VISUAL MUSICAL INSTRUMENTS

by

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Dedicated to: Father Louis-Bertrand Castel, 1688-1757.

Abstract. Two of my experimental projects in chaos and vibration theory, over these past fifteen years, have developed into visual musical instruments. The *Macroscope Project* flourished from 1974 to 1979, and the *MIMI Project*, from 1985 to the present. In this brief memo, a personal history, their genesis is traced.

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For High Frontiers/Reality Hackers, Fall, 1988.

1. My walkabout in chaos. Once upon a time, I worked on a single mathematical problem for six years. The project culminated in two books, written simultaneously. When the manuscripts were done, I looked up to see what was happening in ordinary reality. It was Princeton University in 1967. The Sixties were happening. A full-bore revolution was on. A lot of people were departing ordinary reality for one-day trips. Like Joseph Knecht, I decided on the spur of the moment to try it out. For me, this was no one-day trip. When I came down, it was 1973.

During this six-year walkabout, I moved from Princeton to the University of California at Santa Cruz (UCSC), toured spiritual groups and techniques, saw my family expand and contract, took leave to explore Europe Hippie style, searched the Himalayan foothills for traditional knowledge, trekked to the borders of Tibet. In Santa Cruz there were rock concerts with light shows. In Amsterdam there were esoteric books and video artists, and floors to sleep on. In India there were yogis, gurus, classical North Indian music teachers, Sanscrit texts in English translation, and caves to sleep in.

Reentry was difficult. After a cooling off period in Tahoe, supported by mathematics applied to blackjack, I returned to my post at the University of California in January, 1974. I tried to integrate what I had gained from my journey with my work as a professor. I gave seminars in vibrations, combining the Vedic concepts with European mathematics. My goal, inspired more by desperate need to communicate than the ideals of Boddhisatva or Toynbee, was to share the essential visual aspect of the vibratory fields I had seen in my travels. The whole experience of the Logos could not be shared, but perhaps a visual representation would excite the full field in the viewer's mind by morphic resonance.

The underlying idea was a vibration analogy for mind, brain, and human behavior. At present, these ideas have become widespread and familiar, in the form of neural nets, excitable media, cellular automata, and complex dynamical systems. But at the time, they belonged to the fringe. Further, the edge of the wave of the chaos revolution had just arrived at the shores of the physical sciences. Some students, still under the influence of the lost Sixties, were attracted. Together, we began the macroscope project.

2. The vibration metaphor. During the European phase of my walkabout, in February of 1972, I was invited for a short visit at the Institute des Hautes Etudes Scientifiques near Paris, the French equivalent of our Institute for Advanced Study. This is the home institution of Rene Thom, who invented catastrophe theory in 1966, and David Ruelle, who brought chaos theory to the attention of physicists in 1973. Thom showed me Hans Jenny's book, *Kymatik*. I was struck immediately with a feeling of urgent importance. I called Jenny in Basel to arrange a meeting. Soon I was at Jenny's home, where he showed me slides and films of his work, and shared his ideas on the significance of vibrations and Chladni patterns in human physiology. He was a follower of Rudolph Steiner.

Later that year in India, Jenny's ideas were echoed in my readings in the Vedas and the teachings of the yogis and gurus, especially Neemkaroli Baba. My own experiences, repeated during regular inward journeys over the six years, provided further teachings on the vibration model for the mind and consciousness. My study of Indian music furthered my understanding of the wave metaphor, which is basic to the Samkya philosophy.

Dynamical systems theory, including catastrophes and chaos, provides a mathematical framework for the elaboration of the vibration model. Indeed, this elaboration was already underway in the work of Thom. In fact, Christopher Zeeman described to me his own explicit model for memory, based on catastrophe theory and excitable media, in Amsterdam, shortly before I flew to India. However, it was Jenny's work, providing visual representation of the basic concepts and phenomena, which seemed to me to have the greatest potential for furthering our understanding of human consciousness.

3. The macroscope. With the aid of students from my seminar at UCSC, I reproduced Hans Jenny's kymatic device in my lab. Our device was larger and less precise than Jenny's. We used a four-inch dish for the water/glycerol solution, four-inch telescope mirrors loaned by Lick Observatory, and a color schlieren filter developed by Gary Settles. An analog electronic tone synthesizer was built especially for the device, and an industrial xenon arc lamp provided the illumination. When finished, I alligned the optics approximately by eye, turned everything on, and glanced at the screen. I was astonished to see a perfect Jenny-style Chladni pattern, in full color. The experience overwhelmed me, and I retired to the corridor outside the lab to recover my composure.

An official opening was planned for the lab, renamed the *Jenny Four-Inch Macroscope,* in July, 1974. On impulse, I asked my Indian music guru, S. D. Batish, to sing at the opening. We attached a microphone to the amplifier which vibrates the fluid in the dish, in place of the pure tone generator. This event provided my first experience of visual music based on Chladni patterns, the essential forms of vibration in three-dimensional media. It connected, all at once, my experience with Indian music, Samkya vibration theory, Thom's catastrophe theory, and the light shows of the Sixties. Math, music, mysticism, all are one!

Subsequently, we made systematic use of the instrument (with the tone generator, not my master's voice) to study the bifurcations of chaotic motions of vibrating waves until 1979. A video is available from Aerial Press describing the instrument and the experiments. No other direct reports have been published in scientific journals, but the understanding gained from my experience with the Macroscope has illuminated all of my writings (especially those collected in my books *On Morphodynamics* and *Complex Dynamics).* Recently we did revive the macroscope to record a "music video" of Jill Purse's overtone chanting. The routine use of such a device for visual music is inconvenient but highly recommended, and this direction has been developed by Gary Settles.

4. The Visual Math Project. Soon after the beginning of the Macroscope Project, computer graphics arrived at UCSC. In 1975, with computer scientist Evan Schaffer, I taught a special section of calculus using computer graphics for demonstrations. This grew into a state- and federally-funded project to develop a massive teaching system for the beginning math courses, called VISMATH. It ended in 1982.

Part of our VISMATH program was an annual film show, at which almost all computer graphics films on mathematics were shown. Each year it was longer, and eventually multiple shows were neccessary. As film artist John Whitney and his family, coworkers, and followers were using mathematics in their works, we added a number of art films to the programs. In this way we became familiar with the visual music medium, as used by frame-by-frame film animators. We also got to see Tom Banchoff's great classic of mathematical animation, *Hypercube,* and Nelson Max's all-time great *Inversion of the Sphere,* and to meet their authors. In these two films, in particular, I recognized actual images from my own inner experiences during my walkabout. Some were so accurate that a prior experience in 1969 might almost have been a precognition of sitting in the film show in the UCSC auditorium in 1975. Patiently I waited for computer graphic hardware to evolve the capability to create and manipulate these images in real-time, so that I could use it to share my own inner visual experiences with other people. Meanwhile, I tried to create suitable images with video feedback. Although these efforts failed, they did provided some fundamental concepts relating dynamical systems theory (especially bifurcation theory and chaos) to the visual music context. Some of these are illustrated in an excellent video made by Jim Crutchfield with an analog video synthesizer, available from Aerial Press. But we wanted affordable, programmable digital video.

5. The MIMI Project. In the early 1980's, satisfactory digital video hardware became available. The Fairlight *Computer Video Instrument (CVI)* was an early application. Soon, a cellular automaton machine (CAM) appeared at scientific conferences. The new era for digital video music had arrived. For me, this meant the possibility of replacing the Macroscope with a digital clone. This could be *portable, affordable,* and *programmable.* Further, because of the recent evolution of the MIDI standard for the interconnection of digital musical instruments, a digital video based visual musical instrument could be *playable,* via a keyboard, guitar, flute, violin, or even voice.

In 1983, people began inviting me to speak at non-mathematical events. My path along the New Age campsites eventually led to a stage in Hollywood, where I proposed a design for a *Mathematically Illuminated Musical Instrument (MIMI).* This is nothing but the digital-video based clone of the Macroscope, connected via MIDI to a digital keyboard instrument. Sitting at the keyboard, one might sing, play sound, and play picture, all at once. The picture part was envisaged as a modulation upon ordinary reality, in the form of real-time video. This sort of reality hacking is used in the Fairlight CVI. However in MIMI, the operation on a real picture would be defined mathematically, through the algorithms of dynamical systems theory. Among these algorithms are the cellular automata invented by Von Neumann to simulate the human brain, cellular dynamata based on the heat and wave equations of mathematical physics, neural nets, excitable media, turbulent fluids, and so on.

For example, with no keys pressed, we might be watching an ordinary video of a dancer or surfer. On pressing a key and holding it down, we get a note. An organ tone *and* a MIMI note. The MIMI note stops the ordinary reality action on the screen, and begins a mathematically defined deformation of the freeze-frame image on the screen. In the case of an image processing algorithm based on the heat equation, the picture would fade slowly to grey. This process would continue as long as the key was held down. The pace might depend on key pressure or velocity, pitch wheel, or other MIDI controller. Upon, release of the key, the grey would fade back into the ordinary reality of the moving surfer. Similarly, there are different ways to interpret a MIMI interval. Two keys pressed at once could initiate a combined effect, which may be totally unrelated to the individual effects programmed to follow each of the two keys singly. The program attaching a dynamic image process to a key (or combination of keys) runs in a personal microcomputer, and is available to the performer. Finally, the dynamic image process (a mathematical rule followed by the digital video processor) may have parameters, under control of the performer via breath controllers or other MIDI devices. Thus, chaotic bifurcations of vibrating fluids such as seen in the Macroscope may be called up at will by the visual music artist in real-time performance. This may provide a new level of performance for reality hackers of the future.

The first prototype MIMI is now under construction at UCSC, under a contract from Pacific Shift, a high-tech studio in Santa Fe, NM. It consists of a MIDI keyboard and sound synthesizer, a personal computer with MIDI interface, a real-time digital-video image processor, and a rack of analog video studio gear. All this has cost about $100,000 so far, but prices are rapidly falling for most of the components.

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Box 1: THE HISTORY OF VISUAL MUSIC

Visual music is a traditional art medium, with an extensive (if little known) history. It probably played a basic role in the arts and rituals of the cave cultures of the European epipaleolithic, and the early civilizations of the Anatolian neolithic. The cave sanctuaries and rituals of Minoan Crete, and the derivative mystery schools of Ancient Greece may have continued this artistic tradition, along with its mystical religious associations. The performances of Father Castel in Paris of color music created with candlelight and cloths were famous in the eighteenth century.

In recent times, visual music reappeared in the Theosophical Revival at the turn of this century. Aleksandr Scriabin intended *Prometheus: The Poem of Fire* (1910) to be accompanied by a light show. (By the way, it begins in chaos.) Alexander Wallace Rimington performed live color music in London at about this time. Claude Bragdon and Thomas Wilfred in New York created keyboard instruments for the live performance of color music in the 1920's. In the same period, color music compositions in the form of animated films were laboriously made by Arnaldo Ginna and Bruno Corra in Italy, and Oskar Fischinger in Germany. In 1936 Fischinger moved to California, where he continued his work, influencing John Whitney and others of a major group of color music film artists in America.

The live performance of color music survived in the work of Mary Hallock Greenewalt in Philadelphia in the 1940's (she invented the rheostat for her organ), Charles Dockum in New York and California in the 1950's, and of course in the Hippie culture of the 1960's.

Box 2: THE HISTORY OF ACOUSTICS

The glass harmonica was invented by Benjamin Franklin in Paris in 1761. It was popular until about 1800, and many composers made use of it, including Mozart and Beethoven.

Ernst Chladni was the father of modern acoustics. He was born in Wittenberg, Saxony (near Bonn, Germany) in 1756, and earned a degree in jurisprudence at Leipzig in 1782. He was an amateur musician, and he designed and constructed two glass harmonicas. In connection with this work, he developed the technique (now called *kymatics)* of sprinkling sand or powder on glass plates, and bowing them with a cello bow. The sand would move to a filigree of ridges, like the ridges of sand dunes, now called the *Chladni nodal lines*. The regions between the nodal lines, called *antinodes,* are responsible for the sound produced by the vibrating glass plate, its pitch, timbre, and so on. Chladni was searching for designs which would have a specified timbre, like the electronic synthesizer programmer of today. His first report of this research was published in 1787. Besides his acoustic researches persued at home in Wittenberg, Chladni travelled extensively around Europe giving performances and demonstrations of music and sand figures. In 1800, he arrived in Paris, and made a presentation to the Academy of Science, at the invitation of Laplace. Chladni had a private audience with Napolean, which resulted in a prize competition in 1809 for a mathematical explanation of the nodal lines. Napolean's prize was won in 1815 by Sophie Germain, one of the first great women in mathematics. As women were prohibited from attending university classes at that time, she obtained her mathematical training by impersonating a truant male student, Lucian Leblanc, at the Ecole Polytechnique in Paris. Her prize paper founded the branch of mathematics, now known as *continuum mechanics,* upon which is based the modern science of acoustics and the mathematical theory of nonlinear vibration.

Chladni's experimental work has been repeated and extended regularly over these two centuries, most notably by Mary Waller (London, 1961), and by Hans Jenny (Basel, 1967, 1972).