"Live electronic music performance: innovations and opportunities"
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Robert Gluck
University at Albany

Music making is a defining characteristic of human life. While social dynamics, function, aesthetics, constructed meanings and performance practices have ranged widely throughout times and place, an impulse to make music pervades all cultures across time and place.

The relationship between music making and technology is, for some, a controversial topic. Some prefer acoustical instruments or fear that electronics may supersede traditional musical performance. But in truth, all musical instruments are inherently technological. If the voice is the original instrument, to quote the title of Joan La Barbara's 2003 recording, the second instrument was created when human beings first joined available technology with musical expression, adapting early tools, maybe bones or sticks, to create sound by striking another object. Soon, a hollowed out bone was used as an early flute. Generations later, the first plucked stringed instruments evolved, using sophisticated ideas about string tension and division and knowledge about resonating materials. In Western Europe, highly technological means were developed to mechanically pluck and strike those strings, leading to the clavichord and harpsichord. New technologies have continually opened new possibilities for the nature of performance. Earlier instruments have generally continued to coexist side-by-side with new inventions, offering new ways to perform historical works and pushing the edge on new compositional approaches.

Musical instrument builders first began to harness electronic technologies around the turn of the 20th century. Among the many idiosyncratic new instruments, the one that has continued to be utilized in performance is the Theremin, invented around 1920 by Russian scientist, Leon Theremin. This instrument consists of two antennae that create electro-magnetic fields that are disrupted by hand motions proximate to the antennae, each one controlling the amplitude or frequency of sound produced. One characteristic of many new instruments, in contrast with acoustical instruments that have evolved over long periods of time, is idiosyncratic design features. These tend to reflect the interests of their creators and rapid changes in available technologies and fashions.

Electroacoustic music, the generic term used to describe electronic music composition and performance within the historical experimental traditions, emerged outside the realm of performance. Musique concrete, developed by Parisian radio engineer Pierre Schaeffer, a type of sonic collage, was tied to recording media. musik Electronische, from the Cologne studio made famous by Karlheinz Stockhausen, was similarly dependent upon studio production techniques. The "tape music" of their successors was so-termed not only due to its dominant production medium, but also because its mode of performance was tape playback. The only performative aspect of these genres, often experienced by audiences sitting in darkened auditoriums and theaters, was its spatial diffusion of sound and the unwatched act of the recording technician who pressed the "on" button to start playback.

John Cage is generally considered to have pioneered live electronic music performance, beginning in 1939 with the first in a series of works titled *Imaginary Landscape*. These works moved the locus of studio activity into live performance settings by treating variable speed phonographs and radios as vehicles for the playback of prerecorded sounds. Live electronic performance was further developed by Cage's protégé David Tudor, four composers associated with the Sonic Arts Union, David Behrman, Alvin Lucier, Gordon Mumma and Robert Ashley, and Musica Elettronica Viva (MEV) members Richard Teitelbaum, Alvin Curran and others.

David Behrman's *Runthrough* (1967), the first live electronic work witnessed by this author (in 1974), is a characteristic work of that formative era. In *Runthrough*, performers crawl through a small tunnel, directing

flashlight beams in space. These beams trigger analog circuitry to create and shape sounds. A key idea was that physical gestures were the means by which musical sounds are generated and changed. This represents a restoration of the association between physicality and music making, a major element in traditional performance practice. In this work, however, that relationship is anything but conventional. Whereas the sound of a piano is initiated by depressing its keys (after which one lacks any control over the trajectory of the sounds), in *Runthrough* the flashlight gestures result in continuous changes. Also unlike the piano, the sound output bore no necessary relationship to the mechanics of the physical instrument. Live electronic performance breaks many conventionally anticipated associations between specific movements (such as pressing a bow on the surface of a violin string) and the resulting sound. In fact, any sound can be controlled by any type of interface, creating a new or expanding upon a conventional association between sound production and sonic outcome.

The idiosyncratic nature of new instruments represents both a strength and a weakness. It is a positive feature in that the only limitation on instrument design becomes the human imagination. It is a limitation in that the emotional power music is at least in part due to audience expectations of the connection between performer gesture and what is heard. In conventional music, the intense vibrato created by the repetitive motions of a violinist's fingers on a string or the placement of a guitarist's fingers at the point where the fretboard meets the instrument's body both cue an observer into a nexus of musical and emotional content and meaning.

As live electronic performance evolved, instrument design began to play an integral role in a web of musical elements that include aesthetics, instrument design and technique, and content. The design and interplay between hardware, computer circuitry and its programming becomes a part of the compositional process. The new integrated performance system can be termed a performance "interface", the vehicle by which a human being can engage with sounds and the controllers that enact and change them.

A true integration of physical interface and electronics had to await the invention of small scale computing in the 1980s. However, some of the earliest work, using single board computers in live performance dates to the mid- and late- 1970s. Composers at Mills College, in Oakland, California, built their own systems from kits. Among this group was David Behrman and several composers who pioneered networked computer performance, including John Bischoff, Jim Horton and others.

The four essential elements in the further development of live performance interfaces include "haptic" devices that can track physical performance-related gesture (such as the movement of a hand holding a violin bow), the conversion of that data to a format that can be interpreted by technology that electronically transforms the sound, computer software by which such transformation may be achieved, and fast, portable computers that can achieve the necessary data conversion and interpretation and run the software, in real time. Some of these elements fell into place with the development of a computer capable of real-time audio processing, the IRCAM 4X, designed in 1981 by Giuseppe Di Giugno; Miller Puckette's design, in 1985, of a real time scheduler that allowed control software to communicate with that computer; the adoption, in 1983, of a communication standard, the Musical Instrument Digital Interface (MIDI), allowing hardware and software devices to interconnect; and real-time software that accessible by any computer user, such as Music Mouse, by Laurie Spiegel in 1985, and M, by David Zicarelli, Joel Chadabe, and Antony Widoff, in 1986.

Live electronic performance entered its maturity with the introduction of interactive elements, which may be described as mutually influential dialog between a human being and a machine. The technology responds to human performance gestures in a manner that is not completely predictable to the performer, whose gestures can be understood, but not completely predicted by the technology. The introduction of relative levels of chance turns the participants in this two-way system into partners in an unrepeatable creative process. Early examples of this approach include Richard Teitelbaum's interactive multiple player-piano performance system (1980) and George Lewis's performance analysis and response computer software, 'Voyager' (1985 – 1987). A later development of the IRCAM 4X real-time scheduler led to the creation of a flexible visual

programming environment, Max, that is now arguably the software standard for interactive musical systems. A new generation of electronic controllers also began to emerge in the early 1990s that were uniquely suited to interactive systems. These drew upon technologies that track a performer's physical movements using infrared, video and other technologies. Among them are Donald Buchla's "Thunder", David Rokeby "Very Nervous System", and Michel Waiswicz's "The Hands."

One of the most fascinating approaches to live electronic performance has been the electronic expansion of acoustic instruments. This concept builds upon existing performance possibilities of traditional instruments, but extends them in several ways. Sounds produced by these hybrid instrument systems can include the sounds of the actual acoustical instrument, untreated except for amplification or digitally processed, with the additional of any additional sonic elements of the composer's choosing. The initiation, shaping, and triggering of sound components can be achieved by tracking a performer's physical gestures, using sensing technologies. Gestures can include conventional instrumental techniques, which are now harnessed for additional uses, or novel motions or other performance elements (visual features tracked by video, aspects of room acoustics, audience engagement, and others). Some of the first pioneering expanded instrument systems included Peter Beyls' proximity sensor violin, Richard Teitellbaum's use of the Marantz Pianocorder, especially in a three-piano system, Neil Gershenfeld and Joe Chung's "hyperinstruments" (developed at the MIT Media Lab for Tod Machover's music), Jon Rose's 'Hyperstring', Dan Trueman and Perry Cook's 'Rbow', Curtis Bahn's 'Sbass', and others.

The author's 'eSaz', an electronic expansion of a Turkish classical lute, includes sensors that track hand position and pressure along the neck, as well as hand pressure against the instrument's body, adjacent to the spot where the performer plucks the strings. The neck sensors provide information about the performer's conventional fret board technique, which can be used to shape the digital processing of the resulting saz sounds. The body pressure sensors require the performer to adjust to their presence while plucking the strings, and control additional sound elements. However, the sonic results that emerge as the performer engages with the sensors subtly influence and alter that performer's relationship with traditional performance practices. The results point to new approaches to performance. The expanded instrument becomes a new instrument in its own right, with ties to the past. The author has developed related systems built upon other instruments, among them 'eShofar', an expansion of the traditional ram's horn, held with a glove fitted with pressure sensitive fingertips.

The early 21st century has proven to be an exciting time for live electronic musical performance. One of the new trends being explored are multi-media performance integrating musical, visual and other performance elements within one conceptually organized system. As computers increase in power while decreasing in size, new approaches to physical interfaces can be explored, including more intuitive performance instruments. Technological change is only one side of an equation that is equally driven by new musical ideas. As in the past, music is only as good as its aesthetic ideas. In these terms, how might we evaluate the musical results of new instruments? No doubt, the quality of music during the present era will be no different than that of the past: results will be mixed. What is new is that the accessibility of computing translates into more new musical performance activity than in the past – and the continual changes in instrument design occasioned by continuous technological developments. Only time will tell whether new approaches electronic performance provide lasting music. On the other hand, accessibility and innovation creates a folk-like culture, where designers, composers and performers share new discoveries and together craft new evolving traditions. The results may be a cultural change in the means by which music is conceptualized, performed and enjoyed by listeners.

More information about the works and technologies noted in this article may be found in a new historical website edited by Joel Chadabe and the present author: The EMF Institute is located at http://www.emfinstitute.emf.org. The author's own instruments and compositions are documented at http://www.electricsongs.com.