Current Trends in Electronic Music Interfaces

Guest Editors' Introduction

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1) History and Evolution of Musical Controllers

Throughout history, each set of technologies, from woodcraft to water pumps and from electricity to computers, has ushered its own set of changes into the way people generate and interact with music. Acoustic musical instruments have settled into canonical forms, taking centuries, if not millennia, to evolve their balance between sound production, ergonomics, playability, potential for expression, and aesthetic design. In contrast, electronic instruments have been around for little more than a century, during which rapid, often exponential (Kurzweil, 2000) advances in technology have continually opened new possibilities for sound synthesis and control, keeping the field in continual revolution and allowing few instruments to be mastered by a significant community of players. In fact, one might well ask what does "mastery" of an electronic musical instrument mean? A by-product of the power to create and manipulate artificial sounds is the ability to decouple the synthesis of an instrument's sound from the physics of the instrument's sound-producing mechanism, allowing musical controllers to diverge from the familiar physical forms of acoustic instruments. While this frees controllers to evolve along different paths, it also imposes constraints on an instrument's playing qualities because of limited control over and lack of connection to the sound production mechanism. Thus the normal path to learning an instrument - acquiring an increasingly complex representation of the relationship between one's actions as a player and the instrument's response - no longer holds because each instance of an instrument, controller plus synthesis model, requires that this mapping be learned anew. Indeed, electronic music controllers evolve so rapidly that it's rare for a musician to work long enough with one to develop virtuosic technique.

Although bound by the limitations of available analog and vacuum tube or dynamo-based technologies, the very early pioneers of electronic music were highly motivated to explore expressive and unusual channels of articulation and control for achieving an evocative performance, perhaps because the electronic instruments were then in such an obvious contrast with their highly-expressive acoustic contemporary cohorts. We see this in the depression-sensitive, just-intonation keyboard and timbre controllers of the Telharmonium (Weidenaar, 1995), the radical free-gesture Theremin interface (Glinsky, 2000), the movable keyboard, knee pedal, and timbre stops of the Ondes-Martenot (Rhea, 1984), and the wonderfully expressive left-hand controller and multimodal keyboard of the Electronic Sackbut (Young, 1989). The introduction of voltage-controlled and modular analog synthesis (Pinch & Trocco, 2002) enabled the controller to be easily separated from the synthesizer, producing a range of dedicated musical interfaces; stand-alone devices that captured gesture but by themselves generated no audio. A variety of such interfaces began to appear, including portable and wearable keyboards (Milano, 1984), continuous ribbon controllers, touch-

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sensitive pads (Baxter, 1997), and even controllers responding to biological and brainwave signals (Rosenboom, 1976), not to mention the variety of knobs needed for the synthesizer itself that opened many parallel channels of real-time control. As electronic instruments became packaged commodities (e.g., the MiniMoog, Arp Odyssey, and their progeny), alternative and expressive controllers became sidelined, and the market was dominated by the simple on-off diatonic organ manual, perhaps with the addition of a couple of wheels for the left hand and a pedal or two.

In the early 1980's, the advent of MIDI resulted in an even cleaner separation between the interface and the sound production module, with a simple serial cable connecting control and synthesis. This was accompanied by the definition of a set of standards ushering in the expressive keyboards of today, that respond to hit velocity and sometimes pressure. MIDI also re-launched a fledgling "alternative controllers" fad, and although monthly columns along this theme began appearing in the commercial music press (Wiffen,1988), no alternative controller has yet significantly rivaled the popularity of those based on the form factors of traditional acoustic instruments.

There are many indications that this is changing. The low cost and increased availability of cheap and powerful personal computers have made them a common part of any electronic music studio or performance rig. It is normal to find a personal computer inserted between MIDI controller and synthesizer, allowing complex mapping functions to interpret musical gesture in very sophisticated ways. Interposing a computer into the path between the musical controller and synthesizer enables any kind of gesture to be software mapped onto essentially any musical response, from the most delicate and intimate control of a virtuoso playing a fine instrument to the limited, high-level direction of a child stomping through an interactive installation. On the hardware front, today's sensor technologies enable virtually any kind of physical expression to be detected and tracked. Sensors to measure all kinds of parameters are readily available (Fraden, 1996), and with only limited knowledge of hardware, a player, composer or performer can now embark on the building of their own alternative music controller. Several inexpensive analog interface boxes are now produced (e.g., see Fléty and Sirguy, 2003; Sensorlab, 2003; Mulder, 2003; Wilson et al., 2003), providing a straightforward means for the computer to access sensor data directly. At the same time, simply-mastered musical mapping software packages allow the composer or performer to define a set of programmable parameters that can direct and continuously sculpt the detailed nuances of essentially any sound. Indeed, in the post-MIDI world, we have witnessed the birth of a very powerful new instrument composed of a controller connected to a general purpose computer that directly generates highly complex real-time audio without the need for an external synthesizer. This system architecture grants the controller deep hooks into an arbitrary number of synthesis parameters while still reserving sufficient cycles to build sophisticated and intelligent gesture-to-audio mapping algorithms.

2) Playing New Interfaces for Musical Expression

No volume that is devoted to new interfaces for musical expression would be complete without addressing issues that arise in playing these new instruments, especially issues concerned with gestural control and mapping. Loosely defined, the term mapping relates to the question of matching the capabilities of the human sensorimotor system to the parameter space of the instrument being played, in order to provide the performer with appropriate control of music's four fundamental elements - time, pitch, timbre and amplitude. For the performer, manipulation of these dimensions is embodied in physical actions such as striking a piano key or bowing a string. In acoustic instruments these "instrumental gestures" are constrained by the sound-producing mechanisms of the instrument. The sound produced, in turn, carries the characteristics of the movement that gave rise to it (Cadoz, 1988).

As we have already suggested, a by-product of electronic sound synthesis is the ability to decouple the generation and articulation of an instrument's sound from the physics of the instrument's sound-producing mechanism. Thus the affordances of a synthetic music controller can be very different from those of the instrument being controlled. A piano keyboard, for example, might be used to control a physical model of a bowed string. One direct consequence of a mapping such as this is that simple keyboard instruments, unlike bowed instruments, are characterized by a one-to-one mapping between a note and the finger movement that produced it; each note is an isolated event with controls for its pitch, duration, timbre and amplitude, that cannot interact. For bowed instruments, however, this one-to-one mapping is the exception rather than the rule, since many notes of a single slurred phrase will be executed with one bow stroke and hence a single arm movement. Not only does this single arm movement cause notes of a phrase to be linked, but its trajectory also embodies expressive nuance, shaping the dynamic and timbral arc of the phrase. Parameters for dynamics and tone color are thereby correlated and co-vary in response to the trajectory of the movement of the arm. In considering the mapping between arm movement and the parameter space of a string model, therefore, it is more useful to consider the entire gesture, not just the note, to be the primary unit of musical articulation. Sometimes a single gesture will encapsulate several notes, as in a slurred phrase, while for others a single note may require a series of gestures, such as rapid repeated motion of the bow for a tremolo. Accordingly, several researchers, most notably (Cadoz, 1988; Chafe, 1988; McMillen, 1994; Wright, Freed & Momeni, 2003), have proposed that music controllers and the protocol that supports their communication with synthesis algorithms should be founded on a hierarchical structure with the performance gesture, not the score-based note list, as its unit of currency. As (McMillen, 1994) points out, players of non-keyboard instruments have been reluctant to embrace the digital revolution in music, although there are now small, but enthusiastic communities behind particular families of controllers, (e.g., Wind, 2003). One reason for this reluctance is that woodwinds, bowed strings, and brass instruments all place the player in direct physical contact with the instruments' vibrating element --- reeds, strings, or columns of air --- providing the player with fine control of a single note or a small group of notes. In contrast, most commercially available control devices provide limited control of multiple notes and are inappropriate for most melodic instruments. Faced with trading fine control of a real instrument for the infinite timbral possibilities but coarse control of today's synthesis models, most players opt to remain in the acoustic world.

One fledgling field of research that has the potential to address some of these concerns is that of haptic music controllers[1]. These controllers typically contain one or more actuators, which provide force and/or vibrotactile feedback to the player. Their efficacy rests on the fact that, though the primary source of feedback to the musician is their instrument's sound, the presence of a

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[1] The term "haptic" refers to both tactile and kinesthetic senses. Haptic interfaces are actuated devices that provide feedback to these senses under software control.

mechanical coupling between player and instrument in many acoustic instruments provides a second channel through which important information about an instrument's state can pass. Under software control, haptic music controllers can simulate a custom-designed “feel” which can be responsive to the state of parameters in a synthesis model (Cadoz, 1988). Thus a physical model of a bowed string can be coupled to a haptic controller that simulates the friction of the bow as it moves across a string and the force as it is pressed into the string. The audio model parameters, in turn, can be derived from the behavior of the haptic string simulation (O’Modhrain et al., 2000; Nichols, 2002). Such tight coupling returns to the player of the computer-based instrument something of the immediacy of the instrumental gesture, while still providing the flexibility and power of software synthesis and programmable mapping (Cadoz, 1988). Whether haptic feedback can provide for designers of computer-based instruments a way to restore the balance between finesse of sound and simplicity of control that is the hallmark of a well-designed acoustic instrument is still an open question. Early in the past century, electric motors represented forefront technology, and it was rare to have several in a home. Now, with modern fabrication techniques and new materials, motors are commonplace, with myriads embedded in everything from home stereos to microwave ovens - computers have recently followed a similar trajectory (Norman 1998). As actuators continue their advance into our environment, the introduction of programmable haptic response into musical controllers becomes much more feasible. Who knows, perhaps digital musical instrument designers will one day be trading software designs for the feel of musical instruments in the same way as they now sell sound synthesis software.

One aspect of musical performance that is often overlooked in the design of electronic musical instruments is that of the audience’s understanding of how the instrument is played. An artist playing an acoustic instrument usually exploits a mental model that the audience has of the instrument’s action-to-response characteristics, allowing virtuosity to be readily appreciated. In contrast, electronic controllers, especially those with overly complex high-level mappings or relatively hidden interfaces (e.g., a laptop keyboard or bioelectric sensors) can often confuse an audience, who often can't follow and relate to what the performer is doing (Paradiso, 1999). One of the main challenges facing the designer of musical interfaces used in performance is to produce mappings that, at least periodically, strip away layers of abstraction, allowing the audience to smell the digital sweat as the artist pushes their instrument to the edge. One technique that relates to this issue involves projecting captivating and causal real-time graphical representations that tightly correlate with the audio component (not necessarily like a light show, with visuals independently slaved to the sound, but instead generating both audio and video streams at a higher level, perhaps through the same algorithm or via a video-game metaphor). In this way, the performer nudges and stokes a musical process that produces captivating visuals that, in some sense, replace the presence of the physical instrument. The graphics produced by the audiovisual environment ground the audience and the performer, effectively becoming the instrument’s “body”. Such audiovisual musical environments are becoming increasingly common, e.g., (Levin, 2000; Collopy, 2000; Stanza, 2002; Blaine & Fels, 2003; Kapur et al., 2003).

3) Where Are We Heading?

Although there are still important innovations emerging from the music synthesis community, computer-based sound generation is now a mature technology. As it has matured, it has become evident that newer sophisticated synthesis techniques, such as physical modeling (Smith, 1988) actually tend to require additional or continuously sculpted channels of articulation in order to achieve their full potential for the generation of expressive sound. An increasing amount of institutional and corporate research in this area is therefore being devoted to the control, rather than synthesis, of music. This in turn has lead to an explosion in the quantity and variety of electronic music interfaces that are being developed. One wonders whether this effort will result in the common acceptance of new form factors for music control that verge far from those of the keyboard, string, percussion and wind structures that still dominate the commercial landscape. The vocabulary in this field is likewise developing – no common set of standards exists to evaluate designs, and as goals are so varied in different applications, it is unclear whether this can ever be effectively accomplished. Moreover, the practitioners of this new art spring from many walks of life – academic researchers, musical performers and composers, dancers and choreographers, artistic designers, video game developers, interactive and media installation artists, teachers (from university to grammar school), and therapists (special needs, exercise, and relaxation), to name a few. It's certainly exciting to have many perspectives under one umbrella, although such a broad convergence may be a temporary phenomenon. A major question is whether this field is becoming so diverse that it will fragment into subgenera with different goals and motivations, or are there deep principles in common that can be applied throughout? Conversely, even though they have some aspects (and several researchers) in common, one can ask how deep a union research in musical controllers will be able to forge with the larger field of Human-Computer Interfaces, which generally emphasizes ease-of-use rather than improvement with long years of practice. Although aesthetic design can influence both endeavors, this emphasis is far greater with musical instruments. The electronic performer (or perhaps performance artist) is often a modern shaman, dazzling the audience with an armada of technology and instruments that want to look interesting and provide some degree of spectacle, from glittering electric guitars and massive modular synthesizers to laser harps and necktie-keyboards.

A further exciting aspect of this field is its unpredictability, as new technical capability rapidly revolutionizes the way we generate and interact with music. The computer that's now between the controller and synthesizer engine will certainly become more sophisticated, and advances in perception and machine intelligence will produce mapping algorithms of increasing capability, enabling it to become more of a partner than a crutch. Perhaps instruments will adapt to the player, customizing to their nuance and style. Such an intelligent controller would limit the options for an amateur (still sounding good and being satisfying to play) while allowing more expression as the player becomes progressively more adept.

As we move towards a future of smart objects and ubiquitous computing (Weisner, 1991), most devices will be overdetermined with many sensors that produce a multitude of parameters available to any application, allowing almost any artifact, environment, or event to produce music. Indeed, will the musical instruments of the future be even recognizable as such to people living today? For several decades, people have been exploring the use of biological signals (e.g., EMG's, heart rate, skin resistance, brain waves, etc.) to control music (Rosenboom, 1976). At the moment, such measurements tend to be quite coarse, but once direct noninvasive neural/electrical connections are perfected, as are now being pursued for application in aural/ocular/muscular prosthetics (Geary, 2002), direct bioelectrical musical interfaces could enable a much more deft and intimate musical interaction than their clunky mechanical forebears. Indeed, it is now commonly believed that the world will be radically changed by the impact of biotechnology. Looking at music, perhaps a catchy tune or infectious melody will gain more literal ramifications…

4) NIME 2002 and This Special Issue of JNMR

In the past two years, the field of musical interfaces has grown sufficiently to justify its own annual conference. Sprouting from a 15-person workshop held at the CHI 2001, New Interfaces for Musical Expression (NIME) grew into a standalone international conference of over 100 participants held at the MediaLabEurope (MLE) in Dublin in May of 2002 (see *http://www.mle.ie/nime/*). In this special issue of JNMR, we, the NIME 2002 chief organizers, are happy to present a set of papers that explore some of the themes emerging from NIME 2002 and capture some of the work at the forefront of musical interfaces. As physical modeling becomes a dominant synthesis technology, controllers and mappings that appropriately address its capabilities are needed. This thrust is explored in two of the papers contained here – one on the development of an electronic tabla controller by Kapur, Essl, Davidson, and Cook and another on a very novel controller based on the buckling mechanism of a Cicada's tymbal (an interesting departure, being a controller inspired by the sound-generating mechanism of an arthropod instead of a pre-existing acoustic instrument). Although ongoing research, as outlined above, explores endowing electronic instruments with programmable haptic response to adaptively hone their physical feel and ultimate playability, the paper by Gunther and O'Modhrain takes the opposite approach, and presents a musical output interface consisting of a suit providing distributed vibrotactile stimuli to accompany and enhance the listening experience. As musical mapping algorithms gain complexity, musical processes can be effectively controlled and performed with tangible interfaces, following a trend in HCI research (Ishii & Ullmer, 1997) where physical objects are activated with the addition of sensors and electronics, enabling essentially anything to control music. Two papers in this issue represent different aspects of this approach. The paper by Newton-Dunn, Nakano, and Gibson outlines an intriguing method of programming and interacting with musical sequences by manipulating and joining various blocks in a planar musical "construction kit," while the paper by Paradiso, Pardue, Hsiao, and Benbasat traces the development of a musical controller created by embedding very small wireless magnetic tags into an armada of objects, turning them into tactile and free-gesture musical interfaces. Tangible interfaces of this sort invite musical collaboration, as their various components readily tempt multiple participants to pick them up and join in, perhaps a harbinger of the jam session of the future. Taking the theme of collaborative musical experiences farther, the paper by Blaine and Fells surveys several multiplayer interfaces for interactive musical experiences, cataloging some directions that these very topical systems are evolving towards. Finally, the essence of a controller depends very much on the rules by which the actions of the player are mapped into sound – the paper by Hunt, Wanderly, and Paradis describes recent research that evaluates the musical equivalent of "usability" for different classes of mapping algorithms.

As the field of musical controllers is indeed very broad, with instruments, innovations, installations, and algorithms of all sorts being developed by technologists and artists across the globe, the physical bounds of this special issue are unable to by any means do justice to the entire genre.

We're delighted, however, to pause for a moment here and serve up a tasty sample of current work, sharing the excitement before Moore's Law again revises the rules of the game and enables musical interactions that we can barely anticipate.

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