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The 21st Century Virtual Reality Color Organ

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The 21st Century Virtual Reality Color Organ is a computational system for translating musical compositions into visual performance. It uses supercomputing power to produce 3D visual images and sound from Musical Instrument Digital Interface (MIDI) files and can play a variety of compositions. Performances take place in interactive, immersive, virtual reality environments such as the Cave Automatic Virtual Environment (CAVE), VisionDome, or Immersadesk. Because it's a 3D immersive world, the Color Organ is also a place—that is, a performance space.

We are the principals of the Organ project and have collaborated with a growing list of contributors from both industry and high-performance computing universities (see the "Acknowledgments" section for more information). Britton handles the graphics programming and the metaarchitecture of the programming structure (see the sidebar "The Technology Behind the Color Organ"), while Ox contributes the concept, visual images, musical analysis, visualization systems, and texture maps.

This interactive instrument consists of three basic parts:

1. A set of systems or syntax that provides logarithmic transformations from an aural vocabulary to a visual one.

2. A 3D visual environment that serves as a performance space and the visual vocabulary from which the 3D environment was modeled. This visual vocabulary consists of landscape and/or architectural images and provides the objects on which the syntax acts.

3. A programming environment that serves as the engine of interaction for the first two parts.

Ox has a 20-year history of visualizing music by devising systems of equivalences that "translate" organized collections of data, gleaned from preexisting compositions. This self-authored language involves the interaction of multiple layers of information in a complex way. She has been developing and using an almost living, always expanding system for the specific purpose of making visual the structures of varieties of music.

The artworks that have emerged from this process embody principles of *intermedia* as defined by Dick Higgins,[1] the late avant-garde theorist and Fluxus artist. Intermedia is a completely different concept from multimedia, although it can be included in a multimedia environment. With multimedia, content/information is presented in more than one medium simultaneously. However, intermedia is a combinatory structure of syntactical elements that come from more than one medium but combine into one. The final form can only be seen after going through the entire process.

Collection of data: Analysis of music

The first part of the analysis task is to determine the structural parameters of the piece of music to be visualized. In other words, what are the operating principles and which data sets should be collected? Does the composition exist within a diatonic/chromatic harmonic framework, or is it composed from layers of carefully chosen timbres (sound qualities)? These two approaches mean very different things and are therefore visually depicted with completely different color systems.

Ox makes a detailed analysis of each set of information present in all performances. For instance, if a piece of music can be reduced to a piano score, then it doesn't depend on the timbre of different instruments to be that composition. For example, when Ox analyzed the *Eighth Symphony of Anton Bruckner*, she made a traditional harmonic analysis. For Kurt Schwitters' 41-minute sound poem called

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the *Ursonate*, she did a phonetic analysis.

The compositions Ox has worked with also contain data sets including patterns of rising and falling melodic lines, changes in dynamics (loudness), and rhythmic units, and patterns with the initial "attack" of the notes and their articulations. The Color Organ encodes this information in MIDI files.

Creation of corresponding data sets: Visual vocabularies

Ox chooses appropriate visual vocabularies, that is, images that express attributes of the music in a metaphorical way.

Images and their reordering

Ox gathers images by making very high-resolution photographs on location, then does detailed pencil drawings in the studio, often combining three or four photographs into one large view (see Figure 1). The drawings must be information rich and well rendered so that during the extensive processing they will hold their character and be recognizable.

She then cuts up the original two-dimensional, hand-drawn images and reorders them based on the previously mentioned analyses of dynamic changes, and melodic and rhythmic structures. Changes of image scale represent louder or softer music. The length of the units representing a single note or chord is determined by its corresponding time value. Melodic changes create shifts in the vertical placement of image units in the virtual reality 3D space. When the visual units finally appear in their new abstract formations, the original representational themes become subliminal in their appearance to the viewer. These multivaried changes occur through complex interactions of multiple simple systems.

Currently, the Color Organ has one visual environment and vocabulary, which corresponds to the idea of a "stop" in a traditional organ. An organ stop is a particular voice in sound. In the future, other artists will be invited to contribute to a collection of visual organ stops. The first stop has eight different desert landscapes gathered from real places in California and Arizona. Each landscape is connected to a particular family of instruments because the structure of the earth and rocks mimics their sound production. Each image is itself a collection of data, containing content in both patterns of lines and colors, and also the metaphorical connection to the instrument family (see Figure 2, next page).

The Technology Behind the Color Organ

The Color Organ is a virtual reality installation implemented as an ANSI standard C++ application that can be compiled for either Windows NT or SGI Irix. Britton built the core graphical rendering engine with the EAI Sense8 World Toolkit VR library (WTK). This library provides an OpenGL-based, rich, cross-platform application programming interface (API) for rendering 3D objects in an immersive computer display and contains the central simulation loop governing behavior and movement from one frame to the next. With high-powered graphics hardware, frame rates approaching 30 fps can be achieved, depending on texture resolution and polygon count.

Of particular interest is the ability of WTK to import graphical 3D objects built with common and relatively inexpensive off-the-shelf 3D graphics packages, such as Kinetix 3D Studio. The background of the initial "stop" (the desert landscape) is a set of very high-resolution textures (2D images) applied on a relatively low polygon count (about 10,000 polygons) wireframe structure. Richard Rodriguez of Umagic did the modeling in Caligari TrueSpace and Kinetix 3D Studio Max, and Ox created the texture maps (not images) in Adobe Photoshop. These 3D objects and texture images are read in at the start of the piece by WTK functions. WTK paints these highly detailed and complex structures with OpenGL code.

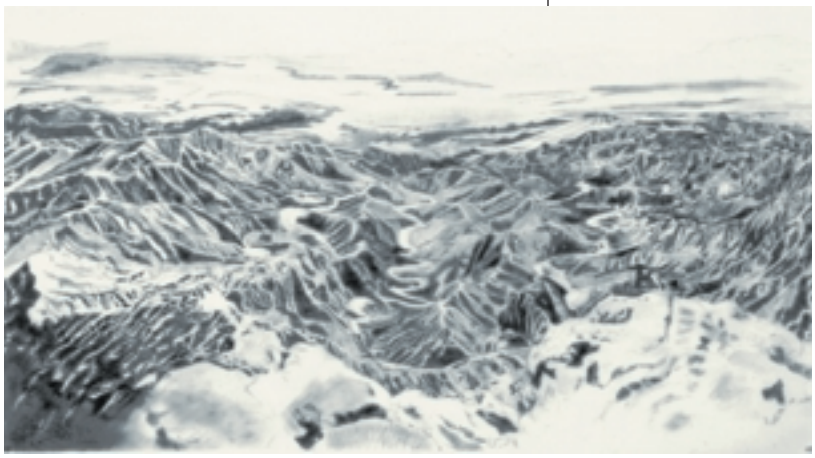

Figure 1. An original pencil drawing of a desert floor hill sculpture from Fonts Point in the Borrego Springs desert (near San Diego) that represents the family of stringed instruments. Ox imagined that if a bow moving back and forth across strings were tracked, it would leave hills shaped like these. Note that Ox created this image before the reordering process.

Transparent color systems

For the second part of the visual vocabulary, Ox applies a transparent layer of color over the displaced and reordered images. Early in the process she determines which information these overlaid

Figure 2. An original pencil drawing of the desert ground just as the sun goes down in the Borrego Springs desert. This image serves as the ground cover texture map in the Color Organ's environment and represents the visual vocabulary for percussion instruments like sandpaper blocks or rocks.

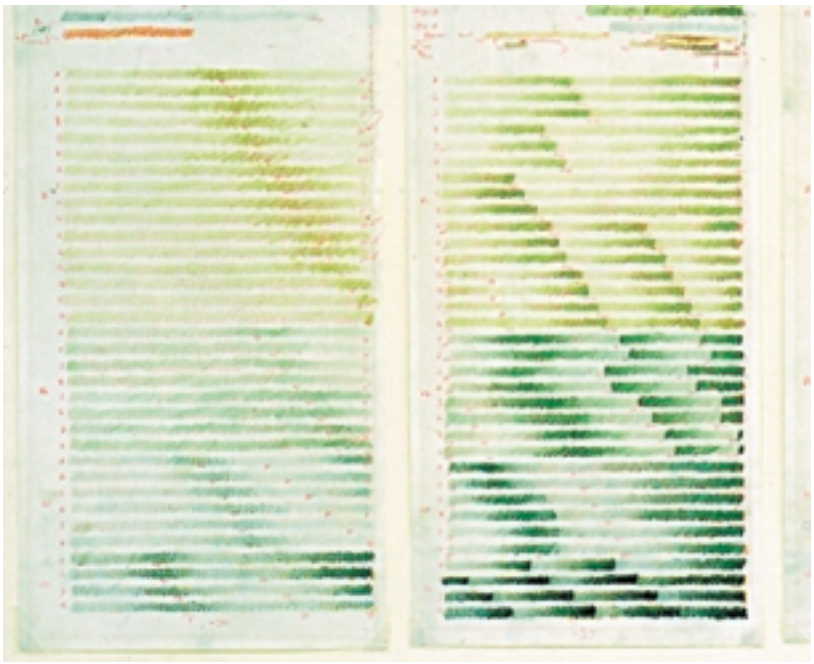

Figure 3. Ox created this timbre score for a string section of Quanta and Hymn to Matter by Dary John Mizelle directly over the original score. It tracks both timbre and dynamics with timbre represented by hue and dynamics by saturation.

color systems should express. For harmonically based music Ox developed a system to visualize both harmonic movement and harmonic quality. She superimposed a 12-step color wheel over a circle of fifths, since the ordering of both is a 12-step circle. A circle of fifths is a circular ordering of keys with closely related keys lying next to each other and those not related directly across from each other. Keys next to each other are closely related because they share many of the same notes in their scales. The minor keys are three steps behind in an inner wheel, also in emulation of the circle of fifths. As the music modulates through keys, the same pattern occurs as movement through colors.

Harmonic quality refers to the relative dissonance or consonance of two or more notes playing together. It's a sliding scale between the two extreme ends within a given style of music. If a pure hue represents extreme consonance, then a 50-50 mixture of the original color and its complimentary color—that is, 50 percent orange with 50 percent blue—represents dissonance. (This makes a gray hue.) There are six steps of relative dissonance/consonance between the ends.

The most recent color system Ox created is based on timbre, literally meaning the color of sound. Music structured on timbre combines specific, differentiated sounds, much like a painter chooses to use color (see Figure 3). Whereas the color system based on the circle of fifths maps harmonic movement and quality in music that takes its structure from these concepts, this later system is effective with music whose actual sounds form the structure. Ox created a list of more than 130 mixtures of red, green, and blue (RGB) hues where families of instruments are represented by sets of colors in a graduated series, further modified by different mutes' and/or playing techniques' visual equivalences. The color system describes timbre changes for vocal lines, much as changes in the vocal-tract shape alter timbre.

The viewer's experience in the Color Organ

When the performance begins, viewers are in a world of hand-drawn landscapes modeled in 3D. All the landscapes are black and white, with the sky completely black.

The Organ handles MIDI data read in from a standard format MIDI file, which serves conceptually as the musical score, since it contains instructions about how to produce the music, not the actual sounds. From this informational content—based on Ox's choices for color, texture, and placement—the system creates a set of 2D colored and textured planes dynamically, at the same time the music is playing (see Figure 4).

The system builds the planes from the flat pictures of the landscape images representing the instrument families that produced them. Each plane represents a note, or more accurately, it executes or visually realizes a note from the MIDI score. They're colored a specific hue based on a timbre analysis of which instrument is being played

and what the particular playing technique is at that moment (see Figure 5). The saturation of the color reflects changing dynamics (loud and soft). These flat strips of landscape are placed up and down in vertical space by their pitch. A higher pitch will be higher in space and a low pitch will be placed closer to the landscape below. The signal's volume (attack) controls the width of the strips.

After the music has played, there remains a complete sculpture that can be further explored interactively. Viewers can move through the space and touch elements of the sculpture and hear the sound that originally produced it.

The future

The Color Organ will be able to function on two levels in the future. It will play preexistent compositions as now, but Britton is redoing the program architecture so that different musical parameters can be plugged in and out easily. The second goal is for the Organ to translate the MIDI signals from live, improvising musicians, who could be located in different locations along the AccessGrid, a network of supercomputing universities on Internet2. The visualization and sound will appear in the immersive environments also located on the Grid. If the musicians are improvising, it then becomes a complex adaptive system. **MM**

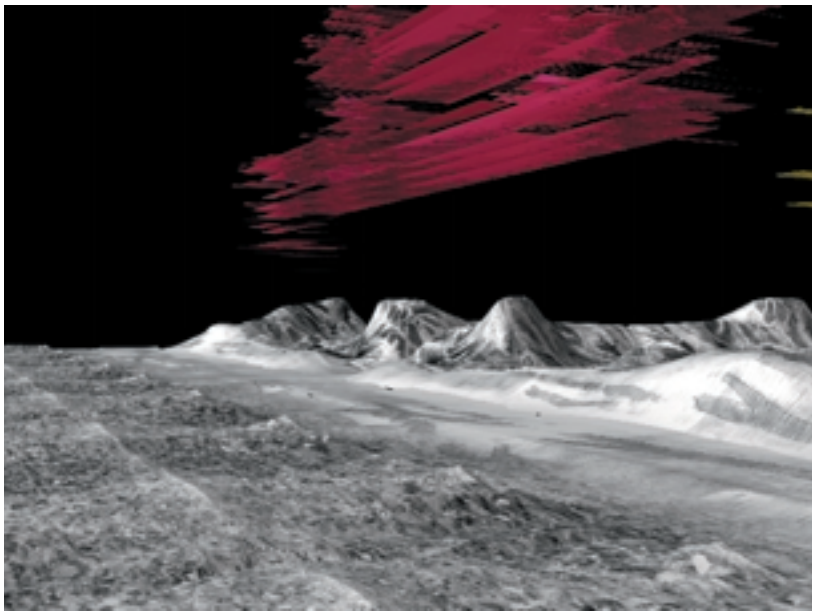

Figure 4. A still shot from the Color Organ from the ground showing the strings landscape with a red structure over it generated by piano MIDI files.

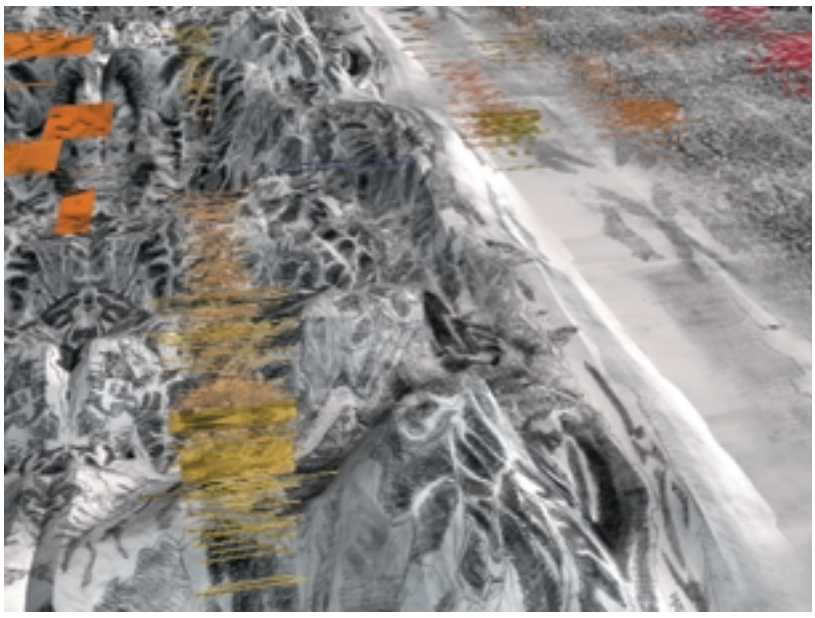

Figure 5. A still shot from the Color Organ taken from above. The colored strips were created by percussion with very thin, therefore short, beats directly below.

Acknowledgments

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Reference

1. D. Higgins, "Intermedia," *Something Else News*, No. 1, 1966. Also in *The L=A=N=G=U=G=E Book*, B. Andrews and C. Bernstein, eds., Southern Illinois University Press, Cabondale and Edwardsville, 1984.

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