The Helio: A Study of Membrane Potentiometers and Long Force Sensing Resistors for Musical Interfaces

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Abstract

This paper describes a study of membrane potentiometers and long force sensing resistors as tools to enable greater interaction between performers and audiences. This is accomplished through the building of a new interface called the Helio. In preparation for the Helio's construction, a variety of brands of membrane potentiometers and long force sensing resistors were analyzed for their suitability for use in a performance interface. Analog and digital circuit design considerations are discussed. We discuss in detail the design process and performance scenarios explored with the Helio.

Keywords: Force Sensing Resistors, Membrane Potentiometers, Force Sensing Resistors, Haptic Feedback, Helio

1. INTRODUCTION

Continuous control plays a critical role in music. In acoustic music, the continuous uninterrupted control available on fretless instruments allows for performance techniques and expressivity not available on instruments with discrete input techniques. With the advent of electronic musical instruments, knobs quickly became the continuous control method of choice. Knobs, however, lack the ability to clearly provide audiences with visual feedback: through their small size and compact nature, knobs cannot easily convey their positions to the audience.

Thanks to the widespread availability of touch responsive sensors from vendors such as Sparkfun Electronics[1], along with microcontroller systems capable of driving many such sensors, musical interfaces can now be built that take advantage of the sensors' large sizes to readily provide clear visual feedback to audiences.

To further explore the potential offered by touch sensors, we designed and built the Helio, a musical interface consisting of eight membrane potentiometers. These membrane potentiometers are arranged in an upright manner, allowing audiences to observe parameter changes in real time. In building the Helio, a series of membrane potentiometers and long force sensing resistors (FSR's) were studied and tested. After the completion of the Helio, its use as a performance tool was analyzed and the lessons learned through various performance scenarios were reported below.

After exploring related research in Section 2, we examine the technical details of membrane potentiometers and long FSR's. Section 3 examines technical details of the sensors tested for the Helio. Section 4 contains data about major brands of FSR's and membrane potentiometers, complete with experiments analyzing musically relevant parameters. In sections 5, we discuss the design and construction of the Helio. Section 6 focuses on musical performance scenarios explored using the Helio.

2. RELATED RESEARCH

Strip-based and similar continuous controllers have been around nearly as long as electronic musical instruments. The ondes Martenot, invented in 1928, included an expressive continuous ring-based controller. Later synthesizers, including the Moog modular synthesizer, featured a linear ribbon controller input device[2].

In more recent years, highly creative uses of membrane potentiometers and long FSRs have broadened the sensors' expressivity. While not an exhaustive list of projects utilizing long FSRs or membrane potentiometers, the following interfaces have influenced our work: Dan Trueman's BoSSA makes use of two FSRs to measure bow pressure and relative position and a long FSR to determine playback position [1]. Perry Cook used long-FSR's for parametric control on physical models in his COWE [2]. The second author's Etabla made use of long-FSRs for expressive parametric control [3]. The EDholak uses a long-FSR for filter parameter modulation of rhythmic elements [4]. Curtis Bahn's SBass places long FSRs in a manner allowing for easy manipulation during performances [5]. Tomás Henriques'

[1] http://www.sparkfun.com/commerce/categories.php, April, 2010

[2] www.synthmuseum.com/moog/moomods.html, April, 2010

Double Slide Controller [6] makes use of a membrane potentiometer to provide sensor data from the trombone's slide.

All of the above make use of linear position sensors to extend traditional playing technique. The Stribe[3], and Leif Krinkle's flat_hand[4] utilize the continuous nature of the sensors to create highly ergonomic interfaces.

3. TECHNICAL DETAILS:

Force Sensitive Resistors (FSRs) function by exhibiting lower resistance as pressure is increased. This is accomplished via a matrix of printed leads that come into contact with a printed substrate as pressure is applied. Traditional FSRs are not location-specific while long FSRs return location data by comparing resistance changes at a specific point via a third pin.

Membrane potentiometers function in a similar fashion to traditional potentiometers[6]: Source voltage meets a substrate of resistive material at the location of the wiper. In a membrane potentiometer, the wiper position is determined by the user's finger location. Depending on the wiper position, the source voltage will have to travel through varying amounts of resistive material. The consistently with which the resistive substrate is applied governs in part the linearity of the membrane potentiometer's response.

Membrane potentiometers are typically covered in a plastic protective layer. While at rest, the wiper resides above the resistive substrate: the air gap between the two prevents any voltage from flowing when no user input is present. Upon receiving input, the wiper is pushed into contact with the substrate, changing the resistance.

FSRs are high-impedance devices, requiring buffering circuitry in order to behave in the desired manner. In contrast, membrane potentiometers require no additional circuitry to function as expected. We found that the low-impedance design of membrane potentiometers allowed for easier prototyping and testing.

3.1 Connecting to Analog Input Pins

To connect to the ADC pins on the microcontroller in a manner that avoided noise and signal fluctuation, both analog and digital solutions were explored. An analog circuit making use of buffering capacitors to store voltages was built and tested with marginally acceptable results: the analog circuit held its value for a short time before beginning to slowly discharge. To counter this tendency to discharge, a digital solution making use of value thresholding was implemented and is currently used in the latest version of the Helio interface.

4. EXPERIMENTS

To understand the musical potential for membrane potentiometers and long FSR sensors, a series of experiments were run. These experiments aided us in choosing which sensors would be used in the Helio interface by allowing us to quantitatively examine aspects of the sensors deemed significant to expected applications of the interfaces.

[3] http://www.soundwidgets.com/stribe/, March, 2010
[4] http://itp.nyu.edu/~zl316/PCOMP/flathand.htm, March, 2010
[6] http://itp.nyu.edu/physcomp/sensors/Reports/SoftPot, Jan. 2010

The experiments performed consisted of a test of resistance linearity and a test of sensor consistency over time, characteristics felt to be important in interfaces wherein gestures need to return consistent results.

4.1 Sensor Brands

4.1.1 Steadlands Interlink Force Sensitive Resistors

Steadlands produces a line of long FSR sensors[7]. These low-profile devices are distinguished from non-location specific FSRs by their third lead. Compared to the membrane potentiometers listed below, the Interlink Force Sensitive Resistors are high-priced but are available in a wider array of shapes and configurations. These sensors appear to be available only from the Steadlands website.

4.1.2 Spectrasymbol HotPot

Spectrasymbol[8] manufactures a membrane potentiometer optimized for high-temperature, high-stress applications. This fiber-reinforced sensor is available from Sparkfun Electronics and has a typical three-pin configuration. The touch surface of the HotPot is finished in a matte fashion, providing good tactile feedback.

4.1.3 Spectrasymbol SoftPot

In addition to the HotPot, Spectrasymbol manufactures the slightly less expensive SoftPot membrane potentiometer. The SoftPot, also available from Sparkfun Electronics, is not ruggedized to the degree of the HotPot and lacks the matte finish of the HotPot, resulting in a smoother, slicker feel.

4.1.4 Sensofoil Membrane Potentiometer

Sensofoil's line of membrane potentiometers[9], which are available from Potentiometer-Shop.com, are less expensive than the above sensors, but offer a smaller overall resistance range and very slightly less accurate linearity on the models tested. The Sensofoil membrane potentiometer is not ruggedized in the manner of the Spectrasymbol HotPot: it is more comparable to Spectrasymbol's standard SoftPot in terms of tactile feel.

4.2 Linearity

	Length as tested	Resistance Range (KOhm)	Linear	Cost as tested
Steadlands FSR	600mm	0-20	Yes	$125
Spectra Symbol HotPot	500mm	0-20	Yes	$40
Spectrasymbol SoftPot	50mm	0-10	Yes	$17
SensaFoil Membrane Potentiometer	300mm	0-7.5	Yes	$35

Table 1. Information about Long FSR sensors and Membrane Potentiometers

[7] http://www.steadlands.com/interlink/pages/fsr.htm, Jan. 2010
[8] http://spectrasymbol.com/, April, 2010
[9] https://www.sensofoil.com, April, 2010

When interfacing with a linear sensor, the degree of linearity in output data is significant: to provide predictable responses when inputting gestural data, it was found that linearity of response contributed greatly to usability. Without a predictable linearity curve, repeatability in control is not possible. It was found that all sensors tested were acceptably linear. See table 1 for results.

4.3 Sensor Consistency

When inputting data on a membrane potentiometer or long FSR, the degree to which subsequent input events will be similar to the current event proves important: this allows for repeatability and predictability, allowing for repeatable performance scenarios to be explored. To test the sensors' repeatability in input data, a region was actuated many times while its resistance level was measured. See Table 1 for details.

4.4 Test Conclusions

The sensors tested were found to behave acceptably for musical interface design. As a result, the sensors ultimately used in the Helio were chosen due to economy and availability. The tactile feedback offered by SpectraSymbol's HotPot membrane poteniometer was deemed preferable for performance situations: the rougher matte finish was deemed to provide superior user feedback than the glossy finishes of the other sensors. Spectrasymbol's HotPot membrane potentiometers were used on the Helio.

5. CONTROLLER DESIGN

We describe the building of the Helio, a membrane potentiometer-equipped controller, making use of the above data.

5.1 Helio: A Touch Sensor Interface

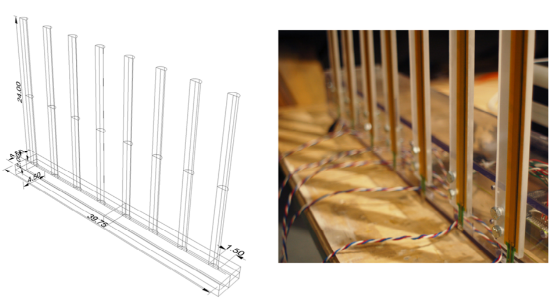

Figure 4.: The Helio Interface prototype and final rendering, featuring eight upright-mounted membrane potentiometers.

The Helio features eight 500 mm HotPot membrane potentiometers arranged vertically. The vertical orientation allows for audiences to view the performer's actions.

We were influenced by the performance paradigm explored by Meason Wiley with his MLGI controller [7]. Through the use of the MLGI, the performer can interface with audiovisual software while facing the audience. The MLGI's use of lasers and light sensors, though, necessitated performances to occur under special lighting conditions. The Helio trades some of the free-form expressivity offered by light sensors in favor of the flexibility in deployment offered by touch sensors.

The ability for the Helio's sensors to maintain sensor position after the performer releases the sensor was deemed an important design objective. This allows for toggle-type button emulations, graphic equalization simulations, and other interfacing techniques (see section 3.1 for more information).

5.2 Design Principles

5.2.1 Haptic Feedback.

The Helio differs from the above interfaces in numerous ways. Primarily, the Helio allows for a visual connection between the interface user and the audience due to both the prominent upright position of the sensors and the visual feedback provided by the Helio's LED array. While other interfaces utilizing linear touch sensors have provided one or the other, the Helio differs from these in that it provides both simultaneously. The prominent positioning of the sensors places the performer in a position that emphasizes his or her performance to the audience.

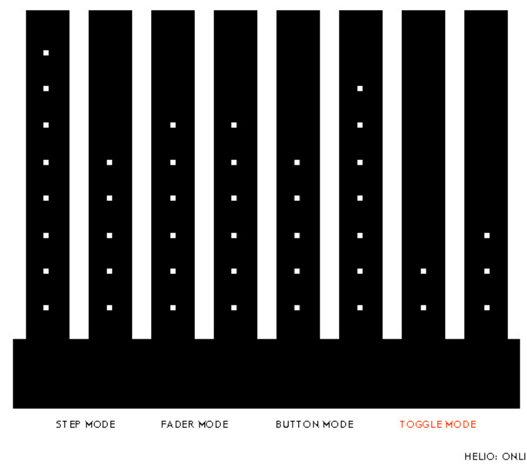

Figure 5.: The Helio GUI: a custom graphical interface for providing real-time feedback related to the Helio's input and output.

In addition to an up-front playing style, the Helio promotes a great deal of audience interactivity through its user-mappable LEDs. These LEDs receive MIDI or OSC data and can provide real-time feedback to the audience on user-defined parameters. The highly gestural and expressive playing style encouraged by the interface, along with its real-time visual feedback for the audience and our extensive analysis of long-FSR sensors and membrane potentiometers make the Helio a novel interface.

6. MUSICAL PERFORMANCE SCENARIOS

6.1 Melodic Performance Techniques

The eight membrane potentiometers used in the Helio interface allow for a wide range of melodic possibilities. To use the Helio with tuning systems consisting of more than eight tones, two options were proposed. The first was using thirteen rather than eight membrane potentiometers. The use of thirteen potentiometers would allow for a full octave of chromatic pitches. The second option focused on using eight membrane potentiometers and splitting the sensor areas on the potentiometers into enough zones to allow for any tuning system. The second option was chosen due to cost and space considerations.

Generative and procedural rhythmic generation was also explored with the aid of the Helio interface. Parameters in generative music production tools were mapped to be affected by the sensors, allowing for real-time crafting of generative algorithms.

6.2 Rhythmic Performance Techniques

The discrete sensor assembly in the Helio lends itself to rhythmic control. During performances, the individual sensors were used to control steps. Software was written to allow each sensor to be addressed sequentially. The software allowed for several "pages" of data, allowing for multiples of eight steps to be used. In the Helio Step Sequencer software, each sensor controlled its particular step's parameters, which could be mapped in real time during performance.

Generative and procedural rhythmic generation was also explored with the aid of the Helio interface. Parameters were mapped to each membrane potentiometer and could be manipulated to alter the procedural generation of the rhythm.

In addition to controlling sample playback and drum synthesis, the Helio interface was used to trigger solenoid-driven drums on musical robots.

6.3 Extended Techniques

The linear control and innovative interactive elements between the performer and the audience allow for extended performance techniques such as control of live visuals and control of robotic instruments. Through the use of a performance interface that provides visual feedback, we found that the role of the live visualist became a more performance-oriented task.

Thanks to the performance-oriented interface, the live visualist can perform expressively onstage, no longer limited by interfaces lacking in audience feedback and expression. As with the other performance paradigms, the visual feedback provided by the integrated LED arrays allowed for a visual connection between the live visualist's interactions with the interface and the resulting projected visuals.

7. CONCLUSION

Membrane potentiometers allow for expressive control in a variety of musical situations. Furthermore, their compact ergonomic design allows for easy integration into haptic interface designs. For performance scenarios, a wide variety of membrane potentiometers and long FSRs were found to be adequately accurate to allow consistent performance. Membrane potentiometers were ultimately chosen due to their availability and economy. Thanks to the accuracy and consistency of membrane potentiometers, multiple performance paradigms were explored using the new Helio interface. The Helio was found to behave as expected, providing audiences with clear views of real-time musical parameter changes.

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