Isomorphic MIDI Controller

Jay Wyatt

LAES 462

June 12, 2013

Abstract

This paper briefly touches on the history of MIDI and documents the design and build of an Isomorphic MIDI controller.
## Contents

1. Introduction 1  
2. Background 1  
3. Deliverable 3  
4. Design/Implementation 3  
5. Analysis 9  
6. Related Work 10  
7. Conclusion 11  
8. Future Work 11  
9. References 12
1 Introduction

The MIDI controller has always been a cool pseudo instrument that I’ve played around and worked with since my high school years. Its capability to trigger sounds of virtually any instrument (with the help of music studio software) is appealing for a variety of reasons. A well-designed MIDI controller can be a versatile tool of music production when put into the right hands. However, some MIDI controllers can be difficult to play because of their clunky or awkward designs.

My original goal was to create a more ergonomic device but after some exploring online I found some alternative keyboard layouts that were very fascinating. I found one design in particular called an isomorphic keyboard that laid out musical notes in an intuitive manner. This design was appealing to me because it seemed like a more user friendly instrument to people who are new to computer music and might not have strong music theory backgrounds.

2 Background

The Musical Instrument Digital Interface (MIDI) became a standard protocol for electronic devices to communicate with computers and other digital devices in the early 1980s. MIDI operates by sending digital messages that contain information about the parameters of a sound. Every note that is triggered is translated into a MIDI message with details about its velocity (loudness), sustain (how long its held), along with many other variables. When a MIDI track is completed it will appear to look much like sheet music but comprised of digital events.
A MIDI “controller” is any device that uses the MIDI protocol to send signals to a computer. Traditionally, MIDI devices have transmitted information through 5 pin a serial connection with each “message” consisting of 8 bits. More recently USB and Firewire have become the more common interfaces but the same MIDI messages are sent through them. MIDI over USB has become increasingly popular over the years because of its ability to plug into any computer and send messages at faster speeds than original MIDI cables.

![Figure 1: 5 Pin MIDI Port](image.png)

Perhaps the most impressive element of MIDI controllers is their ability to be used in conjunction with Digital Audio Workstations (DAWs) on the computer. These DAWs come loaded with libraries of software instruments that emulate many classic hardware synthesizers and create even newer sounds. This allows users to play an enormous amount of instruments on a small and portable workstation. There are dozens of DAWs available to users but for this project I chose to use Ableton Live because I was already somewhat familiar with it prior to this project.

Once a MIDI controller is “mapped” or synced up with a DAW, any instrument or sound clip (sample) can be triggered by the user. MIDI signals can also be
mapped to navigate and control the software itself just like a mouse or keyboard peripheral. For example, a button on a MIDI controller can tell the software to start recording when it is pressed. The ability for piano keys, knobs, switches, and other electronics to send MIDI messages have allowed for a great deal of diversity of MIDI controllers. Not every controlled resembles the traditional piano keyboard like most early synthesizers did. They now come in all shapes and sizes, sporting unique layouts and new technology. There are now even MIDI wind and brass controllers that can measure breath pressure to send messages.

3 Deliverable

The finished product for this senior project will be a working MIDI controller that features an innovative design. All schematics, components, digital files, and plans will be compiled in an easily reviewable archive. The controller will be housed in a wooden MDF enclosure and sport a sleek acrylic faceplate.

The controller will properly produce MIDI signals that will be mapped to the Ableton Live DAW. Finally this device will be demonstrated to my peers and advisors near the end allotted time (Spring quarter).

4 Design/Implementation

The design of this MIDI controller revolves around its unique “isomorphic” layout. The isomorphic layout is a honeycomb grid of notes that incorporates musical intervals in its geometry. This idea was originated by a Swiss mathematician in
the 18th century but has never garnered much popularity in instrumentation. The interval relation to the hexagons can be seen below in Figure 1.

![Figure 1: Harmonic Isomorphic Layout](image)

Figure 2: Harmonic Isomorphic Layout

The goal of this design is to promote a faster learning curve and increase a user's ability to “jam” on the MIDI device. An isomorphic design also allows for transpositional invariance while playing. This means that a melody can be easily transposed to another key as long as the shape of it is preserved. This feature is not available on MIDI keyboard because the musical intervals are not consistent throughout device.

To create the finished design for the controller, I used Adobe Illustrator to create
a schematic. With this software I was also able to map all the cutout holes and etching lines needed for the laser CNC machine to create my faceplate. Initially I used a cardboard sheet and printout to simulate the design. Later on I used a tinted acrylic sheet with 3/16” thickness and made the cuts with the laser CNC machine in the Bonderson Projects lab. The design template made in Adobe Illustrator easily translated to the laser CNC with a few RGB adjustments. The machine was also able to do the thin etching that represents the hexagonal outlines.

The enclosure was built using 1/2” MDF wood cut to match the dimensions of the acrylic faceplate. A slight 7-degree slant was incorporated on the edges to give the user a better viewing angle of the device. The box was then sanded down and coated with three layers of flat black paint to accentuate the glossy black of the faceplate.

Figure 3: Unfinished Encloser
The design supports a 53 key isomorphic keyboard with blue and black arcade buttons. The blue buttons represent the seven natural notes (C, D, E, F, G, A, B) while the black buttons are augmented notes (C#, G#, D#, A#, F#). Aside from the isomorphic keyboard I have chosen to implement four fader potentiometers, two large touch potentiometers to serve as pitch/modulator modifiers, and four rotary potentiometers to be mapped to volume and track control. There is also a blue LED placed in the top right of the controller to relay the ON/OFF status of the device.

Figure 4: Final Design Template
Once the buttons, knobs, and faders were mounted to the faceplate, the next step was to wire them into a matrix and connect them to the Livid Brain v2 micro controller (see Figure 5). This micro controller is able to recognize voltage signals that the buttons and potentiometers relay to it translating them into MIDI signals that can be interpreted by a computer. A small wiring example for a 4 button matrix can been seen in Figure 6. The positive rail (red wire) of the buttons need to be placed in parallel with each other and ran to the first pin on the ribbon cable. The negative rails sends the signal and needs a diode between itself and the ribbon cable. Clearly, this was done on a much larger scale than the four button example but the complexity wasn’t much more difficult. Once each button or potentiometer was wired to the ribbon cable the cable could be placed on the corresponding column (Button, LED, or Analog) on the left half of the Brain seen in Figure 5.

Figure 5: Livid Brain v2 Micro Controller
Below is a parts list of the components used for this project along with their respective costs (rounded).

- Livid Brain v2 Microcontroller - $200
- 58 x Competition Arcade Buttons - $110
- 12x24” Acrylic Sheet- $30
- 4 x Linear Slide Potentiometers (Medium) - $11
• 4 x Slide Pot Caps- $4
• 4 x Rotary Potentiometers- $4
• 4 x Rotary Pot Knobs- $6
• 100 pack of Diodes - $8
• 10 x .01uF Capacitors - $2
• 3/8" MDF Sheet- $10
• Blue 3.6V LED- $2.50

5 Analysis

The functionality of the MIDI controller will be shown during the demonstration portion of the project previously discussed. Progress on the project has been displayed in status reports and semi-weekly discussions with my advisors and peers.

Once the MIDI controller was assembled and properly mapped to Ableton Live its usability immediate was apparent. As long as the user moves to adjacent keys (diagonally, vertically, or horizontally) a harmonic melody will be created. It turned out to be very difficult to play something that is musically dissonant, therefore most things sound pleasing to the ear.

The analog knobs and faders can easily be mapped to the Ableton Live software and prove useful in controlling pitch bends, volumes, and envelopes during live playing.
6 Related Work

MIDI controllers have been around for nearly 30 years so an enormous amount of designs have been used. The most common types of controllers on the market today resemble a keyboard or sport a 4x4 grid of pads that can be triggered. A popular example of this design can be seen in the figure below.

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{mpd32.png}
\caption{MPD 32 MIDI Controller}
\end{figure}

In recent years there has been a large increase in the amount of DIY MIDI controllers because of the increased access to circuit boards and micro controllers. As a result there are many unique MIDI controller designs online. One called the Axis 64 also uses an isomorphic design, which is pretty similar to mine in a lot of respects. This device uses hexagonal pressure sensitive pads to measure how hard the user hits a note which is an improvement over my implementation – it also retails for around $1600.

Currently there is also an iPhone/iPad app called Musix that allows users to play an isomorphic keyboard. It is very portable and customizable but lacks the ability
to communicate with existing computer software (DAWs). Also most players prefer the tactile feel of MIDI hardware over the flat touchscreen of an iPad.

7 Conclusion

This senior project is a great opportunity for me to apply many of the electrical engineering, computer science, and music theory concepts I have learned in my concentration classes for the LAES program. I hope isomorphic design of my controller can offer a unique yet functional approach to MIDI devices. After only a few days of playing the device I have recognized its ability to pump out great sounding melodies with little practice time put into the controller.

8 Future Work

When addressing the ability to customize MIDI devices the sky is the limit. If future designs were pursued they might support some of the following ideas:

- LED status lights in the buttons to give the player visual feedback
- Velocity sensitive hex pads to allow for different loudness to be played live
- LCD display to toggle through sound banks without using the computer
- More fancy enclosure to house the electrical components of the device
- Addition of shortcut keys
Given more time I would likely redo the wiring behind the faceplate and make it more organized, possibly showcasing the cleanliness with led backlights. Aesthetically this would make the front view a bit more pleasing and give the device more of a mechanical look.

9 References


Catchlove, Lucinda (April 1, 2002), Wendy Carlos (electronic musician), Remix Magazine


The Complete MIDI 1.0 Detailed Specification, MIDI Manufacturers Association Inc., retrieved 2008-04-10