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Thesis Report
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String Thing

Exploring expressive complexity in music controller hardware interaction

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Abstract

The sight of a musician playing a traditional instrument, perhaps particularly a stringed one, is a satisfying and intelligible visual counterpart of the sound. Computer-generated and computer-enhanced sounds have enriched musical language and expression. But computer-based music performances still mostly involve people sitting rigidly behind a laptop, their fingers hidden by the screen. String Thing is a cello-like electronic instrument played by stroking or beating metal rods with the hands. The use of bodily gestures, infinitely variable and visible to the audience, avoids the ‘robotic’ and visually uncommunicative quality typical of computer music.

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1. Introduction

The goal of this thesis is to design a new control interface for interacting with music software, using familiar musical forms and techniques to create a highly responsive audiovisual connection between the musician, the sound and the audience. Computer music controller products available at this time can be disappointing to use, especially for musicians with experience in the complexity and sensitivity common in traditional instruments. I am exploring combinations of new technology and easily understood interactions to craft a physical interface that both inspires and requires complex new musical skills, beyond those of existing alternatives.

1.1 Expressive complexity

My interest is in the development of expressive and imaginative hardware controllers for new music and creative sound orientated software, intended to enhance the performance aspect of using music software in a live context. I wanted to explore ways of recreating the highly tangible qualities of traditional analogue musical instruments (such as physical feedback and resistance and a high level of dynamism) into music software controller devices, which essentially just send information (usually MIDI data) to a computer.

Much work has been done in this area, as seen in many emerging electronic drum kits, guitars, violins etc. simulating known instruments and established interaction techniques, as well as more abstract devices and controllers. However I feel there is still a great need for new devices and controllers that could be seen as ‘real’ instruments in their own right, where a live performance of computer music could be as thrilling as seeing a real live band playing real instruments and where there could be a similar level of appreciation for the ability to learn to use and master an instrument.

In my opinion, attempts to replicate the excitement of playing ‘real’ musical instruments, with computers, has been mostly unconvincing. I want to find out why this is. I am interested in investigating the raw qualities of popular musical instruments, to explore ways of applying these established interactive qualities to new structures that can open up new creative possibilities. It’s been a while since anyone made any really new musical instruments in the traditional sense of the self-contained sound producing device, although there are software programs which may be considered to be musical instruments.

1.2 Research questions

The research questions raised in this thesis are;

- How can music or creative sound orientated software be controlled or accessed through more expressive forms of hardware that can possess the levels of detail and subtlety found in traditional musical instruments, to allow scope for really learning to play software as if it had physical properties which affected sound?
- How might haptic feedback technology be utilised here to provide a more intuitively satisfying acoustic experience?
- How can these controllers or devices contribute to more exciting and convincing live performance involving electronic or computer music?
- What could this thesis bring to the realm of music software controllers that is new and interesting?

1.3 General thoughts about music controllers

The area of research this project primarily concerns is the design of hardware controller devices for digital/computer music software environments, and new developments that might suggest possibilities for future hardware designs, as musician’s needs and wants evolve. This subject area is very broad, potentially involving a seemingly infinite number of hardware and software issues, and the subject of much attention over the last thirty years or so, as modern electronic music has evolved with technological developments and cultural shifts. So it is important to isolate the elements of particular interest and importance to the theme, without missing vital information from the rich history of electronic and computer music hardware and software interaction.

A major question motivating this thesis topic, as much a cultural issue as a technical one is why since its introduction in 1982-83, MIDI based hardware control and networking has not progressed dramatically. Why are we still limited to basic keyboards, knobs and sliders (as well as the computer keyboard and mouse) to control music software? As an alternative to playing traditional musical instruments, these MIDI controller devices seem of quite low resolution in terms of expressivity, detail and dynamics, qualities that once learnt from a traditional instrument can be greatly missed once the musician enters the digital domain. There is a considerable technical challenge in translating into useful digital data, all the subtle nuances and techniques used by a musician who may have spent a considerable amount of time learning to control and manipulate the acoustic qualities of a refined physical structure.

The other factor important in this process is time; how long it takes for the translation of physical gesture to digital information, also known as ‘latency’ (more commonly in the realm of processing real-time audio) or ‘lag’ (more commonly in the case of converting analogue action to MIDI note/pitch/velocity tracking).

An often used phrase in the realm of digital music is ‘real-time’, an ideal of many music systems to maintain the illusion of the imagined instantaneous virtual-physical reaction to a musical action. For a truly convincing experience when playing digital instruments, the time taken between the musician’s action and the resulting sonic feedback must be imperceptible.

Electronic or computer music hardware control use needs some attention in terms of providing the satisfying and challenging tangible experience anticipated by those musicians possessing many skills for playing traditional, analogue instruments. This subject area is problematic for a variety of reasons, the most obvious being that it is and has been well explored for many years by many talented and intelligent people. Bringing something new, useful or even interesting to this area of research and design is a big challenge. For all the seemingly revolutionary controller devices and gesture-recognition systems constantly being created around the world, the main tools most commonly used by musicians incorporating computers into performance still seem to consist of the same old MIDI controllers and keyboards we have had for the last 20 years or so.

My immediate thought is that many of these inventions seem to exploit various technologies for the sake of exploring the interactive potential of the technology, as opposed to really concentrating on musician’s needs and expectations, and equally, live performance and audience interaction. I want to explore the blend of elements involving the physical, visual, aesthetic, feedback and control qualities that make an exciting acoustic experience, and how these elements can be successfully integrated into an interactive or computer system to enhance some aspects of computer music performance. While I can't claim this to be a *new* approach to exploring computer music interaction, I feel I have a strong sense of 'what I want and expect in an instrument' as a practicing musician, which should drive the project to towards something useful and desirable. There is still a healthy appetite in this area of computer interaction, for more innovation combined with a serious understanding and passion for playing and performing with musical instruments.

An interesting confusion that I have observed in discussing this topic is the difference between the concept of a *musical instrument*, and a *musical controller*. It seems the boundary between what defines the two objects is becoming slightly blurred in terms of design criteria and function?

This is potentially serious for any proposal for new music controller designs, where the common comparison of computer music systems to traditional analogue instruments can often be seen as unfair. The traditional idea of a musical instrument suggests that it should function as a completely stand-alone system. The design is often a refined assimilation of physical and sonic harmony, with a clear historical and cultural position. The computer music controller has a simpler but not necessarily less sophisticated main function of inspiring and capturing the musician's physical gestures.

Designing and producing controllers allows far more freedom in terms of physical qualities because they generally do not need specific sonic properties. As designers produce increasingly complex controllers and utilise new technologies, while also borrowing from traditional instrument design, it seems inevitable that this comparison becomes more complicated. Before looking in detail at some of the technological aspects involved in computer music controller development, it is interesting to take into account the *Principles for Designing Computer Music Controllers*[1] by Perry Cook – representing the author's philosophy developed over 15 years of designing and constructing computer music controllers.

Some Human/Artistic Principles
1) Programmability is a curse
2) Smart instruments are often not smart
3) Copying an instrument is dumb, leveraging expert technique is smart
4) Some players have spare bandwidth, some do not
5) Make a piece, not an instrument or controller
6) Instant music, subtlety later

Some Technological Principles
7) MIDI = Miracle, Industry Designed, (In)adequate
8) Batteries Die (a command, not an observation)
9) Wires are not that bad (compared to wireless)

Some Other Principles
10) New algorithms suggest new controllers
11) New controllers suggest new algorithms
12) Existing instruments suggest new controllers
13) Everyday objects suggest amusing controllers

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[1] Cook, Perry. *Principles for Designing Computer Music Controllers*. Conference Proceedings NIME (2001) <http://www.csl.sony.co.jp/person/poup/research/chi2000wshp/papers/cook.pdf>

1.4 Inspiration and frustrations

As previously stated, the field of musical controller development is vast, with the underlying fundamental problem of designing interfaces to make sense (or nonsense) of the infinite combinations of computer gesture recognition and sound manipulation processes. Since the computer was first used for creating musical sounds, by Max Mathews in 1957, people have been thinking about and building processes for physically grasping the sound within the computer, to be able to play these sounds as one plays the sound of the traditional concept of the musical instrument.

In the case of computer music, the emerging trend for thinking about sound and physical interface as separate entities has split the concept of the traditional musical instrument into two clearly defined parts, the interface connecting the musician outside the computer to the digital sound floating around inside it, with varying degrees of success.

How can a combination of sound and interface be judged successful or not? This is largely a personal opinion, when essentially any sound can be controlled with any interface design, and the quality of the arrangement will widely vary in comfort, acceptability, and aesthetics. Manipulation and performances of certain sounds by seemingly unrelated or ridiculous physical systems may make perfect sense in the future.

In this thesis I have chosen to look at music controllers aimed at performing the task of being generic tools; platforms for musicians seeking methods for creating highly configurable and useful ways of controlling and performing with computer based music.

String interface designs are of particular interest to this thesis, mainly due to personal preference. Stringed instruments and the way they are played usually have an effective sound and visual harmony, that the audience can easily make sense of what they see the musician doing and the resulting music. An instrument like the cello or guitar visually broadcasts the player’s actions, due to its physical design and the way it relates to the body of the performer. A clear and satisfying visual performance language matches the sonic properties and physical control apparent in many stringed instrument designs, a major source of inspiration for this thesis.

The interaction model of string manipulation to create musical sound, as well as breath control in wind instruments and rhythmic physical attack in percussion instruments, where the player has a direct, continuous physical connection with a sound-producing element can result in a very direct, emotional musical quality. This may be because of the way the human ear perceives sounds and recognises the similarity of the human voice to these continuous sonic qualities. The texture of these sounds can be considered to have personality, something very difficult to create or emulate using the keyboard model, a far more mechanical and rigid model of interaction. The interest for this thesis lies in the fact that the keyboard model of interaction is successfully catered for by computer music controllers; the problem lies in the ability to provide more expressive control.

The common techniques used in the research and development of string-based instrument models and computer music controllers are primarily based around sensing the player's finger position along the length of a string, and the method of attack used to make the string vibrate. Interpretation of these gestures can be used to control other sound sources and musical systems. In the case of the guitar, the attack is a varying degree of striking the strings with the fingers or another tool; for classical stringed instruments such as the violin, cello and double bass, there has been great interest in mapping the expressive motions and techniques used in bowing the strings. Other string-based models hold interest for exploration; these examples are simply among the most universally studied.

Two projects important and inspirational to the focus of this thesis, based upon explorations of digital enhancement of the stringed instrument model as a controller interface, are the Hypercello, designed by Neil Gershenfeld and Joe Chung and built by Tod Machover in 1991 as part of the Hyperinstruments project at the MIT Media Lab, and the Vbow designed by Charles Sabin Nichols at Stanford University in 2003.

The Hypercello is a cello modified and enhanced to both allow the computer to listen to the instruments audio output and sense the player's gestures in considerable detail, including bowing motions. The setup allows sensing of the player gestures to be used to further process the acoustic sound of the cello, so in effect the player possesses more sonic possibilities with existing gestures and techniques not necessarily associated with any direct sound manipulation before.

The Vbow '…was designed to accurately sense the component physical motions of a violinist's bowing gesture, while providing the performer with both the auditory feedback of the sound synthesis and the tactile sensations of the haptic feedback, produced by the system'[2]. This is particularly interesting due to the investigation into the use of haptic feedback for musical controllers.

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[2] Nichols, *The VBOW An expressive musical computer controller Haptic Human-Computer Interface*, iv (Abstract)

1.5 Some interesting software

Powerful examples of software music environments to work with are ‘Max/MSP’[3], and ‘Audiomulch’[4]. Max/MSP is a graphical programming environment where the musician can build programs involving a range of powerful sound processing and synthesis objects. This type of software is known as a ‘real-time algorithmic composition environment’, of which there are currently many variations emerging, dealing with sound, video and 3D virtual space. Audiomulch is an interactive music environment (currently Microsoft Windows only), somewhat like Max/MSP in appearance, with specific sound sampling, processing and synthesis objects that can be arranged and played in real time to build open sonic structures.

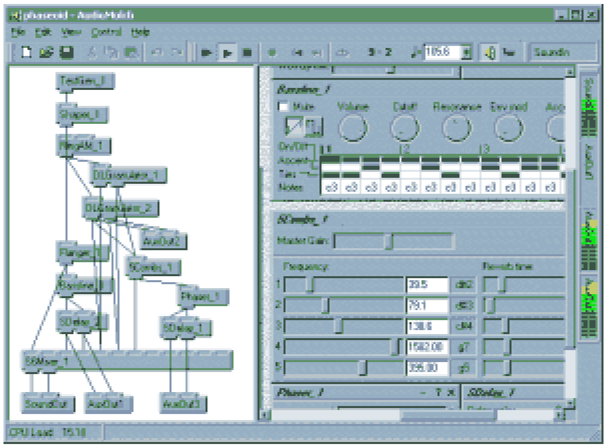

Figure 1 - Audiomulch music software environment

Donna Hewitt’s E-mic: Extended Mic-stand Interface Controller[5] uses Audiomuch (along with PD, an open source real-time computer music software package alternative to Max/MSP, from it’s creator Miller Puckette[6]). E-mic is a physical interface designed to translate a singer’s microphone stand gestures into MIDI data to directly manipulate the microphone’s output, giving the vocalist new access to the sound processing possibilities available in a live music performance setting.

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[3] <http://www.cycling74.com/products/maxmsp_2.html>

[4] Audiomulch Interactive Music Studio <http://www.audiomulch.com/>

[5] Hewitt, Donna, Stevenson, Ian. *E-mic: Extended Mic-stand Interface Controller*. Conference Proceedings NIME (2003)

[6] <http://www-crca.ucsd.edu/~msp/software.html>

The creator of Audiomuch, Ross Bencina is involved in some interesting projects relevant to this thesis, including Simulus[7], an improvisory, collaborative live performance, using various computer music software environments running on networked laptop computers. The Simulus project also involves development of the P5 virtual reality glove[7], converting hand gesture into MIDI data for real-time music software control in the live performance situation.

1.6 Some interesting hardware

This section is primarily concerned with commercially available products.

When questioning the apparent lack of progress in the expressivity of commercially available computer music controllers and the ongoing success of the basic keyboard model as the primary vehicle for physical input, it should be taken into account the important role of the basic MIDI keyboard of providing an easy-to-use interface for the uninitiated to get into the world of computer music. As a replacement or virtual piano, the MIDI keyboard as a controller is highly successful, yet when venturing beyond the piano to other instruments or more abstract sound synthesis and manipulation, the mental model associated with the piano keyboard starts to feel limited, or even creatively restrictive. While it is understood that the plethora of easy-to-use commercial MIDI controller hardware currently available fulfils a valuable purpose in the general spectrum of computer music and its clientele, this thesis explores the needs of the more demanding, experienced musician who wants more control and performance possibilities in the realm of computer music interfacing hardware.

Interesting commercial hardware products have been emerging recently, innovative for suggesting new ways of sending MIDI information/controlling music software. The Korg Kaos pad[8] features an active surface, similar in use to a laptop touch-pad, where the user’s finger movements can be translated as XY coordinates to control simultaneous parameters of the unit’s built-in effects processor, or to send MIDI data.

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[7] <http://listen.to/simulus>

[8] <http://korg.com/gear/info.asp?A_PROD_NO=KP2>

Figure 2 - The Korg Kaos Pad

The Alesis airFX[9], while not a MIDI controller, offers a Theremin-like, gestural interface for sound manipulation. It is a stand-alone device with an integrated sound processor that is operated by waving one's hand (or anything else!) above the device. The position of the hand over the device's sensor alters preset parameters for real-time sound-effect processing. The airFX uses a 3 dimensional coordinate to control the sound processing:

> The Axyz controller works by sending a beam of invisible infrared light out of the top of the unit. There are sensors all around the dome which see the light when it is reflected back. By moving your hand around the dome, you reflect the light to different sensors, and this changes the sound of the effect.
>
> There are three sets of sensors in the Axyz controller, they are known as the X-axis, Y-axis, and Z-axis.
>
> The *X-axis* sensor reads your hand position from left to right.
> The *Y-axis* sensor reads your hand position from the front to the back of the unit.
> The *Z-axis* sensor reads how close your hand is to the sensor (up and down).[10]

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[9] <http://www.alesis.com/products/airfx/about.html>

[10] Alesis Studio Electronics (2000). *Alesis airFX reference manual* <http://www.alesis.com/downloads/manuals/airFX_Manual.pdf>

Figure 3 - Alesis airFX

One could imagine a version of the airFX as a MIDI controller, but this would go against the minimalist, easy-to-use design of the overall unit, requiring considerably more complexity, and most likely cost increases. In its current form, the airFX seems only an interesting music toy.

Increased bandwidth provided by interfaces such as USB and Firewire allows for more MIDI information to be transferred, allowing higher resolution in terms of how much information can be used. As a result, sensors can be used in more effective ways to provide a highly detailed translation of the musician's actions into digital information. One example of the new breed of high-bandwidth, high-resolution MIDI controller is the Continuum Fingerboard[11]:

> The Continuum can track the positions in three dimensions of up to ten fingers in real time and spit MIDI out the other end, with responsiveness that would make any conventional MIDI keyboard controller blush.[12]

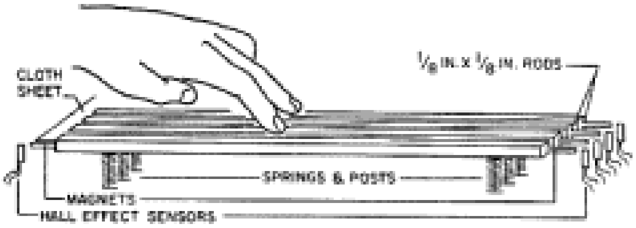

Figure 4 - The Haken Continuum Fingerboard, how it works

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[11] <http://www.hakenaudio.com/Continuum/>

[12] <http://www.keyboardmag.com/archive/0804/0804_r5.htm>

Figure 5 – The Haken Continuum Fingerboard

The Continuum Fingerboard appears to offer some of the exciting and challenging musicianship that MIDI controllers have often been missing. However this advanced MIDI controller functionality comes at a price considerably more than that of most conventional keyboards, which leaves the instrument more in the realm of custom creations for professionals and artists who can both afford and justify such costs. The continuum's musical model has as much in common with a fretless stringed instrument as the keyboard, as well as aspects of the Theremin[13]. This continuous nature of control and manipulation might more difficult to play initially, in comparison to the discreet structure of the keyboard control model, yet in the hands of a highly practiced musician offers an unparalleled expressive quality as notes subtly slide up and down in pitch and attack.

Continuous, string-like control of musical sound allows the musician to feel a strong connection with the sound itself, allowing individual styles to develop as the range for variation in the way one plays a note is so much more open than in the push-button keyboard model. It is often noted that well known guitar players can be recognised simply through the tones generated by subtly unique string attack techniques; 'the tone is in the fingers'.

The popularity of the guitar in its various forms has assured the instrument's continued development and integration of new technologies. The idea of a guitar that can be used to control digital music is appealing, both for guitarists looking to expand their sonic palette and the musical hardware/instrument manufacturer. Opening up an existing hardware platform to new outputs would sell new hardware to an existing customer base, ever hungry for new musical applications.

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[13] The Wikipidia , Theremin <http://en.wikipedia.org/wiki/Theremin>

There have been two main approaches to achieving the partnering of existing instrument models with computer control output, both experimentally and commercially.

The first is to equip and modify existing instruments with specialised sensors to allow the computer to effectively listen to the instrument's analogue output and use this to interpret the musician's actions and produce resulting control data, all in real time (or as close as possible). This approach is commercially facilitated today by marketing add-on technology and accessories, allowing people to build a collection of controller-enabling devices and associated sound-generating modules. The other main approach is to build new hardware designs, intended to resembling existing instruments in form and playing action, usually with a more direct electronic connection to the computer than the existing instrument 'listening' approach. A commercial example of this is the MIDI 'guitar' controllers made by Starr Labs[14], basically collections of sensors assembled in a vaguely familiar form, designed to interpret established guitar playing techniques.

Figure 6 -The Mark III Midi controller by Starr Labs

Often the reality of these approaches is confusion and general disappointment, as expectations attained from one form of musical control do not seem to transfer to another as seamlessly as hoped. The recurring problem seems to be that the technology, usually MIDI, is not powerful enough in its current most common state to capture all the detail generated when playing a traditional acoustic instrument. As new technologies and standards emerge, it will be interesting to see how this challenge progresses. By presenting a computer music controller in a certain form or context, the designer sets the player's expectations of how that interface should work.

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[14] <http://www.starrlabs.com/>

Another interesting product, using the latest technology to create hybrid analogue/digital instruments, is the Line 6 Variax guitar[15]. Line 6 refer to this type of instrument as a Modelling Guitar, where string activity is sensed and used to control internal processing to output selectable, digitally modelled sounds. The concept is that the guitarist can now own one guitar, yet produce the sounds of many different ones.

Figure 7 - The Line 6 Variax guitar

This product is interesting because it presents a new dilemma; the technology clearly works well yet there is an uncomfortable conflict between the traditional player's concept of the experience of playing different guitars as a whole, and the apparent reality of one guitar sounding like many. This is a relatively new product, and it remains to be seen such designs one accepts.

> What this boils down to for me is that they've got QUITE CLOSE to the sound of the guitars they're emulating.
>
> Not the feel.
>
> Not the look/vibe.
>
> I don't buy guitars just for the sound. It's a combination of all the above factors.[16]

It is easy to underestimate the importance of the multitude of elements that make up the relationship between the musician and the instrument, the detail, response and feel of the materials used. But it might be a possibility that over time, musicians place less importance on such traditional qualities, in order to be truly free of material constraints.

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[15] <http://line6.com/variax/overview.html>

[16] Posted by "Noisepolluter", 27th February 2005 <http://forum.intermusic.com/>

2. Concept

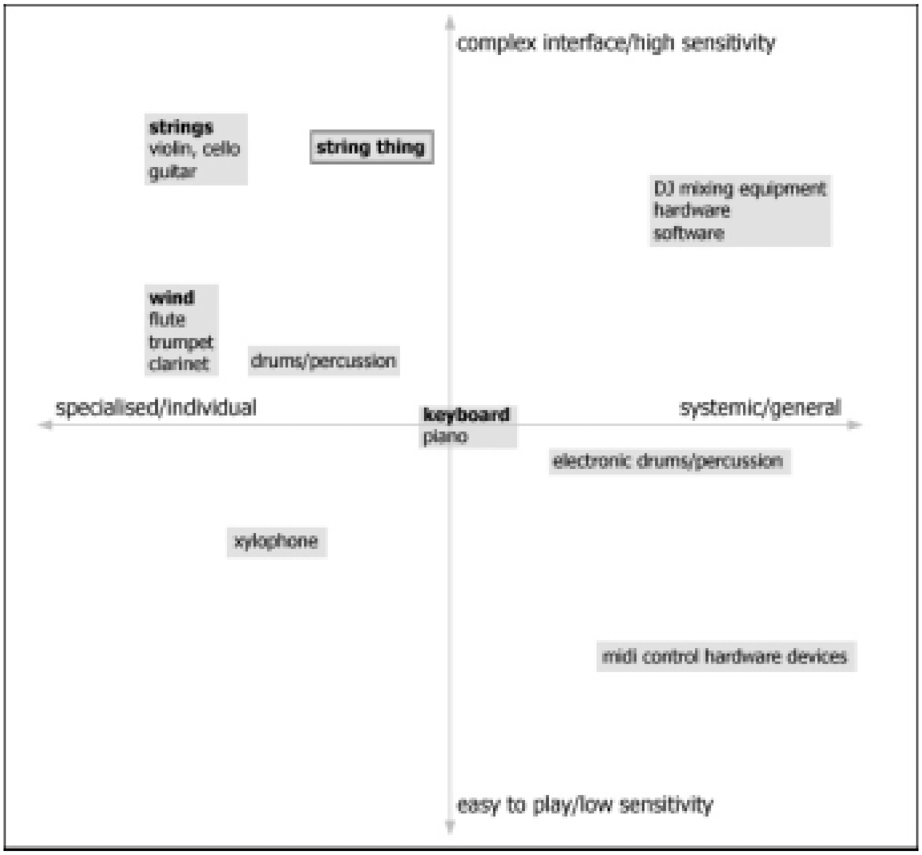

Figure 8 – mapping musical interfaces

A useful exercise in placing the concept was to map the main types of established musical interfaces or instruments, most commonly observed. Figure 8 shows a simplified version of this mapping, indicating where I thought my design should sit in this general musical instrument ecosystem.

The initial phase of concept development asked:

- What generally motivates people to choose particular instruments or play a musical instrument at all?
- What do musicians currently involved in computer music environments look for in interface designs?
- What questions do instrument/interface designers ask or answer when developing new designs?

A difficulty encountered throughout this project has been that many decisions are based upon personal taste, the type or genre of music preferred, preferred physical forms and so on. It is also apparent that in discussing a certain perspective of a musical model, personal interpretations and understandings can vary greatly. Personal interpretation is one of the factors that make this area of design so challenging yet enjoyable.

Early in this analysis stage, emails were sent to contacts known to be involved in some aspect of music production, requesting responses to the above questions. Responses ranged from entertaining casual observations to very specific desires for interface design.

I explored some thoughts regarding different 'types' of musicians and their motivation for playing particular instruments;

> You can usually spot what kind of a musician someone is. Guitarists tend to be small and spindly. Bassists are usually tall and big. Singers love themselves and look in the mirror a lot. Drummers either have crazy hair or big feet. Most musicians start [by] imitating the styles they like.[17]

The observation that many musicians are motivated to play certain instruments because of the inspiration to imitate a sound or style they like is a useful starting point for considering new instrument/controller form designs.

This thesis primarily concerns the concept of the musical interface/controller as an object, resembling a musical instrument in physical form and interaction, with an emphasis on the focus and presence of a physical structure to facilitate musical performance and musician – audience communication. Having stated this, it was somewhat surprising to read this response from Ross Bencina, writer of the Audiomulch software platform and a frequent live performer using software-based music:

> I guess perhaps I'm more interested in direct musical expression with the human body than perhaps you are... if I didn't need a physical device to interface with the computer I would probably be happiest.[18]

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[17] Martin, Gary. 'Re: help - words of wisdom and musical musings wanted (please)'.

[18] Bencina, Ross. 'Re: audiomulch hardware controller development'.

2.1 Computer music and live performance

> The most commonly cited ‘deficiency’ in laptop performance is that, with the performer seated behind the laptop, there is an inherent lack of gestural communication between performer and audience due to the fact that gesture is so small and often hidden from view. As a result, the performance can have a detached, non-communicative quality.[19]

Ever since the computer was first used for a musical application, a clear understanding of where exactly the computer can fit into the established form of live musical performance has been missing. As technology has moved on and computer music systems deal with large amounts of real-time sound manipulation and sequencing with increasing ease, computer music in general seems more acceptable as a form of live music production.

This thesis concerns issues regarding the interface between the musician and the computer, in the live performance context. The use of the laptop computer in live music performance is becoming such a regular sight that the laptop computer itself might be considered as a musical instrument itself, it is entirely self contained and portable, the musician ‘tunes’ the laptop with infinite combinations of acquired and self made software platforms and the sound quality is consistently manageable through digital standards.

In a traditional live performance structure involving a main stage as the audience’s primary source of attention, the laptop computer alone does not sit comfortably among the traditional form of musical instruments and musicians on a stage. This situation is sure to evolve as people invent new ways to deal with the issues of computers, music and performance. The increasingly popular phenomenon of Live “Laptop Jams” consist of groups sat in serene stillness before laptop computers, as trance-like abstract sounds float around the room. These events are as much live performances as group improvisation sessions, which appear to be successfully forming their own accepted musical language.

There have been many novel and entertaining methods of presenting computer based music in a live performance context, usually custom made for particular artists, sometimes verging into the domain of art installation.

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[19] Hewitt, Donna, Stevenson, Ian. *E-mic: Extended Mic-stand Interface Controller*. Conference Proceedings NIME (2003)

There are few generic techniques established or tools available to enhance the process of performing computer music on a stage beyond the common use of screen projection to provide visual interest for the audience, which can seem like more of a distraction than a means of strengthening audience – musician communication.

2.2 What might musicians like to see in new computer music controllers?

The majority of design work in this project has been based around myself as the user, concentrating on what I have experienced and feel is needed, a personal approach.

Future hardware controllers should offer more dynamics, more variation and sensitivity in the responsiveness of hardware in the translation of gesture to audio output, digital acoustic response perhaps?

Future devices should reflect the enhanced complexity and organic nature proposed by advanced music and multimedia environments as seen in software platforms such as Max/MSP, CSound, PD, Audiomulch, SuperCollider etc.

Something often apparently lacking in commercially available musical controller products, is a sense of inspiration and confidence in the form of the device itself, where these products are usually similar in physical construction to computer peripherals. The quality of construction and physical appeal of computer music related products can sometimes seem quite disappointing in comparison to similarly priced traditional musical instruments. It is interesting to consider the physical construction, use of materials, appearance and feel with as much sophistication as is found in the function of these devices.

There is a combination of qualities found in a highly crafted and well designed acoustic instrument that can be an inspiration in itself; the object itself should be desirable and look and feel ‘right’. If the correct combination of qualities is achieved, then the instrument can inspire confidence in the user that otherwise might not occur.

2.3 Developing ideas

As a result of the research and experience of existing music controllers, a set of desired qualities was established to be met by the new design, in order that it will make a worthy and interesting contribution to the music world.

The design should:

- Allow more expressive musical interactions than existing generic controllers.
- Possess both a new physical form and a familiarity that makes sense to experienced musicians.
- Promote a convincing sense of physical response.
- Effectively communicate visually as well as sonically, the musician's actions, functioning as a powerful live performance tool.

In the early stages of idea generation, one question that surfaced repeatedly was; what kind of music is the design intended for? This is a difficult question to answer, as history shows that people have a habit of inventing fresh styles and genres of music, using existing instruments in new ways to make original sounds and musical structures. Invention makes music exciting and unpredictable, to prescribe a specific music application seems problematic, yet it is helpful, if not vital to have some suggested guidelines for the use of a new musical design. If the design inherits familiar aspects of a traditional instrument, it automatically inherits the instrument's styles and genres, at least upon first impression.

In response to this question, Lippold Haken, the creator of the 'Haken Continuum' states:

> I definitely did not have one style of music in mind for the continuum... In some sense I think people are not taking new instruments very seriously when they assume the new instrument is only for one style of playing. It is true that some experimental instruments have been designed and built for only one style of playing, and maybe even only for one particular piece, and developing such an instrument has much artistic merit. But I think there also needs to be room for new controllers that are generic instruments in their own right, useful for the same variety of styles played on any acoustic instrument.[20]

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[20] Haken, Lippold. 'Re: interest in developing more expressive controllers'.

It was decided that the design should be able to function as a fairly generic tool, as opposed to a highly specific or conceptual single use piece. This should enable the design to mature as people interpret and use it in different ways, with space for discovery and individual expression.

> It seems people love as much to create new controllers and software as they love to make music.[21]

In terms of user research and testing, I designed primarily for myself, with the aim of designing an instrument that I would want to own and use, and rely on.

The concept originated as an exploration into ways in which we can literally touch sound in a musical fashion, the various ways that people physically connect with musical tools and how these processes make sense to us. There is an intuitive understanding when it comes to dealing with sound generation and its manipulation through physical object interaction. It is this understanding which can be an interesting source of confusion or success in designing new interfaces for electronic and computer music.

From the start, the main focus was on continuous control of pitch, which can be viewed as both a powerful new development in the area of controller technology, and as a rather retro move in the general realm of music progress. This continuous pitch control in intended to serve as a highly sensitive input process intended to explore potential use for increased bandwidth interfaces. This continuous control would be achieved through interaction with metal rods, intended to act as a string metaphor, providing a direct and highly tangible surface on which to touch the sound. Using a string based interface suggests a desirable familiarity that should appeal to musicians already experienced and skilled in playing traditional stringed instruments, while also providing a platform for further experimentation in use as a control mechanism.

Another element intended to further enhance the idea of touching the sound in the computer, is the inclusion of physical feedback. Acoustic instruments provide a complete experience of feeling the sound produced, the physical vibrations of the instrument providing a continuous sense of feedback that reinforces the whole process of musical interaction, particularly valuable in a live performance setting. This part of the acoustic experience is largely missing from most controller designs, and is something that is thought to play an important role in our ability to understand and react to a physical musical process.

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[21] Kieslinger, Michael. ‘Re: music controller thoughts and advice...maybe?’

Initially, the focus was purely on the hardware interface design, with the assumption that the sound production part would be an open ended component, dictated by the nature of the interface and the requirements of the user. This approach was clearly not sufficient to prove the value of the design, and attention was needed in this area. The most immediate solution was to use MIDI as a prototyping tool, allowing access to a vast collection of established digital and electronic instruments and providing a convenient source of example sound applications for the interface design.

3. Design and implementation

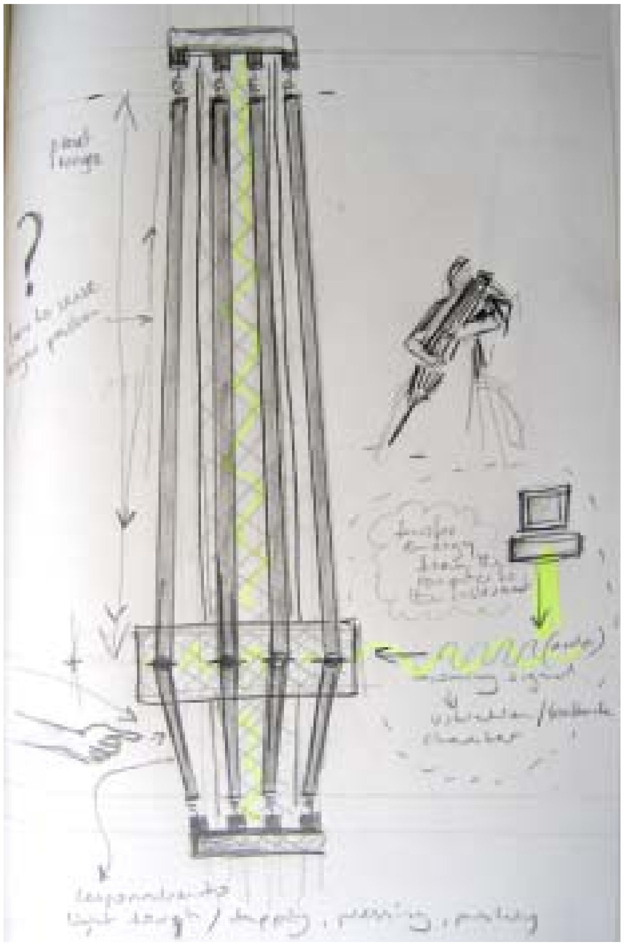

Figure 9 – The original idea for the String Thing, showing the two sections, separating control of pitch and volume

For the duration of this thesis there was one main overall design (Figure 9), particular aspects of which were developed and iterated as separate components with the intention of assembling at the end to form the complete object; a haptic feedback enabled string based interface for continuous control of MIDI/software instruments.

A substantial amount of learning was required for the design and implementation of the different phases of this project, both in hardware and software technology applications. For the software side of the prototype, the main software used was Cycling 74’s Max/MSP, which was used to process incoming serial data.

This application is convenient for both building complex, processing structures, and creating rapid experimental examples, all responsive to real-time alterations, something particularly useful for the constant 'tweaking' nature of working with musical applications.

The hardware prototyping revolved around the 'Wiring' board and programming environment[22]. Wiring is used as a tool to format sensor output, and deliver this data to the computer's serial port for software interpretation. The 'Wiring' platform is easy to use and relatively fast for trying ideas, something appreciated in musical hardware development and experimentation.

3.1 My first controller

Figure 10 – The first controller, using guitar strings suspended over magnetic tape

Figure 11 – Showing the use of each hand for controlling pitch (pressure) and volume (position)

At the start of the project, it was established that a design was needed that would provide a continuous input to control pitch, as well as the usual musical control data such as velocity, attack and volume. The first experiment was to design and build a simple hardware interface providing a continuous sensor output which could then be interpreted by Max/MSP to produce a variable sound. The main goal of this exercise was for to become familiar with some of the electronics principles and materials involved in building a continuous control interface, while enabling a 'hands on' experience of exploring some basic musical applications such as manipulating the pitch and volume of a sine wave.

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[22] Wiring prototyping environment <http://atari.uniandes.edu.co/wiring/index.html>

The first controller was constructed from a trouser hanger, a length of wood with metal hanging pieces on each end, one of these was retained to use as a lever with which the whole device could be pressed down, squeezing two pieces of conductive foam placed between the underside of the active surface and a wooden base. When the conductive foam is compressed, a connection between two wires is increased allowing more voltage to be detected by the wiring board, acting as a pressure sensor. This pressure data was then used to control volume.

The pitch control was achieved by using a material with a linear variation in electrical resistance, in this case magnetic tape from a MiniDV cassette, and a guitar string acting as a ‘wiper’, in what was essentially a large variable resistor. The guitar string was suspended over the tape, so that when touched, it would make contact with the tape. The tape was wired in a circuit as a voltage divider, so that when the guitar string touched the tape, it would pick up a varying voltage reading depending where along the length of the tape contact is made. The guitar string was wired to an analogue port on the wiring board, giving a continuous voltage reading, which translates to finger position on the controller surface. This voltage range is then used in Max/MSP to control the pitch of a test sine wave. Effectively I had made what is often called a ‘ribbon controller’, an add-on device for many keyboard synthesizers intended to provide keyboard players with an extra level of expressive capability, albeit without pressure sensing abilities.

3.2 First controller insights

While not being a particularly innovative concept itself, this initial experiment was a valuable exercise in getting acquainted with the tools needed for the later stages of the project. It performed well, providing a detailed control and feel for the process of using a continuous pitch control, as well as highlighting the effectiveness of using physical pressure to control the volume and intensity of a synthesised sound. This application of pressure created a mild fatigue, a sense of physical feedback in itself, something present in the playing of many existing instruments and lacking in most controller designs. This was an interesting aspect, allowing the computer to respond to constant variations in physical human effort provides a convincing sense of ‘realness’ in controller interaction.

As predicted, controlling pitch in order to play specific musical sequences on an open and continuous scale is quite difficult, especially with no visible or tangible markings to distinguish key note intervals.

This inspired thought about a possible custom marking system, which could be as simple as a blank surface for the user to make their own markings, acting as a guide for playing particular music styles or pieces. This blank canvas for making ones own pitch interval might be an interesting way to free musicians from conventional use of notes and scales. The use of tangible markings would also be helpful, such as a minimal indication of the halfway point of the total pitch range. This could be a small notch in the playing surface, which would make a positive difference to the player’s ability to navigate the device’s pitch control, and develop a sense of physical familiarity as well as a clear mental model.

3.3 My second controller

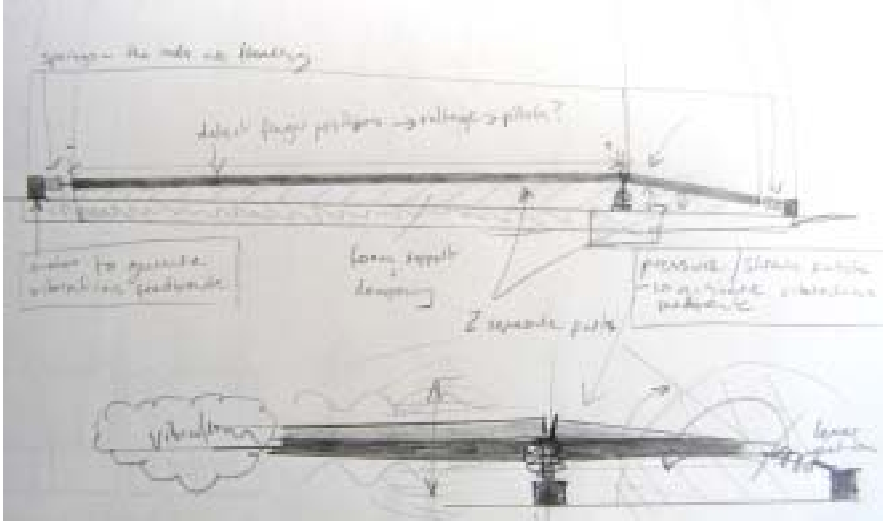

Figure 12 – The suspended metal rod sensor design

Having completed the first experiment, I proceeded to build a second, more detailed prototype. This prototype was intended to explore ways of:

- Continuously sensing finger position along the length of a metal rod.
- Continuously sensing finger pressure on a metal rod.
- Sending haptic feedback to a metal rod; making it vibrate in response to finger pressure.

The second controller was an example for one rod, one of the four as shown in Figure 9. This was intended to create a fully functioning one-rod system, which could then be duplicated to create the full array of four rods.

This second prototype primarily consisted of a basic wooden frame supporting a main suspended metal rod, with two other smaller rods. In terms of sound, this prototype used some simple examples much like in the first prototype; the emphasis at this stage was still on the physical interaction.

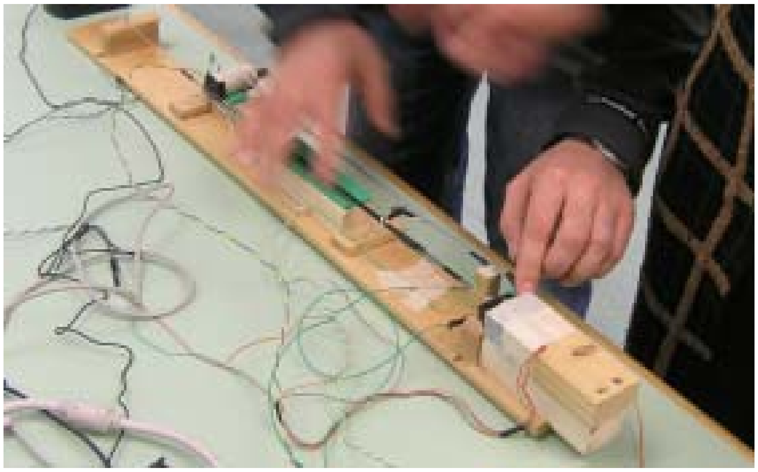

Figure 13 – playing and testing the second prototype

3.3.1 Finger position

As the central design become more detailed, the need to continuously sense finger position along the length of a metal rod became a problem that would demand much time and experimentation to solve. It soon became clear that sensing the player's finger position on suspended metal rods would be more difficult to achieve than sensing position along a static, flat surface. I decided that it was worth pursuing this goal, the use of metal rods provides a more satisfying and tangible interactive surface than a flat plane. Another reason for using metal rods is the use of magnets for activating the vibration for the haptic feedback aspect.

A range of methods were used to test for the most suitable way of sensing finger position, these included; capacitance sensing, webcam tracking, resistance sensing and an infra-red rangefinder. The important factors in assessing the success of a position sensing technique are; speed of response, and consistency in the readings obtained, aspects crucial in attempting to create a reliable music tool. It is also desirable to use a minimal quantity of parts so that the interface is as simple and robust as possible.

Figure 14 – A steel rod covered in magnetic tape, to provide a surface with a linear change in resistance

Figure 15 – Using a finger to connect the voltage sensor to the metal rod

The position sensing method selected for this prototype was resistance. As in the first prototype, magnetic tape was used for the resistant surface. The tape was used to cover the metal rod, providing a surface with the required linear variation in resistance. In order to maintain the simplicity the metal rod interaction, another smaller metal rod was installed in parallel. The parallel rod acted as a voltage sensing probe connected to the wiring board to provide the detected voltage from the different positions along the metal rod. This allowed a connection to be created by the user’s finger between the voltage sensing probe and the resistive surface on the main rod, as shown in Figure 14.The was a rather cumbersome solution, but useful for testing the idea at this stage. The voltage read from the sensing probe was then used to control pitch.

3.3.2 Finger pressure

Figure 16 – The pressure sensitive rod section

A solution for sensing finger pressure was required, more responsive and consistent than the previous attempt using conductive foam pieces. During experiments for the position sensing element, it was found that the capacitive sensor, the QT301 chip[23], in combination with the steel rod provided a sensitive pressure sensor, reacting specifically to human touch. The sensor detects the capacitance of skin, and as the user's finger presses with increased force against the metal, the surface area of the skin in contact with the metal increases, resulting in an increase in the capacitance level detected.

This sensor is adjustable, allowing the minimum and maximum detected capacitance levels to be set, varying the system's sensitivity. This is a useful feature in the overall setting up of a musical interface, allowing for custom, individual player's configurations. An interesting characteristic of the use capacitance sensing for continuous pressure values, is that it responds specifically to the physical properties of human touch, and so will vary slightly in response to different people. The pressure value is used to control volume, velocity and attack, as well as drive the physical feedback process.

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[23] Quantum Research Group, touch control and sensor ICs <http://www.qprox.com/>

3.3.3 Physical feedback

Figure 17 – Using a solenoid to vibrate the metal rod.

The primary source of physical feedback was to be sent through vibrating the metal rods. The simplest methods for achieving this are motors to directly move the rods, or magnets to attract or repel the rods.

There are products available for electric guitars that use combinations of magnetic pickups, amplifiers and magnetic drivers to vibrate a (steel) guitar string. An example of this is the Ebow[24]. These systems work by sensing the vibration of the metal string as a disturbance in the magnetic field of the pickup, this signal is then amplified and sent to a driver, which is essentially the reverse of the pickup, acting like a speaker it makes the string vibrate (instead of the cone of a speaker). This is a feedback loop, much like the effect of holding an electric guitar near a loud amplifier.

I intended for each rod to have its own individual physical feedback arrangement, so implementing a full feedback system as previously described would be quite complex and require many parts. Also it was not necessary to use the rods for any sonic properties and the vibration was required only for the physical sensation. After experimentation with some simplified feedback loop ideas, I arrived at the solution of simply using one solenoid as an electromagnet, that could be switched on and off at a high frequency. This attracts and releases the rod at the frequency set by the wiring programme, giving the impression of vibration. The next stage was to then make this frequency of vibration variable, depending on the amount of pressure sensed by the pressure sensing rod section, pressing harder makes the rod vibrate more, as well as gradually fading to rest when pressure is completely released. Used this way, the vibration feedback informs the user of the intensity of the sound controlled (by that particular rod).

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[24] Electronic bow for guitar <http://www.ebow.com/>

Another potential route explored for sending haptic feedback to the controller, was to make the body of the whole device vibrate at the frequency of the notes produced, enhancing the overall acoustic experience for the player. An experiment using a motor from an electric toothbrush attached to the body of an electric guitar showed potential for this idea. The guitar's output was amplified as send to the motor, which sent vibrations back into the body. The vibrations in turn make the strings vibrate, generating more output signal and driving the feedback loop. This was an interesting development, but was not further developed at that stage; the vibrating rods provided sufficient physical feedback for the general purpose of this exploration. If developed in future iterations of the overall design, it would be interesting to create individual motors or vibration generators for the sound output controlled by each rod. This would also require a multi-channel sound card to prototype, the use of independent sound sources would be more effective as the motor only effectively responds to monophonic sound.

If successfully implemented, this system would act as a convincing, synthesised acoustic response, which should aid the player in 'feeling' the sound.

Figure 18 – Using a motor as a speaker, sending vibrations through a solid object

3.4 Second controller insights

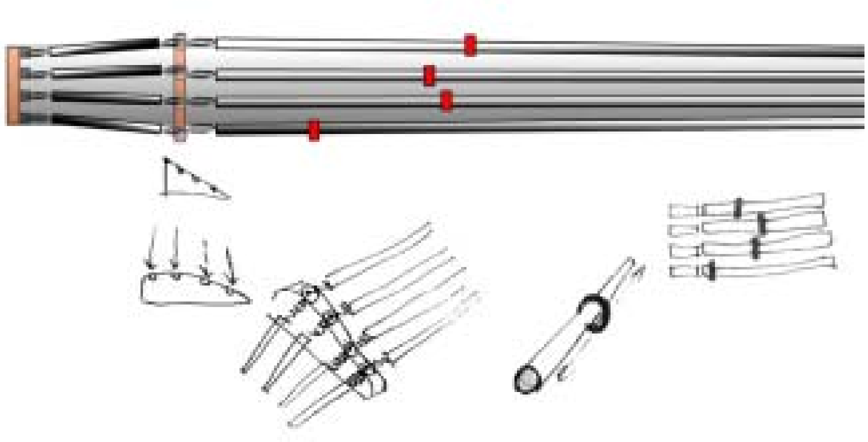


Figure 19 – Ideas for developing the interface

This prototype was useful in determining the success of using capacitance sensing for detecting finger pressure, as well as highlighting the instability of measuring resistance for detecting finger position along a suspended metal rod. The fact that the rod is floating and is three dimensional, means that the pressure applied by the user's finger will always vary. The result is pressure as well as position affecting the pitch control information, something that is makes achieving a consistent pitch very difficult. This showed the importance of preventing one control parameter affecting another.

The use of a solenoid as a vibration generator was successful in creating haptic feedback.

At this point in the design process, some more ideas (Figure 19) emerged for the complete structure, regarding the form of the 'bridge' piece and the four main rods. One was to reflect a gradient in pressure response, and the other was the use of sliding rings on the main rods; allowing the player to make preset chords (or semi-chords) over which extra notes can be played.

When demonstrating this prototype, it was suggested that the main position sensing rod could also sense pressure, so that simply touching this rod would provide both pressure and position information. This would allow the player to use both hands to create chords along the whole length of the rods, while using the smaller, solely pressure sensing section to play the open 'unfretted' notes. This structure negates the need for the sliding 'chord-making' rings as mentioned previously.

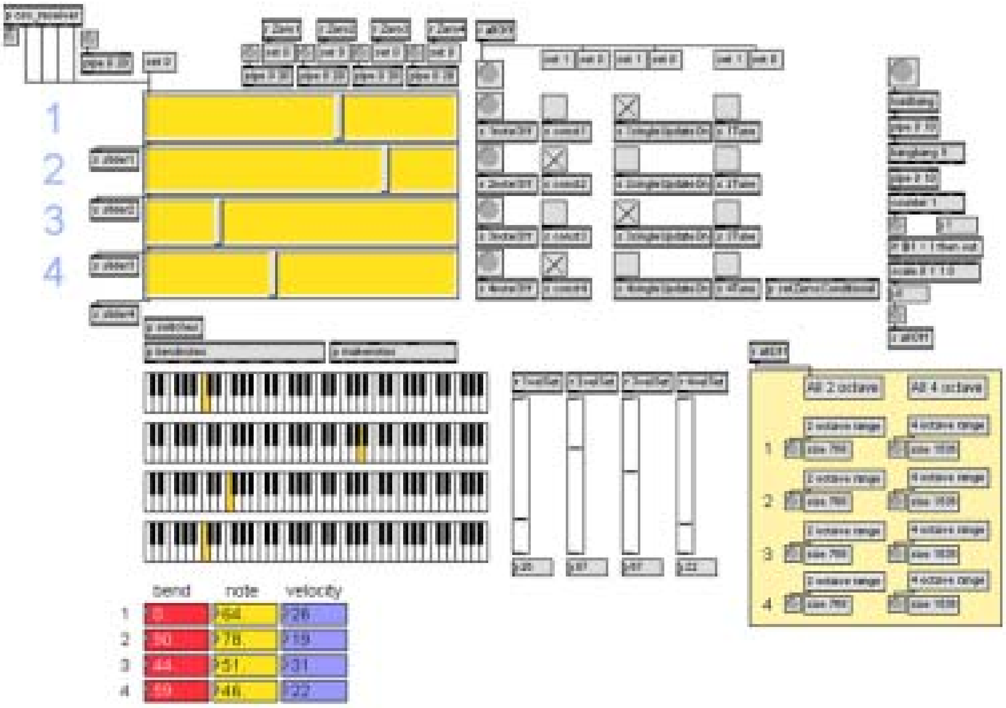
Another plan for exploring in future iterations was to use piezo sensors to measure the vibration each metal rod. This could be achieved be playing piezo disks obtained from electrical buzzer devices, directly underneath the rod so that the rod exerts pressure on the piezo disk. Any movement of the rod is then detected by the piezo disk, and when combined with an LM386 amplifier chip, the generated signal can be clearly read as an analogue input in the wiring board. The capacity to measure the vibration of each rod would allow a natural and tangible control for volume, attack and intensity, and then the existing pressure sensor would only be needed to drive the mechanical process of generating the vibration.

As the complexity of the physical prototyping increased, example sound and musical output remained at a very basic level, this was a problem in presenting the idea. More work was needed in this area.

3.5 Sound control

After some early attempts to create simple sound synthesis examples in Max/MSP, it was decided to use controller data to generate MIDI values, which can then be used to control any number of existing software instruments. Despite the limitations of MIDI previously discussed, it is a well established tool, useful for rapid prototyping by providing easy connection and testing with a range of good quality, compatible instruments. I conceded that it was not necessary to create new instruments for this thesis.

Proceeding with the foresight that I would be using four sets of continuous pitch and volume controllers, I built a Max/MSP patch that would translate incoming data into MIDI bend value, which has a fixed range between 0 and 127.



	bend	note	velocity
1	0	64	26
2	90	78	19
3	44	51	31
4	69	46	22

Figure 20 – The main part of the MIDI note+bend generation Max/MSP patch

The concept was that the user would ‘tune’ the instrument, by selecting a base note for each rod, the note the rod would make when ‘open’ or untouched, then the pitch data would be used to increase the MIDI bend value from this base. At the maximum bend of 127, the note value generated is in effect four notes above the original note, so the patch is programmed to automatically generate a new note four notes higher than the one before, with a bend value of 0 and restarting the cycle. Figure 20 shows the main part of the Max/MSP patch that performs this task.

The goal of this is to create a seamless bending between notes, so that any MIDI compatible instrument can be played like a fretless instrument. Four of these MIDI ‘note benders’ were made, one for each rod, and each one using a separate MIDI channel. This allowed the possibility to use a different MIDI instrument for each rod, if desired. The length of the sliders is preset to a selection of either a two or four octave range. Also I included rough visual guide to slider position’s equivalent position on the standard keyboard layout.

Figure 21 – Using Audiomulch as a VSTi host

For testing the software, I used Audiomulch to host a variety of VST instruments (Virtual Studio Technology, developed by Steinberg Soft-und Hardware Gmbh[25]). This is a powerful combination, providing high quality sounds and flexible control settings through the application of MIDI control values to software parameters.

With this software structure in place, it was possible to play instruments by dragging the sliders with the mouse. While limited to pitch control (and just one slider at a time), this gave a good sense of how the design would ‘sound’ and how different instruments respond to the continuous pitch change, as opposed to the usual discreet keyboard pitch intervals most of these instruments are designed for. Some are based around continuous, fluid electronic sound, where others aim to reproduce sounds and characteristics of traditional instruments such as the pluck and decay of a string, the strike of a percussive surface or the breath of a wind instrument. As well as these familiar characteristics, there are also instruments that blend these elements for new sounds and complex organic sound interactions, affected by the velocity of the note and other control parameters.

The nature of the MIDI note generating and bending means that a new ‘note-on’ message is sent every time the maximum bend is reached, so that, in the case of an instrument where sound decays over time, a noticeable new note is played when the intention is only to bend the pitch of an existing note. This artefact of the note bending system used motivated two ideas for solving the problem and enhancing the musical effect.

The first idea was to have a mode for each rod to just bend a new note within the minimum and maximum range, until a ‘note-off’ message is sent, in the case of String Thing, when a rod has stopped vibrating.

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[25] Steinberg <http://www.steinberg.de/>

This setting allows a safer method of playing, so that new notes are not unintentionally triggered, while the continuous note interface still applies; with this setting active, the control system acts like an acoustic instrument.

The second idea was to have a mode where a new note is triggered every time the pitch is changed, so in the case of a pluck attack based instrument, a kind of stuttering effect can be created when the pitch is varied, as the player’s finger is dragged up and down the length of the rod. This setting has little effect on continuous sounds.

These modes should be settable at any point by the player, so that they can be part of the playing experience. For example, if the continuous new note setting is activated by an on-off toggle switch, one might set it to active, virtually dragging a sound then releasing it at the desired pitch where it can be further manipulated in the normal mode. These two modes of playing can be combined as desired.

Another important mode required for the final design, was the ability to easily tune each rod at any point in time, to allow any adjustments to be made while playing; something useful in a live improvisation environment. Tuning could be achieved by adding a set of dedicated dials on the controller body, but for the sake of keeping the interface as uncluttered as possible it was decided to add another mode switch for the rod interface, so that when active, the tuning mode uses the rod as a keyboard to select the desired note. When the tuning mode is exited, the slider automatically resets to zero, initialising the new note and its range. Using the rods as the tuning interface as well as the main playing interface allows the user to quickly change the base note of a rod during playing the instrument, while having minimal impact on the user’s playing position.

3.6 Returning to the position tracking problem

At this stage in the project, everything was ready for iteration number three, this time with all four rods functioning. However the problem of achieving an appropriate and successful method of sensing finger position on the metal rods was still a major obstruction in the project progression, especially problematic considering the emphasis of continuous pitch control within the overall concept.

After further experimentation and research, a solution was arrived at. The idea was a combination of various methods of distance measuring encountered in research, such as laser and infra-red rangefinder technology, and video tracking. The previous attempt at using an infra-red rangefinder was promising; it provided an accurate and consistent output without any interference from other factors such as finger pressure.

Unfortunately the speed at which the sensor outputted data was too slow for a convincing sense of musical responsiveness, such latency is an unpleasant handicap where one is trying to play to a rhythm. Industrial laser distance measuring systems would provide the needed speed of operation, but they are too expensive for the scope of this prototype (one set would be needed for each rod), and probably too expensive to be feasibly implemented in a commercialised version of the thesis 'product'.

Figure 22 –Webcam and laser pointers as a distance measurer

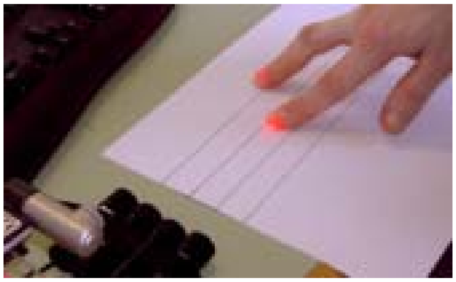

Figure 23 - Testing position tracking

So the compromise was to use laser pointers, one for each rod, aligned just above the rod so that the laser is aimed down the length of the rod. When a finger is placed on the rod, the beam is interrupted and reflected on the finger as a bright dot of light. A webcam placed just above the rods where the bridge would be on the final model, 'sees' these reflected light dots and processes the position of the dots. Effectively the webcam's viewpoint provides the image of dots of light moving up and down this movement can then be tracked and translated into data to be used by the Max/MSP patch, to then be used for the pitch control.

This solution still had a fundamental problem; the camera needs to be able to distinguish between the four dots of light, which do not move in perfectly straight lines due to the perspective distortion of the camera's viewpoint (Figure 24). The answer was to draw sections representing each rod's space, and fill these sections in with different colours (Figure 25).

Figure 24 – The camera's view of the rods

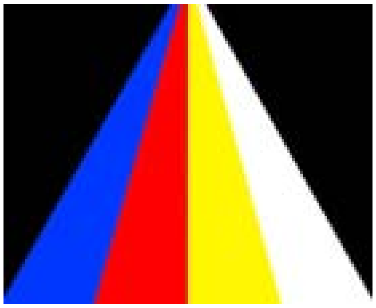

Figure 25 – A test image for the camera's perspective view of colour-separated rod spaces (blue, red, yellow and white strips)

Using Eyesweb[26] software environment for video tracking, the incoming video signal was mixed with the colour division template, to create the effect of the light dots in each colour region being coloured accordingly. This generated image could then be used to track the movement of light on each individual rod. The four streams of data are sent to the main Max/MSP patch via an Open Sound Control connection (see Appendix 1.3 and Appendix 3) to be used as continuous pitch control.

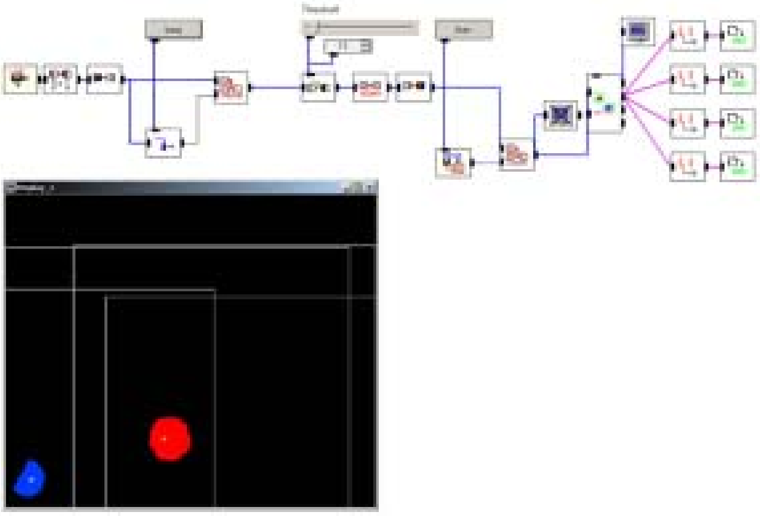

Figure 26 – The Eyesweb video tracking patch (red and blue blobs)

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[26] The EyesWeb project <http://www.infomus.dist.unige.it/eywindex.html>

The performance of this light tracking method of movement measurement was adequate, as expected there is a slight delay due to the video processing involved, but for the purpose of prototyping this was acceptable. The system requires a dedicated computer for the task of video processing alone, the most processor intensive part of the prototype. When using a single computer to do the video tracking, and all MIDI processing as well as running multiple software instruments, performances slows down dramatically.

The advantages of this method; the quality of interaction using video tracking is particularly sensitive and ‘analogue-like’, and the system is also mostly unaffected by elements such as finger pressure and other electrical interference. A pleasant side-effect of using the laser pointers is that the player’s finger’s become illuminated, clearly visible in a dimly lit environment as commonly seen in a live performance situation. This adds another layer of drama to the playing process, as well as further emphasising the player’s visually broadcasted actions.

3.7 Physical form

The final prototype form was designed, initially sketched as a 3D model. The rods are assembled on a metal pipe-like body, which has an adjustable stand allowing the controller to be played sitting down, like a cello. The stand should also travel far enough to allow a standing-up playing position. The body design uses a mixture of wood and metal to provide a reassuringly strong and heavy structure, using wood where there is most contact with the hands so that the player does not have to have to endure only the cold touch of metal. The use of a hollow pipe-like structure for the body allows for all electronics to be contained within a central inner channel, as well as providing a comfortable ‘edgeless’ form to be held in the hand and against the body.

The lower section of the body hosts a selection of toggle switches, each with an LED to indicate status at a glance. These switches control the modes for single note triggering, continuous note triggering, and tuning, for each individual rod. Also it was decided it would be useful to have a simple volume control knob for each rod, for a rapid setting and alteration of maximum channel volume, a useful function in the case of a ‘musical emergency’ where something unexpected happens with the sound. The function of these knobs can also be changed in the controller’s MIDI setup, to allow control of other instrument expression parameters as required.

The central bridge section (Figure 29), made from wood (as are the rod beginning and end pieces), houses the webcam and four laser pointers, positioned a small distance above each rod. This bridge separates the two main rod sections, the longer position sensing or pitch control part and the shorter pressure sensing part. The rods are steel tubes, suspended by a wire that runs through the length of both long and short sections, so that the two sections are linked; touching either section will effect the overall vibration detected. The main wire running for each rod group passes through the bridge unit, over the vibration sensitive piezo disks.

The controller interfaces with the computer through two USB ports at the base of the body, one for the wiring board and one for the webcam. A power socket is also necessary for providing a 12 volt supply to the solenoids (these are placed near the top of the body; one beneath each rod).

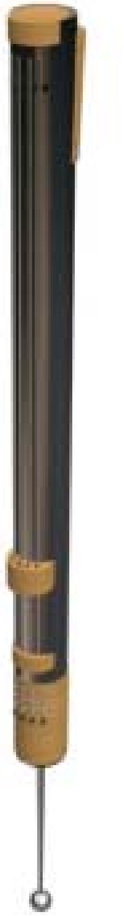

Figure 27 – The body design, with adjustable stand

Figure 28 – Switches for setting playing modes, and volume knobs for each rod

Figure 29 – The central bridge unit, housing laser pointers, a webcam and piezo pickups

3.8 Final prototype demonstration parts list

- String Thing control interface.
- Two networked computers.
- MIDI compatible instruments of choice.
- Speakers (preferably high power, with sub-woofer).
- Dimly lit environment (prevent daylight from interfering with the camera tracking system).

3.9 Design timeline

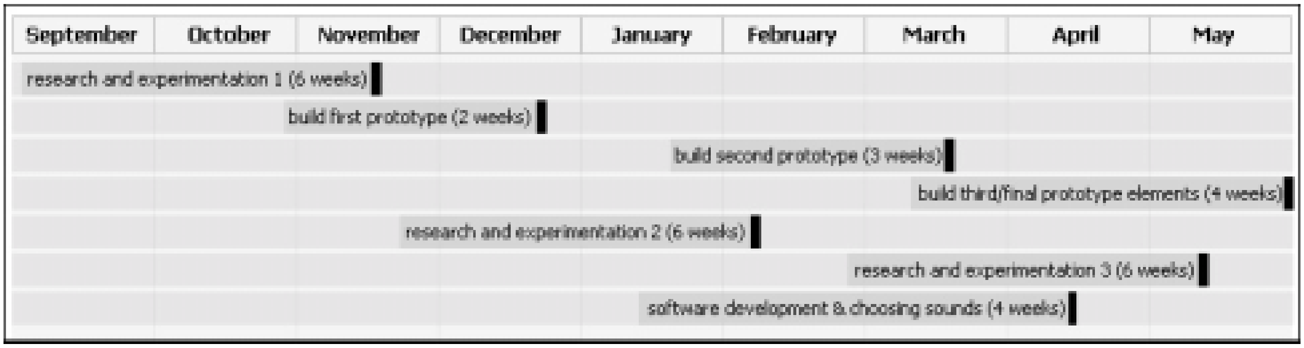

Figure 30 – Timeline to indicate the approximate time spent on each part of the design process

Figure 30 shows a general overview of the project timeline, over nine months. The project can be broken down into three periods of research and experimentation and three periods of prototype building and testing, as well as a period devoted to software development and sound or instrument selection and setup. Research and experimentation usually means a series of small, detailed exercises in solving the various problems encountered in individual aspects of the physical design.

4. Economic Study

This thesis has been clearly product-based, focusing on design and production of a quality musical object, so thinking about the economic possibilities for a commercial version of the design is quite straightforward

This object was initially intended to follow the lead of custom-built products such as the Haken Continuum, expensive instruments for serious (wealthy) and professional musicians, attaining a degree of exclusivity with such high price and limited availability. The Haken Continuum is hand made to order and uses a large number of expensive components, so a high cost is inevitable, especially in comparison to other generic MIDI controller products. This method of production limits the growth of the product, it will be difficult for it to advance beyond the current status of ‘obscure and interesting musical device, but too expensive for an experimental or impulse purchase’. As a result, the acceptance of a new musical platform will be slow if at all. I would imagine there are many musicians or ‘musically-curious’ who would buy such a product purely out of interest, if it was not such a serious financial investment, this is true of my own feelings towards this product.

4.1 From prototype to product

It is not difficult to imagine the String Thing as a mass production progression of the current prototype form. It uses relatively cheap and commonly available components, and assuming the current use of extra computers for the video tracking and MIDI processing could be replaced by embedded microprocessor hardware, the design could be entirely self-contained and easy to set up ‘out of the box’. Another technological aspect that would be interesting to explore, particularly in the case of a mass-produced product, is to use the industrial laser measuring devices as encountered during researching solutions to the finger tracking problem (they were too expensive for prototyping use). This would negate the need for the camera tracking method used in the current prototype. In a large scale, bulk purchasing situation, these devices may become affordable alternatives, improving the overall robustness of the product without dramatically impacting production costs.

4.1 Possibilities

There are two apparent possibilities for pushing the design as a business opportunity, either as a small start-up operation producing handmade to order, high-quality, high-priced pieces, or to sell the design to a large musical instrument and technology company such as Yamaha, who would then produce the design on a larger scale and sell it for a competitive price.

The smaller scale operation is appealing for the sake of keeping the design as an exclusive, ‘special’ object, where quality can be maintained at a high standard and relationships built with selected musicians. However, there is an important consideration for the need or desire for a new type of musical interface to be accepted amongst musicians in general. If the product remains as an expensive, obscurity in the universe of musical interfaces, it will be unlikely to ever achieve status as a true generic tool. Ideally a compromise of these two possibilities could be reached.

In the case of a mass produced design, one could imagine different versions emerging, different sizes, a range of materials and details to appeal to all musicians, interests and age groups. The technology and design allows a modular approach to production, allowing for future customisation and enhancement of a product, such as rods with different properties or weights, decorative wooden parts, additional controller elements and so on. Assuming an acceptance of the design, the possibility for developing the product in a wide range of areas is considerable.

4.2 Launch strategy

The design will struggle to progress beyond the prototype stage unless musicians are aware of it and its possibilities; there must be an interest and demand for such a product. Fortunately the music technology and gadget community is always hungry for new ideas and products, so assuming the idea is a good one, it would not take very long to generate a demand, especially in this age of ‘blogs’ and forums where interest in new products and ideas spreads rapidly.

It is proposed that a basic marketing strategy would be needed in the earliest stages, possibly even beginning during this current state of prototyping. There would be a pre-launch phase of between six months and one year, where a general sense of interest and buzz around the new design is generated.

Preproduction models would be sent to a range of musicians in order to get general user feedback, and begin establishing a language of playing styles and musical example applications, so that people can be presented with a reason for wanting the product. This pre-launch would require an initial investment to produce a number of prototypes and promotional material.

When the pre-launch phase is complete, the designer will be well positioned to either begin a small scale commercial production run or try to sell the design to a larger established company, or indeed a phased combination of these two paths.

5. Evaluation and analysis

In retrospect, this thesis has been a particularly focused study, following a logical progression in development and complexity. I found myself frequently zoomed in on the smallest details of the design and playing experience, quite possibly at the expense of a broader study of musical controller innovation.

5.1 Use of time

I think as a result of the processes of primarily designing for myself, I became somewhat obsessed with some aspects of the design and functionality, painfully aware for example, of the impact of excessive latency in controller responsiveness in a live performance or improvisational environment, where timing is everything. As a result of this, much time was spent tweaking and fine tuning the performance of each part. At some points in the development process, it felt as though too much time was being spent trying to solve engineering problems, instead of investigating more general design possibilities, a symptom of basing the thesis around one primary design project, explored in great depth.

Looking back and considering the amount of learning required making a working prototype, I believe this time invested in experimenting and learning was necessary. It was important to build physical working prototypes to fully understand how people could use new objects and how new objects relate to the human body. Many interaction design projects succeed with a simplified or faked prototype example that conveys the design intentions without going into unnecessary detail or requiring a fully functional product. For this thesis where there is a focus is on the functionality itself, working examples were needed.

5.2 The playing experience

In playing the prototype, there is a new level of difficulty in playing that does indeed approach that of a traditional acoustic instrument with a level of variation in micro-tonality and response to subtle, individual techniques that existing controller designs do not offer. As predicted, having experience of playing stringed instruments allows the player to get to grips with the interface relatively quickly. I have played various stringed instruments in the past, and enjoy the ability to alter pitch in the linear manner provided by manipulating a string.

In a live performance situation, usually involving some aspects of improvisation and unpredictability, it is this seamless, sliding pitch facility that allows the player to play ‘around’ a desired pitch, to cover mistakes and tentatively enter a new pitch region to see (hear) if it works, if not then an easy retreat is possible without breaking musical flow. This quality is present in String Thing, something that I find exciting in a MIDI controller, following conflict with the rigid constraints present in using a conventional keyboard interface. It is accepted that this quality is a matter of personal preference, and something that requires skills and the motivation to invest time in acquiring these skills. Admittedly it is a simple concept; the difficulty lies in controlling the interface’s high sensitivity, and player’s finger dexterity.

I found that playing the interface, or instrument, was quite addictive. Playing the instrument on its own, with no rhythm element can be a trance-like experience; depending on the choice of instrument sounds used, continuous pitch sliding nature of the control is effective for creating hypnotic ambient textures. Alternatively, the sliding notes can be used to make rather creepy noises, much like the use of violins in classic horror films; it would be useful for creating film soundtracks, especially with the expressive quality of unusual and unsettling variations in pitch.

5.3 General insights

A fear present throughout the development process was that of the need to innovate or at least bring something interesting to the well trodden field of music controller design. With so many people around the world consuming, inventing and recycling instruments and related interfaces, it is unclear why the commercial state of things has remained somewhat stagnant. I propose that the majority of musicians are reasonably conservative, placing high value upon reliability, quality and expressive interactions that make sense.

This might explain the generally safe and traditional nature of most commercial products available. I hope there will be completely new and successful types of musical interaction emerging, but I recognise the value of using established forms and gestures in allowing an immediate understanding for an interface. When someone in a musical context sees a suspended string-like structure, a level of intuition can be assumed in relation to the way physical interaction will affect sound.

One comment observed during presenting the idea at an early stage, was that I was being conservative. I think there is room for conservative interaction design in developing musical interfaces and devices, in some ways this thesis was inspired as a reaction against the abundance of highly abstract novelties in the field. Essentially String Thing is just another string based analogue controller, but it has been designed to address performance and expressivity in subtly new ways as well as re-using well-established ones.

In early prototype demonstrations, people seemed to grasp the interaction very quickly, and enjoyed the physical feedback. One person commented that the rod's vibration feels 'spooky'. There is indeed an unnatural quality to the rod's constant vibration, refusing to fade away unless contact is broken, a feature originally intended to allow the player to feel the continuous quality of computer and electronically generated sound. The abstract and rough form of the early prototypes required instructions for use; the lack of familiar form provided little suggestion of how the thing works. The final prototype design improves on this, although a basic playing example is often still required. When showing pictures of the final design, people's initial understanding indicates some confusion; for example one person thought it looked like a kind of flute. Without a clear representation or prior explanation of how the design relates to the human body and the intended playing position, it can be difficult to understand what the object actually is. Once a person has seen someone playing an instrument, generally they quickly understand enough to start playing, learning and experimenting for themselves.

I think the design process followed in this thesis was successful overall. There were two main objectives set from the start, one being to increase my personal knowledge in this area of music, technology and interaction design, the other was to contribute interesting ideas to an area so rich in possibilities. Music is a very powerful medium, a great source of pleasure and entertainment, I think it is too easy to lose sight of this initial attraction to such work and become stuck in technical details, as fun as the details themselves may be. If I were to do this or a similar project again, I would like to involve more people, more experienced in the technical aspects, as well as other musicians to give the project a stronger element of 'user testing'. This project was quite an isolated experience.

Involving more technically experienced expertise might save one from potentially 'reinventing the wheel', a risk faced by many musicians tackling technology. I had always planned to use or test my design in a live music environment, to really hear and feel how it performs when used at high volume with other musicians, a relatively high pressure setting where any design problems would quickly become obvious. Due to logistical and timing issues, this has not yet been possible, but it is something I intend to do in the near future.

The current state of the design and prototype shows that the use of detailed continuous control in hardware interfaces is a valuable method of musical control, and a useful tool for driving the related technology forward. If people become more aware of a reason for improving the detail and responsiveness of computer music controllers, then more designs should emerge that meet this demand. Another notable insight gained in this project is the value of physical feedback in musical hardware interaction. A system as simple and cheap to implement as the one explored in this design can greatly enhance the personal playing experience, and therefore the value of the design.

5.4 Future developments

Possibilities for further exploration in the design:

- Implementation of wireless connection; it would be nice to not have to deal with a tangle of cables in a hectic live performance environment.
- Transfer of software processing to an embedded hardware processor, so that the user needs run a minimum of ‘extra’ software.
- Further responsiveness refinement.
- A range of different body designs, and materials used.
- Continue exploring the idea of extending the haptic feedback into the instrument body.
- Design a simple system of marking on the instrument’s playing surface, to aid accuracy in playing.
- Begin documenting a ‘language of gestures’ used for playing.
- Involve more musicians, from a range of backgrounds and styles.

6. Conclusion

This project has been a challenging exercise in rapid learning and experimentation, at times resembling a collection of engineering problems. I started the thesis working with the quite overwhelmingly general topic of computer music interaction and expressive complexity, looking at ways in which musicians might be released from the laptop and keyboard. As time passed, the design became increasingly detailed and focused as I established three primary qualities important to me for expressive complexity in a musical interface: continuous and rapid response to specific gestures, an informative sense of physical feedback, and an appropriate physical form that makes sense and fits in with either a clear new musical mental model or a traditional one.

The idea of musical interaction with continuous pitch is not new; it is the oldest of musical techniques if you include singing as continuous pitch control. It is the application of continuous pitch control within a generic MIDI controller interface, combined with a string metaphor and physical feedback mechanism that is interesting in this field. In some ways, the design is attempt to find new ways to improve interaction and control within an established set of constraints. The hope is that people can access new modes of interaction without needing to invest in an entirely new infrastructure, enabling new musical discoveries and driving the development of improved technology from within.

What can interaction design bring to the field of computer music control? I asked myself this question throughout this thesis, often when it felt as though the focus was drifting too far towards electronics or hardware, where other disciplines might be better suited. I still don’t feel that I can fully answer this question, as the definition and boundaries of the term ‘interaction designer’ are still open to debate, yet in the broad understanding of the world of interaction design, I feel that the subject matter of this thesis is clearly relevant. Interaction design projects tend to place an emphasis on a range of values and qualities; this one happens to be quite a technical and focused one. This makes me wonder how far can a project go in any direction within the boundaries of interaction design, what is the least amount of technology one can use? How technical is too technical? The general answer to this appears to be ‘enough to prove the idea’. The idea is the main product of an interaction design project, the means to communicate that idea can and should flex as required. In reality this process can be quite unclear.

The combination of computers and music present a bewildering world of possibility, one where interaction design can create ways to exploit this musical power, in ways that make sense, as well as all those which don’t.

Appendices

Appendix 1 - Musical Instrument Digital Interface (MIDI) overview

> MIDI allows computers, synthesizers, sound cards and drum machines to control one another, and to exchange system information.[27]

Appendix 1.1 - MIDI, the past

The 1960s and 1970s saw a great boom in new electronic musical instrument development, running in parallel with new sound production and recording technology emergence. The electronic synthesizer’s increased popularity amongst musicians eager for new sounds prompted experimentation with technology to try to allow different synthesizers to interact with each other, as people saw the expansive possibilities opened up by networked musical instruments.

Jazz musician Herbie Hancock invested in his own custom digital interface on his instruments, to allow them to connect and mix sounds and control devices, a custom precursor to the MIDI standard. The industry started to recognize the need for individual electronic musical devices to connect, and synthesizer manufacturers such as Roland and Oberheim introduced proprietary interconnectivity.

As more devices emerged, such as early digital sequencers, there still was no interface standard for compatibility across devices from all manufacturers. The rapidly growing, diverse range of electronic instruments and devices available in the early 1980s must have further emphasized the need for compatibility in musical technology, much like the computer industry has succeeded to implement and grow from. In 1982, a group of synthesizer manufacturers proposed the UMI standard, Universal Musical Interface. After revisions and consultations, in 1983 the MIDI (Musical Instrument Digital Interface) standard was included on keyboards from Roland, and eventually became the ubiquitous communications standard for electronic musical devices, as well as related performance aspects as such lighting control or sound-mixing hardware.

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[27] The Wikipidia, Musical Instrument Digital Interface.
<http://en.wikipedia.org/wiki/Midi#Beyond_MIDI>

Appendix 1.2 - MIDI, the standard

> The MIDI standard consists of a messaging protocol designed for use with musical instruments, as well as a physical interface standard. A physical MIDI connection consists of a one-way (half-duplex) serial current-loop connection running at 31,250 bits per second.[27]

Through the MIDI protocol, devices can transmit these standard musical messages:

- Note-on
- Note-off
- Volume
- Pitch-bend
- Modulation

MIDI devices usually have these connections:

- MIDI-IN
- MIDI-OUT
- (Occasionally) MIDI-THRU
    - This echoes the messages received from the MIDI-IN connection, to allow daisy-chained devices to receive the same information. This allows players to control multiple instruments through one MIDI controller.

MIDI signals are generated by a CV (control voltage)-MIDI converter, where analogue control voltage from a keyboard key, button, knob, fader or more experimental musical interfaces and controllers is converted to MIDI values. For controlling other devices the opposite process is attained, where a MIDI value is converted to a voltage through a MIDI-CV converter. Though this interface it is possible to use MIDI to control other electrical devices, such as lighting faders.

Another component of the MIDI standard is General MIDI, a set of agreed, standard instrument sounds corresponding to the MIDI control change parameter (0-127), established by the MIDI Manufacturer's Association (MMA).

The MIDI protocol is a serial connection, which can have disadvantages for more complex setups where long strings of messages can take a noticeable time to travel through the MIDI network. This can have a significant and dramatic effect on the experience of a performing musician, as any delays between a musician’s actions and the corresponding instrument output can feel unnatural and cause problems with rhythms and timing.

Appendix 1.3 - MIDI, the future

A major limitation of the MIDI standard is the speed of the communication. It is important to retain backwards compatibility for all devices that use MIDI, yet if the bandwidth of the MIDI standard could be increased; there would be greatly enhanced possibilities for more complex and powerful music environments, as well as the ability to send audio and video data over one connection. In that sense, a high-bandwidth version of MIDI could be for multimedia performance devices what the original MIDI was to early synthesizers.

A new standard ZIPI[28] was introduced in 1994 as a high bandwidth successor to MIDI, but it didn't seem wanted by the industry. MIDI configured to pass through USB and Firewire looks to offer the bandwidth increases proposed by ZIPI.

One emerging technology which suggests a total replacement of MIDI altogether is the Open Sound Control[29] (OSC) protocol, developed by CNMAT[30] (Center for New Music and Audio Technologies, Berkeley, California, USA). It is a new protocol for creating musical networks between digital multimedia systems, which can run over a computer Ethernet network infrastructure. OSC is not proprietary, it is an open source technology, but has only currently been implemented in more advanced computer music software systems such as Max/MSP and CSound[31], sophisticated software environments where the MIDI standard presents increasingly obvious limitations with regard to the potential uses for new music and multimedia programming languages, where musical data can be combined with real time networked video and 3D graphics.

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[28] The Wikipidia , ZIPI <http://en.wikipedia.org/wiki/ZIPI>
[29] <http://www.cnmat.berkeley.edu/OpenSoundControl/>
[30] <http://www.cnmat.berkeley.edu/>
[31] <http://www.csounds.com/>

Appendix 2 – Selected research emails (edited for relevance)

From: Ross Bencina
Sent: 29 September 2004 13:13
To: Ben Dove
Subject: Re: audiomulch hardware controller development

Hi Ben

I guess when I talk about 'no physical device' I might not mean exactly what you think, in the sense that I'm not thinking of a way to "jack in" to the computer, or escape physicality, but rather of ways to provide unhindered interfaces between body movement and sound. Any device which is relatively unintrusive (body suits which aren't clumsy or video based tracking systems) would fit into this category.

On the other hand, I agree that at least in some quarters there is an expectation that a musical instrument is a physical object which facilitates "the spectacle of performance".

Best wishes

Ross.

----- Original Message -----
From: Ben Dove
To: 'Ross Bencina'
Sent: Wednesday, September 29, 2004 12:30 PM
Subject: RE: audiomulch hardware controller development

Thanks for the reply Ross – I find it interesting that you say you would be happiest with no physical device to interface with the computer. At the moment all my thinking has been based around the design of objects/instruments, I think I like the idea of being able to lose yourself in playing an instrument, something to fight against (or to hide behind)…

At the moment I am generally trying to soak up lots of information about previous work and the kind of things musicians want, or any interesting issues with expressive control for computer music.

Thanks again,
ben

From: Gary Martin
Sent: 22 October 2004 10:38
To: Ben Dove
Subject: Re: help - words of wisdom and musical musings wanted (please)

There is the whole 'musician' angle. I wasn't really a musician before I came to University and even then some people would still debate whether or not I was. There are really two types of musician, and each of them will probably go for a certain set of instruments.

Type 1. Life-time musician, who was probably introduced by a relative or encouraged at a young age (parents have to be quite willing to give their children noisy instruments). These guys turn out to be musical geniuses (if they are really interested in what they are doing). Musical instruments go from simple to mega complex (bass-harp), but they are outstanding at whatever they have trained for)

Type 2. Trying musicians, who get into playing music quite late, although probably wanted to get started much earlier. They probably play something easy (not harp or violin) like guitar, bass, drums or piano. Some late starters are naturally gifted, but most develop enough skill to get by. Skill increases the most while playing 'on-the-job', where it all becomes more meaningful.

You can usually spot what kind of a musician someone is. Guitarists tend to be small and spindly. Bassists are usually tall and big. Singers love themselves and look in the mirror a lot. Drums either have crazy hair or big feet.

Most musicians start like you say, imitating the styles they like.
Accident rather than deliberate playing usually takes musicians off at a tangent. Accidents that sound nice move the focus of a musician’s style.

I don't play much anymore, but I often doodle in my head.

Gary

From: Lippold Haken
Sent: 16 February 2005 17:49
To: Ben Dove
Subject: Re: interest in developing more expressive controllers

Hi Ben!

Thanks for your Email! Thanks for your kind comments about the continuum
-- and congratulations on your work! I am very impressed, with both your thoughts/concerns as you develop a controller, and with the fact that you are actually getting a design working!

In one part of your web article you mention:"It would be nice if the musician, who has spent years mastering an acoustic instrument and all its subtle characteristics, could make a seamless transition into computer music interaction, at least in terms of physical interface."

I am proud of the continuum, and I think it is a useful contribution to the musical world -- but it does fail in this point. Since the continuum does not have offset black and white keys (the spacing of notes is in straight cents), it does not make use of all the years of experience piano players have in learning piano fingering. In fact, it is a rude surprise to some keyboard players how different the continuum is than a keyboard. Much like a Theremin, it inherits only minimal technique from piano or other instruments. (But, to be fair, I do think the continuum is quite a bit easier to play than a Theremin!)

To answer your question "Did/do you have predefined ideas of the kind of music ": No. Early on, when I started showing the continuum, people told me I had to develop a new music notation, since the continuum is continuous pitch, and thus would have a new and different style of music particular to the continuum alone. This in itself is not bad, but as you observe, musicians can play in many different styles. Certainly a violin or a trombone has continuous pitch, but that does not prevent people from playing music written in standard music notation; it is possible to play in many different musical styles.

I definitely did not have one style of music in mind for the continuum, and I have been trying to show a variety of styles on the web site. In some sense I think people are not taking new instruments very seriously when they assume the new instrument is only for one style of playing. It is true that some experimental instruments have been designed and built for only one style of playing -- and maybe even only for one particular piece -- and developing such an instrument has much artistic merit. But I think there also needs to be room for new controllers that are generic instruments in their own right, useful for the same variety of styles played on any acoustic instrument.

In your case, since your instrument does inherit much technique from cello playing, I think people will be able to learn it quickly. All the same, to really become an expert at your instrument will take longer -- because the people that become experts will develop new techniques, and do things not possible on a cello.

Most people assume a 'good' electronic instrument will be easy to play. In fact, the more it costs, the more immediately the performer should sound great on the instrument. This is very different than classical instruments. No proficient piano player would say "Gee, I would like to play a trumpet concerto", and then expect to become a trumpet virtuoso in a month. But almost every piano player (or synthesizer keyboard player) expects to become a continuum virtuoso in a month. The double-standard reflects an immaturity in electronic instruments in general; unknowingly people don't take electronic instruments seriously in the way that people take classical instruments seriously.

Thanks again, and best wishes for your work!
Lippold

From: Michael Kieslinger
Sent: 22 February 2005 22:56
To: Ben Dove; Ben Dove
Subject: Re: music controller thoughts and advice...maybe?

Hi Ben,
Here are some comments on your work. Sooner than expected :)

First of all,
I really liked your video. It is impressive what you have accomplished. Build a sensor and have different sound examples with it!

As you wrote yourself, the topic you chose has been and is being widely explored.

I am not sure if you ever will be able to create a new musical instrument if there is a computer next to it that processes data from an input. only if there is a compete unit of hardware and software, it could be accomplished, but even then there might be software updates, which is somehow strange for the concept of an musical instrument.

Your work definitely has potential, and the video proved that.
I would keep your goal very reasonable. Don’t try to make a new musical instrument.
Just focus on creating a device that is nice to touch and handle and a software with it that generates nice sounds and allows ways to learn and explore.
If you get it right and it does exactly that, feels and sounds nice. You have managed a lot!
But if anyone else will use it? Maybe.
But it seems people love as much to create new controllers and software as they love to make music.

In the world of computers any controller can theoretically produce any kind of output.
Which doesn't mean that it makes sense.
Even if you match the character of sound to the character of the controller you have huge amount possibilities.
Just think about gestures of a conductor in a silent video: of course the first thing that comes to mind is the classical music, but on the same way his gesture could generate modern, strange, disharmonic music.

My strategy would be:
Play with the sensor every day, try to feel into it! Listen to the sound that is being produced within your mind.
Try to build this using software.
Play again and see if it fits.
Play again with just music in your mind.
Repeat this process many many many times.
And slowly you will create your personal ideal connection between the gestures, the controller and the sound it generates.

But there is never ever an objective match between your controller and your sound.
It is and always will be subjective.

Looking and listening to the video makes me confident that it is worthwhile.
But don't expect too much, there have been people working on these things for decades!!
Most important is that you love to do this and that you love your controller and you love the sound that comes out of it!
Then you will be convincing and others will be convinced and enjoy as well.

The famous pianist LangLang recently said in an interview:
If I play on stage I only concentrate on the music and not on the audience and if they like it.
If I concentrate on the performance and it works out it will automatically work out for the people.
But it never works if they are the other way around.

I hope this all made sense,
And it helps you somehow.

Good luck and keep me informed.
Michael

Appendix 3 – Max/MSP patch details

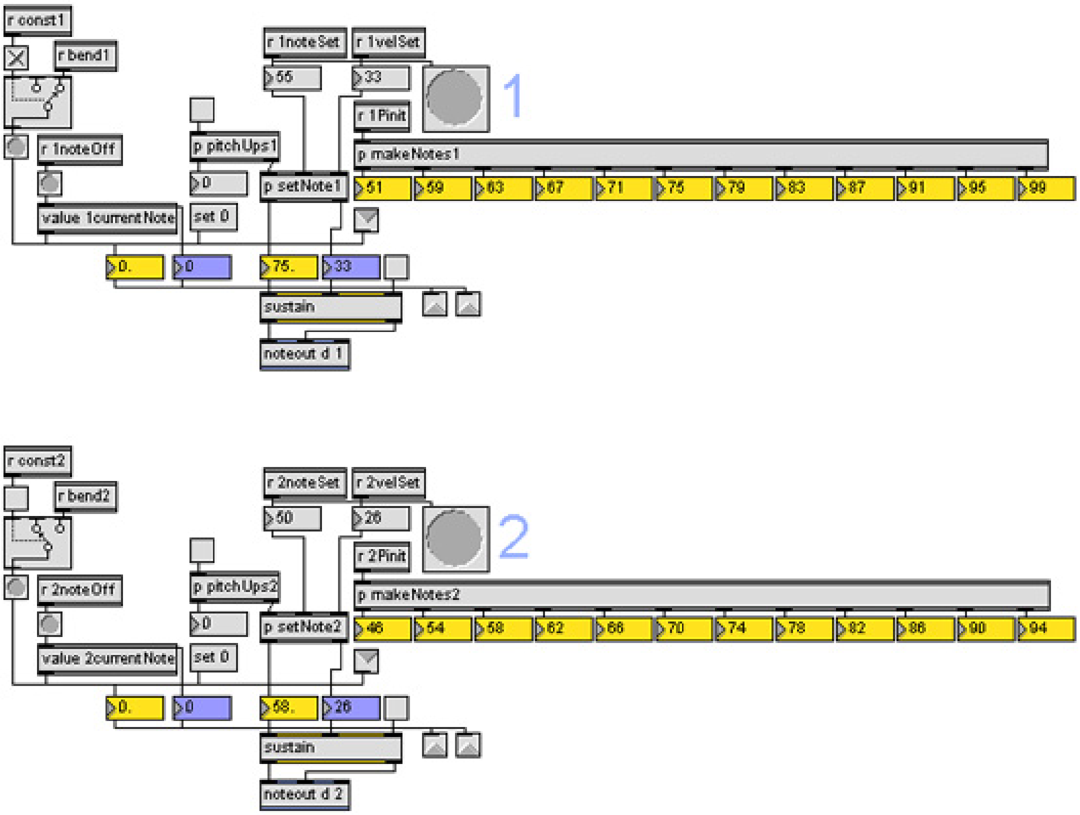

Figure 31 – Two MIDI note generators in the main Max/MSP patch, showing the note numbers generated for all the possible notes within the range (a maximum of 4 octaves or 12 notes).

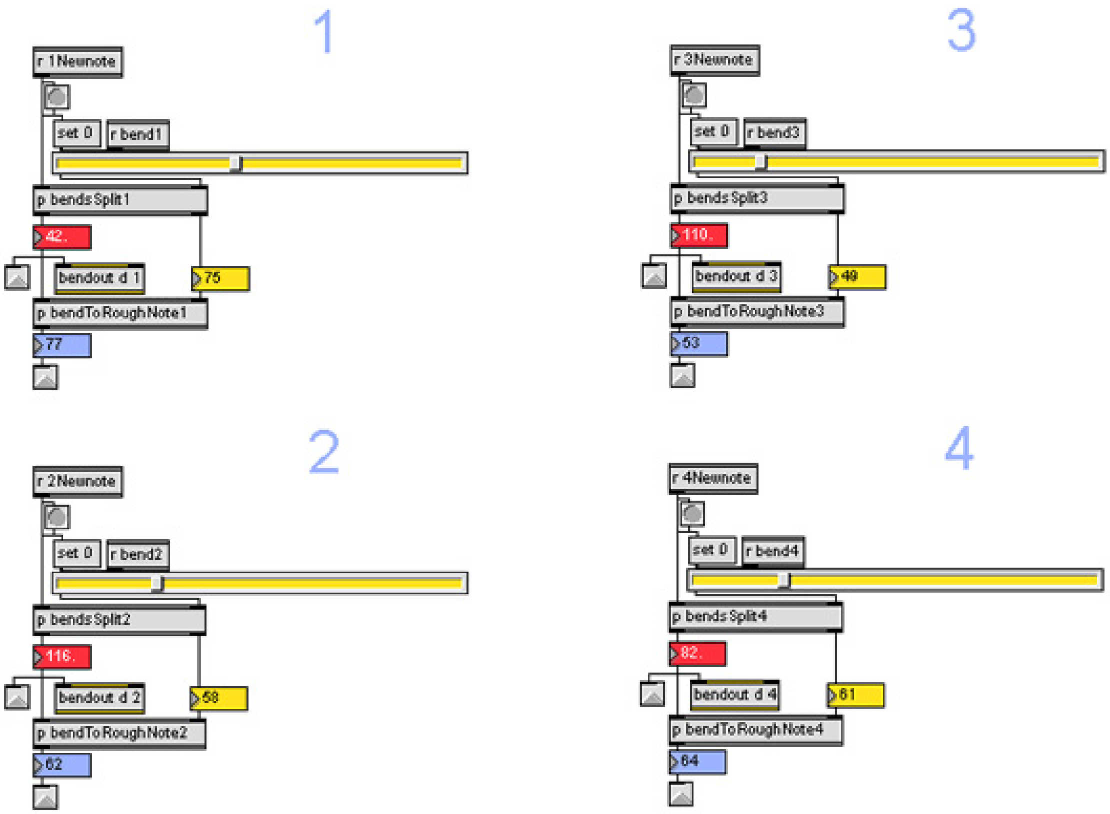

Figure 32 – Four note bending devices, splitting values from one large slider into multiple sets of 0 – 127 values. Each value is updated and sent on a channel with the corresponding current note value.

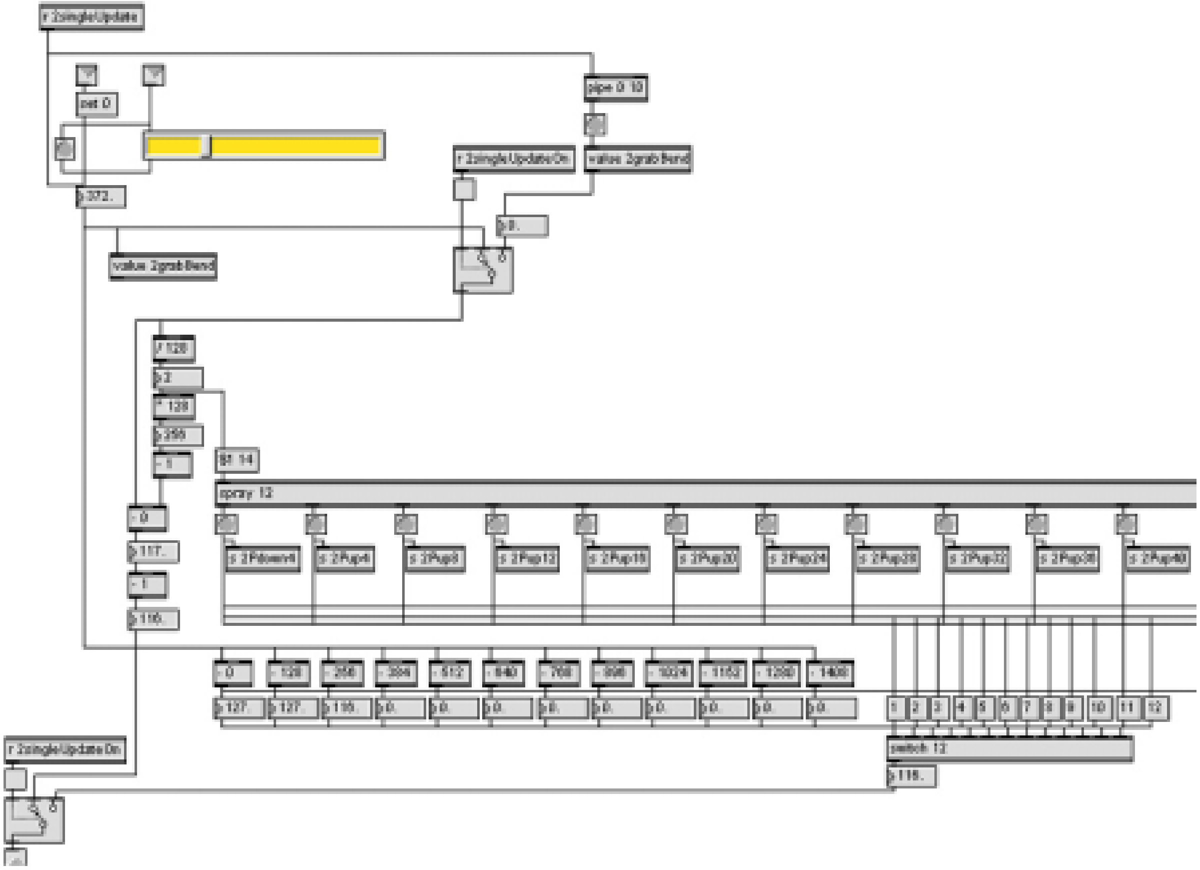

Figure 33 – Detail for one of the note bending devices, the main slider (representing one of the rods) is divided into a series of points, at which a new note is sent, and the bend value resets to zero.

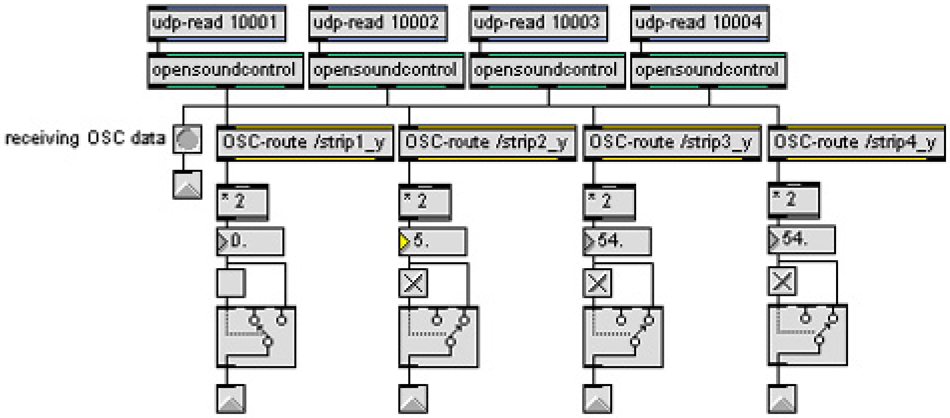

Figure 34 – The Open Sound Control input, continuously receiving input. These inputs are set to only affect the rest of the patch if the input is higher than zero, to reduce processor load and help prevent unintended jumps in slider movement.

Appendix 4 – Prototype detail and dimensions

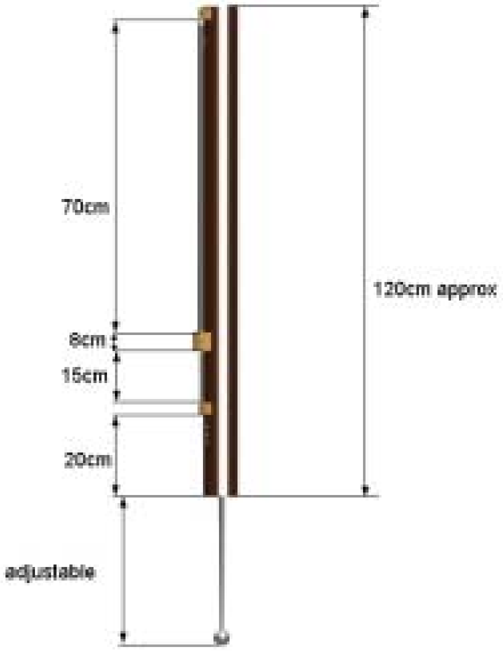

Figure 35 – Prototype side view

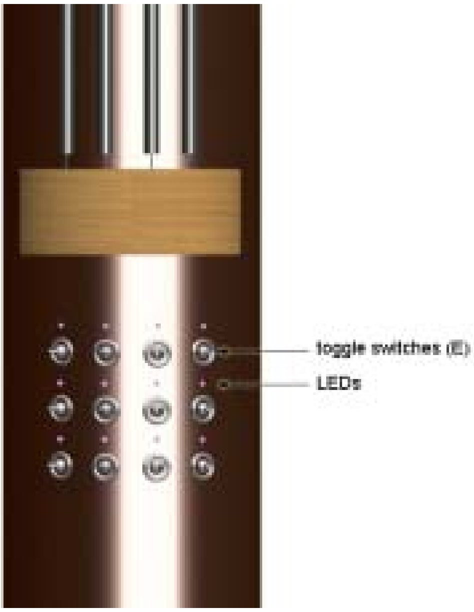

Figure 36 - Prototype front view, front lower control panel

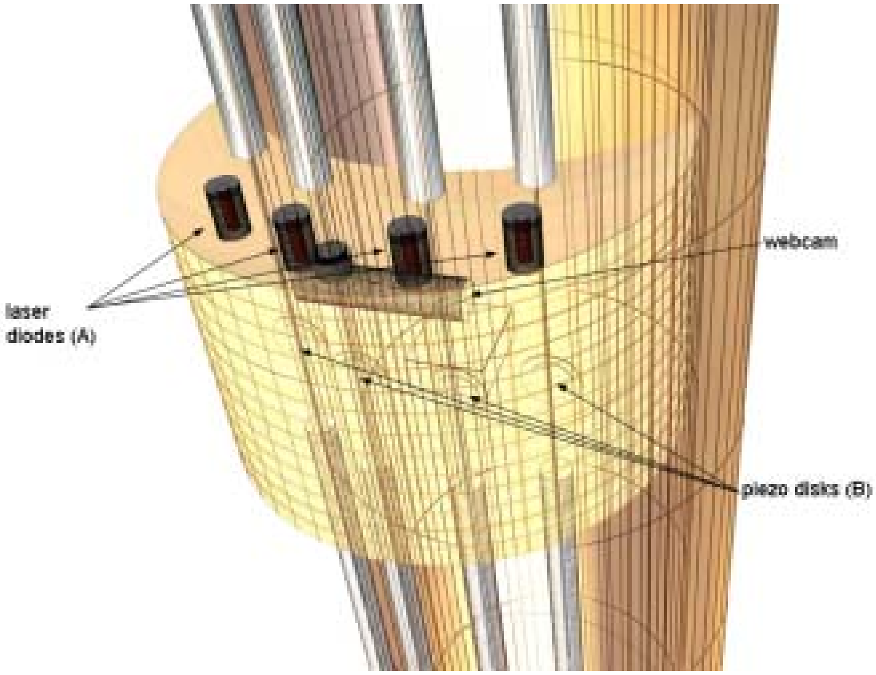

Figure 37 - Prototype central bridge element

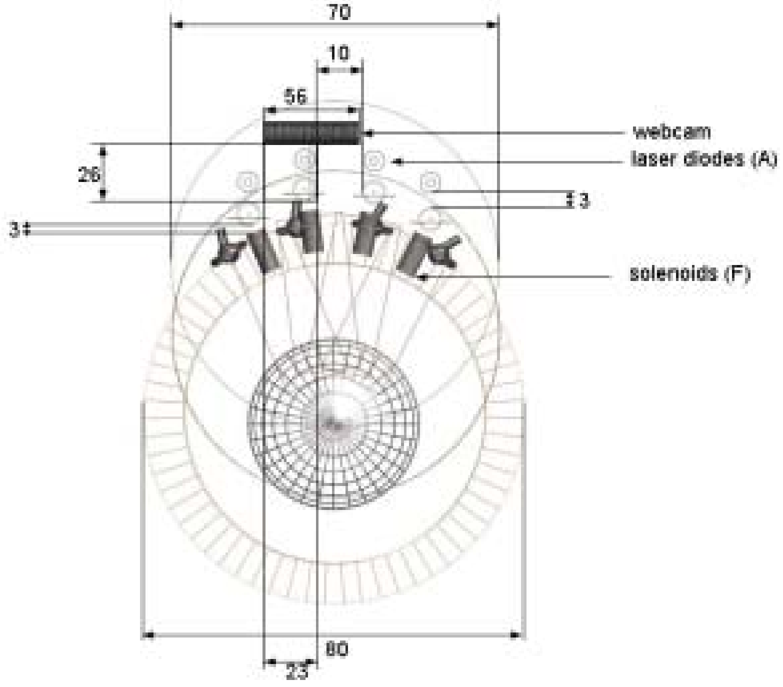

Figure 38 - Prototype central bridge cross-section

Source List

Benade, Arthur H. *Fundamentals of Musical Acoustics*. New York: Dover, 1990

Garland, Trudi Hammel and Charity Vaughan Kahn. *Math and Music Harmonious Connections*. New Jersey: Dale Seymour, 1995.

Pierce, John R. *The Science of Musical Sound*. New York: Freeman, 2000.

Articles and Reports

Alesis Studio Electronics (2000). *Alesis airFX reference manual*, <http://www.alesis.com/downloads/manuals/airFX_Manual.pdf >

Hewitt, Donna, Stevenson, Ian. *E-mic: Extended Mic-stand Interface Controller*. Conference Proceedings NIME (2003)

Cook, Perry. *Principles for Designing Computer Music Controllers*. Conference Proceedings NIME (2001) <http://www.csl.sony.co.jp/person/poup/research/chi2000wshp/papers/cook.pdf>

Holton, Terry, *MLAN Time To Pay Attention*. Resolution Magazine V2.4 May 03 <http://www.mlancentral.com/mlan_info/mLAN_resolution_v24.pdf>

Nichols, Charles Sabin. *The VBOW an expressive musical computer controller Haptic Human-Computer Interface*. PhD Dissertation: August 2003

Online Sources

Alesis AirFX product page <http://www.alesis.com/products/airfx/about.html>

Audiomulch Interactive Music Studio <http://www.audiomulch.com/>

Center for New Music and Audio Technologies <http://www.cnmat.berkeley.edu/>

Csound programming language <http://www.csounds.com/>

Electronic bow for guitar <http://www.ebow.com/>

The EyesWeb project <http://www.infomus.dist.unige.it/eywindex.html>

Guide to sound synthesis <http://www.sonicspot.com/guide/synthesis.html>

Guitarist magazine reader forums <http://forum.intermusic.com/>

Guitar digital modelling products <http://line6.com>

Haken Audio, The Continuum Keyboard <http://www.hakenaudio.com/Continuum/>

Improvising electroacoustic ensemble <http://listen.to/simulus>

Korg Kaos Pad <http://korg.com/gear/info.asp?A_PROD_NO=KP2>

Keyboard Magazine <http://www.keyboardmag.com/archive/0804/0804_r5.htm>

Machover, Tod. Hypercello/Yo-Yo Ma
<http://brainop.media.mit.edu/Archive/Hyperinstruments/hypercello.html>

Max/MSP graphical programming environment
<http://www.cycling74.com/products/maxmsp_2.html>

A Mellotron history <http://www.mellotron.com/history.htm>

MIDI performance controllers <http://www.starrlabs.com/>

Online tutorials on computer music <http://x.i-dat.org/~csem/UNESCO/1/index.html>

OpenSoundControl Home Page <http://www.cnmat.berkeley.edu/OpenSoundControl/>

Paradiso, Joseph. Electronic Music Interfaces. March 1998
<http://web.media.mit.edu/~joep/SpectrumWeb/SpectrumX.html>

Quantum Research Group, touch control and sensor ICs <http://www.qprox.com/>

Software and documentation by Miller Puckette <http://www-crca.ucsd.edu/~msp/software.html>

Steinberg <http://www.steinberg.de/>

Wiring prototyping environment <http://atari.uniandes.edu.co/wiring/index.html>

The Wikipidia, Musical Instrument Digital Interface
<http://en.wikipedia.org/wiki/Midi#Beyond_MIDI>

The Wikipidia , Theremin. <http://en.wikipedia.org/wiki/Theremin>

The Wikipidia , ZIPI. <http://en.wikipedia.org/wiki/ZIPI>

The Wikipidia, Digital Signal Processing <http://en.wikipedia.org/wiki/Digital_signal_processing>

Other Sources

Bencina, Ross. ‘Re: audiomulch hardware controller development’.
Email to the author. 29 September 2004

Haken, Lippold. ‘Re: interest in developing more expressive controllers’.
Email to the author. 16 February 2005

Kieslinger, Michael. ‘Re: music controller thoughts and advice...maybe?’
Email to the author. 22 February 2005

Martin, Gary. ‘Re: help - words of wisdom and musical musings wanted (please)’.
Email to the author. 22 October 2004