David Wessel's Slabs: a case study in Preventative Digital Musical Instrument Conservation

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ABSTRACT

David Wessel's Slabs is being conserved as an important element of CNMAT's collection of electronic music and computer music instruments and controllers. This paper describes the strategies being developed to conserve the instrument and how we are reaching for the goals of both maintaining the symbolic value of the instrument as a prize-winning, highly-regarded example of the "composed instrument" paradigm and "use value" as an example students and scholars can interact with to develop their own composed instruments. Conservation required a sensitive reconfiguration and rehousing of this unique instrument that preserves key original components while rearranging them and protecting them from wear and damage.

1. INTRODUCTION

We are losing the generation of pioneers of digital computer-based musical instruments – notably most recently Max Mathews in 2011 and David Wessel in 2014. Conserving their existing instruments serves this and future generations of musical instrument makers, performers and composers. It will also yield insight into important questions about the ephemerality of certain approaches to contemporary instrument and controller building.

This paper outlines the plan for conservation of David Wessel's award winning "Slabs" instrument [4]. This represents the current snapshot of a plan that by necessity is in flux as new solutions are sought to the inevitable impacts of entropy. Conservation is a process that never ends, one that requires an explicit plan and documentation to guide future custodians of the instrument who in turn will update the plan.

Our plan is informed by a valuable survey of the ethical and practical issues involved in conserving electronic instruments [2] that emerged from the challenges of conserving and restoring an important collection of Ondes Martenot instruments. Practical issues to be considered include the management of trapped moisture and exposures to light, causes of accelerate aging of metals and plastics respectively.

The first author has had direct experience with such issues when called on to repair ailing Ondes Martenot instruments in the San Francisco Bay Area In one case keyboard contacts were corroded by saline, humid air trapped with the instrument when it was returned to its case on a particularly foggy day [1].

Figure 1: David Wessel with his Slabs

2. SIGNIFICANCE OF THE SLABS

While other digital musical instruments have some of the following valuable qualities, the Slabs is a unique example of an instrument that integrates all of them:

- High temporal resolution (6kHz) and repeatability
- Homogeneous, Many-touch Surface Controller
- Continuous, wide dynamic range of force control
- Played regularly over relatively long period from its predecessor instrument the Buchla Thunder in 1990 until October of 2014.
- Calibration, control structure mappings sound and spatialization programmed by David Wessel qualifying it as a "composed instrument"
- Incorporates 8-channels of audio output for flexible diffusion
- Audio rate gesture representation
- Supports conventional hand drumming gestures and supports, new stroking gestures
- Articulated design aesthetic: "no ceiling on virtuosity"

- Invites and affords practice and rehearsal and coevolutionary design
- Reliable throughout all performances
- Survived numerous airport luggage and security inspection cycles
- Award winning and the subject of many keynote presentations and concert invitations
- Typifies an important design pattern: a custom gesture controller attached by high speed link (Ethernet) to a laptop computer running a media programming language (Max/MSP)

3. GOALS OF CONSERVATION

The Slabs will enter CNMAT's collection of input devices, musical controllers and instruments – a collection maintained of working instruments that support our pedagogical mission and research into the design of future instruments. This diverse collection includes game controllers, computer pointing devices, Buchla Thunder, Lightening, a Mathews Radio Drum, guitars with hexaphonic pickups, midi keyboards and "alternative controllers," and numerous research prototypes. The rarity of some of these holdings and cost constraints means we have to take the position of preventative conservation–not precluded playing the instruments entirely but managing storage, access and use of the instruments to prevent accelerated ageing.

These goals reflect an institutionalized enthusiasm at CNMAT for showing composers and performers how they can use experience with existing instruments to inform the design of new ones.

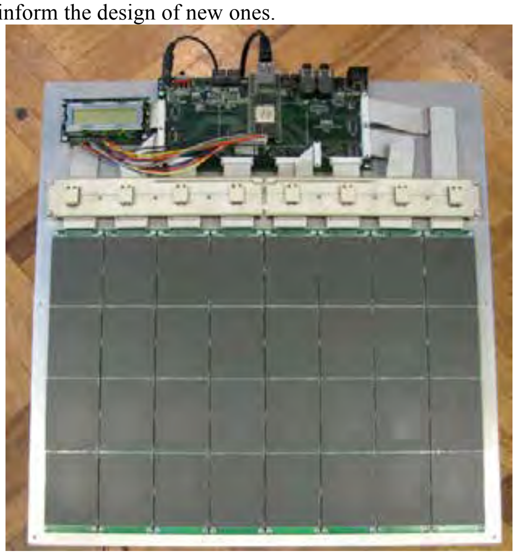

Figure 2. Slabs Controller

4. ANALYSIS

4.1 Macintosh Laptop computer

As a component manufactured in high volume, the original laptop computer from Apple that controls the Slabs is readily conserved by being carefully stored and replaced by a second machine of the same type that has been optimized for longevity in the face of the rigors of performance. The unique component of the original laptop is the bit pattern stored on its hard drive that reflects the bulk of the intellectual effort that went into the instrument including the sounds and control software chosen and written by David Wessel. After being backed up, the data from the original hard drive was transferred to an SSD drive which is inherently more reliable because it has no moving parts and lower power consumption.

To maximize the working life of the new laptop, its hard drive and airport wireless card were removed, it was cleaned of dust and new fans were installed. The SSD drive is powered and installed externally to simplify its replacement and minimize power drawn from the laptop. The following related measures are intended to minimize the accelerated aging that electronic components exhibit at higher temperatures:

- Tuned Energy Saving Settings
- Laptop cooling stand
- Minimizing GPU usage
- Eliminating unnecessary daemons and associated CPU and disk activity unrelated to playing the instrument, e.g., Spotlight.

It is not practical to continuously update the operating system, special Ethernet driver or Max/MSP because of the prohibitive high cost involved and the likelihood the look and feel of the instrument would change. This represents a conservation conundrum because one of the key distinguishing features of digital musical instruments such as the Slabs is that they can be reprogrammed.

Our solution to this conundrum is to provide access to a locked (read only) version of the original Max/MSP software for the machine that supports exploration of the machine in the state David Wessel left it in. Complementing this is a set of baseline patches on which new control structures may be built for the purposes of exploration. Developers of new patches bring their own storage media for this purpose to minimize ageing of the locked SSD drive.

For more ambitious development a patch will be provided that transmits the gestural information from the Slabs as OSC messages to external computers that people can connect up and develop without constraints of legacy operating systems and Max/MSP.

4.2 DAC

Standalone D/A converters with ADAT optical interfaces are readily available as replacements should the original unit fail. After careful dust removal from plug and socket, the optical cable connecting the Slabs to the DAC is plugged in and the seam between plug and socket is sealed with silicone to prevent dust from entering. The silicone can be easily removed and replaced should the cable or DAC need replacement.

4.3 The Slabs Controller

The Slabs controller itself is the most challenging component from the conservation perspective.

4.3.1 The 4x8 Touchpad Array

The VersaPad semiconductive touchpad (by Interlink Electronics) is used to estimate the X and Y position and applied force (Z) of fingers touching its surface. It is usually used as a pointing device in laptop computers and in hand-written signature recognition applications.

The VersaPad consists of a stack of four layers: a base, two sensor layers of resistive film, and a touchpad surface on top. Each sensor layer is made up of two conductive traces (at opposite ends of the device) that are connected to each other through a resistive material. The two sensor layers are rotated 90 degrees with respect to one another, so there is one conductive trace along each edge of the device. These 4 silver, conductive traces are brought to the exterior of the pad by a short length of plastic, flexible flat cable. When an object touches the touchpad the two sensor layers come into contact at the point of applied pressure.

This results in a pressure-dependent resistance between the two layers at the point of contact, and a position-dependent resistance between the point of contact and the conductive traces on each sensor layer. By measuring these resistances it is possible to estimate the location of the point of contact and the amount of force being applied. Interlink usually measures these resistances using an inexpensive PIC based microcontroller circuit (with only a few passive components) to sample the X, Y and Z values 40 times a second. Their patented approach is economical for a single trackpad but did not satisfy the goal for a higher sampling rate of 6kHz and furthermore it does not allow for concurrent sampling of the three measurands. Interlink's approach is to steer currents through the array and infer resistance values from the charge rates of capacitors. This introduces temporal uncertainty and delay which are avoided in a novel circuit by supplying a small constant current through the series-connected X, Y, Z resistors and concurrently converting the induced voltages across these resistors into digital values using a a multi-channel ADC.

4.3.2 Data Acquisition Hardware

The hardware system is made up of nine discrete PC boards shown in Figure 2. Eight of the boards are identical, with 4 touchpads mounted on top and analog conditioning circuitry and multichannel analog-to-digital converters on the bottom. These eight sensor boards are connected to the controller board, which is based around a Xilinx Virtex4 FX12 FPGA. The FPGA has an embedded PowerPC core that runs at 300 MHz. In addition to the FPGA, the controller board has 64M of DRAM, 8M of flash memory, a gigabit Ethernet interface, clock oscillators and a power supply.

4.3.3 Sensor Measurements via OSC

As there are the three X, Y, and Z (force) measurements from each pad there are a total of 32 x 3 = 96 values acquired and transmitted. The design operates in one of two modes. In the first mode, the touchpads are sampled at a low rate (0-200 Hz) and Open Sound Control (OSC) packets containing the measurement data are transmitted as UDP packets over the Ethernet interface. Each OSC packet gives the current X, Y, and Z values only for the pads that are currently being touched.

4.3.4 Sensor Measurements via Audio Signals

The second mode provides for audio sample synchronous output from the pad array. The touchpads are scanned at a one eighth the audio sampling rate (up to 6000 Hz), the data is up-sampled to audio rates (44.1 or 48 kHz), converted to 32-bit floating point, and then encapsulated in a stream of UDP packets which are sent over the Ethernet interface. To avoid performance limitations of the TCP/IP stack on the operating system, a custom driver on the host computer receives these packets and presents them to the operating system as a collection of audio input channels, thereby enabling high-rate control signals in audio processing applications. Max/MSP, provides for up to 512 audio input channels, more than enough for the 96 sensor inputs. This synchronous approach provides for more control intimacy as the gestures are encoded as jitter-free signals locked to the audio sample clock. Sampling the sensors at 1/8 the audio sampling rate results in high temporal resolution (or, equivalently, a wide bandwidth in the frequency domain) on the gestural signals produced by the human performer.

4.3.5 Conserving Baseboards

Only one controller baseboard was built and a key component, the digital FPGA module that sits on it, is no longer manufactured. This module was never made in large quantities and uses parts that have been obsoleted by the manufacturers. Spare parts for the trackpad baseboard and the controller baseboard are available as they were designed at CNMAT.

4.3.6 Conserving the Trackpads

The most troublesome components from the conservation perspective re the Interlink FSR Trackpads. Six months after the construction of the Slabs, it was discovered that the plastic flat cable that carries the four electrical connections from each Versapad is susceptible to brittle plastic failure. The design requires this cable to be bent through 180 degrees to attach to a connector under the pads.

Interlink refused to replace any of the spare parts that were bought ALL of which broke when attempts were made to bend the cable. Interlink claimed that they had never seen this problem due to the special manufacturing techniques they used. We believe the problem resulted from us being suppled old parts from a manufacturing overrun. These had become brittle and that the "special" manufacturing technique that Interlink didn't share with us was simply to bend the cable and insert it into a socket soon after initial manufacturing so that it never needs to be stressed later on as the plastic aged. This theory is supported by the fact that the current pads continue to work and it implies that that they are fragile and their removal would result in cable failure. We plan to build two replacement strips of Versapads using recently manufactured parts that have just entered the distribution channel as spares and eventually it would be wise to build a full set of new strips.

These difficulties with the Versapad turned out to be a productive stimulus for further research that resulted in new designs and new materials for piezoresistive pressure and position sensing surfaces. The recent availability of inkjet-printed conductive and resistive inks suggests that future instruments wouldn't need to be so dependent on a particular manufacturer and its processes. However reproducing the feel of the particular Versapad design used in the Slabs appears to be prohibitively challenging. Professor Wessel learned how to take advantage of the Versapad's strength at capturing low pressure gestures while also avoiding issues of hysteresis, drift and saturation at higher pressures. To learn about such techniques one has to be able to interact with the particular material properties of the Versapads.

Interlink FSR's rely on air gap to avoid the resistive layers sticking to each other from a vacuum that would otherwise form. This suggests that there may be a slow failure mechanism for the pads as dust enters the air gap. Cleaning with bursts of air may be possible but dismantling the pads themselves is not advised because they are so easily damaged in the process. The Versapad surfaces are separated by a thin layer of air and an array of very small, silicone dots which are difficult to repair or replace.

4.4 Stands and Enclosures

The circuit boards constituting the Slabs controller are attached to a solid aluminum base plate that sits (via a bracket) on a foldable floor stand. Although the possibility was often discussed, no case was ever built for the instrument. A small piece of acrylic was bent into a "U" shape and used during shipping to protect the electronics. A sheet of polyethylene foam served to protect the trackpads. Professor Wessel transported the Slabs by wrapping the controller in bubble wrap and packing it into a large polycarbonate suitcase. This is not a tenable arrangement in the long term as we cannot be sure future users of the instrument will be as careful and we can't risk transportation of this unique instrument in checked luggage.

A case is being built that the Slabs can sit in that is designed so that it doesn't interfere with the way the instrument was originally played. A lid will protect the instrument and control dust accumulation while avoiding the possibility of trapped air. An important part of this new case is that it extends sufficiently beyond the back of the instrument to allow for the cables required to configure the instrument to be permanently installed and attached to the case. This relieves wear and tear on cables and connectors and keeps the controller correctly wired to the other components of the instrument. The case includes a shelf below the Slabs to store the DAC, laptop and power supplies. Strong handles are provided so that the entire instrument can be carried from its shelf in CNMAT's musical instrument and controller library to nearby studios for exploratory performance.

Figure 3 The Slabs on collapsible stand

5. CONCLUSION

A wide range of strategies have been presented for conserving the Slabs instrument covering the problems of bit rot, heat accelerated aging, fragilities and wear of mechanical parts and electrical connections and to mitigate the effects of built-in obsolescence. A new case was described that better suits the planned uses of the instruments in the foreseeable future. All these choices were made in the context of the complex ethical issues associated with conservation of musical instruments [3] and in the spirit of Professor Wessel's intention that his instrument be a source of ideas and inspirations for others to design and build their own composed instruments rather than a model instrument to be directly replicated.

Acknowledgments

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6. REFERENCES

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