Bridging the Gap Between Art and Science Education Through Teaching Electronic Musical Instrument Design

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ABSTRACT

Electronic Musical Instrument Design is an excellent vehicle for bringing students from multiple disciplines together to work on projects, and help bridge the perennial gap between the arts and the sciences. This paper describes how at Tufts University, a school with no music technology program, students from engineering (electrical, mechanical, and computer), music, dance, and visual art areas use their complementary skills, and teach each other, to develop new devices and systems for music performance and control.

Keywords

Science education, music education, engineering, electronic music, gesture controllers, MIDI.

1. INTRODUCTION

Tufts University is not a place one might expect to find a course in Electronic Musical Instrument Design (EMID). The music program at Tufts is very traditional, emphasizing theory, musicology, composition, and ethnomusicology, with no program in music technology and no electronic music studio *per se*. The electrical and computer engineering program emphasizes high-level design and development and has no specific courses in audio electronics or recording engineering.

However, there has been in recent years a strong push from the administration to develop programs that are multidisciplinary in nature, bridging the gap between C.P. Snow's "Two Cultures," the arts and the sciences.[1] Because it draws from so many disciplines simultaneously, EMID has generated quite a lot of interest.

The student population at Tufts is extremely diverse, intelligent, and talented, and also, as befits a campus close to a large culturally-oriented city such as Boston, very aware of current trends in popular culture. Besides traditional performance ensembles, many students are active in extracurricular musical groups and music production projects that use electronic instruments and performance systems, with surprisingly sophisticated results. So the raw material for this kind of course is definitely there.

2. HISTORY OF THE EMID COURSE

The idea for the course emerged from two other multidisciplinary programs at Tufts.

2.1 Musical Instrument Engineering

The Musical Instrument Engineering (MIE) program, which offers both a minor and a concentration, began in 1994 as a "half-course" in the Mechanical Engineering department for first-year students called "Design and Performance of Musical Instruments."[2] It was "intended to pique the interest of students in engineering by teaching them principles of engineering using musical instruments as the educational medium."[3] It soon caught the attention of Steinway Musical Instruments, the parent company of Steinway & Sons Pianos and Selmer Musical Instruments, who formed an alliance with the university to work on a variety of research projects for the two companies. Out of that alliance, and with the participation of the Electrical Engineering (now Electrical and Computer Engineering) and Music departments, the MIE program was developed. The first students in the program were enrolled in 1999.

Today the MIE program encompasses courses in:

- Musical Instrument Design and Manufacture
- Dynamics and Vibrations
- Fluid Mechanics
- Physics of Music and Color
- Music Composition
- Acoustics
- Materials Science
- Finite Element Analysis
- Technical Writing
- as well as individual research projects and seminars

The certificate program is open only to mechanical engineering majors, but the minor program is open to any student with a good mathematics background and an interest in the field.

2.2 Multimedia Arts

The second multidisciplinary program is the minor in Multimedia Arts (MMA), which is administered by the program in Communications and Media Studies. The MMA program, which prepares students for research and careers in all aspects and combinations of media, draws from the Music, Drama, Dance, Fine Arts, Studio Art, and Electrical and Computer Engineering departments. Among the facilities that this program created was the first computer-based laboratory on campus for music composition and digital audio editing. This author was asked to join the faculty at Tufts in 1999 to teach courses in these subjects and to act as supervisor for the lab, which is also used for courses in digital photography and web design.

2.3 Electronic Musical Instrument Design

The EMID course was proposed in 2000, and was first offered in Fall 2001, when it had an enrollment of seven. It was next offered in Spring 2004, with an enrollment of 10, and is being given in the current semester (Spring 2005) with an enrollment of 12. The students have come from many disciplines, including mechanical engineering, electrical and computer engineering, computer science, chemical engineering, music, sociology, mathematics, economics, entrepeneurial studies, and the School of the (Boston) Museum of Fine Arts, with whom Tufts has a cross-registration arrangement.

The course is listed by both the Music and Engineering Science departments. Financial support comes primarily from the Mechanical Engineering and Music departments, with technical support from the Mechanical and Electrical and Computer Engineering departments.

3. CURRICULUM

The curriculum covers seven general areas. While this list is more or less in chronological sequence, many of the topics overlap.

- Broad analysis of what constitutes "music:" elements of melody, harmony, rhythm, timbre, dynamics, orchestration.
- Gesture controllers: analyzing the types of physical gestures that are used to control musical parameters in existing instruments, followed by conceptualization of other ways in which physical gestures could be used to control musical parameters.
- Study of existing commercial and prototype electronic musical instruments and performance systems, including live demonstrations by their inventors and/or expert performers. The companies and institutions represented have included Buchla Associates, Alternate Mode Inc., Sonic Implants Inc., Yamaha, Immersion Music Inc., Rensselaer Polytechnic Institute, Northeastern University, and the MIT Media Lab.
- Finding and working with a wide variety of sensors for measuring force, acceleration, distance, pressure, position, and other factors, and designing circuits for obtaining meaningful data from them.
- Study of MIDI and how it is used to control performance parameters.
- Study of IRCAM/Cycling '74's *MAX* and how it is used to process MIDI data.
- Study of Propellerheads' *Reason*, particularly the *NN19* sampler and *SubTractor* "analog" synthesis modules, and how they are controlled by MIDI commands.

4. EQUIPMENT

Tufts has dedicated a laboratory space approximately 10' x 20'. In the lab are two complete development systems built around Macintosh "Sawtooth" G4s with 1 GB of memory in each, running *Reason* and *MAX* under OS X 10.3.

Two MIDI keyboards are provided, each of which has a large number of configurable controllers: an M-Audio *Oxygen8* and an Edirol *PCR-30*. These are used to help program *Reason* sounds and to act as a source of consistent and reliable data for testing *Max* patches.

Originally we used M-Audio *USB Audio Quattro* interfaces for both audio output and MIDI input, but they proved so unreliable that we went back to the Macintoshes' own audio outputs, which are fed through Advent and Bose powered "multimedia" speaker systems. Given the small space of the lab, these are more than adequate, and for public presentations we bring in a larger system. For MIDI we use Mark of the Unicorn *FastLane USB* MIDI interfaces.

In the first semester the course was taught, we used the *I-Cube* sensor/MIDI converter system, but it was problematic in a number of ways, primarily in the consistency of the data and the cost of expansion.

For the second semester we obtained two each of the *Pocket Electronic* and *CTM 64* circuit boards from Doepfer Musikelektronik GmbH, of Graefelfing, Germany. These boards were custom-mounted (see Figure 1) on two Lexan bases by our Electrical Engineering staff, so that each system can read 64 discrete switch closures and 16 potentiometers or DC circuits, and translate them into MIDI note and controller commands, respectively.

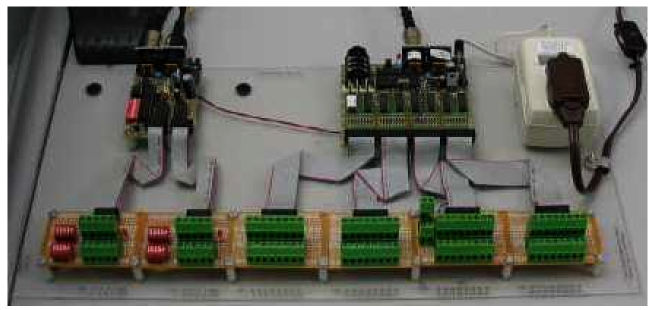

Figure 1. The custom-mounted Doepfer modules

While the Doepfer devices are programmable, we use them in their factory default configurations to reduce the number of parameters the students need to keep track of. They have proven to be very reliable.

5. STUDENT ASSIGNMENTS

5.1 Readings

Required readings include several chapters from *Towards a choice of gestural constraints for instrumental performers,* edited by Axel G.E. Mulder (IRCAM); *MIDI For The Professional*, by the current author and Tim Tully (Music Sales); *Users' Guide to Propellerhead Reason*, by Debbie Poyser and Derek Johnson (Muska & Lipman), and selected articles from *Electronic Musician*, *Keyboard*, *Computer Music Journal*, and *IEEE Spectrum* magazines. Students are also given several written assignments and one take-home exam which are primarily intellectual exercises designed to stimulate their thinking about the relationship between physical gestures and the production and control of musical sound.

5.2 Design and construction

There are three construction assignments during the semester. The first assignment is to build a simple one-parameter MIDI controller, the second is to build a multi-parameter controller and connect it to Reason through MAX, and the third, which is considered the term project, is to build a complex performance system and learn to play it.

6. CREATING WORKING GROUPS

Perhaps the most important contribution to the success of the course has been in its creation of working groups comprised students with complementary skills. In each group there was at least one student with at least one of these qualifications:

- musical literacy and performance experience
- familiarity with MIDI and *Reason*
- ability to assemble simple electronic circuits
- woodworking and/or metalworking skills
- sufficient computer programming experience to be able to master *MAX* quickly

Fortunately, most students had two or more of these qualifications, since considering the small size of the class, it would have been difficult to constitute more than one group had it been otherwise!

Among the students in 2004 were the following individuals:

- a computer science major who had the previous semester started working on an independent project to design a granular synthesizer using Max/MSP
- a student from the Museum school who was also an active DJ
- a chemical engineering student who was a fine guitarist and woodworker
- an electrical engineering major who not only loved breadboarding but was an accomplished pianist and composer
- an art history major who was a talented bass player, record producer, and sound designer
- a music and entrepeneurship major who had taught himself *Reason*
- a mechanical engineering major who was an excellent carpenter
- and an ethnomusicology graduate student with a degree in recording engineering

The students were divided into four groups for their first assignment, and when the assignment was completed, I asked them to evaluate themselves and their teammates, and indicate whether they would like to continue with the same team. The response was almost unanimous that they would, and so I kept the teams the same for their final projects.

7. SPRING 2004 STUDENT PROJECTS [4]

7.1 Sequence-oriented projects

Two of the groups' final projects took advantage of *Reason*'s built-in sequencer, and used their controllers to manipulate sequencer tracks in real-time, rather than generate individual musical events.

7.1.1 The Carstrument

This team built a mock-up of an automobile steering column with directional and windshield wiper levers attached to toggle switches, a steering wheel (which they obtained from a plastic child's car that had been left in someone's rubbish) attached to a rotary potentiometer, a slide potentiometer with a shift-lever-style handle, and two foot pedals with springs pushing down on pressure sensors.

The position of the toggle switches determined which of several procesing or timbral parameters would be controlled by the steering wheel. The slide potentiometer turned on and off individual sequencer tracks. The foot pedal controlled delay feedback.

7.1.2 Edward Sensorhands

This team used two garden gloves, equipping one with a force-sensing resistor on each finger tip and the palm, and the other with a flex sensor on each finger (see Figure 2). The flex sensors were mapped to Controller commands and the FSRs to notes. In *Max*, the incoming notes toggled mute switches (touch on/touch off) for each of the sequencer tracks. The FSR in the palm was interpreted as a MIDI Start command, which reset the sequencer. The incoming controllers were mapped to various timbral parameters in the Reason modules.

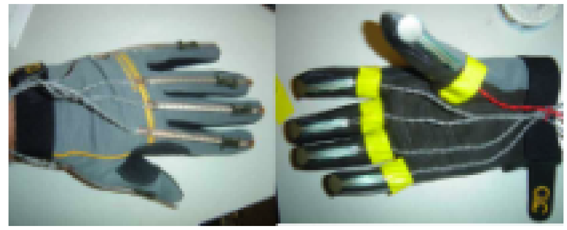

Figure 2. "Edward Sensorhands"

The students had also hoped to influence tempo and more complex timbral changes using distance and tilt sensors, but were unable to get them to work reliably.

7.2 The Digital Washboard

This two-person team bought an old-fashioned washboard made by the Columbus Washboard Company, who claim to be the last manufactuer of such items in the United States, at a local hardware store. They put caulk along each of the 18 ridges on one face, and then attached conductive copper tape to the caulk, anchoring each piece of tape with a screw, and then soldering a lead to each screw.

Each lead was attached to a different terminal on the *CTM* module, so that completing a circuit through the tape would generate a different note. To complete the circuit, the students glued thimbles to the five fingers of a cloth glove, and wired all of them to the +5VDC output of the *CTM* module (see Figure 3).

In *Max* the students created 12 matrices which mapped incoming MIDI notes to degrees of various scales and chord arpeggios. On the top of the washboard they mounted 12 buttons, which were connected to the *Pocket Electronic* module (see Figure 4).

Pushing any of the buttons sent a Controller command which selected one of the note-mapping matrices in *Max* and also changed the MIDI channel of subsequent notes. A slide potentiometer on the board was also wired to the *Pocket Electronic* module and served as a transposer with a range of one octave: the Controller value it generated was divided by 10, and the result was added to the MIDI note numbers. A second slide potentiometer was mapped to *Reason*'s amplitude envelope release time (which is the same for all of the different modules) on the outgoing MIDI channel.

In *Reason*, the students created 12 different patches using the *SubTractor* and *Maelstrom* pseudo-granular synthesis modules.

The students were able to play a reasonable version of Herbie Hancock's *Rockit* on the device. In effect, they created a stringless, highly-flexible digital autoharp—which, interestingly enough, was an instrument that neither of them was familiar with.

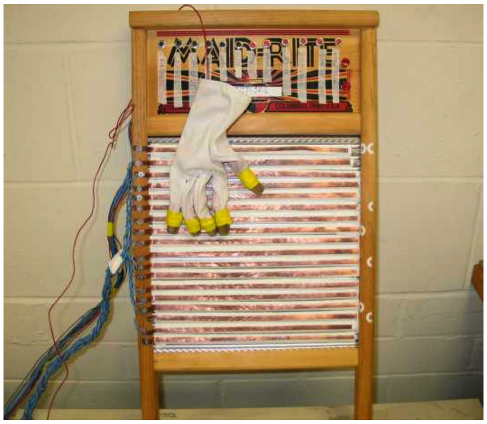

Figure 3. The Digital Washboard and glove

Figure 4. Detail from the Digital Washboard

7.3 The Virtual Lunga

This project was different from the others in that the students were not constructing an electronic performance instrument: they were essentially de-constructing, using similar technology, a traditional instrument.

The project was undertaken at the request of Dr. David Locke, professor of ethnomusicology at Tufts, whose specialty is the drumming of West Africa. During the semester Prof. Locke was hosting Dolsi-naa Abubakari Lunna, one of the most renowned master drummers of the Dagbon region of Ghana, who was in residence at Tufts. Dolsi-naa's instrument is the talking drum, or Lunga, which is played by hitting one of the drum's two heads with a crooked stick with one hand, and changing the tension on the head by pulling on a set of cords connecting the heads, using the wrist, forearm, and elbow of the other arm.

Prof. Locke has recorded and studied the musical language of the Dagomba drummers extensively, and asked for the class's help in creating a database of musical gestures employed by Dolsi-naa. Dolsi-naa contributed one of his drums, which he makes by hand., to the project.

The students analyzed Dolsi-naa's playing and determined that the musical events could be distilled down to four parameters:

- how hard the stick hits the head
- where on the head the stick makes contact
- the angle of the stick when it hits the head
- the tension on the cords

They then placed two force-sensing resistors on the face and side of the stick head, three piezo-electric pressure sensors underneath the head, and a short-range distance sensor on one of the cords (see Figure 5).

Figure 5. The Lunga with distance (L) and force sensors (R)

The plan was to record Dolsi-naa using audio and video, at the same time feeding the data from the sensors into the *Pocket Electronic*, where they would be translated to MIDI controller commands and recorded in parallel with the audio, using Mark of the Unicorn's *Digital Performer*. The second phase of the project would be to extract samples of individual events from the recording and use them to create a sampled instrument that would respond to the recorded MIDI data in such a way as to re-create the original performance.

Due to restrictions on Dolsi-Naa's time and difficulties in getting certain parts, the students were not able to complete the first phase of the project before the end of the semester. But they laid some fine groundwork, and it is the author's hope that this coming semester when Dolsi-Naa again visits Tufts, the class will be able to make much more progress.

8. CONCLUSIONS

In the Electronic Musical Instrument Design course at Tufts University we have hardly broken new ground in the field of interface design, but we feel we have sparked the imagination of a group of students and inspired them to think in new ways about combining art and technology. The course was unanimously praised by the students and several of them reported on their formal evaluations that it was one of the best courses they had taken at Tufts. The musicians were grateful for the new perspectives on music and musical tools that they were exposed to, and the engineers were happy that they had done so much hands-on engineering, and learned so much about music. As a vehicle for bringing together students from very different disciplines, teaching them and watching them teach each other, while having fun in the process, we have found the course to be eminently successful.

9. ACKNOWLEDGMENTS

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