Patch-corde: an expressive patch cable for the modular synthesizer.

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ABSTRACT

Many opportunities and challenges in both the control and performative aspects of today's modular synthesizers exist. The user interface prevailing in the world of synthesizers and music controllers has always been revolving around knobs, faders, switches, dials, buttons, or capacitive touchpads, to name a few. This paper presents a novel way of interaction with a modular synthesizer by exploring the affordances of cord-base UIs. A special patch cable was developed using commercially available piezo-resistive rubber cords, and was adapted to fit to the 3.5 mm mono audio jack, making it compatible with the Eurorack modular-synth standard. Moreover, a module was developed to condition this stretchable sensor/cable, to allow multiple Patch-cordes to be used in a given patch simultaneously. This paper also presents a vocabulary of interactions, labeled through various physical actions, turning the patch cable into an expressive controller that complements traditional patching techniques.

Author Keywords

Cord Interface, Modular Synthesizer, Interaction Design

CCS Concepts

•**Hardware** → *Analog and mixed-signal circuits;* •**General and reference** → Design; •**Applied computing** → Performing arts;

1. INTRODUCTION

The comeback of the modular synthesizer as a compositional and performative electronic music instrument in the past decade has been showing increased adoption and interest [12]. The decentralization provided by core standards of modulars (1V/Octave and 5V gates) dates back to the old Moogs. The conforming Eurorack format, originally designed in 1996 by German engineer Dieter Doepfer, made it possible to freely mix modules within a single crate [2]. This enabled various small businesses to innovate with designing modules that went beyond the classical boundaries of traditional analog synthesis while attaining an immediate market, putting the modular synthesizer back into an experimental, yet affordable, music making space. More companies make synthesizer modules now than ever before. Modules today vary from classical voltage-controlled oscillators, filters and amplifiers, to novel dynamic distortion modules and interesting sequencers that rely on mathematical algorithms such as Euclidean sequencing [16]. Digital modules pack even more functionality than traditional analog modules, although the common language in programming a modular synthesizer is still based on control voltages and logic gates/triggers. Whether analog or digital, the whole point behind the modular synthesizer, and the biggest reason with it being embraced today, lies within the concept of “patching” [11]. Controlling such a synthesizer from a novel interface that inspires electronic musicians has been a subject of interest and experimentation since the 60s, starting, for example, with the innovative capacitive touchpad inputs that Don Buchla included with his first sequencer [7]. At the time, modular synthesizers became popularized by Bob Moog's adoption of the keyboard interface and 1V/Octave exponential oscillators and filters, making the instrument more appealing for the average composer and musician. The modular synthesizer of today, however, paves the way for electronic musicians to design sounds and compositions using a plethora of innovative techniques, defined by the ways in which the modules are patched together. Modulars become a hybrid instrument that highlight a fusion of many schools of synthesis and just plainly innovative/hacking ideas into a personal, unique and utterly dynamic sonic palette. Opportunities and challenges, of course, exist in controlling and performing with a modular synthesizer. Nominally, modular musicians don't want anything to vary in how their cables respond – they are optimally thought as zero-impedance connections. This paper, however, turns this concept on its head, presenting a special type of patch cord, that allows multimodal interaction to be performed with a modular synthesizer – e.g., focusing on immediate and natural actions such as plucking, stretching, bending, pressing, snapping, etc.

Figure 1: 1996 Michel Waisvisz's Small Web or ‘Belly Web’. Courtesy of crackle.org

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2. RELATED WORK

2.1 Cord-like controllers

The field of expressive controllers has been widely explored since the 80s and early 90s [10]. The best-known early work that utilizes cord-like interfaces is called The Web and was originally built by Michel Waisvisz at Amsterdam's Stichting voor Electro Instrumentale Muziek (STEIM) [9]. The Web, inspired by spider webs, consisted of an octagonal frame holding multiple radials and circles made out of nylon and special sensors to detect the player's physical tension. The player had access to over 24 degrees of freedom, making it an excellent timbral controller compared to traditional controllers that can only affect the pitch, velocity and pressure of a given sound [6]. Manipuller is a more recent example of a gestural controller based on a string manipulation and multi-dimensional force sensing technology [5]. The Sonic Banana is another cord-like interface, essentially a MIDI controller in the form of a flexible rubber tube that is augmented with multiple sensors to detect bending [15]. Tangentially, the FabricKeyboard exhibits a similar behavior to cord-like interfaces through its multimodal tactile interaction. Wicaksono et al., explore a corpus of user interactions provided by the affordances of textile – interactions such as stretching, pressing, and deforming, allow expressive control to be injected into a digital patch [18]. Earlier work, such as Zstrech, explored similar interactions without using a skeuomorphic interface like the keyboard [8]. A user study carried out by Giovanni et al., explored how musicians interact with stretchable controllers. From their findings, several musicians relied on stretch and deformation while playing an instrument similarly to how they interacted with expression pedals or mod wheels on a synthesizer, they are generally patched to manipulate the timbre of a sound, or parameter of a time-based effect, rather than discrete notes [17].

2.2 Cords in HCI

Several projects in the field of human-computer interaction (HCI) explore the usage of cords as input devices. The earliest and most impactful work, by Schwarz et al., demonstrates the power of cords as an interface for controlling music players, while exploiting the cord's many and interesting physical affordances [14]. Moreover, Wimmer et al.'s implementation, senses the user's input at various points of a headphone's cord to adjust the volume through time domain reflectometry [19]. Detecting knots on a rope embedded with flex sensors was implemented and explored by a project called Minguet, which also connects to a smartphone to generate audio and visuals [13]. Moreover, Cord UIs explored the usage of metaphors through augmenting cords with various sensors while showing many applications in controlling appliances. For instance, a knot presented in the power cord of a desk lamp, turns off the light [13]. These are but examples that showcase the distinctive explorations of cords and their affordances in the world of HCI.

2.3 Eurorack's Patch Cables

Cables terminated in 3.5 mm mono audio jacks, known as patch cords, are adopted by the Eurorack standard to transmit signals (audio or control-voltage (CV)), from module to module. Several companies have been evolving the patch cable while maintaining the integrity of the signal through its zero-impedance connection. For instance, a special patch cable, called Stackable (Figure 2), by Tiptop Audio [4], allows multiple signals to be routed together similar to stackable banana cords (used to patch a Buchla synthesizer). This is a very useful cable for patching a compact Eurorack synthesizer, as it avoids the need of using a distinct signal "multiple" module in the rack. Another series of patch cables, sold by Logsdon Audio, embed the cable with LED that react to the signal; it is even possible to illuminate one end with positive polarity and the opposite end with negative polarity through dual polarity LEDs [3]. The integrity of the signal could be affected by this cable if the transmitting module had no buffered outputs, since a voltage drop is needed to turn on the LEDs.

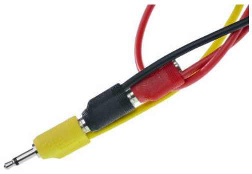


Figure 2: Stackable patch cables by Tiptop Audio. Courtesy of schneidersladen.de

This paper proposes to alter the functionality of certain traditional patch cables in a patch, sacrificing the integrity of the signal that they transmit at the expense of turning them into expressive input devices. This paper doesn't suggest replacing entirely all the patch cables in a given patch, rather, it pushes the player to think creatively about interesting routes that could benefit from having a performative patch cable. This paper builds upon existing prior work by demonstrating several use cases in patching a modular synthesizer with a stretchable cable made out of a piezoresistive rubber cord and other commercially available and affordable components that manipulate with physical gestures elements of the patch.

3. TECHNICAL IMPLEMENTATION

3.1 Conductive Rubber Cord

The cable as an interface is based on a commercially available carbon based piezo-resistive rubber known to work well as a stretch sensor. The cord is impregnated by carbon that resides within the rubber, thus making it conductive. Given the movement of electrons through the chain of carbon, a resistance R is observed when the rubber band is at resting position. When stretched apart, the distance between particles of carbon increases, and therefore an increase in the resistance of the overall material is observed. The opposite effect is noticed when the rubber cord is squished together; the overall resistance of the material decreases. Similar effects can be registered with other interactions, i.e., tying and pressing a knot, bending or randomly deforming the cord. The manufacturer specifications show that the resistance fluctuates around 350 Ohms per inch at rest. For instance, a 6" Patch-corde has a total resistance of about 2.1 kOhms. When stretched to about 10", the resistance fluctuates around 3.5 KOhms. This conductive rubber can be stretched to 50 to 70 percent of its length. The resistance takes several milliseconds to show change as the rubber returns to its original resting state, and that is due to the hysteresis presented in the rubber during deformation. Therefore, a gradual decrease of resistance is registered upon relaxation [1].

3.2 Cable Assembly

The following process is presented to transform a conductive rubber band into a functional patch cable that meets the Eurorack requirements. First, crimp-connectors on both ends of the rubber band are capsuled to securely ensure the transmission of signal to the audio-jack from the piezoresistive material. Second, an insulated cable coils around the rubber band, transmitting the ground line, as indicated by Figure 3. Third, two sleeves are inserted as well as two heat-shrink tubes. The latter are used to ensure an insulation between the hot signal and the ground line. Last but not least, the crimp-connectors are solder to the inner-tip of the mono jack, then reinforced with another heat-shrink tube, whereas the coiled wire is soldered to the outer sleeve.

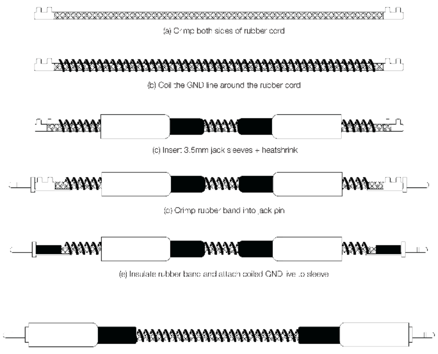


Figure 3: Patch-corde's assembly process.

3.3 Circuit Design

To sense the change in resistance of this piezo-resistive rubber band, an analog circuit consisting of two stages, a sensing stage, and a gain/bias stage as shown in Figure 4, has been developed. A current that flows through the cord connects to the inverting pin (V-) of a transimpedance amplifier (TIA). The feedback resistor was carefully selected to maximize the voltage observed on the output terminal without saturation. The second stage of the circuit constitutes of two gain circuits. The first adds a fixed voltage boost through a non-inverting configuration, while the second allows an adjustable gain using a potentiometer wired in negative feedback through the inverting pin (V-) and the output of an inverting amplifier. The op-amp in use in this circuit is the TL23704 and is powered by +12 and -12V from the Eurorack power buses. Finally, an envelope follower connects to an LED at the output terminal to indicate signal.

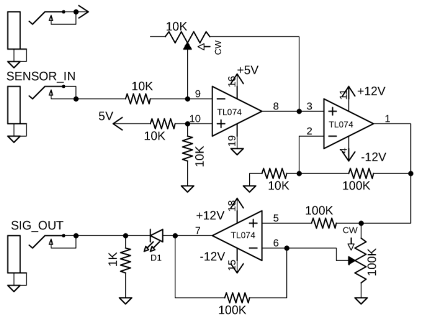


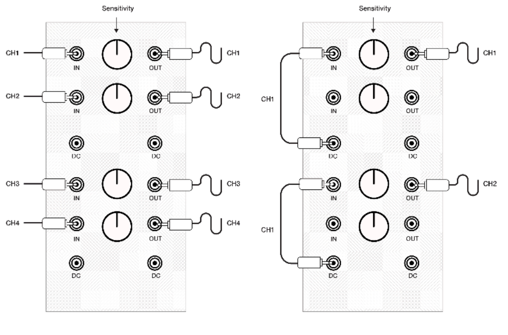
Figure 4: Two stages in the conditioning circuit.

3.4 Module Design

A module compatible with the Eurorack standard was designed to integrate the Patch-corde with other modules on the modular synthesizers. The module is 10HP wide (horizontal pitch) and 3U long (rack units). It includes 4 instances of the circuit shown in Figure 4. The module can operate in two modes, one using an external AC signal from another module presented on the right side of the panel with a regular patch cable, and the other on the left side where the Patch-corde connects the module to any other module in a given patch. In this configuration the transmitted AC signal will be affected by the manipulation of the Patch-corde, i.e., an amplitude drop in the original signal is observed while stretching the Patch-corde. When used in a self-patched mode, using the module's internal DC outputs, a dynamic DC signal is noted on the output terminals of the module based on the Patch-corde's state.

4. DESIGN AND INTERACTION

A single patch-corde is designed to look and feel similarly to other patch cables in the modular synthesizer scene, and through its form factor of a stretchy rubber band it provides a number of affordances that can be explored as physical music gestures. A vocabulary of interactions is created based on the Patch-corde for altering the output signal of the patch through the physical manipulation of the cord. A basic language of gestures is proposed to make use of the stretchiness, malleability and thin/flexible form factors as a foundation for a number of expressions. Two different dynamics are identified, that were applicable to how the cable is manipulated. One dynamic refers to slowly deforming the cable to generate small changes over time; this refers to a continuous type of gesture performed by the player. The second is discrete, where burst in the signal are creatively used in a certain patch. Given these dynamics we divided our interaction vocabulary in two types: continuous vs. discrete.



AC Signal IN / FlexPatch OUT

Self Patch Mode DC IN / FlexPatch OUT

Figure 5: The module's modes of operation.

4.1 Continuous Gestures

Continuous interactions refer to gestures where the performer applies a constant force to the rubber band by varying the direction and amount of force in their action. The rubber band therefore, either stretches or compresses. A few examples of continuous interactions include: stretching, where the cord is pulled apart in opposite directions; this causes the resistance of the cable to increase and therefore attenuating the signal. For instance this motion could be used to modulate the cut-off frequency of a low pass filter. Pressing gestures allow the performer to roll the cable and press with a single hand, same as the rubber cord is pressed the resistance decreases, causing the opposite effect of the stretching motion. Pinching is a variant of pressing and consists of the fine grained gesture of pressing on a given part of the rubber cord. In continuous gestures, the resistance will be kept at a constant level as long as the cable is being either stretched or pressed – allowing the performer to 'hold' on a specific output voltage and vary it by applying more force, or letting the patch cable flex back to its original state of relaxation.

4.2 Discrete Gestures

Discrete gestures are composed of momentary, short burst actions where the performer generates spikes by quickly manipulating the patch cord. One example is plucking, where the performer can pluck the cord in a similar motion as to strumming a guitar or bass. This gesture will cause a quick variation in resistance and consequently resulting with sudden variation in the patch. The same effect can be observed by hitting or patting the cable quickly. Due to their momentary nature, the discrete gestures can work well for rhythmic or percussive sounds that require a trigger or short impulse. A few examples of gestures include wiggling where the performer moves the rubber band in a zig-zag motion or twisting where the band is quickly twisted in back and forth motion. We have successfully implemented filters to separately produce fast and slow gestures at separate control outputs allowing each type of motion to control a different parameter.

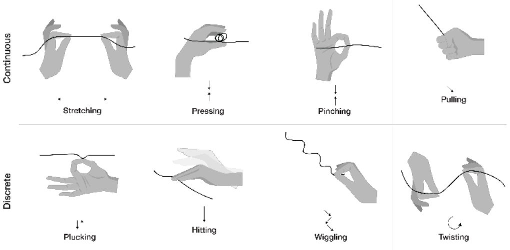


Figure 6: Physical gestures interaction vocabulary.

5. FUTURE WORK

To better understand and explore the affordances of using a deformable patch cable as an input device in a given patch, a user study could be formed that invites modular synthesizers builders and hobbyists, as well as professional. On the other hand, both the board and the face-plate could be revised and re-designed to explore different functionality and aesthetics. Moreover, an entire new circuit design, printed on a flexible PCB, could integrate within the patch cable itself, removing the need of having a separate module while exhibiting similar interactions.

6. CONCLUSION

With the renaissance of the modular synthesizer in today's age of music making, and with the abundance of modules in the market, the number of modular synth builders have increased. Several challenges remain in providing novel ways to controlling this personal and unique instrument. This paper proposed a new family of patch cables, inspired by years of research in HCI and novel music interfaces, that rely on deformation through stretching, plucking, pressing and other known physical interactions with cords. A vocabulary of interactions was presented through use cases, and was labeled into two categories: continuous vs discrete. Finally, a technique to developing this special patch cable was documented, as well as a sensor conditioning circuit and a module allowing several cables to work all at once within a given patch.

7. REFERENCES

[1] Conductive rubber cord stretch sensor specifications. *https://www.adafruit.com/product/519.*

[2] Doepfer a-100 technical details. *http://www.doepfer.de/a100_man/a100t_e.htm.*

[3] Lighted patch cables. *https://www.logsdonaudio.com/synth-cables/.*

[4] Tiptop audio's stackable patch cable. *http://tiptopaudio.com/stackcable/.*

[5] A. Barenca and G. Torre. The manipuller: Strings manipulation and multi-dimensional force sensing. In *NIME*, pages 232–235, 2011.

[6] B. Bongers. Electronic musical instruments: Experiences of a new luthier. *Leonardo Music Journal*, pages 9–16, 2007.

[7] D. Buchla. A history of buchla's musical instruments. In *Proceedings of the 2005 conference on New interfaces for musical expression*, pages 1–1, 2005.

[8] A. Chang and H. Ishii. Zstretch: a stretchy fabric music controller. In *Proceedings of the 7th international conference on New interfaces for musical expression*, pages 46–49, 2007.

[9] V. Krefeld and M. Waisvisz. The hand in the web: An interview with michel waisvisz. *Computer music journal*, 14(2):28–33, 1990.

[10] J. A. Paradiso. Electronic music: new ways to play. *IEEE spectrum*, 34(12):18–30, 1997.

[11] J. A. Paradiso. The modular explosion-deja vu or something new? In *Voltage Connect Conference, Berklee College of Music, Boston MA*, 2017.

[12] B. Rossmy and A. Wiethoff. The modular backward evolution–why to use outdated technologies. In *Proceedings from the International Conference on New Interfaces for Musical Expression (343-348). Porto Alegre, Brazil*, 2019.

[13] P. Schoessler, S.-w. Leigh, K. Jagannath, P. van Hoof, and H. Ishii. Cord uis: controlling devices with augmented cables. In *Proceedings of the Ninth International Conference on Tangible, Embedded, and Embodied Interaction*, pages 395–398, 2015.

[14] J. Schwarz, C. Harrison, S. Hudson, and J. Mankoff. Cord input: an intuitive, high-accuracy, multi-degree-of-freedom input method for mobile devices. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 1657–1660, 2010.

[15] E. Singer. Sonic banana: A novel bend-sensor-based midi controller. In *NIME*, pages 220–221. Citeseer, 2003.

[16] G. T. Toussaint et al. The euclidean algorithm generates traditional musical rhythms. In *Proceedings of BRIDGES: Mathematical Connections in Art, Music and Science*, pages 47–56, 2005.

[17] G. M. Troiano, E. W. Pedersen, and K. Hornbæk. Deformable interfaces for performing music. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*, pages 377–386, 2015.

[18] I. Wicaksono and J. A. Paradiso. Fabrickeyboard: multimodal textile sensate media as an expressive and deformable musical interface. In *NIME*, pages 348–353, 2017.

[19] R. Wimmer and P. Baudisch. Modular and deformable touch-sensitive surfaces based on time domain reflectometry. In *ACM symposium on UI, software, and technology*, pages 517–526, 2011.