Methods of Musical Interaction: An investigation into the tools utilised in a studio environment

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Abstract

Many names describe the role that a person facilitates in a studio scenario: artist, producer, engineer, writer. The system with which we choose to record music can greatly affect the outcome of the product. Speed, quality and comfort are all aspects of creating a record. The workings between an engineer and his chosen Digital Audio Workstation can be extended from mouse and keyboard to further their understanding of sound recording, the methods we use to mix, and the ways we interact with expressive instruments. Controllers can expand expressive capabilities can influence the creation of music, and devices that expand mixing capabilities have the ability to change the workflow and approach of an engineer, thus influencing the record. This investigation will examine the specifications of which the industry is built off and the technologies which facilitate mixing in and outside the DAW. It will also frame an argument into the inner workings and attitude of the developers in relation to the audio industry, presenting an experiment analysing how the usage of certain equipment can aid in the production of a record in a studio environment.

Impact of COVID-19

Beginning January 2020, the World Health Organisation reported on social media of a cluster of pneumonia cases which developed into a global pandemic known as COVID-19 (referred to as 'Coronavirus'). The coronavirus has caused interruptions and cancellations of parts of this investigation. Due to COVID-19 the University of York was closed which prevented access to its studio facilities. As a consequence, a location to conduct the experiment under a controlled environment wasn't available. Government-mandated social distancing restriction meant that any sort of experiment became impractical and was halted, additionally, the libraries were closed meaning research was primarily conducted online with limited access to particular sources. Because of the 'niche' surrounding the central discussion of this investigation, most books relating to this topic are not digitised. These are potential points in which the information provided may have been further reinforced with a greater resources base.

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Table of Abbreviations

ACM	Assignable Controller Message
ADSR	Attack Decay Sustain Release
API	Application Programming Interface
AU	Audio Units
CGI	Computer Generated Images
CV	Control Voltage
DAW	Digital Audio Workstation
DCA	Digitally Controlled Amplifier
DCB	Digital Control Bus
DOS	Disk Operating System
DSP	Digital Signal Processing
EDO	Equal Division of the Octave
EQ	Equalisation
GM1	General MIDI
GUI	Graphical User Interface
HUI	Human User Interface
ITB	In the Box
LCDs	Liquid Crystal Displays
MCU	Mackie Control Universe
MIDI	Musical Instrument Digital Interface
MIDI CC	MIDI Continuous Controllers
MMA	MIDI Manufacturers Association
MPE	MIDI Polyphonic Expression
NAMM	National Association of Music Merchants
NKS	Native Kontrol Standard
RCM	Registered Controller Message
SDS	Sample Dump Standard
Sysex	System Exclusive
UMP	Universal MIDI Packet
USB	Universal Serial Bus
V/OCT	Volt Per Octave
VCA	Voltage Controlled Amplifier
VCF	Voltage Controlled Filter
VST	Virtual Studio Technologies
VU Meter	Volume Unit Meter

Definitions of Colloquialisms

Aftertouch	The process of pushing down after a key has been pressed to alter the sound through pressure opposed to initial velocity
Bottleneck	Where one part of a system causes slowdowns
Channel Strip	Usually comprising of all the controls required for basic mix function. Typically, input gain, gate, EQ, compressor and output level.
Continuous Encoders	A knob which does not have a beginning or end point, it simply rotates in one direction indefinitely.
Control Mapping	The act of assigning parameters to physical or digital controls.
DAW remote/controller/control surface	A unit or application that allows control of functions inside the DAW such as volume, pan and sends.
Instrument Articulation	Different methods of playing an instrument, for example: Pizzicato, Legato, Sustain.
Large Format Console	Sound desks with large channel counts, purpose built for live or studio work
Master/Slave	A relationship between two or more networked devices.
Metering	A visual instrument which producers use to check levels of music.
Microtonality	The use of pitches outside the Western Standard Tuning System.
Polyphonic	Synthesisers which allow multiple keys to be pressed
Sample Library	A collection of sound clips where, when played together form a convincing recreation of an instrument.
Trigger Pads	Pads which are conventionally used for finger drumming
Velocity	When relating to music, velocity is the strength or effort put into a note, usually resulting in a volume difference.
Western Standard Tuning System	Relating to the twelve-tone equal temperament tuning system.
Menu Diving	The act of trawling through lists and menus to find a single parameter to change.
Plugin	A piece of software which inserts itself into another program to provide a certain processing.
Compressor	A type of processing designed to reduce the dynamic range of audio.
Ride the Fader	A term used to describe manually changing the level of a channel while it is playing.
In the Box	Using a computer as the sole source of audio processing.

Introduction

This text makes heavy use of acronyms, abbreviations, and colloquialisms. It is advised to refer to the table of abbreviations and definitions of colloquialisms below the table of contents.

A bedroom producer is someone who commonly writes, performs, engineers, and produces from a home studio as a hobby or profession. With the advent of DAWs and the first commercial digital recording system - the Sony PCM-1 in 1977[1] - processing power has only increased and the tools to create digital music have become more accessible. In 1989 Steinberg released Cubase and pioneered the VST format in 1996[2], giving the power of a studio to laptops and home computers around the world. With the price of electronics falling and the power ever increasing, more and more people were able to harness the power of a professional recording studio from anywhere with a computer. This has brought about the development of consumer-grade peripherals targeted towards these bedroom producers. Be it tools for expressive playing, emulation of vintage gear, or workflow enhancements to aid in creating a comfortable, effective recording setup. Each producer obtains their workflow through experience, some decide that they would like a large format desk console with a 48 track tape machine. Others seek to create a streamlined workflow inside their computer of choice, creating templates and presets that speed up the innovation of a musical idea. Some choose a hybrid approach utilising analogue and digital technologies to create their sound. However, the need for the performance of the artist persists. This is where performance controllers are important. For example, when writing a

[1] Curtis Roads, *The Computer Music Tutorial* (Massachusetts: Massachusetts Institute of Technology, 1996), 10.
[2] Michael Prochak, *Cubase SX: The Official Guide* (SMT, 2002), Introduction and Overview.

piano piece, the sound should reflect the weight and effort going into each note as opposed to a dry, robotic sample. This delicate melding between hardware and software enables a system which works for an effective performance. Other instrumentation such as winds or strings are unable to be played convincingly by a simple controller, thus the implementation of custom expressive controllers makes MIDI more accessible to classical musicians as they do not need to abandon their expressive interaction with their instrument.

> There is something about that blurring of lines between that analog and digital that is just so fascinating. The digital analogue of the analogue is intriguing, there is nothing analogue about it, it is just another interface. - Lawrence T Levine[3]

[3] MIDI Manufacturers Association, "MIDI 2.0 For Musicians," *MIDI.Org*, 2020 Accessed May 30 2020, https://www.midi.org/.

MIDI

The Birth of a Standard

MIDI is an interface which has dominated the digital realm since its introduction in 1983. Originally allowing automated sequencing of synthesisers, it now impacts all major DAWs and communication control data, allowing a vast network of messages to connect a studio. An important distinction to make is that while communication into and out of a DAW is most likely to be MIDI; the communication inside a DAW may use a different communication technique while presenting itself to be MIDI. This innovation has unquestionably shaped the landscape of how music is produced using computers, and the history of the specification has encouraged a multitude of innovations in musical expression and accessibility.

Musical Instrument Digital Interface, or MIDI for short was first introduced in the Prophet-600 synthesiser designed by Dave Smith in 1982.[4] The implementation of MIDI allowed for note data, program change, as well as pitch and mod wheel support. This allowed for a keyboard to control pitch and modulation in addition to accessing preset sounds onboard the synthesiser. However, the Prophet-600's integration of MIDI differs from its present use as its purpose was primarily applied in creating a master/slave relationship between two Prophet-600s simultaneously. Several issues arose when transferring settings between synths, and the Prophet-600 possessed the Program Dump feature, allowing the master synth to 'dump' its program onto the slave and reprogram it to produce an identical sound. Through the System Exclusive (SysEx) data format. This

[4] Tom Bateman, "How MIDI Changed the World of Music," *BBC*, 2012 Accessed March 20 2020, https://www.bbc.co.uk/news/technology-20425376.

demonstrated that control data could be sent over the then-recent 5pin din connector.[5] The impact of this was that remote programming and playback of synthesisers were capable, allowing automation of band members.

Ikutaro Kakehashi highlighted the need for interconnected synthesisers from within the MC line of sequencers produced by the electronic instrument manufacturer Roland. The DCB, a Roland proprietary interface, presented issues of limited compatibility and interaction. The DCB was a CV interface made for the OP-8 through the Roland MC-4 Microcomposer.[6,7] The DCB's interaction between the MC-4 and a synthesiser was limited to the sending of Clock, Note, Program and VCA/VCF data,[8] which in turn limited synthesiser integration as each function required its own pin. In contrast, the 5 Pin Din MIDI connector was capable of sending digital signals across large distances with minimal latency. Additionally, the MIDI specification was expandable to increase the functionality programmable to an existing synthesiser, making MIDI a superior interface for widespread adoption.

CV is a control interface now used most commonly in Modular Synthesis. However, CV for music was pioneered by Robert Moog with the V/OCT standard. It allowed tuning of synthesisers through their full frequency range according to the western standard tuning system, usually done with a patch cable.[9] The CV V/OCT controls were often paired with a Gate control sent to either an amplifier or an ADSR Envelope to allow a binary state to be applied. This means that when a key was pressed, the Gate would open, and the signal

[5] Stanley Jungleib, *Prophet-600 Synthesizer Operation Manual* (Mijdrecht: Sequential Circuits, 1982).
[6] Roland, *JP-8 Owner's Manual*, 1981.
[7] Roland, *Juno-60 Owner's Manual*, 1982.
[8] Roland, *Juno-60 Service Notes*, 1983.
[9] Trevor Pinch and Frank Trocco, *Analog Days* (Cambridge, Massachusetts, London: Harvard University Press, 2019), 24.

could be heard. Problems with this standard became apparent incompatibility as certain controls were meant for specific voltage ranges, while there also existed issues with some parameters requiring a logarithmic voltage curve to function properly while others required linear.

The CV and Gate interface was cumbersome due to each voice requiring a patch cable and perhaps extra modules such as splitters. However, this standard did allow for easier visualisation of how a patch works with a visual representation of signal flow when relating to the synthesizer.

The MIDI specification was finalised and released in 1983[10] by the early MIDI Manufacturers Association (MMA), which included founding members Ikutaro Kakehashi of Roland, and Dave Smith from Sequential Circuits[11]. Despite its innovation since, the initial concept was criticised extensively for its technological sacrifices. Due to MIDI's unique connector, it was widely believed that the individual cable would lack utility within other scenarios. However, during the National Association of Music Merchants (NAMM) show in January 1983, manufacturers were persuaded when both the Jupiter-6 and Prophet-600 were linked, playing and transmitting together.[12] This demonstrated that a universal specification was achievable and easy to integrate into previous control systems. By the end of 1983, most synthesiser manufacturers were supportive of the concept of a universal communication protocol.[13]

[10] Future Music, "30 Years of MIDI: A Brief History," Music Rader, 2012 Accessed March 20 2020, https://www.musicradar.com/news/tech/30-years-of-midi-a-brief-history-568009.
[11] Ibid.
[12] MIDI Manufacturers Association, "MIDI History: Chapter 6," MIDI.org, 2015 Accessed May 25 2020, https://www.midi.org/articles-old/midi-history-chapter-6-midi-is-born-1980-1983.
[13] Peter Manning, *Electronic and Computer Music*, 2011, 267.

Developments

Though the original MIDI specification has been widely applied and developed extensively since its inception nearly 40 years ago, extensions were necessary to enable its spread beyond the domain of musical instruments and controllers. For example, MIDI Show Control was an extension approved by the MMA in early 1991, which aimed to provide a reliable standard upon which multimedia and theatrical systems could be developed. Integrating MIDI into the lighting and stage show with industry standards such as Qlab.[14]
Created in 1991, GM1 was a new standard created so that two sound modules could sound alike and allow cross-platform playback of MIDI files. Most importantly for this was software and early DOS video games: often in the sound settings games would allow switching to the General MIDI standard, meaning that even with different digital sound modules, the soundtrack would sound vaguely similar. GM1 allowed for 16 voices of melody/harmony and 8 voices of percussion. Roland had multiple product lines to attract the GM1 market, one of the most popular was the Sound Canvas SC-55, this was a powerhouse for Microsoft DOS games and early music production. The GM1 standard allowed later revisions of these units to improve sound quality and allow the developers of games and software to ensure that program one, was an acoustic grand piano.

MIDI currently supports 128 notes, 40 more than a standard 88 note keyboard. This was due to 128 being the nearest power of two that allowed the full range of the western standard keyboard.[15] As a result of this plugins and hardware can take advantage of these extra keys in the form of key switches. The MIDI specification also incorporates 16 channels,

[14] MIDI Manufacturers Association, *The Complete MIDI 1.0 Detailed Specification*, 3rd ed. (Los Angeles, CA: MIDI Manufacturers Association, 1996), 156, https://www.midi.org/downloads?task=callelement&format=raw&item_id=92&element=f85c494b-2b32-4109-b8c1-083cca2b7db6&method=download.
[15] Ibid, 42.

providing users with 16 different signals per chain, enabling synths and interfaces with a 'MIDI Thru' port to be chained together. The effect in the studio or live performance is a reduction in cables used, making for a more simple, effective setup. MIDI uses a rate of 31.25 Kbit/s, because it is an exact division of 1MHz, a common speed for microprocessors at the time. As a result, clocking was easier for early microchips, this allowed for greater adoption.[16]

Due to the MIDI interface being based on a serial protocol, timing issues have emerged. Because serial communication transmits and receives message by message, there were concerns that chords would not sound correct since the message to turn on the notes of the chord were not being sent simultaneously. However, the speed at which the data is received and acted upon is quicker than any professional musician would be able to discern. Thus, it sounds like two notes are being played at the same time even when they are microseconds apart. Criticisms of MIDI have focused on the fact that using MIDI thru chains means going through several optoisolators. These components were put in place to help with ground loops, meaning that noise, hum and interference were cut down.[17] However, there were concerns that with 16 MIDI systems chained together with the MIDI Thru ports, problems would occur.[18] A possible solution to this was MIDI splitting units, giving each channel its own cable. This solved the issue because each cable was now passing through one optoisolator. MIDI Choking was an issue with larger setups running through a single MIDI interface. Binary note data was easy for the interface to handle, while Continuous Controllers such as Mod/Pitch Bend Wheels were far more difficult. An analogy to explain

[16] Manning, *Electronic and Computer Music, 316*.
[17] J Byron, "MIDI: Hardware and Electronic Implementation," *Spark Fun*, n.d. Accessed May 2, 2020, https://learn.sparkfun.com/tutorials/midi-tutorial/hardware--electronic-implementation#signaling.
[18] Ibid.

this is a single lane road attempting to fit two or three cars side by side. Data is will be pushed aside and lost, or the system will slow down leading to latency and inaccuracy in time accurate playback. This presents a clear ‘bottleneck’ which could only be solved with splitting.

Musicality and Expression

MIDI is now commonplace in the home and professional studio. There are multiple ways in which it can support the communication of musical ideas into the music we hear. Sound on Sound magazine, noted hereafter as SOS, commented specifically on the state of MIDI controllers when searching for musical expression in their January 2020 issue:

> There's always been something slightly unsatisfactory about controller keyboards - even top-of-the-range models, decked out with ribbon controllers, continuous encoders, trigger pads and aftertouch sensitivity, often fail to replicate the immediate, intuitive expression available to skilled players of simple acoustic instruments like pianos or acoustic guitars.[19]

Much in the same way that an acoustic piano can be felt, or a violin can have pressure and vibrato, MIDI must also reflect these traits. These 'inflexions of the human body infuse the music with signs of life: breath, body rhythm, a sense of effort, motion, and feeling.'[20]

The MIDI Polyphonic Expression (MPE) specification was adopted as an MMA standard in early 2019, allowing once lost expressive techniques to be reintroduced to the forefront of controller development. 1977 saw the introduction of the Yamaha CS80, containing a polyphonic aftertouch key-bed providing each note of its 8 voices with their own expressive control.[21] Because the original MIDI specification in 1983 did not support poly-aftertouch or per-key expression, the polyphonic aftertouch key-beds were reserved

[19] Sound on Sound, "Osmose — Keyboard Technology Takes a Giant Leap Forward," *Sound on Sound*, January 2020, https://www.soundonsound.com/news/osmose-keyboard-technology-takes-giant-leap-forward.
[20] Roads, *The Computer Music Tutorial*, 624.
[21] Yamaha, *CS-80 Polyphonic Synthesizer: Owners Manual* (Hamamatsu, Japan, 1977).

only for the high-end keyboards and synthesisers. Recently, however, per-key aftertouch has seen a resurgence in the consumer market at a decreased price amid the arrival of MPE devices. Understanding MPE requires a comprehension of how modulation works in standard modern MIDI. All modulation, except for aftertouch, be it pitch bend or voice filter is global, meaning that the pitch bend wheel applies a bend to all notes being played. If a user possessed multiple pitch bend wheels to manage the additional notes, it would still not be possible as a consequence of the MIDI specification. Therefore,

> the traditional instrument model has disadvantages. The full power of a synthesizer may be limited by a traditional instrument in control. To exploit the full sound palette of today's synthesizers, we also need special input devices tailored to their unique capabilities.[22]

This is where MPE functions; a per-note modulation approach means that with one chord a user can open the filter on specific notes, while bending a top note slightly out of tune. MPE devices can grant a greater level of gestural expression, however, the given control and gestural opportunities were not designed for the western standard of a keyboard, as a note's tuning is no longer stationary but fluid. The form factor of a keyboard required reworking, and in 1999 the Continuum was made commercially available. Developed by Lippold Haken, this model broke the norm of how keyboards were expected to be constructed and played. With a synth engine installed in 2008,[23] the device presents a neoprene surface coloured to distinguish western tuning, without being limited to that system. The Continuum is one continuous playing surface, allowing for three dimensions of touch control. Similarly, the Linnstrument, made by Roger Linn, was released in 2014 with a

[22] Roads, *The Computer Music Tutorial*, 624.
[23] Schneiders Freunde, "Haken Continuum – New Firmware and New Features," *Stormkult*, 2017 Accessed May 11 2020, https://www.stromkult.com/haken-continuum-new-firmware-new-features/.

similar concept of using a different visual metaphor for discerning where a note is placed on the keyboard.[24] It presents a similar layout to a guitar neck, though not limited to its tuning. Despite the use of the Continuum by keyboardists such as Jordan Rudess as seen in the music of Dream Theatre since 2005, where Rudess uses the Continuum to solo using similar expressive techniques as an electric guitar[25]. The technology remained largely unadopted given both its price and the piano metaphor being the standard in music production equipment. 'From a commercial standpoint, an input device that looks like a familiar instrument probably stands a better chance in the music market place than a bizarre-looking strap-on appliance.'[26] The Roli Seaboard attempted to bridge this gap in combining modern advancements of MPE and the visual metaphor of a piano, bringing greater accessibility for contemporary piano players. Similarly, a device currently in the prototype stages is the Osmose by Expressive E, which aims to give more expansive control to a normal keyboard. It appears on the surface as a standard keyboard bed; however, it contains multiple features possessed by an MPE device. A unit of the Osmose was analysed by SOS, which emphasised that 'the notes in a chord or melody can sound radically different depending on whether each note is tapped, hit, stroked or gently depressed.'[27]

Another important feature of MIDI is its parameter control set, allowing control over sustain pedals, expression, and DAW features. When the feature set of a full console is not required (or the budget or practicality is unsuitable in the given the situation), a DAW remote or controller may be incorporated. Encompassing all major functions of a large format console but on a digital metaphorical recreation, these controllers range from single

[24] Roger Linn, "LinnStrumnet: A New Way to Play," n.d. Accessed May 25, 2020, https://www.rogerlinndesign.com/linnstrument.
[25] Dream Theatre, "The Dark Eternal Night," 2007, 7:49-8:51.
[26] Roads, *The Computer Music Tutorial*, 624.
[27] Sound on Sound, "Osmose — Keyboard Technology Takes a Giant Leap Forward."

fader tabletop units allowing for single parameter control to large format console replacements. The difference, however, is that these 'consoles' are digital and can, therefore, represent an infinite number of tracks via scrolling, enabling larger sessions to be mixed on a single fader if necessary. Since 1997, Mackie and Digidesign have developed the HUI protocol, leading to Mackie's own specialised MCU protocol. These allow for VST parameter control and implement deeper functional control of the host DAW. The popular music technology press commented on the newly announced Softube Console 1 Fader: 'For as long as software mixing has been a thing, there have been things to make it less like software mixing. A Pointing device isn't necessarily the best means of adjusting hundreds of parameters.'[28] This presents an argument that computer mice are neither appropriate nor practical in a recording studio.

Research conducted at the University of York where a virtual instrument was controlled by a joystick as opposed to the traditional keyboard interface, shows that expressive control is an important factor to consider when creating an interface. They concluded that,

> Cymatic provides the player with an increased sense of immersion, which is particularly useful when developing performance skills since it reinforces the visual and aural feedback cues and helps the player internalise models of the instrument's response to gesture.[29]

[28] Sam Inglis and Sound on Sound, "Softube Console 1 Fader," *Sound on Sound*, January 2020, https://www.soundonsound.com/reviews/softube-console-1-fader.
[29] David M. Howard and Stuart Rimell, "Real-Time Gesture-Controlled Physical Modelling Music Synthesis with Tactile Feedback," *EURASIP Journal on Applied Signal Processing*, no. 7 (2004): 1001–1006.

This explains why MIDI often feels stilted and void of human contact. The addition of gestural based controllers allows the musician to pull more expression from each instrument.

An interesting example to aid in explanation is an orchestral conductor. The University of Detmold created a system to track hand gestures displayed by a conductor: time, dynamics, and articulation were all examined. However, there was not one specific gesture which everyone displayed, at times there were overlaps in gestures potentially creating confusion for the performers, or potentially leading to a common gestural which saw fit everywhere. Timbral gestures were the hardest to convey as '[They] collected 36 suggestions (70.6%) of 27 poses and 15 suggestions (29.4%) of 12 bimanual gestures.'[30] The example of a conductor being asked to create a grand gesture with a mouse, keyboard and a pull-down menu illustrates the extent to which the mouse and keyboard are impractical in a musical environment. There is no easy way to convey, 'gradually louder and more aggressive while simultaneously speeding up' in a timely manner without gestural recognition and control.

Similarly, the gestures regularly conducted in a studio setting are difficult to reproduce with a mouse and keyboard. Specifically, fader movement is one-dimensional, while turning a knob is a rotary motion, neither translates to the mouse and keyboard (covered in the Product Design section of this investigation). This may be due to the relationships built between controls and function. The fader is a simple up and down movement, commonly relating to perceived loudness. We often visualise volume on a vertical axis; most metering and audio waveform displays follow this theme. This

[30] Axel Berndt, Simon Waloschek, and Aristotelis Hadjakos, "Hand Gestures in Music Production" (Detmold, 2016).

relationship conditioning could be why audio engineers have used the fader as a visual metaphor for volume. However, SOS suggested that with a universal standard comes limitation in adoption. Some proprietary standards are better suited for certain DAWs given the claim that 'it's almost impossible to create a generic controller that gets the best from each DAW.'[31] This is because each DAW focuses on something specific and they all have slightly different workflows. Ableton Live 9 focuses on the creation of loops for live playback, Reason focuses on sound design and studio rack emulation, and FL studio focuses on the creation of patterns to be used in a grand timeline. Eucon, for example, is AVID's version of a DAW control protocol, allowing deeper integration with the industry-standard Pro Tools.

A blossoming subset of these control interfaces are those that do not control a DAW but instead control a plugin. TC Electronics has been recreating famous units from their legacy equipment in plugin format, they operate with optional desktop controllers allowing for physical control of parameters. They have two reverb units, one digital delay and a spatial expander unit to create their product line.[32] All of these desktop controllers mirror the faceplates of the legacy equipment. An advantage of this is that a user can manage as many instances of this effect as desired in a session; users are no longer tied to a single processor, and additionally, all of the settings are recallable and stored within the VST, minimising the time lost to re-enter settings. Much like TC Electronics, Softube has also created a plugin controller, though this is a channel strip, meaning it could act as the main mixing interface as if using a large format console from a desktop.[33]

[31] Inglis and Sound on Sound, "Softube Console 1 Fader."
[32] Music Tribe, "TC Electronic," *Music Tribe*, n.d. Accessed May 25, 2020, https://www.tcelectronic.com/Categories/Tcelectronic/Computer-Audio/Desktop-Controllers/DVR250-NATIVE-DVR250-DT/p/P0DCR.
[33] Softube, "Softube: Console 1," *Softube*, n.d. Asccessed May 25, 2020, https://www.softube.com/console1.

At the time of writing, the author of this paper has owned the Softube Console 1 MKII for over 6 months. This author's background in sound did not come from a studio or production setting but from live sound, providing a background of large format mixing before using a digital mixer/DAW. The physical presence of a channel strip interface entails more efficient work as each knob functions to control a certain parameter. The default console with which Console 1 is distributed with is the SSL 4000 E, allowing for the workflow of a large format mixer despite only utilising the space of a single channel strip, and considerably less power. As a result of this, a studio's control room can be much smaller and cost less to build and maintain.

In the author's experience, this has vastly sped up the mixing process given the integration with the host DAW allowing for Volume, Pan, and send control from onboard the mixer. The company has recently released a new unit called the Console 1 Fader, a 10-fader unit designed to complement the original channel strip by giving comprehensive control over writing fader automation and deeper DAW control, including playback.[34]

[34] Inglis and Sound on Sound, "Softube Console 1 Fader."

The Future of MIDI

MIDI as a specification is now almost 40 years old, and in that time, it has become globally adopted and allowed many musicians, producers, and artists to write music. However, the MIDI specification is now showing its limitations amongst larger sized studios and live setups. MIDI 2.0 however, worked to fill this void. The research for a MIDI 2.0 specification began in 2005; the information discussed below, obtained from the MMA's website,[35] focused on three main points. these three 'B's cover the indent for this new specification: bidirectional (two-way communication), backwards compatible (allowing integration with MIDI 1.0), and 'both' (meaning that MIDI 1.0 should be extended where possible and should remain supported).

The Bidirectionality of the new standard allows for MIDI Capability Inquiry or MIDI CI, meaning the hardware at both ends of the signal are aware of each other's presence and capabilities. Three applications are possible as a result: Profile Configuration, Property Exchange and Protocol Negotiation.[36]

Profile Configuration allows common commands to be coded in the same way from developer to developer. It provides a framework upon which virtual instruments and mixing plugins can be developed, allowing the generation of universal standard MIDI layouts to work with sample libraries or emulations of older gear.[37] For example, Orchestral libraries have articulation key switches that lie beneath or above the range of that instrument, accessible with a MIDI keyboard or using the UI. This, however, is specified by the developer of the sample library, meaning that each developer has a different layout.[38] The Profile

[35] MIDI Manufacturers Association, "Details about MIDI 2.0™, MIDI-CI, Profiles and Property Exchange," 2019 Accessed March 31 2020, https://www.midi.org/articles-old/blogger/the-midi-association.
[36] Ibid.
[37] Ibid.
[38] Ibid.

Configuration in MIDI 2.0 is designed to provide the developers with a standard upon which to work. Whereas before, articulations would be different across a user's collection of sample libraries causing confusion and time wasted searching, it is now more efficient to select the articulation.[39] Another example of this is a drawbar organ where a many of its controls are similar across various plugin implementations, where a standard set of controls would aid in speed and efficiency when in use by a musician less versed in specific controls of a drawbar organ.

Property Exchange is a feature many synths have supported in the form of synchronised program changes. This can be seen in the Prophet 600's demonstration at the NAMM show in 1983, where a Prophet 600 could reprogram another Prophet 600 to reproduce an identical sound.[40] However, this brings a standard layout and full control to the synth or controller increasing compatibility and accessibility. Property Exchange allows the device to receive and transmit properties, allowing remote control. An example of this behaviour is providing the cut-off control on one synth with the ability to control the filter of another.

[39] Ibid.
[40] Jungleib, *Prophet-600 Synthesizer Operation Manual*.

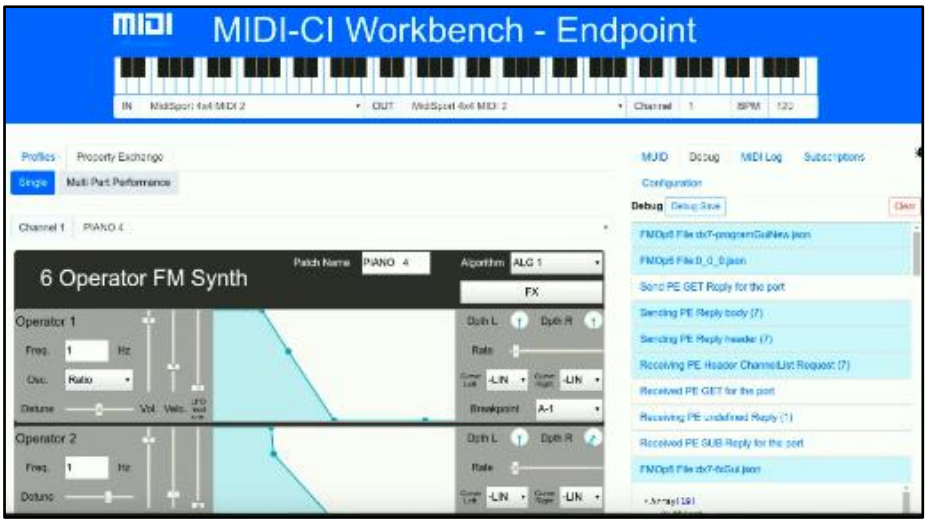

Figure 1 - A GUI generation tool [41]

There have also been attempts to create an auto-generated GUI based on what the software receives in terms of controls from the synth (Figure 1). Consequentially, this could lead to total remote control of all parameters on all analogue synths directly from a user's computer screen. A further application to this technology is accessibility for a preferred interface or users with physical disabilities. This allows total automatic mapping of a synth's features to any interface be it digital, knobs, or faders.

Protocol Negotiation allows the MIDI host to separate the older 1.0 specification from the new 2.0 specification and translates it to work across MIDI generations. If the MIDI host does not receive confirmation from the slave, then it defaults to the MIDI 1.0 specification as it is not able to send a confirmation given its one-way characteristic. This defaults the configuration to the UMP version 1.0 which utilises the new Universal MIDI Packet (Figure 2).

[41] MIDI Manufacturers Association, "Details about MIDI 2.0™, MIDI-CI, Profiles and Property Exchange."

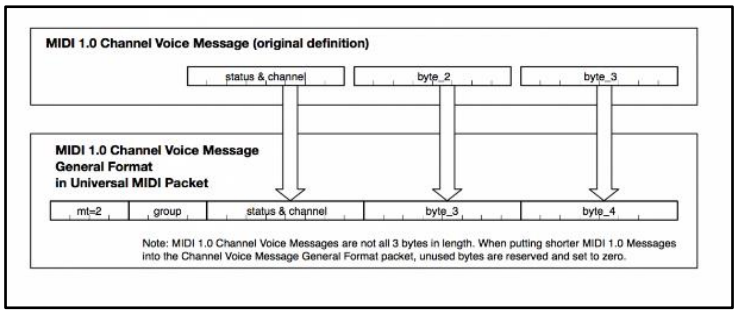

Figure 2 - Example of MIDI 2.0 -> 1.0 conversion [42]

The Universal MIDI Packet or UMP is a new layout for packets of MIDI 2.0 data to be sent. It consists of up to 4 'words' of 32-bit packets, compared to MIDI 1.0's 8-bit packets. This configures depending on the message type: the first 4 bytes are used to define what type of message is being sent (Figure 3).

MT	Packet Size	Description
0x0	32 bits	Utility Messages
0x1	32 bits	System Real Time and System Common Messages (except System Exclusive)
0x2	32 bits	MIDI 1.0 Channel Voice Messages
0x3	64 bits	Data Messages (including System Exclusive)
0x4	64 bits	MIDI 2.0 Channel Voice Messages
0x5	128 bits	Data Messages
0x6	32 bits	Reserved
0x7	32 bits	Reserved
0x8	64 bits	Reserved
0x9	64 bits	Reserved
0xA	64 bits	Reserved
0xB	96 bits	Reserved
0xC	96 bits	Reserved
0xD	128 bits	Reserved
0xE	128 bits	Reserved
0xF	128 bits	Reserved

Figure 3 – List of available message types [43]

Bandwidth on the new standard is far higher as the MMA have replaced the 5 pin MIDI connector with a primarily USB2 interface, enabling more MIDI channels to be sent. However, MIDI CI Profile Configuration and Property Exchange are capable through legacy transports such as USB 1 and 5 pin DIN.[44]

[42] Ibid.
[43] Ibid.
[44] MIDI Manufacturers Association, "MIDI 2.0 For Developers," 2020 Accessed May 23, 2020, https://www.midi.org/forum/5339-midi-2-0-for-developers-webinar-sat,-may-23rd?page=last.

MIDI channels are now sorted into groups where one group represents 16 channels in 16 groups. This totals to 256 channels of MIDI over a single bus.[45] A limitation of this is that, due to the layout of the UMP and how it interacts with the original MIDI 1.0 specification, a group must be labelled as it is in MIDI 1.0. As a result, if a user possesses only one MIDI 1.0 device, 15 channels of a total 256 channel bus will be lost.

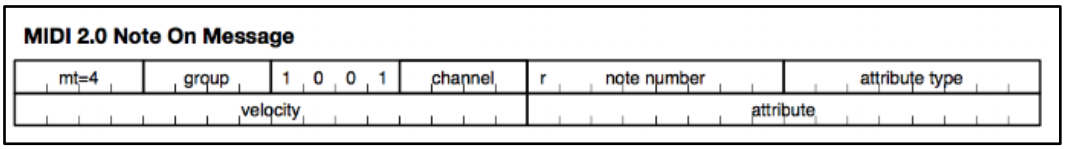

Figure 4 - Example of a standard MIDI Note On Message [46]

A typical MIDI 2.0 Channel Voice Message now appear as in Figure 4. Much like MIDI 1.0, there are only 128 notes available for use. However, the 'attribute type' could be set to '0x03' or 'fractional tuning', which allocates 9 bits or 512 fractions per note of tuning allowing for microtonal tuning, and remapping of the keyboard using the remaining 7 bits to create custom scales or inverted sequences natively. This will affect the use of scales and the breadth of styles capable in computer music; non-standard tunings such as Gamelan will now be possible natively. Due to each developer owning a unique developer ID it leads to the ability for developers to create their own attribute language, examples put forth in a talk on the integration of MIDI 2.0 to the VST3 format was articulation.

> If you use articulation as the Attribute, you could have a higher-res controller where the very front of your key is pizzicato [in a string library], and as you move towards the back of the key you change the articulation[47].

[45] MIDI Manufacturers Association, "Details about MIDI 2.0™, MIDI-CI, Profiles and Property Exchange."
[46] Ibid.
[47] JUCE, *Panel: Support of MIDI2 and MIDI-CI in VST3 Instruments* (YouTube Video, 2019), https://www.youtube.com/watch?v=zXnHaoN2Cig&feature=emb_logo.

Additionally, the velocity increments have more than doubled. Now using 16 bits, there are 65,536 levels of velocity, far exceeding the 128 values in the MIDI 1.0. Though this seems excessive for an application such as the strike of a piano key, these small increments will be useful in constant notes with varying velocity allowing for smoother transitions from soft to hard. Though this is beneficial for the consumer, it is possibly detrimental to the developers who now have to support greater pressure increments in their sample libraries.

Per-note control specifications such as the MIDI Polyphonic Expression or MPE are now natively included in MIDI 2.0. In the 'Registered Per-Note Controller #3 (Pitch 7.25)' (Figure 5) packet there are 25bits dedicated to fractional pitch across the keyboard. Though this seems to serve a similar purpose to the Note On Message this message relates to changing pitch as opposed to initial. Meaning that on a standard 88 note keyboard there are ~381,300 points of pitch between each note, granting the ability for higher resolution slides and bent notes. This is beneficial for players of instruments where bending a note is expressive, as in guitar solos. These notes are not stored in the standard 'note number' section but instead as an 'index', which removes its entry once the note is turned off. This means it is possible to have multiples of the same note with independent fractions of a given pitch. The 'index' is an 8-bit value, theoretically able to play 256 of the same note simultaneously. In this instance, each with independent micro pitch shifts, allowing the possibility for lush super-saw like textures. Notably, there are no MIDI controllers able to make practical use of this. However, in a DAW setting, this may be used as a composition tool.

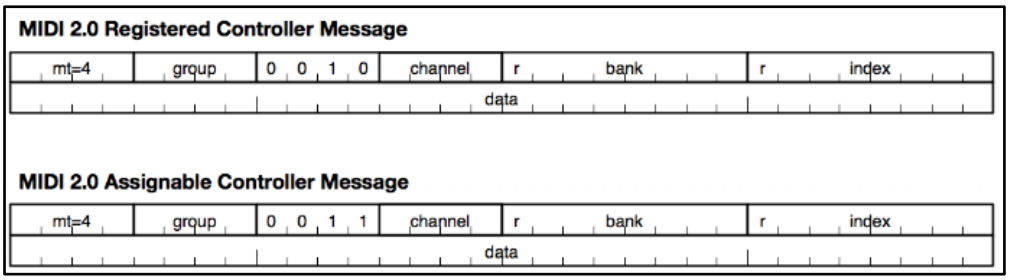

Figure 5 - Layout of control messages sent by MIDI 2.0 [48]

MIDI CC are now given 32bit resolution for Registered Control Messages instead of two 7bit most/least significant bits. They are now counted as a 'Registered Controller Message' (RCM) which will be specified by the MMA for developers to use, and an 'Assignable Controller Message' (ACM) which are for the user to define. In Figure 5, the layout of how the future of CC becomes RCM & ACM is made visible. These are laid out in 7-bit (128) banks, each with a 7-bit (128) index translating to 16,384 control points for each, registered and assignable. These registered CCs could be set to standard controls of a synth such as OSC_A_Pitch or FILTER_A_CUTOFF, thus, creating an industry standard for labelling each control. In turn, this works with property exchange to allow the easier integration of synths, hardware, and software into a MIDI system.

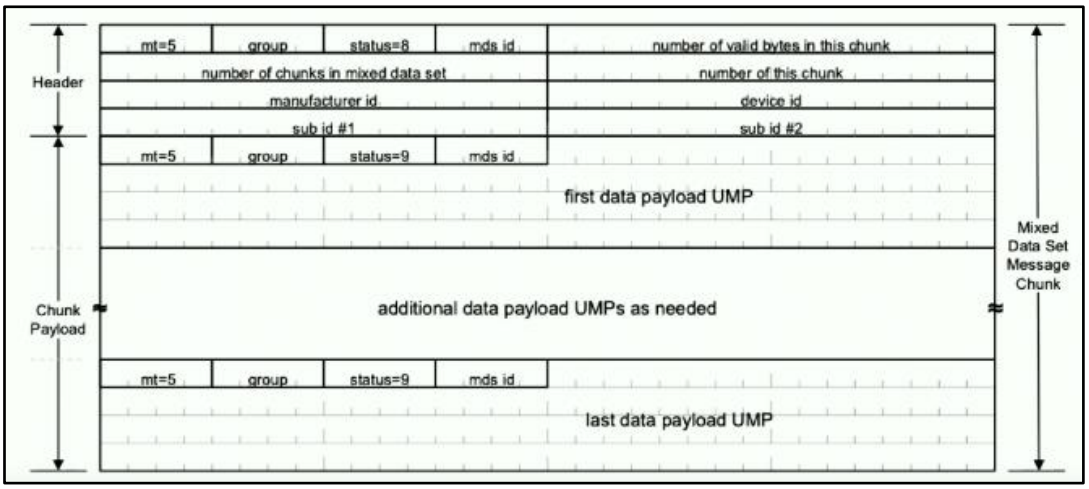

Figure 6 - Layout of SysEx messages in MIDI 2.0 [49]

[48] MIDI Manufacturers Association, "Details about MIDI 2.0™, MIDI-CI, Profiles and Property Exchange."
[49] Ibid.

The last component to the MIDI 2.0 specification improvement is the fact that System Exclusive messages are formatted in such a way that they use a full 128-bit packet (Figure 6). However, if more data is required, 128-bit packets can be sent following the SysEx message containing the data payload, creating a sandwich-style layout requiring only the beginning and the end message, with the payload making up the contents. File speed constraints of MIDI 1.0, in turn, are mitigated, and newer formats and larger files are capable of being transferred. It was discussed that even formats not recognised by MIDI, (such as photos) are capable of being sent through this formatting layout. MIDI 1.0 was capable of this style of System Exclusive Message in the form of the Sample Dump Standard (SDS) since 1986, allowing the transfer of samples from a host to its slave.

MIDI 2.0 Integration

Integration of MIDI 2.0 into DAWs is up to the developers, the endpoint given that the MIDI 2.0 message can be sent back could be the 'track' or, an 'instrument'. It is determined by the profile and controls established by the developer at the time. MIDI 2.0 has the ability to adjust according to the situation as required.

Plugins such as Audio Units (AUs) and Virtual Studio Technologies (VSTs) are an important part of the everyday workings of a studio. VST3 was released in 2008 to scepticism, as it appeared as an upgrade without utility for many users, while VST 2.4 was still notably capable for many. VST3 as a standard is already prepared for MIDI 2.0. It includes improved preset management due to MIDI-CI allowing the transition of data both ways, custom GUIs based off of parameter exchange, and better support for protocols such as HUI, MCU & EuCon. In addition to this, VST already contains standard mappings for CCs, Notes, and Articulation or Key Switches. Orchestral libraries such as Spitfire Audio Chamber Strings are now capable of taking multiple MIDI inputs for the separate articulations of a certain instrument, negating the need for key switches.[50] These are all features that will be improved with the development and improvements made to MIDI 2.0.

[50] Spitfire Audio, *Spitfire Chamber Strings User Manual* (Spitfire Audio, 2018).

Notable Additions - MIDI.org Webinars

These additions are from live webinars hosted by the MMA, they may not be published at time of submission, the recordings of these webinars will be published to MIDI.org, however, at time of writing there is no ETA. The author has an unedited screen capture from the webinar available upon request.

Some notable additions have been published since first starting this investigation, the official specification documents have been available since the 20th of February 2020 [51]. In webinars hosted by the MMA on the 23rd and 30th of May 2020, several developers of MIDI were present to answer questions regarding the state of MIDI 2.0 development.[52]

A topic that was discussed during the webinar was how Property Exchange affects people outside of a DAW or Music setting, specifically relating to configuration tools for peripherals. With MIDI CI, each device can now draw its own controller and configuration automatically, meaning that there is a single application which can configure several devices all from different manufacturers. This negates the need for developers to supply bespoke software, easing the work on developers and benefiting the user as they no longer need an individual program for each peripheral device.

Small business owners such as John Kimble of Social Entropy posed the question if 'supporting MIDI 2.0 makes sense for a small manufacturer of hardware-only devices (sequencers) - or if MIDI 2.0 will make the most sense for use cases which use a PC as "the

[51] MIDI Manufacturers Association, *MIDI 2.0 Specification Overview*, 1st ed. (Association of Musical Electronics Industry, MIDI Manufacturers Association, 2020).
[52] MIDI Manufacturers Association, "MIDI 2.0 For Developers."

brain"'[53] This question was answered with Figure 7, displaying the different types of MIDI 2.0 support a developer could use.

Device Description	MIDI 1.0 Device	MIDI 2.0 Device on Legacy Transports	MIDI 2.0 Device with Universal MIDI Packet	MIDI 2.0 Device with Universal MIDI Packet & High Res Messages
Message Types Supported		MIDI-CI Profile Configuration	MIDI-CI Profile Configuration	MIDI-CI Profile Configuration
		MIDI-CI Property Exchange	MIDI-CI Property Exchange	MIDI-CI Property Exchange
			MIDI-CI Protocol Negotiation	MIDI-CI Protocol Negotiation
			UMP Message Type 0: Utility (Timestamps)	UMP Message Type 0: Utility (Timestamps)
	System Messages	System Messages	UMP Message Type 1: System Messages	UMP Message Type 1: System Messages
	MIDI 1.0 Channel Voice Messages	MIDI 1.0 Channel Voice Messages	UMP Message Type 2: MIDI 1.0 Channel Voice Messages	
	SysEx	SysEx	UMP Message Type 3: Data Messages: SysEx	UMP Message Type 3: Data Messages: SysEx
				UMP Message Type 4: MIDI 2.0 Channel Voice Messages
			UMP Message Type 5: Data Messages (SysEx8, MDS)	UMP Message Type 5: Data Messages (SysEx8, MDS)
Data Format	Byte Stream	Byte Stream	Universal MIDI Packet	Universal MIDI Packet
Transports	5pinDIN	5pinDIN		
	USB MIDI	USB MIDI	USB MIDI 2	USB MIDI 2
	BLE MIDI	BLE MIDI	TBD	TBD
	RTP MIDI	RTP MIDI	TBD	TBD

Figure 7 - A table detailing the support for developers creating[54]

Athan, the moderator for the webinar and the Digital Marketing Strategy Manager at Yamaha answered questions regarding microtonality and the room for expression of absolute pitch. 'Note number for 12-EDO and tuning data for 19-EDO would be enough to disambiguate enharmonic equivalents, MIDI 2.0 protocol has various ways to express absolute pitch with up to 33 million steps between notes.'[55] In addition to this Craig Anderton spoke regarding the new attribute function for each MIDI Note On message and how he will utilise it.

> I have a Linnstrument and a ROLI seaboard, so I am familiar with how great it is to move sideways, back and forth and press to get different articulations and I've be spending a fair amount of time

[53] Ibid.
[54] Ibid.
[55] Ibid.

> going back and programming synthesiser patches to respond to those controls, it really makes a huge difference I can only imagine what is going to happen in the future.[56]

Mike Kent of MK2 Image reinforced this opinion,

> It's a great thing when you see somebody who is a master at their instrument play something like a ROLI seaboard and how expressive that is, and I think MIDI 2.0 is well suited to encourage those kinds of new expression capabilities in electronic instruments.[57]

Considering that at the time of writing, MIDI is 37 years old, the author posed the question as to the longevity of MIDI 2.0. Mike Kent stated that, 'MIDI 1.0 is 37 years old. We joke, but are somewhat serious that we expect MIDI 2.0 to carry us for another 37 years. But the UMP has room for a MIDI 3.0 as well.'[58] This directs us to think that the precautions the MMA has taken in making a protocol which we see as excessive may simply be futureproofing the specification.

On a similar topic, the rise in resolution of continuous controllers was questioned. The webinar host's all explained various points of view as to where these could be an advantage. DAW's and Plugins support a higher resolution on controls that MIDI 1.0 can offer[59], a video posted by the MMA demonstrations the advantage of higher resolution for use in fader units or DAW controllers.[60]

[56] MIDI Manufacturers Association, "MIDI 2.0 For Musicians."
[57] Ibid.
[58] Ibid.
[59] Ibid.
[60] MIDI Manufacturers Association, *MIDI 2.0 Fader Demo* (Youtube Video, 2020), https://www.youtube.com/watch?v=bkbqFNZcSQk.

Product Design

ADC 2019

Skeuomorphism and UI design concepts were featured heavily during a panel on product design at the Audio Developer's Conference in 2019. Chris Randall (Audio Damage), Matt Jackson (Ableton), Mino Kodama (Native Instruments), and Nick Dika (Sound Toys), represented different opinions and backgrounds within the product design industry. Though of note is that the panellists' experience was not limited to the audio industry.[61]

On the first prompt, they note that before the musician or engineer hears the DSP engine, through social media, advertising, or website, they first see it, which is why GUI design is crucial. A major function of product design teams is to transport the user to the listening stage; Chris Randell reinforced this claiming that 'The DSP has to sell the product, but we have to get them there to listen to it'. Though this relates to the sales of a product, it is important to understand the impact of creating an 'attractive' interface as opposed to an 'intuitive' one. Another significant view to consider is user expectation when investing in software that looks like a specific brand. In an email to the author on the 24th November 2019 Arthur Carabott, a User Experience Engineer at Output, mentioned that some companies are built on the model of 'have this classic piece of equipment for a fraction of the price', however, he also made the point that this type of practice is not sustainable as 'there are only so many old bits of hardware to emulate'.[62]

Mino Kodama from Native Instruments raised an important point regarding the synergy between developing hardware and software simultaneously. Native Instruments

[61] JUCE, *Panel: Product Deisgn* (YouTube Video, 2019), https://www.youtube.com/watch?v=WsWyIYGX4tM&t=31s.
[62] Arthur Carabott, "Email," 2019.

offer a range of plugins and hardware, ranging from composition tools and DAWs (such as 'Maschine' with the accompanying hardware) to mixing plugins such as their 'VC 160', 'VC 2A' and 'VC 76' emulating the 'dbx 160', 'LA-2A' and '1176' respectively.[63] This is informed by the visual design closely representing the classic equipment (covered later in this paper). Native Instruments also produces a range of performance controllers, from DJ gear to full-sized keyboards. The principal system this technology runs is Native Kontrol Standard (NKS). Integration of the software and hardware allows for a deeper level of interaction between the artist/producer and the virtual instrument that they are playing. For example, the Kontrol S line of keyboards features 2 LCDs and 8 encoder controls, which links to the Komplete Kontrol software, allow the artist to quickly audition and manipulate sounds with the physical encoder controls. These knobs are dictated according to the controls that the manufacturer believes best applies to that instrument. Sketching ideas, therefore, requires less movement and less 'menu diving' to refine the sounds. All of the base level relevant controls are presented on real, tactile controls, in turn saving time in writing automation, auditioning sounds, and sketching out ideas. It also aids in developing ideas quickly since thousands of sounds are accessible directly from a keyboard, as opposed to using a mouse and keyboard inside of a DAW. Mino Kodama states that 'I think the very special thing about native instruments is that we have software, hardware system so that controllers only run with the software'.[64] However, this use of proprietary software limits the usage of this system to users with the budget to purchase both hardware and software. In addition to this, the life cycle of a plugin and hardware are drastically different; Chris Randell states

[63] Native Instruments, "Native Insturments Vintage Compressors," n.d. Accessed May 22, 2020, https://www.native-instruments.com/en/products/komplete/effects/vintage-compressors/.
[64] JUCE, *Panel: Product Deisgn*.

that, 'you can iterate software code until the shipping date'[65], and even beyond that point with updates.[66] However, hardware requires '18-20 months' from sketch to shipping. This means that any functionality changes require a firmware or software update as nothing can be changed physically without a second product version.

Matt Jackson noted that this product timeline was present when Ableton brought out the Ableton Push hardware controller, along with the 9.0 software update to Ableton Live.[67] This controller allowed many of the main DAW functions to the extent that people were able to write, produce, and mix a full song without looking at the screen. It presented itself as a controller that enabled total control of the Ableton Live software. However, despite its many advancements, there were notable missing features at launch. This was cornered by Native Instruments with their MK2 Maschine controller, a full pixel-based screen compared to the Push with a segment display. As a result, the Maschine was able to manipulate samples with a waveform display allowing for greater versatility, while the Push was unable to do so. It was also able to function well with third-party plugin parameter control, whereas the Push struggled to optimise this workflow. A central discussion during the panel was how Push and Maschine were developed. Ableton Push was to be brought out after eight revisions to the Ableton Live software, in contrast to Maschine which was developed alongside the first revision of the hardware. The Ableton Push also had functionality that was innovated in conjunction with Akai with the APC40 since Ableton Live 6.[68] The APC40 presented the user with a physical version of Ableton's clip view, allowing

[65] Ibid.
[66] Ibid.
[67] Music Rader, "Ableton Push Review," Music Rader, 2013 Accessed May 25 2020, https://www.musicradar.com/reviews/tech/ableton-push-571894.
[68] Ableton, "Creating Your Own Control Surface Script," n.d. Accessed May 12, 2020, https://help.ableton.com/hc/en-us/articles/206240184-Creating-your-own-Control-Surface-script.

the ability to trigger clips from the faceplate of the unit[69], a feature that the Push developed further. Despite both serving the same purpose as a DAW controller/beat machine, in the author's experience, the Push performs better as a total DAW and mix controller due to the full 8 channel simultaneous control. Additionally, the Push had 64 pads, oppose to the Maschine's 16, allowing for larger scales to be played and recorded. For sample manipulation, however, the tools available to the Maschine MK2 make it a superior choice, due to the heritage of the Akai MPC line serving as the main inspiration for the Maschine. The unit's higher-resolution screen allowed waveforms to be displayed, leading to better workflow when sampling and remixing. This conclusion was drawn after extensive time using both the controllers and software. The Ableton Push 2 could bring the Push name controllers up to the standard established by the Maschine; With a full-colour screen, it allowed for a whole new GUI to be developed. Several new challenges emerged as the original was developed by the Ableton team but manufactured by Akai, differing from the Push 2 which was manufactured by Ableton themselves.[70]

Creating a GUI for a product with physical controls and a screen presents evident challenges. It must be decided how to display values when a skeuomorphic display does not make sense. This is due to having those same interactive qualities directly in front of the user in the form of a real knob or fader. Matt Jackson commented that 'controls that are derived from physical controls - knobs are a really weird pattern for software, but it is something that musicians have this knowledge of and history of using.'[71]

[69] Akai, "Ableton Live Performance Controller APC40," n.d. Accessed May 12, 2020, https://www.akaipro.com/apc40.
[70] JUCE, *Panel: Product Deisgn*.
[71] Ibid.

A resulting argument emerges for using control knobs in a digital realm. The physical action of turning a knob requires a sensation of touch and depth, the power to pinch, and then the articulation to twist. This presents a difficult action to simulate when using a mouse and keyboard as neither controller feature rotational axis tracking and pinch sensors. In the author's experience there are three different approaches when recreating a 'knob' based control in a GUI: making a node at the edge of an encoder and using that as a pivot point, a single axis to model using a knob, and simply replacing this with a more familiar type of interaction, such as a slider/fader. FabFilter appears to have created some of the most popular plugins for their simple, efficient, and intuitive design. FabFilter offers four methods of interaction: at the edge of the knob the user can apply the turn method with a node offering a pivot point, and at the centre, it can be controlled through the vertical axis. Additionally, it can be controlled by the mouse wheel or a value can simply be typed if double-clicked.[72]

[72] FabFilter, *FabFilter Pro-Q 3 User Manual* (FabFilter, 2018), https://www.fabfilter.com/help/ffproq3-manual.pdf.

Skeuomorphism

One of the major arguments brought up at the ADC 2019 panel was skeuomorphism versus a minimalist or flat design.[73] This refers to a discussion that questions the attitude towards gear and potentially common studio practices when using it. Skeuomorphism describes a concept in which graphic user interfaces (GUIs) try to emulate or recreate their real-world counterpart, in effect creating a digital metaphor.[74] This was prevalent during the early age of GUIs when the Xerox Alto/PARC was the first computer derived from a GUI Operating System.[75] In 1970, the product showed simple boxes emulating windows and toolbars, many concepts more familiar today. This created the metaphor of a Desktop. However, the first real GUI that informed the future of GUIs was Smalltalk, a programming language built for the Alto, developed in 1974.[76] This was the first time that a window was represented, allowing for true multitasking. The concepts of a click and drag action were also introduced by the advent of scroll bars. Due to the Palo Alto Research Centre using a modified version of Englebart's mouse, there was no scroll wheel and, thus, the click and drag action was first implemented.[77] The first commercially available GUI computer in 1981 was the Xerox Star 8010, a stripped back version of the Alto II.[78]

Nick Dika from Sound Toys expressed that, because of the nature of the VSTs that 'Sound Toys' make (emulations of vintage gear), it is important to maintain a similar look when using a digital recreation of this equipment.[79] Dika claimed that skeuomorphism is

[73] JUCE, *Panel: Product Deisgn*.
[74] Sam Judah, "What Is Skeuomorphism," *BBC News Magazine*, June 2013, https://www.bbc.co.uk/news/magazine-22840833.
[75] Jeremy Reimer, "A History of the GUI," *Ars Technica*, 2005 Accessed April 9 2020, https://arstechnica.com/features/2005/05/gui/.
[76] Ibid.
[77] Ibid.
[78] Ibid.
[79] JUCE, *Panel: Product Deisgn*.

relevant with a modelled product like the Little Plate, explaining that it is an emulation of the EMT140 with a few extra features.[80]

'When you're working on a product like that, that has a heritage to it. It almost is selling it short to flatten it out - one thing with the whole going flat thing that it has kind of been a step back is being able to quickly identify controls - Sound toys stuff is rendered at a very parallel perspective (Orthographic).'[81]

The orthographic perspective relates to representing a three-dimensional object in two dimensions. This is done by flattening the image while retaining the visual design and information. In the author's opinion, this combines the best of both approaches, as developers can communicate use, technique, and expected sound while still retaining the easy distinction of a 'flattened' interface. The orthographic design concept presents without shadows or needless metaphors for creating a three-dimensional looking object. This is due to its acknowledgement that the medium through which it passes is two-dimensional.[82] Another disadvantage of skeuomorphism is an art director is necessary to design the interface with all its realistic characteristics such as scratches, screws and surface imperfections. These could delay the product from being released quicker, or mean that resources are diverted from the DSP to the art team making the quality of the DSP of the product questionable. This presents a delicate balancing act between intriguing a potential customer with design and ensuring that the DSP meets a suitable standard for a market product.

[80] Soundtoys, "Sound Toys: Little Plate," n.d. Accessed May 26, 2020, https://www.soundtoys.com/product/little-plate/.
[81] JUCE, *Panel: Product Deisgn*.
[82] Patrick Maynard, *Drawing Distinctions: The Varieties of Graphic Expression* (Ithaca: Cornell University Press, 2005), 23.

One of the notable controversies which Matt Jackson highlighted was the addition of a VU meter into the 'Glue Compressor' in the native Ableton Live 9 Plugins.[83] Primarily, this was due to the GUI design of Ableton adhering to a flat design.[84] All of their plugins offer a very simplistic and intuitive interface which tries to avoid the skeuomorphic design philosophy. However, when developing the Master Bus Compressor, they aimed to provide the sound of an SSL Master Bus Compressor also known as the Glue Compressor. The name 'Glue' originates from the purpose the compression, used to sum of all the tracks and compress in a gentle manner. The compression didn't hit hard but was applied gently, providing the final touches to 'gel' or 'glue' the sound together. The plugin which Ableton was creating was certainly inspired by the SSL Master Bus compressor, this is evident by the main controls being the 'Threshold' and 'Makeup'. However, this is very common on many VCA based compressors. The Ratio selection indicates that the SSL G Bus Compressor served as the stimulus. Users have the ability to switch between a 2:1, 4:1 & 10:1 ratio, the same as the original SSL G Bus Compressor first seen on the B Series consoles. In short, if the controls on the plugin mirror that of a particular well-known analogue product, it will likely operate in a similar manner. 'With glue, what really worked was that in the context of Live is the most conservative of all DAW UIs, this little hint of anachronism was just so perfect with the VU meter.'[85] Controversy emerged as it was the first FX unit without continuous knobs but switched knobs and a VU meter, as they were aiming for the impression of using the SSL Bus Compressor which used similar monitoring technologies.

In this author's experience, it has been found that when using digital recreations of vintage gear, a workflow emerges that is similar to using the real gear. This may be due to

[83] JUCE, *Panel: Product Deisgn*.
[84] Ableton, "Ableton Live" (Berlin: Ableton, 2013), https://www.ableton.com/en/live/.
[85] JUCE, *Panel: Product Deisgn*.

the author's unique opportunities to use both the real equipment and many different digital versions. This calls into question the nature of the industry at the centre of this discussion. Rarely do other industries within the Creative Media umbrella aim for nostalgia when developing computer programs; visual effects studios tend not use tools to create CGI that were 'photoreal' in the early 1990s. While the plugin market suggests that the audio industry has a notable group referring back to the methods by which records were produced decades ago. This illustrates how nostalgic this industry is as many techniques used during the 1980s have shaped many records today.

A response to this argument is colour grading and 'ageing' of digital video with the intent of giving a 'vintage' tone to a setting or character. Linus Sandgren, Director of Photography for *La La Land* (2016), used CinemaScope55 when shooting the film, a format that was used in the 1950s.[86] Due to the setting and tone of the film, Damien Chazelle wanted to give the film a 'vintage' and 'timeless' appearance to the film similar to many musicals released in the 1950s such as Singing in the Rain (1952) and Guys and Dolls (1955).[87]

In the author's experience, when using an 1176 style compressor, the initial selection is a 6:1 compression ratio when on vocals. In this same way, the GUI design can inform the user how this plugin is supposed to operate and sound. One main reason behind using digitally modelled gear is to reproduce the sound and a similar workflow of that unit. However, confusion is evident in the case of the 1176 as the attack and release knobs work opposite to the conventional directions.[88] Due to this confusion, many plugin developers

[86] Forbes, "What Technology Was Used To Make 'La La Land' So Visually Rich And Colorful?," *Forbes*, 2017, https://www.forbes.com/sites/quora/2017/03/03/what-technology-was-used-to-make-la-la-land-so-visually-rich-and-colorful/#5bcfdf4e3b58.
[87] Ibid.
[88] Universal Audio Inc., *Model 1176LN Solid-State Limiting Amplifier User Manual* (Universal Audio Inc., 2009).

have reversed this, making it similar to the functioning of most modern DAWs.[89] This has caused a small disconnect and raises the discussion of if emulated vintage technology should still be iterated upon, or if users should challenge the developers when improvements to workflow sacrifice authenticity.

A counter in the favour of skeuomorphism that Youtuber 'Tantacrul' brings up with reference to Propellerhead's Reason, is that knobs are an inherently intuitive. For software that has a range of bounds and zero points it communicates the extent to which a parameter is controllable.[90] A frequency cut-off grows exponentially as you turn it up. If this were to be represented by a simple text box with a number, beginners would have no concept as to how far the filter has been opened and where its range lies. Mistakes such as, expecting a change of 50hz to 100hz to sound the same as 18,000hz to 18,050hz would be made without the implementation of an exponential curve. However, provide users with a fader/knob and the process becomes more intuitive. This means that by changing the display you are able to gain or lose information. A lot of software relies on MIDI for its values, a control such as Pan for a channel can have both a positive and negative value displayed on screen. This is due to the parameter controlling the amount of signal being sent to each ear. Often this Pan control has its zero point in the middle with positive and negative values either side of it, with the zero point in the middle or to either extremes. This is very difficult to represent with a number and could be confusing for beginners.[91]

An interesting observation made during the ADC 2019 talk, was that the nostalgic viewpoint appears to be affecting software only from the audio discipline within the

[89] Native Instruments, "Native Insturments Vintage Compressors," n.d. Accessed May 31 2020.
[90] Tantacrul, *Music Software & Interface Design: Propellerhead's Reason* (Youtube Video, 2018), https://www.youtube.com/watch?v=7PFRyONURSo.
[91] Ibid.

umbrella of Creative Media.[92] In other areas such as Visual Effects, though the tools are named Brush or Razor, the options for these and the icons are rarely skeuomorphic. Similarly, in the author's experience using Adobe AfterEffects and Premiere Pro, along with Blender and Cinema4D, none of these applications utilise a skeuomorphic design in the same way. All of the settings for a native and third-party plugins are often simple sliders or rotary encoders. This, however, could be because they often work within a visual medium where feedback is given instantly in a preview window, it could also be because Visual Effects was a physical process as opposed to a single unit or piece of circuitry before computers were commonplace. Rotoscoping and Compositing were processes completed physically, such as cutting a reel of tape, and not done through a rackmount piece of gear. However, an argument against this is the presentation of a timeline in video editing software. Inside each clip on a given timeline there are previews of the start frame to give information to the editor, a feature of film that was used extensively. If zoomed in far enough you are able to view each individual frame, much in the same way as cutting film.

Another counter argument to this is the area of digital art, in which pens and drawing surfaces are popular. These are emulations of the real tools, allowing a user to grasp a metaphorical paint brush or pencil to draw on a digital screen. Attempting to do these actions with a mouse may seem irregular. A normal mouse is simply not capable of transmitting pressure and precise tilt and angle of a pencil or paint brush, demonstrating that the act of creating art digitally using a control surface is easier when using a drawing surface. This is because the user interacts with the surface in a similar manner that they would with the real object. Skeuomorphism relates to the GUI that is used, not a physical

[92] JUCE, *Panel: Product Deisgn*.

item emulating a tactile experience, which in turn introduces the market of control surfaces in music production.

Control Surfaces

Mixing as a Performance

This section of the investigation examines the impact of a control surface on common studio practices, specifically evaluating different aspects and approaches to justifying and quantifying the effect of these controllers.

The reimplementation of faders into the modern studio with DAW remotes/controllers brings into question its effect on the mixing process. The term 'mixing as a performance' is often discussed and debated. Before advancements in volume automation, mix engineers were frequently required to manually change levels, or 'ride the fader' while printing to a master 2-Track tape machine, thus the term, performance.[93] Tony Swain held that 'One thing that [he] used to do a lot and some people didn't was riding the reverberation on vocals – at the end of the lines [he would] quickly turn it up and by doing that you're keeping it alive.'[94]

Research conducted at Griffith University undertaken by Brendan Anthony states that 'With particular reference to mixing, practitioners of today are faced with a reality where the recording studio can be replicated in a virtual world; tactile devices such as faders and pots can now be replaced by a mouse.'[95]

Anthony surveyed professional practitioners from a variety of levels within the industry to examine how they include a control surface into their workflow. The participants ranged from five to 40 years of experience; they were first asked about their attitude

[93] Jez Wells, "Interview With Tony Swain," *Art of Record Production*, no. 09 (2015), https://www.arpjournal.com/asarpwp/tony-swain/.
[94] Ibid.
[95] Brendan Anthony, "Mixing as a Performance: Educating Tertiary Students in the Art of Playing Audio Equipment Whilst Mixing Popular Music," *Journal of Music, Technology and Education* 11 (2018), 104-108.

towards the term ‘mixing as a performance’. One participant mentioned that using a control surface allowed them to connect with the music better as the physical motion of ‘using the faders or rotary knobs to balance or automate a mix’[96] worked to justify the term performance. Conversely, another stated that working in the box with plugins in the DAW was far less ‘poetic’[97] as the participant did not as strongly connect with the music. In addition to this, it also offers convenience, as one participant shared their experience, ‘[I use] Pro Tools with an SSL Control surface as it gives me both tactile faders/Pan pots, along with all the benefits of a DAW and plugins.’[98] A counter argument from another was that by the time that large format consoles were fitted with automation systems of their own, the idea of a ‘performance’ had already died.[99] This suggests that the records made at that time did not require any automation or that a flat mix, using compression to control dynamic range, was preferred.

An important distinction is that an industry which still regularly uses this sort of ‘mixing as a performance’ approach is the live sound world. In the author’s experience, Musical Theatre mixing is one of the most difficult mixing processes, not only because the pressure of failure is much higher during a live performance, but largely because of the process of Line by Line Digitally Controlled Amplifier (DCA) mixing. In the live setting, two or three engineers regularly collaborate to make a performance happen. While the Sound Designer is often directed to make the performance sound pleasing, the Sound Operator deals with ‘riding the faders’ for the characters on stage.[100] DCA mixing is a workflow in

[96] Ibid.
[97] Ibid.
[98] Ibid.
[99] Ibid.
[100] Avid, *Soud Deisgn for Bat Out of Hell The Musical with Gareth Owen: S6L Workflow & Layouts* (Youtube Video, 2017), https://www.youtube.com/watch?v=25-tUKYqcY0&t=177s.

which the desk is programmed with cues to work alongside the script. In turn, on a bank of eight faders, the Sound Operator would know that their main character will always be in the same place and they can group other 'ensemble' actors to be controlled with a single fader. The Sound Operator will raise the fader when a character is speaking and lower it once they are done. This requires muscle memory for the location of the actors on their fader bank, knowledge of the script to follow and know inflection and character, and musical knowledge to follow scores when singing. In addition to this is setup, knowledge of gain staging a prepping each channel, such that when all DCAs are at unity, the cast will sound homogenous and one person doesn't overshadow the rest. For certain parts they will need a level rise or cut depending on the words spoken or inflection used by the actor. This has led to colloquial terms such as a 'bump'; when an actor has a big moment or the climax in a song, the Sound Operator will 'bump' up their volume two or three dB to give the lines more impact. Another example of this sort of control is controlling effects by the sound designer. When this author was Production Sound Manager and Sound Designer of 'Chicago' with the 'Central Hall Musical Society' (CHMS) at the University of York, it provided insight into the roles and common practices within this industry. The directors wished the phrase "not guilty" in the 'Hungarian Disappearing Act' scene to provoke greater emotion. The character of 'Hunyak' is sentenced to be hanged by the neck, and for this scene she repeats the phrase "not guilty". The directors wanted the stage to fade to black with her phrase becoming an echo, signifying that her life had come to an end, which was achieved by the sound designer changing the parameter while the scene unfolded. These are two cases where manual control and a 'performance' was utilised by both the Sound Operator and Sound Designer. In order to elicit a more emotional performance the sound team themselves had to 'act' or 'perform'.

A feature provided by many control surfaces are endless encoders to allow control of several functions from one knob depending on selection. This presents a problem relating to visual feedback of the value of the parameter. Some surfaces with screens such as digital mixing consoles, choose to display this on screen with a skeuomorphic representation, while other control surfaces without screens choose an LED array surrounding the knob. This allows the user to view where the virtual knob is currently positioned and give visual feedback when changing parameters. Faders is another area where visual feedback is important; in a project with more than eight channels most controllers make use of fader banks. Features such as motorised faders allow the position to be changed when scrolling through tracks, making it easier to identify them. Products like the Steinberg CMC series have opted for a ribbon strip in place of a fader with an LED array providing visual feedback of fader position.[101] Finally, when providing visual feedback for DAW features it is important for the producer to know the selected track. Some controllers such as the Behringer X-Touch and Presonus Fader Port use scribble strips allowing display of track name, perimeter values and other messages.[102] Others, such as the Console One have an application which runs on top of a user's DAW allowing the computer screen to be used.[103]

The survey further explores how the professionals felt about connecting on an emotional level while mixing, and how this was impacted by the presence of a controller. Though this is not a numerically measurable response it is crucial to the creative process of

[101] Steinberg, "Steinberg: CMC-FD," n.d. Accessed May 22, 2020, https://www.steinberg.net/en/products/audio_interfaces/cmc_series/models/cmc_fd.html.
[102] Behringer, "Behringer: X-Touch," *Music Tribe*, n.d. Accessed May 19, 2020, https://www.behringer.com/Categories/Behringer/Computer-Audio/Desktop-Controllers/X-TOUCH/p/P0B1X#googtrans(en%7Cen).
[103] Inglis and Sound on Sound, "Softube Console 1 Fader."

mixing. One participant mentioned that 'I want the mix to affect me emotionally and I think the sonic refinements I make are made with the express aim of getting to where I need to emotionally be'[104]

Opinions on control surfaces and the argument of 'performance' in the studio remain debatable. However, quantitative data is crucial to discovering the visibility of the impact, or if personal taste remains key in determining how an engineer's mix system functions.

[104] Anthony, "Mixing as a Performance: Educating Tertiary Students in the Art of Playing Audio Equipment Whilst Mixing Popular Music."

Suggested Experiment

This experiment was planned however, not run. Instead it is put forward as a suggestion for research to be conducted.

Many methodologies for gathering quantitative data utilise an experiment. For this investigation, such an approach was proposed and intended to be carried out. However, given the effect of the COVID-19 pandemic in early-mid 2020 (ongoing at the time of writing), particularly with social distancing and the lack of a space and equipment to conduct it, carrying out this experiment became untenable. The solution was to propose an experiment to be carried out in response to the interviews taken in Anthony's paper[105].

This experiment will aim to explore the difference in efficiency in a studio environment between mouse and keyboard, and a DAW controller, in order to test if using physical controls is beneficial in the workflow of modern Digital Audio Workstations.
The aims of this experiment are:

- To reveal the impact of DAW controllers on the speed and ease of use.
- To evaluate the ergonomic design of both mouse and keyboard versus a bank of faders and knobs, as well as their impact on speed and ease of use.
- To observe the process a user would undergo when first given a set of stems and asked to balance them.

The participants will be presented a Digital Audio Workstation containing nine tracks of audio. Nine was chosen as it requires the participants to utilise the different pages of a DAW controller. Their task, using only Volume and Pan controls inside the DAW is to create a preliminary mix using only a mouse and keyboard. They will be given a limited amount of

[105] Ibid.

time to do so before being presented with another project with nine different tracks of audio, however, this time they are to use a control unit to balance the mix in the same limited time. There will be a short interview conducted afterwards where several questions will be asked based on the experience and prior encounters with the scenario presented in the experiment.

They will be filmed via a non-obtrusive video camera during the experiment. The purpose of this is for later reference and analysis into their workflow, to find any areas where the participant struggled when presented with a situation, and to investigate how they react to the control surface. Furthermore, audio will also be recorded during an interview for later reference.

The details of the experiment are as follows:

- The DAW: Use Reaper as its flat UI allows for easy identification of controls and it is fully compatible with HUI, MCU and OSC, the main control standards for DAW controllers.
- The Stems: Use a set of Drums (kick, snare, stereo OH), Bass, two Guitar stereo totalling nine tracks. Due to most controllers having only eight faders, this presents them with the issue of navigating the extended functions of fader banks. This will test the extent of intuitiveness in shrinking a session's control to only eight faders when more are required.
- The Controller: The selection depends on availability and the representation of the mass market devices available to the majority. Due to the market being so small and adoption of features being slow, the Behringer X-Touch and Mackie Control Pro present two different price points for fully featured DAW controllers.

- The Participants: Participants with a range of experiences will be included in the experiment. This reduces bias and diverts attention from looking at absolute speed of the task, to the time delta of the two scenarios.

As part of the ethical approval process, certain mitigations had to be agreed. Had this experiment gone ahead, these provisions would have been taken:

- The consent will be obtained via a flyer before the experiment, and a copy of the experiment will be copied in a recruitment email.
- The participants will be using equipment that they may not have used before, thus they may feel discomfort or stressed. Therefore, they are permitted to opt out at any time should they feel the need to.
- The video will be framed on the participant's interaction with the hardware, not their faces. The audio will be kept separate from the video as to not cause potential correlation.
- Data collected will be stored on the University Google Drive
    - To ensure data is not lost copies will be stored on a personal computer with password protection and encryption.
- Data collected will be accessible only to the author and their supervisor.

This experiment was approved by the Department of Music's Ethics Committee on the 19th of February 2020.

My expectations for this experiment are as follows. Those versed in DAWs are expected to be able to make volume adjustment quickly and efficiently. However, those who have never balanced a mix before are expected to be left with little time of the limit. This would likely be due to the experience barrier. However, it is believed that with the controller, a much lower delta will be visible. This is due to the subjects lacking exposure to much more than

Play, Pause, Reset, and physical controls that they can touch, and with which build a small amount of muscle memory. Additionally, this also means less distraction from a screen creating a paradox of choice.

Conclusion

The bond between hardware and software is crucial to creating a system which not only works, but thrives. Ultimately, creating a system that works for the producer is what is beneficial, making the most out of time available to create a quality record is paramount. The way a user is introduced to his/her profession is vastly influential into the style of workflow a user would use. The author's own background started using an old analogue console in live sound scenarios, whereas some may start simply on DAWs or Samplers. The author's workflow often sought to recreate the feeling of mixing live as that is where the author felt comfortable and familiar, leading to investments on peripherals which aid in this venture. Recreating the workflow of a console but with the advantages of common DAWs such as footprint and recallability are all concepts which people familiar with working on consoles would understand.

An interesting personal experience is that the author has learnt to use consoles and hardware units through using emulations. Which contrasts to why designs were skeuomorphic to start with, the general idea behind the concept is to help relate the real object to a digital visual metaphor, not the other way around. However, even this argument is questioned with inconsistencies about how parameters are assigned to a control type. Knobs are often represented as circular and are rotated. Most large format consoles typically use knobs for Pan control even though Pan is one dimensional when working in stereo. Presonus' Studio One represents their Pan control as a one dimensional slider.[106] Volume is often represented by a fader, yet knobs are used for sends and returns which are also volume controls. Volume on the Universal Audio 610 console are also handled with

[106] Presonus, "Studio One 4" (Presonus, 2020), https://shop.presonus.com/Studio-One-4-Professional.

knobs[107] which further adds to inconsistencies in parameter assignments. Additionally, equalisation uses both knobs and sliders depending on style and application. This illustrates the fact that experience in the field matters more than a specific code to work upon. If a user becomes proficient in a certain console, it does not mean that they are able to operate all others. Equally there is no way to teach these concepts in a vacuum, meaning that gaps in knowledge are inevitable when learning due equipment available to the user. This is why skeuomorphic design and emulations of gear is crucial to teaching, but may not be as effective in a studio environment. In addition to this is the cost of such equipment often exceeding budget for an institute.

[107] Universal Audio Inc., "100% UA, PART 9, WITH THE 610 CONSOLE," n.d. Accessed May 27, 2020, https://www.uaudio.com/blog/100-percent-ua-610-console/.

Evaluation

Throughout this investigation the author has changed focus many times, starting with the idea of creating teaching resources to better aid the transition from DAWs to console, through to examining how we learn and investigate knowledge acquisition in the field of music, to finally an investigation into how we operate in a studio environment and the objects, peripherals and workflows with which we interact. Though the interruption of COVID-19 has cancelled work conducted for this project it has not stopped the argument as to why we work the way we do. The author started with the intent to write an analysis into the technologies we use accompanied by independent research. COVID-19 affected the experiment which could aid in justifying claims made around control surfaces and their position in the studio. Though there was no experiment conducted, this does not mean that the experiment is without purpose. Science aims to explain with numerical data why phenomena occur and how to reproduce the results. The cancellation of the experiment forced the author to find additional research and uncover portions of their knowledge that the author had not thought to investigate. Due to guidance and support from the supervisor the author was prompted towards texts which filled gaps in knowledge.

The information which was discovered regarding MIDI 2.0 is constantly changing, new webinars and articles are being written. This means that throughout the process of the investigation, portions required updating or amending. Notable additions are the webinars on the 23rd and 30th of May. Though these sources are direct from the MMA, the time at which they occurred are less than ideal, as it only gave nine, and two days, to gather and process the research before submission of the investigation. The extension due to COVID allowed these additions to be submitted as part of the investigation.

Thoughts into further study could be conducted in areas relating to the ergonomics of control surfaces and how the assignment of parameters to certain control metaphors can influence the workflow of a professional, and the way we show feedback visually. A concept which the experiment currently explores is the impact of a control surface when learning the basics concepts of sound. A further study could focus on the ergonomics and features of the control surfaces and at what point the addition of features cease to be effective. Developing studies in this field could prove effective in helping to educate all age ranges in the way that we create, develop and share music. With new emerging technologies and an innovative methods of interacting with music, the future of the audio industry is something to be observed with great interest.

Bibliography

Ableton. “Ableton Live.” Berlin: Ableton, 2013. https://www.ableton.com/en/live/.

_____. “Creating Your Own Control Surface Script.” Accessed May 12, 2020. https://help.ableton.com/hc/en-us/articles/206240184-Creating-your-own-Control-Surface-script.

Akai. “Ableton Live Performance Controller APC40.” Accessed May 12, 2020. https://www.akaipro.com/apc40.

Anthony, Brendan. “Mixing as a Performance: Educating Tertiary Students in the Art of Playing Audio Equipment Whilst Mixing Popular Music.” *Journal of Music, Technology and Education* 11 (2018).

Avid. *Soud Deisgn for Bat Out of Hell The Musical with Gareth Owen: S6L Workflow & Layouts*. Youtube Video, 2017. https://www.youtube.com/watch?v=25-tUKYqcY0&t=177s.

Bateman, Tom. “How MIDI Changed the World of Music.” *BBC*, 2012. https://www.bbc.co.uk/news/technology-20425376.

Behringer. “Behringer: X-Touch.” *Music Tribe*. Accessed May 19, 2020. https://www.behringer.com/Categories/Behringer/Computer-Audio/Desktop-Controllers/X-TOUCH/p/P0B1X#googtrans(en%7Cen).

Berndt, Axel, Simon Waloschek, and Aristotelis Hadjakos. “Hand Gestures in Music Production.” Detmold, 2016.

Byron, J. “MIDI: Hardware and Electronic Implementation.” *Spark Fun*. Accessed May 2,

2020. https://learn.sparkfun.com/tutorials/midi-tutorial/hardware--electronic-implementation#signaling.

Carabott, Arthur. “Email,” 2019.

Dream Theatre. “The Dark Eternal Night,” 2007.

FabFilter. *FabFilter Pro-Q 3 User Manual*. FabFilter, 2018. https://www.fabfilter.com/help/ffproq3-manual.pdf.

Forbes. “What Technology Was Used To Make ‘La La Land’ So Visually Rich And Colorful?” *Forbes*, 2017. https://www.forbes.com/sites/quora/2017/03/03/what-technology-was-used-to-make-la-la-land-so-visually-rich-and-colorful/#5bcfdf4e3b58.

Freunde, Schneiders. “Haken Continuum – New Firmware and New Features.” *Stormkult*, 2017. https://www.stromkult.com/haken-continuum-new-firmware-new-features/.

Future Music. “30 Years of MIDI: A Brief History.” *Music Rader*, 2012. https://www.musicradar.com/news/tech/30-years-of-midi-a-brief-history-568009.

Howard, David M., and Stuart Rimell. “Real-Time Gesture-Controlled Physical Modelling Music Synthesis with Tactile Feedback.” *EURASIP Journal on Applied Signal Processing*, no. 7 (2004): 1001–1006.

Inglis, Sam, and Sound on Sound. “Softube Console 1 Fader.” *Sound on Sound*, January 2020. https://www.soundonsound.com/reviews/softube-console-1-fader.

JUCE. *Panel: Product Deisgn*. YouTube Video, 2019. https://www.youtube.com/watch?v=WsWyIYGX4tM&t=31s.

_____. *Panel: Support of MIDI2 and MIDI-CI in VST3 Instruments*. YouTube Video, 2019.

https://www.youtube.com/watch?v=zXnHaoN2Cig&feature=emb_logo.

Judah, Sam. “What Is Skeuomorphism.” *BBC News Magazine*, June 2013. https://www.bbc.co.uk/news/magazine-22840833.

Jungleib, Stanley. *Prophet-600 Synthesizer Operation Manual*. Mijdrecht: Sequential Circuits, 1982.

Manning, Peter. *Electronic and Computer Music*, 2011.

Maynard, Patrick. *Drawing Distinctions: The Varieties of Graphic Expression*. Ithaca: Cornell University Press, 2005.

MIDI Manufacturers Association. “Details about MIDI 2.0™, MIDI-CI, Profiles and Property Exchange,” 2019. https://www.midi.org/articles-old/blogger/the-midi-association.

_____. *MIDI 2.0 Fader Demo*. Youtube Video, 2020. https://www.youtube.com/watch?v=bkbqFNZcSQk.

_____. “MIDI 2.0 For Developers.” Accessed May 23, 2020. https://www.midi.org/forum/5339-midi-2-0-for-developers-webinar-sat,-may-23rd?page=last.

_____. “MIDI 2.0 For Musicians.” *MIDI.Org*, 2020. https://www.midi.org/.

_____. *MIDI 2.0 Specification Overview*. 1st ed. Association of Musical Electronics Industry, MIDI Manufacturers Association, 2020.

_____. “MIDI History: Chapter 6.” *MIDI.Org*, 2015. https://www.midi.org/articles-old/midi-history-chapter-6-midi-is-born-1980-1983.

_____. *The Complete MIDI 1.0 Detailed Specification*. 3rd ed. Los Angeles, CA: MIDI

Manufacturers Association, 1996. https://www.midi.org/downloads?task=callelement&format=raw&item_id=92&element=f85c494b-2b32-4109-b8c1-083cca2b7db6&method=download.

Music Rader. “Ableton Push Review.” *Music Rader*, 2013. https://www.musicradar.com/reviews/tech/ableton-push-571894.

Music Tribe. “TC Electronic.” *Music Tribe*. Accessed May 25, 2020. https://www.tcelectronic.com/Categories/Tcelectronic/Computer-Audio/Desktop-Controllers/DVR250-NATIVE-DVR250-DT/p/P0DCR.

Native Instruments. “Native Insturments Vintage Compressors.” Accessed May 22, 2020. https://www.native-instruments.com/en/products/komplete/effects/vintage-compressors/.

Pinch, Trevor, and Frank Trocco. *Analog Days*. Cambridge, Massachusetts, London: Harvard University Press, 2019.

Presonus. “Studio One.” Presonus, 2020. https://shop.presonus.com/Studio-One-4-Professional.

Prochak, Michael. *Cubase SX: The Official Guide*. SMT, 2002.

Reimer, Jeremy. “A History of the GUI.” *Ars Technica*. Accessed April 9, 2020. https://arstechnica.com/features/2005/05/gui/.

Roads, Curtis. *The Computer Music Tutorial*. Massachusetts: Massachusetts Institute of Technology, 1996.

Roger Linn. “LinnStrumnet: A New Way to Play.” Accessed May 25, 2020.

https://www.rogerlinndesign.com/linnstrument.

Roland. *JP-8 Owner's Manual*, 1981.

_____. *Juno-60 Owner's Manual*, 1982.

_____. *Juno-60 Service Notes*, 1983.

Softube. "Softube: Console 1." *Softube*. Accessed May 25, 2020. https://www.softube.com/console1.

Sound on Sound. "Osmose — Keyboard Technology Takes a Giant Leap Forward." *Sound on Sound*, January 2020. https://www.soundonsound.com/news/osmose-keyboard-technology-takes-giant-leap-forward.

Soundtoys. "Sound Toys: Little Plate." Accessed May 26, 2020. https://www.soundtoys.com/product/little-plate/.

Spitfire Audio. *Spitfire Chamber Strings User Manual*. Spitfire Audio, 2018.

Steinberg. "Steinberg: CMC-FD." Accessed May 22, 2020. https://www.steinberg.net/en/products/audio_interfaces/cmc_series/models/cmc_fd.html.

Tantacrul. *Music Software & Interface Design: Propellerhead's Reason*. Youtube Video, 2018. https://www.youtube.com/watch?v=7PFRyONURSo.

Universal Audio Inc. "100% UA, PART 9, WITH THE 610 CONSOLE." Accessed May 27, 2020. https://www.uaudio.com/blog/100-percent-ua-610-console/.

_____. *Model 1176LN Solid-State Limiting Amplifier*. Universal Audio Inc., 2009.

Wells, Jez. "Interview With Tony Swain." *Art of Record Production*, no. 09 (2015).

https://www.arpjournal.com/asarpwp/tony-swain/.

Yamaha. *CS-80 Polyphonic Synthesizer: Owners Manual*. Hamamatsu, Japan, 1977.