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MIDI: A Standard for Music in the Ever Changing Digital Age

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Abstract

MIDI (Musical Instrument Digital Interface) is the technology that allows synthesizers and controllers to communicate and manipulate other pieces of gear as well as computer software. This technology has permanently changed the way music is produced and performed. This paper will explore the importance of MIDI technology as a tool for music production as well as for music performance. This will be done by first examining the history and development of MIDI technology, including the reasons why it was created. Many examples will be given of how MIDI is a crucial component in recording studios, music production studios, and live performance. An in-depth look at MIDI controller design will also be provided in order to determine its effect on style of use. A portion of this project has been dedicated to the building of a MIDI controller with a unique design, which this paper will describe. By doing this, MIDI controller design can be analyzed to determine how it can affect music production and performance. The conclusion will illustrate how MIDI technology is important in today's world of music production as well as discuss the possible future of MIDI and music production technology.

History & Development

Although MIDI technology itself was developed only about 36 years ago, automatic musical instruments date all the way back to 850 AD. It was at this time that three brothers from Baghdad, known collectively by the name Banu Musa, recorded descriptions and illustrations of musical devices that played automatically. In this publication, over one hundred ingenious inventions were recorded, two of them being mechanical musical instruments. The first instrument illustrated is a water-powered organ (Fig. 1) that was able to play different musical pieces using interchangeable cylinders to control which notes were played. The second device was an automatic flute player (Fig. 2) controlled by steam (Koetsier). Although developed almost one thousand years before significant developments in electricity were made, these inventions share one of the basic goals of MIDI technology: to automatically control a musical instrument (The MIDI Association, “MIDI History:Ch.1”).

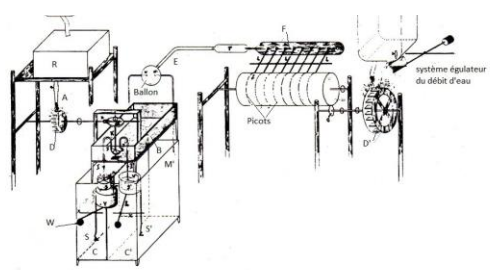

Fig. 1 Water Powered Organ, The MIDI Association “MIDI History:Ch 1.”

Fig. 2 Steam Powered Flute Player, Koetsier, Teun 23 December 2000

Other significant developments in automatic music playing came in the late 1800s and early 1900s. The player piano, a piano that could automatically play itself, was developed around this time. This technology used what is called a “piano roll”: a perforated roll of paper that contains musical data interpreted by the piano and played as notes (see Fig. 3). The rolls of paper used to control these player pianos are visually similar to the piano roll that you would typically see in a digital audio workstation (see Fig. 4).

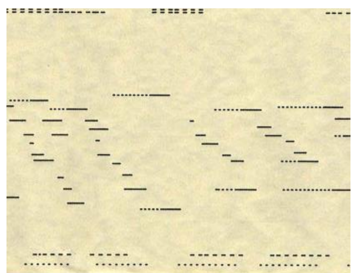

Fig. 3 Player Piano Roll, Reublin, Richard (November 2007)

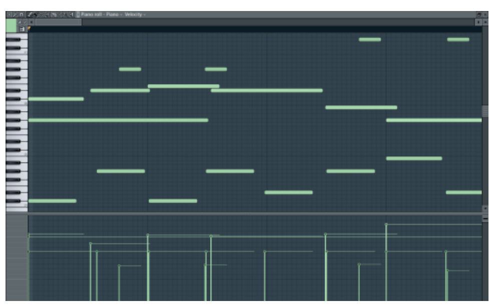

Fig. 4 DAW Piano Roll, District Onagi (2017 October 30)

Around the same time that player pianos were being developed, other automated musical instruments were being invented. One significant instrument was the orchestrion (see Fig. 5). This invention worked similarly to the player piano and its predecessors with regards to the way the machine knew what to play. Musical information was transferred to the early orchestrion using pegged cylindrical barrels that contained musical information, much like the cylinder inside of a music box. Later models utilized perforated paper rolls such as a player piano would use. One major difference that set the orchestrion apart from its ancestors was that it could imitate the sound of an entire orchestra (hence the name). This was done by the use of a large organ and percussion instruments all with the ability to be controlled by the machine (“History of the Pianola”).

Fig. 5 Maelzel's Panharmonicon at the Industrial Museum in Stuttgart, The Pianola Institute “History of the Pianola - Orchestrions”

The instruments that have been described so far have lacked one aspect that modern automatically controlled instruments have. That aspect is the connection between computers and music. It wasn’t until 1957 when Max Mathews, an engineer working at Bell Laboratories, started to bridge the gap between emerging computer technology and music. During his research at Bell Labs, Mathews created the first computer program that was able to synthesize a sequence of tones into a short song lasting only 17 seconds. Although a magnificent accomplishment for the time, this early program was very limited in the sense that it was only able to use one waveform and had no control over dynamics of the sound that was generated. After making numerous improvements to his initial program, Mathews developed *GROOVE*, or *Generated Real-*

time Output Operations on Voltage-Controlled Equipment (Holmes). This program, developed in 1970, was able to store musical information played by a musician on an external synthesizer. Using the program, the score could then be reviewed, edited in real time, and played back. It was these advancements in computer technology and electronic music that led to what we know today as digital audio workstations (Crab).

By the early 1980s, advancements in computer technology allowed for the practicality of the home computer, whereas before computers were bulky machines that sometimes utilized an entire room full of equipment. These developments in technology aided and paralleled the advancements being made in digital and analog synthesizers of the time. The availability of these emerging technologies gave a new desire for musicians to be able to control and store musical information with their home computers. Although synthesizer developers such as Yamaha created interfaces which could be used to connect and control other synths of the same brand, the technology was very limited due to the incompatibility with instruments from other manufacturers. This pressure from consumers led Dave Smith from the synthesizer company Sequential Circuits and Ikutaru Kakehashi from Roland to propose a universal synthesizer interface that could communicate with all compatible devices. At the Audio Engineering Society convention in 1981, a paper outlining the concept was presented. The following year at the National Association of Music Merchants convention, a meeting was held between the leading synthesizer companies to work out the details of this proposed technology. After months of heated debate between the companies, a standard was agreed upon. This standard is what we know today as MIDI. In

December 1982, the first instrument with MIDI compatibility was released by Sequential Circuits (The MIDI Association, “MIDI History Ch.6”).

The development of MIDI technology created many new possibilities in the way that electronic and analog synthesizers could be used. But the technology was not only limited to instruments. MIDI messages could now be used in conjunction with computers and even to control stage lighting. But with every new development in technology, there are some challenges faced in widespread adoption. For MIDI technology, the biggest challenge was for the many companies involved to agree on a standard language. During the development of the MIDI protocol in 1981, Dave Smith and Ikutaru Kakehashi wrote a specification that laid out only the basics of MIDI messages, such as note value, note on and off, velocity, and changing volume. This led to many of the companies interpreting how they would implement MIDI messages differently. During an interview with Roger Linn, he explains how initially companies had discrepancies in the way they used MIDI messages:

> There are two messages in MIDI, one is called note on and one is called note off…but you could also send a note off message by sending a note on message with a velocity of zero. So that's how Yamaha implemented MIDI… and that confused everyone.

After years of discrepancies, companies agreed upon a standard which is the same that we use today.

MIDI as a Tool for Music Production and Performance

MIDI technology can be used to make music production easier and more cost efficient for musicians of all genres. For electronic musicians like Jalaya, a DJ and producer from San Francisco, MIDI is an invaluable piece to his music production and performances. During an interview, Jalaya explains how using MIDI during music production helps an artist feel more connected to the music they are creating:

> *There's kind of a magic to doing it live as opposed to programming it… When you're forced to make that decision in the moment, you're actually feeling it out and you are more connected to the process.*

Jalaya also uses a MIDI drum pad to incorporate a unique live element to his performances. Having played the drums for about sixteen years, he showcases his talent as a drummer without having to use an actual drum kit on stage. Jalaya talks about the advantages of using a MIDI drum kit:

> Being able to customize my own kits with a ridiculous amount of samples, it really just saves a lot of money compared to having the actual instruments. Not to mention that some of the sounds that I use are not from real instruments.

Jalaya is only one example of electronic music artists who use MIDI in live performances to incorporate a more engaging and unique element to their music.

The electronic music trio by the name of Glitch Mob uses custom MIDI controllers during performances. After gaining popularity in the electronic music scene, the group accumulated the resources they needed in order to take their performance to the next level. The group wanted to break away from the typical DJ setup with a laptop and turntables, and instead they wanted a performance that had “the same feel and drama of live rock" (Pangburn). What the members came up with was a unique cross between an art installation and live digital instrument they called *The Blade*. This incredibly unique setup, used during their 2015 tour, utilizes large drums reminiscent of traditional taiko style drums. Along with these drums, touch screens and MIDI controllers are tilted toward the audience for a greater visual connection with the music for the audience. The group continues to use *The Blade* on tour bringing new improvements almost every year (Pangburn).

MIDI instruments are not only tailored for electronic musicians. Tortoise, an experimental rock band from Chicago, Illinois, uses MIDI technology to make touring more practical. In most of the tracks produced by the group, a marimba is featured. Member of the band Jeff Parker talks about the challenges of touring with bulky instruments: "We would have to rent them when we travelled or we would have to lug our own around, but now we have like a Midi controller but you play it with mallets...so we don't carry the marimba around anymore" (Carr).

It is not only performing or electronic musicians that use MIDI to create their work. Film score composer Hans Zimmer has won numerous awards for his work. Like many other modern musicians and composers, Zimmer also takes advantage of MIDI technology in order to efficiently take his compositions from inception to completion. Zimmer explains how MIDI technology is used not only to compose, but to add elements to real instruments that would otherwise not be possible:

> I could use MIDI CC 11 for putting all sorts of super-duper expressions into every line. Which then became a bit of a problem once we went off to record the real organ, because it can't do that...What I did at the end of the day, after we'd

> recorded all the organ parts, was to put the audio tracks back in the sequencer and superimpose expression maps onto them. (qtd. in Fortner)

Here, Zimmer talks specifically about using MIDI CC, or Continuous Control messages. These are MIDI messages used to control specific aspects of a sound such as volume, panning, and modulation. This further demonstrates the advantages of using MIDI over live recordings of instruments.

MIDI is commonly used by many musicians to connect instrument controllers to computer software. By altering the way MIDI information is transmitted, it has also become an integral part of professional recording studios. MIDI SysEx (system exclusive) is a type of MIDI message that can do much more than communicate with MIDI-compatible instruments. These messages have been designed so that other outboard equipment such as signal processing units and even sequencers can also communicate and share information with computers ("Introduction to Computer Music").

One of the biggest advantages of using MIDI SysEx to control a piece of outboard equipment is that it saves studio engineers time. Effects processing units are usually stored in a rack, sometimes on the complete opposite side of the room from where an engineer is when mixing. Because of this, controlling the settings on something like a reverb unit can be extremely tedious and time consuming. Not to mention most rack mounted processing units have a very small screen and a limited amount of physical buttons or knobs used to control numerous parameters. MIDI SysEx allows these units to be controlled either from a remote controller or computer software. This way, engineers can adjust processing units and even save presets to be used in the future from a more convenient location.

How MIDI Technology Influences Music Production

MIDI technology has come a long way since its inception. Fundamentally, MIDI was created to function with a keyboard instrument as the input device. This is reflected by the basic data sent using MIDI devices, which includes key (note), note on, velocity, and note off messages, much like the function of a piano. One limitation of using MIDI with a standard keyboard interface is the lack of expressiveness a player can use during performance.Throughout the lifetime of MIDI technology, developers have been experimenting with ways to go beyond the keyboard and incorporate the design and playing style of other instruments that would make a more expressive way of playing possible. Developers who are successfully breaking the mold for this type of technology include Roger Linn, ROLI, and Artiphon, just to name a few. These companies use what is called MPE (MIDI Polyphonic Expression) messages to control software from their specially designed instruments.

MPE is utilized in new MIDI instruments such as the ROLI Seaboard or the Linnstrument and allows for what is named “multidimensional touch.” This variation on the use of standard MIDI messages allows for a player to have more control over what they play. MPE messages utilize a separate MIDI channel for each note. By doing this, gestures such as pitch bend can now effect only one selected note or multiple notes at a time. Whereas when using standard MIDI messages, pitch bend messages would affect all the notes being played. This goes for any other MIDI CC message such as velocity, modulation, and panning (Linn, “Linnstrument”).

Roger Linn, designer of the first programmable drum machine built in 1979, has a long history of designing consumer electronic music products. After having no success with his own instrument production business, Roger Linn was contracted by the major consumer electronics company Akai in 1988 (Linn, “About Roger Linn). Roger Linn also worked closely with Dave Smith in the early years of MIDI and was a major proponent in the development of the technology. More recently, Roger Linn is known for the development of the Linnstrument (see Fig. 6). This device uses MPE technology to very accurately emulate performance qualities of many different instruments, including string instruments and wind instruments. This is done by having 5 different types of polyphonic expression: strike, pressure, x-axis movement, y-axis movement, and release velocity. The instrument can be played either while laying on a flat surface or against your body held by a strap much as a guitar would be held. Linn describes the advantages of the Linnstrument design compared to traditional (piano layout) MIDI controllers:

> *If you want to do the sorts of pitch gestures that people do on acoustic instruments…like note bends, sliding from note to note on a violin or a cello…on a piano layout, it is very cumbersome to do it because the notes are not evenly spaced in pitch, and the black notes are behind the white notes. The design on Linnstrument’s note arrangement is that you have a series of semitones in a row, one after another. So if you do that, that happens to be like a string…That's why it is important; otherwise you just can't perform those gestures in the same way on a piano note layout.*

Fig. 6 The Linnstrument, Thomann 2018

Another MIDI controller designed to emulate real instruments is the *Aerophone* made by Roland. This instrument also uses the MPE protocol to accurately replicate the sound of wind instruments. Along with a mouthpiece, this controller is designed with buttons arranged in the same way as a traditional saxophone. This makes for an easy transition for someone who already plays the saxophone to pick up this controller and immediately start playing. Just as a traditional saxophone works, the *Aerophone* allows the player to control dynamics, articulation, and even overtone changes by use of the mouthpiece. Like any other MPE controller, the *Aerophone* can connect to a digital audio workstation to input MIDI data and control other synthesized sounds (Roland Corporation).

The Linnstrument, the *Roland Aerophone*, and other MPE based controllers are a good indication of where MIDI technology is headed in the future. The demand from consumers for controllers with a more realistic feel and sound control will likely continue revolutionize the way this technology is developed.

Limitations of MIDI

Although MIDI has a reputable background along with consistently reliable functionality, there are many limitations to using the MIDI protocol to control musical devices. This is mainly due to the fact that the messages themselves can only be transmitted using an 8-bit format. Not only this, but MIDI messages can only transmit integer data. Having a limited amount of data that can be sent limits how the protocol can be used. Because of these limitations, alternative protocols have been developed. In 1997, developers Matt Wright and Adrian Freed released *Open Sound Control,* otherwise known as *OSC*. This technology can best be described as a network data transport control system, meaning that it inherently works over an established local network. This protocol was developed to provide alternatives to the shortfalls of the MIDI standard (Phillips).

One limitation to the MIDI protocol is the fact that it must be transferred over dedicated cables. This means that to be able to control an instrument or other piece of hardware, the player must be in the same building if not in the same room as the instrument. Although there are computer applications that allow users to send MIDI data over the internet to control remote devices, it is not possible with most MIDI devices alone. The alternative, OSC, inherently works over an internet network and can be sent to great distances. This makes it possible for multiple users to control devices compatible devices from remote locations (Phillips).

Another limitation to the MIDI standard is its lack of expressiveness, which was briefly discussed earlier. One reason expressiveness is limited is because the MIDI protocol favors a twelve-tone equal temperament scale. This is because MIDI was first designed to work with synthesizers that had a keyboard interface. Although MPE is a workaround to this issue, allowing players to slide in between the traditional notes on a piano layout, it is not being implemented at full force by product developers. This is because of inherent limitations of the technology. MPE sends each note being played over a separate MIDI channel, and this is done so that continuous control operations, such as pitch and volume, can be implemented on a single note or group of notes by choice of the player. The limitation with this is that the MIDI protocol is limited to 16 channels per instrument. By design, the OSC protocol is not constrained by separate channels of information. This means that it has no limit to how many notes can be played and modified in real time, besides bandwidth limitations which would be difficult to reach (Wright).

Obviously, there are drawbacks to using the MIDI protocol as the standard for controlling electronic musical instruments. Yet this technology remains the standard for may hardware and software developers. This may be due to the fact that there is a limited demand by consumers for a controller that can exceed the capabilities of MIDI. Another reason that MIDI is still a standard is the way that it came into existence in the first place. As described earlier, MIDI was developed to create a unified way to connect and control hardware from various manufacturers. It would take not only a significant amount of consumer demand, but also the cooperation of many companies who create consumer products to agree that a new protocol would be beneficial and necessary.

Designing a Custom MIDI Controller

In order to more deeply investigate how the design of a MIDI controller affects the way it is played, I developed a MIDI controller of my own. My intention with this project was to design a controller with a button layout like nothing on the market today. During the design process, I had no intent to create a design that was extremely functional; instead I focused on uniqueness of button layout. I also aimed to keep the design very simple and budget friendly. I drew inspiration from the MIDI Fighter, a 16-button MIDI controller that uses arcade buttons. My design uses these same buttons because they are very inexpensive and work perfectly for the application. My design utilizes twelve arcade buttons in the layout based on the geometric pattern *Metatron's Cube*. I also use two different colored buttons, green and white. The "brain" of this MIDI controller is a *Teensy* microcontroller. This device, about half the size of a credit card, contains computer code that sends MIDI data to a computer that has been translated from the on-off messages received from the connected arcade buttons. All of the parts are housed in two pieces of clear plexiglass held in place by nuts and bolts (see Fig. 7).

While experimenting with playing music using this unique controller, I found that playing percussion instruments is very fun and easy. When using standard 16 button drum pad MIDI controller that is laid out in 4 rows of 4, I sometimes find that it is hard to mentally keep track of which buttons correspond with each drum sound. Because the design of my controller is so unique in terms of its geometric layout of buttons, it seems easier to mentally record the location of each sound. The different colored buttons also greatly help with this.

Fig. 7 MIDI Controller Taylor Romo, 11 December 2018

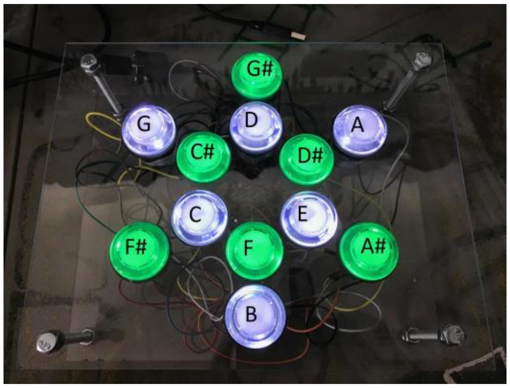

Fig. 8 MIDI Controller Button Diagram, Taylor Romo, 6 December 2018

This is also true when playing melodic sounds. The MIDI notes on my custom controller are arranged in a clockwise fashion. Starting with what would be middle C on a piano, the notes go up by a half step in a clockwise manner. Middle C is located in the center group of buttons, and after the last button in the center group the next note jumps to the outer group and continues the sequence (see Fig. 8). The unique layout of notes intuitively leads you to create unique chords by following color and shape combinations. Admittedly, it is a bit difficult to play standard chords because some of the notes that wouldn't be far away from each other on a piano keyboard layout are actually a great distance from each other in this design. This is one example of how MIDI controller design can influence the way in which they are used.

The custom built MIDI controller that I have designed has many limitations. For one, the controller only has twelve buttons. This means that when playing melodic instruments such as a piano or synthesizer, you are limited to using only notes from middle C to the next B. Most controllers that use a keyboard layout at least have 2 octaves. The single octave greatly limits the melodies that you can play using my custom controller. The chords you can play are even more limited because chords are limited to a single voicing. The limited range of my custom controller, although challenging to use at times, can actually inspire the player to creatively use what is available. I believe that this applies to all MIDI controllers because all have some limitations in terms of what can be played and how it is played. Even all traditional instruments, such as the piano, have limitations on what sounds can be created and how they are played.

In this paper, I have shown how MIDI technology was developed. I have also shown how, through technological advances, it has evolved to become such a useful and flexible tool for not only music production, but for music performance as well. Numerous examples of how MIDI technology is used by artists have been provided to show the vastness of different applications the technology can be used for. Through constructing a very uniquely designed controller, I have demonstrated the way that the design of a controller influences the music that is produced while using a controller. This build has also given insight on how design of a controller can create musical and technical limitations for an artist. In closing, MIDI is an essential piece of music creation in the twenty-first century. With modern advances continually being made to this technology, MIDI will continue to give artists a unique way to play and produce music for many years.

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