TaGlove – a New Interface for Musical Expression (NIME)

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28th August 2007

Submitted in partial fulfilment of the requirement of London Metropolitan University for the degree of MA by Project (Music Technology)

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1. Abstract

This paper describes the TaGlove, a New Interface for Musical Expression (NIME). The TaGlove consists of a hardware glove and software performance environment programmed in Max / MSP (a software package from Cycling 74) submitted as a partial and final submission of MA by Project (Music Technology) at London Metropolitan University, 2007. The paper starts with a brief overview of other similar studies in this field (with particular focus on other interface gloves). A brief introduction to the different parts of the project follows in addition to a detailed description of the TaGlove in detail and the issues surrounding the expressiveness of gestural controllers.
Areas of particular focus are *the pre-stage of mapping* (preparing the sensors for programming use), *mapping* (the designed link between the instrument's playing interface and its sound source), and *granular synthesis* (the sound source).

3. Contents

List of Illustrations

4. Acknowledgements

I would like to thank my supervising tutor Allan Seago for the constant support I have received throughout the course of this degree and Javier A. Garavaglia at London Metropolitan University for his aid. I would also like to thank the course co-ordinators Linden Reilley and Lewis Jones, for the flexibility that enabled me to undertake full-time work and continue my full-time studies in the spring semester of 2007.

I would like to thank my former co-student and friend Bobby Whelan for his valuable help with the electronics side behind TaGlove.

Finally I would like to thank my parents Bente and Trond for their support and financial help throughout my studies – and last but not least, my girlfriend Aysem for her patience and valuable support.

5. Introduction

Converting movement by capturing gesture with sensor technology to the digital domain is a field that has interested artists since the emergence of MIDI in the early 80's (or earlier still if we include the analogue domain of the Theremin from the early 1900's. One are to also look to the more recent times of the 1960s and 1970s when several composers rediscovered the exploration of movement to create electronic music. Of particular note is *Variations V* (1965), a collaborative work featuring music by John Cage and choreography by Merce Cunningham, with a system designed by Gordon Mumma and David Tudor to derive sounds from the movements of dancers, who produced music based on their proximity to several electronic sensors placed on stage. “The entire floor was transformed into a musical instrument responsive to movement throughout the space.” Nyman, M. (1980)

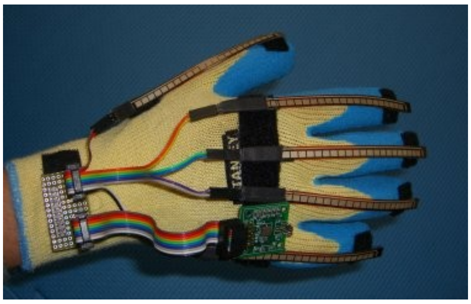
With new methods of synthesis (e.g. the possibility for real time granular synthesis) and more advancing computer technology, this is a field that has grown significantly over the last 20 years. Today there are communities such as the NIME conference (New Interfaces for Musical Expression), Music Technology corporate research and product innovation, scholars and enthusiasts driving this field forward (See Skotvold, T. (2006) for a more comprehensive introduction).

There have been few projects that are similar to the technology or ideas used on the TaGlove, namely converting hand gesture to the digital domain for musical expression. The most widely known is Michael Waisvisz's “The Hands”, 1984 – present (also mentioned in Skotvold, T. (2006)), which uses the idea of hand gestures controlling a synthesis environment with MIDI controllers.

Illustration 1: Michael Waisvisz's “The Hands” (2005)


Illustration 2: Laetitia Sonami's “Lady's glove”

Also noteworthy, is Laetitia Sonami's “Lady's glove” which was built and has been continuously developed since 1994. This project is similar to the technology of the TaGlove as it uses the same bend sensors from the Mattel gaming glove. This was known to be a cheap way of acquiring bend sensors, but is now increasingly expensive because the glove has now become a collectible item. The version of the glove shown in illustration 2, made of golden Lycra, had the bend sensors sown along the fingers and wrist. These were taped at the centre and generated two streams of data when bent. A pressure pad was sewn on the inside of the index finger and an ultrasonic transmitter was sewn on the inside palm, with one receiver located on the right arm and one on the left foot. These calculated the distance between both hands and the height of the left hand. In total, all these signals were fed into STEIM's Sensorlab. STEIM's Sensorlab is a Computer User Interface that conditions the signals and converts them into MIDI which is then fed to a G3 laptop. Max / MSP software (Cycling'74) is programmed to map the sensors to a variety of sound parameters. The mapping and sonic material changed in each composition.



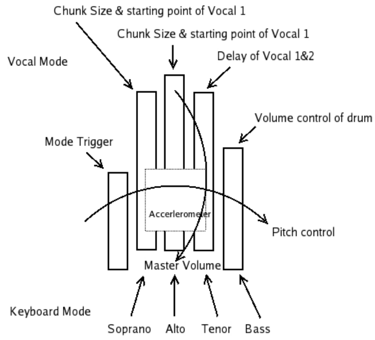


Figure 2. Controller Layout

Illustration 3: Kevin Kuang's "Blue Glove", 2005

In 2005, Undergraduate Kevin Kuang created the "Blue Glove" at Stanford University, a percussive gestural interface for the live performance of computer music and control of computer-based musical activities. As with the TaGlove, it uses both bend sensors and an accelerometer.

According to Kuang, the roll of the hand is used to control the pitch of a MIDI percussion patch and a vocal sample. The thumb is used for mode switching (2 modes) whilst the other fingers continuously control specified parameters (non-changeable). In vocal mode, two different vocal samples are played in loop. The chunk size and the starting point of each playback sample are mapped to the bend sensors on the second and third finger. A delay effect is added and is mapped to the fourth finger. A five seconds drum sample is also played when the glove is in vocal mode with its volume mapped to the fifth finger. When the thumb sensor is bent, the keyboard mode is switched on and the vocal mode is mute. The other four fingers were used to control the pitch of four different instruments. Kuang used four low-pass phasors to simulate soprano, alto, tenor and bass. Turning the hand clockwise would change the pitch of every instrument.

Although I have not heard the "Blue Glove" in action, it is apparent that the glove controls a relatively small set of parameters. He uses samples and relatively simple synthesis methods for his sounds and the mappings are mostly one-to-one relations. In this paper and accompanying practical work I will demonstrate that a more complex approach could potentially be more successful.

5.1 Introduction to the TaGlove

Illustration 4: The TaGlove

The TaGlove consists of three sub-units; a leather glove (with four bend sensors in the palm of the hand), a touch sensor in the tip of the thumb and index finger, an accelerometer and a CUI (Computer User Interface), which powers the sensors and sends the data via Bluetooth to any computer with a Bluetooth card and the appropriate software installed. The accelerometer, the CUI and the battery unit are in a sealed plastic box, designed to be strapped on the top of the player's arm.

5.1.1 The Three Sub-Units

The TaGlove project eliminates the use of excessive cabling by sending the data from the sensors wirelessly. It consists of a glove, with all the sensors mounted, and a plastic box to keep the accelerometer and the CUI safe. The CUI is especially fragile, as this is where the cables are attached and transmitted via a Bluetooth chip. The player is able to move freely and does not require a cable to be connected to the laptop or computer.

With regards to the interfaces discussed in the introduction of this paper, I wanted to avoid using MIDI as the communication protocol because of the resulting data in Max / MSP. The solution was to use the OSC protocol which produces a smoother signal curve (Contextualisation essay, Skotvold 2007). This allows for a more natural representation of the force applied to the sensors, as they are scaled smoothly rather than step-wise (The MIDI protocol always has 127 steps).

5.1.2 Introduction to the Accelerometer

The accelerometer I use is a Nintendo Wii remote. The reason why I chose to use a Wii remote accelerometer, is because the Wii remote is mass-produced and therefore its components are cheaper. The Wii remote costs approximately £30 to buy and is available on the high street. My initial idea of using the ADXL330 accelerometer was discarded because it is also used on the Wii remote chip. From a specialist electronics supplier the ADXL30 costs in excess of £60 including shipping.

The Wii remote has three axis: x, y and z allowing 6 degrees of freedom: 3 linear translation directions (X, Y, Z) and 3 rotation angles (pitch, roll, yaw), as shown in illustration 5.

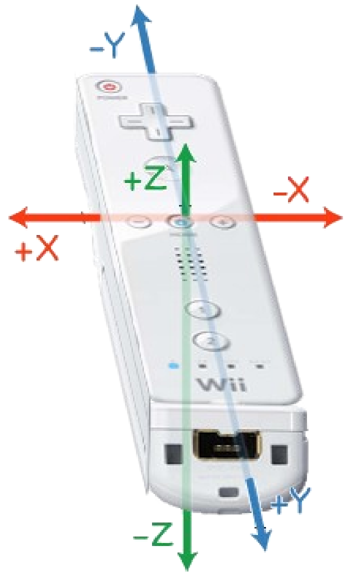


Illustration 5: The Nintendo Wii Remote

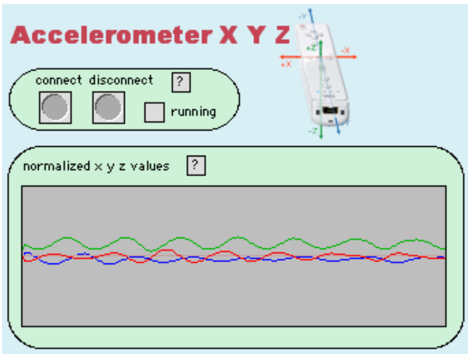


Illustration 6: Accelerometer x,y and z

In the TaGlove performance environment in Max / MSP we can continuously monitor the x, y & z axis of the accelerometer and how much force, moreover, how much movement is applied on each axis.

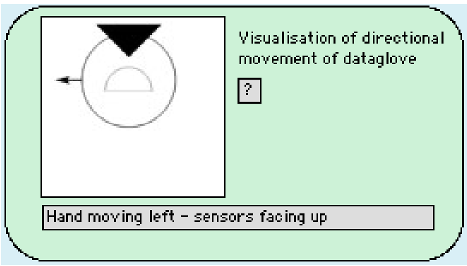


Illustration 7: Gesture visual feedback

I have made my own notation for the ease of observing what gestures the system can detect. This feedback is continuously updated in Max / MSP. This will be further discussed later in this paper.

I will revisit how the parameters from the accelerometer are used in a musical context later in this paper.

5.1.3 Introduction to the Bend and Touch Sensors

Since the bend and touch sensors only operate in one axis at any one time they have a less complicated behaviour than the accelerometer. They are both force sensors which means that they output data when force is applied to them; either by bending or pressing respectively. To summarise briefly, these sensors output a variable voltage and this variation is applied by affecting the amount of air that is allowed to flow in the air pockets that sits inside the sensors. In illustration 8 and 9 below (taken from the performance program accompanying the TaGlove), one can observe the sensors with no output in the first illustration and force applied to the touch sensor on the thumb and the bend sensor on the ring finger.

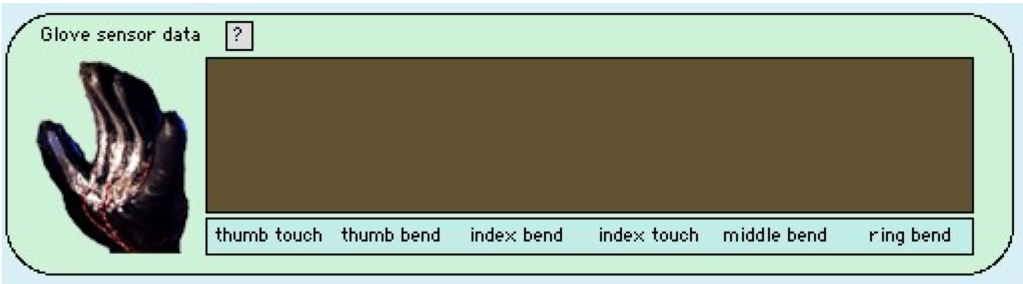


Illustration 8: Sensor glove with no force applied, in TaGlove Max / MSP performance program (Skotvold 2007)

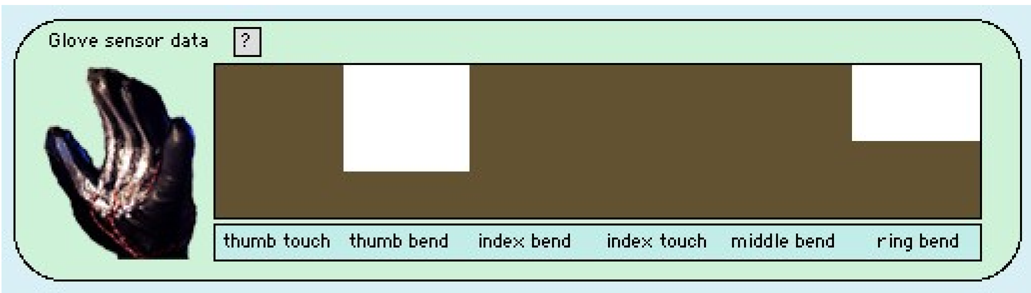


Illustration 9: Sensor glove with force applied, in TaGlove Max / MSP performance program (Skotvold 2007)

I will look at how the parameters from the touch and bend sensor are used in a musical context later in this paper.

5.1.4 Introduction to the Synthesis Engine

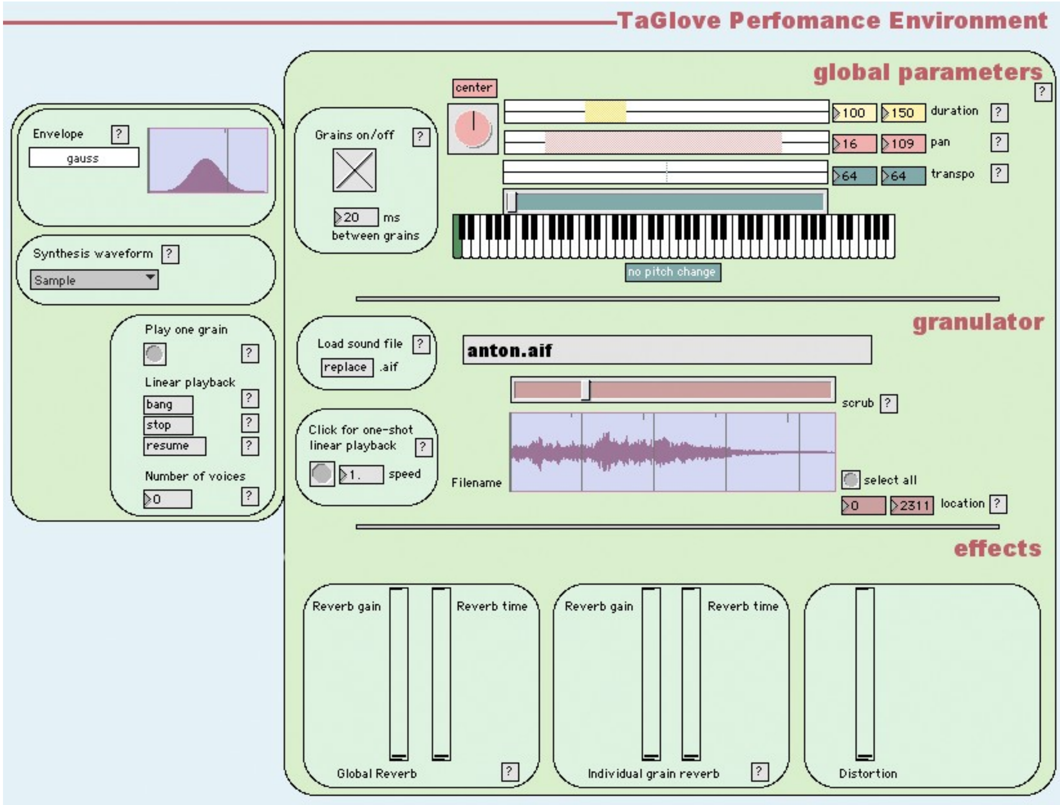


Illustration 10: The synthesis engine (T. Skotvold), 2007

The programming part of this project is written in Max / MSP, which has been widely covered in the Intermittent Project Report, Skotvold, 2007. The synthesis (sound making) part of the project is based on the "granulizer" patch by Stuck, Les and Richard Dudas who are engineers for the software company that created Max / MSP; Cycling74. As this is only an example patch, I have taken the rough idea and expanded on it. Instead of having just one feature, which originally was granulating a sample, the user can use synthetic waves such as a sine, triangle or square wave. This, combined with the use of for example envelope shapers or other synthesis parameters creates a wide sound palate for the performer using the patch. The performer has a full overview over the sensor inputs which are 'mapped' (a term I will revisit later in this paper) to the synthesis parameters to control this environment.

5.1.5 Introduction to Granular synthesis

The seeds of granular synthesis can be traced back to Greek and Roman antiquity, although it was only after the papers of the inventor and mathematician Dennis Gabor 1946-1952 (who also won the Nobel price for inventing the holographic method in 1971) and the architect educated composer Iannis Xenakis (1971) that these seeds began to take root.

A grain of sound is a brief microacoustic event with a duration near the threshold of human auditory perception, typically between one thousandth of a second and one tenth of a second (from 1 to 100ms). Each grain contains a waveform shaped by an amplitude envelope (see illustration below)

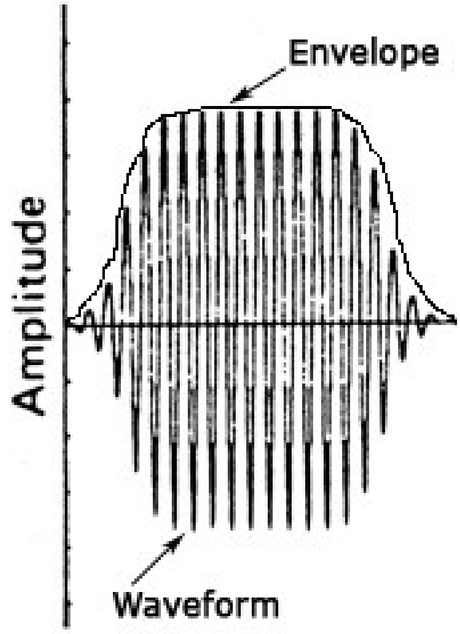


Illustration 11: Grain in the time domain. The duration of a grain is typically between 1 and 100 ms.

A single grain serves as a building block for sound objects. By combining thousands of grains over time, we can create animated sonic atmospheres. The grain is a suitable representation of musical sound because it captures two perceptual dimensions: time-domain information (starting time, duration, envelope shape) and frequency-domain information (the pitch of the waveform within the grain and the spectrum of the grain). This stands in opposition to sample-based representations that do not capture frequency-domain information and abstract Fourier methods which account only for the frequency domain.

Granular synthesis requires a massive amount of control data. If *n* is the number of parameters per grain, and *d* is the density of grains per second (see illustration 10), it takes *n* times *d* parameter values to specify one second of sound. For example, if we have a density of 20 ms between each grain, there are 200 grains per second. So in this instance, and reflective of the TaGlove performance environment, we would require 200 x 13 = 2600 *n* parameters per second. Since *n* is usually greater than ten and *d* can exceed one thousand, it is clear that a global unit of organisation is necessary for practical work. In the TaGlove performance environment, the sounds are specified in global terms while the granular synthesis algorithm fills in the details. This greatly reduces the amount of data that must be supplied and we can work in real time with the sensors associated with the glove. The major difference between the various granular techniques are found in global organisations and algorithms.

5.1.6 Time Scales of Music

"Music theory has long recognised a temporal hierarchy of structure in music compositions. A central task of composition has always been the management of the interaction amongst structures on different time scales. Starting from the topmost layer and descending, one can dissect layers of structure, arriving at the bottom layer of individual notes." Roads, C. (2004)

These microsonic layers were long invisible, but today with the modern tools such as the computer, we have the possibility to view and manipulate them. Roads distinguishes between nine time scales of music shown below, with its outer limits too extreme to be used directly in ordinary music composition.

1. *Infinite* The ideal time span of mathematical durations such as the infinite sine waves of classical Fourier analysis
2. *Supra* A time scale beyond that of an individual composition and extending in to months, years, decades, and centuries.
3. *Macro* The time scale of overall musical architecture or form, measured in minutes or hours, or in extreme cases, days.
4. *Meso* Divisions of form. Groupings of sound objects into hierarchies of

phrase structures of various sizes, measured in minutes or seconds.

5. *Sound object* A basic unit of musical structure, generalizing the traditional concept of note to include complex and mutating sound events on a time scale ranging from a fraction of a second to several seconds.
6. *Micro* Sound particles on a time scale that extends down to the threshold of auditory perception (measured in thousandths of a second or milliseconds).
7. *Sample* The atomic level of digital audio systems: individual binary samples or numerical values, one following another at a fixed time interval. The period between samples is measured in millionths of a second (microseconds).
8. *Subsample* Fluctuations on a time scale too brief to be properly recorded or perceived, measured in billionths of a second (nanoseconds) or less.
9. *Infinitesimal* The ideal time span of mathematical durations such as the infinitely brief delta functions.

"All sound is an integration of grains, of elementary sonic particles, of sonic quanta. Each of these grains has a threefold nature: duration, frequency, and intensity. All sound, even all continuous sonic variation, is conceived as an assemblage of a large number of elementary grains adequately disposed in time." Xenakis, I. (1963)

Xenakis wrote the above in 1963, long before the luxury of powerful home computers. Today, with various audio applications, anyone can have easy access to these time scales (subsample – macro). An audio application enables us to easily zoom in to the desired resolution on any sample and it is then possible to see that every sound in the digital domain is made up from small segments of sound.

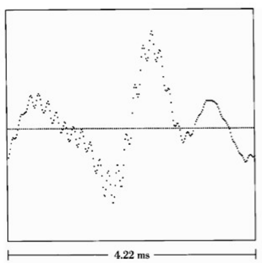


Illustration 12: Sample points in a digital waveform. Here are 191 points spanning a 4.22 ms time interval. The sampling rate is 44.1 kHz.
Roads, C. (2004)

Xenakis introduced the term “screens” to illustrate how these particles are distributed over time:

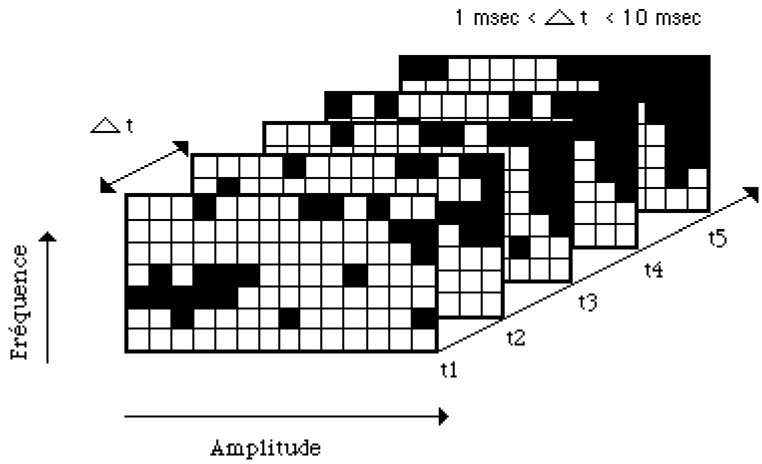


Illustration 13 – Xenakis's “book filled with screens”

Xenakis's theory of regarding grains as the smallest building block of sound combined with the microsonic layer theory of Roads can also be transferred to apply to all things measurable in time. As an interesting thought experiment, one could possibly imagine the life span of a human being, which is on the *Supra* time scale, which can then be divided in to all 8 sub layers, effectively dividing the life span down to fragments of a second. Every movement, down to electrical changes in nerves (*Infinitesimal)* can then be distributed to a screen and divided over time.

If we imagine a studio setting, where we have sounds distributed over several channels, illustration 13 will work equally well if we see each “page” of the screen as a snapshot (e.g. in milliseconds) of all channels and their outputs.

5.1.7 Relationship Between Physical Gesture and Musical Gesture

Gesture capture has recently witnessed a considerable expansion as an area of technological research (e.g. Nintendo Wii gaming console and the accelerometer controlled iPhone). In musical terms, the concept of gesture capture is a simple one that nevertheless has an enormous range of creative applications. Gesture capture may be used to refer to the tracking of the physical actions of a musical performer of an acoustic instrument (key movements, finger action, breath control and so on) or of an electronic instrument (where performance information is mapped to control synthesis parameters). Gesture capture may also be used to describe any system that analyses acoustic data to obtain information concerning musical performance. In interactive works, the information 'captured' in such a process is mapped in such a way as to have an effect on some other aspect of the performance, for example, the real-time processing or synthesis of other musical material. It may also be used to describe any system that tracks visual movements through optical means (Ears, Electroacoustic resource site).

The term gesture has been used widely but inconsistently in describing music, largely in terms of analogies and metaphors of human physicality and rhetoric. The term is useful in electroacoustic music studies, where it also receives wide and precise usage in the areas of Interactivity and Spectromorphology. Much research in the field of Interactivity and the construction of new musical instruments and interfaces is concerned with the detection and translation of physical movement. The terms gesture mapping and gesture capture are highly relevant in this context.

Denis Smalley has written extensively on the concept of the pairing of Gesture and Texture as structuring principles in electroacoustic composition and analysis. "Gesture is concerned with action directed away from a previous goal or towards a new goal; it is concerned with the application of energy and its consequences; it is synonymous with intervention, growth and progress, and is married to causality". Smalley, D. (1986).

The feeling of interactivity depends on the amount of freedom the performer has to produce and perceive significant results, and the ability for the computer to respond in a way that makes sense and naturally triggers the performer's participation. Highly interactive systems are more complex but potentially rewarding. With more parameters available for change, performers will need extra practice time to "learn by ear" the distinctive features of a system capable of intricate connections between movement and music. The computer's response must be believable in the sense that it seems appropriate for the action taken, and appropriate for the style of music and movement. Interactive music succeeds when it encourages spontaneity while residing within the boundaries of a dynamic artistic context that is whole and engaging.

5.1.8 Introduction to Mapping

The mapping of the gestures made with the TaGlove to the synthesis parameters are vital to the sonic outcome of the project and is also crucial for the feeling of interactivity (see section 5.1.7). The concept of mapping has also been covered in Skotvold, T. (2007) and can briefly be described as the designed link between the instrument's playing interface and its sound source.

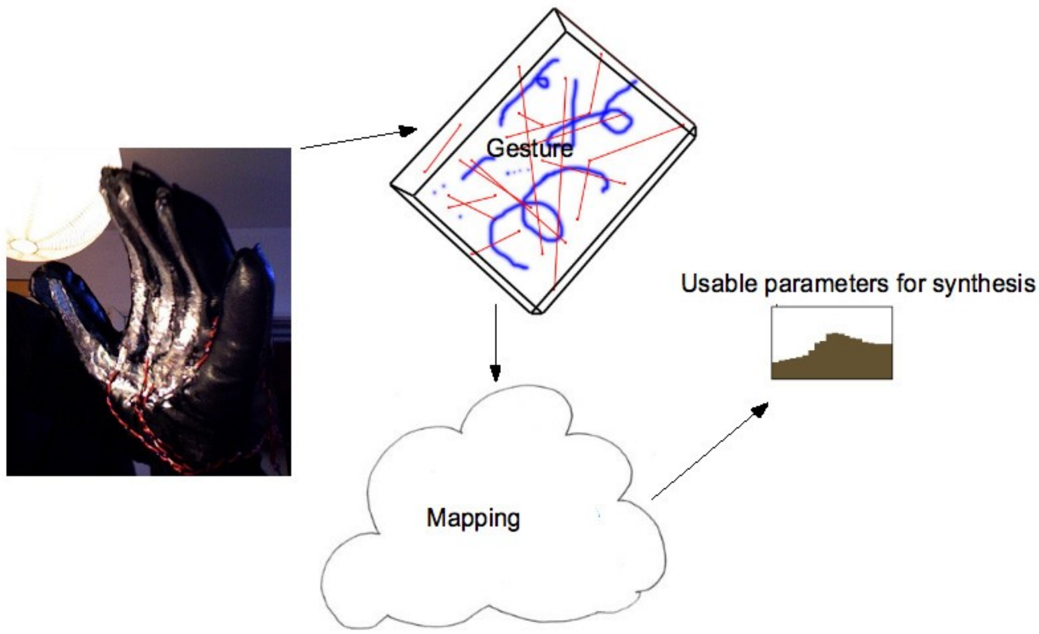


Illustration 14: Relationship between gesture and sound (Skotvold, T. 2007)

For both programming purposes and for the player to see what gestures are detected at any time, I have made a visual motion-feedback system in the TaGlove performance environment where the gestures made with the glove are reflected on screen (see illustration 7).

The mapping in the TaGlove performance environment is designed to be both educational in one-to-one up to many-to-many mappings and to be enjoyable and rewarding to explore and play. The performer chooses which mapping mode the glove is in at any one time by pressing the 1 and 2 button on the arm strap box (comprehensively explained in the appendices of this paper).

Instead of using the TaGlove to directly affect the synthesis engine, the engine is constantly running in the background where a global definition of sound is made (see section 5.1.5). The TaGlove controls the low-level parameters such as grain duration, panning, transposition (pitch), ms between grain, scrub (if a sample is used) and reverb. This decision was made after working with the sensor data, and studying their behaviour. This is based on weighing spontaneity versus reflection. There are two contrasting approaches in the field of electronic music; on one side we have the immediate spontaneity of improvisation in performance against the careful, reflective process of studio-based composition. This can be said to be particularly strong in the case of real-time systems that have a constant swarm of sound particles such as in the Max / MSP performance environment for the TaGlove. "To control this flow in such a way as to make interesting musical gestures is not easy. The musicians interface can either help or hinder this process." Roads, C. (2004)

To assist the programming and compositional preparation for the mapping relations, I studied several types of alternative relational gesture notations and musical notations. A discussion on notation is worth mentioning in this context. Unfortunately the research in this area is too comprehensive to be covered in this paper. However, one finding that struck me in particular was Stockhausen's relational notation from the piece *Microphonie I* (1966), where the development and interaction of the individual parts is organised according to a simple set of relational and transformational symbols.

Wishart (1996) argues that Stockhausen's notation is insufficient in showing the details of interaction between the internal structures of sonic objects which occur in the actual performance. Wishart also argues that the experience of the counterpoint of the performance is quite separate from the rational of the score.

In the programming of the TaGlove performance environment, I found Stockhausen's relational notation to be helpful in determining different mapping relations for movement set 1-4 (discussed further in section 6.2.1).

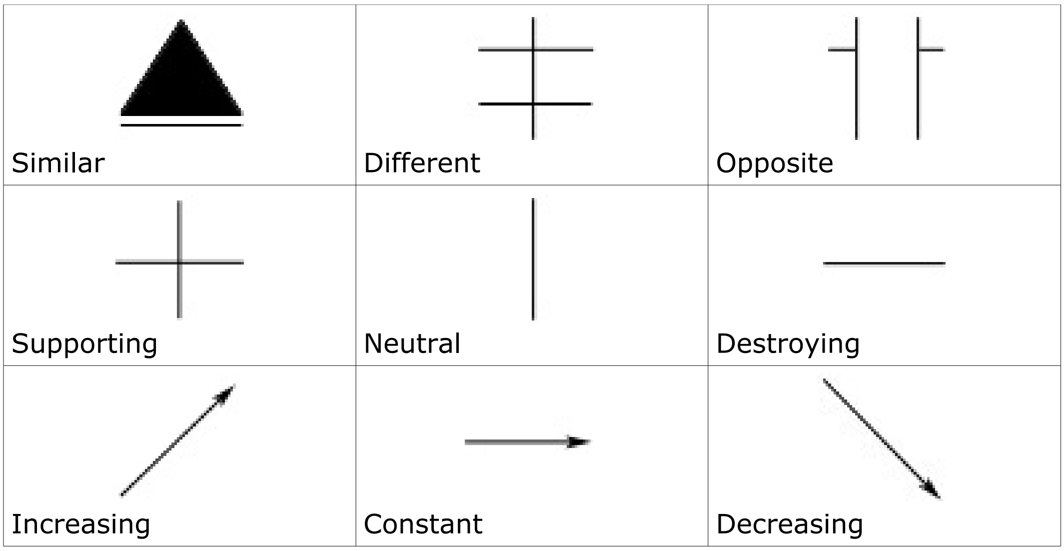


Illustration 15: Relational notation from Stockhausen's Microphonie I

To classify the four energy levels of movement set 1-4 I studied my own hand movements, and how they are most likely to behave in the four base positions found in later in this paper in illustration 20. I linked this with Wishart's (1996) four base gestural types to the sets of movements:

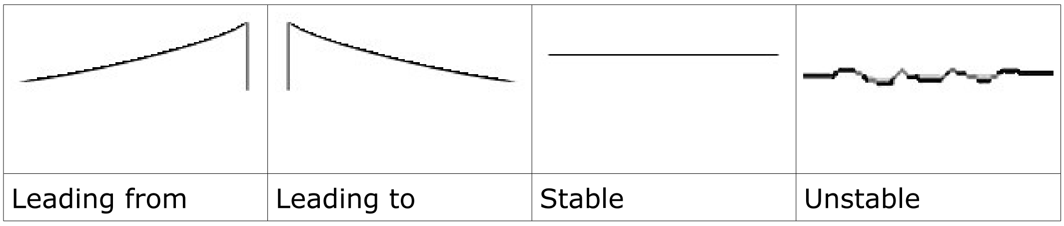


Illustration 16: Wishart, T. (1996) Base set of gestural type

The energy levels for these four base movements are from my experience:
Movement set 1: Soft set (Stable)
Less energy is used when in this position.
Movement set 2: Medium set (Left) (Leading from)
In this position it is relatively easy to move freely and I have classified this as a medium energy level set which is leading from a lower energy.
Movement set 3: Harsh set (Unstable)
In this set more energy is usually used naturally and I have programmed this set to be more active.
Movement set 4: Medium set (Right) (Leading to)
Same as 2, but has the feeling of more freedom of movement.

For a further study of the mapping relation of the gestures to synthesis parameters in the TaGlove performance environment, please refer to the appendices 10.1 - 10.3 of this paper.

6. Project Progression

During my research and practical work, the project has (naturally) changed a lot during the last 12 months. From being a vague idea of conceiving a device that would control a synthesis environment to a functioning NIME has admittedly been long. I had little notion of how much work was involved especially in the mapping side, electronics and the programming challenge. The following sections reflects where I am today with this research. Which is not perfect by any means. It is a culmination of one years intense research and represents the TaGlove project how as it is today.

6.1 Applied Granular Synthesis

As previously discussed, granular synthesis is a general term that encompasses various kinds of synthesis techniques based on a grain representation of sound, i.e. Sonic events are built from "elementary sonic elements" of a very short duration. Different organization techniques can lead to very different timbral and compositional results. One of the main questions arising while working with grains is how to move from single grain level (*micro* time scale) up to compositional design (*macro* time scale), possibly passing through note level (*sound object*) and rhythm level (*meso* time scale). We can distinguish two major approaches: the note approach and the stochastic approach.

"Stochastic music is based on a process in which the probabilities of proceeding from one state, or set of states, is defined. The temporal evolution of the process is therefore governed by a kind of weighted randomness, which can be chosen to give anything from an entirely determined outcome, to an entirely unpredictable one." Wishart, T. (1994)

In the case of the note approach, the focus is on the micro time scale as embedded in a sound object: this defines the sound objects and granularity defines the timbre of each object (i.e. drum roll, rolled phonemes, fluttertongue). Granular synthesis and granulation of existing sound objects are methods to create/transform elements at the “note” level. As in traditional composition, there is a logic gap between sound and structure. This is the approach implemented in grain-based modules of DSP applications such as Max / MSP.

More radically, in the stochastic approach granularity is intended as a compositional feature. Having to work with a finely fragmented matter, composers involved in granular synthesis have often decided to avoid an “instrumental-music approach” to promote textural shaping as a general compositional feature in order to “unite sound and structure”. Various stochastic methods and strategies have been used to control grain densities, distribution in frequency spectrum and waveshape in the time course (see the “classic” works by Xenakis, Roads, Truax). Iannis Xenakis thought of the sound as an evolving gas structure. Each instant is described through the stochastic activation of certain cells in the diagram (a “screen”) and each screen has a fixed temporal duration. The sound composition is an aggregation of screens collected in a “book” (see illustration 13) in “lexicographic” order (as in the series of sections of a tomography).

In Barry Truax's theory, massive sound texture is obtained via the juxtaposition of multiple grain streams (“voices”, like in polyphony): the parameters of each grain stream are controlled through tendency masks representing variations over time (i.e. timbre selection, frequency range, temporal density). This approach is well known in the literature as Quasi-Synchronous Granular Synthesis, which is the same type of synthesis used in the TaGlove performance environment.

Curtis Roads uses a technique where grains are scattered probabilistically over frequency/time plain regions (“clouds”). The compositional work relies on controlling cloud global parameters (i.e. start time and duration of the cloud, grain duration, density of grains, etc.).

In these three cases, compositional strategies are based on the direct control of the creative process with an empty uniform time/frequency canvas. Not surprisingly, the compositional metaphor in Roads is explicitly related to painting, using different brushes with different (sound) colours.

6.2 Use of Accelerometer Sensor Data

The aka.wiiremote external Max object written by Masayuki Akamatsu handles the connection and signal processing by the accelerometer.

As previously described in Skotvold '06 and '07, the accelerometer sends out an electrical charge each time it is subjected to movement. This charge can be represented in several ways in Max. The chosen method is very much down to personal preference; one is the vector display where both time and peaks are displayed, other options are sliders, knobs or pure numbers. All of these options depend on what one wants to do with the signal. An important decision is how the signals are conditioned, as they all have a range where the middle value is no charge (no movement) and the high / low values represent movement.

This is illustrated by the vector display below where the x axis represents time and the y axis represents the peaks of the incoming signal.
The red line illustrates the horizontal accelerometer plane. The first peak has a positive to negative dip (an increase to decrease in value) which signifies a movement in the left direction. A movement in the right direction will produce the opposite curve (a decrease to increase in value) with a negative to positive dip.

Illustration 16: Vector display of accelerometers x axis

This concept is also valid for the y and z plane of the accelerometer. This means that we can determine the direction of movement in all directions (left, right, up, down, forwards and backwards). We can also measure the force of each x, y and z movement since a greater force results in bigger peaks.

6.2.1 Determining Direction of Movement

To detect the direction of movement, the only data relevant is the first peak of the curve. The data following the peak (either negative or positive) is obsolete data. Max needs to be told that first a peak is detected (sudden increase or decrease from 0). From this we can determine the direction of movement. Then we extract the height of the peak, which tells us the force of movement. Following this the rest of the data is ignored for 1 second, eliminating all the information that is obsolete as illustrated below.

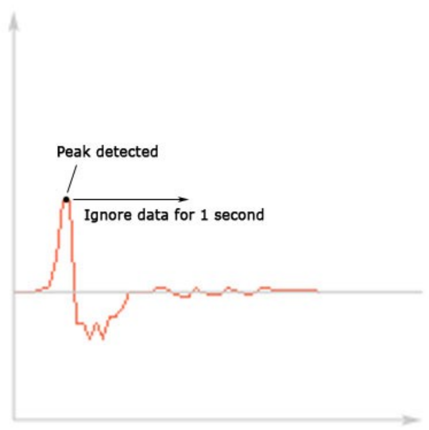


Illustration 17: X axis left motion detection from peak, accelerometer

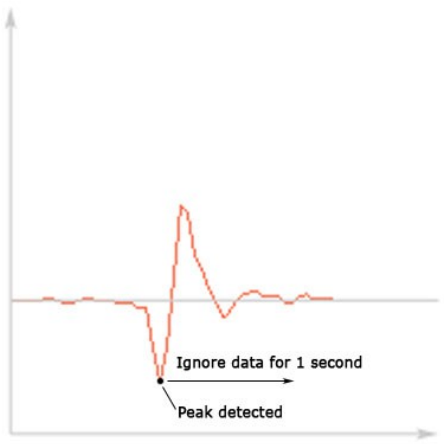


Illustration 18: X axis right motion detection from peak, accelerometer

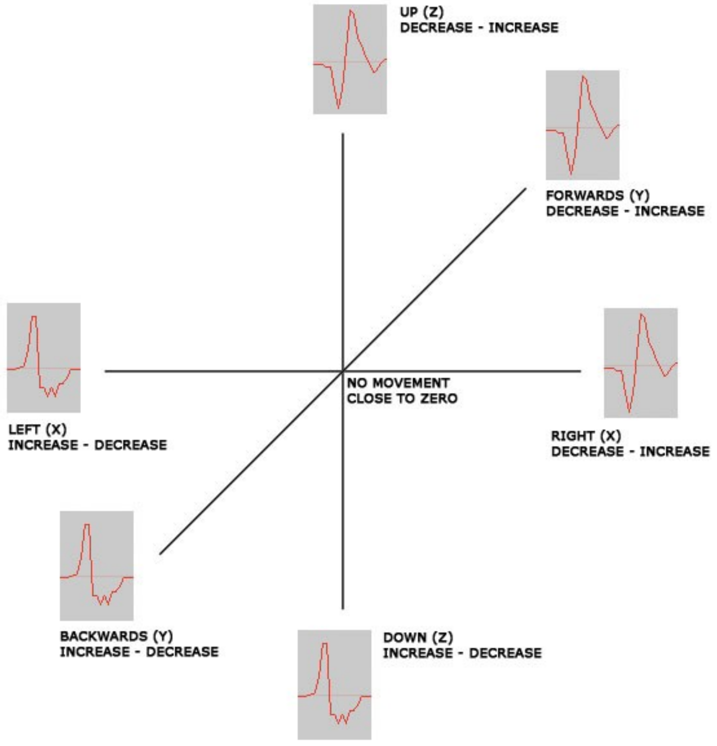


Illustration 19: Chart of detectable movements

Unfortunately, we are unable to determine spacial positioning. This is a natural consequence of there being no reference position from which to derive spatial data. What we can determine, however, is the roll of the accelerometer (illustrated below) which is a static parameter which only changes when the positioning is absolute.

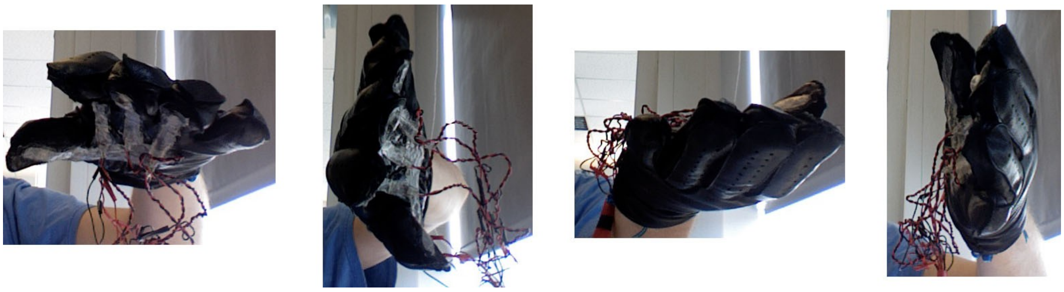


Illustration 20: Four base positions for movement

Position 1	Position 2	Position 3	Position 4
Hand flat, sensors facing the ground	Little finger facing up from ground	Hand flat, sensors facing up from ground	Thumb facing up from ground

One issue with these four base positions is that the x and y plane is swapped around once we have a roll of 90˚ to the left or right. This can be explained if one imagines three static axis that are fixed in one position. When this position is rolled 90˚ to the left or right, the axis that was measuring the x axis is now 90˚ to the left or right: The x axis is now acting as the y axis and the y axis is now acting as the x axis (shown in illustration 19 below).

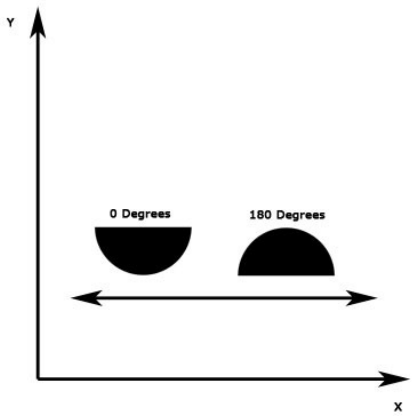


Illustration 21: Accelerometers x plane shown with a 0˚ and 180˚ roll

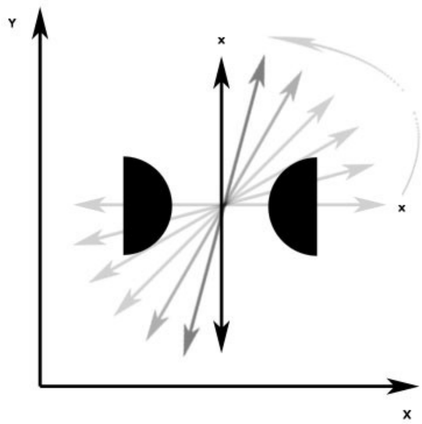
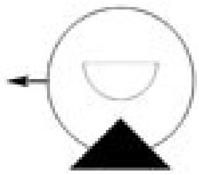


Illustration 22: Accelerometers x plane shown with a 90˚ roll

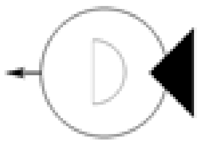
I have solved this by determining that if x = 0˚ and 180˚ roll; keep the focus on this axis. If x = 90˚ roll to the left or right, swap x with y. This makes it easier for the player who does not have to worry about how many degrees the accelerometer is rolled as the axis stays the same, regardless. This was also applied to the y axis. The z axis (depth plane) stays the same regardless of roll.

By varying the direction of movement and the tilt of the hand (right, left, up, down, forwards and backwards) we have six different identifiable parameters for each movement set. This means we have 6 x 4 (24) different movements that is identifiable in Max for the accelerometer movements. I have divided this into four different movement sets based on the positioning of the sensors. I will now show the first movement from the first four sets for explanation purposes (a full list of movements and their results can be found in the Appendix 10.1 of this paper).

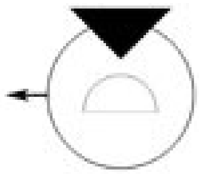
<u>Movement set 1</u>

	- The circle represents the hand - The arrow represents the direction of the movement - The semicircle represents the roll of the accelerometer (here it is rolled in a upright position. This equates to position 1 in illustration 20) - The triangle represents the other sensors or the palm of the hand. Here they are facing downwards (also equates to position 1 illustration 20)

<u>Movement set 2</u>

	- The circle represents the hand - The arrow represents the direction of the movement - The semicircle represents the roll of the accelerometer (here it is rolled to the left. This equates to position 2 in illustration 20) - The triangle represents the other sensors or the palm of the hand. Here it is facing left (also equates to position 2 in illustration 20)

<u>Movement set 3</u>

	- The circle represents the hand - The arrow represents the direction of the movement - The semicircle represents the roll of the accelerometer (here it is rolled in a upside-down position. This equates to position 3 in illustration 20) - The triangle represents the other sensors or the palm of the hand. Here they are facing up (also equates to position 3 in illustration 20

Movement set 4

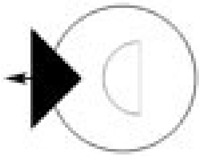
	- The circle represents the hand - The arrow represents the direction of the movement - The semicircle represents the roll of the accelerometer (here it is rolled in a right position. This equates to position 4 in illustration 20) - The triangle represents the other sensors or the palm of the hand. Here they are facing right (also equates to position 4 in illustration 20)

Illustration 23-26: The four base movement sets

As described previously, we can measure the force of each of the x, y and z plane of the accelerometer, which is useful for movement specific measurements. A more general force parameter is one we can extract from the three constant values of the accelerometer (x, y and z) which is the moving average of these three combined. This is done with the help of the ftm object set which perform complex matrix data handling. This has proven to be extremely helpful, as we have three continuous streams of data for which we need to calculate the moving average of.

The four movement sets are detected by the roll of the accelerometer. This is a simple, static, four value state (number 1-4) in the Max / MSP environment. We can then, combined with the detection of direction, separate the four movement sets and assign the 6 different ways of moving in that movement set to different synthesis parameters.

Practically speaking of the TaGlove performance environment, this is controlled by the 2 button on the arm box. The roll of the arm (left, right, flat, up side down) then controls which movement set we are in (which is also shown on screen). This list assigns the 6 movements in the sets to preselected scaled parameters so that the moving average of x, y and z controls different parameters according to which direction the arm is moving in. The 2 button also switches the glove parameters off so that only the accelerometer data is used. In brief, the 2 button sends two messages: A) Ignore the glove sensor data and B) Switch to either accelerometer mode 1 or 2 (mode 2 is described in section 6.4, "Combined use of sensor data").

6.3 Use of the bend and touch sensor data

Similarly to the accelerometer data, the glove sensor data is assigned to a list of preselected parameter relations. These are accessed by pressing the 1 button on the arm box. This list consists of duration, panning, transposition, ms between grains, reverb and two to many (which controls all of the previous simultaneously). These are all controlled by the index and middle bend sensor's amount of bend. When the 1 button is pressed there are two messages sent: A) Ignore accelerometer data and B) Scroll through glove parameter relation list.

The thumb bend sensor controls the envelope and synthesis waveform respectively. If it is fully bent towards the palm of the hand or bend outwards from the hand, it scrolls through a list for each parameter selection.

6.4 Combined Use of Sensors

The third option combines the use of all the sensor data simultaneously. It combines the features described in section 6.2 with the two-to-many feature of section 6.3, which changes focus according to which movement set the TaGlove is currently in. This option is accessed by pressing the 2 button on the arm box (once from its initial setting, and pressing it again reverts to focusing just on the accelerometer).

7. Critical evaluation of project

A new NIME is naturally met with scepticism by anyone who is not acquainted with such a device. They are often perceived as a musical instrument when asked 'what does the glove do?', and the reply is 'controls music' – but those one who study the phrase NIME (New Interface for Musical Expression) should note that the word 'instrument' is not used nor is the word 'composition' or any other word that implies a traditional compositional structure. It is not the same as a 'traditional instrument'. Another stigma that needs to be broken is that of the word 'expression' used in the same sentence as music. Expression in music is usually strongly related to melody. In a NIME context, expression is usually more linked to timbral changes. This is linked to the fact that the synthesis environments that NIME's are used with are often in the electro acoustic domain of music which is often defined as 'timbral music'.

We do not need to look further than the new and already established areas of for example sampling culture and Turntableism to see other areas where the traditional meaning of expression has been altered. In sampling culture the composer has an extreme array of choice as to how he or she wants to manipulate the sound. For example, in Turntableism a sound piece is altered all together by the flick of the wrist or a new piece of music can be produced in an instance with beat matching and mixing.

The success and quality of a NIME lies in the ability to control these new approaches of sound and to deal with expressive timbral control in a meaningful way. Translation of gesture parameters to synthesis parameters are often done in a one-to-one relationship, and the mapping definition is crucial for the piece.

One freedom in NIME design is not being restricted by physical characteristics of the sound synthesis system. Unlike in most traditional instruments, there is not an unbreakable mechanical relationship between the 'keyboard' and the sound producing mechanism. This means that the relationship can even change during a performance.

Can NIMES replace traditional instruments as viable performance tools? The notion of 'traditional' instruments is not a very stable one. Traditional instruments have been recreated all the time and changed according to trends that depict what is 'authentic' or 'in' at that time. The concepts of traditional instruments have always been, and are, dynamic. The point of building NIMEs are not to replace traditional instruments. Instead of becoming 'viable performance tools' in the traditional sense, the new tools do not need to prove themselves in terms of the cultures of the past. They should be judged by their function in our present new cultures.

7.1 Strengths

I think the main success of this project is the mapping solution in the TaGlove performance environment. This was the most time consuming part of the concept, and as previously described, this is the key factor to making a NIME successful. I think that the mapping is complex enough to keep the interest of the player for a very long time. Although this is quite a specialist project and the audience is most likely to be people with a special interest in this field.

7.2 Weaknesses

The glove still has room for improvement. Both the pressure sensors and the bend sensors are very fragile and in time they deteriorate in quality. One of the bend sensors (ring finger) stopped working in the final days before the hand-in of this report and both pressure sensors broke. This was due to unforeseen twisting of the sensors which caused the previously described air pockets inside the sensors to burst. The thumb bend sensor replaced the thumb pressure sensor as being a switch for the envelope and synthesis waveform used.

During the early experiments with the CUI, two of these were short-circuited when soldering on the leads from the sensors adding £250 to project expenses.

Another issue occurs when connecting the Wii via Bluetooth as sometimes this is a process that needs repeating a few times before it connects successfully. The reason for this is unknown, but I believe that it could be related to the Wii remote it self as this does not happen with other Bluetooth devices connected in a similar way. The CUI can also unexpectedly stop sending data from the glove. This is related to the Bluetooth chip on the CUI which sometimes switches itself off for unknown reasons. This is solved by pressing reset button on the CUI and reconnecting the CUI in the TaGlove performance environment.

Finally, the TaGlove performance environment sometimes crashes. This is thought to be related to the amount of data that the program has to handle. This could potentially have been solved with using a even more powerful computer but in theory, however, my MacBook Pro should have been sufficient. One solution to this could be one computer handling the sensor data and another handling the synthesis.

7.3 Changes to Design Aspect and Decisions Made During the Project

The arm strap box was originally meant to be a lot smaller and more light weight. The battery box for the CUI weighs approximately 37 grammes and the batteries in the Wii control weighs approximately 50 grammes. If I had implemented an accelerometer like the ADXL330 (which was my original plan) this would have cut the weight of the box and the size down significantly. The weight means that the box is not very comfortable to wear because it needs to be strapped quite tightly so as not to fall off the performers hand.

7.4 Further developments and potential

Although widely covered in Skotvold, T. (2007) the MnM external mapping was not used to the extent that I had hoped in the TaGlove performance environment. This could have given a new dimension to the project, one of my aims was always to make the system intuitive so that it would adapt to the performer playing the system, recognising gestures and gradually becoming more familiar with the player's playing style. This was something that I found to hard to implement in the end and is an area of the project that could be developed a step further.

I have observed an increasingly more friendly approach by the industries that deal with gesture capture technologies and I believe that gesture capture is in many ways "the future technology". Increasingly, accelerometers can be found in mobile phone technologies (iPhone), games controllers (the Wii remote) and even in sporting equipment (Nike trainers with piezo step counter + iPod).

I think it is only a question of time before we will see gesture capture technology exploding in every mobile technology area, and resulting increasingly in commercial NIMEs. A recent example of a NIME that was developed by Yamaha (seen as a brave step by the industry) is the Tenori-On. "The TENORI-ON is a unique 16 x 16 LED button matrix performance controller with a stunning visual display. For DJs & producers it is a unique performance tool enabling them create spectacular live & DJ audio-visual performances." Tenori-On website, first accessed August 2007

The research field of gesture capture and music technology is something that I would like to pursue further. I am likely to try other concepts and design more NIMEs now that I have the base knowledge of building and designing these devices and I am currently looking into the possibilities of studying a Ph.D. Degree in this field.

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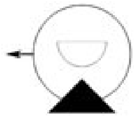
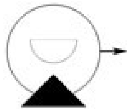
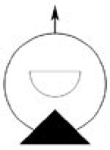
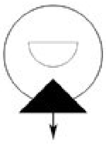
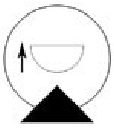
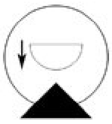
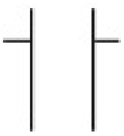
10. Appendices

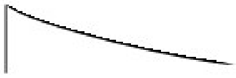
10.1 Accelerometer Gesture and Parameter Relationships

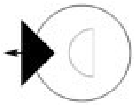
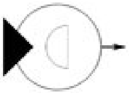
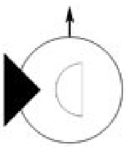
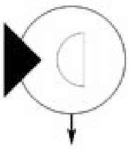
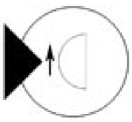
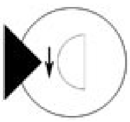
MOVEMENT SET 1 (Soft set) (Stable)

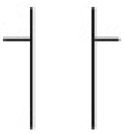
Abbreviation	Movement	Analogy	Relation	Parameters
 HLSD	Hand moving left, sensors down	Horizontal low-energy floating	 Constant	X panning left
 HRSD	Hand moving right, sensors down	Horizontal low-energy floating	 Constant	X panning right
 HUSD	Hand moving up, sensors down	Vertical low-energy wave	 Increasing	Y Transpose +
 HDSD	Hand moving down, sensors down	Vertical low-energy wave	 Decreasing	Y Transpose -
 HFSD	Hand moving forwards, sensors down	Forwards low-energy push	 Increasing	Z Ms between grains - Z Reverb +
 HBSD	Hand moving backwards, sensors down	Backwards low-energy pull	 Decreasing	Z Ms between grains + Z Reverb -



This set is opposite to set 3

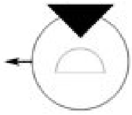
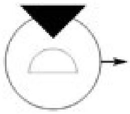
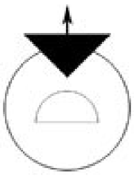
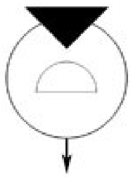
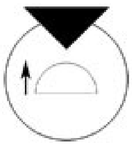
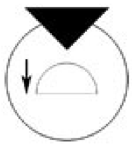
MOVEMENT SET 2 (Medium set left)  Leading from

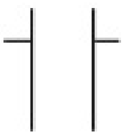
Abbreviation	Movement	Analogy	Relation	Parameters
 HLSL	Hand moving left, sensors left	Left medium energy shift	 Decreasing  Supporting	X Duration - X Panning left X Transpose up
 HRSL	Hand moving right, sensors left	Right medium energy shift	 Increasing  Supporting	X Duration + X Panning right + X Transpose down
 HUSL	Hand moving up, sensors left	Upwards medium energy shift	 Increasing	Y Transpose up X Ms between grains + Z Reverb +
 HDSL	Hand moving down, sensors left	Downwards medium energy shift	 Decreasing	Y Transpose down X Ms between grains - Z Reverb -
 HFSL	Hand moving forwards, sensors left	Forwards medium pushing energy shift	 Increasing	Z Reverb + X Right pan + Y Duration +
 HBSL	Hand moving backwards, sensors left	Backwards medium pulling energy shift	 Decreasing	Z Reverb - X Left pan - Y Duration -

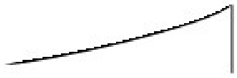


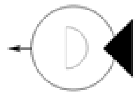
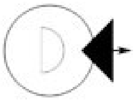
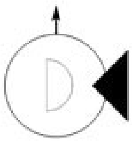
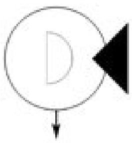
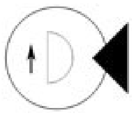
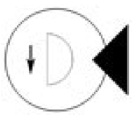
This set is opposite to set 4

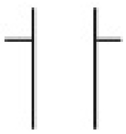
MOVEMENT SET 3 (Harsh set)  Unstable

Abbreviation	Movement	Analogy	Relation	Parameters
 HLSU	Hand moving left, sensors up	Static high energy energy shift	 Decreasing  Supporting	X - Panning X - Scrub Y - Reverb Z + Ms Between grains
 HRSU	Hand moving right, sensors up	Static high energy energy shif	 Increasing  Supporting	X + Panning X + Scrub Y + Reverb Z - Ms Between grains
 HUSU	Hand moving up, sensors up	Static high energy energy shift	 Increasing  Supporting	Y + Transpose Y + Scrub X + Reverb Z - Ms Between grains
 HDSU	Hand moving down, sensors up	Static high energy energy shift	 Decreasing  Supporting	Y - Transpose Y - Scrub X - Reverb Z + Ms Between grains
 HFSU	Hand moving forwards, sensors up	Dynamic high energy energy push away from body	 Supporting	Z + Transpose Z + Reverb Z - Ms Between grains Z - Duration
 HBSU	Hand moving backwards, sensors up	Dynamic high energy energy pull towards from body	 Supporting	Z - Transpose Z - Reverb Z + Ms Between grains Z + Duration

 Is opposite to set 1

MOVEMENT SET 4 (Medium set right)  Leading to

Abbreviation	Movement	Analogy	Relation	Parameters
 HLSR	Hand moving left, sensors right	Left medium energy shift	Decreasing + Supporting	X duration - X panning left - X transpose up +
 HRSR	Hand moving right, sensors right	Right medium energy shift	Increasing + Supporting	X duration + X panning right + X transpose down -
 HUSR	Hand moving up, sensors right	Upwards medium energy shift	Increasing + Supporting	Y – ms between grains X + transpose Z reverb +
 HDSR	Hand moving down, sensors right	Downwards medium energy shift	Increasing + Supporting	Y + ms between grains X - transpose Z reverb -
 HFSR	Hand moving forwards, sensors right	Forwards medium pushing energy shift	Increasing	Z + Duration X Left panning + Y + Reverb
 HBSR	Hand moving backwards, sensors right	Backwards medium pulling energy shift	Decreasing	Z - Duration X Right panning - Y - Reverb

 Is opposite to set 2

10.2 Glove Sensors Gesture and Parameter Relationships

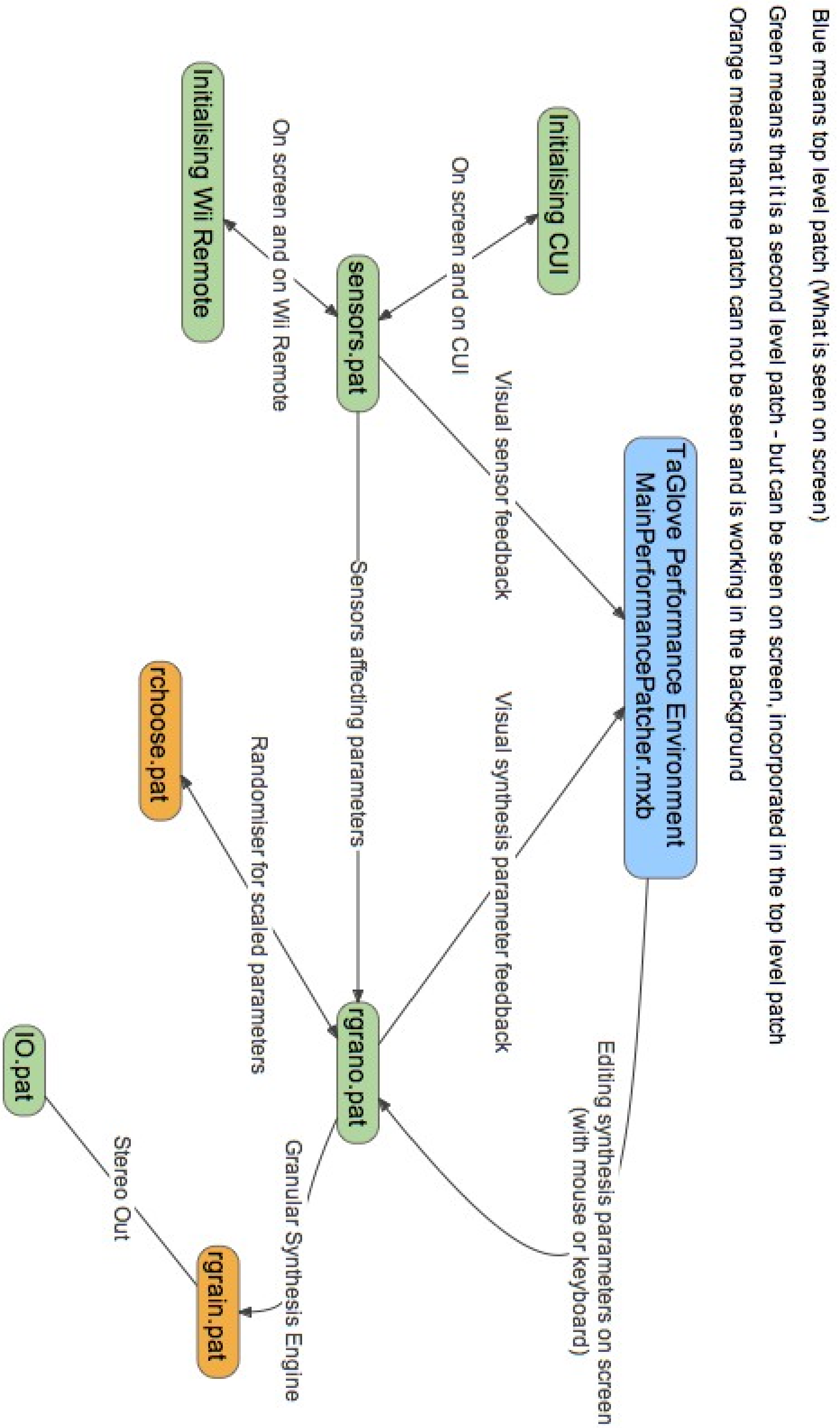
Movement set 5

Glove sensor	Controls	When	How
Thumb bend high (outwards)	**Granular wavetype:** Sine Sawtooth Square Sample	Always on	Activated when fully pressed
Thumb bend (in towards palm)	**Filter type:** Gaussian Quasi-Gaussian Triangle 3-Stage-Linear Hanning Hamming Blackman Blackman-Harris Expedec Recpodec	Always on	Activated when fully bent
Thumb touch	Inactive sensor		
Index touch	Inactive sensor		
Index bend (1 & 2 button on accelerometer pans through controls list)	Duration high value Panning high value Transposition high value Reverb gain Two to many mapping	Only when selected in list	Has scaled bend range
Middle bend (1 & 2 button on accelerometer pans through controls list)	Duration low value Panning low value Transposition low value Reverb time Two to many mapping	Only when selected in list	Has scaled bend range
Index and middle bend average (1 & 2 button on accelerometer pans through controls list)	Ms between grains	Only when selected in list	Average combined scaled bend range (no bend – high value = less grains per ms, more bend – low value = more grains per ms)
Ring bend	Inactive sensor		

10.3 Combined Use of Sensors and Parameter Relationships

Accelerometer: Same as section 10.1	Glove (Middle and Index finger bend)
HLSD	Reverb
HRSD	Duration and reverb
HUSD	Duration, reverb and ms between grains
HDSD	Duration, reverb and ms between grains
HFSD	Transposition
HBSD	Transposition
HLSL	Reverb
HRSL	Reverb
HUSL	Duration
HDSL	Duration
HFSL	Transposition
HBSL	Ms between grains
HLSU	Ms between grains
HRSU	Ms between grains
HUSU	Ms between grains
HDSU	Ms between grains
HFSU	Ms between grains
HBSU	Ms between grains
HLSR	Reverb
HRSR	Reverb
HUSR	Duration
HDSR	Duration
HFSR	Transposition
HBSR	Transposition

10.4 Max / MSP TaGlove Performance Environment Patch Relations Overview Flowchart



10.5 Max / MSP TaGlove Performance Environment Patch Relations Detailed Overview Flowchart