MUSICAM – AN INSTRUMENT TO DEMONSTRATE CHROMAPHONIC SYNESTHESIA

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ABSTRACT

This paper details the design and development of a novel musical controller. Inspired by a type of Synesthesia where colour typically induces musical notes, MusiCam explores the potential benefits of this idiosyncrasy as a mode of Human Computer Interaction (HCI), providing a host of meaningful applications. Colour data is interpreted by means of an off the shelf webcam, and music is generated in real-time through regular speakers. This simple design flexibility allows for any personal computer to take on the identity of an interactive musical device.

1. INTRODUCTION

The term synesthesia (from the Greek, syn = together + aisthesis = perception) means 'joined sensation' and as such refers to an involuntary physical experience in which the stimulation of one sense causes an additional perception in a different sense or senses [4]. For example, a synesthete might feel, see or taste a person's voice as well as hearing it; might detect a scent on seeing a particular colour; or when looking at printed black numbers might see them in colour, each with a different hue. Synesthetes represent a group of otherwise 'normal' people who experience the ordinary world in extraordinary ways due to their senses of touch, taste, hearing, vision and smell getting mixed up rather than remaining separate.

2. BACKGROUND AND RATIONALE

This MusiCam project aims to explore a particular type of synesthesia where colour will typically induce musical sound. Whilst it is impossible to replicate exactly different synesthetes' personal perceptual abilities, through the use of digital multimedia techniques we can create virtual synesthesia [3] demonstrations that give a close approximation to what a person with synethesia might experience. In addition to studying the perceptions of synesthesia, the system explores the issues of colour sound combinations more generally with regard to using them as a computer based communication medium, for relaxation or rehabilitation purposes or as a static or interactive ambient display.

With these goals in mind, there are three intrinsic areas of interest which have influenced and inspired the development of the MusiCam system:

- The colour/sound phenomenon and audio/visual art.
- The synesthesia condition and chromaphonia in particular.
- Human Computer Interaction (HCI), musical controllers and Interconnected Musical Networks.

Colour/pitch scale systems were devised as early as the 16th century and 'colour organs'[1] developed by the 18th century [1]. In these early systems the relationship between colour and pitch was normally determined by the inventor of the system using mathematical techniques. Even today's counterparts still use scales that are fundamentally drafted from assumption; but with computers frequently involved in producing arbitrary mappings between colour and sound [3].

In chromaphonia, (coloured hearing), a type of synesthesia [4], those with the condition will naturally associate a particular colour with a corresponding musical note and in effect create their own colour scale; often this is unique for each synesthete.

Aside from investigating the characteristics of the condition, also encouraging this project is the study of HCI science. Discovering novel ways to interact with the personal computer will unquestionably improve human creativity and in consequence improve communication and cooperation between humans. The benefits of sound and music in computer interaction are often forgotten even though auditory stimuli may leave longer lasting impressions than visual stimuli [5], better recall can be attained if information is received aurally as opposed to being read, and humans can react faster to auditory stimuli than to visual stimuli [6]. Music is one of the most highly structured auditory mediums and communicates through parallel streams, which can be

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[1] Colour organs are interactive musical controllers capable of creating abstract audio/visual compositions in real-time. A phrase coined by Rimington in 1893 [2] the earlier machines looked like typical instruments and when played controlled coloured gas lamps or coloured paper strips lit by candles.

effortlessly extracted and differentiated by our human cognition processes. Additionally, the inspirational qualities of music naturally spawn a multitude of research areas such as music in education, music therapy and more recently Interconnected Musical Networks (IMNs) which allow players to independently share and adapt each others music in real time [7].

3. THE MUSICAM SYSTEM

The MusiCam system uses image processing techniques to extract colour data from a webcam. The colours that result from the extraction determine what note, track or instrument is played. Adding more colours can result in richer textures and increasing the level of a particular colour manipulates the dynamics of the system. Different banks of sound clips can be loaded into the system generating new sound/colour mappings, changing the character of the system and forcing different user interactions.

The test platform currently used is displayed in Figure 1 below. This particular arrangement is composed of a slowly rotating plinth on which coloured objects are placed and a mast which houses the webcam, positioned so as to allow a section of the disc to be examined.

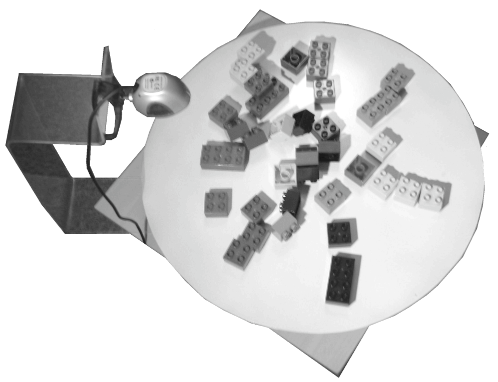

Figure 1. Test platform

In this configuration, users can carefully organise blocks in an orderly manner away from the webcams view. This can lead to structured connections as clips can be played in specific timing with one another. Since the plate is continually spinning, few or little interactions can still result in continuous, highly textured music.

3.1. Implementation tools

MusiCam was implemented using Microsoft's C#.NET programming language. Two additional libraries were also used in the development of the system. The first is a camera server [8], which employs DirectShow to capture single frames from the webcam, the other is DirectSound, and is used to manage the banks of sound played in this system. These libraries are part of the Microsoft DirectX SDK [9] and are freely available to researchers.

3.2. Colour Filtering and Performance

It is common that the raw image from the webcam will contain a few dark areas and shadows, and may generally lack definition. To address this, any part of the image in the application can be selected for processing, making it possible to eliminate the darker regions surrounding the edges as well as limiting the number of blocks examined at any one time. The brightness and contrast can also be adjusted in real-time. Increasing the brightness is simply done by increasing all the values of the colour for every pixel, and changing the contrast is performed by exaggerating the difference of the RBG value from GREY(128, 128, 128). The figure below shows a series of screen captures taken from the test application.

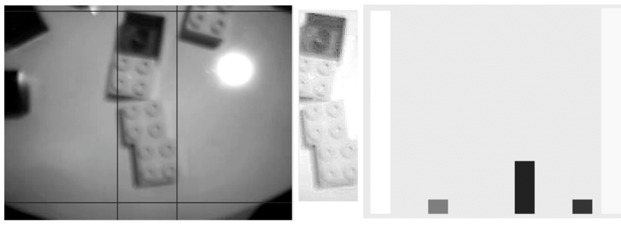

Figure 2. Colour extraction

The idea of the colour filtering tool is to allocate pixels based on their RGB values into a discrete colour set. There are two possible ways of accomplishing this. One of which is to use some discrete set of comparisons, refined using existing knowledge of colour recipes. The alternative is to employ some adaptive structure like a neural network, where calibration typically involves training the network against known data sets

After consideration the first method was employed, as it was proven to be less demanding, quicker to compute and also much simpler to implement than the alternative.

It works by passing each RGB pixel value through a framework of logical operations, and after rational deduction, the function then selects the best colour of which it matches closest. At present, the system is able to distinguish between 10 different colours; the levels of these correspond to the volumes of the individual sound clips, and are illustrated on a dynamically changing bar chart on the form. By adjusting the volume this way helps to make transitions smoother, between objects and no objects.

3.3. Background masking

Currently MusiCam is programmed to nominate a single colour to ignore so that this can be used as the background mask. This allows the system to easily distinguish between moving or foreign objects. Without this mask, MusiCam would continue to play music with or without; user interactions. Whilst this might be appropriate for a static ambient display it limits greatly the number of possible webcam arrangements. For this reason a further background masking module is introduced. The concept is to capture the image without the foreign objects present, and then subtract this image from all subsequent frames. By using this process it is possible to display all the pixels that have significant change (new objects in the frame) and to replace non-changing pixels with white respectively. This new image can then be processed and filtered for its levels of colour as before.

Since even the smallest changes of intensity could be detected, a thresholding equation similar to that developed in [10] was introduced. The values were tweaked accordingly so that only the larger changes were displayed. The modified equation is presented below, where change in intensity is the difference in intensity between a pixel in the background mask and the corresponding pixel in the captured frame, and the new intensity referring to the intensity of the pixel in the captured fame.

$$Output = \begin{cases} DrawPixel, & if \ \dfrac{ChangeInIntensity^2}{(NewIntensity+1)} > 1.02 \\ MakeWhite, & otherwise \end{cases} \quad (1)$$

Although this background removal technique works well with simple backgrounds, in more demanding and busier backgrounds the image resulting from the background removal process often does not exclusively contain the foreign blocks, it will also contain noise representing shadows, small changes in the scene and changes in lighting.

The existing process is refined with the addition of another algorithm, which works on the principle that a pixel in a densely populated (non-white) row and column is more likely to belong to a group of pixels making up a foreign object than that of noise. Simply, the method works by firstly totalling the number of non-white pixels for each column and row, after this each suspect pixel is ranked by multiplying the corresponding column and row value. By using this method it is possible to eliminate some of the noise in the image. In Figure 3 a coloured block is introduced into the picture, the background is removed using thresholding equation and then with the added noise filter to remove the light nuances.

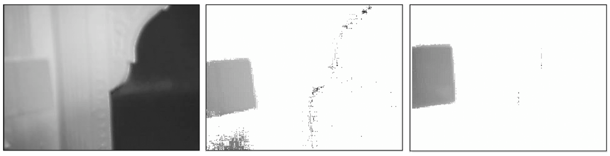

Figure 3. Background masking and noise filtering

3.4. Multiple tracks

A straightforward way of achieving much richer and interesting sound from MusiCam is to increase the number of voices being used at a time.

The image is divided horizontally into equal parts according to the number of voices selected. Each of these segments can then be assigned to a different voice or sound bank, leading to multiple colour-to-sound mappings. For instance, if the picture were to be divided into two parts, it would be entirely possible to use the same colour to trigger off two independent sounds by moving it from one half of the image to the other.

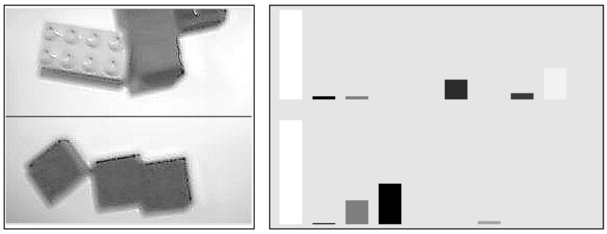

Figure 4. An example of two voices

By using this function it is not only possible to increase the number of different instruments, but also to extend the range of a single instrument, for example by having a higher register of notes in the upper segments and vice versa.

3.5. User modes

For demonstrative purposes there are three modes which aim to exploit the diversity of the system. Each mode encourages a different type of interaction and consequently has different application potential.

In the first mode, collections of ambient sounds are used. This encourages minimal or moderate exchanges and suits therapeutic purposes. It also is attuned to other ambient based applications. For example by positioning the webcam in a hallway or lobby it could serve as an ambient device, playing music to passer-bys.

Much different to the ambient mode is that of the synthesiser. Funky drum, guitar and bass loops make up this mode, and promotes almost aggressive interactions as users cope with mixing multiple tracks in real-time. It is much preferred to have the platform stationary in this mode and not continuously rotating. Areas of interest can be set up in different parts of the circle and activated by spinning the plate manually, the action similar to that of a DJ spinning a turntable deck.

It takes some ability and practice to manually mix the tracks together so that they are in time, and because of this element of skill it is much more rewarding. For those that might find this troublesome or annoying, an extra option is incorporated. This option intelligently synchronises the tracks so that the music is never out of time. It does this plainly by muting all the tracks to begin with, and because a track is never stopped it is unlikely for any of them to fall out of time.

A collection of musical notes make up the sound-banks in the last mode. Aiming to play virtual instruments much like a keyboard would, this mode has as much appeal as a toy xylophone, and thus benefits as an introductory music aid or educational toy.

4. USER FEEDBACK AND FURTHER PLANS

To date, around a dozen users have experimented informally with MusiCam and feedback has been very encouraging. As well as giving users an insight into synesthesia, users have frequently remarked on the quirky originality of the concept, and positively gave ideas, prompting the future implementation of extra features and functionality, which could heighten the user experience. An idea currently under consideration is to include sound panning. So if an object was to enter the frame on the left and leave on the right, the system would emulate this by panning the sound from left to right accordingly. The rate of object movement could also be studied and used to influence the pitch of a sound. However, both of these new additions require some form of object tracking, and hence the system would need to take into account previous states.

Indeed the novelty of using colour as a musical controller is not restricted to it being an ambient, interactive musical platform. MusiCam also has considerable scope for developing into a tool for music education, much like the Hyperscore system [12]; a graphical compositional software utility which interprets gestures and strokes as musical ideas.

Modern music artists nowadays use computers to create and manipulate sounds. It is quite often that a band will bring on the stage a laptop as a supporting musician. Triggering these sound clips and tracks can be to the audience visually dull and un-stimulating. By using the MusiCam software as a real-time musical controller instead of the typical keyboard would allow more freedom and expression to the performer and also bring more to the live music experience.

5. CONCLUSIONS

"The sound of colour is so definite that is would be hard to find anyone who would express yellow as a bass note or dark lake with treble…" Wassily Kandinsky

The novelty and curiosity of chromaphonic synesthesia has been the main driver for the development of this project. The demonstration applications have shown that this form of HCI is not only a gimmick but of much value, and only hint at the new possibilities achievable by such a device.

A major benefit of the system developed is that it is easily accessible by others. Since the system is software based, and only requiring the additional support of an off the shelf webcam and regular computer speakers, potentially any personal computer can take on the identity of an interactive musical device.

At present, plans have been made to visit a primary school for further experimental purposes to trial possible applications in both music education and music therapy. Studies have shown that music therapy is especially of value for pupils who through differing forms of autism find it difficult to communicate in more traditional ways [11]. An aim therefore is to establish whether this type of HCI serves as a useful interaction mechanism for these students, as well as an interactive toy. Just as Hyperscore [12] allows children to leap over the obstacle of musical notation and technique in order to express their compositional creativity, the MusiCam software hopes to give children the opportunity to make instrumental music before they have achieved the mastery of the techniques of a conventional instrument.

Acknowledgement: The author would like to express gratitude to Dr. Rachel McCrindle, the supervisor of this project for her assistance and expertise.

6. REFERENCES

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