SQUISHBOI: A Multidimensional Controller for Complex Musical Interactions

Odie DeSmith
California Institute of the Arts
24700 McBean Parkway
Valencia, CA 91355
marceldesmith@
alum.calarts.edu

Andrew Piepenbrink
California Institute of the Arts
24700 McBean Parkway
Valencia, California 91355
andrewpiepenbrink@
alum.calarts.edu

Ajay Kapur
California Institute of the Arts
24700 McBean Parkway
Valencia, California 91355
akapur@calarts.edu

ABSTRACT

We present SQUISHBOI, a continuous touch controller for interacting with complex musical systems. An elastic rubber membrane forms the playing surface of the instrument, while machine learning is used for dimensionality reduction and gesture recognition. The membrane is stretched over a hollow shell which permits considerable depth excursion, with an array of distance sensors tracking the surface displacement from underneath. The inherent dynamics of the membrane lead to cross-coupling between nearby sensors, however we do not see this as a flaw or limitation. Instead we find this coupling gives structure to the playing techniques and mapping schemes chosen by the user. The instrument is best utilized as a tool for actively designing abstraction and forming a relative control structure within a given system, one which allows for intuitive gestural control beyond what can be accomplished with conventional musical controllers.

Author Keywords

tactile interaction, gesture, mapping, machine learning

CCS Concepts

•**Human-centered computing** → **Gestural input;** •**Applied computing** → *Sound and music computing;* •**Hardware** → *Sensor devices and platforms;*

1. INTRODUCTION

Modern communication protocols such as MIDI and OSC have allowed for the development of parametrically driven hardware performance interfaces for controlling large-scale multichannel systems in real time. These systems have led to a blending of traditional instrumental performance techniques and multitrack mixing techniques common in DJing. However, we believe that for this blending to better accommodate the multitrack potential of modern computer processors, we will need better interfaces — interfaces with the ability to abstract simple gestural interactions into high-dimensional control data for computer music systems. SQUISHBOI's nine time-of-flight (TOF) distance sensors and its rubberized touch surface offer the potential for high-dimensional macro control within a single tactile interface.

This controller takes aim at the space to the left of the traditional keyboard, where the mod wheel and pitch bend have sat more or less unchanged for decades; even more sophisticated interfaces like the left-hand 'drawer' of the Ondes Martenot [5] and its modern descendant, the Expressive E Touché[1], are still of relatively low dimensionality. SQUISHBOI provides its user with a method for utilizing muscle memory within complex parametric systems and offers a unique gestural interface designed to inspire new sounds and musical interactions.

2. BACKGROUND

Figure 1: Installation at Supplyframe DesignLab.

2.1 Motivation

Many hardware interfaces are at a stage where they are struggling to keep up with the flexibility and modulation potential of computer music software. The advent of sophisticated controllers like the Ableton Push demonstrates that in order to control the high level of complexity in modern DAWs, controllers must become systems in and of themselves. This new paradigm in computer music interaction carries on the tradition of hardware production platforms such as the Akai MPC; such tools made it possible for individuals to perform complex musical arrangements with a user-programmable method of interaction. While these systems have liberated individuals to both create and perform musical compositions in new and exciting ways, they also

[1]https://www.expressivee.com/buy-touche

NIME'20, July 21-25, 2020, Royal Birmingham Conservatoire, Birmingham City University, Birmingham, United Kingdom.

often fail to demonstrate concrete gestural relevance to the sonic output. When there is no directly visible method of interaction with a musical system, audience members are forced to speculate as to how sounds are being produced [6]. What if we could have controllers that are both smart and performative? What if there were a controller that could highlight the importance of physicality and muscle memory and also offer high-level control? These were the questions that led us to design and implement a gesturally driven controller for real-time interaction with complex musical systems.

2.2 Prior Art

Although SQUISHBOI's tactile rubberized surface may put it into a category of its own, the interface stands on the shoulders of giants when examining the history of interfaces for interacting with high levels of musical complexity in real-time. Grid-based MIDI controllers are nothing new; the history of such controllers essentially began with the Monome[2]. Since then, we have seen numerous reinterpretations of grid-based controllers for managing complexity in digital music production, including the Sensel Morph[3], Madrona Labs Soundplane [3], and the Reactable [4]. What sets SQUISHBOI apart from these interfaces is the inclusion of a rubberized touch surface with considerable depth displacement (i.e. in the Z-axis); while others may leverage the Z-axis for pressure sensing, our interface exploits large depth excursions on the order of the size of the performer's hand. While these earlier interfaces are often geared towards program change messages rather than continuous control, the concept of controlling large-scale computer music systems from one tactile playing surface remains consistent with our goals for the development of SQUISHBOI's interface. MIDI Polyphonic Expression (MPE) controllers attempt to add additional layers of control to familiar interfaces, most notably the conventional piano keyboard. SQUISHBOI takes a different approach and allows for the design of complex tactile networks that can be physically manipulated like an instrument. While this separation from a note-based playing surface may make SQUISHBOI's interface seem more like a controller than an instrument, its parametric coupling, user-programmability, and flexibility give it a set of performative functionalities that stretch beyond the scope of conventional MIDI control surfaces.

3. SYSTEM DESIGN

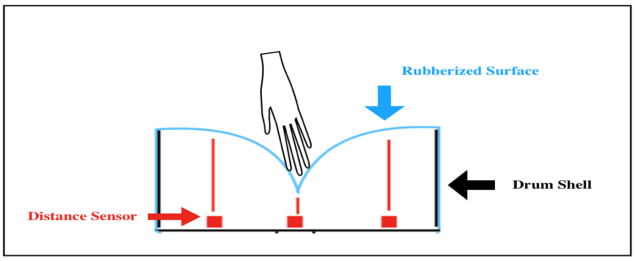

Figure 2: Instrument Layout.

The rubberized membrane surface is a key component of SQUISHBOI's design. We needed a material that could be easily stretched, but also one thick enough for the distance sensors to properly register measurements. Furthermore, the surface needed to be flexible yet durable, and capable of sufficient depth excursion to support the intended gestures. Cross-coupling between individual distance sensors is achieved through the inherent physical properties of the rubberized surface. We eventually settled on a form of industrial-grade latex sheet that fit the bill perfectly and allowed us to develop our initial prototypes. The physical enclosure for the controller was adapted from a 14"x4" snare drum. While in the future we may look to fabricate a custom enclosure for the controller, the existing form factor and hardware made the modified snare drum an appropriate choice for the initial prototype. Although this was certainly the path of least resistance, we learned quickly that the form factor of the instrument often shaped how users would interact with it. In subsequent user testing, a notable percentage of participants seemed to think that the interface's drum-like shape meant that it was meant to be struck rather than stretched. We viewed this as a strong indication that we needed to either redesign the enclosure in an effort to avoid these expectations entirely, or modify the circuit to better accommodate short transients.

3.1 Hardware

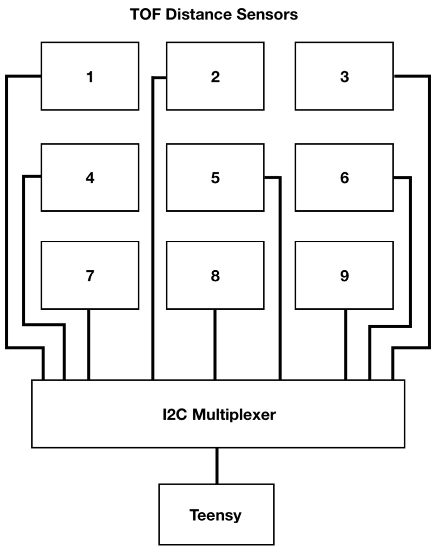

Figure 3: Sensor System Architecture.

SQUISHBOI's functionality is achieved through a sensor array comprised of nine VL6180X[4] time-of-flight distance sensors. These sensors are used to make parallel measurements from the base of the instrument to the rubberized latex playing surface mounted above. The sensors are connected via the I2C bus to a microcontroller, where the data is converted into MIDI CC messages accessible via USB. The VL6180X is a time-of-flight distance sensor, which carries significant advantages over older distance sensing technologies. Ultrasonic sensors were off the table immediately, since the cone of sensing was too wide and would result in nonstop crosstalk between the sensors. Traditional infrared sensors were also ruled out, since their readings would be based on the amount of light returned back to the sensors' receivers, which would cause many issues with linearity and double imaging. The VL6180X has neither of these limitations, using a cutting-edge form of Micro-LIDAR that is currently being aggressively developed for use in self-driving

[2]https://monome.org/
[3]https://sensel.com/pages/the-sensel-morph
[4]https://www.st.com/resource/en/datasheet/vl6180x.pdf

cars, drones, and robotics. We can expect to see more musical and art-based applications of LIDAR technologies in the near future as these sensors become more ubiquitous and affordable.

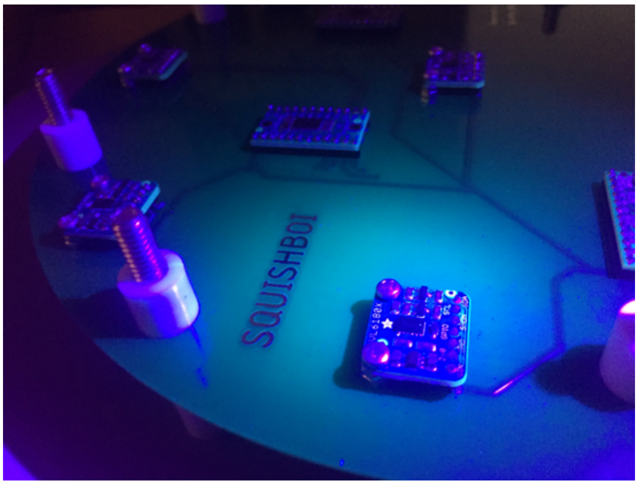

Figure 4: Circuit board with sensors.

SQUISHBOI's printed circuit board has been fabricated both to position and interface with its nine distance sensors. The rubberized membrane cover helps keep lighting conditions consistent, and also ensures adjacency between the beams of each sensor's laser, which is crucial to the intended functionality of the interface. Placing the entire circuit on one large disc-shaped board greatly improved the placement accuracy of each sensor within the array, and allowed for the shortest turnaround time between prototyping and final assembly.

3.2 Software

SQUISHBOI's multidimensional sensor network and tactile rubberized membrane allow for its use as a physical interface for gesture recognition and interactive abstraction via machine learning. This type of non-linear system interaction enables performers to forget about the governing parameters of a sonic system and focus on how their gestures produce different sonic outputs. This system makes apparent the complex feedback network existing between musician and instrument, further highlighting the role of muscle memory in musical performance.

Complex parametric changes within computer music systems often lack the intuitive gestural link that is inherent to more conventional forms of musical performance. For example, an audience member can easily form a connection between a guitar player's physical interactions with his or her instrument and the corresponding sonic output. When this connection becomes obscured, many computer-music artists rely on the projection of synchronized visuals to help subsidize this important multimodal relationship. This visual substitution however, does little to benefit the performer in terms of spatial and tactile connection, traits that are essential to most all forms of traditional instrumental performance. In [8], Wessel and Wright speak to the importance of metaphors for musical control when dealing with systems of high dimensionality. With the assistance of machine learning algorithms, SQUISHBOI enables this sort of high-level gestural control over parameters within a computer-music system.

A user can easily set up SQUISHBOI for continuous gestural morphing, where output parameters are interpreted via regression in Wekinator [1]. The relative value of a given

Figure 5: Instrument Shell.

sensor's real-time input data is reinterpreted and mutated by user-generated training data specified beforehand using input from the controller itself. This allows the interface to function as a system for complex high-level control, or as a tool for abstraction of a given parameter, influenced and governed by physical interaction. What if rather than outputting a continuous and relative signal as a distance measurement between the sensor and rubberized surface changes, the system outputted an envelope or LFO once a certain threshold was met? What if these interactions could be mapped and retrained based on a series of governing principles reinforced through the inherent dimensionality of the sensor-circuit network? These are the key questions that influenced and guided our thinking on the design of the SQUISHBOI controller's interface.

4. MAPPING AND INTERACTION

4.1 Integration with Other Systems

SQUISHBOI's high level of dimensionality and tactile responsiveness make it an apt interface for controlling often unwieldy systems. One such system, growing in popularity over the last decade, is the Eurorack modular synthesizer format. In conjunction with a DC-coupled audio interface, SQUISHBOI can send its relative sensor data as continuous control voltage (CV) signals for interfacing with analog systems. The relatively open format embraced by most modular architectures offers a unique entry point for cross-referenced multichannel control data. This data can be used to develop a control surface for real-time interaction with hardware synthesizer patches, or even to facilitate tactile control over the governing aspects of signal flow, such as the internal routing of modulation signals.

Modular synthesizer patches often include dozens of parameters that quickly become difficult to manage with only two hands. Furthermore, X/Y joysticks or pad controllers lack the requisite complexity needed to adequately interface with a modular synthesis network. When a computer-music system becomes too large in scale, any given method for control should include a relative strategy for the simultaneous abstraction of parallel parameters. Without some generative structures in place, a user simply doesn't have the physical or mental bandwidth to steer the ship without feeling like a cartoonesque one-man band. Interfacing SQUISHBOI with machine learning software allows for an additional layer of multidimensional control that can be implemented independently or in parallel with the raw signals generated from each individual distance sensor. This setup is illustrated in Figure 6. If an additional neural network were used to further abstract the nine TOF sensors' signals relative to a different set of user-specified training data, the output signals from this secondary network could be sent to any number of additional parameters if deemed necessary. This could even include things such as generative gestural accompaniment as demonstrated in prior work like *GestureRNN* [2]. The limiting factor when it comes to the breadth of control is not the interface itself, but rather the computer processor and/or imagination of its user.

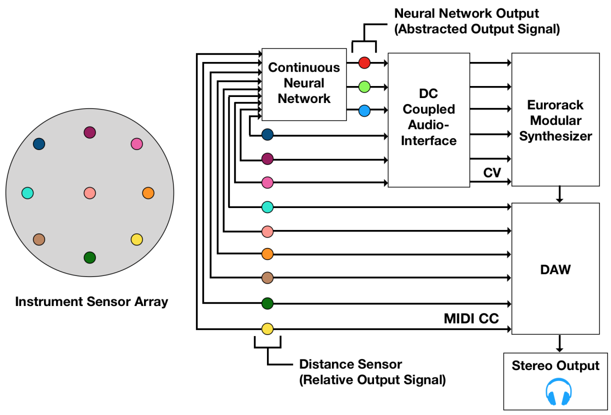

Figure 6: System Overview

4.2 Performance Techniques

SQUISHBOI is a flexible and powerful interface for controlling complex sound synthesis systems in real time. With each new mapping, the way a user might interact with SQUISHBOI changes. Much like the natural relationship between an acoustic instrument's note-range and timbre, SQUISHBOI's inherent dynamics allow for cross modulations to occur naturally (or be designed) through the assignment of each MIDI CC value. We've found that it really excels with complex FM sounds. When modulating the amplitude and fine frequency controls on Ableton's Operator, we were able to produce complex and highly interesting drone textures that morphed harmonically across the different clusters of the sensor array. We also achieved startling sonic results while jamming on a mapping that we had trained to control the parameters of an arpeggiator, using real-time classification via dynamic time warping. SQUISHBOI can be thought of as a "composed instrument" - a term borrowed from David Wessel's description of the *SLABS* interface [7], a controller that is similar in that it was designed for expressive control across a user-programmable array. The main difference with SQUISHBOI lies in the tactile quality and inherent coupling of parameters within the array that result from its flexible rubberized surface.

5. CONCLUSION

We have demonstrated a continuous controller for interacting with complex musical systems. This controller builds upon the tradition of array-based instruments, while providing users with a tactile interface built from the ground up to prioritize complex interactions along its Z axis. We have showcased how the sensor circuit network of our interface makes it a prime candidate for exploration of musical interaction with continuous neural networks. Furthermore, this work highlights how physical controllers with a high level of dimensionality can be used to reintroduce muscle memory and gestural interaction as focal points within a given computer music system.

6. ACKNOWLEDGMENTS

The authors would like to thank Marijke Jorritsma and Christine Meinders, whose collaborative efforts have been a guiding force in both the aesthetic and technical development of this project. We would also like to thank the CalArts community as a whole for fostering a welcoming and supportive network wherein this type of work can thrive.

7. REFERENCES

[1] R. Fiebrink, D. Trueman, and P. Cook. A meta-instrument for interactive, on-the-fly machine learning. In *Proc. NIME*, pages 280–285, 2009.

[2] L. Hantrakul and Z. Kondak. Gesturernn: A neural gesture system for the roli lightpad block. In *Proc. NIME*, pages 132–137, 2018.

[3] R. Jones, P. Driessen, A. Schloss, and G. Tzanetakis. A force-sensitive surface for intimate control. In *Proc. NIME*, pages 236–241, 2009.

[4] S. Jordà, M. Kaltenbrunner, G. Geiger, and R. Bencina. The reactable. In *In Proceedings of the International Computer Music Conference (ICMC 2005*, pages 579–582, 2005.

[5] J. Loriod. *Technique de l'onde electronique type Martenot*, volume 1: Le Clavier. Alphonse Leduc Editions Musicales, Paris, 1987.

[6] W. A. Schloss. Using contemporary technology in live performance: The dilemma of the performer. *Journal of New Music Research*, 32(3):239–242, 2003.

[7] D. Wessel, R. Avizienis, A. Freed, and M. Wright. A force sensitive multi-touch array supporting multiple 2-d musical control structures. In *Proc. NIME*, pages 41–45, 2007.

[8] D. Wessel and M. Wright. Problems and prospects for intimate musical control of computers. *Computer Music Journal*, 26(3):11–22, 2002.