Interactive Musical Chair: Seated percussion with real-time visualisations

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Abstract. This project, *Musical Chair,* explores the visualisation of percussive sounds, and rhythmic and temporal interplay through an interactive, multimodal installation. Building on the software developed through an earlier project, the *Colour of Music*, the visualisations will explore graphical representations of percussive timbre and rhythm. Multiple sound sources, in this instance cajons, have been used in order to allow group playing with multi-user visualisations and a machine 'playing companion'. The challenge is to visualise communal music making in such a way that individuals can identify their own sounds and recognise how they fit together into a whole improvised performance. This paper discusses the design of the *Musical Chair* system, alongside an overview of the software developed for its installation at the Centre for Life, Newcastle, UK, concluding with a data capture and evaluation plan for the installation.

Keywords: Interactive, Installation, Colour, Visualisation, Sensor, Synaesthesia.

1 Introduction

We experience an inherent and intentional multimodality during many of our multimedia experiences, often incorporating combinations of visual and auditory stimulation. Combining different media forms is a common method of creating more engaging experiences by stimulating audiences through different sensory channels. This is particularly effective in places, such as museums, that have a wide array of optional activities and a large footfall, by facilitating highly interactive and explorative environments that could be considered key to heightening audience engagement.

As part of the *Colour of Music* (CoM) project (Ng *et al.* 2013, Ng *et al.* 2014) , we have been working on the concept of sound-colour mappings as a means of exploring *visual hearing*; this has primarily been through the application of reactive graphics that are generated from documented synesthetic phenomena. The concept has been prototyped and successfully premiered in a concert at the Sage Gateshead, in collaboration with the Royal Northern Sinfonia at the International Colour Science Convention, AIC 2013 (Association Internationale de la Couleur).

Building upon this existing project, *Musical Chair* seeks to further extend the core concepts behind CoM and transport it to a wider, more varied audience as an installation. Focussing on the development of a creative application for sound-colour synaesthetic mappings, this work is realised as an interactive multimedia installation for generative visualisations. Hosted at the International Centre for Life (http://www.life.org.uk/), Newcastle, UK, the work will be open to the general public between November and December 2014. This paper gives an overview of the project.

2 Background

2.1 Synaesthesia

Synaesthesia is a neurological phenomenon where by stimulation of one sensory modality results in an extra sensory perceptual response in another. Common manifestations of this sensation include the perception of colour for music, phonemes, numerals and letters, and 'tactile shapes' for taste. In the context of this project, the music-colour synaesthetic relationship is explored. There has been a range of research to study and quantify both the neurological and perceptual response of synaesthetes. When measuring a subject's response to musical tones, Neufeld *et al.* (2012), measured increased activity in a region of the brain involved in multimodal integration for music-colour synaesthetes. Paulesu *et al.* (1995) derive similar results when analysing brain activity in music-colour synaesthetes.

Music-colour association has a rich history within both the sciences and arts. An early scientific association of the two domains is detailed by Newton (1704). Historically, visual and auditory artists have mutually served as each other's inspiration. A direct transposition of this is characterised in the impressionist movement, particularly the work of Debussy. Additionally, musical timbre is frequently described as the 'colour' of music. Research into the music-colour synaesthetes perception of stimulatory audio has produced varied responses, reflecting the subjectivity of the phenomenon. Colour synaesthesia is generally individual. Despite this, there are several features that exhibit more comment trends (Hubbard 1996; Marks 1974). These include: (i) pitch and brightness; (ii) loudness to size; (iii) colour and frequency. Many composers and artists, including Messiaen, Ligeti and Sibelius report synaesthetic responses that influence their work. This body of research, alongside other pre-existing literature, provides the basic principles behind the mapping strategies developed in this project.

2.2 Technology-enhanced Learning and Visualisation

Through effective mappings, visualisation can enhance aspects of the data that are not apparent in its raw form. MacRitchie, Buck and Bailey (2009), visualise musical structure through motion capture of a pianist's performance gestures. This visualisation confirmed a relationship between upper body movements of a pianist and composition structure. The techniques have been applied in a wide range of application contexts including multimedia performance and technology-enhanced learning. Oliver and Aczel (2002) and Ng (2011) reported accelerated learning using visualisation. Ng *et al.* (2007) and Ng (2011) discuss the i-Maestro 3D Augmented Mirror system, which increases awareness of bowing gesture and body posture using real-time visualisation and sonification.

3 Design and Development

We have adapted existing visualisations and mappings, transforming them into an interactive installation. The installation features up to three sensor seats integrated with a cajon percussion instrument that can be played either as an ensemble or solo. Through the sound-colour synaesthetic mapping, visitors will be able to *see* the musical sounds that they are creating in real-time. Participants will be able to sit and play the instrument, improvising rhythmical patterns and musical sounds, which will affect and interact with the visualisation.

3.1 System Design

The use of the cajon provides an accessible instrument interface, available in a range of sizes. It is both easy to start playing, even by young and non-musicians, whilst also being able to produce a wide range of sounds that can be mastered and captured.

Each cajon is augmented with a contact microphone (we use a piezo for this installation) and load bar cell sensors. The piezo signal is amplified and connected to a Raspberry Pi via a USB audio interface and the audio signal is used for hit detection and spectral analysis. The sensors consist of four strain gauges connected to an mbed microcontroller (http://mbed.org/). The set of load bar cell sensors measure a seated person's weight distribution These are enclosed under the top surface and are used to determine the seated balance of the player. The audio data and position information are then packaged and transmitted over a local network to a central PC for visual mapping, rendering, and audio prompt (or a machine playing companion) (see Fig. 1).

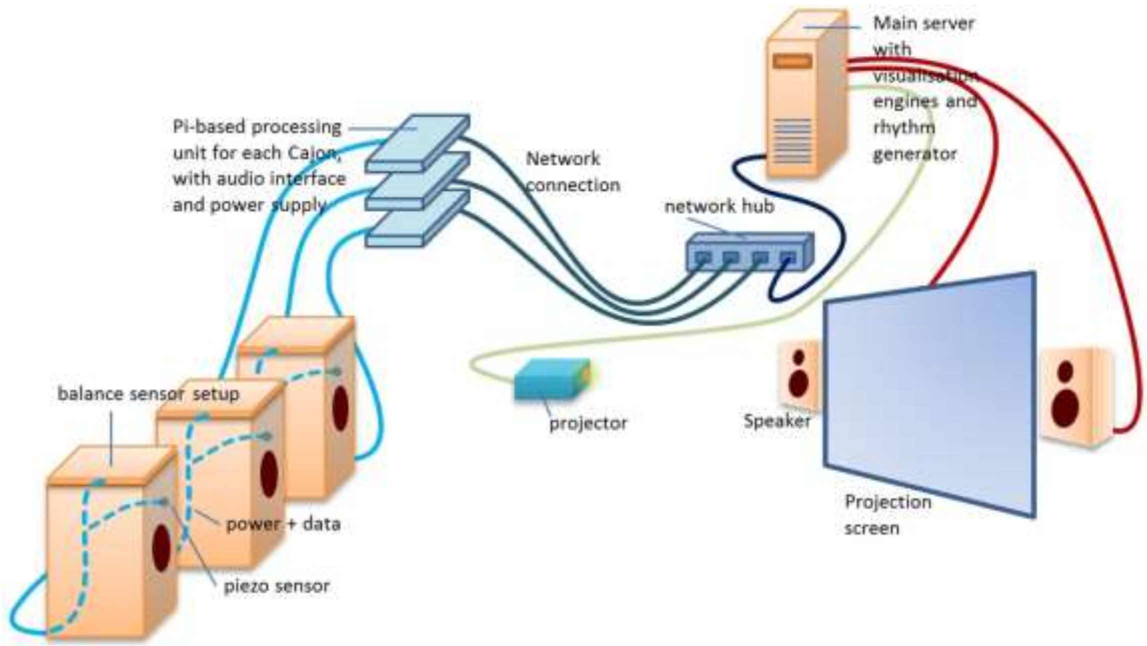

Fig. 1. System setup

3.2 Detailed Description

3.2.1 Seat Movement

An existing cajon build-kit design by Meinl (http://meinlpercussion.com/) was adapted for the purposes of this project. This included the addition of a wooden top that houses four load cells (or strain gauges) on each side. This arrangement means the movement of someone seated on the device will cause resistance changes in one or more of the load cells, which are converted into voltage changes and individually amplified and then digitised before being transmitted to an MBED microcontroller.

3.2.2 Microphone

A single contact microphone (consisting of a Piezo electric element) is secured to the front panel inside the cajon, to pick up vibrations when the panel is struck; this signal is then amplified before being transmitted to the Raspberry Pi, via a miniature USB interface for audio analysis (see Section 3.3).

3.2.3 Audio Analysis

Audio is streamed from the contact microphone at 44.1kHz/16bit using a USB audio interface. Advanced Linux sound architecture (ALSA) is used to digitise the audio signal. Hit detection is performed using a dynamic threshold at 3 times standard deviation with the background (non-hit) signal mean updated on the last 30 seconds of data. The threshold can be configured to reflect upon the acoustic characteristic of the environment.

Once a hit is detected, a buffer of 2048 samples is passed to a fast Fourier transform (FFT) engine to detect the fundamental frequencies and their related amplitudes that are used for the sound-colour mapping. To perform the FFTs, Andrew Holme's GPU_FFT library has been integrated. Due to the Pi being headless, the GPU can be utilised for processing. According to Holme (2014), the approach is up to 10 times faster than running the FFTs on the main processor. The magnitudes of the FFT array are estimated as square sum of the real and imaginary parts, and the frequency domain data is analysed.

We select up to 5 FFT bins with the largest magnitudes. These frequencies, their corresponding magnitudes, along with the RMS of the detected hit and time-stamped onset, are added to the socket send with the unique identifier of the cajon. Additionally, the package also consists of a flag bit to identify whether someone is sat on the instrument and data from the load balance sensors and sent to the machine handling visualisations. The data sent to the main PC can be mapped to visual and sonic parameters for rendering.

3.3 Installation

Two cajon instruments are being installed at the Centre for Life, Newcastle, UK and will be open to the public between 15th November and 15th December 2014. Software including a visualisation and a machine playing "companion" package are installed on a machine that receives data from the cajon instruments.

The visual projections include an instructional video that will be playing when the system is dormant. When a member of the public sits on the cajon, it brings the installation to life, guiding them through a percussive exploration of tempo and simple rhythmical patterns with visual and auditory instructions. The software has been designed to provide a 'tempo challenge' to the museum visitors.

The tempo of an accompanying drum machine decreases and increases over time. The challenge for the visitor is to stay in time with the machine drum tempo, supported by the visualisation. The machine tempo information is sent to the visualisation engine for comparison with detected onsets. From a bank of pre-set patterns, the companion's rhythmic content changes over time. Allowing the musical structure variation, whilst encouraging a progression of complexity, through increased syncopation and polyrhythm.

The visualisations build on work from the aforementioned Colour of Music project; transforming the sound and gestural input from the players into real-time visual interactions. With this installation, we are exploring a concept to use visualisation to convey the feeling of tempo and rhythms. A visually represented interplay between the animations from the visitors and machine-companion is used to communicate the correlations and synchronicities of their individual tempi as well as highlighting differences in their rhythmical patterns. By cycling through different programs, the system keeps the visualisations fresh and engaging for the users. Each program features different textural qualities and frequency-to-colour mappings.

The visualisation system is driven by multimodal user input to provide an intuitive system of visual feedback. The underlying design of the system consists of centrally positioned, user-controlled objects and peripheral machine-controlled objects (see Fig. 2). The peripheral objects respond to the auto accompaniment, and act as visual cues – conveying rhythmic information to the user. The central objects respond directly to the users' interactions.

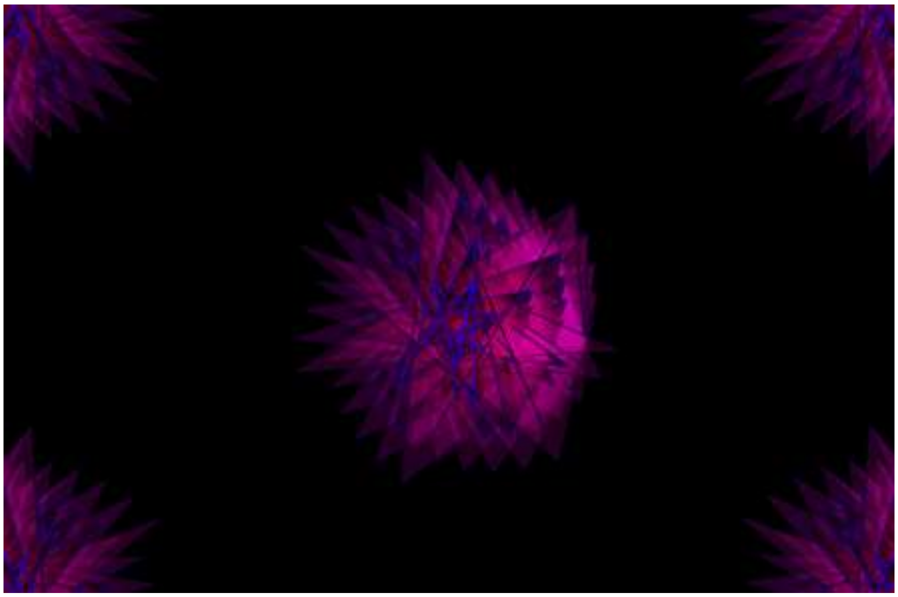

Fig. 1. Example visual feedback.

User-controlled objects respond to user input via three parameters: position, colour and size. The position of the object is controlled by the position of the user on the cajon (via information received from the strain gauge sensors). The colour and size of the object are controlled by information from the audio analysis, where the colour fluctuates according to the frequency content of the hit, and the size changes according to the absolute value from the audio stream. If two visitors are interacting with the cajons, the screen divides in half to create space for two central objects. The visualisation strategy is also applied to the machine companion player, located around the edges of the display and growing towards the centre in accordance with loudness.

4 Conclusion and Next Steps

Based on the concepts outlined in this paper, the approach of ICSRiM's visual mapping strategies has transitioned from real-time concert performance to live interactive interface for installation. The next step is to collect the data during the installation and analyse how people interact with the system to understand the impact of visualisations as a tool to guide percussion tempo interpretation in an edutainment scenario. At the Centre for Life, public evaluations will be conducted to measure users' time difference verses the machine drum to measure how long individuals take to match tempo and rhythmical pattern changes and variations. Furthermore questionnaires will also be handed to visitors to validate the overall concept.

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