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1. Introduction

The rapid evolution of the computer in the 90s introduced further developments in Artificial Intelligence, Artificial Life, and Virtual Reality, not to mention advances in multimedia and internet technology which are now an essential part of our lives. The people who have applied these technologies, are not only researchers, but also artists whose work could potentially change the way art is viewed. During the interplay of art and digital technology, many new amalgamated fields in the world of art have arisen: Interactive Music, Interactive Installations combining sound and imagery, Performance Art, Interactive Imagery etc.

Since the 1990s, I experimented with numerous compositions and performances using new technologies. Besides compositional concerns, my work has been based on questions of whether we are able to further develop the aesthetics that have been built by various artists in these different fields using interactive computer technology, and to create a new field of which the robot is the point of contact.

This paper is intended to cover my recent works: the virtual violin "SuperPolm" (1996), the "BodySuit" (since 1997), "RoboticMusic" (2003) and the project "Augmented Body and Virtual Body" (since 2002), both from the technical and aesthetic points of view.

2. "SuperPolm"

The Virtual Violin "SuperPolm" which was created with the collaboration of Patrice Pierrot and Alain Terrier in IRCAM, France in 1996, is one of the Virtual Musical Instruments that I created. Virtual Musical Instruments, which are defined as systems containing gesture, gesture interface, mapping interface, algorithm, and sound synthesis, consist of a gesture interface or controller, which cannot produce sounds by itself (Fig. 1).[1]

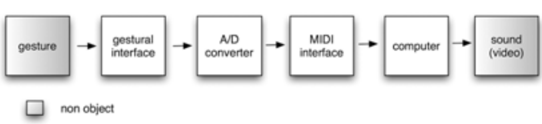

Fig. 1. Components of Virtual Musical Instruments

1 Goto 2000, p. 220

It merely sends signals that produce sounds by means of a computer or a sound module. It may be regarded as an interface between the performer and the computer insofar as it translates the energy derived from body movements into electrical signals. At the same time however, it allows the performer to express complex musical ideas. With the capabilities of gestural interfaces of a controller, which can be modified by programming, a tiny gesture can trigger any number of complex musical passages at one and the same time in a real time context, whereas a traditional instrument can produce only a limited range of sounds. I use this principle of gesture interfaces as 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 (Musical Instrument Digital Interface), OSC (Open Sound Control) etc.[2]

Fig. 2. The Virtual Violin, the "SuperPolm," is based upon the idea of short-range motion capture, such as finger, hand and arm movements.

The basic idea behind the SuperPolm is to interface gestures that resemble the playing of a musical instrument – in this case a violin – in order to control sound or images. These gestures are translated into parameters of position, pressure or distance by sensors based on the idea of short-range motion capture, such as finger, hand and arm movements. The resulting voltage is converted by an analogue-to-digital interface into MIDI signals that can be fed into a computer. The computer controls or generates the sounds in real time and can modify these signals by means of algorithms. For example, a single channel signal can be altered to become a rich and complex sound such as that of an orchestra (Fig. 2). 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 without hand movements using chin pressure and/or bending the upper body forwards.

The SuperPolm can be played in a similar manner to the violin, except that the fingers touch sensors on a fingerboard instead of pressing strings,

2 Goto 1999

since there is neither string nor hair of bow: A gesture of performance with a violin is merely modeled (Fig. 2). However, movements of the bow causing variations in resistance can, assign new functions as well as modify sounds. An eight-button keyboard situated on the body of the instrument can change both the program in Max/MSP/Jitter and the sounds, as well as triggering different pitches, like a normal keyboard. Hence, new functions of programming can be taken into account according to the compositional needs of each piece: for instance a sensor can be used to trigger sounds in one composition, whereas in another it can be used to change the pitch.

The SuperPolm was originally intended for use in a piece I composed at IRCAM in 1995-1996, entitled "VirtualAERI". The first performance of this piece was given in 1997 at IRCAM's *Espace de Projection*. It consisted of four sections, each of which dealt with a different kind of space, large, medium and small. The SuperPolm was designed for one particular section of this composition focusing specifically on the possibilities opened up by the controller.

The SuperPolm can control not only the parameters of sound synthesis, but also those of images in real time (Fig. 3). For instance, it can superimpose live or sampled images on top of each other, add effects, such as delay, and speed up, reverse or repeat these images. It can also mix several images in different proportions and modify their colour, brightness and distortion, while the sampled images can be started and stopped at any point.

Fig. 3. The SuperPolm can also control the parameters of images in interactive videos (Photo and Copyright: Arianna D'Angelica).

3. "BodySuit"

In my projects, Virtual Musical Instruments have been used in a performance context. Another instrument I have designed is the "BodySuit", a suit fitted with bending sensors that are attached to each joint of the body. It was built between 1997 and 1999 with the aim of a motion capture for the entire body, so that a performer wearing it can merely produce sounds with his gestures by bending and stretching each joint, without controlling any instruments in his hands.

The "BodySuit" is equipped with 12 sensors which are attached on each joint of the body. Depending on a movement, sound and video images are changed in real time. This differs from a traditional instrument or an instrument-inspired controller. A player performs with larger movements, such as stretching and bending joints, twisting arms and so on. This gesture does not function like dance or theater. It contains, however, an element of "performance" within the live, musical context. The gesture is not previously decided in a strict sense. An audience may observe an obvious difference of intensity of movement between a static section and a kinetic section in the composition (Fig. 4). This suit is therefore an ideal tool in a musical theater situation.

Fig. 4. The BodySuit enables to make wide, sweeping movements that can easily be observed by the audience. Performance at the University of Cologne in April 2004 (Photo: Franca Lohmann)

Although the performer's gesture does not resemble those used for playing a musical instrument, I used the BodySuit exclusively as a virtual musical instrument. In particular, this works efficiently with percussionist-like gestures, as designed for my project "RoboticMusic" which will be described in section 3 in detail.

4. "RoboticMusic"

The act of performing music is not only about the control of a complicated set of body movements. On the one hand, music can be seen as a logical sequence of events over time which occur as a result of problem solving and rely on the interaction of a set of parameters. On the other hand, music derives itself from less calculable things such as 'good' rhythm sense and poetic significance and expression.

Taking into account such aspects of music performance, I was interested in the question of whether it would be possible for a robot making music to think logically, to play with emotion, to have a good sense of rhythm, to realise poetic expression, to achieve proper pitch (frequency) and delivery of sound, and to have a sense of proportion through comparison. Therefore I have been engaged in projects using robots in music performances, especially robots playing musical instruments.

My project "RoboticMusic" was designed for robots that consist of Snare Drum, Bass Drum, Cymbal, Gong, and Pipe. These have a specially designed springs to imitate human muscles. Each holds a mallet at the end of its arm (Fig. 5). One of the robots plays numerous pipes, and rapidly spins to create Flute-like sounds, which are generated as the air goes through them. These pipes are different lengths according to the pitches one desires. As it spins faster, the pitches become higher, moving up the overtone series. These mechanisms are created by me with technical help from Fuminori Yamazaki, iXs Research Corporation in 2003.

These robots performing on musical instruments are connected by computer and controlled with a program. Max from Cycling'74 is utilised both as an interface and to generate musical data. With this, one can also send basic parameters to the robots such as a position of the robot's arm, an offset position, intensity (how hard it hits) and so on. This sends the signals to another computer running Linux via UDP (Universal Data Protocol). This software in Linux is developed by iXs Research Corporation. This plays an important role since it controls the robot's movement. The Linux computer and robots are connected via USB (Universal Serial Bus). Each robot has its own interface which is connected with an actuator and a sensor.

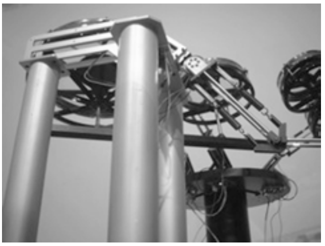

Fig. 5. Each holds a mallet at the end of his arm and can play any instruments as long as these can be played with Mallets.

The major advantage of "RoboticMusic" is that it interactively plays an acoustic instrument with the aide of a computer. There is no problem with playing complex rhythms which easily outperform human capabilities. Therefore, it gives new potentialities in composition for acoustic instruments. While a computer generated sound has many capabilities, an acoustic instrument has rich sonority and enormous possibilities of expression, especially from the composer's point of view. With staged peformance the vast possibilities of the acoustic aspect are obvious when compared to sound coming from speakers. Another benefit is that the audience may observe both the source of the sound and the accompanying gestures necessary for its production.

I explored some musical compositions in order to see what only these robots could play. For instance, five robots in the project "RoboticMusic" played on musical instruments with different tempos at the same time, or intricate accelerando and ralentando, and yet synchronisation was maintained during the playing process. Each algorithm is assigned to each robot, but these 5 algorithms are controlled by one central program.

Other possibilities allow the robots to improvise and compose by themselves in real time during their performances with the aide of the computer's algorithm. During these performances, they sometimes played with computer-generated sounds at the same time. While I played a laptop, the robots accompanied me. In these performances, the lights were much emphasised, as well. As the robots changed their performances, the automated lights communicated with them via MIDI. The music, gestures on stage, and the

Fig. 6. Especially, these robots can show a lot of potentialities in concerts. The robots can certainly perform faster and more accurately than human players.

visual elements of the lights were integrated into one whole stage performance in RoboticMusic (Fig. 6).

5. "Augmented Body and Virtual Body"

This project "Augmented Body and Virtual Body" originally started in 2002. The system used for this project consists of the Data Suit, "BodySuit", and the Percussion Robots, "RoboticMusic", controlled in real-time by gestures produced with "BodySuit". This system was intensively experimented with and shown on several occasions during 2005. The last performance was realised in, "Le Cube," in France in April 2006. The idea behind the system is that a human body is augmented by electronic signals in order to be able to perform musical instruments interactively. A gesture of a performer with "BodySuit" is translated to gestures of "RoboticMusic." One of the important elements is the relationship and the communication method explored within this system. One may consider "BodySuit" and "RoboticMusic" as a relationship between a conductor and an orchestra, where dance-like gestures trigger instruments. In other words, this is an instrument that relies on physical gestures. Another point is the method of translation used by the computer. For example, signals from "BodySuit" are transformed by mapping interface and algorithm in a computer, and routing them into "RoboticMusic." One gesture may trigger one attack on one instrument. However, it is also possible to trigger five instruments at the same time. Otherwise complex, musical data, which is automatically generated by a computer and then reproduced by "RoboticMusic", is altered with gestures from "BodySuit" to modify the parameters of an algorithm in real time.[3]

The robots' reactions to the "BodySuit" performer's gestures can be either direct or indirect. For example, a rapid arm gesture from a higher position to lower could trigger the percussion robot to hit an instrument, or a gesture triggers an algorithm of particular behaviour that sends signals with various values of delay to each robot. The robots which are controlled by the computer, only play in certain sections of the composition. While the passages which are controlled by "BodySuit" make it possible to create a more complex musi-

3 Goto 2006

cal material. The robot solo with the computer allows realisation of complex, high speed performance, which is impossible for human instrumentalists.

While the communications of gesture with "BodySuit" and "RoboticMusic" are observed, one notices different phases of interaction, which are the interaction with its perception, and the interaction with its consciousness. These two poles are important keys in this field. With the articulated visual and oral experience in this work, one may recognise different experiences that constantly deal with something to expect, to understand, to notice, and to perceive. Furthermore, the relationship between gesture and sound is also seen differently with this system. In other words, the idea of, "music to see, visibility to hear" brings a different context into theatrical performance.

Let us see the relationship between "BodySuit" and "RoboticMusic". The first is designed to control others with the will of a performer. The latter is designed to be controlled by someone else. However, both of these equate to bodies that are extended with the medium of electronic devices. The meaning of body, which can exist as being virtual or being augmented, are intentionally mixed. On the other hand, when we see the relationship between "BodySuit" and "RoboticMusic", this appears as a relationship between the physical world and the virtual world. While the robots consist of artificial bodies compared with human bodies, they could also be physical bodies contrasted with virtual bodies.

Fig. 7. The BodySuit works well with percussionist-like gestures. This is one of the best controller conjunctions with "RoboticMusic".

6. Conclusion

The idea underlying my projects sketched above is to explore the dualism of the real and the virtual and the relationship between artificiality and reality of the human body. Artificiality and reality sometimes seem to be in conflict with each other, but they can work together, or their meaning can be transformed for an audience depending on the context. The context provokes the audience into playing with the ideas of reality and artificiality. A performance involving "BodySuit", and "RoboticMusic" challenges the audience by confusing the line between virtuality and reality. As a composer I intend to create such a composition which emphasises the importance of performance aspects with this system.

While the concept of “Extended Body” was conceived to be realised with these systems mentioned above, the theme “Augmented Body and Virtual Body” is meant to question what a human body is and what its own identity is with this. Man and Machine seem to be dualistic, more precisely, one may think that they are conflicted against each other. In my projects, however, they coexist within an interactive, artistic system: man and machine are regarded as being one – an “Extended Body”. As a result, our identity is not merely confined within the boundaries set up by our body, but becomes extended.

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