CARME: A MULTI-TOUCH CONTROLLER FOR REAL-TIME SPATIALISATION OF GESTURAL BEHAVIOUR

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ABSTRACT

Expressivity has been the primary driver of recent research and development in the field of mechatronic musical systems. In the search for greater expressivity, however, the complexity of systems tends to increase concomitantly, thanks to the proliferation of control parameters, and the desire to group multiple mechatronic units into 'ensembles'. This then gives rise to the problem of how to control such a complex system in a real-time and intuitive manner. This paper proposes some novel solutions to the conceptual and logistical problems inherent in the 'data explosion' of expressive mechatronic systems, through the context of the design and development of a multi-touch app, *Carme*, custom-built to control *The Polus Ensemble,* a mechatronic sound sculpture ensemble. The potential for *Carme* to control other ensembles as well as sound-spatialisation systems is also considered.

1. INTRODUCTION

1.1. The Polus Ensemble

The Polus Ensemble is a collection of six mechatronic sound sculptures, each with a single string and a bowing mechanism (Johnston et. al. 2014). Its design focuses on two main considerations: a) allowing for a range of musical controls, and b) that the objects should be both physically and visually compelling, whilst blurring and relating the sonic, visual and physical characteristics. For more detailed explanation of the aesthetics and motivations see Johnston et. al. 2014.

Jim Murphy defines expressivity in the context of mechatronic instruments as 'the ability of a mechatronic musical system to affect a wide range of musical parameters' (Murphy 2013). The desire for each sculpture to be musically expressive led to designing a system that afforded control of: a) the pressure of the bow on to the string, b) the speed and direction of the bow, and c) whether or not the string was dampened.

The Polus Ensemble draws upon both the mechatronic instrument field, as well as the mechatronic sculpture field, blurring the line between the two. The range of controllable parameters in each unit plays a part in the musical expressivity of the ensemble, although the ensemble as a whole should be seen as one mechatronic system. Therefore, part of the complexity comes from the spatial distribution and relationship between each unit.

Although *Carme* was developed to specifically accommodate the controllable parameters available in *The Polus Ensemble*, it has been designed in such a way that it could also control other, similar, mechatronic systems.

Figure 1. The largest of *The Polus Ensemble* sculptures. Provided by Victoria University.

1.2. Mechatronic Instruments

The field of mechatronic instruments has blossomed in the recent past, as the technology to rapidly prototype and create inexpensive systems has become more readily available. These new instruments tend to draw upon a conventional instrumental design paradigm, being influenced by, or even emulating, existing instrument designs.

A comprehensive overview of the field is outside the scope of this paper,[1] although two exemplars of complex, expressive mechatronic instruments can be seen in Jim Murphy's *Swivel 2* (Murphy 2013) and *MechBass* (McVay et. al. 2011), the latter collaboratively built with James McVay. *Swivel 2* is a six-string mechatronic slide guitar with a rotating arm, which allows for different pitches to be stopped, and the pressure against the string varied. Furthermore, each string can be plucked by a rotating plectrum, with a range of force possible. *MechBass* is a four-stringed mechatronic bass guitar, affording a fine degree of pitch control, picking velocity and dampening. Instead of the rotating arm of *Swivel 2*, linear fretting mechanisms move along each string to control pitch. A similar rotating plectrum design is used.

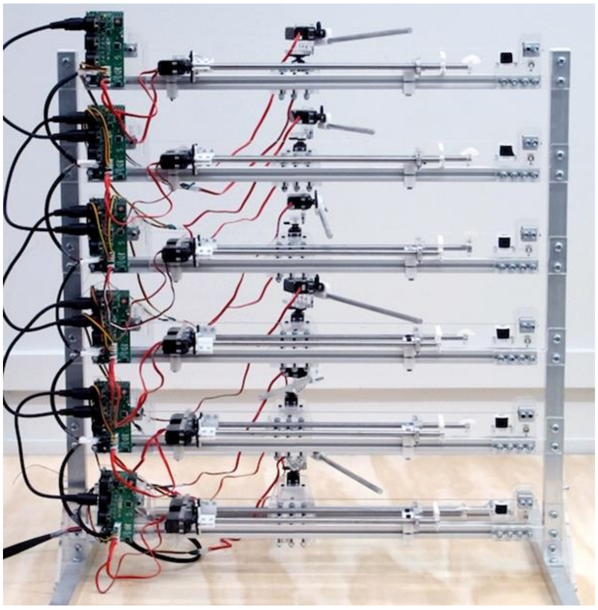

Figure 2. Murphy's mechatronic slide guitar, *Swivel 2*.

Both *MechBass* and *Swivel 2* have a wide range of control parameters to afford greater musical expressivity.

1.3. Mechatronic Sound Installations

As well as conventional instrumental paradigms, there are many examples of mechantronic technology being used in sound installation art. From simplistic units to complex kinetic sound sculptures, the integration of mechatronic systems is widespread in sound-based art. A full overview of the field of mechatronic sound installations is outside of the scope of this paper, although the work of Swiss artist Zimoun is illustrative of similar complex control problems that emerge from this field.[2]

Zimoun creates complex emergent systems from large arrays of simplistic mechatronic elements. DC motors with attachments are often used to strike a physical object, as in *329 prepared dc-motors, cotton balls, toluene tank* and *157 prepared dc-motors, cotton balls, cardboard boxes 60x20x20cm* (Zimoun 2013, 2014).

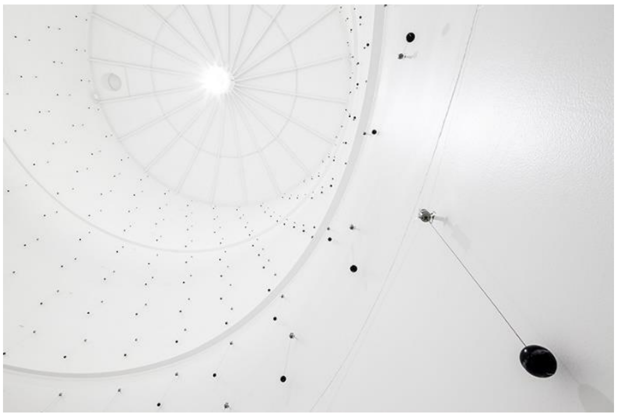

Figure 3. Zimoun: *329 prepared dc-motors, cotton balls, toluene tank*

Martin Messier combines existing technology with mechatronic control systems in his works *Projectors* and *Sewing Machine Orchestra*. In a similar vein, Nicolas Bernier has used tuning forks with mechatronic actuating systems in *frequencies (a)* (Messier 2012, 2014; Bernier 2012).

Figure 4. Martin Messier – *Sewing Machine Orchestra*

Mo H. Zareei has produced a series of mechatronic noise-intoners, the *Brutalist Noise Ensemble*, consisting of three modules: *Rippler, Rasper,* and *Mutor* (Zareei 2015). Each module is a series of noise-intoners that use

[1] For a comprehensive overview of the mechatronic instrument field: Kapur 2005; Murphy 2012, 2015; Maes 2011; and Singer et al. 2004.

[2] For overviews of sound art that include mechatronics: Licht 2007, LaBelle 2006, Kim-Cohen 2009 and Voegelin 2010 offer examples. At time of writing, there does not seem to exist a comprehensive overview of mechatronics in sound art.

simplistic mechatronic parts to create highly controllable bursts of noise. With a focus on rhythmic structuring of noise, the ensemble as a whole is capable of producing complex, rhythmic noise works.

Figure 5. Mo H. Zareei – *Brutalist Noise Ensemble*

1.4. Control Systems for Mechatronics

In comparison to the developments in these mechatronic systems, the state of the controller field has been far more stagnant. As Murphy recognizes,

> ‘although expressive control allows for a wide range of musical possibilities for the composer to explore, a pressing need for increased user friendliness in human-robot interactions has been identified: To compose for these systems in their current state is to manually direct every action that the robot undertakes. To write music in this manner is quite time-consuming, requiring much actuator management rather than higher-level musical composition. (Murphy, 2015)’

1.4.1. Existing Controllers for Live Performance

Most of the mechatronic systems use MIDI as the basis of their communication design. While this means that many commercial MIDI controllers are compatible with their communication system, allowing for off-the-shelf real-time control, MIDI controllers are not designed to specifically control mechatronic systems and, thus, are not well suited to interacting with the more complex, continuous and non-linear mechatronic systems.

1.4.2. Non Real-time Composition

Due to the limitations of existing controllers, composers often opt for a software solution and compose MIDI scores to be played back. While this allows a high degree of control, and ensures repeatability through playback, it imposes many limitations on the interaction a user can have with the system. For instance, only expert users who have learned the specifics of how each control parameter is mapped will be able to control the mechatronic system with any degree of precision. This can be a cumbersome method, even for these expert users, as they try to deal with a large number of parameters at once. This method also limits real-time interaction, which makes it ill-suited for real-time performance, or a public, interactive installation setting, in which untrained, non-specialist audience members may be invited to provide some degree of interactive control.

This lack of intuitive, real-time control system was a strong driving force for designing *Carme* for the *Polus Ensemble*, in an attempt to realise the interesting interactions possible with a mechatronic system in both a performance and installation setting.

2. SYSTEM OVERVIEW

2.1. Designing for The Polus Ensemble

Each sculpture in *The Polus Ensemble* has a bowing mechanism that allows for a range of control. This control is manifested through four controllable parameters: arm direction, arm speed, bowing wheel direction, and bowing arm speed.

The bowing wheel acts as a continuous bow, rotating as it is brought into contact with the string by the arm. Once in contact with the string, the arm can also control the amount of pressure of the wheel against it. This pressure, in combination with the speed of the bowing wheel, controls the loudness of the sculpture—adding depth to the possible sounds that can be created.

The design of the bowing mechanism allows for a small range of behaviours, each with some expressive control. A basic continuous tone can be controlled, and the speed of the wheel vs the pressure against the string can be explored—resulting in a continuous range of timbres between overpressure (‘scratch tone’) and light pressure (*flautando*). Through changing the direction of the bowing wheel during a held note, rhythms can be articulated and, with fast repetitive changes, a tremolo effect can be achieved. A percussive strike can also be performed by controlling how the bow approaches the string, quickly striking and sounding.

With six sculptures in *The Polus Ensemble*, this design allows for 24 control parameters in total, a large number to attempt to control in real-time.

Figure 6. *The Polus Ensemble*

2.2. Communication Framework

Each sculpture has its own set of electronics attached to the instrument. This includes an Arduino, motor driver shield, and a custom-made PCB board that allows for MIDI communication, and a data feedback loop for motor control.

The ensemble is chained together through MIDI INs and MIDI THRUs, with each unit having a separate channel to route messages. The firmware on each electronics module is directly passing the MIDI information on to the four control parameters, allowing for more complex and configurable control to be done on the computer

The MIDI information received by each electronics module is sent from a computer that is running Max/MSP. This mid-point is where the majority of the data handling and processing occurs.

The Max/MSP application receives OSC data, wirelessly sent from the iPad. OSC was chosen as its highly configurable, and with the possibility of transmitting data wirelessly, the control chain from the computer to the ensemble can be isolated, allowing for the user to focus on the interaction with the ensemble.

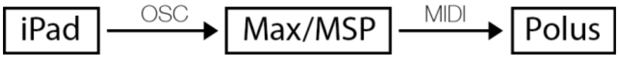

Figure 7. Control flow of *Carme* communication framework

2.3. Hardware Platform

The iPad was chosen as the hardware platform for three main reasons. Firstly, the iPad, and other touch based devices, have become widespread and common. This means that for most people, interacting with an iPad is not confronting, and there is an understanding of possible interactions with it. This is essential in an interactive gallery setting to encourage audiences to interact with a work.

Secondly, the popularity of the device means that the application can be potentially used with other mechatronic systems easily, without the need of building a new physical interface.

Finally, the iPad allows for a very reliable, accurate multi-touch hardware platform, with built-in gestures that can be used to add functionality.

3. APP DESIGN

3.1. Design Approaches

The app is designed with a simple ‘spatialized behaviours’ model, which, while to some degree abandons the possibility of fine-grained control over every possible control parameter, has the benefit that it greatly simplifies the user experience, while still allowing for complex behaviours to result. The design approach for *Carme* considered the two different complexities that exist in *The Polus Ensemble*: 1) the spatial distribution of multiple sculptures, treated as one mechatronic system; and the multiple parameters of control that each sculpture presents.

The app expands on the spatial concepts of *The Polus Ensemble* by using the virtual space of the iPad, and mapping this with the physical arrangement of *The Polus Ensemble*. Spatial relationships in the virtual space of the iPad are realised by creating sound, actuated in the real, physical space of the distributed sculptures.

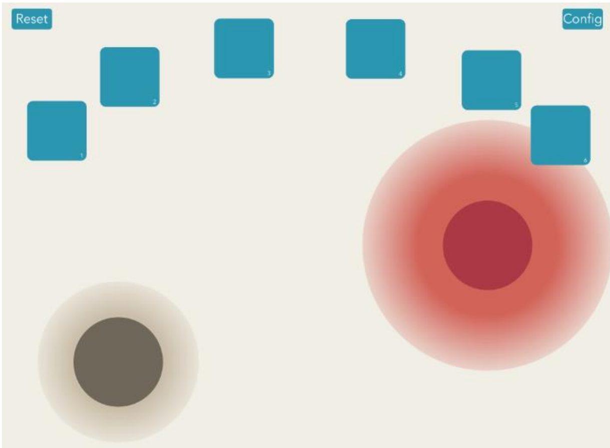

Figure 8. Carme showing six instruments for the Polus Ensembles and two behaviours: one expanded and overlapping with an instrument, and another to the side.

Two major types of abstract shapes are shown. The rectangles represent the individual instruments, while the circles are behaviours.

Due to each unit having four raw control parameters, behaviours were abstracted to allow a more intuitive interaction. This means if a user wanted to create a held continuous note, they would not have to set the direction of the arm and adjust the speed, as well as, control the speed of the bowing wheel. Instead these behaviours offer an abstract control like intensity, which are interpreted in the Max/MSP application to control these parameters accordingly.

By dragging a behaviour in close proximity to an instrument, the relevant behaviour is created in the instrument. This design can easily be customized to have any amount of instruments and behaviours on the screen, catering to the specific mechatronic system. This behaviour is only triggered when the shapes overlap. The degree of proximity is used to control a parameter within the behaviour. An example would be the intensity of a continuous note.

Each shape is not fixed in space and may be grouped in any way. This allows for an interesting approach to organising sound, as sculptures can be spatially grouped together to create chords, or separated to make small sections in the ensemble.

The size of the behaviours can be altered by using a spreading gesture with two fingers. This allows for the influence of a behaviour to dilate and cover a large space. By making the behaviours larger, the user can have finer control over the proximity, as the resolution is effectively higher.

A configure screen is also implemented to set the wireless communication parameters of the specific network. Two parameters need to be set accordingly, the I.P. address of the target device, and the port that OSC will be sent over.

4. EVALUATION AND LIMITATIONS

Figure 9. *Carme* with the *Polus Ensemble* in a public setting.

So far, the application has been used in a public demonstration at Victoria University. The application allowed for two behaviours to be spatialized through the ensemble: a held continuous note, and a percussive strike.

Through using the application, and designing behaviours to be controlled, the strengths and weaknesses were revealed in this approach to controlling a complex mechatronic system. For instance, the spatialisation of a simple behaviour around the ensemble worked well. The bowing behaviour allowing A for interesting chords being created through grouping the instrument shapes together and overlapping the bowing behaviour. The percussive strike behaviour created interesting rhythmic interplay through the separation and spatial distribution of short pitched hits.

However, more complex behaviours were less intuitive and not as well suited to this method of interaction. A tremolo bowing behaviour, for instance, could possibly have a parameter for speed of tremolo, as well as loudness, but due to the simplicity of the spatial interaction between an instrument shape and behaviour shape, only one continuous data stream is given per interaction. This means that only one of these parameters can be controlled by a user, and makes trying to control other similar parameters problematic.

A complex system like Murphy’s *Swivel 2* that has continuous control over pitch as well as picking intensity would be problematic for this spatial approach. The application could be mapped so that instead of representing a physical space, an abstract pitch space could be explore, although it may be that another approach is needed to intuitively control those systems.

5. FUTURE WORKS AND APPLICATIONS

In the evaluation section, the strengths of this application were explicated, allowing for the potential applications of *Carme* controlling mechatronic systems beyond *The Polus Ensemble* to be imagined. What *Carme* does well is allow for a non-linear spatialisation of simplistic gestures through a possibly large array of mechatronic units.

Works like those of Zimoun—complex through the amount of simplistic modules distributed through space—are strongly suited to being controlled by this approach. This interaction afforded by the spatial design approach would allow an audience to interact in a way that would be heretofore not possible. This spatial complexity can be seen in many other mechatronic works including that of Zareei, Bernier and Messier.

A range of settings are planned that explore the spatial relationships of *The Polus Ensemble*. This includes a performance, controlled by *Carme*, with the ensemble stacked vertically, creating a near four meter tall structure; exploring the vertical spatialisation of pitch space in the overtone series.

What *Carme* affords is not only a way of performing with large, complex spatial mechatronic systems; but a tactile way of giving the audience the power of interaction, in a way that is intuitive and approachable.

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