

# Development of a Synesthetic Music Experience Communicator

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## ABSTRACT

The Synesthetic Music Experience Communicator combines research in the areas of human computer interaction, music technology, and human perception to illustrate the experience of Synesthesia in response to musical sound. Synesthetes have reported positive benefits from the augmented awareness of sound in the areas of pitch identification, memorization, composition, and improvisation. This project attempts to communicate both the experience and performance benefits associated with this cognitive phenomenon. Several virtual worlds have been developed to facilitate group education, rehearsal, and the artistic transformation of live performances into informative and entertaining visual presentations. This brief paper highlights the motivations, implementation, exhibitions, and experimental study of this system.

**CR Categories:** I.3.7 [Computer Graphics] Three Dimensional Graphics and Realism-Virtual Reality; H.5.5 [Information Interfaces and Presentation] Sound and Music Computing-Signal Analysis, Synthesis, and Processing; J.5 [Computer Applications] Arts and Humanities-Music

**Keywords:** Synesthesia, Music, Virtual reality, Human computer interaction

## 1 INTRODUCTION

The Synesthetic Music Experience Communicator (SMEC) is a collection of virtual environments that are designed to simulate the experience of Synesthesia in response to musical sound. Synesthesia-based mental images (photisms) are transformed and colored in response to both MIDI (Musical Instrument Digital Interface) and DSP processed multi-spectrum audio. Specifically, Synesthetic photisms are generated and colored according to the spectral content of the audio and/or pitch of the MIDI events.

This application is designed to provide insight into Synesthesia and Music. The intent of this work is to stimulate thought in the area of multi-disciplinary learning and communication. Another goal is to provide non-Synesthetic musicians with the benefits of this type of musical awareness.

The SMEC has been used to educate students, augment musical and dance performances, and to facilitate musical rehearsals. This paper discusses the motivations and background research conducted in the development this system. The visual modules, their public exhibitions, and results of a preliminary audience study are presented.

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## 2 MOTIVATION

The primary inspiration for this project comes from the one of the authors' life long experiences with Synesthesia and musical performance in a variety of small ensembles. This section highlights key concepts in Synesthesia, describes some musical concepts that have been illustrated through SMEC, and details potential technology applications for use in small ensembles.

### 2.1 Synesthesia

Synesthesia is an involuntary transformation of sensation between sensory modalities [1]. Individual experiences are quite varied and can cross any sensory boundaries. For example, some Synesthetes experience touch, temperature, pressure, or flavors as colors or sound. For others, numerical concepts are translated into spatial relationships. While Synesthetes are aware that these mental projections are not physically present in the real world, the projections are nonetheless real in their minds.

Two key characteristics of Synesthesia are the automaticity and consistency of the experiences. The mental pairings are not explicitly learned or memorized. Rather, they are consistently generated without any conscious effort.

The author, Lewis Hill, has experienced color-grapheme Synesthesia since early childhood (Figure 1). In this condition letters and numbers have an associated color that appears to be projected 'onto' the true color of observed text. These color pairings can also be triggered by hearing and/or thinking of words. This cognitive experience is reported to have added benefit in memorizing and recalling information [1].

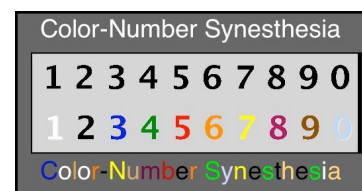


Figure 1. Color Grapheme Synesthesia

This research focuses on colored hearing, the transformation between sound and mental imagery. Often referred to as photisms, these images appear to be projected at the source of the sound or in its perceived spatial location. Photisms can be colored by the pitch of the individual tones as is the case in Chromesthesia, or the photisms may appear to modulate in color and texture in response to the sound stimulus [2].

Synesthetes report benefits from this experience through increased awareness of the nuances of sound. Synesthetic textures and color can be an additional mode of creative inspiration. Colored hearing has been applied in composition and has also been used as an aid for performance, pitch recognition, and memorization [3].

## 2.2 Music

Pitch, harmony, texture, tone and dynamics are some elemental musical concepts that can be illustrated through this Synesthetic approach. Also the circle of fifths is incorporated into some of the visual modules. The project aims to enhance music education by giving students feedback about their performance, reinforcing their meaningful interactions with the sounds, and by demonstrating the relationships between instrument layouts [4].

## 2.3 Observations

Several expanded applications of music technology and computer graphics have been identified while performing in various small ensembles. Included among them are the desires to:

- Augment the live performance with visual imagery to emphasize the vocal content and themes of the music
- Paint, generate, and/or control visual imagery directly from a musical instrument
- Translate the musical performance into intuitively discernible imagery
- Communicate musical parts, concepts, and song structure to other members of the ensemble and audience
- Facilitate rehearsal and practice settings through increased awareness of individual performances.

These application concepts have been refined to leverage other documented reports of Synesthesia, the goals of musical education, and HCI design principles. This project seeks to expand beyond basic concepts demonstrated in other research and commercial software tools.

## 3 IMPLEMENTATION

The SMEC is implemented in C++ and OpenGL on the VRJuggler [5] virtual reality platform. Two Mac OS X based command line programs capture MIDI events and real-time audio data. The first program, *FFT\_Transmitter*, uses PortAudio [6] and FFTW [7] to compute a sixteen band audio power spectra. The second program, *MIDI\_Transmitter*, uses MidiShare [8] to intercept MIDI events. Audio spectra samples and MIDI events are sent through a socket connection to the VRJuggler application. Audio and MIDI updates are received and cached by the VR application. The updates are sent to the visual modules and rendered. Four categories of modules are listed below.

### 3.1 Chromesthesia MIDI Modules

Chromesthesia, a form of Synesthesia, is the pairing of color to pitch classes. In this simple pairing, each note in an octave is mapped to one of twelve array entries. Each entry contains a single RGB color value. A sample pairing is C to red, D to orange, E to yellow, and so forth. The Chromesthesia modules (Figure 2) feature a variety of arrangements including: grids, spiraling arrays, frequency plots, L-systems trees, life simulations, note-reactive pillars, a color-speckled wall and more.

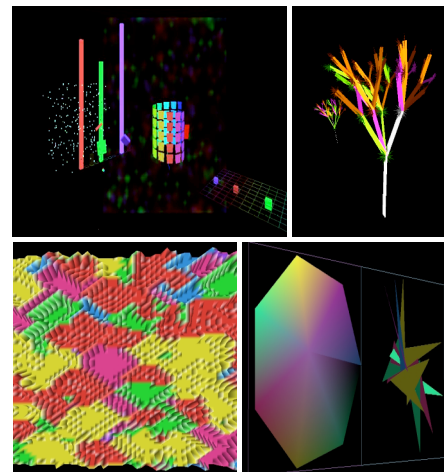


Figure 2. MIDI/Chromesthesia Modules

### 3.2 Real-time Audio Modules

In these modules, each of the sixteen audio bands is used to animate concentric or parallel layers of the displays. These modules are fashioned after the photisms depicted in [1]. These visual modules are patterned after the radial symmetry, parallel movement, geometric lines, and scintillation form constants. Depicted in Figure 3 are a Musical River (top), SpeakerBoxx (left), Lollipop (right), and a Multi-Colored Ribbon (bottom). In the two middle modules, the intensity of low frequency audio spectra drives the color or brightness of the inner sections, and high frequency drives the outside. The resulting module makes a very clear distinction between percussion sounds. The river and multi-colored ribbon show the progression of audio over time. In the upper figure, audio intensity is matched to a multi-colored spectrum. In the bottom, each individual band is assigned a single color and the width of that band is based on the intensity of that power spectra.

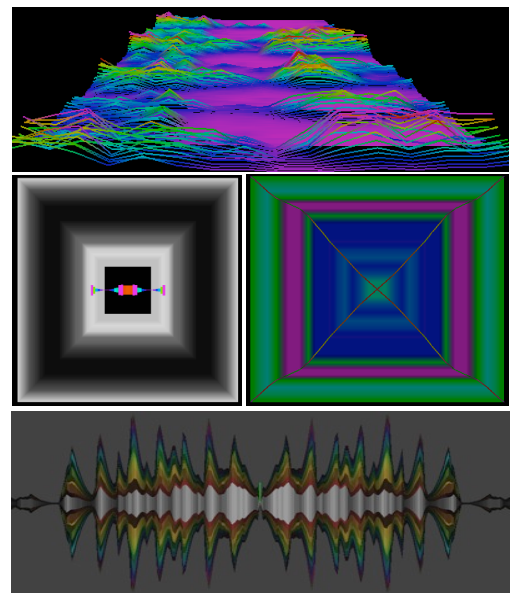


Figure 3. AUDIO Modules

### 3.3 Audio\_MIDI Hybrid Modules

These modules are driven by a combination of MIDI data and real-time audio. They perform an adaptation of Xenakis' technique [9] for charting audio spectra and intensity. One of his approaches plots pitch, intensity, and time on perpendicular axes, resulting in a three-dimensional volume view of sound. In the first two modules, shown in Figure 4 below, MIDI information is plotted along the vertical axis and audio data along the horizontal. Frames recede outward and fade into the virtual space over time. The resulting output resembles amorphous blobs depicted in Cytowic [1]. Photism color and size are determined by the intensity of each band.

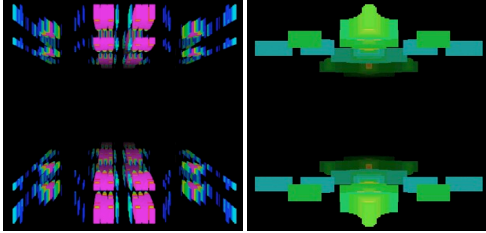


Figure 4. AUDIO\_MIDI\_HYBRID Photisms

Other examples of these hybrid Audio MIDI modules (Figure 5) implement colorings, scaling, and/or placements that blend and change in response to the power spectra of the input audio. These modulated images depict the dynamic and responsive nature of photisms.

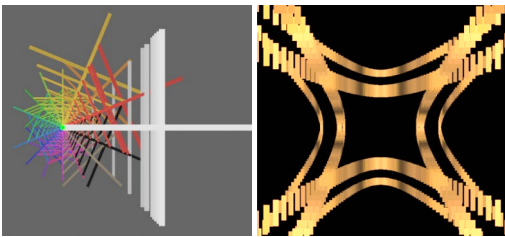


Figure 5. AUDIO\_MIDI Color and Placement



Figure 6. MIDI\_AUDIO Mandala

The MIDI Mandala (Figure 6) combines both Chromesthesia and scintillating extrusion of the audio data. In this module, the MIDI notes drive the background colors. Notes are depicted as vertically collapsing lines and as particle emitters arranged according to the circle of fifths. The central portion of the Mandala features concentric rings of spectrally colored audio

information that collapses towards the center point. Lines are drawn connecting the peak intensity band in every frame.

### 3.4 Ensemble Support Tools

The Computer Augmented Percussion Trainer (CAPTAIN) and Small Ensemble Trainer (SMET) are designed to inform the ensemble and/or instructors about the musical performance. Musical events are depicted on a real-time scrolling display. The horizontal length of the bars indicates note duration. The horizontal placement indicates note onset and the vertical thickness is proportional to the intensity of the notes. Vertical lines are drawn to indicate the start position of the tones. Each member of the ensemble is depicted in the CAPTAIN display as a unique color (Figure 7).

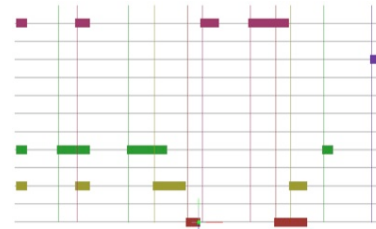


Figure 7. Computer Augmented Percussion Trainer

The Small Ensemble Trainer, (Figure 8) depicts multiple octaves of notes in a similar scrolling display. It also includes a bass guitar fret-board and a simulated piano keyboard, both of which indicate the position of all active notes. This module was conceived to improve communication of notes and chords to ensemble members who are less knowledgeable in the areas of theory and/or musical notation.

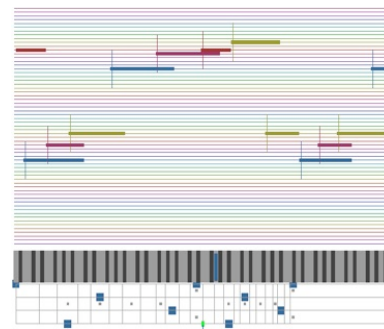


Figure 8. Small Ensemble Trainer

## 4 EXHIBITIONS

These modules have been demonstrated in education, entertainment, and rehearsal settings. The SMEC has been used to illustrate musical concepts in classrooms, immersive projection technology systems, and large 225-seat stereo-enabled auditoriums. Elementary through post-graduate level students were excited by the opportunity play music and explore a virtual world of music, color, mathematics, and sound.

These modules have been projected on stage during electronic, Caribbean, and jazz-fusion ensemble performances in live music venues. The SMEC has also been used to augment modern dance performances. Custom audio-driven scenes were constructed to

depict imaginary locations (Figure 9), such as a musical water fountain (top) or a metallic echo chamber (bottom).

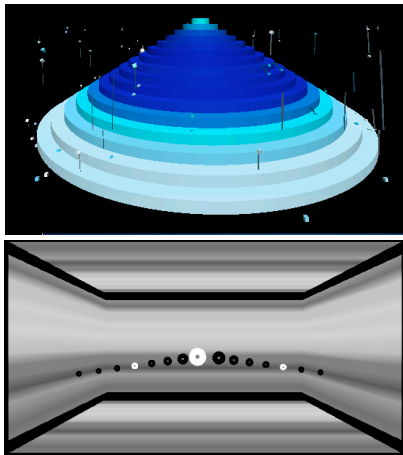


Figure 9. MIDI Fountain, Metal Room

## 5 EXPERIMENTATION

Audience feedback and lessons learned from the various exhibitions have indicated some benefits, limitations, and areas for improvements. An introductory user survey was conducted to ask specific questions about participants' experiences. The SMEC modules were presented in three small focus sessions to a total of twenty-five participants. Participants were given the opportunity to interact by using the keyboard and/or making vocal sounds.

The visual modules were divided into four categories as presented in section three above. Participants were asked to complete a brief survey after each set of modules and to provide some background information about their musical experiences. The participants in this study reported an average of 8.5 years experience with instrumental music and 6.5 years experience with vocal music performance. 64% of the group reported novice or greater ability with the piano. Several had experience with other instruments.

### 5.1 Audio and MIDI Modules

Initial results of this study indicate that the participants understood the Chromesthesia mapping between colors and tones. Subjects reported that the real time audio modules gave them a very clear picture of the flow of the music over time and reflected the changes in the input sounds. Subjects also indicated a stronger preference for multi-colored audio spectra mapping than attenuated single color or grey scale color mappings. The hybrid-audio MIDI modules were fairly effective in communicating the concept of a color shift in response to the texture of the input sound.

Subjects were asked to evaluate the ability of each of the MIDI, AUDIO, and MIDI\_AUDIO\_HYBRID module sets to communicate pitch, harmony, and texture. As anticipated, subjects indicated that the Chromesthesia MIDI modules best communicated individual pitches and were not very effective at indicating the texture of the music. The AUDIO modules were rated fairly effective in communicating pitch and texture. The MIDI\_AUDIO hybrid modules communicated texture well, though less effectively than the AUDIO only modules. There seemed to be some confusion when both the MIDI and AUDIO

data were combined together, indicating a need for improved mapping strategies in that area.

### 5.2 Ensemble Support Tools

The ensemble support modules were highly rated for their ability to represent the relative timing and number of notes being played. Subjects felt the modules were less effective at representing the intensity of the notes. Both ensemble modules were estimated to have high potential to facilitate ensemble rehearsal. Written comments revealed areas for future extensions of these modules.

### 5.3 General Perceptions

The participant group indicated that the Synesthetic virtual environments were moderately effective at making the musical experience more accessible to non-musicians. The visuals they had seen were moderately different from those found in WinAMP or iTunes. Subjects written comments indicated that these modules performed a very explicit transformation of the musical data. The overwhelming majority of subjects did feel that this system would be an interesting visual addition to a live performance. Also, subjects estimated high potential for use in entertainment, education, and rehearsal.

While the data gathered in this study are very preliminary, the written comments have suggested several important considerations for future work on this project. User comments also reflect the intent and goals of this research effort. Participants could clearly see the benefits, difference, and practical applications of this research.

## 6 ACKNOWLEDGMENTS

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