THE LATTICE HARP: A NEW HYBRID INSTRUMENT AND CONTROLLER

Colin Raffel, Nick Kruge, Diane Douglas, Edgar Berdahl, Wendy Ju
Stanford University
CCRMA, Stanford, CA, USA
{craffel,nkruge,eberdahl,wendyju,ddouglas}@ccrma.stanford.edu

ABSTRACT

This paper describes the Lattice Harp, a new musical instrument which functions simultaneously as an acoustic instrument and a hardware controller. The Lattice Harp consists of two overlaid, perpendicular planes of strings which are electrically connected to a microcontroller. The microcontroller detects when two strings are touching and treats this data as a button being pressed. Furthermore, each string has an individual piezoelectric pickup, which allows for the strings to be separately amplified and processed while providing a method for continuous control. The pairing of normally separate performance paradigms affords new, interesting, and unexpected performance techniques.

1. INTRODUCTION

Most modern music controllers use knobs, buttons, and similar components which are mapped to sound generation parameters. However, an instrumental music performer has historically been considered to be someone who plays a physical instrument, not someone who manipulates control devices, as expressed in [9]. Most products fall either into the category of a musical instrument or a controller, and most frequently those that qualify as both owe much more to one type of device than the other. For example, augmented guitars have been designed which can be used for musical software control, but they maintain the form factor of a guitar, which was not intended for such use [2].

The main motivation behind the Lattice Harp is to explore the possibilities of a device which is designed for both instrumentation and control purposes. The end result is a useful tool for either application, but is more importantly an exchange between these two paradigms. With a typical hardware controller, few unexpected "features" arise. After all, such devices are typically engineered so that they work exactly as intended, with very little room for error or side effects. However, the process of discovering unexpected uses of an instrument can promote creativity and musicality. For example, John Cage's prepared piano is an entirely unintended performance method for the piano but has proven to be a popular modern use of the instrument [10]. The Lattice Harp brings the artistic process of discovery to the hardware world.

While many single-plane instruments exist, such as the hammered dulcimer, harp, and zither, the concept of a two-dimensional string instrument has not been fully explored. By adding a second layer of strings and allowing them to be tuned freely, different string crossings can represent different music intervals between notes. For example, if both planes are tuned to the same major scale, each crossing along a single string corresponds to a distinct interval in the scale. Furthermore, the strings can act as visual cues for distances along each string because of the regular placement of the bridges. This is particularly useful when finding harmonic node locations; for example, the midpoint of a string is delineated by the fourth and fifth strings on the opposite axis.

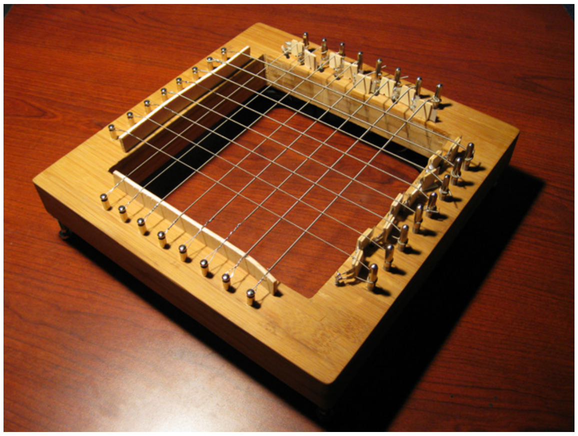

Figure 1. Prototype of the Lattice Harp

2. DESIGN AND CONSTRUCTION

A prototype Lattice Harp can be seen in Figure 1. The Lattice Harp consists of a wooden frame on which sixteen strings are mounted, organized in two sets of eight traveling perpendicularly. For the prototype's frame, we chose a solid block of bamboo. Bamboo has a high strength-to-weight ratio, which ensures that the frame does not buckle under tension and makes the instrument more portable. To allow the user to play the strings from above and below the frame,

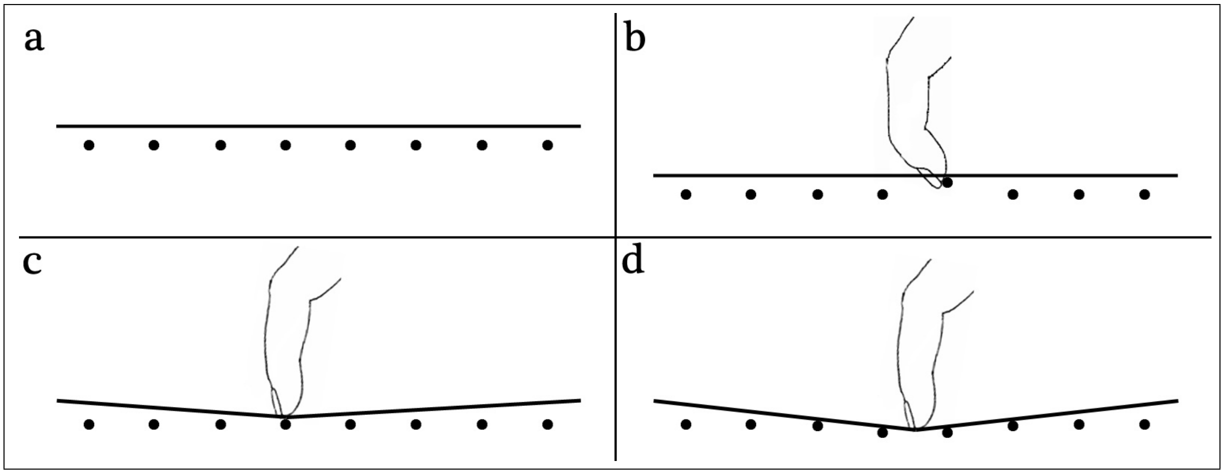

Figure 2. Different ways of creating button presses. a) Cross section of the strings with no pressing. b) Plucking the strings with the fingernail to create a momentary button press. c) Pressing the strings together to connect them electronically without sound. d) Pressing multiple strings at once.

we hollowed out the center section of the wooden block. Each side of the frame terminates eight of the strings. On two sides, the strings are wrapped around tuning pins and travel over individual, two-layer bridges in which piezoelectric transducers are sandwiched. On the other two sides, the strings share a large bridge and terminate at fixed end pins. The horizontal distance between strings generously approximates a normal picking finger size. The string planes are vertically offset by a few millimeters so that the strings only touch when they are meant to, as shown in Figure 2a.

Each of the end pins is connected electronically to an AVR microcontroller. The microcontroller treats each string as a row or column in a typical scanning button matrix [6]. Specifically, one dimension of strings acts as a series of normally high input pins, while the other dimension cyclically sets its pins low. In this way, when two strings touch, the microcontroller detects a low voltage on the corresponding input and subsequently sends out a serial message. To ensure reliable press data, we also used a counter-based debouncing method [7]. With two planes of eight strings, the Lattice Harp functions as a 64-button controller, with a virtual button at each string intersection. Each of the bridge-mounted piezoelectric elements is separately connected to a DB25 connector by shielded audio cable. We created a number of breakout snake cables to connect to the DB25 jack according to various Lattice Harp setups.

3. TUNING AND ACTUATION

The Lattice Harp's design allows it to be freely tuned as a sixteen string instrument. On a basic level, if each string plane is tuned equivalently, the Lattice Harp begins to act like a mandolin, piano, or other instrument that relies on sympathetic vibrations [8]. A more interesting tuning involves one plane of strings tuned to a major scale, with the other eight strings tuned to accidentals or major mode extensions. In any tuning, the different string crossing locations represent different intervals, allowing for a graphical way of playing music. This concept has been explored in commericial hardware controllers such as the AXiS 64 and Omnichord. As an example tuning, a major scale with extensions in the key of B is shown in Figure 3. As each vertical string is traversed, the corresponding interval increments or decrements by one, making the tuning more intuitive.

	E3	F#3	G#3	B4	F#4	B5	C#5	D#5
B4	P5	P4	m3	P1	P5	P8	M9	M10
C#4	M6	P5	P4	M2	P4	m7	P8	M9
D#4	M7	M6	P5	M3	m3	M6	m7	P8
E4	P8	m7	m6	P4	M2	P5	M6	M7
F#4	M9	P8	m7	P5	P1	P4	P5	M6
G#4	M10	M9	P8	M6	M2	m3	P4	P5
A#5	P11	M10	M9	M7	M3	m2	m3	P4
B5	P12	P11	m10	P8	P4	P1	M2	m3

Figure 3. A possible tuning of the Lattice Harp, with intervals labeled at each string crossing

The instrument's strings can be made to vibrate through a variety of methods. The orginal intention was to have the strings plucked with the players fingers or a pick, so that when two overlaying strings were plucked together, a button press would simultaneously occur. Similarly, the player can actuate the strings by striking them with a mallet, in the way that a hammered dulcimer is played. The strings can be set to vibrate gradually through use of electromagnet devices, including the commercially available eBow and the Electromagnetically Prepared Piano [1]. Sympathetic vibrations can also occur, depending on the instrument's tuning.

4. DATA MAPPING

The connected microcontroller sends messages over USB which loosely conform to the Monome serial protocol [3]. In this way, the Lattice Harp can make use of the growing number of software applications written for button matrix devices [4]. On the connected computer, the serial messages can also be translated to OSC (Open Sound Control) [11] or MIDI and sent to compliant software. Output levels from the piezoelectric transducers can be treated as separate control data by processing the signals in software. In this way, a button press event can occur when two perpendicular strings are vibrating, as shown in Figure 4b. The amplitude output of the transducers can also be used as analog control, so that as the player causes a string to vibrate more, a software parameter increases. One possible mapping could measure the time between any two button presses to set the tempo of an echo effect, use the location of a button press to determine what strings the effect was applied to, and use the output levels of the corresponding strings to set the regeneration rate and timbre of the echo signal.

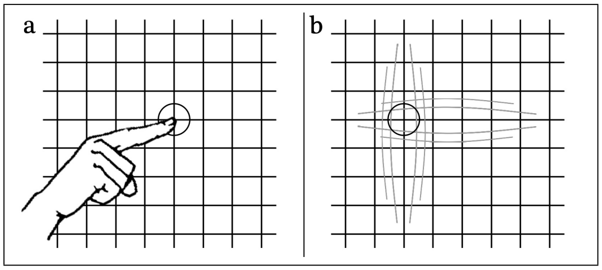

Figure 4. Possible ways of treating string crossings as buttons. A circle represents an interpreted press location. a) When strings touch. b) When two crossing strings are vibrating.

5. USAGE

When experimenting with button press data, the most reliable results were obtained when plucking the strings with metal picks such as those used with banjos. In this way, whenever two crossing strings touched the conductive metal pick closed the circuit and the microcontroller registered a button press. The main drawback of this method was that a press event would occur before the string was plucked if the user rested the pick on a string intersection. We also obtained fairly reliable control data when relying on strings touching during a pluck without a metal pick. This method is shown in Figure 2b. When treating two vibrating strings as a press location, the data was not as reliable, but nevertheless provided interesting additional control possibilities. On the Lattice Harp, it is also possible to cause a press event by physically pushing crossing strings together, much like a force-feedback version of a typical button pad. Figure 2c visualizes this type of pressing. This also gave reliable data, and provided a way to control software without any resulting acoustic sound. One interesting side effect of this method was that as the string was pressed down further, it would begin to touch additional strings, so that multiple button presses were registered as a result of more pressure, as seen in Figure 2d. Finally, when simply placing or dropping metal objects onto the strings, the microcontroller registers press locations where the objects rest. Because of the physicality of this method, the player can create press event patterns with a clear visual basis.

One anticipated problem with the Lattice Harp was ghosting. Ghosting is a well-known effect in button matrices which appears when multiple button events occur simultaneously [6]. Because of the way the matrix is scanned, if three button presses occur in locations that correspond to corners of a rectangle, the button at the fourth corner of the rectangle will also be registered as down. This effect is typically engineered out of button matrix systems. In the Lattice Harp, however, it can be used to create more interesting press patterns. For example, the player can simultaneously press a row and a column of strings together to create filled square of presses. Ghosting also occurs when treating string vibration as button presses, but when anticipated, can similarly be interpreted as useful control data.

Because each string is given its own pickup, many audio mappings are possible. In a room with multiple speakers, different groups of strings can be panned to locations in the room. When connected through an audio interface to a computer, strings may be individually processed in software. One useful application of the Lattice Harp system is to use press data to determine what processing is being applied to each string. Because the tuning of the lattice harp is known, it is easy to apply processing or synthesis which is harmonically related to the vibrating strings. For example, different press locations can be interpreted as members of a harmonic mode to which the Lattice Harp is tuned. This method was explored in *Tracing Patterns With the Cobwebs*, a piece composed for the Lattice Harp [5].

6. CONCLUSION

Our main difficulty when building our first prototype was ensuring that different aspects of the instrument were built accurately enough. For example, to guarantee reliable press data, the distance between the two planes of strings needed to be constant and accurate. Another difficulty was preventing audio interference between our button detection circuitry and the piezoelectric pickups. It is also tedious to wire and tune a sixteen-string instrument. We are hoping to remedy some of these problems in future Lattice Harp prototypes.

We have found that the combination of a musical instrument and controller allows for unexpected and interesting performance techniques. In particular, the various possible button press techniques, side effects such as ghosting, and string vibration methods together create a unique feature set. By correlating the software mapping and instrument tuning, a strong link can be made between the sounds generated acoustically and on the computer. The Lattice Harp borrows ideas from typical musical instruments and hardware controllers, making a new, but immediately familiar device. As a hybrid instrument and controller, the Lattice Harp represents a new musical performance paradigm.

7. ACKNOWLEDGEMENTS

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8. REFERENCES

[1] E. Berdahl, S. Backer, and J. O. Smith, “If I had a hammer: Design and theory of an electromagnetically-prepared piano,” in *ICMC 2005 Proceedings*. International Computer Music Conference, September 2005.

[2] E. Berdahl and J. O. Smith, “A tangible virtual vibrating string,” in *NIME08 Conference Proceedings*. New Interfaces for Musical Expression, June 2008, pp. 299–302.

[3] B. Crabtree, “Serial protocol,” http://docs.monome.org/doku.php?id=tech:protocol:40h, February 2008.

[4] ——, “Application list,” http://docs.monome.org/doku.php, December 2009.

[5] D. Douglas, C. Raffel, and N. Kruge, “Composition and interface design for the lattice harp: ”Tracing Patterns With the Cobwebs,” January 2010.

[6] D. Dribin, “Keyboard matrix help,” http://www.dribin.org/dave/keyboard/keyboard.pdf, June 2000.

[7] J. Ganssle, “A guide to debouncing,” http://www.ganssle.com/debouncing.pdf, August 2004.

[8] B. Hopkin, *Musical instrument design: Practical information for instrument making*. Tucson, Arizona: See Sharp Press, 1996.

[9] A. Luciani, J.-L. Florens, D. Courouss, and C. Cadoz, “Ergotic sounds,” in *Enactive 07 Conference Proceedings*. Enactive, November 2007, pp. 373–376.

[10] T. Ovens, “The sound collector the prepared piano of John Cage,” in *Anarchische Harmonie - John Cage und die Zukunft der Künste*. Anarchische Harmonie, April 2002, pp. 141–149.

[11] M. Wright, “Brief overview of OSC and its application areas,” in *Open Sound Control Conference 2004 Proceedings*. CNMAT, July 2004.