Trends of Electronic Music, 1983 - present

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INTRODUCTION

The past thirty years in electronic music has been a period of expanding digital horizons. These expansions–the increase in computer processing power and disk storage space, the availability of multi-track audio editing software, the rise of new digital instruments, the standardization of digital protocols and wireless connections, the broadening of internet bandwidth and audio/video resolution, and the enhancement of open source programming languages and environments–have created a vast, fertile environment for electronic composers and artists. Today, electronic composers are rarely technologically limited in their explorations, and they are able to take full advantage of real-time audio processing systems.

With the prodigious amount of available hardware, operating systems, software, and programming languages, the field of electronic music is indeed vast; yet, major trends exist that can help sketch a framework for electronic music. Building a framework is integral to understanding electronic music past to present and may also provide insight to future musical directions. The major trends of today's electronic music includes, but is not limited to: sound synthesis, sound modification, sound design, sound control, sound performance, digital standards, and acoustics.[1]

Sound synthesis is the generation of sound through synthesis techniques and includes techniques developed by *elektronische Musik* and furthered by institutions like CCRMA (Center for Computer Research in Music and Acoustics), including FM (Frequency Modulation) and WaveTable synthesis.[2] Sound modification is the manipulation of audio through signal processing, analog or digital, and includes techniques employed by composers

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[1] Categorizations by author. Sound synthesis (synthesis techniques and digital audio [live or sampled]), sound modification (analog or digital signal processing), sound design (creating new sonorities and compositions based upon a selection of techniques from the first two trends, whether constructed by ear or with algorithms), sound control (simple to complex procedures for controlling musical parameters, either via hardware controllers or internal software functions), sound performance (fixed media multichannel spatialization or gesture-based performance using alternate controllers), digital standards (connecting and communicating between software and hardware devices), and acoustics (including psychoacoustics and physical acoustics, i.e. spatialization)

[2] Sound synthesis that incorporates *elektronische Musik* is partly based upon the fact that Herbert Eimert, Cologne's studio founder viewed electronic tone generation, in particular additive and subtractive synthesis, as an extension of serialism, and as such, as a new way for composing music. Joel Chadabe, *Electric Sound: The Past Promise of Electronic Music* (Upper Saddle River, NJ: Prentice Hall), 36-37.

of *musique concrète* as well as DSP (Digital Signal Processing).[3] Sound design is the formulation of new sounds through a combination of sound recording, sound synthesis, and sound modification. Sound design, while basing its model on concepts developed by *elektronische Musik* and *musique concrète*, owes much of its debt to film, especially Jack Foley, father of film sound, and includes the fields of TV/film, sound FX, and fixed media composition. Sound control is the method of controlling one or more parameters of sound by digital means, and includes algorithmic composition, data mapping, music notation programs, and new, alternative digital instruments (most of these new instruments are controllers, not sound generators).[4] Digital standards refer to protocols like MIDI (Musical Instrument Digital Interface) and OSC (Open Sound Control) and connections like ADAT Lightpipe and Firewire. While many composers do not have the scientific background in acoustics and psychoacoustics, many seek out topics in these fields related to music, e.g. spatialization.

Of the trends in electronic music, three salient points emerge that will be addressed in this paper. First, standardized protocols have helped revitalize performance in electronic music. What began with the MIDI communication protocol, standards for digital music have become faster and have increased resolution. Most connection standards today can handle streams of live audio, and fast, network protocols like OSC allow non-traditional commercial devices, like the iPod, iPad, and Nintendo Wii to be used as controllers for musical actualization.[5] The art of electronic music, once removed from human performance through tape machines and slow computing power, is now returning to the concert space with the ideas of touch and live performance control brought on by standardized digital protocols.

Second, composing electronic music today revolves around the personal computer. From MIDI events to live audio manipulation, the computer has become powerful, small, and cheap enough that the electronic composer can work and perform from just about anywhere.

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[3] Pierre Schaeffer worked with audio manipulation techniques, including tape delay, pitch shifting, tape splicing for loops and reverse playback. Research by corporations (e.g. Waves, Digidesign) and institutions (CCRMA, UCSD) concerned with signal processing expanded the field of sound modification. Joel Chadabe, *Electric Sound: The Past Promise of Electronic Music* (Upper Saddle River, NJ: Prentice Hall), 27-35. EMF, "Pierre Schaeffer," http://www.emfmedia.org/artists/schaeffer.html (accessed February 10, 2011).

[4] The five parameters of sound are frequency, amplitude, timbre, duration, and relative location.

[5] Noteworthy connections handling live audio transfer include Alesis ADAT lightpipe, IEEE 1394 or FireWire, and USB 2.0.

The computer can carry out multiple processes simultaneously, from digital synthesis to digital audio editing, and can perform various roles, from syncing multiple external hardware components to controlling live multichannel spatialization. The personal computer gives the composer flexibility and control, replacing many of the oversized and expensive pieces of equipment historically necessary for the creation of electronic music.

Third, the availability of programming languages and microcontrollers have increased electronic performance opportunities and have helped bridge technologies that were once otherwise proprietary. Electronic music presently resides within an age of open source software and protocols, wireless networks, and integrated media. The Arduino physical computer platform as well as open source programming environments like pureData and OpenFrameworks assist the digital artist and electronic composer in utilizing technology as a creative tool. Composers may today integrate audio and video for live performance controlled by microcontrollers and programming environments.[6]

Since the advent of MIDI and the personal computer in the 1980s, electronic music has burgeoned into diverse fields. These fields are supported by current research, including scientific inquiries (e.g. acoustics, signal processing at institutions like McGill University and Stanford), digital music interface design (e.g. NIME (New Interfaces for Musical Expression), algorithmic and traditional composition (e.g. ProTools, cSound, Finale, Max/MSP, and Kyma hardware/software), and performance (e.g. STEIM (STudio for Electro Instrumental Music). Of course, fields like TV, film, music recording, and groups like AES (Audio Engineering Society), EBU (European Broadcast Union), and ICMA (International Computer Music Association) work simultaneously within many of the named fields above. It is important to consider that in the history of electronic music, trends have evolved with the expansion of technology, and the motivation has stemmed from the composer's need for real-time control of music.[7] The two main contributions to electronic music, a unifying communication protocol (MIDI) and a powerful multi-processing system (the computer),

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[6] Max/MSP/Jitter, while not open source, also serves as a graphical programming environment for music, audio, and media.

[7] Composers like Gordon Mumma, Laurie Spiegal, and Donald Buchla express the need for real-time control in instruments and software. One suggested method was feedback. Nicolas Collins, "Live electronic music", in *The Cambridge Companion to Electronic Music* (Cambridge: Cambridge University Press, 2007), 41, 72-73. Joel Chadabe, *Electric Sound: The Past Promise of Electronic Music* (Upper Saddle River, NJ: Prentice Hall), 94-95, 161-164.

helped satisfy the needs for real-time control and, today, aids the current directions of electronic music.

DEVELOPMENT OF MIDI PROTOCOL

The popular, commercial market was the driving force behind the creation of the MIDI protocol. The economic success of synthesizers systems by Donald Buchla and Robert Moog in the United States, as well as Peter Zinieff's VCS synthesizers (EMS) in the United Kingdom, helped promote new electronic instruments and music systems.[8] With exposure of electronic instruments on popular albums–Wendy Carlos' "Switched on Bach" (1968) and ELO's "Electric Light Orchestra" (1970)–which prominently featuring the Moog synthesizer, electronic music systems catapulted into the mainstream. The commercial venues for these new instruments altered production methodology, as many companies, including Moog and EMS, directed their attention to the larger, popular market.[9]

Across the globe, similar trends developed. Roland, Korg, and Synton were introducing electronic instruments for the commercial market as other start up companies emerged: Sequential Circuits, New England Digital, and Oberheim, among others. Combined with composers creating new devices to aid in their compositions, like Gordom Mumma's "Hornpipe" (1967), and Salvatore Martinaro's SalMar (1972), electronic music began to utilize external hardware devices and computer software. Along with the boom of microprocessors in the 1970s, microcomputers and digital keyboard synthesizers became possible.

Competition was fierce and by 1980, large companies dominated the market– Roland, Korg, Yamaha, Kawai– all with similar instruments and modules, sharing one major flaw: proprietary hardware. What was missing was the ability to communicate between devices manufactured by different companies. Discussions between key electronic Japanese companies, Dave Smith of Sequential Circuits, and Tom Oberheim in the early 1980s led to the introduction of the Musical Instrument Digital Interface (MIDI) protocol. MIDI

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[8] Hans Fjellestad, *Moog* (Pixelfilm) 2004.
Joel Chadabe, *Electric Sound: The Past Promise of Electronic Music* (Upper Saddle River, NJ: Prentice Hall), 144, 152.

[9] Joel Chadabe, *Electric Sound: The Past Promise of Electronic Music* (Upper Saddle River, NJ: Prentice Hall), 163-179.

specifically addressed the issue of proprietary hardware, by allowing a serial connection between any manufacturer's hardware. According to Roland's Ikutaro Kakehashi, "It's wasted energy if people can't communicate, so in the digital era, the question was how to share data, and not to have standard was not possible." [10]

After the MIDI protocol implementation in August 1983, hardware became modular.[11] Composers could reliably connect various devices together. MIDI could be attached to computers, time code machines, synthesizers, sound samplers, and even audio recording & video devices. The modular mode of developing a music system or music studio offered flexibility and cost-effective solutions to the composer.

While MIDI was initially outfitted on keyboard synthesizers, MIDI allowed musicians to step past the keyboard as the central controller, and many composers/artists began creating new devices that used the protocol. Max Mathews's The Radio Baton, Michel Waisvisz's The Hands, and Gary Lee Nelson's MIDI horn among others, all take advantage of MIDI as a way to send information into a sound synthesizer or computer for creating and controlling music in real time. Because MIDI offered the capability to send information to and from the computer, software also became available that supported control, sequencing, and composition via MIDI: David Zicarelli's "Jam Factory" and Joel Chadabe's "M" are examples of software specifically designed for writing, editing, and manipulating MIDI data.

Computer software allowed MIDI data to be easily cut, copied, and pasted, giving the composer considerable control over his/her music. Digital sounds and sequences recalled from MIDI files would perform the same each and every time, and listening to the playback of MIDI files was instantaneous. Sequencing music using MIDI became more flexible than analog sequencers because of total recall and powerful editing features. Transposition and

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[10] Joel Chadabe, *Electric Sound: The Past Promise of Electronic Music* (Upper Saddle River, NJ: Prentice Hall), 194.

[11] Modular is defined as building a system based upon combining smaller, self-contained systems. If one looks back to Robert Moog's modular synthesizers in 1964 to the introduction of MIDI devices in 1984, MIDI allowed the modular music system model to perpetuate into the digital age.

note correction could be done quickly and efficiently inside the computer without having to worry about linear, time-based editing.[12]

The MIDI protocol offered more to composers, musicians, and artists than just compositional tools. MIDI could also control sound generators, FX processors, lighting, and video animation. Because of the event-based control, standardized hardware, and relatively cheap set-up, MIDI increased the flexibility for composers to artistically schedule real-time multi-media performances. Performances like Bruno Spoerri's *In and Out* (1991) used MIDI to generate sound based upon dance movements captured by a video camera. Spoerri used David Rokeby's 'Very Nervous System' as the basis for his compositions.[13] Today, cheap video tracking systems are now available to the consumer via the Kinect gaming system for PS3 (Play Station 3), and digital artists are hacking the device to again make similar expressive music systems.[14]

Because MIDI emerged as a compromise between several music companies, many issues followed the protocol. MIDI is event-based, not time-based. In other words, MIDI is incapable of handling "phase-level control of waveforms," and cannot be used to process live audio.[15] MIDI is a serial protocol and is considered slow by modern standards.[16] For example, one note-on message takes roughly one millisecond of computation time, from event to sound. While the human ear can perceive changes downward to 10-20 milliseconds, stacked MIDI events have potential to create audible latency. Furthermore, the inherent latency of MIDI will cause phasing issues for polyphonic sounds generated by MIDI.

In the performance realm, MIDI's 7–bit range (0-127) is unable to capture the full range of subtleties of gesture and motion, and MIDI resolution is not effective for controlled

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[12] Software utilized the three ways for recording MIDI data: real-time, step-time (one note at a time), and algorithmic (generated by a composition program), which provided composers a set of various working methods. Christopher Yavelow, "Music and Microprocessors: MIDI and the State of the Art," in *The Music Machine: Selected Readings from Computer Music Journal*, 199–234, ed. Curtis Roads (Cambridge, MA: MIT Press, 1989), 206–208.

[13] The video tracking for David Rokeby's system used three 16x16 pixel cameras. David Rokeby, "Very Nervous System", http://homepage.mac.com/davidrokeby/vns.html (accessed February 02, 2011).

[14] Russell Maschmeyer, "School of Visual Arts Thesis Project 2011", http://strangenative.com (accessed February 02, 2011).

[15] Gareth Loy, "Musicians Make a Standard: The MIDI Phenomenon," in *The Music Machine: Selected Readings from Computer Music Journal*, 181-198, ed. Curtis Roads (Cambridge, MA: MIT Press, 1989), 190.

[16] Serial protocols transmit bits of data one at a time in a series, unlike parallel protocols (IEEE 1394) which can send and receive data simultaneously.

parameter nuance. While the MIDI protocol may never become obsolete in its usefulness in providing event based control in real time, the existence of new motives and expanded technological resources create a high demand for a new type of communication protocol. There is a "motive to reclaim performance gesture as a part of the process."[17]

In order to accommodate for performance nuance and time-based control, a faster and higher resolution protocol was necessary. Other standards developed for the transmission of digital data and digital audio. Alesis ADAT, S/PDIF, USB 2.0, and IEEE 1394 (Firewire) connection standards for electronic devices supported fast communication of digital audio. For example, the ADAT Lightpipe standard can transmit up to eight tracks of 24-bit digital audio at a 48kHz sampling rate in real time.[18]

New connection standards like Firewire and Ethernet address the parallel structure of communication, which enables for a more flexible, interactive musical environment with increased bandwidth and simultaneous two-way communication. Modern computers can now handle the increased bandwidths and high resolution rates, enabling the capture of performance gestures and facilitating real-time control of audio and video. In addition, communication based on local networks have enabled high resolution wireless control.

One protocol in particular that has gained traction in the last few years is the Open Sound Control (OSC) protocol. Developed by Adrian Freed and Matt Wright in 2002 at CNMAT (Center for New Music and Audio Technologies), the protocol has taken off as a stable and fast protocol used for interconnecting hardware controller devices to the computer, as well as software on one or more computers.[19] The protocol utilizes UDP/IP (User Datagram Protocol/Internet Protocol) packets, which are user-defined packets of information sent to/from computers and devices on the same local network. The wireless protocol gives the electronic composer power in defining control and event assignments.

Because OSC offers flexible, programmable messages served on a local network, the protocol is now supported in most musical software and hardware including Max/MSP,

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[17] Gareth Loy, "Musicians Make a Standard: The MIDI Phenomenon," in *The Music Machine: Selected Readings from Computer Music Journal*, 181-198, ed. Curtis Roads (Cambridge, MA: MIT Press, 1989), 195.

[18] Presonus, "Digital Audio Connections and Synchronization", http://www.presonus.com/community/learn/musicians/digital-connections-and-sync/ (accessed March 01, 2011).

[19] Open Sound Control, http://opensoundcontrol.org/spec-1_0 (accessed February 03, 2011).

Kyma, Supercollider, Serato, Reaktor, Ableton Live, VDMX, ChucK, CSound, vvvv, Processing, and Pure Data.[20] While not all hardware/software supports OSC, common consumer devices like the iPhone and the iPad can be now equipped to send and receive OSC messages. Programs like TouchOSC and OSCulator allow the user to build interface controllers and assign individualized message packets. Since its inception, OSC has extended outside of its musical origins, finding its way into software like Isadora and CCV (Community Core Vision) for sending motion tracking information. The TUIO (Touch User Interface Object) open framework, the standard for tangible devices including multitouch, has a protocol encoded using OSC.[21] OSC may not replace MIDI, but the OSC protocol has become much more prevalent in the past few years, and with its wireless capability and increased resolution, OSC appears set to become a communication standard.

Throughout the history of MIDI, the protocol has influenced the state of performance, instruments, software, and the electronic music studio. In fact, as new developments of software and external hardware are introduced, most include MIDI support. Understanding the strengths and weaknesses of the MIDI protocol enable the composer to make effective composition and performance decisions. MIDI has survived more than twenty-five years in the age of electronic music, a long time for a digital protocol and a hallmark for computer technology.

COMPUTERS

In 1984, about six months after the introduction of the MIDI protocol, Apple released it's first Macintosh personal computer. The Macintosh computer expanded the horizons for electronic composers by offering a cost effective device for composing music without the financial backing of an institution or corporation.[22] Eventually, the computer became powerful enough to not only run multiple programs simultaneously, including MIDI, audio, and video software, but the computer could also store large amounts of data. With the

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[20] Hexler.net, "TouchOSC", http://hexler.net/software/touchosc (accessed February 01, 2011).

[21] TUIO, "Table-Top User Interfaces Objects", http://www.tuio.org/?specification (accessed February 03, 2011).

[22] Large corporations were once necessary to create and maintain an electronic music studio. Nicolas Collins, "Live electronic music", in *The Cambridge Companion to Electronic Music* (Cambridge: Cambridge University Press, 2007), 48.

computer being able to generate, manipulate, and control sound, the computer became the central focus of both the professional and home studio.

Several developments for the computer helped enable this shift in focus. One reason why computers succeeded in becoming the epicenter of electronic music was the GUI (graphic user interface). Unlike LOAC (League of Automatic Composers), who had to program their music with an assembly language using a calculator, the computer's GUI offered functional simplicity to the user. The ability to equate icons and other graphic information to represent commands and functions allowed the composer to easily use the computer as a creative tool. [23] The learning curve for interacting with the central computer was intuitive rather than inhibitive. From the commercialization of Apple's first personal Macintosh computer, which standardized GUI formats for computer interfaces, composers could explore the creative uses of the technology, without having to learn large amounts of technical line commands.

Software developments in digital sound editing provided another reason for computers relevance in electronic music. "Soldered systems were *vertical* in conception: stacked and parallel. Software systems were *horizontal* in nature: sequential and time-based."[24] Digital Audio Workstations (DAWs) replaced the need for manipulating sounds with tape (analog or digital). Program's like Digidesign's SoundTools offered composers the ability to work with audio on the computer, even if the software was initially limited to two-tracks.[25] As computer processing became more powerful, the ability to handle, edit, and process multiple tracks of audio became the standard, eventually replacing bulkier, analog-tape machines and other recording equipment.[26] Transferring recorded sound from tape over to digital audio, composers could utilize the computer to analyze and manipulate audio without the hassles of splicing tape. "Often the first software used by a computer musician is

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[23] Joel Chadabe, *Electric Sound: The Past Promise of Electronic Music* (Upper Saddle River, NJ: Prentice Hall), 325, 332.

[24] Thom Holmes, *Electronic and Experimental Music*, 2nd ed. (New York, NY: Routledge, 2002), 235.

[25] SoundTools was the precursor to Digidesign's popular ProTools digital audio software/hardware system, which, when running ProTools LE 9.0, can handle 48 tracks of simultaneous audio at 96kHz sampling. http://www.sweetwater.com/store/detail/003Complete/ (accessed March 01, 2011).

[26] Author's personal account from working as an assistant engineer at Brooklyn Recording (2006-2008).

a sound editor."[27] Because digital audio could be spliced and re-worked without the physical process, editing time shortened, which meant more time that could be spent on composition and exploration.

Not only did DAWs offer a cost-effective and time-saving alternative to magnetic tape, but the simultaneously developments of digital signal processing software, like AU (Audio Units) and VST (Virtual Studio Technology) plug-ins, made the use of DAWs more suitable for electronic composers. DSP (Digital Signal Processing) expanded the techniques and processes developed by electronic composers and professional recording engineers by making available sound manipulation techniques on the computer.[28]

The increase in processing speed and disk storage capacity also helped the computer become the focus of the studio. The computer offered cheap, software replacements for processing and recording audio; the computer expanded music storage capability (external hard-drives); the computer provided powerful features including alternate sound synthesis (software instruments), audio processing (plug-ins), and total recall (digital mixer presets and MIDI Machine Control); in short, the computer improved virtually every element of the electronic music studio: sound synthesis, sound modification, sound design, and sound control.[29]

As the computer evolved, so did the ability to allow composers real-time feedback and control. Composers and engineers designed new ways to implement real-time control.

> "With the advent of computers, many of music's past restrictions can begin to fall away, so that it becomes possible for more people to make more satisfying music, more enjoyably and easily, regardless of physical coordination or theoretical study, of keyboard skills or fluency with notation…It lets us focus more clearly on aesthetic content, on feeling and movement in sound, on the density or direction of experience, on sensuality, structure, and shape–so that we

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[27] Christopher Yavelow, "Music and Microprocessors: MIDI and the State of the Art," in *The Music Machine: Selected Readings from Computer Music Journal*, 199–234, ed. Curtis Roads (Cambridge, MA: MIT Press, 1989), 208.

[28] The capabilities and effects offered by digital signal processing, especially DAW plug-ins, closely parallel sound modifications found in tape music of the 1950s and 1960s. See early recordings by Otto Luening, Pierre Schaeffer, as well as Atlantic records engineered by Tom Dowd. For DSP examples, please refer to Waves and Isotope FX plugin bundles.

[29] "Improved" here does not automatically assume sound quality, but does include the improvements of cost, speed, and physical space.

> can concentrate better on what each of us loves in music that lies beyond the low level of how to make notes, at which music making far too often bogs down."[30] ~ Laurie Spiegel 1987

While at IRCAM in the 1980s, Miller Puckette wrote the MAX software to work with Giuseppe DiGuigno's 4X synthesizer.[31] MAX was a real-time scheduler with a graphical interface, which made programming more intuitive and enabled simple, yet real-time control of music, like tempo changes and sound events. Today, Max/MSP/Jitter has evolved to not only serve as an institutional learning standard, but offers possibilities in data dissemination, control, and composition using music, digital audio, and video.[32]

Advances in computers and computer software including notation software, polyphonic sound synthesizers, digital-audio recording, and graphic-oriented programming (Max/MSP, Kyma) have given the electronic music composer powerful music tools at his/her fingertips. The electronic composer simply has to learn how to generate, control, and modify data in order to create new music. The computer enables electronic composers to achieve real-time audio processing and control for performance. Before the introduction of the personal computer, composers had limited capabilities to control music in real time.

MICROCOMPUTERS | MICROCONTROLLERS[33]

In May 1976, an advertisement came out for the KiM-1, an inexpensive single-board computer.[34] The computer ad piqued the interest of many composers at Mills College, including David Behrman who bought a KiM-1 in order to explore its potential for controlling music. [35] One year later, David Behrman's "On the Other Ocean" (1977) appeared, which used a KiM-1 to control harmonies of two handmade synthesizers based

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[30] Joel Chadabe, *Electric Sound: The Past Promise of Electronic Music* (Upper Saddle River, NJ: Prentice Hall), 332.

[31] Joel Chadabe, *Electric Sound: The Past Promise of Electronic Music* (Upper Saddle River, NJ: Prentice Hall), 183-184.

[32] "Institutional learning standard" is based upon course curriculums found at many well-known electronic music centers, including NYU, McGill, Bennington College, CCRMA at Stanford, CNMAT at Berkeley, Mills College, and the University of Oregon, among others.

[33] The microcontroller has replaced the function of the microcomputers of the 1970s and 1980s–a reprogrammable microprocessor that serves the tasks and needs of a composer or artist.

[34] Wikipedia, "MOS KiM-1", http://en.wikipedia.org/wiki/KIM-1 (accessed January 4th, 2011).

[35] Joel Chadabe, *Electric Sound: The Past Promise of Electronic Music* (Upper Saddle River, NJ: Prentice Hall), 296, 298-299.

upon the pitch information of a flute and bassoon improvisation.[36] The piece demonstrated how microcomputers could control live music in real time.

Other composers at Mills College had also purchased KiM-1 computers, and in 1978, Jim Horton, John Bischoff, David Behrman and Rich Gold formed the League of Automatic Composers (LOAC). The first computer ensemble, LOAC consisted of connected KiM-1 computers that could distribute home-written programs and audio to others in the group. The shared audio information and data could be altered to control the music.[37] Because LOAC predated MIDI, the group connected their systems together using individually built hardware and software. The idea of distributing data between players for manipulation in an improvisatory way, was a huge step in performance computer music. One data stream could be used, altered, and reused. This type of data manipulation is commonplace today, with synthesis and software programs like Max/MSP and Kyma offering countless ways to share and manipulate digital information.

Stemming from a natural progression of live performers – David Tudor, Gordon Mumma, Pauline Oliveros– LOAC performed without being constrained to standardized musical notation.[38] The group explored the possibilities of electronic music free from conventional practice. However, the musical set-up for the group was extremely time-consuming, and the performers had to manually link each computer together.[39] After the introduction of MIDI, members of LOAC formed the HUB, an ensemble that utilized MIDI to connect every player. This new ensemble provided a reliable connection for each player, and subsequently, every performer could control, send, and receive data from his/her own instrument to every player in the group. MIDI allowed for more editing and interactive possibilities.[40] "The emphasis was on the network being a shared instrument."[41]

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[36] David Behrman, "On the Other Ocean" (1977) album notes, http://www.lovely.com/albumnotes/notes1041.html (accessed December 26th, 2010).

[37] Julio d'Escrivián, "Network Music," in *The Cambridge Companion to Electronic Music,* Nick Collins and Julio d'Escrivián eds., (Cambridge: Cambridge University Press, 2007), 145.

[38] Scot Gresham-Lancaster, "The Aesthetics and History of the Hub: The Effects of Changing Technology on Network Computer Music," *Leonardo Music Journal* 8 (1998): 39.

[39] The setup time was due in part to the fact that the group pre-dated a standardized musical protocol and connection system.

[40] Also, in 1985 the HUB held its first concert, which was wireless, predating the commercialization of email and the Internet. Kyle Gann, "Music Telephonica," *Village Voice,* vol. 23 (June 1987): 83.

[41] Joel Chadabe, *Electric Sound: The Past Promise of Electronic Music* (Upper Saddle River, NJ: Prentice Hall), 295-301.

The HUB was not free from problems, and the group's issues outline important concepts for today's electronic music performance ensembles. First, the HUB interface did not "fail gracefully," as the entire system was dependent on all the individual components working. The "non-duplicity" of the HUB meant that any hardware or software error caused the entire system to fail.[42] Slow processors could miss receiving data, and if performers did not send out data, the music could end abruptly. Tim Perkis recalls having to send out multiple data requests in order to keep the system working.[43] Today's ensembles must be able to function if a technical issue arises; the HUB could not perform with even one missing component.

Second, the exchange of information and ideas in the HUB was not entirely visible to the audience as members of the HUB sat behind their computers for performances. The lack of transparency of physical action to musical actualization in performance was inherit in the ensemble's setup, which came mainly from working with the computer as interface. Today, programmable environments like Max/MSP, which enables network event control, and the speed of computer processing, which allows for real-time audio manipulation, provide electronic ensembles flexibility in moving away from the computer as interface and offer the audience a more transparent, action-based performance. [44]

The importance of groups like LOAC and the HUB is that they appropriated technology for the benefit of a social, musical practice. While their technology today seems archaic, the methodology for interacting musically with group members was important for electronic performance. Indeed, aspects of HUB performances may be argued over (i.e. composers sitting behind their machines lessens an audience's experience), but the group has influenced modern computer ensembles, like laptop orchestras.[45]

Electronic music today has grown to include musical practice on non-traditional devices. Initially, composers programmed microcomputers for real-time control, today,

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[42] Scot Gresham-Lancaster, "The Aesthetics and History of the Hub: The Effects of Changing Technology on Network Computer Music," *Leonardo Music Journal* 8 (1998): 42.

[43] Ibid: 43.

[44] Groups like OEDO (Oregon Electronic Device Orchestra) are concerned with electronic performances that incorporate alternate digital controllers as instruments.

[45] The HUB influenced the PLOrk (Princeton Laptop Orchestra) and SLOrk (Stanford Laptop Orchestra) ensembles in particular. Dan Trueman, "Why a laptop orchestra?", *Organised Sound* 12: 2 (2007): 172-179.

composers take advantage of microcontrollers, which offers powerful flexibility for musical performance, most commonly in the form of alternate controllers.[46] The Arduino physical computing platform has enabled easy access to microcontrollers by providing an open-source platform for building and programming microprocessors. Because Arduino is a physical piece of hardware as well as a programming language that implements some type of touch interface (force sensing resistors, potentiometers, accelerometers, etc.), composers can quickly and efficiently create new digital musical instruments.

The improvements in connection standards and computer processing speeds have allowed for flexibility in programming, and physical computing expands the possibilities for real-time control in performance. In addition to constructing and programming microcontrollers, inexpensive digital controllers can be bought and appropriated by mapping the controls in software to control music.[47] In fact, the availability of consumer devices, like the Wii Controller, gives electronic composers access to controllers first advanced by Michel Waisvisz and Laetitia Sonami.[48]

Today, the composer must artfully choose the best tool for the task at hand. Working with the physical design of sensors and controllers, a composer becomes acquainted with the differences between sensors and how the instrument design may physically effect the interaction in a performance or installation. Whether it's a new electronic instrument, an interactive sound installation, or reprogramming the use of existing devices, there is an incredible of amount of focus on how the composer approaches the physical interface and the digital information inside the computer.[49]

With the cost, the speed, and the flexibility of software and hardware, there is a trend to bring the concept of touch back to electronic music. New groups like NIME (New Instruments for Musical Expression), founded in 2001, exist to share knowledge about new

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[46] Eduardo R. Miranda and Marcelo M. Wanderley, *New Musical Digital Instruments: Control and Interaction Beyond the Keyboard*, (Middleton, WI: A-R Editions Inc., 2006), 21.

[47] Today there exists common, standardized connections (USB, TCP/IP, Bluetooth) and programming environments (Max/MSP, Arduino) that enable microcontrollers and non-traditional devices (i.e. commercial products like iPod, iPad, Wii) to be used as controllers for musical practice without the expense of extraneous hardware.

[48] Specific controllers referenced are Michel Wasivisz's The Hands and Laetitia Sonami's Lady's Glove. http://www.steim.org/michel/ and http://www.sonami.net/lady_glove2.htm (accessed March 03, 2011).

[49] IDMIL (Input Devices and Music Interaction Laboratory) devotes part of its research efforts dedicated to topics in digital music information. IDMIL. "Projects," http://www.idmil.org/projects (accessed January 28, 2011).

musical instrument design.[50] Annual conferences address topics related to new instrument design: digital protocols, sensors for musical expression, real-time performance, and mapping strategies.

Today's technology, offering cheap and powerful microcontrollers, provides composers the ability to program devices to create more interactive and gestural electronic performances. Musicians provide a visual human link to music, and before the advent of recording technology, musicians were necessary for the creation of music. Groups like the Sensorband use computers and physical computing as a method for bringing physical performance back to electronic music.[51] The power of computers and the availability of microprocessors today has enabled new, alternate digital instrument designs, discussions about coding digital trends, and perhaps the necessity for electronic composers to grasp the fundamentals of not only theory, performance, and digital audio, but also computer programming to design for real-time interactivity and control.

PROGRAMMING – ART THROUGH CODE

> "Learning a programming language is really no more difficult than learning counterpoint."[52]
> ~John Chowning

Today, there exist many open source software and programming languages, such as Processing, Arduino, cSound, OpenFrameworks, CCV, pureData, and Python that offer unique opportunities to the composer, many of which were not available eight years ago. These resources provide cheap and effective tools for composers interested in connecting their musical ideas between the physical world and the digital. Before OOP (object-oriented programming) and the personal computer, musical programs and software were difficult to access. Because of the cost of computers, music software could only be found at large institutions like Bell Labs, Princeton, and Stanford. Even with access to computers, composers like John Chowning at CCRMA had to work with other departments, namely the Artificial Intelligence Labs, in order to work with computer music. The software itself was

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[50] NIME. "Home Page," http://www.nime.org/index.html (accessed January 17, 2011).

[51] Bert Bongers, "An Interview with Sensorband", *Computer Music Journal* 22: 1 (Spring 1998): 13-24.

[52] Michael Rogers, "Programming the Sound of One Hand Clapping", *Rolling Stone* (February 26, 1976), 48.

difficult to use and time consuming because computers like the PDP-10 used punch card programming.[53] With the advent of OOP and the availability of the personal computer, the composer could more easily write programs to control and create computer music, especially programs aimed at realtime performance.[54]

> "Today's network-oriented computer music languages, such as *SuperCollider, ChucK, Serpect or JSyn*,and also communication protocols like Open Sound Control (Wright and Freed 197) and graphical programming systems like Pure Data and Max, are derived from and inspired by such concepts [object-oriented programming]. These systems combine the concept of a program as a group of communicating individuals with a more conversational approach to code. In this way, they allow the network of human relations to include the algorithmic network of the program, and vice versa."[55]

By implementing basic programming skills, composers are able to connect any combination of hardware, software, and protocols together without succumbing to the constraints of consumer products. Through programming, the composer can modify or write software, and even program physical microcomputers tailored to fit his/her own creative needs.

Yet, not all programming is transparently beneficial. Musical coding, like Ge Wang's chucK programming language, challenges common conceptions of audience/performer relationships. Like the difficulties of using a computer interface as instrument in the LOAC and PLOrk (Princeton Laptop Orchestra) ensembles, the use of code as a transparent vehicle for musical performance faces similar challenges. In addition, the performance practice inherent with the chucK language raises questions about the critical assessment of electronic performance practice. While the topic of critiquing electronic music performance is beyond the scope of this paper, it is important to acknowledge the strengths, concerns, and flaws programming contains within the electronic music field.

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53 David Poole, an undergraduate in the Computer Science department helped John Chowning initially program Music V on the Stanford computers. Curtis Roads, "John Chowning On Composition", in *Computer Music*, C. Roads and J. Strawn, eds. (Boston, MA: MIT Press 1983), 2.

54 David Wessel at IRCAM talks of programming and MIDI as serving the goal of realtime electronic performance. Joel Chadabe, *Electric Sound: The Past Promise of Electronic Music* (Upper Saddle River, NJ: Prentice Hall), 204-205.

55 Julian Rohrhuber, "Network Music", in *The Cambridge Companion to Electronic Music* (Cambridge: Cambridge University Press, 2007), 146.

While live coding poses new challenges and raises questions about the assessment of musical performance, programming appears essential for the 21st century electronic composer. What is important is the power of programming to allow for real-time interactivity. Like the fore-mentioned 'Very Nervous System' written by David Rokeby using the C language, computer programming offers tools to the electronic composer to realize progressive, musical ideas in real time. Programming is a tool that enables the interconnection of software, ideas, and working styles and allows for an electronic music performance that is separate from the computer-as-instrument.[56] By understanding basic programming concepts, the composer frees him/herself from software/hardware not well suited to his/her own creative impulses and learns how to connect and execute the ones that do. "The computer should ideally feel in the musician's hands like a musical instrument, needing only to be tuned and then played." [57]

CONCLUSIONS

Music is still a "technical art." [58] Yet, now the skills needed for composing have been expanded, or perhaps, altered to fit the framework of current technology trends. Just as the piano was the instrument of the classical-age composer, and just as the studio became the instrument of the electronic composer in the 20th century,[59] there appears to be a new compositional instrument with the rise of the personal computer. Because the tools of the studio are now available on the computer, and as the composer utilizes the various software, programming languages, signal processing, digital audio editing, and digital protocols on the computer, the electronic composer calls upon the computer in serving the creation of electronic music. The computer and its resources–such as DAWs, digital protocols, and programming languages– serve as compositional aids, and these aids replace many of the traditional methods of composing in electronic music. Because of the flexibility, speed, and portability of the personal computer and its available resources, the computer has replaced

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56 Atau Tanaka, "Sensor-Based Instruments and Interactive Music," in *The Oxford Handbook of Computer Music,* ed. Roger T. Dean (2009), 254.

57 Miller Puckette, "Max At Seventeen" *Computer Music Journal* 26: 4 (2002) 31-43.

58 Atau Tanaka, "Sensor-Based Instruments and Interactive Music," in *The Oxford Handbook of Computer Music,* ed. Roger T. Dean (2009), 255.

59 Ibid: 237.

the studio as the instrument. The computer is the instrument of the 21st century electronic composer.

With the computer being the main focus of electronic studios and composition, there is a need for electronic composers to learn or possess strong, fundamental computer skills. Indeed, the wide dissemination of software and hardware relevant to the creation and playback of electronic music has "upped the ante" for electronic music and composers to hold their own in a world saturated with music. As composer Jeffrey Stolet noted, "You are only good as your last work."[60] Names in electronic music over the past thirty years: Karlheinz Stockhausen, Edgard Varèse, John Cage, Gordon Mumma, David Tudor, Pauline Oliveros, Laurie Spiegel, Pierre Schaeffer, Otto Luening, Iannis Xenakis; and then later on– David Behrman, Nic Collins, Michel Waisvicz, John Chowning (not including technical pioneers like Max Matthews, David Zicarelli, M S Puckette, and Carla Scaletti), provide a wealth of resources and music to the electronic composer. Unlike the DJ who samples music without digging for the context, in electronic music there is much to be learned contextually from composers of the past.[61]

With technological advances in the computing realm (processing speed, disk storage capacity), protocols (MIDI, OSC), other digital communication standards (AES/EBU, Alesis ADAT), and the lowering costs of electronic hardware and software, the cultures surrounding electronic music have been altered dramatically. "People of almost any community on earth can now record their own music without the help of any modern Bartoks. And people almost anywhere can or soon will be able to acquire a computer and involve it in their music-making."[62] Today, professional music studios are adjusting to the digital age and many more have closed their doors.[63] Smaller, home studios have emerged, and it is not only possible for the striving composer to build his or her own studio, but also to orchestrate a performance using only an alternate controller, an I/O interface, a computer, and a set of speakers.

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[60] Jeff, Stolet "Music 645," Lecture, Music room 74 (University of Oregon, Eugene, OR, Spring, 2010).

[61] Thom Holmes, *Electronic and Experimental Music*, 2nd ed. (New York, NY: Routledge, 2002), 274.

[62] Miller Puckette, "Max At Seventeen" *Computer Music Journal* 26: 4 (2002) 31-43.

[63] Referring specifically to large recording studios that have dissolved since 2005, including The Hit Factory, Sony Recording Studios, and Right Track Recording.

The trends of electronic music today– sound synthesis, sound modification, sound design, sound control, sound performance, standardized protocols, and acoustics– may guide the composer to make informed aesthetic and creative decisions, and create, not just music for our time, but works that hold up musically against the changes in technology. Since the introduction of the personal computer, the landscape of electronic music has changed drastically, if not completely, and has opened up the reality of real-time musical control and real-time audio processing. Today's composers have access to all the modes of digital sound technology–personal computers, digital audio editors, microcontrollers, programming environments, standardized protocols, a slew of alternate controllers, and a library of online resource materials–all for a relatively minimal cost. The tools are real and accessible, all that is needed is a formal understanding and a passionate drive to explore, learn, and create electronic music. In the words of Iannis Xenakis, "With the aid of electronic computers the composer becomes a sort of pilot..."[64]

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[64] Joel Chadabe, *Electric Sound: The Past Promise of Electronic Music* (Upper Saddle River, NJ: Prentice Hall), 336.