Minimally Invasive Gesture Sensing Interface (MIGSI) for Trumpet

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ABSTRACT
This paper describes the design of a Minimally Invasive Gesture Sensing Interface (MIGSI) for trumpet. The interface attaches to any B-flat or C trumpet and requires no permanent modifications to the host-instrument. It was designed first and foremost with accessibility in mind—an approach that is uncommon in augmented instrument design—and seeks to strike a balance between minimal design and robust control. MIGSI uses sensor technology to capture gestural data such as valve displacement, hand tension, and instrument position, to offer extended control and expressivity to trumpet players. Several streams of continuous data are transmitted wirelessly from MIGSI to the receiving computer, where MIGSI Mapping application (a simple graphical user interface) parses the incoming data into individually accessible variables. It is our hope that MIGSI will be adopted by trumpet players and composers, and that over time a new body of repertoire for the augmented trumpet will emerge.

Author Keywords
Augmented trumpet; hyperinstrument; minimally invasive; gesture sensing; arduino; force sensing resistor; interface for improvisation

ACM Classification Keywords
H.5.2 [Information Interfaces and Presentation] Interface Design–Prototyping, I.2.9 [Artificial Intelligence] Robotics–Sensors, H.5.5 [Information Interfaces and Presentation] Sound and Music Computing.

1. INTRODUCTION
The augmentation of acoustic instruments has tremendous potential to expand the creative limits of musical composition and performance practice. Researchers and music technologists have been compelled by the idea of electronically augmenting instruments for numerous years, resulting in exciting technological developments and a growing body of literature. Certain music technologists such as Perry Cook, among others, have looked beyond the scope of traditional musical instruments by turning every day objects such as coffee cups and salt shakers into augmented gestural controllers[2]. These controllers, while quite simple in design and in function, respond to gestural input in real time to create interesting pieces of music.

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Miranda and Wanderly[12] break down the concept of a gestural controller into four general categories:

1. *Augmented Musical Instruments*: acoustic instruments augmented by the use of various sensors;
2. *Instrument-Like Gestural Controllers*: modeled after acoustic instruments, with the goal of completely reproducing original features;
3. *Instrument-Inspired Gestural Controllers*: inspired by pre-existing instruments, but do not try to reproduce them exactly; and
4. *Alternate Gestural Controllers*: which do not bear a resemblance to pre-existing instruments.

This paper focuses on the *Augmented Musical Instrument* category, and presents a new design for the augmentation of an acoustic trumpet. Augmented instruments—also referred to as hyper, hybrid, meta, or extended instruments—can be further defined as acoustic instruments that have had digital sensors strategically attached to them, with the purpose of collecting performative and gestural data, as well as providing the performer with extended digital control[7].

Although research and development in this field had begun years earlier, the term *hyperinstrument* was first formally introduced by Tod Machover in 1987[10]. In his writing, Machover stated that he believed hyperinstruments would become the "instruments of the future", and that they would positively impact the development of music by giving musicians—both professional and amateur—tools through which they could explore their full creative and expressive potential. Examples of early hyperinstruments are the *Metasaxophone*[1], *Hypercello*[10], the *Hyper-Flute*[15], and the Cook/Morrill trumpet controller[3], among others. This type of instrument was designed to provide musicians with a deeper level of possible interactions, allowing them to not only produce individual notes or melodies, but also to trigger and manipulate additional sounds that exist beyond the acoustic and technical capabilities of their instrument[11].

However, despite the fact that hyperinstruments have the potential to enhance performance to such a degree, their adoption by musicians other than the original creators has been minimal and idiosyncratic. Generally speaking, most new interfaces for musical expression are created expressly for the creator[11], which suggests that concerns for accessibility may simply have not been highly considered in the design process. Furthermore, Jenkins, et al. highlights the fact that hyperinstruments are expensive and difficult to replicate, frequently require permanent modifications to the host-instrument, and often require significant technical expertise for maintenance and ongoing operation—all factors which could certainly pose a challenge for adoptability[7].

This paper describes the design of a Minimally Invasive Gesture Sensing Interface (MIGSI) for trumpet. In this paper we will present:

- A history of augmented trumpet controllers, detailing different approaches and designs.
- Discussion of hyperinstrument design ideals centered around adoptability.
- The creation of a new gesture-sensing interface for trumpet.
- The creation of a standalone application for mapping, monitoring, and personalization of sensor data.
- A description of MIGSI being used in live performance.

2. RELATED WORK

The trumpet controller built by Perry Cook and Dexter Morrill[3] used sensors on the valves, mouthpiece, and bell for pitch detection and extended computer control. Although one of the initial musical applications of the Cook/Morrill trumpet was unfortunately deemed a "miserable failure"[2], this revolutionary project laid the groundwork for the development of numerous new musical interfaces, and inspired many others to explore the possibilities of trumpet augmentation.

In the years that followed the pioneering work of Cook and Morrill, many significant contributions were made to the field of trumpet augmentation. Well known examples include Ben Neill's *Mutantrumpet*[13], the *Meta-Trumpet*[6] created by Bert Bongers and Jonathan Impett, and Hans Leeuw's *Electrumpet*[9].

The *Mutantrumpet* originated as an acoustic instrument that combined parts of three trumpets and a trombone into one hybrid instrument. In the mid 1980's, electronics were added to the instrument in collaboration with Robert Moog, which were then refined by Neill in subsequent years[13]. The *Mutantrumpet* is performed on by its creator Ben Neill, however it has not been widely adopted by other trumpeters, likely due to the extensive modifications required and the expense of recreating the instrument[7].

The *Meta-Trumpet*, created by Bongers and Impett, employs magnetic "Hall Effect" sensors permanently affixed to the bottom of each valve piston, numerous buttons, switches, and pressure sensors, as well as a number of ultrasound sensors and an accelerometer on the bell of the trumpet. This instrument also requires permanent modifications to the host-instrument.

Hans Leeuw created the *Electrumpet*, a wireless hybrid instrument that does not require direct destructive modification of the original instrument. The *Electrumpet* employs an array of buttons, knobs, a second mouthpiece with breath control, an infrared emitter/detector placed in the bell, and a series of other touch-activated sensors. This instrument also contains facilities for sonic analysis and re-synthesis when used in conjunction with external microphones and a software of Leeuw's creation. Leeuw continues to develop and perform with the instrument. While the technology is removable, it does not lend itself to frequent installation/removal, due to the complexity and quantity of components.

MIGSI is notably distinct from the above augmented trumpets due to the fact that it was designed to be minimally invasive, easily removable, and readily adoptable by experienced trumpet players. Much like a mute, MIGSI can become a part of a trumpeters toolkit—something that can be attached to the performer's personal instrument to give them extended musical control and expressivity, without impeding playability or quality of sound.

3. MOTIVATION AND DESIGN

Our primary goal was to design an augmented trumpet that could be easily adopted by expert trumpet players (who are not necessarily expert technologists), for both composed and improvised music. This means that accessibility and playability are fundamental to the design. An important distinction to make is that in this context "playability" does not exclusively refer to ease or simplicity of playing, but rather to having a full spectrum of musical and expressive control, just as an expert musician would expect from their regular instrument. It is not enough to build an instrument that can simply play notes. There must be enough fine-grained control that the notes can be played expressively, with subtle inflections and changes to timbre, intensity, taper, and articulation[11].

Our design allows us to take advantage of a professional trumpet player's years of training and experience by capturing physical gestures that are inherent to trumpet technique. Furthering this point is Cook's design principle that "Copying an instrument is dumb, leveraging expert technique is smart"[2]. As lifelong trumpet players ourselves, our approach was to build a flexible yet minimal interface, through which the quality of sound production, range of motion, and overall instrument functionality are not impeded.

3.1 Design Considerations

Our approach was inspired largely by the recently developed *Easily Removable Optical Sensing System* (EROSS) for trumpet[7]. EROSS is unique among the other augmented trumpets referenced in this paper, insofar that it was not designed for a specific trumpet player or musical application, but rather as the beginnings of an exploration into a minimal, easily removable, user-accessible trumpet interface. To date, there is only a small body of literature which discusses the accessibility and adoptability of augmented trumpets[18][7][17]. It is our hope to be able to bring more awareness to this field, and to encourage musicians and music technologists to consider these concepts in their designs.

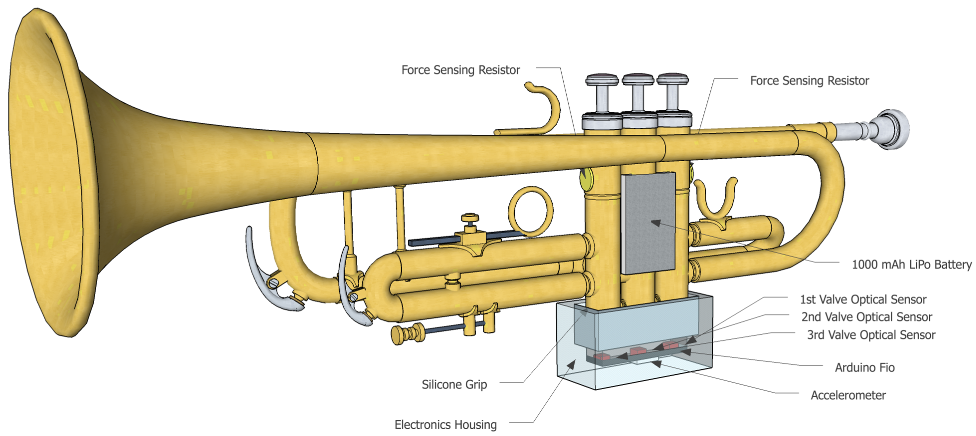

Figure 1. Preliminary design rendering of MIGSI. The 1000 mAh battery and two Force Sensing Resistors are housed inside of the trumpet's hand guard, which is not illustrated here.

The following criteria formed the basis for the design of MIGSI:

- The technology is easy to attach and remove, much like inserting a trumpet mute.
- No damage or permanent modification is required to the host trumpet.
- The interface does not impede instrument playability or discourage use of unconventional and extended techniques (extended techniques are methods for producing non-traditional sounds, such as pressing a valve down only half-way or singing and playing at the same time[19]).
- The interface is minimal enough not to impact the quality of acoustic sound production or the trumpet's functionality, and is familiar enough not to interfere with the performer's ability to play the instrument

3.1.1 Physical Considerations
Similar to EROSS, MIGSI has discreet optical sensors that capture a stream of continuous data from each of the trumpet's three valves. A similar optical sensing technique for trumpet has been proposed as part of a project at Cornell University[5], however it was used to sense binary, or "open" and "closed" states, rather than continuous control. While in traditional and classical trumpet playing valves are predominantly used in a binary fashion, there is a substantial—and continuously expanding—area of practice in which *throttling*, or half-valve playing, is prevalent[19][18]. Being able to utilize all of the microtonal fluctuations and subtle changes to timbre that result from half-valve playing is an important part of contemporary trumpet technique. Our design was therefore developed in order to leverage this technique by capturing continuous rather than discrete valve data.

EROSS is an extremely minimal interface, which uses nothing but the optical sensors beneath each valve. Although compellingly simple, this approach poses some challenges when it comes to playability. The valves on a trumpet are necessarily operational components, meaning that in order to change pitches or to play a musical passage, they must be pressed or released in some configuration. For a composer or improvisor this may be very limiting. If, for example, every time valve combination "1 & 2" was pressed down, "X" happened, and every time "2" was pressed, "Y" would occur, one might find themselves feeling the need to choose between making functional decisions or musical ones.

The approach that we adopted to overcome this issue was to leverage the unused surface area of the interface to add more levels of control that could be used independently from playing the trumpet. By adding sensors that capture hand tension and instrument position in addition to the optical sensors, the performer gains valuable expressive control; now they have the ability to gradually introduce the synthesized sound material triggered by the valve movement, to create subtle and nuanced interactions with the computer, or to transition between different states or modes. In the original designs, the accelerometer was placed on the bell of the trumpet, similar to the *Meta-Trumpet*[6], however this was later reconsidered in favor of a smaller overall footprint. In the later iteration the sensor was placed just beneath the optical sensors. Figure 1 is a computer generated mockup that shows MIGSI's physical layout and sensor placement.

MIGSI is more multifaceted than the EROSS in terms of hardware and sensing capabilities, yet it is just as minimal in terms of design footprint. In fact, a direct contribution of our work to EROSS is the repurposing of unused space on the trumpet's hand guard—which is used in their designs to help secure the optical sensors to the trumpet—to also house the battery. EROSS used two AAA batteries, which were mounted beneath the optical sensing system, below the valve casing. Switching the AAA batteries out for a thinner 1000mAh LiPo and adding a discreet pocket on the inside of the hand guard minimizes the impact of the optical sensing system. Because the LiPo batteries are thin and flat, there is no discernible difference to the trumpet player when the battery is inserted into the pocket.

MIGSI also contains force sensitive surfaces in the hand guard, allowing us to gain additional gestural control without increasing the size or physical impact of the interface. All connecting wires from these sensors are contained inside the hand guard. The rest of the electronics are contained in a small area beneath the instrument's valve casing and therefore do not physically impede normal playing. The electronic compartment is directly attached to a silicone-lined bracket, a small box whose inner dimensions closely match those of the valve casing's exterior. The entire array of electronics is thereby held in place with the slight amount of tension/friction provided from the contact of this silicone-lined bracket with the metal of the valve casing itself (see Figure 2). There are no mechanical components, latching mechanisms, or magnets involved. The electronics securely remain in place during extended use and can be attached to and removed from the valve casing as easily as a mute is attached to and removed from the instrument's bell. Careful consideration was given to using materials that would not scratch or damage the trumpet in any way, even after prolonged and/or repeated use.

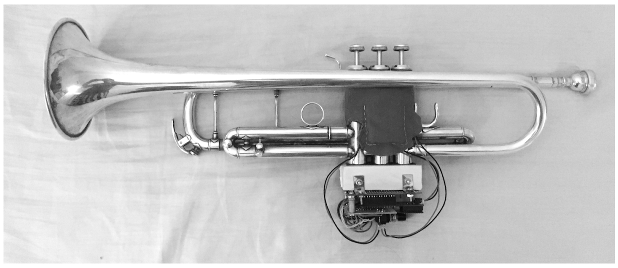

Figure 2. MIGSI prototype.

3.1.2 Cognitive Considerations
Although not the primary focus of this paper, it is important to consider factors such as cognitive load and the performer's relationship with his/her instrument, also referred to as their embodied relationship[14]. Moreover, we believe that it is also beneficial to consider the engagement of the audience members in addition to the performer. There is a lot we can learn from the people who are watching, listening to, and experiencing these performances from the outside.

In his design principles, Cook states that "Some players have spare bandwidth, some do not"[2] and also that "Trumpet players lie squarely in the 'some players have spare bandwidth' category"[2]. While we feel that it is important to focus on a minimal design in the interest of accessibility, it seems there is a necessary balance to be struck between minimality and expressive capability, or playability. In order for the performer to feel engaged and satisfied with the music they are playing, they should have full expressive control over their instrument. Jenkins et al. express concern that requiring a trumpet player to interact with controllers which are beyond their learned technique may result in a cognitive load similar to trying to play two instruments at once[7]. However, not giving the performer enough control can also have adverse effects. Our approach was to carefully consider which sensors were to be used, and to select ones that could be utilized without impeding normal playing technique. Numerous researchers have noted that trumpets lend themselves to the addition of sensors more than other instruments[2][18][9]. During initial pilot testing by three players, the addition of the extra sensors to supplement the control of the optical sensors proved successful in performance and as reported, did not overload the trumpet players' "bandwidth". We look forward to conducting a more in-depth evaluation with a larger sample of performers.

MIGSI is a fully wireless system. The reasoning behind this decision was twofold. Firstly, we wanted to give the performer as much freedom to move about the stage and to interact with other performers as possible. Knowing that the trumpet player would likely be changing the position of their instrument by raising and lowering the bell or tilting from side to side, we also wanted to minimize the chance of any wires being snagged or tripped over. Secondly, we wanted to give the performer the option of not having an onstage computer workstation. Since there is no strict need to interact directly with the computer during the course of a performance, it would just sit idle and unused. It is possible that this could cause an unnecessary distraction or source of confusion for the audience members, causing them to focus more on the technology and "how it works" than on the music itself[16].

4. HARDWARE IMPLEMENTATION

The current MIGSI prototype is built around the Arduino Fio development board,[1] selected for the accessibility of its programming, its reasonable number of analog inputs, its comparatively small footprint, and its intended use as a wireless microcontroller. Using the built-in scheme of integration for the Digi XBee radio module,[2] the Fio can transmit sensory data to any computer equipped with the appropriate XBee radio receiver USB dongle. Though range will vary based on location, our tests have shown that line-of-sight and non-line-of-sight communication are achievable at distances in excess of 50 meters. This should be sufficient for most typical uses, and in situations where XBee range is insufficient, data may be easily rebroadcast via User Datagram Protocol (UDP) over WiFi from the computer to which the XBee receiver is attached. Refer to Figure 3 for hardware block diagram.

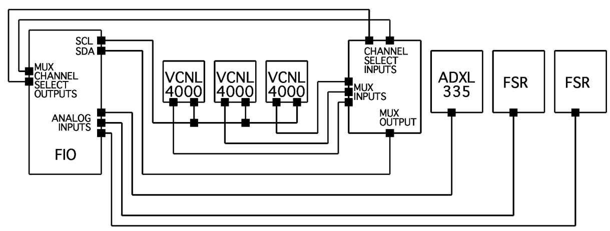

Figure 3. Simple block diagram for MIGSI prototype

4.1 Optical Sensors

The optical valve sensors are largely borrowed in concept and design from EROSS. Once implemented, the valves themselves become sources of continuous data. To a trained trumpeter these become a particularly fast, responsive, and controllable source of data.

A Vishay Semiconductors VCNL4000[3] infrared emitter/ detector placed beneath each valve generates continuous data related to the valve's current displacement. As noted by Jenkins et al.[7], despite the VCNL4000 being an I^2C device it is fixed by Vishay at a set address, so groups of these sensors cannot act as individually addressable slave nodes as would be the case in typical I^2C implementation. In addition to this complication, the Arduino Fio has only one input capable of communicating with I^2C sensors, so simply reading them at different inputs on this microcontroller is not possible. Instead, a multiplexing circuit is implemented in order to rapidly read and store data from each sensor in sequence.

In the EROSS design, this task was handled utilizing an I^2C-based multiplexer, the Texas Instruments PCA9544A[4]. In our own tests, however, we discovered that equally useful results can be had using a simple analog multiplexer. The current MIGSI prototype accomplishes this task by way of a Texas Instruments CD4052BE[5] 2x4-channel multiplexer.

The I^2C serial clock (SCL) line is multiplied from the microcontroller and attached directly to each sensor while the serial data (SDA) line of each sensor is connected to the inputs of the CD4052BE. Three digital outputs from the Fio are assigned to the the multiplexer's logic inputs and activated in such a way that it becomes a sequential switch, with the Fio taking readings as it switches between the sensors in series. These readings are taken mere milliseconds apart, so the resulting data is convincingly continuous.

The CD4052BE analog multiplexer was selected for its easy programmability, low cost, and accessibility for prototyping. Because it is readily available in a Parallel Dual In-Line (PDIP) through-hole packaging, it can easily be used in the process of breadboarding and prototyping without the need for specialized tools for Surface Mount Device (SMD) soldering. Currently, the PCA9544A multiplexer used in the EROSS design is exclusively available as an SMD component. This is a further contribution of our work, considering that not everyone has the means necessary to work with SMD components.

Despite the VCNL4000's 16-bit resolution (yielding 65,535 individual steps across the sensor's range), the usable range yielded within the distance from the bottom of the trumpet's valves in their open and closed states is typically less than 7,000 individual steps. Of course, this resolution is still perfectly usable for most musical applications.

It is also worth noting that the scaling of these sensors is inherently logarithmic, with less change in value per millimeter as the valve approaches the sensor. This can be scaled as needed in the MIGSI Mapping application on the receiving computer (see 5. Software Implementation).

A further issue with this optical sensing system is that the data output range of each sensor varies considerably from trumpet to trumpet. The length of the valve casing varies between different trumpet brands, models, etc., so the practical output range of these sensors varies accordingly. However, a calibration tool in the MIGSI Mapping application solves this problem, allowing for quick and easy rescaling when switching between trumpets. As a result, music written for MIGSI is playable on any standard B-flat or C trumpet.

4.2 Accelerometer

Basic instrument orientation is detected using an Analog Devices ADXL335[6] accelerometer. The ADXL335 provides readings for pitch (vertical instrument angle relative to ground) and roll (left and right instrument tilt). The sensor is located directly below the trumpet valve casing parallel with the trumpet itself so that the pitch output is at ¼ its potential capacity (90º) and the left and right tilt readouts are opposite (180º and 0º respectively) in the typical resting position.

[1] https://www.arduino.cc/
[2] http://www.digi.com/lp/xbee/
[3] http://www.vishay.com/docs/83372/vcnl4000.pdf
[4] http://www.ti.com/lit/ds/symlink/pca9544a.pdf
[5] http://www.ti.com/lit/ds/symlink/cd4051b.pdf
[6] http://www.analog.com/media/en/technical-documentation/data-sheets/ADXL335.pdf

As with the optical sensors, the values yielded from the accelerometer may be scaled as desired in the MIGSI Mapping application on the receiving computer. Conversion of these continuous values into multi-level momentary and latching switches opens up the possibility of creating a multitude of specific physical “behavior zones,” so that both local and global changes in the computer’s behavior become accessible by the player simply altering his/her posture. The MIGSI Mapping application contains facilities for mapping these “behavior zones”.

4.3 Force Sensing Resistors

Physical contact with the valve casing is detected by Force Sensing Resistors (FSRs) placed inside a hand guard at points that make contact with key parts of the instrument’s valve casing. Sensors placed near the locations where a player’s left hand thumb, index, and middle finger make contact with the trumpet are used as a source of continuous control. A trained trumpet player has a high degree of control of their hand tension in these areas, as the fingers that typically make contact here do so for entirely functional reasons: in conventional trumpet playing, the thumb is responsible for frequent manipulation of the first valve slide, while the index and middle finger provide support for the instrument’s weight and balance on the opposite side of the valve casing[19]. Careful placement of the sensors makes them accessible to these particularly well-suited fingers without impeding their normal functionality as instrument support and tuning control.

However, not every musical style, instrument, or player promotes or uses precisely the same hand position. For greater flexibility and easier integration on any player’s instrument, future designs may include arrays of smaller sensors arranged in groups at key points of contact from the player’s left hand. This would allow for definable regions of the valve casing to be mapped and and averaged into individual variables for distribution from the MIGSI Mapping application, and would allow for greater personalization of this aspect of the interface.

5. SOFTWARE IMPLEMENTATION

The several streams of data transmitted by the MIGSI hardware are sent to the receiving computer via XBee radio receiver USB dongle. The MIGSI Mapping standalone application, developed in Max/MSP, provides a simple GUI for sensor calibration and visualization and modification of the received data (see Figure 4). The calibration procedure allows for personalization of MIGSI’s physical response. Ability to monitor the incoming data aids in realtime debugging.

Each incoming stream of data is assigned an OSC variable name, allowing all messages to maintain the original degree of resolution and to be easily utilized in any number of software environments. MIGSI does not inherently generate MIDI data, nor does the MIGSI Mapping standalone in its current form.

We do not consider the lack of MIDI support to be a shortcoming. As noted by Impett[6], standard MIDI implementation is a bit “thorny” in communicating common practice technique from non-keyboard instruments. Additionally, no form of note detection is a goal in our design. We chose not to link the trumpet’s sounding pitch to any aspect of the systems MIGSI controls. We believe that this provides the artist greater creative freedom and control of the audience’s experience, nudging their focus away from the technology itself and toward the music it is used to create.

The MIGSI Mapping application also contains support for data scaling and basic reformatting. Data ranges may be scaled as desired, and continuous data can be reformatted into a series of basic logic functions, including multi-level latching and momentary switches. OSC data is named and sent both before and after this scaling/reformatting process, so both the raw data and reformatted data may still be used as desired.

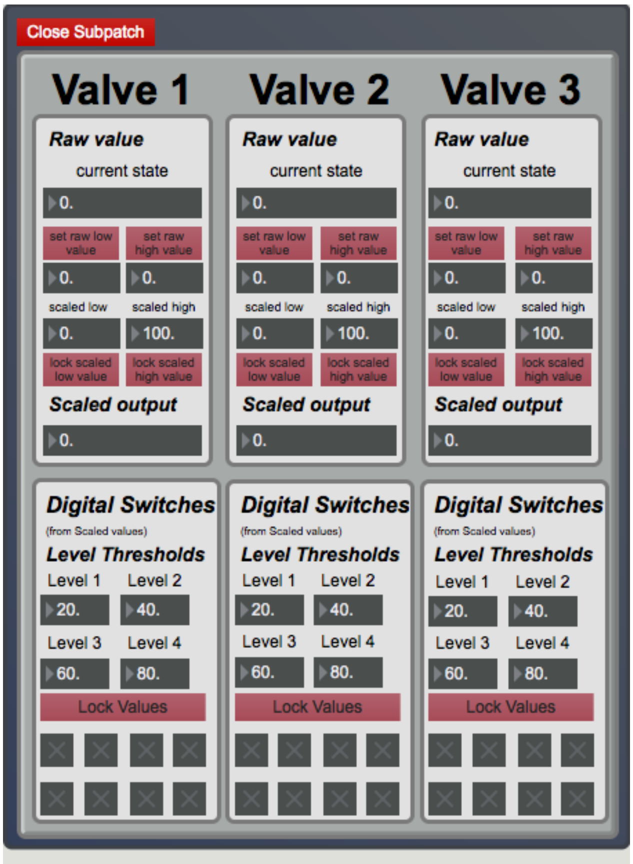

Figure 4. Scaling and conversion module for the valves’ optical sensors from the MIGSI Mapping application.

Mapping configurations may be saved as presets. Presets are a global collection of all of the Mapping application’s internal variable data (scaling ranges, digital conversion thresholds, etc.), saved to the host computer in the form of JSON text files. Presets may be generated and altered either by manually adjusting these individual variable parameters or by editing the JSON file itself via the Mapping application GUI.

6. MIGSI IN LIVE PERFORMANCE

MIGSI was premiered in May 2015 at the Digital Arts Expo hosted by California Institute of the Arts. Two different pieces were presented at the event: a solo improvisation titled “Before North”, and a telematic audio-visual composition in collaboration with Perry Cook called “Stockhausen by Proxy Syndrome”. During the improvisation, data was mapped in such a way that MIGSI became a spontaneous performative partner —gestural data controlled timbre and the level of rhythmic activity of electronic sounds, and accelerometer data was used to spatialize the same material. In the piece with Perry Cook, MIGSI was mapped in part to generate visualizations such as score fragments and phonemes, as well as to manipulate graphics being transmitted from Cook’s performance location. These performances confirmed the functionality of the interface and established an exciting trajectory for future development and creative work. We have continued to develop additional mappings for improvised performance, which we look forward to sharing with the community in the near future (and after more thorough testing).

7. FUTURE WORK

Now past the prototyping stage, MIGSI schematics are being drafted for the development of PCBs with little to no hand soldering required. Being that nearly all involved electronic components are available in various SMD packagings, a printed version of the circuit promises to be considerably more discreet than the already minimally invasive prototype.

We plan to continue experimentation with grouping and placement of FSRs or other touch-sensitive surfaces along the valve casing. This hopefully will lead to a more natural use of left-hand control for the player. Additional hardware developments will include integration of a small number of buttons along the bottom of the interface, primarily for the purpose of enabling and disabling the interface and switching between stored scaling/distribution presets in the MIGSI Mapping application.

New developments in the MIGSI Mapping application itself will include improved facilities for data smoothing, data response curve reshaping, and a more intuitive GUI for defining accelerometer-related "behavior zones." We also hope to incorporate facilities for data recording into the MIGSI Mapping application itself, opening up the interface's potential as a platform for pedagogical analysis of performance technique.

MIGSI and the Mapping application are currently in the hands of several performers and composers. We are already collecting valuable feedback from these musicians in regards to the functionality of the hardware, software, and the new possibilities they are finding hidden within their already highly developed technique and practices. We are excited to continue to explore the trumpet's creative potential and to rediscover exactly what that means.

8. CONCLUSIONS

This paper presents a valuable contribution to the field of augmented instruments and gestural controllers. MIGSI is a Minimally Invasive Gesture Sensing Interface that can be attached to a trumpet as easily as inserting a mute. It requires no damaging modifications to the host-trumpet, is fully wireless, and leverages familiar expert techniques rather than requiring interaction with controllers outside of the trumpet paradigm.

One of the most unique and valuable aspects of MIGSI, is that it strikes a balance between minimal design and robust capabilities—the interface feels familiar and unobtrusive to a trumpet player, and yet is capable of offering a full range of expressive control. We believe that due to its minimal design and strong focus on accessibility, MIGSI has the potential to be adopted by trumpet players and composers in a more widespread manner than is typical of new interfaces for musical expression. Even though it is still in its initial stages, MIGSI has been used in multiple public performances and demonstration, with great success. We look forward to continuing our work in this field.

9. ACKNOWLEDGMENTS

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