



Audio Engineering Society Convention Paper

Presented at the 128th Convention
2010 May 22–25 London, UK

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The Serendiptichord: A Wearable Instrument For Contemporary Dance Performance

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ABSTRACT

We describe a novel musical instrument designed for use in contemporary dance performance. This instrument, the *Serendiptichord*, takes the form of a headpiece plus associated pods which sense movements of the dancer, together with associated audio processing software driven by the sensors. Movements such as translating the pods or shaking the trunk of the headpiece cause selection and modification of sampled sounds. We discuss how we have closely integrated physical form, sensor choice and positioning and software to avoid issues which otherwise arise with disconnection of the innate physical link between action and sound, leading to an instrument that non-musicians (in this case, dancers) are able to enjoy using immediately.

1. INTRODUCTION

Contemporary dance is a highly expressive art form with a strong visual impact [1]. It encompasses a range of techniques, often allowing for a great amount of free improvisation and exploratory movement. In augmenting a performance we sought to translate a dancer's movement into sound in an intuitive manner whilst retaining their expressive intention. Furthermore, we aimed not only to interpret movement but to provoke it and create a dialogue between dancer and sound environment, and for all of these aspects to be clear to an audience. This

desire for clear bidirectional feedback led early on to the creation of an object of interaction visible to the audience—a wearable instrument.

We first provide a brief review of similar work (§2), followed by a discussion of some issues surrounding new musical interfaces that informed the design process (§3). There follows a technical description of the instrument (§4) and how it is used in performance (§5) which will be followed by a discussion on how both our motivations and the development process led this design (§6). We conclude with a summary of the key lessons that have come out of

this project and some future avenues of research it has presented (§7).

2. RELATED WORK

There have been a number of approaches in allowing a dancer to exert control of an accompanying audio environment. Typically, a computer receives information of the dancer's movement either through a video-feed (e.g. [2, 3, 4]), accelerometers attached to the body (e.g. [5, 6]), or motion capture¹ (e.g. [7]) which are then mapped to input parameters of a wide variety of bespoke music systems.

Castellano *et al.* [4] use the EyesWeb [8] platform to map an emotional interpretation of the user's movement into both visual feedback and parameters such as tempo, loudness and articulation, which control the expressive performance of a prewritten piece of music. This high-level control is in contrast to Morales-Manzanares' *Trío de Cuatro* [9], where movement is mapped directly to granular synthesis parameters as well as notes produced by 'touching' particular regions.

Direct mapping to synthesis parameters are also used in the interactive dance piece *Lucidity* [10] alongside more complex genetic algorithms driven by the level of dance activity. In this work, motion capture data is analysed to produce measures such as the correlation between the movements of a dancer's limbs and their position on the stage.

CoIN, a video-based work by Ng [2] making use of the Music via Motion [2] framework uses a mixture of mapping strategies, including a direct one-to-one mapping from positional data onto simple musical input such as pitch and volume, and colour detection triggering sound effects. Ng notes that the direct mapping has the advantage of allowing the audience to easily relate movement to sound but becomes 'tiresome and uninspiring' if used constantly. He addresses this with the use of prewritten background music (that alters certain expressive factors based on the input) with timed pauses for the dancers to use the direct mapping. We refer to this performance-scale organisation of themes, actions and other aspects as the *narrative* of a piece, which in this case is determined prior to the performance.

¹Motion capture requires reflective markers to be attached to the performer which are then recorded by a number of infrared cameras and converted into a 3D animation.

This illustrates the potential dichotomy between highly *reactive* mapping strategies which are intuitive and clear both to dancer and audience but lack expressive power and *dialogical* strategies which have a longer-term impact but are more complex and seem less controllable [3]. Camurri *et al.* [3] propose a *multimodal* framework where an input is analysed on a number of layers. The first layer consists of a direct and reactive mapping between low-level feature analysis synthesizer parameters. This mapping is then adjusted by a second layer, which draws upon high-level (and usually long-term) features such as basic emotions. A third layer then may then alter either of the lower layers and is guided by an overall performance measure, such as the audience's engagement. This use of dialogical strategies allows the dancers greater long-term control over the progression of their performance. Consequently more freedom can be granted without the problem of monotony and a more interactive narrative may be used. Camurri *et al.* have implemented this framework within the EyesWeb [8] framework to draw on lower and higher levels of video-based gesture recognition.

3. SOME DESIGN CONSIDERATIONS

Interactive music systems are typically reasoned about as a mapping from controller or sensor input parameters to synthesis parameters [11]. This modular approach provides creators with a great deal of freedom as generic well-packaged techniques (e.g. gesture recognition [12]) can be routed to audio-generating parameters as easily as traditional controllers such as the MIDI keyboard. But the disconnection of the innate physical link between action and sound in electronic instruments has drawbacks, most notably the resulting lack of 'feel' [13]. Drummond [14, p. 132] presents this as a challenge to 'create convincing mapping metaphors, balancing responsiveness, control and repeatability with variability, complexity and the serendipitous.'. However, Jordà [13, p. 322] demands a more holistic approach:

It becomes hard – or even impossible – to design highly sophisticated control interfaces without a profound prior knowledge of how the sound or music generators will



Fig. 1: Heidi Buehler rehearsing before a performance at Berkeley Art Museum, Berkeley, USA. On her shoulder's sits the headpiece of the Serendiptichord with the trunk extending over and in front of her head. In her left and right hands are the left and right pods respectively. Accelerometers are embedded within the pods, behind her neck and at the end of the trunk. (Photo: Tim Murray-Browne)

work. ... They can be inventive or adventurous, but how can coherence be guaranteed if it cannot be anticipated what the controllers are going to control?

With respect to systems responding to full-body movement, Antle *et al.* [15, p. 74] argue for the use of *embodied metaphors* that 'preserve structural isomorphisms between lived experience and the target domain' with the suggestion that dancers be involved during the design process. By drawing on

modes of action that relate to how our bodies interact with the world in everyday life, an intuitive system can be built with a natural feel.

Another issue that arises from decoupling the sound source from the instrument is a lack of physical feedback, which can result in a sense of restricted control [16]. Both the user and audience need perceptual feedback allowing them to learn how actions relate to consequences, especially when using unconventional or invisible inputs. This issue is of greater prominence in dance-based instruments as the performer often has neither visual nor physical feedback from the system. Furthermore, we argue that as well as understanding the connection between action and sound, the audience must *believe* that it is the dancer responsible for the music. This makes it difficult to include scope for subtle or delayed aspects to a mapping—the reactive/dialogical trade-off discussed in §2.

Finally, there is the question of how to maintain musical coherency whilst providing artistic freedom [17]. In §2 we saw examples of introducing pre-composed music ([2, 4]) as well as compositional decisions that avoided the difficult-to-navigate tonal and harmonic spaces ([9, 10]) as potential ways of avoiding undesirable musical outputs. Camurri *et al.* [18, p. 196] address this issue by drawing a distinction between *autonomy* and *expressive autonomy* with the latter regarding the amount of freedom that is provided specifically 'to take decisions about the appropriate expressive content in a given moment and about the way to convey it'. Dance has a huge expressive capability and we would like to transform as much as possible of this into correspondingly expressive music.

4. THE SERENDIPTICHORD

The *Serendiptichord* takes the form of a headpiece that sits on the shoulders with a 'trunk' that extends over and in front of the head and gently swings with the movement of the performer (see Figure 1). Two handheld 'pods' may be clipped to cords extending from the headpiece or removed and attached to another part of the body. Three-dimensional accelerometers are embedded within each pod, behind the neck and within the trunk. The output of each sensor is smoothed and converted into orientation data.

In order to provide the dancer with a great deal of expressive autonomy whilst still allowing musical coherence to be ensured, sound is generated from a bank of composer-created *sound objects* which in their simplest form are just samples. Each sound object is randomly assigned to a specific orientation of both the left pod and neck sensors—the *noisemakers*—and is triggered when the orientation of these sensors approaches that of the sample. This mapping draws on the embodied metaphor of a percussive instrument as the samples are effectively ‘hit’ into. It is explained in more detail in §4.1.

This intuitive model provides a reactive mapping that is designed to be easy for both dancer and audience to understand. But in order to allow both the dancer to introduce more structure to their performance and the composer to develop their musical ideas it is augmented with the more dialogical control of *intensity*. Each sound object is provided with a continuous intensity value which they composer may interpret as they please. With the present bank of sounds, increasing the intensity of one object causes it to develop in a unique way, as well as making it louder and warmer through the use of digital signal processing effects.

Shaking the right pod—the *intensifier*—within the boundaries of a sound object causes a rapid increase in its intensity value, which will then decay to zero over a period of time. As a composer may choose to implement a subtle or deferred response to intensification, this effect is supplemented by passing audio from the object through a delay for a few seconds.

In contrast to the other three sensors, output from the trunk is directly mapped to the parameters of a frequency shifting effect applied to the master channel. The trunk typically follows the motion of the dancer’s neck making it an effective tool to translate expressive movement into expressive sound. However, its physical construction causes it to gently oscillate after a sudden movement. The resulting vibrato effect is a subtle but essential connection between the physical nature of the instrument and the audio output. As the trunk is visible to the dancer, it also provides them (and the audience) with instantaneous perceptual feedback of the system’s sensitivity to motion. Furthermore, through feeling the trunk follow their movement the dancer is provided with

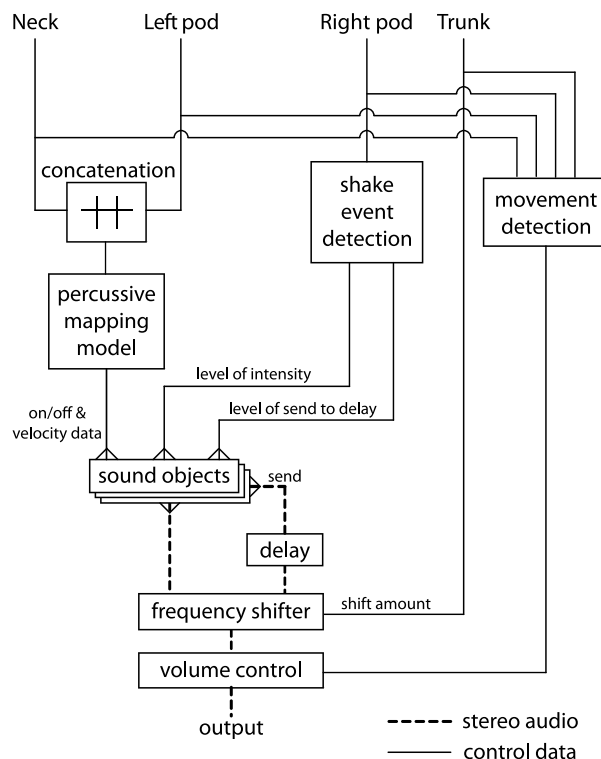


Fig. 2: An overview of the mapping used within the *Serendiptichord*.

a constant physical connection between themselves and the instrument.

An overview of the mapping strategy is shown in Figure 2.

4.1. The percussive mapping model

The percussive mapping model draws on an embodied metaphor of striking an object to provide a relationship between body position and musical output that is intuitive to both dancer and audience and translates a given bodily gesture into a consistent sequence of sounds.

In more detail, sensor inputs from both *noisemakers* are concatenated to produce a position within the combined orientation space. Within this space each sound object is assigned a random position. A sample is triggered when the combined input comes within a (Euclidean) distance d of its respective sound object, with its volume determined by

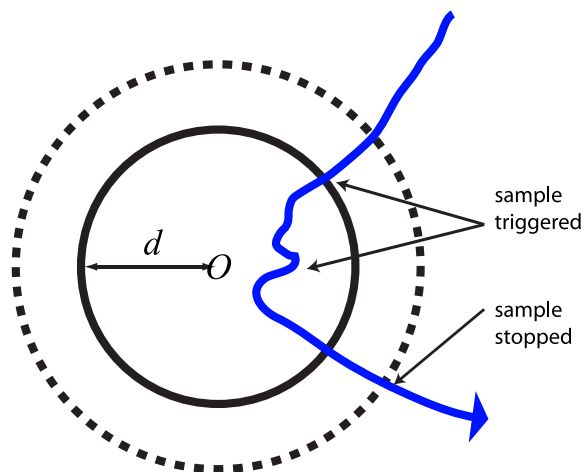


Fig. 3: Diagram showing a dancer's trajectory (blue line) through the controller space and within the boundary of a sound object with centre O . The sample is triggered once from entering the boundary and again from returning back towards the centre having started moving away. The dotted line shows the stopping boundary.

the velocity of movement towards the sound object. Thus sound objects may be seen as spheres of radius d within the controller space that the noisemakers 'hit'. When the noisemakers move away from the sound object the sample is stopped when a boundary slightly greater than d is crossed to provide a slight sense of 'stickiness' to the objects and prevent rapid triggering around the boundary. In initial testing, however, dancers found it difficult to predictably trigger a sample twice in a row as they had no way of explicitly knowing where this boundary was and needed to escape it and return to retrigger the sound. This was addressed by considering the speed of approach towards or away from the sound object. By requiring a minimum threshold of speed towards to trigger a sample and speed away to allow a sample to be retriggered (Figure 3) the interface became more predictable and controllable.

One aspect of acoustic instruments that this mapping strategy naturally emulates is the relationship between the energy put in and how much sound comes out [19]. For example, a wind instrument needs to be blown continuously in order to main-

tain a tone, with greater pressure leading to more volume. When using the percussive mapping model sound objects are only triggered through movement, with the volume of samples increasing with the speed of motion. However we exaggerate this effect for further expressive and dramatic effect by cutting the volume whenever the instrument is completely still for more than a second.

5. PERFORMANCES

The *Serendiptichord* was first shown in performance at the *ACM Creativity & Cognition Conference 2009* in Berkeley, USA (Figure 4). Further performances have taken place in London at the *Kinetica Art Fair 2010*, an exhibition showcasing new art that incorporates motion or technology, and the Barbican as part of the event *Swap Meet*. When showing in a new place we will typically organise to meet and rehearse with a dancer for around three hours the day before the performance in order to allow them to become accustomed to the instrument and its capabilities. During this time we will also consider a skeletal narrative around which they may structure an improvised performance. Typically, this will last between eight and 15 minutes and follow a structure of gradually introducing different aspects of the instrument whilst building up the amount of energy and tension to a chaotic climax.

6. DISCUSSION

The construction of the *Serendiptichord* was a close multidisciplinary collaboration with short development cycles. At every step, we considered how each individual component worked with the whole: *What actions come naturally when wearing the instrument? How should they sound? What action should be done to produce this sound? How can the shape of the instrument accommodate that action?* and so on. Through inviting dancers to test the *Serendiptichord* throughout its development we have observed that as development has progressed under this approach newcomers have tended to be more comfortable and quicker to explore its capabilities without extensive instruction.

This method of interaction design has consequently allowed us to introduce depth to the instrument through ambiguity. Whilst those using the instrument quickly develop a knowledge of how it works,



Fig. 4: Heidi Buehler performing with the Serendiptichord at the *ACM Creativity & Cognition Conference 2009*, Berkeley, USA. Here, the left-hand pod has been attached to the right leg. (Photo: Deirdre McCarthy)

its ambiguous shape does not propose a ‘correct’ way to use it, and we have found that each dancer brings a different interpretation.

The combination of both reactive and dialogical interaction mechanisms follow a similar approach to [3], with two simple but powerful direct mappings—the percussive mapping model and the sway of the trunk—being developed by the more complex mapping used to intensify samples. This combination makes it indisputable to the audience that the dancer has the expressive autonomy and is responsible for the sounds, whilst still providing the means to introduce variety and a narrative structure to the performance. The multilayered mapping approach is thus well suited to interactive systems designed to be performed to an audience.

The mapping of the sensor within the trunk was developed through early experimenting whilst wearing the instrument, which showed that its physical construction causes it to oscillate gently after a sudden movement. Furthermore, when the dancer is moving expressively the trunk swings exaggeratedly following their movement in a manner visible to both dancer and audience. After discussing what possi-

ble effect both *felt* intuitive and complemented other aspects of the sound generation we chose to map the trunk orientation directly to a frequency shifting effect. As well as providing an instantaneous and visible connection between the physical and sonic components of the instrument, this reactive mapping gives the Serendiptichord a unique and characteristic sound. It would, however, behave quite differently if used with another controller, illustrating how a closely integrated development of controller and sound generator can allow the development of powerful interaction mechanisms that draw on the aesthetics of both components.

Finally, developing the both the audience’s and dancer’s understanding of the relationship between movement and sound was greatly supported by using an instrument with a visually striking physical form with a strong stage presence. Rather than being a ‘necessary evil’ hidden from the audience, the Serendiptichord is a character within the dancer’s performance allowing their relationship with it to be one of interaction rather than reaction.

7. CONCLUSION

In this paper we outlined a number of issues faced when designing an interactive music system for use in dance performance. We addressed these when creating the *Serendiptichord* by following a holistic approach to design, construction and performance with the physical, software and musical aspects of the system being developed simultaneously with regular feedback from dancers. This resulted in a wearable instrument who’s physical form naturally suggests how it may be used to produce a musical output and consequently lead the dancer towards the serendipitous.

Many instruments are designed to be performed in front of an audience, especially those that are dance-driven, and so the visual impact of a piece should be considered simultaneously with its musical intention. Furthermore, the visual and tactile aspects are closely entangled with both the interaction design and musical output. This not only informs the performer but also the audience, who must understand how the instrument works in order to believe that the dancer retains expressive autonomy rather than the designer.

Our performance made use of a preconceived narrative with a large scope for free improvisation over the top. Other performances have made use of a fixed narrative provided by background music [2] or a potentially interactive narrative through dialogical mapping strategies [3]. Further user studies are needed to determine the effectiveness of these different approaches both with respect to both audience and performer. If the music follows a narrative, is the performer's experience enhanced by knowing they are responsible? Does the audience benefit? And if so, how can a composer provide the performer with expressive autonomy over the narrative whilst maintaining their musical vision?

8. ACKNOWLEDGEMENTS

This Serendiptichord was commissioned by the Centre for Digital Music under the Platform Grant (EPSRC grant EP/E045235/1) for the *ACM Creativity and Cognition Conference 2009*, produced by Big-Dog Interactive and supported by the Interactional Sound and Music Group. Special thanks to Rachel Lamb, Niamh O'Connor, Judy Zhang and Stacey Grant for creative assistance and Vesselin Iordanov for technical assistance. This research has also been supported by an EPSRC Doctoral Training Account.

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