DOI: http://dx.doi.org/10.14236/ewic/eva2014.3

The Colour of Music: Real-time Music Visualisation with Synaesthetic Sound-colour Mapping

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Multimodality is integrated into the majority of our multimedia experiences, most commonly with intent. However, some experience an unintentional, and subjective perceptual response to a stimulus in another sensory domain due to the neurological phenomena synaesthesia. This paper discusses the application of music-colour synaesthetic mappings in live ensemble performance. A succinct discourse on literature related to synaesthesia scientifically and creatively is presented, followed by an overview of the design and development of the system. Exemplification of the mapping strategies is offered through an illustration of one potential output. Finally, the paper concludes with a brief summary alongside ongoing developments.

Sound-colour. Trans-domain mapping. Visualisation. Synaesthesia. Interactive. Multimedia. Performance.

1. INTRODUCTION

With advancements in neurological and psychological research, increasingly better insights into how we function, sense and feel are being revealed. From our early interests in the mapping between physical movements and musical events (Ng 2004), we have been exploring a range of trans-domain mapping strategies for several different application contexts, particularly multimodal feedback to enhance communication and widen accessibility. Most recently, mapping musical conducting gesture into vibro-tactile and auditory feedback (Armitage *et al.* 2012), and visualisation and sonification of bowing gesture for technology-enhanced learning (Ng 2011).

Focussing on the translation of sonic to visual events, this paper presents synaesthesia inspired mapping models in the context of a live musical performance. This paper is structured as follows: Section 2 presents a background literature survey incorporating, an overview of the neuropsychology behind synaesthesia together with an outline of it's effect. Section 3 presents the design and development of the individual system modules with a potential resultant visual output, and Section 4 concludes with a summary and current developments.

2. RELATED RESEARCH

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.

3. DESIGN AND DEVELOPMENT

This section outlines the design and development of the system with a particular focus on audio-visual mapping strategies and models. First, a system overview is presented, followed by an outline of the project's design. This section concludes with a short description of a sample visualisation output of, Messiaen's *Abîme des oiseaux* that was performed by Royal Northern Sinfonia at The Sage Gateshead, Newcastle Upon Tyne, England.

3.1 System overview

The system in its entirety is highly modular to facilitate multiple application contexts. For this paper, it is presented from the perspective of live ensemble performances; consequentially, the system requires four primary components. First, an analysis of the musical score is required. Then, in order to identify position within the pre-analysed score, an intuitive method of real-time "following" is required. In turn, the sonic-visual mapping algorithm uses this data to create the corresponding graphical visualisation. Software is then required to render the visuals for projection.

3.2 Design

The system design, in this context, is focussed on its application in a varied concert programme; an overall system architecture is presented in Figure 1. Prior to performance, due to the musical complexity of large-scale orchestral works, the score is analytically reduced into a more manageable format using Music21 representation. This process also allows manual selection of particularly prominent or important events and structures; identifying the tonal centre of the work, whilst also highlighting melodic gestures and motivic movement. Other events and cues can be incorporated, including instructions for the lighting control.

In order to capture the temporal progression of a complex and diverse concert (e.g. solo, choral and ensemble works), a flexible method of performance following is required. For this reason, methods of interactive (Source 1), and automated (Source 2) control were implemented. Source 1 requires a user to track the performance using a specially designed interface that allows the user to manually control the current location in the score data relative to the music being played (See Figure 2).

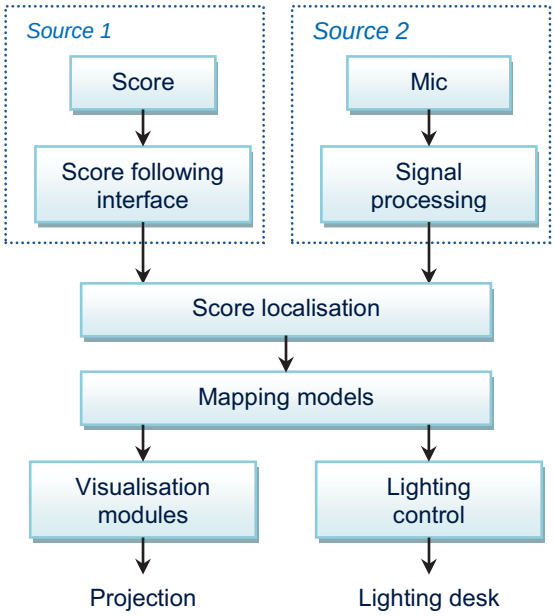

Figure 1: *Overall system architecture*

Simultaneously Source 2 analyses the live audio as it is produced, identifying fundamental frequencies, sent via OSC (Open Sound Control), also to the score. A rule-based agent decides which source to "follow" depending on a confidence measure that is based on the nearest note detection and the overall position within the score. The clear advantage of this approach is its adaptability, enabling the sources to be used both independently, and concurrently with synchronisation. Multiple machines were used for a failsafe and robust system. Each module was running on independent machines that were networked together in distributed setup, in the event that one machine failed, another would take over.

According to the aforementioned literature, mapping strategies have been designed in order to facilitate the translation of sonic to visual events. Developed in Processing (processing.org), the structure of the mapping algorithm is dynamic, with both generic/general associations, and specific mapping using a selected composer's individual synaesthesia mapping, e.g. Messiaen, Ligeti. The

generic mapping is designed to simulate general synaesthetic response to sound based upon findings from psychological research (Hubbard 1996).

Figure 2: *An interface to follow the current location in a score manually*

3.3 A performance

Using the aforementioned technologies to accompany a concert by the Royal Northern Sinfonia on 9th July 2013 at the 12th International AIC Colour Congress (see: http://aic2013.org/the-programme/northern-sinfonia-concert) provided a test-bed to explore the potential visual outcomes this system presents. Synaesthesia-informed mapping strategies were implemented, including mappings based on those reported by Newton, Scriabin and Messiaen, together with graphical designs and animation techniques inspired by musical gestures. Figure 3 shows a snapshot from a live performance with the system, at the Sage Gateshead, Hall One.

Figure 3: *A live performance with the Royal Northern Sinfonia*

4. CONCLUSIONS

Synaesthetic sound-colour associations present a framework to translate between music and visual art. This paper first presented contextualisation of the project together with the overall system aim, after which, a brief literary analysis was presented. The design and development of a prototype to visualise music was considered utilising synaesthesia-informed mapping strategies, including those based on Messiaen and Ligeti together with graphical design based on psychological findings of music-colour synaesthesia. Furthermore, we are currently developing an additional multimodal extension to this concept in the form of a haptic chair and an interactive music installation.

5. ACKNOWLEDGEMENTS

We would like to acknowledge to all project partners and participants, including the Sage, AIC 2013, particularly Lindsay MacDonald and the organising committee, for their interest, contributions and collaborations. Special thanks to Dominic Freeman and Matt Benatan for their support with the visualisation modules, and Ian Symonds for hardware support.

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