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Virtual Musical Instruments: Technological Aspects and Interactive Performance Issues

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Abstract

I have been creating various Gestural Interfaces¹ for use in my compositions for Virtual Musical Instruments². These Virtual Musical Instruments do not merely refer to the physical instruments, but also involve Sound Synthesis³, programming and Interactive Video⁴. Using the Virtual Musical Instruments, I experimented with numerous compositions and performances. This paper is intended to report my experiences, as well as their development; and concludes with a discussion of some issues as well as the problem of the very notion of interactivity.

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1. An interface which translates body movement to analog signals. This contains a controller which is created with sensors and video scanning system. This is usually created by an artist himself or with a collaborator. This does not include a commercially produced MIDI controller.
 2. This refers to a whole system which contains Gesture, Gestural Interface, Mapping Interface, algorithm, Sound Synthesis, and Interactive Video. According to programming and artistic concept, it may extensively vary.
 3. This is a domain of programming to generate sound with a computer. In this article, the way of this programming emphasis the relationship between gesture and sound production.
 4. A video image which is altered in real time. In Virtual Musical Instruments, the image is changed by gesture. This image is usually projected on a screen in a live performance.

Introduction

The problem confronting artists who work with interactive media is the use of commercially-produced computers. Very few of them build their machines from scratch. Individuals tend to purchase computers that have evolved from marketing strategies, while institutions equip themselves with larger computers in accordance with their administrative requirements. Yet these commercially-produced devices are aimed at the mass market, rather than at the individual artist who wishes to develop original ideas based on an imaginary world of his own making. Even if the artist knows how to program his computer, his possibilities are limited by the computer's operating system and by the power of the machine. He might create a controller using sensors and a circuit of his own design, but these signals end up being treated by the computer. The artist has to be aware of the fact that his creativity is always reliant on commercial considerations.

Likewise, we have to be selective with regard to the overwhelming mass of information surrounding us. Otherwise, we will succumb to the totalitarianism of the media. If we are to retain a certain amount of individuality, we have to be aware of these manipulative processes. This is not the case with many artists, which is why many artistic creations are banal and conformist.

We are living a time when technology is accessible to all. The computer may be regarded as the symbol of our democratic society, inasmuch as it is a product that is available world-wide. At the same time, it can be an instrument of power and authority.

However, the artist can also profit from society. Today, the relationship between art and technology is a much closer one than it ever was in the past. Likewise, technology is generally regarded as something that enriches our lives, but this does not always apply in the case of art. However, in some cases, technological developments can trigger new artistic genres. For instance, technological progress has led to the creation of multi-media art and interactive art, and artists have been able to profit from this development.

In recent times, this interaction has been increasingly apparent in music. Although technology does not invent a new art form by itself, it offers musicians many new choices. In this sense, the artist's function is no longer that of conveying traditional values and thoughts. The artist is an intermediary who offers his audience new values and perceptions based on his interaction with technology.

An attitude of naive optimism towards technology is no longer possible. The artist should rather consider how he can confront technology, while remaining aware of its dangers. Technology itself doesn't create a new sensibility, but the interaction between humans and machines can do so. Once we accept the notion of interaction, we can better exploit the new possibilities it offers. The artist will no longer express his

traditional thoughts and emotions, but interact with the machine.

In my view, certain artistic trends, such as the development of Virtual Musical Instruments, can go some way towards resolving these difficulties. Unlike commercialized products, a Virtual Musical Instrument is created by an individual for his own artistic purposes. He can modify his instrument by programming it in accordance with his artistic leanings. Virtual Musical Instruments thus go some way towards answering a question that all art forms have to confront today.

Virtual Musical Instruments

Before the discussion is continued, I will attempt to define the Virtual Musical Instrument. A. Mulder describes about Virtual Musical Instruments as [1] :

"..., analogous to a physical musical instrument, as a gestural interface, that will however provide for much greater freedom in the mapping of movement to sound. A musical performer may control therefore parameters of sound synthesis systems that in real time performance situations are currently not controlled to their full potential or simply not controlled at all."

H. Katayose et al talk about their system, Virtual Performer [2] :

"... the Virtual Performer which is a system composed of gesture sensors, a module analyzing and responding obtained information, and a facility for presentation."

The latter definition rather emphasizes the whole system, instead of merely defining as controller itself. In creating my Virtual Musical Instrument, the SuperPalm (figure 1), which has been designed and realized at Ircam.

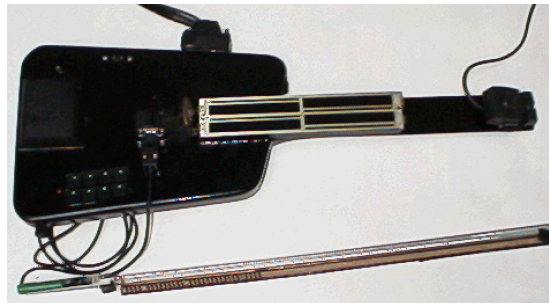


Fig. 1. The SuperPalm.

I started with the idea that the Gesture⁵ of a real violin would be modeled, though without producing any sound in themselves. The sound is instead generated with the aide of a computer. According to the algorithms of Mapping Interface⁶ and Sound Synthesis⁷, the sound may be extensively varied (figure 2).

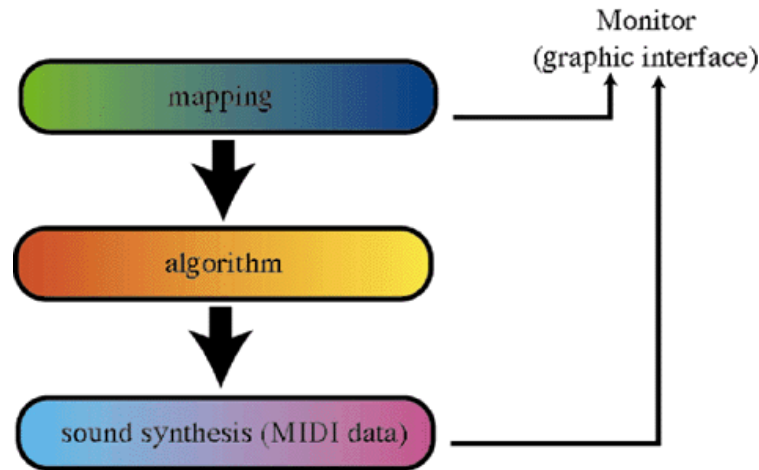


Fig. 2. Mapping Interface and Sound Synthesis.

Another Gestural Interface which I have designed is the BodySuit (DataSuit), a suit fitted with bending sensors that are attached to each joint of the body (Figure 3). This suit is an ideal performance tool: it enables me to make wide, sweeping movements that can easily be observed by the audience. Another instrument I use, the PowerGlove, triggers sounds by means of the bending of the fingers. However, although it opens up new possibilities with regard to performance, the only weak point is that it does not allow for subtle musical nuances.

5. Movement of body. In this article, gesture is defined as an experience of perception, while an audience observes the relationship between movement of body and visual/aural aspects in real time.

6. An interface which translates input signals into a well-organized state. This differs from gestural interface, such as the Virtual Musical Instrument and analog to MIDI interface. Since this is programmed, the function may widely vary according to the algorithm.

7. See note 3.



Fig. 3. The BodySuit.

The SuperPolm, which allows me to make small, subtle movements, can trigger far more complex sounds. The SuperPolm is better adapted to my music, when subtle musical nuances are especially required in my compositions.

Self-produced instruments offer far more possibilities than traditional musical instruments that are augmented by sensors. Such instruments can produce acoustic sounds and control a computer at the same time. Since Gestural Interfaces merely trigger sounds, their capabilities can be modified by programming. This is an essential factor in my compositions. One of my gestures at one moment might produce a sound similar to a traditional instrument but in the following section the same gesture might trigger a very different sound. As well as allowing for more possibilities in terms of sound, it also allows for a certain theatricality in performance.

A controller is adapted to a specific type of gesture. In this case a controller refers to the Gestural Interface, but it also means a remote control device for manipulating a computer from a distance through MIDI, etc. Although the performer is not required to master complex fingering techniques, as with traditional instruments, he still needs to learn how to play the Virtual Musical Instrument. A controller can lead to the creation of new gestures. For example, the SuperPolm contains a force sensor placed in the chin rest and an inclinometer measuring respectively the performer's constraint to maintain the instrument and the angle impressed towards the vertical. Therefore the performer can control two added parameters with chin pressure and the bending of the upper-half of the body forwards front without hand movements (Figure 4).



Fig. 4. The author playing the SuperPalm.

However, these body movements do not convey any particular meaning, nor do they have any choreographic relevance. On the contrary, their sole function is to control the Virtual Musical Instrument. A dancer, for instance, might find it difficult to use such an instrument. Dancers need to control their bodies in order to execute intricate figures, and even a well-trained dancer would be incapable of controlling musical materials at the same time as dancing.

Now these non-functional gestures create some issues, especially in a situation involving sound and image in real time. The crucial point here is "Interaction" which refers to "possibilities" of interaction and "definitions" of interaction in the performance context. Gesture does not signify by itself, though, that it may trigger sound and can be completely altered by a program (Figure 5).

The remainder of the article is intended to discuss each specific subject about my project, the Virtual Musical Instrument, by following the flow chart.

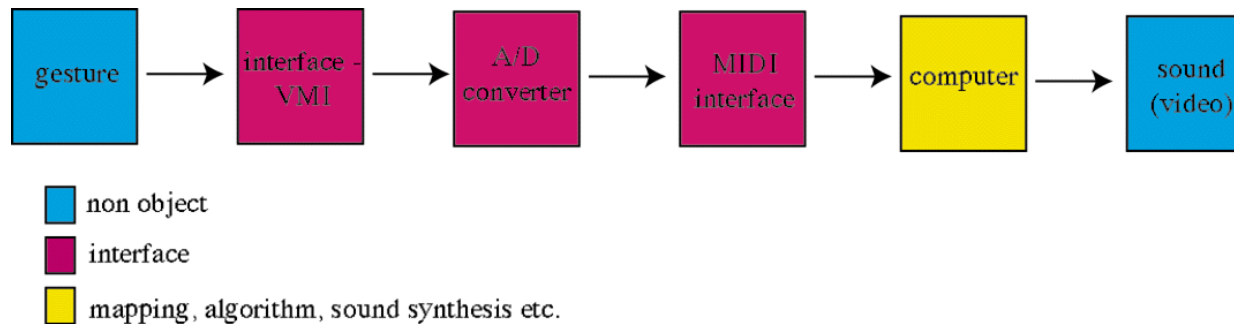


Fig. 5. Gesture triggering process.

Gestures and Music

"The interest is how electronic systems can extend performance parameters and how the body copes with the complexity of controlling information video and machine loops on-line and in real time".
 Stelarc, Host Body/Coupled Gestures: Event for Virtual Arm, Robot Manipulator and Third Hand [3]

We may now raise a relationship between gesture and music, however the further discussion will relate to human perception which may occur during the performance of the Virtual Musical Instrument. Before we continue the discussion, it would be important to define "gesture" in the context of the article.

The gestures of a violin are originally imitated on the SuperPalm, although, it is not necessary to always play in a similar manner. Gestures are translated into parameters. Gestural Interfaces may be regarded as an interface between gesture and the computer insofar as they translate the energy derived from body movements into electrical signals in order to control sound or images.

Virtual Musical Instruments also allow learning new gestures, because they can be assigned new functions by programming. A controller can lead to the creation of new gestures. However, these body movements do not convey any particular meaning, nor do they have any choreographic relevance. While an audience observes this non-articulated gesture, there are many aspects to deal with his perception of the resulting artistic materials. We may define "gesture", especially in the context of the Virtual Musical Instrument here, as an "individual experience of perception".

The German composer, Dieter Schnebel, talks about Sound and Body in his book, *Anschläge - Ausschläge, Text zur Neuen Musik* [5]:

"Most sounds, especially music, are created by actions.

While looking at those, the sound production becomes the dramatic course of the event. Therefore, the gestures of the musicians at the sound production have their own visual lives. If music is however, an art metalanguage of feelings with strong affinities to the consciousness, then the gestures essentially belong to it, and then the feelings appear in sound and gesture. The gesture is like a visual sound. Although a musician clearly expresses his large fantasy through his gesture occasionally on the other hand, it proves to reduce (in order to turn away the attention from sound). The gesture is never autonomous here, but is always related to the progression of music - therefore to the composition.

The listener's experience of gestures and music can also be affected by other factors, such as concurrent stimuli. Visual stimuli can stimulate an aural experience. The listener's environment can also modify his state of mind. In our home listening environment, we can play music at any time and in any circumstances. We can imagine the performer's gesture as we listen to it. We can moreover concentrate on the sound, as there are no visual stimuli to divert our attention from it. My projects, however, are oriented towards the concert environment in which sound and vision interact."

Although music is originally for the ears, some people don't like to listen to it in darkness and some prefer to listen to it in half-darkness. A concert however, where music comes from speakers, may give us some kind of frustration - maybe that is why electronic music was not fully accepted and the need for live electronics was felt.

Nowadays it is quite easy to listen to music with audio equipment at any time of the day or night, yet people still go to concert halls to experience music. What is the difference between listening to a recording with headphones and listening to live music? In a concert hall, acoustic instruments can be heard without loss of quality. Moreover, the audience experiences a different kind of space which differs from its living or working environment and, even more importantly, it can also observe the gestures of the performer on stage. Of course, there is generally a relationship between the sound and the performer's gestures. Broader gestures tend to signify a greater dynamics, and audiences notice a difference in dynamics as a result of the musician's gestures, even though there may be little difference in terms of decibels. To sum up, in the concert situation, music becomes an aural and visual experience, and gestures are of paramount importance. This is where the Virtual Musical Instrument comes in, inasmuch as it makes it possible to incorporate gestures directly into performances of electronic music.

An essential aspect of my solo performances, which I call interactive media art performances, is the interaction between gesture, sound and image. With the SuperPolm, a single body movement can control sound and images at the same time. This relationship can be clearly presented in real time, and can be an unexpected and complex one. It is a concept that could undergo considerable development inasmuch as I can play with notions such as simplicity and complexity, for instance by triggering complex textures with simple hand movements. Sound, image and gesture play an equal part in these events.

Gestural Interfaces

I have chosen to focus on the use of Gestural Interfaces in a performance context. Gestural Interfaces differ from traditional instruments in that they cannot produce sounds by themselves. They merely send signals that produce sounds by means of a computer or a sound module. They may be regarded as an interface between the performer and the computer insofar as they translate the energy derived from body movements into electrical signals.

General Description of "BodySuit"

The "BodySuit" was built between 1997 and 1999. It is intended to be a motion capture for the entire body. Twelve bending sensors are attached to the body, one at each main joint: the wrists, elbows, shoulders, ankles, knees, and the root of both thighs.

Although a performer wears the "BodySuit," this does not mean that he merely controls a physical instrument. As a matter of fact, the physical limitation is light in contrast to playing a traditional musical instrument. Therefore, a performer merely produces sounds with his gestures by bending and stretching each joint.

According to the human body's limitations, bending one joint can cause other sensors to move and unexpectedly change parameters, although the performer does not wish it. When one bends the left knee for instance, it is inevitable that the thigh will move. In such a case, a performer may switch on and off each sensor by using buttons on his arm.

General Description of SuperPolm

The MIDI Violin, the "SuperPolm," was built in 1996. The SuperPolm was created with the collaboration, Patrice Pierrot and Alain Terrier in Ircam. It was originally intended to complete a piece I composed for Ircam in 1995 - 1996. It is based upon the idea of short range motion capture, such as finger, hand and arm movements. The signals are translated into MIDI signals so as to control generated sound in real time. In this project the fundamental concept of motion capture is divided into three categories.

1. Short range movements include finger, hand, eyes, and mouth movements.
2. Medium range movements consist of movements of the shoulders, legs, head, etc. These can easily be observed by the audience.
3. Large range movements involve spatial displacement and include those of the feet and legs. The parameters of these movements can be translated as position or distance.

The SuperPalm may be also regarded as Gestural Interface that remotely operates a computer. While Gestural Interface does not generate sound by itself, it nonetheless allows the performer to express complex musical ideas. The performer plays in a similar manner to a violin, except that the fingers press touch sensors on a finger board instead of pressing strings (Figure 6).



Fig. 6. A view of the SuperPalm.

Sound may also be produced by means of chin pressure or by changing the angle at which the Gestural Interface is held. The original design of the SuperPalm was modified during the course of its development for practical and technical reasons. A great deal of time was spent looking for sensors and investigating their possibilities in a laboratory, and many of them had to be abandoned. Once the electrical circuits were ready, many more changes had to be made so as to adapt the fingerboard and bow to the needs of the performer.

In order to detect finger position and pressure, a sensor from Interlink, called FSR, is used. Four position and pressure sensors are attached to the finger board. Those four sensors, which are 10 cm x 2.5 cm long have to be placed in an irregular way on a finger board. However, this allows to reach all the sensors at the same time in any position.

The capture of the bow movement was the most difficult issue. Many experiment models had been done before arriving at the final model, which uses the bow as a potentiometer. There are more than 100 resistors placed on the bow in a series. In the middle of the instrument's body, a metallic bridge is fixed. When playing, the bow is touching the bridge. The output voltage depends on the contact point of the bow on the bridge. Therefore a performer plays the bow in a traditional manner.

By bending the body slightly forward, the angle of the instrument automatically changes. Another sensor, an Analog Device accelerometer called ADXL is placed inside the body of the Gestural Interface in order to measure the value of the bend. This allows the SuperPalm to be performed by changing inclination with respect to gravity.

A violinist holds a violin between his shoulder and his chin. In the place where the chin touches the violin, there is an internal pressure sensor covered with rubber. One may change parameters by changing the intensity of pressure with the chin.

For the accelerometer and chin pressure sensor, there are switches to start and stop each on the body of the SuperPolm.

There are also buttons on the heel of the bow and on the root of the fingerboard which can control numerous functions depending on the program.

BigEye

The software, BigEye, has been programmed by Tom Demeyer at the STEIM foundation in Amsterdam.

This is an application designed to take real-time video image input and convert it into MIDI information. This may be configured in the program in order to extract objects, based on color, brightness and size. These objects are captured (up to 16 channels at the same time) and their position is scanned according to a pre-defined series of zones.

Instead of a color object, I have chosen two halogen lights in order to have their positions detected in space. One of the major reasons is that the color object can be unsteadily scanned by the computer depending on the lighting conditions of the room. Although the lighting may not be much different for the human eye, the computer "sees" in a different way. Depending on the position on a concert stage, the lighting condition changes. It may cause many unexpected results between the studio preparation and the stage performance, regardless of the function which allows adjusting the brightness in the program. Usually there are much stronger lights on a stage. If a performer holds two halogen lights in her hands, she can easily control the parameters without much disturbance from the lighting conditions, since the two halogen lights themselves emit light. Therefore, the scanned result is much more stable.

As stated, large range movements involve spatial displacement and include those of the feet and legs. The parameters of these movements can be translated as position or distance. These two dimensions are explored with this video scan program, as with the idea of composition previously mentioned.

Analog-to-MIDI Interface

Body motions are first transduced by sensors into electrical signals. We need to clarify the process of transformation of these signals for computer input. Indeed, captured data from body motions needs to be transformed into sound.

With this point of view, gesture and the Gestural Interface are merely located at the very beginning of this process. Although each different sensor has a different construction, with different electrical circuits, the signals vary merely from 0V to 5V. These analog signals need to be translated into digital signals, in order to communicate with a computer. For practical reasons, I chose an analog to MIDI interface. The MIDI signals are then conveyed to the computer and used as parameters to generate sound.

In building the Analog to MIDI Interface, I used the AKI-80 microprocessor board. This had a powerful CPU at that time, the Toshiba, TMPZ84C015BF. The Analog-to-MIDI Interface has 32 analog inputs and outputs. Each channel can be independently controlled by MIDI, through programs such as Max. The CPU was programmed by Assembler. This interface was built with a major contribution from Yoichi Nagashima.

Mapping Interface, Algorithm, Sound Synthesis, and Interactive Video

These subjects are generally based upon the following issues:

- The issue of relationship and connection between one level to another (gesture -> Gestural Interface -> mapping -> algorithm etc.)
- The issue of the Virtual Musical Instrument and Interactivity
- The issue of application in a composition and performance theory

Relationship between Gesture and Interaction

Clear interaction between gesture and sound can be compared to the relationship between the visual and oral aspects in traditional instruments. For example, fingers movements derives differences in pitch, and the intensity of movement derives a different dynamics of sound. On the contrary, a rising hand movement may create a different density of sound texture with Virtual Musical Instruments. This can be much related to the subject of sound algorithm.

This may also involve human cognition while observing interaction simplicity and complexity, and the expected and unexpected results. A good interaction with gesture may yield a successful interactive performance. Gesture can represent immediate sound materials. When the relationship is too simple, an audience easily loses attention. Gesture can trigger repetitive patterns, sequences, or complex textures with algorithms. These may perhaps bring a higher musical quality than a simplistic approach, however, when the relationship is not obvious, an audience may lose interest after a while. This issue is not one of technology; it is necessary for the composer to find his own solution.

The relationship between gesture and interaction can be flexibly changed during the course of a piece and the perception of interactivity can be integrated into a musical context. Gesture can be clearly reflected in the acoustic domain. For example, slow body movements reflect lower dynamic levels, softer articulation, or slower tempo. In another context, the same gesture can produce a sound like a cello which corresponds to the action of drawing a bow across the strings.

Not only is there this abstract perceptual level between gestures and their visual/oral results, but there is also a creative approach to how the physical actions can be interpreted into the digital domain, then how these signals can be efficiently expanded. Therefore, the discussion of the Mapping Interface/algorithms, and sound synthesis, presented in the following section, is closely related to this issue.

Relationship between Gesture, Mapping Interface and Algorithms

The Mapping Interface⁸ refers to the disposal of MIDI signals from an analog to digital interface into various hierarchies of algorithms.

As already pointed out, gestures can be mapped by algorithms, such as the Fuzzy Theory or Neural Networks (figure 7). Gestures spontaneously interact with some of the parameters which control the degree of randomness, the speed of sound texture transformation, and the order of the selection of data.

The functions of the Mapping Interface are as follows :

- a. The value of voltage from the Gestural Interface rarely varies the full range from 0 V to 5 V. Therefore the MIDI value from the Analog-to-digital interface does not range from 0 to 127. On the Mapping Interface, the value is scaled to a full range from a minimum to a maximum value.
- b. Depending on the sensor, the response of a value varies in a different manners. For the sake of a practical performance or a compositional reason, the value is treated either linearly or exponentially.
- c. Although it depends on the speed of the CPU, a performer may be cautious about MIDI overflow in a live performance. The Mapping Interface can regulate the maximum limit of the scanning speed.
- d. The potentiometer of the bow on the SuperPolm merely captures the position of the bow. It however, needs to integrate gesture and sound intensity. The Mapping Interface translates

8. [Note of the editors] The word "mapping" used here is slightly different meaning than in other contributions in this volume. Some of the functions attributes of the mapping interface may be performed by the MIDI interface, for instance, and would't be considered as part of the mapping.

parameters of position into energy of movement in a limited time. The difference of value within a short period is translated to the velocity of sound.

e. MIDI noise is eliminated by the Mapping Interface.

f. Each sensor can be regulated either to be active or non active according to the necessities of the performance or a section of the composition.

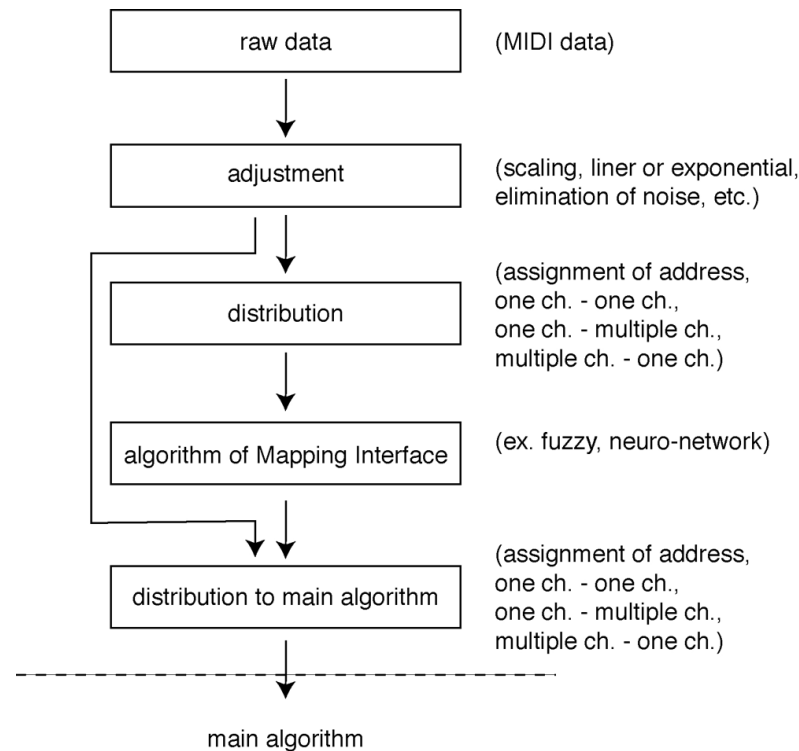


Fig. 7. Mapping Interface network.

In the distribution, a signal (or signals) is divided or are combined in the following methods⁹:

- a. one sensor -> one parameter
- b. one sensor -> multiple parameters
- c. multiple sensors -> one parameter
- d. multiple sensors -> multiple parameters

9. See the articles by F. Iazetta and A. Hunt and R. Kirk in this volume.

After going through the Mapping Interface, the signals are treated in various manners to generate sound. This falls in the domain of the purpose of the performance and compositional taste. It may also facilitate to clarify the conjunction between gesture and musical expression. There are also other aspects which can be considered as follows :

- a. When triggered, sequences, patterns, and lists of data used as accompaniment can start and stop.
- b. Parameters of sensors can be translated into complex musical textures by algorithmic calculations.
- c. Algorithms set according to parameters in the Gestural Interface can enrich timbre or organize the sound.
- d. The algorithms may regulate the parameters in order to communicate with another computer.

Algorithms can be integrated into sound synthesis and signal processing. Applied to Physical Modeling sound synthesis algorithms, gesture can be transformed into an imaginary instrument. Instead of being assigned to each signal processing parameter directly, gesture can control the ratio value of the morphing and interpolation algorithms.

The Virtual Musical Instrument can be widely changed according to sound synthesis programming. As matter of fact, the instrument design regarding sound synthesis is one of its most important factors. Eventually this deeply relates to gesture and the notion of interactivity.

One of the major problems is the limitations of sound synthesis in real time. Although the power of CPUs has been rapidly developing lately, sound synthesis is still an enormous task for a computer. Johannes Goebel pointed out the critical issue of "poor" sound that is generated in real time and the perception of it [6].

Since the 1960s, it has been a long-term computer music project to utilize the gestural control virtuosity of traditionally trained artists (conductors, performers, dancers, etc.) in the digital domain. However, investigating the compositional tools specifically supplied by digital technology for the precision and control of sonic properties has dropped to a low level since digital sound became available as "ready-made", and as the imitation of acoustical instruments became a major aim of real-time synthesis. "Low level" does not refer to the scientific and computational complexity to create such sounds, but rather refers to the compositional level linked to the auditory perceptible result. Listening to a "boring" piece of music set for acoustical instruments, I might still focus on the acoustical properties, of the instruments and find a sensual richness. When I listen to a "boring" piece of electro-acoustic music, however, it will usually also be presented with "boring" sounds, and if the sonic part of a piece with digital sound generation is "not

boring", usually the whole piece is quite a bit closer to being "not boring". Rarely will we find a piece that supplies digital audio signal processing techniques with non-imitative and "convincing" results that we also find musically "boring".

This is not only in the case of a gestural controller, however. Disappointment about "poor" sound is one of major problems in interactive music generally. Concerning the problem of sound synthesis in real-time, alternative possibilities have been experimented in order to find solutions. One of the important elements for those concerned about the possibilities of controlling sound algorithms with gesture could be controlling sound synthesis, changing sound effect, (such as filter, delay/reverb, chorus/flanger, pitch shift/harmonizer), and spatialisation. In other words, the relationship between gesture and the sound algorithm needs to be much more explored. While sending gestural signals, two elements, not exactly the same, are conveyed: playing notes and controlling parameters. These may be interpreted as the physical performance of musical material and the control of effects, especially in a compositional context.

With a complex algorithm, intricate sound textures can be produced by simple gestures. The parameters go through various hierarchies. Signals in one channel can be transformed into masses of sound with randomness. One single movement of the body can be spread into many channels of parameters. As a note produced by an acoustic instrument contains much information, in the same manner, many parameters are assigned to a single note of sound in order to imitate the complexity of the acoustic instruments. Many channels of gestural parameters can be combined into one single note. Eventually this allows to express subtle and complex musical expression simultaneously.

Additional controls may be included at the same time in order to achieve subtle musical expression. The simultaneous control of parameters can also bring richer sound, such as jitter, complex envelopes, or interpolation. Since timbre has features which relate to time, the spectrum may gradually change as time goes by, this technique can be applied to sound synthesis in the Virtual Musical Instrument. However, additive synthesis and FFT can cause many CPU utilization problems in real time. Perhaps these CPU utilization problems can be solved using several computers which communicate with each other via MIDI.

Sound Synthesis is a huge subject that is beyond the scope of this article. Some topics are merely mentioned here.

Frequency Modulation (FM) sound synthesis technique can be extensively varied with a few parameters: carrier frequency, amplitude and frequency of the modulating signal, carrier/modulation frequencies ratio, modulation index. With a gesture, timbre can be easily changed with few channels. When the timbre is not modified, notes are simply triggered by gestures; pitch and amplitude can be changed.

The following parameters in Granular Synthesis can be altered by a gesture either independently or several at a time.

- a. number of samples
- b. sample changes
- c. pitch tables which are previously prepared
- d. random values
- e. speed for triggering notes
- f. duration in sample
- g. position in sample
- h. random values of duration

A sample can be gradually changed from one to another with foggy grain sound texture.

According to the position of the Gestural Interface in space, the sound source can change in real time. Sound is reproduced with 4 speakers. As the position of the Gestural Interface moves circularly, sound from the speakers moves in the same manner. The virtual size of space in sound production may be changed depending on the position of the performer on stage, as well. If necessary, the Doppler Effect may be included in order to simulate the movement of the sound source.

The relationship between gesture and sound synthesis is a crucial theme to explore further, since this decides fundamental elements of interactive compositions. For example, the relationship between composed gesture and predetermined sound synthesis can vary from section to section in terms of compositional technique. This derives further performance models, such as, not only instrumental gesture, but also visual aspects: theatrical or conceptual performance models. While the Gestural Interface physically remains the same, the function of instrumental models can change in each section according to the different sound synthesis used. Therefore, those relationships can be integrated into a compositional concept. In an improvisational context, free gestures can flexibly produce varying sounds according to how much the sound synthesis programming allows the original sound to alter. However, it is not too much to say that sound synthesis has to be sufficiently prepared beforehand; the selected sound may be simply changed during a performance. Free gestures can change pitch/velocity, timbre parameters, sample presets, etc. At this point, it is rather a question of controlling the level of indeterminacy.

In the sense of indetermined composition, sound synthesis can be improvised to a certain degree, but the presets can be changed linearly. In other words, sound synthesis can be changed in each section where the program changes. If it is necessary, the preset can be changed in a non-linear way in order to cooperate with much freer improvisational gestures.

Issue of Interaction in Musical and Performance Contexts

Some issues to be considered:

- a. Criteria of flexible reaction and degree of preparation and chance. In another words, how much the materials are prepared beforehand, how much the materials are improvised with free gestures with a computer in real time.
- b. Feedback (this however, does not refer to physical feedback). Except for automated randomness, there are not so many possibilities of flexible feedback. As matter of fact, there is merely one direction from human gesture -> interface -> algorithm -> sound and image.
- c. Limitations of computer parameters exposed during the programming and sound synthesis process in respect to the complexity of human perception.
- d. Fundamental contradiction between the definition of "interaction" in general and interaction in musical and performance contexts.

Many interactive artists experience problems with these systems. The problems do not come from the computer, but from the way in which we perceive the world. There is always some doubt as to whether an interactive system produces something real or not. The feedback that is triggered by a sensor is only created by a prepared program. The computer merely obeys an order from the user.

Interactive Video

There is a small contact video camera at the top of the neck on the SuperPalm. This can capture finger movements from a close distance. If I change the direction of the camera to face away from the fingerboard, the images widely move according to the angle of the SuperPalm. In the same manner, those images are altered by the parameters of the SuperPalm in real time. The images captured by the camera are processed by software called "Image/ine", which is programmed by Tom Demeyer at STEIM foundation in Amsterdam.

Image/ine is a real-time image processing tool. As a real-time imaging tool, it allows the control of the parameters to all the functions of the program by MIDI. Effect functions contain Keying (Chroma and Luminance), Displacement mapping, image sampling and playback. Image/ine allows the control of image source material from video taken by a video camera, QuickTime movies, image files, and scanned images.

The Virtual Musical Instrument can also control the parameters of images in real time. For instance, it can superimpose live or sampled images on top of each other, add effects, such as delay, and speed-up, reverse, or repetition. It can also mix several images in different proportions and modify their color, brightness and distortion. The sampled images can be started and stopped at any point.

Performance Issues

The Gestural Interface can be regarded as a medium of communication between a human and a computer. The Virtual Musical Instrument contains algorithms and sound and image production. The notion of interactivity is certainly raised as an issue here. Since a performer or an audience may question whether a gesture correctly corresponds to sound in real time, and whether the sound and images are rich enough in the compositional context. The background of the development of the Virtual Musical Instrument is discussed here with the issues of interactivity and their own technological aspects, as well as human perception.

Issues of Human Perception and the Limits of Computers

There is an underlying problem concerning multimedia pieces: although the way each media is used may be interesting in itself, they don't always work together. Theater-based performances get around this problem by stressing the narrative element and adapting the background music and scenery accordingly. But this is not the direction I have chosen. Drama and narrative are of no interest to me. My focus is on perceptual experience. I consider sound, image and gesture as neutral elements that exist in parallel and interact with one another.

This brings further perception possibilities to an audience and eventually creates multiple perception. The meaning of the performance is not given by the work, but the audience creates the meaning according to their own internal perceptual experience.

Our perceptual abilities are extremely complex in comparison to those of a computer. The question as to whether subtle artistic nuances may be conveyed by a computer is an issue that calls for considerable discussion. Indeed, it is one of the challenges that confronts artists working with new technologies. But although the computer offers a limited number of possibilities, it can still inspire an artist. He might wish to exploit its mechanical aspects, such as the repetitive figures and sounds that may be obtained from automated algorithms. Alternatively, he might try to develop his own individual approach to technology, by creating a new type of art work, or he might regard the computer as nothing more than a tool, which is an attitude frequently held by older generations. Admittedly, a computer cannot express subtle variations in pitch and time. While a human player expresses highly complex sound with vibrato, a mechanical vibrato with a computer does not bring subtle variation. In ascending scale, each pitch is usually slightly raised according to the context of phrase, however, a computer does not adequately select varied contexts unless it is fully programmed beforehand. 3D images may hold an audience's attention for a while, but even the most entertaining images produced by a Head Mounted Display and DataGlove will pall after a time.

This is a problem between artist's aim and the limits of the computer's capability, especially in the interactive environment.

Claude Cadoz talks about the problem in another way concerning human perceptual parameters and the monitor parameters in the analysis of a computer [7]: "the most immediate representation of gesture information can consist in the visualization of the signals in amplitude/time coordinates. By graphic edition these signals can be manipulated and transformed. However, this is much too simplistic, and more so since such a representation gives no information concerning the perceptual parameters in question, it is not adapted to displaying the pertinent forms of the gesture. We can also notice that between raw gesture signals and the parameters of gesture behavior, there exists the same anisomorphy as between the perceptual parameters and the monitor parameters of the synthesis algorithms. The representation of the gesture is in this case the dual problem of psycho acoustic analysis. We would point out that this opens a research domain that cannot be approached with the idea of finding immediate and definitive solutions."

Confronted with such experiences, artists react in different ways. In some cases, they might give up on computer-based art, whereas others may feel inclined to take up the challenge and pursue their research. Yet others apply traditional aesthetic concepts and materials to computer art, but they are merely avoiding a fundamental problem that will recur time and again, as computers continue to play an increasingly important part in our lives.

But even artists who approach computer art in non-traditional ways come up against problems. Many interactive artists experience problems with the notion of interactivity. The feedback triggered by a sensor is merely created by a pre-prepared computer program. A computer's improvisational capabilities are extremely limited. The prepared materials are merely reproduced with triggers from a player and are not usually able to react in a flexible manner to their surroundings, nor to specific events or accidents. So is interactivity really possible? We program our computers to react to signals from a sensor or some other such device. The computer merely obeys an order from a signal. In fact, what we call "interactive" is only a one-way process.

Conclusion

Virtual Musical Instruments are much better adapted to the multifarious musical styles and developments in modern-day music than traditional ones. With repeated practice, the performer becomes increasingly adept at controlling the musical output of Virtual Musical Instruments. At this level, the controller functions not only as a Gestural Interface but also as a musically expressive tool. The connection between different types of finger and arm movements and the musical quality of the performance will be clear to most observers. However, the player is not obliged to perform as if he were playing an acoustic violin. The angle at which the SuperPalm is held can be modified by grasping it with both hands. By associating the position and pressure sensors on the finger board with the pressure sensor in the rubber chin block, it is possible to play the SuperPalm as if it were a percussion instrument. In the near future it will be possible to connect this instrument with a real-time physical modeling application. This will make it possible to play a non-existing instrument with ordinary gestures. Physical modeling makes it possible to create non-existing instrument in a computer, such as 10 m long violin or a glass bow, and to relate this construction to gesture in real time.

Virtual Musical Instruments may be also used with Internet technology.

But the technical possibilities opened up by these instruments are not the most important considerations. The area that most interests me is their capacity to modify the audience's perception in new ways, thereby transcending traditional aesthetic values. With the emergence of these new technologies, it has become necessary to rethink the criteria by which we judge art, and hopefully these instruments will help us to do that.

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