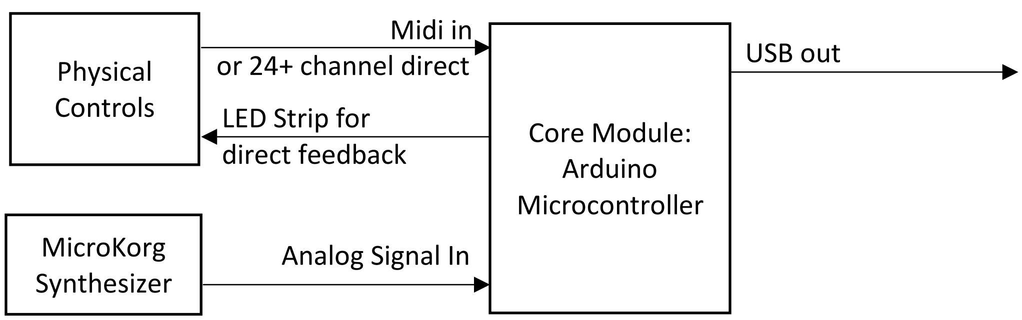

Figure 4 – Schematic of the optical synthesizer at the end of phase 2

Phase 3 – Synthesis Module: This phase will involve developing the synthesizer portion. The MicroKorg is removed and replaced by the newly added synthesis module. Control signals will be sent from the core module to affect various aspects of this analog hardware module. This element will utilize techniques used in sound synthesis but in frequencies that are not audible. It will employ circuitry which produces interesting but predictable results. It is likely that it will use some form of subtractive or frequency modulation synthesis, but will only use those components that create worthwhile effects in the visual domain. The resulting analog signal will be sent to the core module which will perform a modified version of the original FFT that is no longer in the audible range. Depending on the load on the microcontroller a direct midi connection from the control module to the synthesis module may be used instead of controlling via the core module.

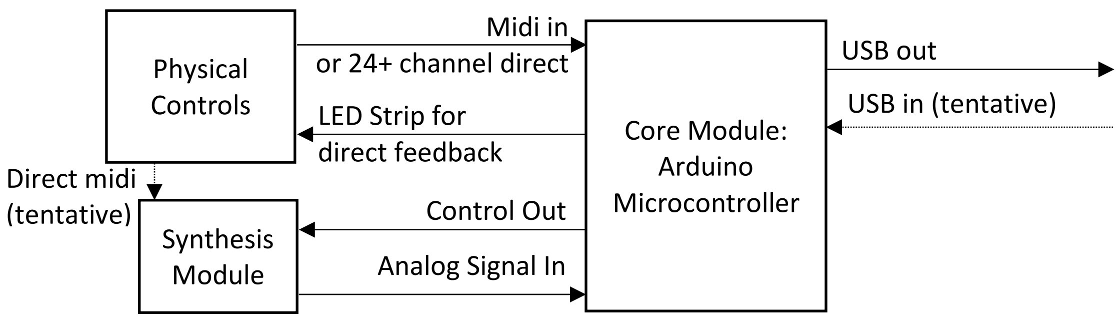

Figure 5 – Schematic of the optical synthesizer at the end of phase 3

Phase 4 – Extended Development: In the event of early completion of phase 3 or if any of the above modules is found to be unattainable or unnecessary, four extended development components may optionally be implemented. The first extension would be receiving an input from the Unity application – this would allow the synthesizer to be affected by various inputs such as the hand position and orientation in space. Secondly, a more comprehensive and extended synthesis module could be developed. Thirdly, a finished PCB could be developed for any or all of the modules. And finally, a chassis using 3D printed components could be developed as a finishing touch.

Timeline

- **February 17**: Phase 1 complete
- **March 3**: Phase 2 complete
- **March 17**: Phase 3 complete
- **March 31**: Phase 4 complete (if applicable)
- **April 10**: Final Report complete

Conclusion

In order to experiment with the concept of using real physical controls in a virtual reality environment, as well as to test virtual reality as a medium through which “colour-music” might find its success, an optical synthesizer will be developed. This hardware device will function as an active peripheral for a VR experience. It will process the user’s input digitally and control an analog synthesis module to produce a rich, lively and yet predictable output that will be used by the VR software. This project is significant in its attempt to emulate the emotive capacity of music in the visual domain without arbitrarily translating an audio signal into visuals.

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[1] “Overview,” *Oculus Rift*, accessed January 28, 2017, https://www3.oculus.com/en-us/rift/; “Hardware,” *HTC Vive*, accessed January 28, 2017, https://www.vive.com/ca/product/.

[2] “Wassily Kandinsky,” *The Art Story*, accessed January 28, 2017, http://www.theartstory.org/artist-kandinsky-wassily.htm.

[3] A. Wallace Rimington, *Light-Music*, (London: Hutchinson, 1912) https://archive.org/details/colouartof00rimi.

[4] Ibid., 177.

[5] “Timeline,” *Rhythmic Light*, accessed January 28, 2017, http://rhythmiclight.com/archives/timeline.html.

[6] Peter Kirn, “Watch the Clavilux, an Ethereal Light Organ From 100 Years Ago,” *Create Digital Media*, accessed January 28, 2017, http://cdm.link/2015/08/watch-clavilux-ethereal-light-organ-100-years-ago/.

[7] “Fast Fourier Transform,” *Open Music Labs*, accessed January 20, 2017, http://wiki.openmusiclabs.com/wiki/ArduinoFFT; “Fast Hartley Transform,” *Open Music Labs*, accessed January 20, 2017, http://wiki.openmusiclabs.com/wiki/ArduinoFHT; “Fast Fourier Transform,” *Arduinoos*, accessed January 20, 2017, http://www.arduinoos.com/2010/10/fast-fourier-transform-fft/.

[8] Rimington, *Colour-Music*, 18.

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