

Jelani Gould-Bailey

*Harmonics*

Research Paper

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## **Introduction:**

A system can be defined as a structured framework with one or more sets of predefined rules that govern or predict behavior within it. Some see the universe as such a system, with an underlying structure and rules that govern behavior on a microscopic and macroscopic scale. Understanding this underlying structure has been a goal of the science, religion, and philosophy for thousands of years. Of particular interest are the areas in which the 3 disciplines intersect.

One such intersection is the concept of interconnectedness amongst all things. This is exemplified in Indian religion and philosophy through the concept of *brahman* and in physics as the law of conservation of energy.

Another area of intersection is the importance of vibration. Vibration holds an important role in Indian religious, philosophical, and mythical frameworks. Sound is one form of vibration and plays an important role in the universe, as established in several Indian religious scriptures<sup>1</sup>. The primordial sound mentioned in these sources, *Aum* (also spelled *Om*), is still used in contemporary yogic practice.

Vibration also forms the underpinning of the leading “theory of everything” in contemporary physics, M-theory (which is an extension of String Theory). Some contemporary physicists believe that tiny vibrating strings are the fundamental building blocks of the universe and that all matter and energy are derived from different vibrations of these strings. Vibration is seen as one of the fundamental elements of the universe’s system in both communities.

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<sup>1</sup> Including The Upanishads and the Bhagavad-Gita.

My MFA thesis project, entitled *Harmonics*, is a system which explores the concepts of structure, vibration, and harmony. *Harmonics* allows the interactants to investigate the concepts of vibration and harmony as related to both the underlying structure of the system and the overall structure of the universe.

### **Project Description:**

*Harmonics* is an interactive audio-visual installation that explores the concepts of interconnectedness, vibration (frequency), and harmony. Interactants generate music using buttons and sliders. The system creates visuals in real-time in response to the user-generated music.

*Harmonics* features a computer, projector and 2 user interface stations. The visualizations are projected onto a large screen. Audio is played back through speakers facing the users. Custom programs written in different computer languages (Wiring, Max/MSP, Processing) gather information from the user interface stations, control communication between different programs, and present visual and auditory feedback to the participants.

The visualizations in *Harmonics* are comprised of 3 separate pieces (scenes) shown on the screen in sequential order. Each piece has a theme based on different aspects of personal development I underwent while making the project. The themes also relate to the historical and conceptual research for the project. The 3 themes are “Structure Beneath the Surface”, “In from Without / Out from Within”, and “Order Out of Chaos”.

The goal of all 3 scenes is to encourage harmony between the users, as expressed through the sounds they generate. The system rewards user interactions which are considered harmonious by increasing the complexity of the visual display.

The 3 visualizations contain common elements, such as representations of notes, ‘harmonic objects’, and the hardware interface (sliders). Harmonic objects are special notes produced when the interactants simultaneously play notes with a specific musical relationship to each other, such as a Perfect

Fifth. Only specific intervals which are considered harmonious by Western musical standards produce a harmonic object.

Each scene uses harmony to change the behavior of the underlying system in a different way. For example, in “Structure Beneath the Surface”, notes and harmonic objects function as moving windows on a black surface, revealing complex artwork beneath. The harmonic objects have fixed movements, providing a more detailed view than the notes. “In From Without / Out From Within” creates a series of layers which dissolve in rectangular segments as free-floating harmonic objects collide into them. In this scene the harmonic objects have a magnet-like property that attracts the notes to them, allowing them to dissolve these walls and reveal different layers of artwork beneath. In “Order Out of Chaos”, the notes “swim” around a white background, and as harmonic objects are created they move to the center of the screen and orbit several times, carving out space before disappearing. Notes cannot travel into the space the harmonic objects have carved and in this way a balance is created between the orderly movement of the harmonic objects and the chaotic movement of the notes.

The controls for *Harmonics* consist of 2 user control stations. The stations each have 2 arcade-style pushbuttons and a slider. Despite the simplicity of the input controls, they allow a range of complex interactions with the system. The first pushbutton (top) creates a note, while the slider controls the pitch. The second pushbutton (front) starts a new percussive track which plays continuously beneath the user-generated sound. The buttons and slider are wired into an Arduino microcontroller, which connects to the computer via a USB port. The interface design is intended to provide a simple, intuitive set of controls with which the participants can control the sound and visual aspects of the system.

### **Literature Review:**

Modern western science and ancient Indian religion & philosophy have several areas of intersection, including theories of universal

interconnectedness and the importance of vibration. Through an emphasis on harmony at a systemic level, *Harmonics* investigates whether users can effectively learn to interact more harmoniously with each other in a musical context, regardless of prior musical knowledge or skill. One of the central underlying questions in *Harmonics* was whether placing a systemic emphasis on harmony would allow the user to make a conscious (or subconscious) connection to the larger underlying spiritual and scientific theories on which the project is based.

The idea of interconnectedness within nature (i.e., “oneness”), is one of the central tenets of early Vedic philosophy, which forms the basis for Hinduism, Buddhism and Jainism. This idea of oneness is referenced in The Upanishads as *brahman*, which can be loosely translated as “absolute reality” (Radhakrishnan and Moore, 4) or “an impersonal absolute that might also be called oneness or being” (Hamilton, 29). The following passage from the Chandogya Upanishad explains the universal nature of *brahman*:

“In the beginning, my dear, this world was just Being (*sat*), one only, without a second. To be sure, some people say: ‘In the beginning this world was just Non-being (*a-sat*), one only, without a second; from that Non-being Being was produced. But verily, my dear whence could this be?... How from Non-being could Being be produced? On the contrary, my dear, in the beginning this world was just Being, one only, without a second.”

-Radhakrishnan and Moore, 68

Several thousand years later, the Western world would explore some of these same ideas within the framework of physics. Modern physics includes a number of theories which purport that empty space is not so empty after all, and that the known universe is in actuality interconnected.

Physics upholds that the universe is permeated by a number of invisible “force fields”. In the early 1800s Michael Faraday developed the concept of a field after “tens of thousands of experiments that exposed hitherto unknown features of electricity and magnetism” (Greene, 40). In the mid-1800s James Clerk Maxwell further advanced Faraday’s concept by developing a set of

equations that showed that electric and magnetic fields are actually part of a combined field, today known as the electromagnetic field.

One of Albert Einstein's more famous discoveries was the General Theory of Relativity, which overturned Isaac Newton's theories about gravity. Under Einstein's theory gravity warps space and time. Einstein developed a mathematical basis for this theory (the Einstein field equations) and "viewed the warping of spacetime as the manifestation - the geometrical embodiment—of a gravitational field" (Greene, 70). The field concept was further extended in the 1950s by C.N. Yang and Robert Mills who developed a theory explaining strong and weak nuclear force fields.

In addition to notions of force fields, contemporary physics also theorizes the existence of 2 other kinds of fields - matter fields and Higgs fields. The concept of probability waves in quantum mechanics can be applied to field theory, whereby the "probability waves...may themselves be thought of as space-filling fields that provide the probability that some or other particle of matter is at some or other location" (Greene, 256). There is also a theory regarding a third kind of field permeating the universe, a Higgs field, which impacts the acceleration of subatomic particles<sup>2</sup>. The Higgs field "interacts with quarks and electrons: it resists their accelerations" (Greene, 261).

The application of the quantum mechanical uncertainty principle also makes the notion of "empty space" questionable. The uncertainty principle can be extended to all fields, which are "subject to frenzied quantum jitters on microscopic scales...these field jitters exist even in space you'd normally think of as empty, space that would seem to contain no matter and no fields" (Greene, 330). So, the contemporary Western scientific view contains several theories (force, matter, Higgs fields; quantum jitters) that uphold that empty space is not really empty<sup>3</sup>. Under these theoretical frameworks, matter and

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<sup>2</sup> Like String/M-Theory, the Higgs field has not been experimentally detected to date.

<sup>3</sup> "The intuitive notion of emptiness, one in which all fields have and maintain the value zero, is incompatible with quantum mechanics. *A field's value can jitter around the value zero but it can't be uniformly zero throughout a region for more than a brief moment.* In technical language, physicists say the fields undergo *vacuum fluctuations.*"

-Greene, 330-331.

energy in the universe can be seen as interconnected in a variety of ways, which all fundamentally deal with the concept of fields spread ubiquitously throughout spacetime. Field theory in physics can be seen as similar to the Indian concept of *brahman*.

Another connection between ancient Indian philosophy and physics is the importance of vibration. Vibration in the western scientific definition is movement (oscillation) around an equilibrium point, and can include periodic motion such as the swinging of a pendulum. What we perceive as sound are vibrations of the air molecules around us.

Sound plays a vital role in Indian religious and philosophic texts. The primordial sound *Aum* (or *Om*) is referenced as the “seed of all that exists” (Shearer and Russell, 37), “the whole world” and “the past, the present and the future”(Radhakrishnan and Moore, 55) in the *Mandukya Upanishad*. The *Bhagavad-Gita* makes explicit connection between *Aum* and *brahman*, stating “He who utters the single syllable *Aum* which is *Brahman*...” (Radhakrishnan and Moore, 130). The *Chandogya Upanishad* proclaims that “as all leaves are held together by a spike, so all speech is held together by *Om*. Verily, *Om* is the world-all. Verily, *Om* is the world-all” (Radhakrishnan and Moore, 65). The Tantric tradition continues this belief in the prominent importance of *Om*, whose 3 syllables “a, u, m ... represent three phases of the cosmic cycle - creation, preservation and dissolution - condensed into a single sound unit” (Mookerjee and Khanna, 34).

Tantric practice involves the combined use of mantras (sound) and yantras (visual representations) in a variety of ways including deity worship, meditation and as forms of protection. Mantras are Sanskrit syllables that are “essentially ‘thought-forms’ representing divinities or cosmic powers, which exert their influence by means of sound vibrations” (Khanna, 21). The syllables representing mantras are often written on yantras in geometric patterns and are considered “as important as form in yantra, if not more important, since form in its essence is sound condensed as matter” (Khanna 21). During ritual worship the devotee may repeat a particular mantra “which is supposed to be

powerful enough, if properly communicated and assiduously recited, to transform the phenomenal consciousness of the devotee into deity-consciousness” (Rao, 24). A yantra is a visual counterpart to a mantra and can be described as “a diagrammatic equivalent of the deity [consisting] of linear and spatial geometrical permutations...harmonized in composition to provide a formal equilibrium which is both static and dynamic” (Mookerjee and Khanna 34). Yantras fall into several categories including devices for worship, protection and meditation<sup>4</sup>. Mandalas are also considered a type of yantra (dhyana), although in contemporary times mandalas are more commonly associated with Buddhist than Tantric practice.

The visual form of a yantra is based on simple geometric forms and is believed to “reveal the inner basis of the forms and shapes abounding in the universe” (Khanna, 11).

The visual elements of a yantra are based on geometry and encapsulate a beliefs that “every form is a vibration of a certain density” and “all that is animate and inanimate are vibrations of a particular frequency” (Mookerjee and Khanna, 33). In this way, Tantric mantra/yantra combination is an extension of the belief that vibration (sound) is the basis for matter and energy in the universe which was espoused earlier in the Vedic texts. This is a belief that is paralleled in contemporary physics in M-Theory.

M-theory (which further extends String Theory) is currently the leading candidate for a “theory of everything”. String Theory is based on the concept that there are incredibly small vibrating strings that exist in 10 spacetime dimensions<sup>5</sup>. Vibrations of the strings at different frequencies create the different subatomic particles (such as electrons and quarks) which comprise all matter and energy.

The basis for this explanation lies in the law of conservation of energy, which states that “the total amount of matter and energy in the universe is a constant” (Kaku, 384), with matter and energy being able to change forms.

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<sup>4</sup> Rao, 14

<sup>5</sup> M-Theory posits an additional 11<sup>th</sup> spacetime dimension.

“Energy is in fact the substance from which all elementary particles, all atoms and therefore all things are made” (Heisenberg, 37). Einstein’s well known equation  $E=mc^2$ , mathematically explains the interchangeable nature of mass and energy. Vibrating strings are thought to produce matter because “the *mass* of a particle in String Theory is nothing but the *energy* of its vibrating string” (Greene, 354). Thus, contemporary physics upholds that everything in the universe can be interpreted as vibrations<sup>6</sup>.

Vibration plays an important role in our daily lives and 2 forms of sensory perception. Sound and visible light are both forms of vibration with periodic motion, and can therefore be expressed in terms of frequency with measurable wavelengths. The frequency range of visible light is far higher than that of sound, but since both can be expressed in a mathematical framework, it is possible to transpose sound into color and vice-versa. “By applying the law of the octave, each color can be correlated to a respective tone” (Cousto, 15).

The ‘law of the octave’ is a concept that draws from the ancient concepts of harmony, whereby differences in pitch (frequency) are expressed as fixed mathematical ratios. Pythagoras is credited with discovering the connection between these mathematical ratios and sound, drawing the “metaphysical conclusion that all nature consists of harmony arising from number”, which predated modern physicists views that “nature conforms to laws expressed in mathematical form” (Ashton, 4). From these ratios, a harmonic (overtone) series can be generated. A ratio of 3:2 results in a musical interval of a fifth; 4:3 generates a perfect fourth, and 2:1 is an octave. “The fifth and the fourth combine to make an octave (3:2 x 4:3 = 2:1)”, while their difference (3:2 / 4:3) creates “a whole tone, value 9:8” (Ashton, 10). Other tones are combinations of the fundamental tones and overtones<sup>7</sup>.

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<sup>6</sup> “if we were to pluck this string, the vibration would change; the electron might turn into a neutrino. Pluck it again and it might turn into a quark. In fact, if you plucked it hard enough, it could turn into any of the known sub-atomic particles....The universe can now be viewed as a vast symphony of strings” –Kaku, 196-197

<sup>7</sup> Cousto, 18-19

Harmony can therefore be expressed in terms of pure math, based on the ratio between the tones.

### **Art Historical Context:**

The art historical context for the project includes interactive environments, particularly those which emphasize sound and music, as well as art which focuses heavily on geometric composition and concepts such as symmetry in pursuit of increasing spiritual awareness in the viewer.

Golan Levin's *Audiovisual Environment Suite* (1998-2000) is a set of five interactive systems which focus on sound/music generation. The systems were used in *Scribble* (2000), a "color-music performance" at Ars Electronica 2000<sup>8</sup>. These projects allow users to manipulate sound in several ways, including translating user-generated marks into sound (resulting in rhythmic emphasis), and displaying a constant cloud-like field which trails behind a user's mouse movement, shifting in color and sound as it moves. The primary interface is a mouse.

Toshio Iwai has created a number of interactive projects which deal with sound and music. His recent project *Electroplankton* (2006) is a game published for the Nintendo DS handheld console, which focuses on an underwater ecosystem inhabited by creatures which make musical tones when they interact with the environment. The movement of the creatures is controlled by the player using the console's directional pad. Iwai developed a previous game for Nintendo (*Sound Fantasy*) which was cancelled in development and later picked up by the company Maxis and released as *SimTunes* (1996). *SimTunes* presents a stage with autonomously moving insects. The user can draw on the stage, like a canvas, with several different tools. As the insects crawl over the user's strokes, they play different musical sounds based on the color. Certain insects play percussive instruments, other insects create melodic sounds. A soundtrack plays continuously beneath the user-generated music.

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<sup>8</sup> <http://acg.media.mit.edu/people/golan/aves/>

## Theory into Practice:

“Every living body physically vibrates, all elemental or inanimate matter vibrates molecularly or atomically and every vibrating body emits a sound. The study of sound, as the ancients intuited, provides a key to the understanding of the universe.”

-Lawlor, 12-13

I believe that vibration and harmony are powerful concepts, and presenting a system where they can be explored in an interactive and collaborative way creates the opportunity for a meaningful and resonant experience. The central question *Harmonics* raises is, “will users be able to understand and create musical harmony without any explicit instruction, using only the interactive framework provided?” The secondary question is, “will this understanding of the role of harmony in the system reinforce the natural feeling of connection (i.e., create harmony) between the 2 users?”

The conceptualization of harmony is based on a combination of Eastern and Western ideas in various disciplines, including the Eastern concept of interconnectedness/oneness, and the Western concepts of String Theory and Pythagorean harmonics. The central question builds on the premise that there is an innate, underlying structure to the universe, which is an idea encapsulated in the Eastern and Western theories, based on the common foundation of vibration. Specifically, the belief that all matter and energy are comprised of vibration<sup>9</sup>.

Western musical theory investigates the concept of harmony, which upholds that specific relationships between vibrating frequencies are commonly perceived as pleasant. These relationships can be expressed as mathematical ratios, and these ratios were used in the programming of the system and are the key determining factor in whether the users create notes or harmonic objects. The separation of the visual objects into “regular” notes and “special” harmonic objects is intended to serve as a visual cue to the user that there is special functionality accompanying the striking of a harmonious, diatonic

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<sup>9</sup> As covered by String Theory in the West and Om/Aum in the East. See Literature Review section for further details.

chord. Providing a special visual event is intended to reinforce the auditory notion of harmony.

The theory of “creation from vibration” was applied to this project as one of the fundamental principles guiding the visual interface and nature of the user interaction. In many of the sound/music visualization systems I researched, the sound or music is generated visually, typically as the result of user stimulus such as making a mark on the screen or pressing a button (either on a hardware control device or a virtual button in the software). In other words, the visual movement in Cartesian space is normally sonified. Since I wanted to place special emphasis on the generation of sound and harmony, the user input is focused on the creation of sounds (as opposed to movement in a visual plane). The sounds then create the visual elements, instead of the other way around. The default behavior for the notes and harmonic objects is to move at random. The user interaction therefore has no direct relationship on the location of the visual elements in Cartesian space. Since Processing does not create visual elements until it receives data from Max/MSP (which makes the audio), this emphasis on sound as the fundamental aspect of the creation process is both literal and symbolic.

The three visualizations each approach the theory of the piece in different ways. “Structure Beneath the Surface” relates to the Eastern idea of cosmic order and the Western idea of fundamental elements of matter/energy expressed as tiny strings. The strings build up the matter and energy of the universe, from subatomic particles to atoms to molecules to rocks, grass and stars, and people. String theory also unifies what are thought to be the 4 fundamental forces in the universe - electromagnetic, strong and weak nuclear, and gravity. Thus, a structure lies beneath the universe, as expressed by physical laws and fundamental units of matter/energy. This piece seeks to express those ideas by providing what appears to be at first glance a blank canvas, which can be said to represent the surface reality or “world” we experience on a day to day basis. However, as users interact with the system, additional complexity becomes apparent beneath the surface of this canvas, as

the notes reveal passing glimpses at the underlying artwork. The harmonic objects reveal even more of this structure as they anchor themselves to a certain section of the piece and move in fixed orbits to reveal a specific part of the artwork underneath. The artwork represents the fundamental level of the world of the piece, which is not immediately apparent at the higher level where the piece starts. The artwork itself is also inspired by yantra theory. I want to make clear that I do not consider the artwork a yantra, because a traditional yantra often possesses an additional layer of complexity (mantra symbols) and a specific ritual purpose<sup>10</sup>, both of which are absent here. However the artwork does incorporate the Indian idea that yantras can express fundamental truths about the universe formed from several key geometric shapes.<sup>11</sup>

“Order Out of Chaos” shares some thematic similarity with “Beneath the Surface”, in that both pieces reveal a hidden structure over time. The basis for “Order Out of Chaos” lies in the cross-cultural, mythic organization of the universe as well as the Hindu myth regarding balancing creative and destructive forces<sup>12</sup>. The notes in this piece serve as agents of chaos, moving at random throughout the space and leaving trails, while the harmonic objects move in specific orbits around the center and create a negative space in which the notes cannot move.

“In From Without / Out From Within” relates to the historic use of yantras in meditative practice. Traditional yantras often contain an element known as a bindu, or center; it is a dot or small circle at the middle of the piece and provides a focal point the viewer can use to help “center”

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<sup>10</sup> “Inseparable from yantras are the subtle vibrations which help to intensify their power. These sound elements are often represented by letters inscribed on the yantra, and in principle all yantras are associated with the mystic combinations of Sanskrit letters. The inner dynamics of the yantra can never be understood in isolation from the system of sound dynamics” (Khanna 34).

<sup>11</sup> The *mantra* utilizes the verbal symbols while the yantra makes use of graphic designs. Even as the entire linguistic behaviour of man is reduced to the essential and undying sound-units (bija-aksharas) in the mantra, the whole of the visible world available to man is reduced to the essential and universal form-units (such as the point, the circle, the triangle, the square) in the *yantra*” (Rao 6-7).

<sup>12</sup> The Brahma, Vishnu, Shiva triad.

themselves.<sup>13</sup> The bindu can be used to progress outwards from the center of the yantra (evolution), or in from the periphery (involution).<sup>14</sup> The user can likewise experience realizations which result from looking within themselves from the outside world (progressing in from without) and then use apply these realizations to their daily life and practices (progressing out from within). “In From Without / Out From Within” also utilizes visual iconography that is based in Indian thought. The docking system for the notes and harmonic objects is based on a diagram from the *Ganita Kaumudi*.

### **Analysis & Synthesis:**

In regards to the physical aspects of the system, there are various criteria one can use for evaluating the success of the final installation. Myron Krueger’s essay “Responsive Environments” provides a theoretical framework with which to evaluate interactive installations. Although *Harmonics* is not intended to function as a responsive environment in the vein of projects Krueger mentions in the essay (which I would consider to be immersive environments) the standards he discusses still hold some relevance. *Harmonics* is in accordance with several criteria regarding responsive environments, but differs strongly in regards to the 6<sup>th</sup> criteria: “The visual responses should not be judged as art nor the sounds as music. The only aesthetic concern is the quality of the interaction” (Krueger, 380). While this criteria is consistent with Krueger’s assertion later in the essay that “Response Is the Medium”, my view is that the strength of *Harmonics* is not solely dependent on the quality of the interaction. Aesthetics are important in *Harmonics* because this is in accordance with 2 of the central theoretical ideas. First, musical harmony is a culturally subjective concept based on the aesthetics of sound; second, there is a specific visual language used in Tantric yantras, comprised of geometric

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<sup>13</sup> “The optical focus of the yantra is always its centre. As the point of intersection, the centre is a supremely creative nucleus from which the etheric force-lines (setu) radiate outwards in concentric circuits and dissolve in the outer circumference (nemi). The nucleus of the yantra is the place of the epiphany of the divine (pitha-sthana). Its central cosmic zone is the inner focus of all the outwardly directed circuits and lines.” -Khanna, 34.

<sup>14</sup> Khana, p. 80

shapes and specific arrangements, which has a ritual as well as aesthetic purpose.

The ideas regarding harmony, attributed to Pythagoras, are based on mathematics as well as aesthetics: mathematical relationships between the notes (which can be visualized using the metaphor of a string folded in halves, thirds, etc.) result in sounds which can be thought of as pleasant or discordant. “The farther apart the numerical values of a partial tone ratio are, the more dramatic or disharmonious the impression will be” (Cousto, 18).

The use of geometric shapes in yantras is also based in mathematics; the “primal yantra shapes” are “based on mathematical equations from the Sanskrit treatise on mathematics, the *Ganita Kaumudi* (1356)” (Khanna, 134). The yantra shapes also have a symbolic purpose as different shapes represent different deities. The aesthetics in *Harmonics* are therefore not “art for art’s sake” but meant to connect the theory and practice and serve a functional purpose within the system.

## **Conclusion:**

Interconnectedness, frequency, and harmony are concepts which ancient cultures in various parts of the world focused on. Philosophers in Ancient India explored the idea that everything in existence was a byproduct of sound. The Indian concept of *brahman*, as an all-encompassing oneness is closely connected with the primordial sound *Aum*.

Thousands of years later, similar ideas have been reintroduced in the West through the discipline of physics. String theory is a leading candidate for a “theory of everything”, and upholds that all forms of matter and energy in the universe are the result of tiny, vibrating strings which exist simultaneously in multiple dimensions.

I find the intersections between concepts which are separated by thousands of years of history and culture a fascinating topic for exploration in an artistic context. *Harmonics* seeks to explore these concepts within the framework of a multi-user interactive audio-visual system that encourages

harmony. Several high profile artists such as Golan Levin and Toshio Iwai have created interactive audio-visual systems in the past. This project seeks to continue in that tradition while placing a stronger emphasis on the creation of audio elements which drive the visuals, rather than the converse. By emphasizing sound (vibration) and harmony the project seeks to tap into the universal spirit of oneness identified as *brahman* by Vedic sages thousands of years ago.

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