PROBABLY/POSSIBLY?

An Immersive Interactive Visual/Sonic Quantum Composition and Synthesizer

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ABSTRACT

This research project is based on 32 years of Kuchera-Morin's research and practice in spatio-temporal music composition and media arts. The project is an immersive interactive visual, sonic computational instrument presented as an installation, which includes the development of an open-source computational language, and Kuchera-Morin's immersive interactive visual/sonic composition PROBABLY/POSSIBLY? Using the mathematics of quantum mechanics, the immersive instrument and computational language facilitates the creation of new, unique visual/sonic art forms. This project allows the artist to drive scientific and technological research for creative expression. This same technology is giving physicists insight into higher dimensional representation. The immersive visual/sonic instrument and language is based on the time-dependent Schrödinger equation splitting a hydrogen-like atom's electron in superposition in various orbitals. The immersive media composition, PROBABLY/POSSIBLY? can be interactively performed using our multimodal computational platform and open source language. The instrument/installation can also be used to compose and perform a number of art works based on the time-dependent Schrödinger equation.

KEYWORDS

immersive multi-modal installation, interactive immersive multimedia art work, immersive multi-modal multimedia system installation

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1 INTRODUCTION

In building our language and immersive computational instrument/installation, we investigate composing elementary wave functions of the hydrogen-like atom. There are several relationships between this physical phenomena and musical composition that facilitates this process. The hydrogen-like atom accurately describes some of the fundamental quantum mechanical phenomena of nature and supplies the composer with a set of well-defined mathematical constraints that can create a variety of complex spatio-temporal patterns [6]. Perceptualizing the atom can assist in understanding emergent patterns, flows, symmetries, and dynamics when multiple hydrogen-like wave functions are mixed in superposition.

In order to represent the wave functions, we use software that we have developed for our large immersive system and instrument, the AlloSphere, a three-story immersive cylinder/capsule placed inside a near-to-anechoic chamber [1, 5]. The AlloSystem software libraries facilitate the interactive visualization/sonification of this information and the AlloSphere facilitates full immersion in the data.

The AlloSphere instrument and software infrastructure is Kuchera-Morins concept-design, based on her research and creative practice in spatio-temporal music composition

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Figure 1: Composer JoAnn Kuchera-Morin on the bridge of the AlloSphere Instrument, performing PROBABLY/POSSIBLY? on the virtual keyboard interface.

Figure 2: Front view of installation in a 1000 square foot installation space. 100 degree curved screen, 2 stereo projectors, 8 channels of sound, and multiuser touch screen.

and instrumental ensemble performance since 1984 [2, 5]. The AlloSphere can provide an intuitive understanding of the hydrogen-like atom through visual and sonic perception, and also permits virtual experimentation by mapping the mathematical coefficients of the equation to an interface that allows researchers to run various scenarios of the equation in real-time. The AlloSphere design facilitates observation of multiple levels of structure in a way that is more natural than a flat display wall.

2 SCALABLE SYSTEM INSTALLATION DESIGN

The AlloSphere instrument is scalable and the software language portable to any system configuration The first scalable system for the hydrogen atom prototype and the composition Probably/Possibly? was a 100 degree curved screen design with 2 stereo projectors, 8 channels of sound and the AlloSystem software running in real time, with multi-user interactivity of trio-style.

2.1 Emerging Technologies Compositional Platform and Instrument Design

This installation pushes the envelope in emerging technologies both from the standpoint of computational design as an instrument and a computational language created as open source software libraries and interfaces based on a visual/sonic/spatio-temporal compositional sketch system design.

As an instrument: the system/installation can be configured to include any number of immersive displays, speakers and input, output, and control devices, assembled in ensemble-style fashion, much in the same way that a group of performers would interact and control instrumental ensembles of various sizes and configurations [4, 5]. Regarding interface design, the visual/sonic interface is designed as a virtual pipe organ, since the eigenfunctions of the Hamiltonian operator are stationary states of the quantum mechanical system and are analogous to normal modes in a pipe.

As a computational language: our open-source software system facilitates the design of any system configuration as described above, while providing software libraries that integrate visual, sonic and interactive material, providing a virtual spatio-temporal n-dimensional sketch system of creating, manipulating and transforming any data, including mathematical equations and real data from instruments or simulations [3].

3 COMPOSITIONAL PROCESS AND PERFORMANCE

The evolution of a quantum state is realized by a process that is analogous to additive synthesis in music. A general time-dependent quantum state is achieved by the superposition of a number of stationary state wave functions, the eigenfunctions, multiplied by periodically varying coefficients. The eigenfunctions correspond to the simple sounds that add together to form the complete synthesized sound. Their superposition produces the complex spatio-temporal pattern described by the time-dependent wave function.

We use the eigenfunctions as basic units to make the visual and sonic language for the composition by scaling the frequencies down by orders of magnitude into the visual and sonic domain. Eigenfunctions are identified by a set of quantum numbers that determine the particular shape of the eigenfunction in space as well as its frequency of evolution through time. Eigenfunctions can be placed in superposition to create a wave function. These wave functions generally have more complex properties than their constituent eigenfunctions. The

hydrogen eigenfunctions provide adequate complexity to be used as building blocks for Kuchera-Morin's composition. Using hydrogen rather than the harmonic oscillator is analogous to using an organ to create music rather than individual sine waves. This lends sufficient interest in using the compositional process of mixing waveforms to build chords that act as building blocks for visualization and sonification. [6].

Kuchera-Morin begins with nine two-wave and three-wave function combinations to design her chordal grammar, using the quantum number combinations designed by physicist, Luca Peliti. The nine basic wave function combinations that we have named and their quantum numbers describing their shapes can be viewed in the supplemantary file, picture 14.

3.1 Playing the Hydrogen-Like Atom Visual/Sonic Instrument

Just as the quantum numbers give rise to the different visual shapes shown in picture 14, and as these shapes move over time, we use visual and sonic agents to track the probability currents and gradients of the electron.

The visual colors show the electrons spin among the various wave combinations, and the timbres are the sonification of the field agents displaying the wave functions. There are six possible spin relationships among the three wave combinations. We have programmed our visual and sonic hydrogen organ so that we can control these sound color combinations through the frequency (f) and weight (w) numbers on our organ controller.

The visual keyboard interface as shown in pictures 5a, 5b, and 5c, in the supplemantary file included with this submission, has the quantum numbers available for creation and transformation in performance.

3.2 Spatio-temporal Composition Considerations

Music unfolds mathematical frequencies in time and space on several time-scales, from individual pitches and sounds (foreground) to musical phrases and sections (middle ground), to large-scale form and structure of a work (background), each involving intertwining spatio-temporal relationships. When a composer begins a composition, usually they have an idea of a large form, thinking of the background level, or they hear a small motive that may begin the process at the micro-structural level. As composers compose music out of time, a very important strategy is to work at the middle-ground level. This facilitates shaping the larger structure through the micro-structural material that unfolds the work [7].

In the self-generative music of composer, Iannis Xenakis, regarding the generative material at the micro-structural level, the local events are decided randomly. A middle ground-to-foreground approach becomes very important in aiding local directional choices as Xenakis uses clearly articulated probability distributions to constrain local events [8]. This approach is similar to the relationship between the deterministic Schrödinger evolution and the probabilistic measurement process in quantum mechanics.

Kuchera-Morin's approach in composing with the hydrogen-like atom is to start with a middle ground, which we identify as interference patterns. Thus, one can experiment with various combinations of multiple wave functions that are scientifically correct and aesthetically pleasing. The process begins with mixing multiple eigenfunctions together. The studies range from the physically motivated to the open-ended, exploring beating and complex interference patterns such as fine splitting. Thus, we are creating the basic musical alphabet by mixing the multiple eigenfunctions together with certain chosen characteristic frequencies.

3.3 Composition of Probably/Possibly

PROBABLY/POSSIBLY? explores the visual/sonic appearance of these various combinations of two and three wave functions of an electron with spin in a hydrogen-like atom, highlighting the resulting symmetries and symmetry changes as a visual/sonic narrative. The composition is a two-movement sonata form. There is a complete analysis of the compositional form and structure in the supplmenatary file on pages 11 and 12.

Complete videos provided at this website:
http://www.allosphere.ucsb.edu/kuchera-morin/

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