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Partial Reflections

Johnston, Andrew.
Marks, Benjamin.

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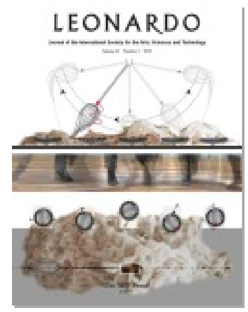

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PARTIAL REFLECTIONS

Andrew Johnston & Benjamin Marks, Creativity & Cognition Studios, Australasian CRC for Interaction Design, Faculty of Information Technology, University of Technology Sydney, Broadway, NSW, 2007, Australia. E-mail: <aj@it.uts.edu.au>.

This paper describes some of our recent work using virtual physical models as a mediating mechanism between a live instrumentalist and computer-generated sound and video.

This work has resulted in the construction of a number of prototype 'virtual sound sculptures' and the composition and performance of a two-movement electro-acoustic work entitled *Partial Reflections*. It is the result of collaboration between a composer/musician and a technologist/musician, both with significant professional experience as musicians as well as additional expertise in composition and software development, respectively.

The initial goals of the project were very broad. We wanted to create performance works for trombone and computer where computer-generated sounds and visuals were shaped and directed solely by the sound of the instrument. Thus, we wanted the software component of the work to:

- respond in real-time—that is, respond directly and immediately to live audio input
- provide some kind of audio-visual representation of or response to the music
- be suitable for use in a concert setting (and also potentially in practice and/or teaching)
- encourage musical exploration
- facilitate musical expression.

When using any software which transforms the sound of live audio in real time, the composer [1] is in a sense composing for 'instrument augmented by software'—a hybrid instrument.

From this perspective one could say that our work involves the design of new musical instruments that are controlled by sound. However, following Perry Cook's advice that instrument designers should, "make a piece, not an instrument or controller" [2], we do not seek to design new general-purpose instruments suitable for use in a broad range of applications. We aim instead to create software/hybrid instruments and music specifically suited to one another. In line with this, we try to avoid situations where a piece of music is composed for pre-existing software or, conversely where software is constructed as a kind of visualization of pre-composed music.

Of course it may be that more general principles for instrument design emerge from this process, but uncovering these principles is not the focus of the project—at this stage anyway.

To summarise, what we produce are not 'simply' new musical instruments, but composed works for trombone augmented by software which has some instrumental characteristics.

Virtual Sound Sculptures

We began to use virtual physical models early in our work because we were attracted to the idea of giving the musician some kind of 'tangible' control over the audio and video generated by the computer. The use of physical models in audio synthesis is an active research area. In our work we do not focus on the use of physical models to directly generate sound. Instead, we use them as mediating structures between the live audio and computer-generated sound and video [3, 4].

In this approach, the software incorporates a physical model which may be thought of as a kind of virtual sculpture. The software designer builds the sculpture by positioning various objects in virtual space and specifying their physical qualities such as mass [5]. These objects may also be linked together with virtual 'springs' of certain lengths, rigidity, etc. Because this sculpture is programmed to apply the laws of Newtonian physics, it responds in ways that appear natural when forces are applied to it. In our case, the forces are mapped to characteristics of the music that is played. So, for example, if the loudness of the input sound is mapped to the quantity of force exerted on the sculpture, then playing a loud note will cause a large amount of force to be applied to the model and, depending on its structure, it may bounce around the screen, change shape and so on. In our work, these movements also cause the computer to output sounds.

To put it simply, the musician's live sound exerts force on the physical model/virtual sculpture and in response it moves in physically plausible ways. Fig. 1 shows a high-level view of how this works. Note that while it does not necessarily have to be the case, in our work the visual output is a direct representation of the physical model itself. The intention is that the musician has a feeling of direct control over the virtual sculpture with their playing and that the audience can readily perceive this.

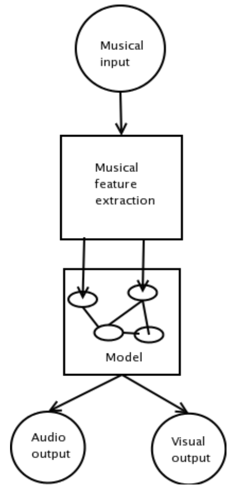

Fig. 1. Block diagram showing the use of a physical model to mediate between musical input and audio/visual output.

Partial Reflections

We have created a number of compositions and associated prototype sculptures to date and premiered a two-movement work, *Partial Reflections*, at the Sydney Opera House Studio in August 2006. Space does not permit a full description of all our work, and so we present here a brief overview of the software/music of the second movement of *Partial Reflections* in order to illustrate the approach. The physical model at the core of this movement is very simple but allows for complex effects (Fig. 2).

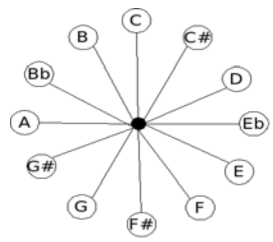

Fig. 2 The physical model used in *Partial Reflections*' second movement.

The model is made up of twelve masses, each one associated with one of the twelve pitch-classes of the equal-tempered scale. Each of these masses is linked to a fixed central point. Initially, the spheres spin very rapidly around this point very close to the centre. When the musician plays, each note causes the associated sphere to be pushed in an anti-clockwise direction which makes the sphere accelerate and thus spin out further from the central point.

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The software records the first 100 ms of each note—the attack—and this recording is associated with the sphere of the appropriate pitch class. Each time the sphere completes a half turn around the central point, the software plays back the recorded sound linked to that sphere with one additional modification: the higher the orbit, the slower the playback. The effect of slowing the playback is to lower the pitch of the played-back note. So, if the sphere has a very high orbit (because it has had a lot of force exerted on it) then the note that plays back every half rotation will be pitched quite low.

An example may help to clarify this behaviour. When the software starts, the spheres are spinning rapidly around a central point at a very low altitude. If the performer plays a Bb, several things happen:

1. The Bb sphere has force exerted on it in proportion to the volume of the Bb;
2. The first 100 ms of the attack are recorded and associated with the Bb sphere;
3. In response to the force, the Bb sphere is pushed out into a higher orbit;
4. Every half turn, the 100 ms of recorded Bb is played back, but with pitch shifted down by an amount proportional to the distance of the sphere from the central point;

Fig. 3. Section of the score for *Partial Reflections*, 2nd movement (© 2006 Ben Marks)

5. When the performer stops playing Bbs, the Bb sphere will gradually spin back into the central point and as it does so the pitch will gradually increase.

Musically, the notated composition developed along with this software is fast-paced and makes use of many different types of articulation. In addition to pitched notes, the performer also produces unpitched percussive attacks at times (such as in the top line of music in Fig. 3).

Discussion

We have learned a lot from our creative exploration of virtual physical models in our work, and a number of what could be called 'design criteria' have emerged from this project.

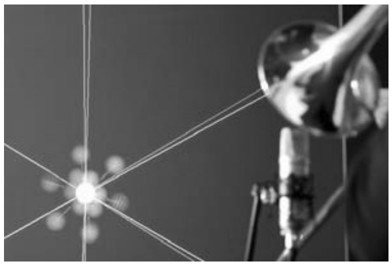

Fig. 4. Solo trombonist interacting with the work. (© 2006 Ros Hodgekiss)

First of all, we are excited by the potential of physical models in this domain. A number of professional musicians have played with our software and have observed live performances. A consistent observation is that using models which behave in physically plausible ways to link live sound to computer-generated sound is both intuitively understandable and aesthetically compelling.

We have observed though that the structure and properties (such as spring tension, etc) of the physical models are critical factors. Mass-spring models are sometimes difficult to work with, and creating structures that are stable, aesthetically appealing and which also enable the musician to create interesting visual and musical effects is not a trivial task.

The need for the software to respond consistently is a key requirement. In our experience musicians do not necessarily want the virtual sculpture to be completely under their control, but they do expect it to behave *consistently*. That is, they expect that the software will respond to two perceptually identical notes in more or less the same way. Musicians seem to like being in control of the basic behaviour of the sculpture but are also pleased to be surprised at times. The surprise element can act as a stimulant to try new sounds and/or musical ideas.

We have found that models do not need to have complex structures to produce complex and interesting sounds—in fact the reverse appears to be the case. The trick for us has been to find the simplest possible structures and mappings that still provide the musician with scope to create a complex palette of sounds. An additional benefit of simple structures is that the audience can more readily perceive the relationships between what the musician is playing and what is happening visually and sonically.

Future Work

We have a lot more work to do. While initially we have been focusing on developing music and software 'custom built' for one another, we are curious about the experiences of musicians who use our software to make their own music. Having created software that is ideally suited to our specific needs, we are now considering how these personal requirements might be extended to provide more general design criteria for virtual instruments of this kind. As such, we have begun to explore the experiences of other musicians using our software, to see if their experiences are consistent with ours and to observe what impact the use of software of this type has on their music making.

Acknowledgements

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References and Notes

1. We use the term 'composer' here in the broadest sense, to refer to creators of pre-composed and/or improvised music.

2. P. Cook, "Principles for Designing Computer Music Controllers," in *NIME '01: Proceedings of the 2001 Conference on New Interfaces for Musical Expression*, National University of Singapore, 2001, p. 1.

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