Physical modelling enabling enaction: an example

David Pirrò
University of Music and Performing Arts
Institute of Electronic Music and Acoustics
Graz, Austria
pirro@iem.at

Gerhard Eckel
University of Music and Performing Arts
Institute of Electronic Music and Acoustics
Graz, Austria
eckel@iem.at

ABSTRACT

In this paper we present research which can be placed in the context of performance-oriented computer music. Our research aims at finding new strategies for the realization of enactive interfaces for performers. We present an approach developed in experimental processes and we clarify it by introducing a concrete example. Our method involves physical modelling as an intermediate layer between bodily movement and sound synthesis.

The historical and technological context in which this research takes place is outlined. We describe our approach and the hypotheses on which our investigations ground. The technological frame in which our research took place is briefly described. The piece *cornerghostaxis#1* is presented as an example of this approach. The observations made during the rehearsals and the performance of this piece are outlined. Grounding on ours and the performers' experiences, we indicate the most valuable qualities of this approach, sketch the direction our future experimentation and development will take, pointing out the issues we will concentrate on.

Keywords

Interaction, Physical Modelling, Motion Tracking, Embodiment, Enactive interfaces

1. INTRODUCTION

Starting from the first and still fundamental attempts to translate body movements into sound by Theremin (the Theremin, the Terpsitone), the design of interfaces for interaction has been a key issue not only in technology development but also for the theoretical discourse around computer music. Questioning and exploring the role of the performer and the performance [2, 8] and the possibilities of the integration of these into electronic and computer music has been since then a central matter of discussion.

In recent years the availability of faster computers allowing real-time sound processing and motion tracking, opened new possibilities for interaction design and gave a great impulse to research. A multitude of novel mapping strategies were developed striving not only to cope with this newly available possibilities but also to find meaningful ways to couple movement and sound. The search for connections of sound and music to movement and gesture has been approached from an aesthetic research standpoint [5] and the embodiment and enaction discourse [1, 12] offered new viewpoints to the development of musical interfaces. From a poietic perspective, possibilities to track movement have been extensively used and questioned in many artistic projects (i.e. Rokeby's VNS[1] or the SICIB system[9]) in particular involving the integration of dance (i.e. the DIEM project[2]) aiming at achieving a high degree of embodiment in sound and music production (the EGM project [3]).

Research and development in this field is not only a scientific and technological challenge, but also an artistic and musical necessity. Interaction design has become a central compositional issue. On the one hand, composers long for strategies and techniques that allow them to "compose" their instruments [10] and interfaces. On the other hand, the performers need to be enabled to enact the sound and music generation through the interfaces they are presented with rather than to merely control them.

Searching for new possibilities in these respects, we propose here an approach of interaction design (in particular using motion tracking) that uses physical modelling as an intermediate layer between the performers' actions and the sound synthesis (including its control).

2. THE APPROACH

Our aim is to provide performers with an interaction system, an environment that they can intuitively learn and cope with. In order to achieve these qualities we search for a method allowing to address the players' tacit bodily knowledge. The strategy we developed relies on the design and implementation of physical models.

Physical modelling is a well known technique in sound synthesis. One of its strengths lies in an intuitive control of the sound synthesis. This method has been widely used in conjunction with various motion tracking technologies to interactively produce sound [6, 11].

In the approach presented here, physical modelling is not used as a sound synthesis engine. Rather it is an intermediate layer placed between the input from the performers' actions and the sound processing or synthesis layer (c.f. figure 1). The intermediate physical modelling layer constitutes an interface at the point where body movement and sound generation or composition meet. The tracked performer interacts with the physical model causing a change in its state. These changes are then used to control the sound synthesis engine. Eventually the resulting sound will reflect the reactions of the physical model and will provide the feedback for the user.

[1]D. Rokeby. Very nervous system, http://homepage.mac.com/davidrokeby/vns.html

[2]The Royal Academy of Music. Aarhus - diem, http://www.musikkons.dk/index.php?id=300

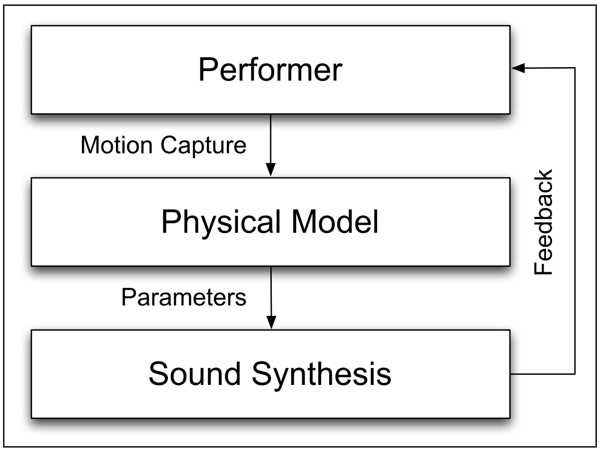

Figure 1: Diagram illustrating our approach to interaction design.

Our fundamental hypothesis is that the behaviour the performers are confronted with by interacting with the physical model, belongs to their intuitive knowledge of the physical world. The reaction generated by the simulation in response to the performers' actions is induced in the sound and exhibits dynamics and behaviour familiar to the performers as it resembles the qualities of our interaction with the real physical world. This interface, by tapping into embodied knowledge and activating already acquired motor skills is an enactive interface - an interface through which it should be possible to truly enact the sound generation and the composition.

The physical model ensures a coherence and continuity in the sound output that is, in our experience, most important for the performers. They can rely on it, can engage with it and possibly play with it as an instrument. Further there is a certain degree of "sensory predictability" inherent to such models. This predictability is not to be understood in a strictly mathematical sense, as even very simple models can be very difficult to predict. Rather this term is used here to indicate the felt consistency of the effects with the performed actions that allows for instinctive guesses about which effects can be expected.

In the setup we delineated (figure 1) the sonic feedback plays an important role. The sound alterations resulting from the interaction with the model are the only available feedback. As such the sound response has to be designed in a way that its changes are easy to follow and to relate to the physical properties of the model. Later we will present a piece, *cornerghostaxis#1*, in which physical modelling was applied in the sense we describe here. In this piece, spatialization was used as the primary cue for the performer to follow the changes in the model and the movements of the modelled objects present in the virtual scene. However there are surely other types of sound manipulation that can carry the information coming from the model in a clear way. The approach we propose and the software we developed so far is open for such possibilities.

We believe that this approach not only provides the performer with an enactive interface but also offers the composer, sound artist or interaction design researcher an intuitive way to conceive the interaction, realize it, and refine it.

3. SETUP

In this section we briefly describe the software and hardware environment we worked with while developing, rehearsing and performing *cornerghostaxis#1*, the piece we will describe in the next section.

3.1 Tracking

The IEM CUBE is the research environment in which our experiments were carried out and the piece was rehearsed. Physically it is a 120 m2 studio space equipped with a 24-channel hemispherical Ambisonics-based sound projection system, which is complemented by an array of 48 ceiling-mounted speakers. Besides the sound projection and rendering infrastructure, a VICON motion-capture system with 15 infrared cameras is installed allowing for high-quality rigid body or full-body motion tracking. A tracking rate of 120 fps is used at which the position and orientation data is provided by the system. At this frame rate the system resolves positions in 3D-space with a precision of about 1 mm.

3.2 Software

For the design of the physically modelled scene used in the piece we developed a software framework in the SuperCollider language. This framework allows rapid prototyping of the physical models, manages motion tracking input and provides a simple 3D visualization. The software has been designed with the openness and flexibility in mind required to react to the particular needs of a project or composition using our interaction model. The new SuperCollider extensions comprise a set of tools for managing and conditioning of motion tracking data arriving via OSC and greatly simplify the process of designing different virtual spaces or "scenes" in which the objects (masses) subject to the physical modelling are added, placed or removed.

The forces acting between the objects can be freely defined starting from a set of the predefined forces to choose from (spring, gravitation, electrostatic force, etc.). Most important is the possibility to define particular constraints that restrict the motion of the objects in different ways.

Aiming at establishing a connection between the virtual space of the physical model and the performing space, the possibility to define the positions of loudspeakers in the virtual space was introduced. Further, using the distances to these virtual loudspeakers, a DBAP (Distance-Based Amplitude Panning[7]) algorithm is used for the spatialization of the sounds "carried" or modified by these objects.

4. CORNERGHOSTAXIS#1

In this section we introduce and illustrate *cornerghostaxis#1*, an artistic work that was developed using the strategy we described earlier. Through this concrete example we hope to provide a better understanding of how we intend physical modelling to be applied in interaction design.

cornerghostaxis#1 was premiered February 27th 2009 at the Cube of IEM Graz, during IMPULS Academy 2009 in the context of the Motion-Enabled Live-Electronics workshop [4] (bassoonist: Dana Jessen) and was also invited to the Bodily Expression in Electronic Music Symposium (BEEM) at Mumuth Graz and performed on November 7th 2009 (bassoonist: Stephanie Hupperich).

4.1 The piece

cornerghostaxis#1 is an electroacoustic composition for solo bassoon. The piece is the result of the collaborative effort of a three people team: Stephanie Hupperich (bassoon), Gerriet K. Sharma (composition) and David Pirrò (physical modelling / interaction design). The aim was to design an environment in which the player interacting with the physical model establishes a gestural and bodily relationship between the sounds she plays on her instrument, her

Figure 2: Stephanie Hupperich performing *Cornerghostaxis#1* at the MUMUTH in Graz on November 7th 2009. The tracking target, made up of five infrared reflecting spheres, is attached to the instrument (upper left corner).

movements in space and four electronic sources that are dynamically spatialized on a loudspeaker array.

In the piece the position and orientation of the tracked instrument is used as input for a physical model. The virtual space in which the physical simulation is taking place is a representation of the real space in which the performance took place including the positions of the loudspeakers and the instrument. The physical objects that move and interact in this space are constrained on the surface of a hemisphere on which also the loudspeakers are placed, reflecting their actual positions. The involved objects have a very clear relationship: one can imagine them as electrically charged masses with the same charge. Thus the forces acting between the objects are repulsive.[3]

The tracking data is used to control the position and orientation of a square with four "charged" masses placed at its corners. The other masses are free to move on the hemisphere spanned by the loudspeakers: they are also "charged" and repelled by the previous ones as well as from one another. The distances of these masses to the virtual loudspeakers are used to control a DBAP algorithm that determines how the four channels of the tape composition by Gerriet K. Sharma are spatialized on the physical loudspeaker array. Furthermore, the amplitude of the four sources is controlled according to the movement speed of these masses and depending on the distance to performer. If the performer is close to one of them (i.e. she "captured" one, see below) that source grows louder.[4]

The piece has been always conceived as a whole, and the development of each parts advanced in parallel to the others. The physical model is not just an effect used to spatialize the tape composition, but it is part of the piece, part of the environment in which the composition unfolds.

In the next section we try to summarize how the approach described before in section 2 reshaped the working routine in the explorations and rehearsals of the piece, with respect to our aims. We therefore collect the most important observations being made by the performers and by us. But we also attempt to condense our reflections based on our own aesthetic experiences gathered throughout the process leading to the realization of the piece.

We understand the whole realization of the piece, beginning with the design of the physical model, passing on to the preliminary explorations with the performer, to the rehearsals and the final performance, as part of an experimentation aimed at putting into practice the strategy we described and observe what and how it "happens". An interpretation or evaluation of these observations is not explicitly given, but will be the object of future research.

4.2 Observations

The most important feedback was given to us by the performers. The musicians involved in the development of the piece underlined that they felt having achieved a clear understanding of the dynamics of the sound spatialization and how they could influence it.

They could quickly established an intimate control of the interface and they could rapidly learn how to play it.

This understanding also changed the communication between musician, composer and programmer. Relying on the physical metaphor, on which the programming and the whole realization of the piece are basing, the performers could more easily communicate with the composer and programmer. In this sense the intermediate physical modelling layer appears as a platform for the exchange and refinement of ideas which are shared among all the participants, regardless of their technical knowledge. For example asking "Could you make the masses *heavier*?" is straightforward for the performer. At the same time it is easy for the programmer to understand and, knowing the model, to accomplish. This is one of the main reasons the performers were actively involved in the setting-up and the development of the piece.

Basically, in performing the piece the musician and the masses play a "hide-and-seek" game. The sources try to escape the performer, always placing themselves at the points most distant to her. This dynamic became very quickly clear to the performer in the first experimental session and her instinctive reaction was trying to find ways of stopping their continuous slipping, blocking one of them by pinning it down, "capturing" it. Also during the performance, the aim for the performer is to "catch" one precise mass out of the four, at a specific moment of the score. But the sound sources, which represent the mass positions in the model, seem to have their own will and try to hinder the musician to achieve her goal, to "win" the game.

It is important to note here that understanding the rules of the play means to understand the laws on which the physical model is based, which are coherently and continuously followed by the simulation and which are inscribed in the sounds' positions and movements. In our experience this gaming quality greatly contributes in making the interaction more clear, interesting and engaging.

The reactions of the model are complex but retain a certain predictability (in the sense already explained in section 2). Thus the performer does not have the perception of erratic reactions of the model, which would destroy the illusion of a coherent environment. However the model and the sources are very difficult to control. It is tough to achieve exactly what the composer or the performer wants. The model "resists" at any moment to the performer's actions, at the same time offering a great detail in interaction, as every little position or rotation changes have audible consequences. In our observations the resistance of the model coupled with the refinement of control, greatly enhances the embodiment. As a matter of fact, the musicians, after a short time of experimenting with the model, feeling challenged, asked for for a more difficult setup, which was

[3] A short video of the model's simulation is available at http://pirro.mur.at/nime11/CGA-Model.mov

[4] A documentation video of the performance at Mumuth Graz is available at http://pirro.mur.at/nime11/CGA.mp4

initially kept simple. That meant more resistance of the environment to their actions, but also more detail for their control.

Resistance and detail of control create a continuous tension between performer and model that can be seen and felt clearly. This tension captures attention and causes engagement for the musician as well as for the audience assisting at the performance.

Given the features of the interaction we described, the performer could fully engage in the play with the environment and with the piece itself. The consistency of the interaction qualities and the resulting sonic feedback, caused a "suspension of disbelief" for the performer, who could truly and bodily trust the coherence of the model's responses, of the connection between her movements and the reactions of the sources. This link was so clear to one bassoonist that she started giving them a "body", regarding them (in her own words) as "colleagues", like she would do with other human players. Furthermore she reported an enhanced sensibility not only in the perception of the spatial location of sound, but also of her own movements, her position in space as well as an increase of her proprioception.

We underline at this point that the model was neither visible to the audience nor to the performer, neither during the rehearsals nor the concerts. It was not clear to the viewer how the model works or exactly which forces were acting in the simulation, as this was not explained before the concerts. It was not our aim to make this aspect evident. In our approach the intermediate physical modelling layer is not intended to be clearly perceivable as such, but its purpose is to enhance the enactivity of the interaction, creating the qualities we described.

Nonetheless, during the informal discussions that took place after the performances, it appeared that the relationship between movement and sound, between action and spatialization, between the player's sounds and the electronic sounds was clear also to the audience attending the performances. The player's efforts, engraved in the qualities of her playing as well as in her body could be seen and could be conveyed to the spectator.

5. CONCLUSIONS

Using physical models as intermediate interaction layer, at least in the example reported, proved to be a very fruitful approach towards the design of enactive environments. This method clearly enhanced the qualities we are trying to achieve, bringing them to light as well as exposing new issues to our observation, which will be addressed in future research.

We think that one of the most interesting features of this strategy is that the performer could play with the electronics as she would in a game. This aspect appears to be of central importance for the "suspension of disbelief" experienced by the performer. The rules and the aim are clear for her and for her counterparts (the sources) and as long as the game unfolds coherently and the reactions remain in a range of predictability, the musician is more interested in playing (and winning) the game than asking herself how she should relate to the electronics and how things work on a technical level.

The physical model resists to the players actions. The modelled objects try to impose their dynamics and behaviour, but at the same time offer to the performer a great variety of ways to guide and control them. These open a whole space of possibilities which is tightly connected to the resulting effects in the model: for example fast and big movements have different effects than slow and little movements. The reactions of the sources scale accordingly to the spatial and temporal qualities of the performer's efforts in opposing their intentions to the environment. This results in a very complex, detailed and rich interactivity and appears as a central quality of the approach we describe.

As we described in section 2, in our approach we employ physical modelling to design an interface that, by tapping into the performers' own embodied knowledge, can be regarded as an enactive interface. In the course of our experiments we realized that an important aspect is that by taking this quality of the interface for granted, it is possible to focus on the connection between physical model and the control of sound synthesis and of the composition and how it is realized. This link (figure 1) will be the central object of further research. Until now we used spatialization as primary feedback from the simulation for the musician. Making this connection available to composition would mean to provide the performer with new possibilities to interact with the composition on different levels. This aspect is strongly related to the type of sonic feedback the performers receive and how this would reflect their interaction with the model and with the composition.

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