THE MACHINE ORCHESTRA

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ABSTRACT

This paper describes the making of the Machine Orchestra, a unique ensemble that combines custom musical interface design, hemispherical speakers, networked performance, and musical robotics. This project is built as part of the final year curriculum in Music Technology at California Institute of the Arts (CalArts), where students amalgamate computer science, digital signal processing, circuit design, metal machining, musical composition and performance, into an immersive multimedia event. This paper describes the process of designing this orchestra, including examples of custom built musical robots.

1. INTRODUCTION

In 2006, Dan Trueman and Perry Cook unleashed the Princeton Laptop Orchestra (PLOrk) [1, 2], setting a new paradigm for teaching, performing and composing computer music. At the time, there was very little precedence of having multiple performers on stage performing on laptops together, and most performances were limited to one musician. Additionally, the projects that did involve multiple laptop musicians such as The Hub[1], generally had less than four performers on stage, nowhere near the 16 -25 in PLOrk. With the invention and mass production of the Hemispherical Speaker [3], it was finally possible for each PLOrk musician to have their own sound source on stage. This permitted the audience to perceive the laptop musicians output localized to where the sound was emanating from in the orchestra, as opposed to the traditional method of a stereo PA mix [4]. A key paradigm shift surfaced in how a "Laptop Orchestra" could be used in education to teach computer science, composition and performance to the computer musicians of the future [5].

And thus began the "Age of the LOrk." In 2008, Ge Wang, a pivotal member of the original PLOrk, emerged from the Stanford Center for Computer Research in Music and Acoustics (CCRMA) and founded the first LOrk on the west coast, The Stanford Laptop Orchestra (SLOrk). Near the same time, other laptop orchestras began appearing around the world. Direct collaboration with SLOrk and PLOrk led to the creation of the Oslo[2] and Boulder[3] Laptop Orchestras. Other groups unaffiliated with educational institutions also started to materialize, including the Moscow[4] Cyberlaptop Orchestra, the Tokyo[5] Laptop Orchestra, and the Seattle[6] Laptop Orchestra. In 2009, The Virginia Institute of Technology[7] founded the first LOrk created through fully open source technology, aptly named the Linux Laptop Orchestra, L^{2}Ork. The concept of a LOrk has also transitioned to mobile devices, with the first mobile phone orchestra (MoPho) performing in 2008 [6]. Since then, other networked ensembles of phones have

[1] http://en.wikipedia.org/wiki/The_Hub_(band).

[2] http://fourms.wiki.ifi.uio.no/Oslo_Laptop_Orchestra
[3] http://cismat.org/blork.html
[4] http://cyberorchestra.com/
[5] http://laptoporchestra.net/
[6] http://www.laptoporchestra.com/
[7] http://l2ork.music.vt.edu/main/

surfaced, including the Michigan[8] Mobile Phone Orchestra, The Helsinki[9] MoPho, and the Berlin Mobile Phone Orchestra.

Influenced by all these projects, our team endeavored to design our own "LorK" inspired laptop orchestra. Adding the pedagogical disciplines of the "Lorks before us", our project focuses on training new computer musicians on other skills including: metal machining, mechanical engineering, interface design, and musical robotics. These additional elements which are unique to the Machine Orchestra, and which are instrumental to the CalArts Music Technology curriculum, were realized by combining forces of the CalArts Music department with the CalArts Theatre Department who train students to be Technical Directors.

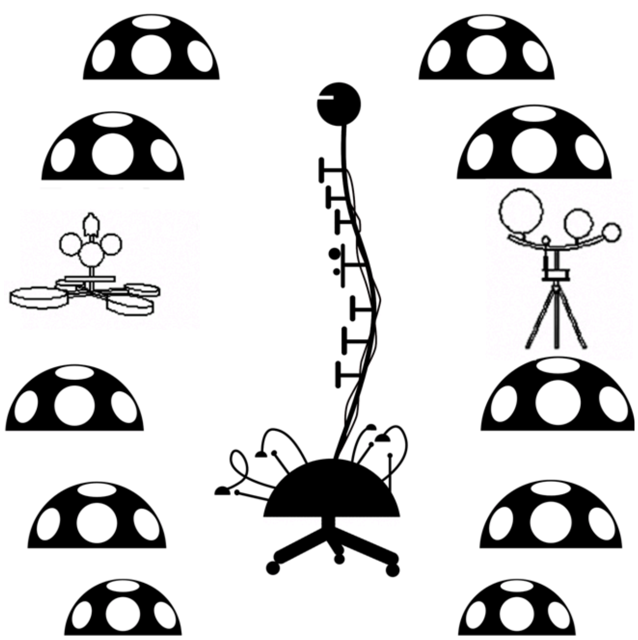

Figure 1 - Overview of Machine Orchestra with HemiSpherical Speakers and Robotic Musical Instruments.

In this paper, section 2 describes curriculum design at California Institute of the Arts, and the track required to prepare an artist for participation in the Machine Orchestra. Section 3 introduces the five robots that are currently members of the Machine Orchestra. Section 4 describes the sonic aesthetic considerations. Section 5 describes the visual aesthetics of the machine orchestra and set design considerations. Section 6 describes our custom network framework developed for networking 10 human stations and 5 robots.

2. CURRICULUM DESIGN

The Music Technology program at CalArts is designed to breed well-rounded electronic musicians that have an equal balance of musicianship and compositional skills, as well as technical expertise. Each student is required to take a rich core-curriculum in music theory, composition and performance. They undergo extensive ear training, music sight-reading, and are prepared work in virtually any type of musical setting.

The technical training is based on a 4-year curriculum. During the first year, each student is introduced to object oriented (OO) programming using the Chuck programming language [7]. This familiarizes the students with text based programming concepts and techniques, so they can easily move to other languages in the future. The second year is centered around digital signal processing, and students learn how to build classic software synthesizers and audio effects. The goal at the end of the second year is for each student to have built a set of custom tools to make their own sound. In the third year, the students learn electronic circuit-design and how to build their own musical interfaces to control their software instruments. Finally, fourth year students are ready for the Machine Orchestra, a performance-based course where they are involved in designing and building custom musical robotics, software infrastructure and musical compositions that culminate into a final performance.

3. ROBOTIC DESIGN

This section describes the five robotic instruments used in the Machine Orchestra.

[8] http://mopho.eecs.umich.edu/
[9] http://www.acoustics.hut.fi/projects/helsinkimopho/

These instruments were custom built by students and faculty at CalArts. *Tammy*, *Raina*, *GanaPatiBot*, the *Robotic Reyong*, and *MahaDeviBot* are all described.

3.1. Tammy

Students of the Robotic Design class engineered three distinctive instruments making up *Tammy's* (**Figure 2**) body, including a handcrafted and tuned marimba, a self-plucking drone device, and 5 bells. The Marimba was tuned to a C# pentatonic scale using custom machined pieces of rosewood and struck by push solenoids mounted behind each block. The bells were struck using rotary solenoids and re-purposed from parts of aluminum gate-posts along with a bell from an old rotary phone. The percussive string instrument on *Tammy* is designed using a fan motor from a broken fan to strum the string, with two push solenoids to change the pitch of the string by intersecting the string in two locations. Built using recycled objects found in an electronics junk yard and classrooms at the Institute, *Tammy* stands six feet tall with 14 actuators (and counting!).

Figure 2 - Tammy Robot Marimba (left), Bells (right)

3.2. Raina

Raina, our Robotic Rainstick stands 8 feet tall and is constructed from a long piece of PVC pipe. The pipe is plugged with over fifty dissecting lateral sticks that rattle sand, lentils, and BB gun pellets as the pipe is slowly turned around by a chained DC motor. We use the rainstick throughout the concert as an ambient sonic texture, providing a gentle "wave" of sound which ties the concert together.

3.3. GanaPatiBot

The *GanaPatiBot* (**Figure 3**) is the re-engineered successor to the *MahaDeviBot* (described in section 3.5). Each drum is equipped with a multi-solenoid striking system, allowing a variety of sonic textures as well as increasing roll speed. *GanaPatiBot* also has a series of shakers, noisemakers and wood slappers to add various textures of sound to the Machine Orchestra's palette. In addition, two speakers are attached to the backside of the *GanaPatiBot* in a propeller powered Leslie-like system, which plays sounds and drones from an iPod Mini.

Figure 3 - GanaPatiBot Leslie Speaker (left), Tri-beating Drum (right)

3.4. Robotic Reyong

The reyong is a series of upside-down metal pots suspended on a frame used in Balinese gamelan. Influenced by Eric Singers Gamelatron[10], we designed a 7-armed robot (**Figure 4**) to perform a reyong using simple push solenoids.

Figure 4 - Robotic Reyong (left), Gamelan (right)

[10] http://gamelatron.com/

3.5. MahaDeviBot

The development of the *MahaDeviBot* serves as a model for various types of solenoid-based robotic drumming techniques, striking 12 different percussion instruments gathered from around India, including frame drums, bells, finger cymbals, wood blocks, and gongs. The machine also has bouncing head that can portray tempo to the human. More information on the *MahaDeviBot* can be found in [8].

4. SONIC AESTHETICS

Another important aspect of the Machine Orchestra is the addition of ten hemispherical speaker arrays following the paradigm established by Dan Truman, Perry Cook, and Curtis Bahn, as well as Ge Wang's design for SLOrk. The placement of the speaker arrays (**Figure 5**) within the context of the Machine Orchestra, allowed for precise spatial positioning of each laptop performer, accentuating each individual laptop in a manner not possible through the use of conventional stereo speaker arrays. Due to the frequency limitations of the hemispherical speaker arrays, we found it necessary to reinforce each laptop performer with additional mid-range and low-range speakers and sub woofers.

Figure 5 - CalArts Hemispherical Speaker System

5. VISUAL AESTHETIC

A strong emphasis was placed on the visual elements of the Machine Orchestra in order to effectively communicate the intricacies of the technologies to the audience, while adding an additional level of creative coherence to the show. A chief concern during the visual design phase of the Machine Orchestra was to highlight two critical elements of the show,,the robots and the performers' custom digital interfaces. In order to give the audience a clear view of the moving robotic parts, each robot was joined with a number of security cameras, complete with three projectors and custom built screens.

Additionally, visual focus was placed on the various custom-built interfaces used by the human performers. Like the robotic instruments, these highly expressive interfaces played a crucial role within the performance in terms of the performer/audience communication. In order to provide the audience with a clear visual line of site to each interface, the performers were positioned on a series of two-tiered platforms, arranged similar to a terrace, with the piano and various gamelan instruments positioned at stage level. This arrangement provided enough isolation to highlight each individual interface, while maintaining the close-sense of connectivity between performers necessary for creative musical interaction.

6. NETWORK

The Machine Orchestra has unique requirements that separate it from existing laptop orchestras. In addition to providing all laptop performers with an extremely stable sync source in both OSC and MIDI protocols, The Machine Orchestra ensemble also requires a low-latency/low-jitter network solution for connecting multiple laptop musicians to the musical robotics. Additionally, the server/client framework has been made extensible in order to support the widest possible configuration of musicians, and timing issues have been addressed to allow for real-time performance with the musical robotics.

The client and server applications were developed in ChucK. We found that a wireless network latency of 40 to 50 MS was too great to reliably synchronize the robots and performers. Our solution implements a high-performance network switch that directly connects the server and clients. If any clients drop from the server during the performance, we have created a "kick start" function allowing performers to re-insert themselves into the clock stream. The server also parses incoming MIDI to quickly and accurately relay serial to the robots.

7. CONCLUSION

The Machine Orchestra represents a framework for live-electronic performance that allows for great exploration of new compositional materials and practices. As more students partake in the curriculum, and bring new interfaces and robotic instruments to the orchestra, this project will continue to mature and expand. Similarly, as new mechanical sculptures and robotic instruments are designed, new possibilities will emerge.

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