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Musical applications of Physical Computing

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Abstract

This paper presents a music technology portfolio consisting of 5 distinct projects, which are each concerned with the concept of physicality in digital music. The work seeks to address acoustic ecologist R. Murray Schafer's concept of *schizophonia* by imbuing digital music systems with signatures from the analog world through the use of emerging technologies of physical computing. Physical control methods were developed and explored for this purpose as well as the use of computer controlled mechanical actuators operating on acoustic objects. The resultant projects vary in form - encompassing aspects of automated musical performance, installation and interactive art as well as design and programming - but in all the link between sound and source is in some way given physical tangibility.

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1. Introduction

This paper serves to contextualize and comment on the accompanying portfolio of works, which in various ways deal with the interface between the physical world and digital music technologies. The work is grounded in the field of physical computing and seeks to address issues relating to tangibility and interface through exploration of the theme of physicality in digital music.

The portfolio includes a number of different projects in pursuit of these aims, the exploration of which has led to differing forms of output, encompassing aspects of musical performance, installation art and visual art as well as design and programming. The musical application of various existing gestural input devices is explored as well as the use of computer controlled electro-mechanical actuators to make sound. Due to the interdisciplinary nature of the work, this thesis will include technical explanation, discussion of design and aesthetics as well as musicological and artistic context.

I will begin with a short discussion concerning context and motivation for the work, followed by commentary and technical explanation of the individual projects, concluding with an analysis of issues and themes raised.

2. Background

The development of technologies for the mechanical reproduction of sound in the late 19th century promoted a shift in the way in which sound was viewed and conceptualized. This shift was outlined by Walter Murch in the foreword to Michel Chion's *Audio-Vision: Sound on Screen*, where he describes the effect that recording technology has had in elevating sound from what he conceived of as its subordinate role as a 'shadow' of physical events:

> "Recording magically lifted the shadow away from the object and stood it on its own, giving it a miraculous and sometimes frightening substantiality (…) the shadow of sound had learned to dance."[1]

This developing view of the role of sound was crystallised in Pierre Schaeffer's pioneering work, *Traite des Objets Musicaux*, in which he introduced the concept of the *sound object* as a means to study and classify sounds in an objective manner without reference to their cause or context. [2] The Schaefferian ideal of sound as object independent from acoustic sources is heralded by Trevor Wishart as, 'the central watershed in changing our view of what constitutes music', because it allows composers and sound artists the freedom to use the elements of sound as a painter uses paint, without the necessity of representational forms. [3]

The acoustic ecology movement, which developed from the writings of Raymond Murray Schafer in the 1970s, opposes this nonrepresentational use of sound suggesting that the acousmatic situation is an inherently unhealthy one. The acoustic ecologist's proposition is that acousmatic art exists in a virtual or imagined space, separate from acoustic space and therefore is uncertain and ambiguous. In his 1977 text *The Tuning of the World*, R. Murray Schafer outlines his concept of *schizophonia*, which he describes as, 'the split between an

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[1] Michel Chion, *Audio-Vision: Sound on Screen* (New York: Columbia University Press, 1994).
[2] Pierre Schaeffer, *Traite des objets musicaux* (Paris: Editions du Seuil, 1966).
[3] Trevor Wishart, *On Sonic Art*, revised edn (London: Harwood Academic Publishers.Knopf, 1996).

original sound and its electroacoustic reproduction'.[4] This notion problematizes all electroacoustic sound at its most basic level and Schafer is explicit in his judgment of its 'aberrational' effect:

> "Original sounds are tied to the mechanisms that produce them. Electroacoustically reproduced sounds are copies and they may be restated at other times or places. I employ this "nervous" word ['schizophonia'] in order to dramatize the aberrational effect of this twentieth-century development."[5]

The work of Pierre Schaeffer and R. Murray Schafer then present opposing theories of sound. While Pierre Schaeffer's theories are based on a Husserlian phenomenology of sound, R M Shafer's concept of the schizophonic suggests that an essential element of the natural standpoint is lost when sounds are disconnected from their physical causes.

The questions raised by the opposition of these views are clearly important to the field of acousmatics in electroacoustic music but they also bear an interesting relation to the context of physical computing. Physical computing is a rapidly developing branch of computing that seeks integration and interaction beyond the limits of the Graphical User Interface (GUI). Dan O'Sullivan and Tom Igoe of the Tisch School of Arts describe its aspiration as, 'to bridge the gap between the physical and the virtual […[and]…] make a more interesting connection between the physical and the computer world'.[6] These integrations are made possible through recent developments in sensor and microcontroller technologies.

The aim of my portfolio is to address Shafer's premise of the schizophonic, through an exploration of the musical potential of recent developments in the field of physical computing afforded by new consumer microcontrollers. These technologies are presented here as a means of imbuing digital music systems

[4] Raymond Murray Schafer, *The Soundscape. Our Sonic Environment and the Tuning of the World* (Rochester, VA: Destiny Books, 1994 [1977]).
[5] Murray Schafer, *The Soundscape*, p. 273.
[6] Dan O'Sullivan and Tom Igoe, *Physical Computing, Sensing and Controlling the Physical World with Computers*, (Boston: Thomson Course Technology PVR, 2004), p. xvii

with signatures from the analog world in an attempt to address the schizophonic effect of the separation of sound from its physical origins.

As the portfolio has developed a number of themes have emerged which I will trace through the following commentaries. Some of these relate to my primary research question, some arose as a response to issues raised as the work developed, and some were seemingly unrelated to my main question but nevertheless recurred across the projects. An analysis of these emerging themes will follow the commentaries.

3. Works and Implementation

3.1. Input Device Review

3.1.1. Overview

This initial project – the Input Device Review - was intended as an exploration of ways of directly manipulating digital musical elements through a physical device. As a starting point I decided to explore the functionality of two widely used controller devices in electronic music – the Monome 40h and the Nintendo Wiimote and Nunchuk. Both of these controllers have been used as Digital Musical Interfaces (DMIs) to give performers a more tangible or realistic interaction with the digital domain and to provide a visual element to electronic music performance.

Monome is a New York based company who make minimalist, grid based USB interfaces. The 40h is the smallest iteration with 64 (8x8) backlit buttons. Functionality of the buttons and lights is separate and controlled by software via USB. Since its initial limited release in 2006 the 40h has been used by a range of electronic musicians and artists including Daedelus and Imogen Heap.

The Nintendo Wiimote and Nunchuk are Bluetooth-enabled controllers for Nintendo's Wii games console. The Wiimote is widely available and affordable and has become a popular software controller used in a number of interesting projects including Yann Seznec's *Wiimote Loop Machine*[7] and Johnny Chung Lee's interactive whiteboard project[8]. The Wiimote features 7 buttons, a D-pad and a 3-axis accelerometer and the Nunchuk features 2 buttons, an analog stick and a 3-axis accelerometer.

My exploration of these devices led to the development of two short projects, which are explained in the following sections. *Monomnichord* is a project based on the Monome 40h and *Wiimote Looper* is based on the Nintendo Wiimote and Nunchuk. My intention here was to explore various forms of gestural input with a view to utilizing them further in this investigation. These projects also served

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[7] http://www.theamazingrolo.net/wii/ [accessed 25 September 2010]
[8] http://johnnylee.net/projects/wii/ [accessed 25 September 2010]

as a primer for further programming in Max/MSP, particularly in mapping gestural data.

3.1.2. Monomnichord

A revisioning of a Suzuki Omnichord using a Monome 40h and Stribe touchstrip.

Overview

The Suzuki Omnichord is a discontinued electronic instrument produced in Japan in the 1980s. Its form is based on an Autoharp (or Chorded Zither) and is designed to be playable by the relative novice. It features push-button chord selection and a magnetic touch plate and is suited to providing simple chordal accompaniment. Because it is based on analog circuitry its tuning is affected by heat and humidity.

I devised *Monomnichord* as a computer/controller instrument based on the original Omnichord. This new instrument retains successful aspects of the original design (ease of use, chord selection buttons, chord memory and 'strum' gestures) whilst adding additional functionality such as tempo accurate button presses, a sample based rhythm section and perfect A=440Hz tuning.

Implementation

The hardware elements used in this project were a Monome 40h[9], a Stribe[10] touchstrip and an Arduino Duemilanove[11] microcontroller. The 40h was connected directly to the host computer via USB and the Stribe touchstrip was connected via the Arduino using a multiplexer shield. The Stribe and the multiplexer shield were both built from kits from the Curious Inventor website[12]. The code running on the Arduino microcontroller was written by Stribe inventor Josh Boughey. It uses the SimpleMessage library for Arduino and allows functionality of the Stribe's LEDs and touchstrip to be controlled via the serial

[9] http://monome.org/40h [accessed 25 September 2010]
[10] http://www.soundwidgets.com/stribe/ [accessed 25 September 2010]
[11] http://arduino.cc/en/Main/Hardware/ [accessed 25 September 2010]
[12] http://store.curiousinventor.com/stribe.html [accessed 25 September 2010]

object in Max/MSP. Data routing software Monomeserial[13] was used to convert serial data from the 40h to OSC messages for use in Max/MSP and vice versa.

The Patch

The Max/MSP patch uses James Drake's externals *monomecontrol*[14] as a means of further simplifying communication with the 40h from Max/MSP. The main features of the patch are a chord section, a lead section, a rhythm section and a touchstrip section. A *monomeslider* object is used as a volume control for each section. *groove*~ and *buffer*~ objects are used for the rhythm section but all other sound is synthesized in Max/MSP using the *phasor*~ object.

A demonstration of the project as well as supporting materials can be found on the accompanying DVD in the folder:
DVD/1 Gestural Input Review/1.1.monomnichord

A complete list of functions appears in Appendix 1.

3.1.3. Wiimote Looper

Wiimote controlled audio loop recorder

Overview

This project uses a Nintendo Wiimote and Nunchuk to control the recording, playback and arrangement of a number of live and prerecorded loops. Part of my aim with this project was to use a method of control with little or no visual feedback requiring the functionality of the patch to be simple and easy to navigate.

13 http://monome.org/data/app/monomeserial [accessed 25 September 2010]
14 http://docs.monome.org/doku.php?id=app:monomecontrol [accessed 25 September 2010]

Implementation

The Wiimote and Nunchuk were wirelessly connected to the host computer via Bluetooth. I used communication software OSCulator[15] to convert the Wiimote serial data to OSC messages that could then be mapped in Max/MSP.

The Patch

The Max/MSP patch consists of three main sections – a set of input recording loopers, an effects section and a file looper. The Nunchuk is used exclusively for the rhythm section with speed and playback controllable via the C and Z buttons and Yotaro Shuto's *repeat~* effect[16] controllable via the analog stick. The recording, playback and effects functions can all be assigned to a specific loop via the D-pad. There is also the option to control all loops simultaneously. The accelerometer on the Wiimote is used to control delay time and feedback as well as delay mix level.

A demonstration of the project as well as supporting materials can be found on the accompanying DVD in the folder:
DVD/1 Gestural Input Review/1.2.wiimotelooper

A complete list of functions appears in Appendix 2.

3.1.4. Analysis

These exploratory projects were helpful as a starting point for my work in physical computing since they introduced themes and methodologies that would be of use in later projects. They also establish an aesthetic musical context for the rest of the portfolio, reflecting my background in electronica.

These projects represent my first experience of making music with self-developed software and an aspect of this I found of particular value was an emphasis on process over output. In each project the music that was made was inseparable from the development process in that it reflected the character of

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[15] http://www.osculator.net [accessed 25 September 2010]

[16] http://www.maxobjects.com/?v=authors&id_auteur=309&PHPSESSID=888db5752b77452e01145a8a5367b087 [accessed 25 September 2010]

the software as much as the momentary intention of the performer. As such, the coding process became an augmentation of the composition process. A characteristic of both projects was therefore a focus on the setting of specific conditions for music to occur, a theme that I will revisit later.

3.2. Guitar Glitch

3 mechanically actuated acoustic guitars

3.2.1. Overview

In this work sound is made by computer-controlled mechanical actuators acting on various parts of three acoustic guitars and from the resulting resonances of the guitars themselves. Solenoids and DC motors are used variously to hammer the body of the guitars, to fret the guitar at various points on the neck and to mute the strings. LEDs are linked to the actuators, giving a visual cue as to the source of individual sounds.

Having first encountered ‘project ready’ consumer microcontrollers when building the Stribe interface in the last project, the development of my next work came in large part as a result of further inquiry into the musical possibilities they might afford. Having explored some input functionality in the previous project I was particularly drawn towards the possibilities of using the microcontroller for output. Representing a shift in my focus from looking purely at control methods I found the idea of computer controlled mechanical music compelling and highly relevant to my research question.

Since technological concerns had shaped the development of the work initially, I felt it was necessary to balance this with a concern for creation of a strong musical identity. The project was based around the classical guitar and as such this gave the material a referential grounding in a historically recognised acoustic music tradition. This effect arose not from specific compositional intent but from the exploratory process of ‘re-instrumentalising’ the guitars.

Guitar Glitch could best be described as an *acoustic* electronic instrument. The importance of the experience of direct sound was carefully considered throughout the development process and the character of the piece is in part due to considerations of inherent limits of acoustic environments. Although the work does translate to audio and video recording this vital acoustic character can only be transmitted through physical presence. To this end the piece was performed at the GLEAM electroacoustic music concert on 21st March 2010.

3.2.2. Implementation

Hardware

The work features a total of 17 solenoids of various sizes, 2 DC motors and 2 microcontrollers. The majority of actuators were controlled via an Arduino Duemilanove microcontroller, which was running code from the SimpleMessageSystem library to allow communication from within Max/MSP.

For each actuator, the output pin on the Arduino was connected to a TIP120 transistor circuit on a breadboard to allow control over the 12v needed to power the solenoid. The motor was connected to +12v from an external power supply and to the transistor's collector pin. A 10k Ohm resistor was used between the analog pin and the base pin of the transistor and a rectifier diode was placed between the collector and emitter pins on the transistor to protect the Arduino board from any power leakage. The transistor's emitter pin was connected to the ground pins on both the Arduino and the external power supply. For each actuator, an LED was also connected to the relevant output and ground pins via the breadboard. The circuit schematic can be seen in Appendix 3.

6v DC motors were mounted on the guitars' headstocks to act upon the strings between the nut and the machineheads. In order to give the fine control needed for their strumming action, a microcontroller with variable output voltage was necessary. Although possible using the Arduino's PWM output pins, the complexity of implementing this at the software stage was off-putting. An Eroctronix™ Miditron microcontroller, which allows for variable output via its analog pins, was used to allow the necessary control.

The Patch

A Max/MSP patch converted MIDI input to ASCII messages, which were then sent to the Arduino via the serial port. Each solenoid is mapped to a midi note allowing independent on/off functionality. The DC motors are mapped to control change messages allowing a 127 stage fine control over their voltage.

The Music

A musical composition for the guitars to play was sequenced using Logic Pro. It consists of a number of short movements, each examining a different character of the instrument. An element that is explored and manipulated throughout the piece is the playability of the music by human performers. At times the combination of the guitar and percussive elements sound plausibly like a Flamenco ensemble and at others the mechanical nature of the instrument is explicit due to the complexity of the material. The composition is framed within the context of current styles of electronica through the use of step sequencing in repeating blocks and the inclusion of repeating and varying beats.

One experimental aspect of the composition process was the use of visual patterns in a matrix editor to sequence some of the music. Using this process the musical material was generated as a result of a visual composition. A clear example of this occurs at 5m30s where blocks of notes were entered into a matrix editor and were then cut into patterned segments. See Figure1 below.

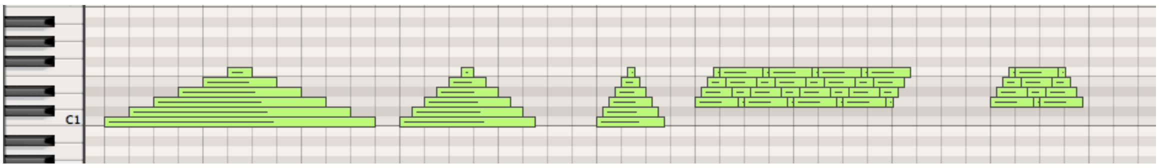

Fig 1

A video of the work as well as supporting materials can be found on the accompanying DVD in the folder: DVD/2/guitarglitch

3.2.3. Analysis

The piece raises some questions relating to acousmatic theory. In one sense it presents as the antithesis of the acousmatic since the sound heard is experienced directly from the physical object. However the relationship between the act of sound creation and the listener is less than direct. The 'acousmatic veil'[17] here is not at the loudspeaker (as in the prevalent reading of electroacoustic art) but is around the 'performer' who is not seen. Attention is also drawn towards the 'creator' (programmer and manufacturer) who again is not physically present.

The pianola works of Conlon Nancarrow were of influence when designing this piece and various parallels to these instruments emerged. I wanted to create a piece that resembled a traditional instrument and would therefore give the effect of the absent player. The composition element is pre-prepared and fixed, as is the case with piano rolls. Another parallel is the overtly mechanical nature of the composition and the inclusion of material that would be unplayable by a human performer. This was a significant feature of the work of Conlon Nancarrow who is best known for his frenetic player piano studies. Nancarrow attempted to overcome the 'timbral homogeneity' associated with these instruments by building his own prepared player pianos however his aim remained to 'de-domesticate' the sound of the player piano by emphasizing their mechanical nature. [18] My focus however was to create material which combined allusions to these traditions with a subtler, more 'human' nuance. The direct experience of sound was important here also, something which in retrospect was a unique aspect of the consumer pianola.

Once again, the design stage had a major compositional impact on the work. The placing of the solenoids on the fretboard and the resulting implications for the guitars' tuning set the tonality of the piece and the usable range of the instrument at an early stage. Further extension of my developing focus on process can be seen in the inclusion of musical materials derived from messages used for testing at the construction stage in the final composition.

The performance of the piece in the GLEAM concert in March 2010 raised a number of concerns relating to audience and intention. In light of the

[17] Pierre Schaeffer, *Traite des objets musicaux* (Paris: Editions du Seuil, 1966).
[18] Philip Carlsen, *The Player Piano Music of Conlon Nancarrow: An Analysis of Selected Studies* (New York: Institute for Studies in American Music Monographs, 1988)

exploratory nature of the work I found the concert environment an uncomfortable one because I felt the work acquired an authority of purpose that was not intended. In other words, it would seem in this context that the audience might expect the piece to be communicating the intention of a composer rather than sounding the result of a process set in motion. In particular I felt that the implication of finality that the setting gave the work was at odds with its process-driven nature. These concerns raised the idea of intentionality, or unintentionality as a focus for work, which I would go on to explore in my next piece.

3.3. Reactive Singing Bowls

Movement sensitive mechanically actuated singing bowls, strings and cymbals

3.3.1. Overview

This project was developed for installation in a public space that sees both heavy traffic and solitary users. Movement-sensing algorithms trigger actuators on singing bowls, strings and cymbals via Max/MSP and a Miditron microcontroller board. The software responds variously to movement as well as lack of movement.

The development of this project was influenced in part by the performance of Guitar Glitch at the GLEAM concert in March 2010. I became aware that aspects of the concert environment had affected its reception and had become an unintended feature of the work. As a result I wanted to create a piece that could be exhibited away from a traditional performance environment and that had a more inclusive and less directly intentioned focus.

The intention was for the piece to be *passively* interactive. That is to say that the work would respond to human action without the participants' knowledge of the interaction, removing the issue of intention from the experience.

3.3.2. Implementation

The sonic palette of the piece is founded on four Tibetan singing bowls, which are struck with solenoid driven piano hammers. The string section is constructed from guitar strings and machine heads and is tuned to the same frequencies as the bowls. The strings are struck with piano hammers, which rest on the strings and are momentarily raised and released giving a bouncing effect. The cymbals are struck at various points, again with solenoid driven piano hammers, completing the piece.

I used a Miditron microcontroller board to interface with the actuators because I wanted to be able to vary the voltage sent to each solenoid. A TIP120 transistor circuit similar to that used in my previous project was used to allow control over 12v from an external power supply via the output pins on the microcontroller.

The Patch

After experimenting with PIR and PING sensors I decided to use a USB camera as the movement sensor. This allowed me to poll a wide area for movement and have visual feedback in Max/MSP allowing easy calibration of the system. I used the Jitter object *jit.rgb2luma* to convert the RGB image (4 layers) to monochrome (1 layer) and *jit.op* to detect any change. A demonstration of this part of the patch is included on the accompanying DVD.

A *counter* object that counts bangs from the tracking section selects various 'modes' or combinations of modes. A sensitivity control for the tracking section and refresh rate control for the *counter* allow for on-site calibration. The various modes are all built with the *metro* and *random* objects and become sequentially more animated as the amount of detected motion increases.

A demonstration of the work and footage from the installation as well as supporting materials can be found on the accompanying DVD in the folder: DVD/3/singingbowls

3.3.3. Analysis

The work was installed for a short period in the entrance hall of the Hunterian Museum, University of Glasgow Campus in August 2010.

A number of issues became apparent after seeing the work in an installation context. Firstly, that the environment that the work was in was crucial to the participants' expectations and had therefore affected their interactions with it. The Hunterian Museum entrance hall is in a gallery configuration with various exhibits around the room. Patrons visit the museum expressly to view the exhibits and my work was consequently received as a further exhibit to look at. At times the piece successfully worked on a subconscious level with participants unaware of their effect on the work, however an interesting but unintended dimension to the piece arose when participants engaged with it directly. A common interaction was the following:

A visitor moves around the space looking at the exhibits –
the work responds.
The visitor approaches the work and stops –
the work responds and then stops.
The visitor watches and waits –
nothing happens.
The visitor goes to leave –
the work responds.
The visitor realises that there is an interactive element and plays with it –
the work responds.

Interestingly, the work unexpectedly addresses some of the issues I was considering when designing it since *intention* actually becomes the focus of many of these interactions. However I found this new aspect somewhat undesirable as it gave the work a more confrontational tone. The visitors' realisation that they had been unconscious participants and that they had been 'watched' by the installation piece also raised for me issues relating to privacy. This was particularly apparent since the sensing device I happened to use was a camera; the quintessential tool of covert surveillance.

The issue of intentionality in the piece is dealt with on two levels. Firstly, the intention of the participants was at issue as described above but also my intention as composer was removed, or at least diminished, by the piece's use of coincidental gestures as well as generative algorithms based on the *random* object. The piece served as an experiment in relinquishing control over aspects of the work and helped to develop my thinking about this emerging theme of control and unintentionality. I was aware that in the practice of setting up and then allowing unforeseen consequences to arise, this role of 'allowing' was in marked contrast to the themes of performance and control in the first projects.

By reducing my intentioned presence at the output stage, my role inevitably was focused towards the preparation stage, again reflecting the focus on process developing through the portfolio. The visual aspects of the work have a rough 'DIY' or homemade aesthetic - no attempts were made to beautify the piece by covering screws or sanding edges - and this also served to bring into focus its means of construction.

The work's ambiguous intentionality raised for me issues about the necessity for intention in art. If I have constructed the circumstance of a work but someone else has triggered the event, then who has created the art? Is it in fact, important to whom the work is attributable? These questions of ownership (and therefore ego) are at play in the work and are in opposition to the idea of intentionalism, which asserts that the meaning of a text (or work) is restricted to the intentions of its author. This line of thought raises broader questions of authorship, which have some historical precedence. Harold Rosenberg - interpreting of the work of the action painters in the 1940s and 50s – famously redefined art as an act rather than an object[19]. The implications of this idea on musical discourse were seen in the 'indeterminate music' movement whose proponents included Morton Feldman and John Cage. In particular Cage's writings on indeterminacy, chance and process are of relevance to some of the reoccurring issues in my portfolio. In his Experimental Music lecture he writes:

> "One may give up the desire to control sound, clear his mind of music, and set about discovering means to let sounds be themselves rather than vehicles for man-made theories or expressions of human sentiments."[20]

Cage links this more open intentionality with his ideas regarding composition as process and use of chance in composition. These ideas are particularly relevant to this work and are explored further in the remaining projects.

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[19] Harold Rosenberg, *The American Action Painters* (Artnews, 51, Dec. 1952).
[20] John Cage, *Silence* (London: Marion Boyars Publishers, 1978).

3.4. Musical Dominoes

Tilt sensitive musical dominoes

3.4.1. Overview

The game of dominoes is thought to have originated in China in the 12th Century before appearing in Europe in the 18th Century, however the origin of the tradition of domino-toppling is unclear. By the 20th century at least, the practice was widely enough known to lend its name to the term 'domino effect'.[21]

The practice of domino toppling has a unique aesthetic with emphasis on chain reaction, cause and effect, long preparation times and one-off events. The practice has been growing momentum in recent years with the introduction of the now annual *Domino Day* in the Netherlands in 1986 where numerous World Records are set every year[22][23]. With builds taking more than 2 months and comprising millions of dominoes the most recent events have elevated the perception of domino toppling towards a form of public art.

Although not widely theorized, the practice has resonances with other momentum-based artistic endeavors such as kinetic art and Rube Goldberg machines. Rube Goldberg machines - named after the American cartoonist whose illustrations inspired them - are constructions which employ overly elaborate mechanisms in order to perform a simple or arbitrary task. Based on the resultant momentum from a seemingly minor event and typically including toppling dominoes as one link in a series of dependant events their aesthetic qualities relate interestingly to other forms of impermanent art such as improvisatory performance and Tibetan sand mandalas.

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[21] http://www.domino-games.com/domino-history.html [accessed 25 September 2010]

[22] http://www.guinnessworldrecords.com/adjudications/090106_Domino_Day.aspx [accessed 25 September 2010]

[23] http://www.recordholders.org/en/records/domino-toppling.html [accessed 25 September 2010]

In order to explore these interesting and relevant themes I decided to construct a Tangible User Interface (TUI) based around a set of 48 dominoes (plus blanks) that sound when toppled. The dominoes were color-coded with each color representing a different sound allowing the user to physically sequence the music. The piece transplants the practice in music technology of sequencing using grids or patterns from the virtual into the physical domain. The visual art element is integral to the project, exploring the graphic as well as musical potential of pattern making. My intention was for the work to take on those aspects of domino toppling that are resonant with my exploration of the themes of process made visible and compositional intentionality.

3.4.2. Implementation

On this project, technical considerations were not addressed until after the concept was well developed. Because of this a number of possible implementation solutions were considered and discounted at the planning stage. I have included explanation of this stage for interest and in order to demonstrate possible future strategies.

Wireless Sensor Network (WSN) or Sensor Node

One such system considered was using the dominoes as triggers in an array or wireless sensor network. The Texas Instruments MSP 430 series was considered as a low cost microcontroller to use with this approach. Advantages of this approach are that the system would be easily adaptable since the functionality would come from code on a host computer. However this approach was discounted because the audio source would have had to have been separate from the sensor and I felt that it was important for the sound to come from each domino so that the link between action and sound was explicit.

ISD4003

Another avenue explored was to use an Arduino Mini[24] microcontroller with a Winbond ISD4003 audio chip and a speaker in each domino. This system would have had the advantage of having some programmability built in (via the Arduino's data pins) as well as maintaining the link between the object and the sound however the cost of implementing enough instances of this design for the project to work was insurmountable.

Voice Recorder Modification

For the sake of time and in order to prototype the concept I decided to modify an existing product that is based on the ISD4003 audio chip. Each domino is made from a modified voice recorder from Talking Products[25] that can hold and play back up to 20 seconds of audio via a small speaker. On each unit the original push button was removed and a tilt switch was soldered directly onto the PCB. Test tone sine waves were then recorded onto the ISD chips via the analog pins.

Each unit was mounted inside a case and the cases were color coded to indicate the frequency of the tone held on the chip. Felt was used on the outside of the cases to eliminate as much percussive noise as possible from the cases hitting one another.

A video showing various iterations as well as supporting materials can be found on the accompanying DVD in the folder: DVD/4/dominoes

3.4.3. Analysis

This work could perhaps be seen as a distillation of the essence of the whole portfolio because it successfully transposes elements of digital music creation into a clear and simple physically-manipulatable form. The physical computing ideal of integration is best achieved in this work because the experience doesn't exhibit like

[24] http://www.arduino.cc/en/Main/ArduinoBoardMini [accessed 25 September 2010]

[25] http://www.talkingproducts.co.uk/ [accessed 25 September 2010]

a typical interaction with a computer. In fact, with no processor in the piece, the interaction occurs instead with individual digital elements. Computing does however remain present as a reference point with clear allusions to pixel art and step sequencers in the work.

Process is again at the heart of this work as it is in all domino toppling. Immense effort goes into the building of a domino topple in contrast to the brief 'performance'. As such, particularly relevant to this piece is the practice touched on earlier of designing potentialities in the preparation stages instead of using control methods during performance. Related to this, the idea of impermanence is also particularly strong in this work. As already discussed, some context for the piece can be provided through looking at issues surrounding other examples of impermanent art. The idea of impermanent art is, I think, related to that of process art. Both require humility on the part of the artist in that they do not fit with classical notions of authorship and legacy. Both also draw focus to the present moment. In impermanent art, this is because it may not exist at any other time, and in process art it is because attention is being drawn to the act of creation *as it happens*.

A major limiting factor on the success of the project was the clarity with which the sound from the speaker in each domino was distinguishable from the acoustic sound of the cases. This was important in order to link the dependency of the sound to the physical act, however the project suffered from the low volume achievable from the small speakers used. Although the visual element was successful, it would, I think, have benefited from being implemented on a larger scale. The visual element was conceived of as a form of pixel art and although patterns could successfully be made with the dominoes available, the number of dominoes required to create more complex shapes or representations was prohibitively expensive.

Despite these limitations, the project worked well and could be used as proof of concept for future work on a larger scale. There is great potential for the concept to form the basis for a future participatory public art project. Funding could be sought for such a project or further work could be done to address some of the issues encountered within a smaller budget. As I have mentioned, with another budget frame, other technologies could be used to give a more flexible functionality.

3.5. Physical Computing Ensemble

A group of computer controlled mechanical instruments intended to be played by one performer as an ensemble

3.5.1. Overview

The previous three projects are all characterized by an emphasis on preparation and process as against control during performance. For my concluding project I wanted to try to combine the hands on control techniques explored in the first project with some of the mechanical aspects of later projects. This project involved the creation of three distinct instruments - combining gestural control techniques with the use of mechanical actuators to make sound with physical objects – to be played as an ensemble.

As these instruments were developed, idiosyncratic aspects of the technology that was used became apparent. These elements were encouraged and developed wherever possible in order to emphasize the mechanical nature of the instruments and to promote the suggestion of autonomy that they provided.

3.5.2. ServoDeskBells

Monome controlled servos striking desk bells

This instrument is based around a set of 8 diatonic desk bells, which are struck by beaters driven by hobby servos. The control element is provided by a Monome 40h, as described in the Monomnichord project.

The instrument used 8 Hitec HS-55 hobby servos as actuators, which were controlled by an Arduino Duemilanove microcontroller. The code running on the Arduino is based on Max2ArduinoServo[26] by Mark David Hosale. However this code was significantly expanded to allow control over the 8 servos.

[26] http://www.mdhosale.com/md_arduino/ [accessed 25 September 2010]

A Max/MSP patch was used in order to interface the Monome 40h with the servos. The patch uses a Javascript in order to communicate with the code running on the microcontroller. Monomecontrol is again used to provide easier coding functionality within Max/MSP. Each column of buttons on the 40h acts as a control strip for an individual servo. The first row turns a *metro* on and off and each subsequent row controls its speed in subdivisions of 2400ms. All code used (Max/MSP, Javascript and Arduino) is included on the Media DVD.

3.5.3. Potentiometer soup cans

Solenoids mounted inside four soup cans are controlled via potentiometers

This instrument comprises 4 empty soup cans that are actuated by solenoids mounted inside them. Control over the solenoids was provided via analogue potentiometers on the surface of the cans.

The potentiometers interfaced with the solenoids via an Arduino Duemilanove microcontroller. Code running on the Arduino was from its Firmata library and a Max/MSP patch based on maxuino[27] by Chris Coleman was used to control functionality.

The patch uses the analogue values from the potentiometers to control the speed of a *metro* object for each solenoid. Quantisation is implemented with a *slide* object, which is set to gravitate towards subdivisions of 2400s. This allows for a gradual control over the *metro* via the potentiometer but when it is released, the stream of data drives the *slide* object towards its nearest subdivision.

A ‘shuffle’ function is implemented via the space bar, which starts a new set of *metro* objects. These objects are fed values from the potentiometers but each serves 2 soleniods instead of one giving the effect of newly generated but related cross rhythms.

[27] http://www.maxuino.org/ [accessed 25 September 2010]

3.5.4. Movement sensitive guitars

DC motors suspended over strung instruments are activated by the movement of the servodeskbells

A USB camera trained on the desk bells tracks movement, which is then mapped in Max/MSP to the speed of 3 DC motors. The motors are suspended above 2 guitars and an autoharp and are connected to the computer via the same Arduino microcontroller as the solenoids in the soup cans. The coding for this project is included in the Max/MSP patch for the soup cans instrument in the 'camera' subpatch. The movement sensing part of the patch is similar to that used in the singing bowls project and is connected to a *counter* object which drives the DC motors. A 'hold' function is implemented via a key command (*select 29*).

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A demonstration of the individual instruments and a video of a performance as well as supporting materials can be found on the accompanying DVD in the folder: DVD/5/ensemble

3.5.5. Analysis

This project was constructed as an experimental merging of some of the varied techniques and ideas that have characterized the portfolio. As already mentioned, a developing feature of this project were the unplanned idiosyncratic elements which first appeared in the servodeskbells instrument. This was an unexpected consequence of the elaborate nature of the software stage and caused the servos to 'wander' between messages giving an interesting effect of implied autonomy. This theme was further apparent in the soup cans instrument where the software caused the solenoids to miss beats due to the processing limits of the computer.

The suggestion of autonomy that was created through these limitations led me to develop methods of creating inwardly generated material. This idea of cross-fertilization can be seen in the ‘shuffle’ function in the soup cans patch which mimics the idea of crossed patch cords, and in the way in which one instrument is used to animate another.

This notion again raises questions about direct control, and direct communication of specific ideas that are at issue in the other projects. The reason that these idiosyncratic elements are interesting, I think, is that they are not a result of the direct will of a performer and first arose unintentionally. By designing in further elements of chance into the performance I am again extending the reoccurring subject of intentionality in my work.

In practice I found the ensemble to be an interesting performance tool. One control element that worked particularly well was functionality for the timing to be fluid whilst still being syncable. This was achieved with un-quantised start times on the *metro* objects controlling the bells and *slide*-based quantisation of the soup cans, allowing either instrument to be synced to the other.

4. Discussion

This portfolio of work has sought to examine and address R. Murray Schafer's concept of the schizophonic through an exploration of musical applications of physical computing technologies. In pursuit of this aim, the implementation of physical interfaces other than the loudspeaker and the GUI were explored. Specifically, physical control methods were developed and explored as well as the use of computer controlled mechanical actuators operating on acoustic objects.

This initial aim has resulted in a range of interesting and varied works, which have raised a number of other themes. Some of these themes have related directly to my research question whereas others are perhaps related to intrinsic aesthetic properties of the technologies themselves. Of course my own artistic concerns cannot be overlooked; I have chosen to focus on and develop those aspects of the works that I have judged as particularly interesting and pertinent to further research. These themes, including issues surrounding artistic intentionality and process-focused output, have informed my thinking as the portfolio has progressed. This thematic development and fertilization across projects has given added continuity and depth to the portfolio.

My focus has shifted considerably since embarking on this project. My initial concerns reflected my background and were based on ideas concerning interface with digital music technologies. This remit has widened markedly as I have explored available technologies and broadened my practice base of techniques by . learning the necessary programming, electronics and construction skills as I have progressed. In particular, the exploration of different forms of output (such as installation, performance and design) has promoted a shift away from conceptualizing my aims as strictly within the field of computer music towards thinking about sound, art and technology in general. Although there were restrictions placed on the scale of much of the work due to cost, these limiting factors have had a positive effect on the work's aesthetic.

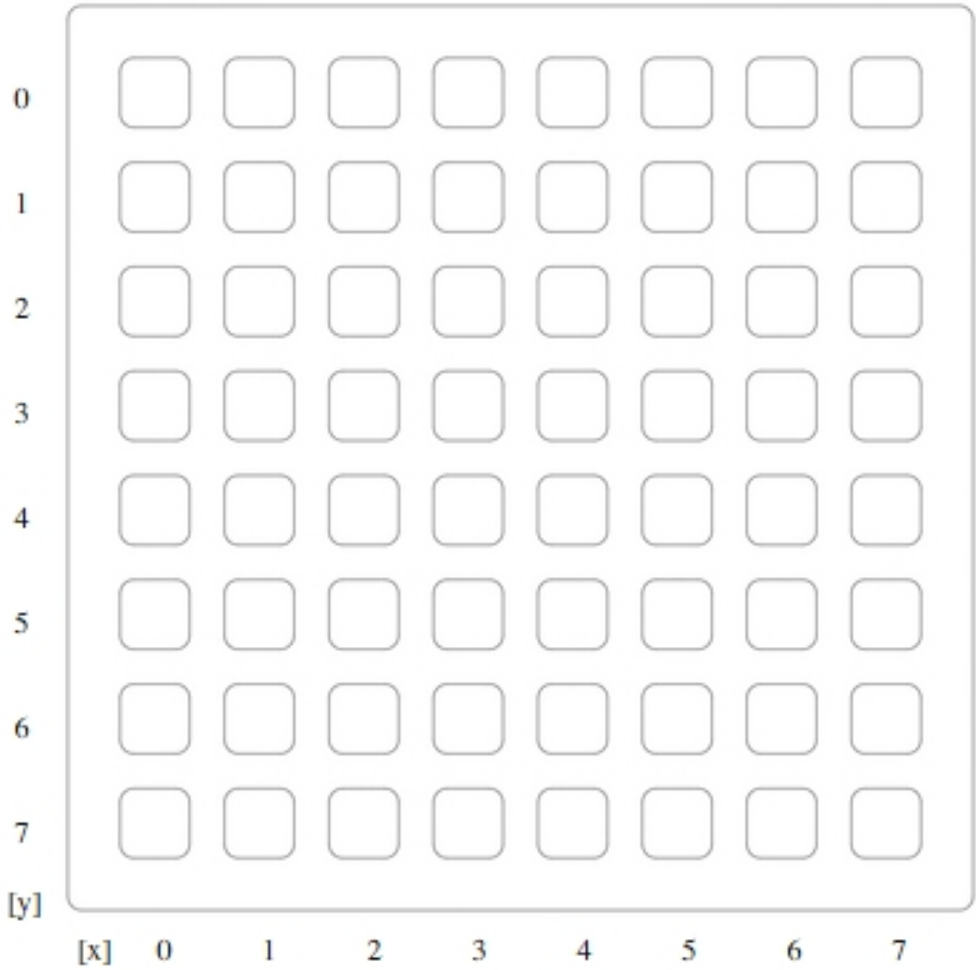
The works outlined in the previous chapter each deal with my research question in different ways. The *Input Device Review* successfully explored methods of linking physical gestures to the creation of electroacoustic sound in order to address aspects of sonic experience that are problematized by the schizophonic effect and also served as a useful introduction to technologies that would be used in further projects. *Guitar Glitch* used computer controlled electro mechanical actuators to make acoustic sound. In one sense the use of this technology negated the schizophonic problem since the sound created was not acoustically separate from its source however the piece raised further interesting questions regarding the acousmatic situation and gave rise to a number of concerns that have been developed throughout the portfolio. *Reactive Singing Bowls* was conceived in order to address some of these concerns relating to audience and intentionality and again reinstated a physical sonic presence with the use of mechanical actuators in order to create acoustic sound. Although *Musical Dominoes* used electroacoustic reproduction as its sound source, it linked the sounds created to tangible physical objects and to repercussions from a single physical act. *Physical Computing Ensemble* attempted to use some of these explorations of physicality in a performance instrument that allowed physical control over acoustic sound through interface with physical computing technologies.

In all of the projects, the link between sound and source was in some way given physical tangibility. The work presented here does not claim to solve what RM Shaefer characterizes as the schizophonic problem of the separation of sound from source nor to accept his characterization of the problem wholesale. Rather, as can be seen from the portfolio, it suggests that technologies of physical computing can be used in order to give computer-based works some qualities of the natural standpoint in order to lessen the schizophonic effect.

The work outlined in this paper has sought to use the implementation of physical computing technologies to address specific concerns relating to the separation of sounds from their sources. This has given rise to a number of further avenues of inquiry, which have only briefly been touched on here. Future work around the topic could include further exploration of connections and interactions across

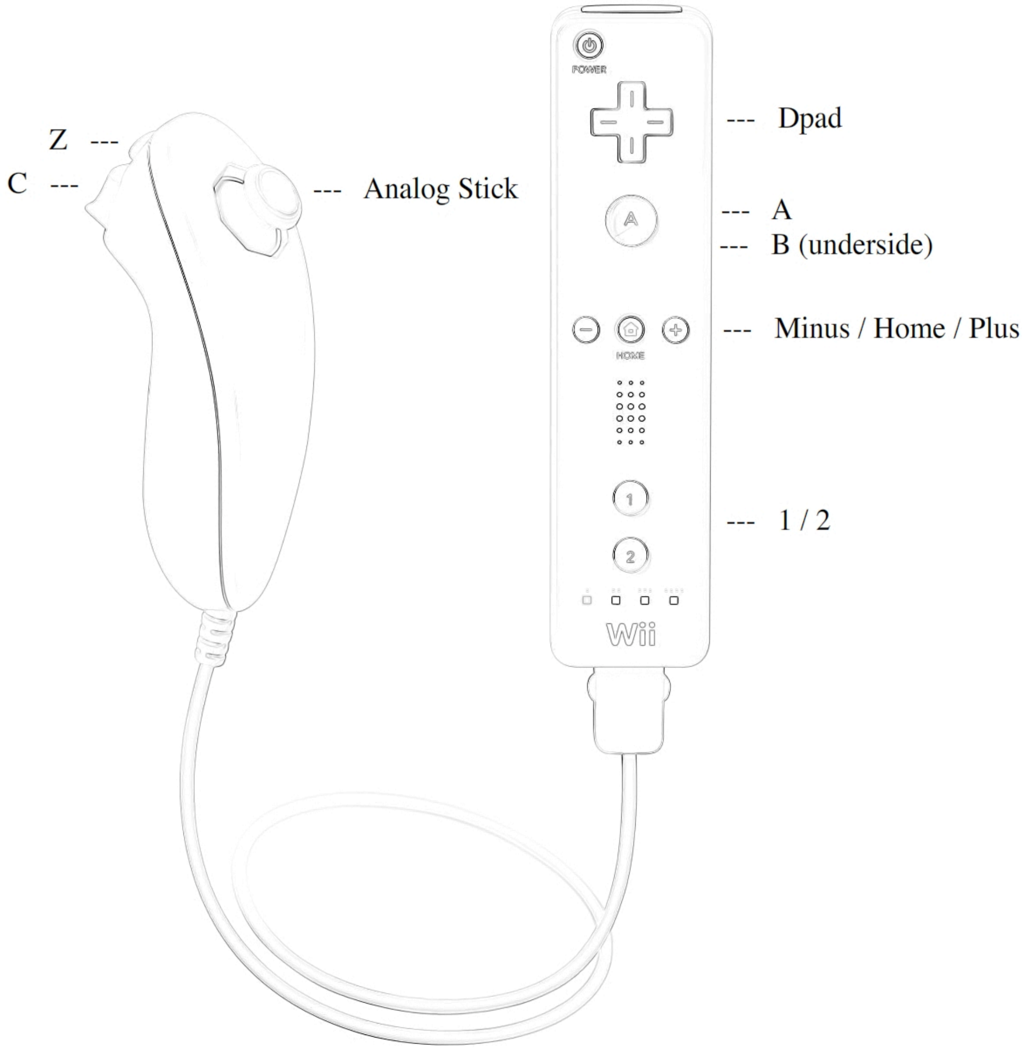
apparently dualistic popular conceptions of technology such as analogue and digital or physical and virtual. Of particular interest is the research of historical aspects of current concepts of technology and how these might be applied to artistic work, for example exploration of the history of computing as mechanical technology.
Finally, having sought to address the schizophonic problem through the use of physical computing, the portfolio has revealed further issues, which may be inherent to the technologies used. More work is needed in order to identify and address these issues as well as the wider questions they raise relating to the effect of technology on the sonic experience.

Appendix 1 – Monomnichord Functions



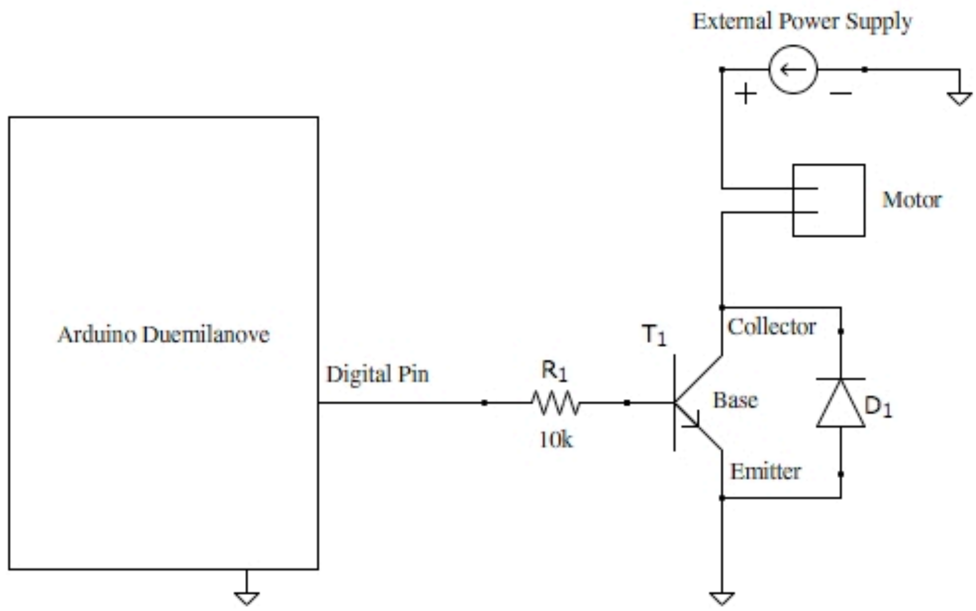
[x,y]	
[0,0]	Chord section on/off
[1,0] – [7,0]	Chord section volume
[0,1] – [6,1]	Chord select
[0,2]	Lead section on/off
[1,2] – [7,2]	Lead section volume
[0,3]	Bangs the lead section's *urn* object
[1,3]	Lead section sequencer on/off
[2,3] – [5,3]	Lead section sequencer speed
[0,4]	Drums1 on/off
[1,4]	Drums2 on/off
[0,5] – [7,5]	Drums volume
[7,6]	Start/stop *noise* metronome
[7,7]	Start/stop transport, metronome flash

Appendix 2 - Wiimote Looper Functions



D-pad	– Loop select
1	– Toggle input recording on/off
2	– Loop clear
Home	– Route accelerometer data to delay
A	– Delay on/off (one touch)
B	– Delay hold
Plus and Minus	– Loop speed select
Z (Nunchuk)	– File loop start/stop
C (Nunchuk)	– File loop speed toggle
Analog Stick (Nunchuk)	– File loop repeat~ effect enable/modify

Appendix 3 – TIP120 Circuit Schematic



Bibliography

John Cage, *Silence* (London: Marion Boyars Publishers, 1978).

Philip Carlsen, *The Player Piano Music of Conlon Nancarrow: An Analysis of Selected Studies* (New York: Institute for Studies in American Music Monographs, 1988)

Michel Chion, *Audio-Vision: Sound on Screen* (New York: Columbia University Press, 1994).

Raymond Murray Schafer, *The Soundscape. Our Sonic Environment and the Tuning of the World* (Rochester, VA: Destiny Books, 1994 [1977]).

Dan O'Sullivan and Tom Igoe, *Physical Computing, Sensing and Controlling the Physical World with Computers*, (Boston: Thomson Course Technology PVR, 2004).

Harold Rosenberg, *The American Action Painters* (Artnews, 51, Dec. 1952).

Pierre Schaeffer, *Traite des objets musicaux* (Paris: Editions du Seuil, 1966).

Trevor Wishart, *On Sonic Art,* revised edn (London: Harwood Academic Publishers.Knopf, 1996).

URLs

http://www.theamazingrolo.net/wii/ [accessed 25 September 2010]

http://johnnylee.net/projects/wii/ [accessed 25 September 2010]

http://monome.org/40h [accessed 25 September 2010]

http://www.soundwidgets.com/stribe/ [accessed 25 September 2010]

http://arduino.cc/en/Main/Hardware/ [accessed 25 September 2010]

http://store.curiousinventor.com/stribe.html [accessed 25 September 2010]

http://monome.org/data/app/monomeserial [accessed 25 September 2010]

http://docs.monome.org/doku.php?id=app:monomecontrol [accessed 25 September 2010] http://www.osculator.net [accessed 25 September 2010]

http://www.maxobjects.com [accessed 25 September 2010]

http://www.domino-games.com/domino-history.html [accessed 25 September 2010]

http://www.guinnessworldrecords.com/ [accessed 25 September 2010]

http://www.recordholders.org/en/records/dominotoppling.html [accessed 25 September 2010]

http://www.arduino.cc/en/Main/ArduinoBoardMini [accessed 25 September 2010]

http://www.talkingproducts.co.uk/ [accessed 25 September 2010]

http://www.mdhosale.com/md_arduino/ [accessed 25 September 2010]

http://www.maxuino.org/ [accessed 25 September 2010]