A Pedagogical Paradigm for Musical Robotics

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ABSTRACT
This paper describes the making of a class to teach the history and art of musical robotics. The details of the curriculum are described as well as designs for our custom schematics for robotic solenoid driven percussion. This paper also introduces four new robotic instruments that were built during the term of this course. This paper also introduces the Machine Orchestra, a laptop orchestra with ten human performers and our five robotic instruments.

Keywords
Musical Robotics, NIME pedagogy, digital classroom, Dartron, solenoid, laptop orchestra, Machine Orchestra.

1. INTRODUCTION
The age of mechanical musical instruments has emerged with the advent of cheap microcontrollers, open source schematics for circuits, and readily available actuators affordable for artists. Artists such as Trimpin [1], Eric Singer[2], Gil Wienberg[3]. Godfried Raes[4], Chico Macmurtrie [5], and many others have helped pave the way with many ingenious inventions. This has motivated us to design a course to teach about the work of these artists, and get students on track on building their own mechanical systems for music making.

Musical robotics have been used for pedagogical purposes in a variety of different ways, especially in Japan. The Department of Systems and Control Engineering in Osaka Prefectural College of Technology built robotic instruments to show interdisciplinary skills in arts and science [6]. In Waseda University, their anthropomorphic flute robot is used in the music practice room to help reproduce human flute playing and evaluate human performance with graphical feedback [7].

A key inspiration for our course was learning about PloRK[8] and SloRK[9]. We were interested in making our own digital orchestra, "The Machine Orchestra", which focused on spatialized sources on stage. We wanted to take the hemispherical speakers[10], a step further by building mechanical instruments which could be placed around the stage. These robotic instruments which are unique to the Machine Orchestra, were realized by combining forces of the CalArts Music Technology program with the CalArts Theatre Department who train students to be Technical Directors in our course entitled "Robotic Design for Music and Media".

In section 2, we describe the curriculum for our musical robotics course. Section 3 describes the Dartron, a mechanism for solenoid driven percussion. Section 4 introduces the four robotic instruments that have been built from our class. Section 5 describes the beginning of our Machine Orchestra that has emerged as a result of this course. Section 6 describes performance scenarios and gives a brief overview of a few of the different compositional techniques taught and practiced as part of the Machine Orchestra.

2. CURRICULUM
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. In the Technical Direction program in the Theatre School, students are trained in many aspects of professional construction of set design. They learn how to conceptualize an idea using AutoCAD, and the tools needed to build their concept out of wood, aluminum, steal, etc. The marriage of both these groups of students provide the perfect corpus to build robotic musical instruments.

The class begins with a history of musical robotics and mechanical forms of art. It is important for each student to be exposed to what has been accomplished, to help inspire new ideas, and shape a world they never knew existed. Next, an introduction to machining is covered. Students learn how to use the drill press, mill, lathe, cold cut saw, table saw, weld, and other tools in the scene shop. Next there is a series of lectures on actuators and electronics. Students learn about solenoids, DC motors, stepper motors, relays, transistors and more. We teach this section using the Arduino[1] and point students in the direction of a large body of open source tools.

[1] http://www.arduino.cc/en/

Next, building time begins. We start the students off on building the “Dartron” robotic drum striker, described in detail in section 3. This gives them experience on building a known device that we know works, and helps complete the circle in the students minds, very quickly. Then we go on to designing the large scale robotic instruments the class as a team builds together. Students are give time to go to the junkyards, walk around the school, and draw a design for an element on the final robotic machine. These ideas are compiled together and a larger scale instrument begins to emerge. Generally there are experts in one specific field: welding, lathe, mill, soldering, programming, etc. Each student is given an assignment based on their expertise, and a due date for completion. At the end of the class, we generally have 2-3 different robotic instruments ready to perform.

3. DARTRON

The Dartron was developed as a basic example of the mechanics of the “beater” or “mallet” used with different percussion based instruments. It is designed on the principle of locomotion in which linear motion is transformed into rotational motion, which allows a solenoid that moves up and down to control the rotational motion that is the percussionist. The Dartron may be constructed out of any available material including wood, plastic or metal. In its present state it consists of a turned aluminum flywheel, machined to accept 5/16 ball bearings, a brass pushrod, an aluminum stemmed mallet and cheeks and bottom section made from .25 clear acrylic machined to accept linear solenoid. During the creation of the Dartron several shop techniques must be first introduced and are listed: Machining (turning and milling), Tap and Die, Drilling, Pattern making, Plastics Fabrication, & Woodworking.

The design of the Dartron is such that it is mechanically open source, meaning that it can be easily created with basic shop skills and is easily customizable which allows it to be used on both existing instruments as well as student created ones.

The construction of the Dartron takes on many visual considerations due to the fact that they need to be showcased as the working parts of the robot in a performance setting. First and foremost the materials chosen for the mechanics need to be read as very mechanical in nature. To do this we used polished metals such as brass and machined aluminum so to ensure it is accepted visually as “robotic” and “inorganic”. The choice of the clear acrylic comes from the idea that the mechanics need to be observed. To help achieve this in performance video cameras have placed at and around the points of mechanization and high powered led lamps have been place as to allow the Dartron to be shadow puppeted onto the face of the drums.

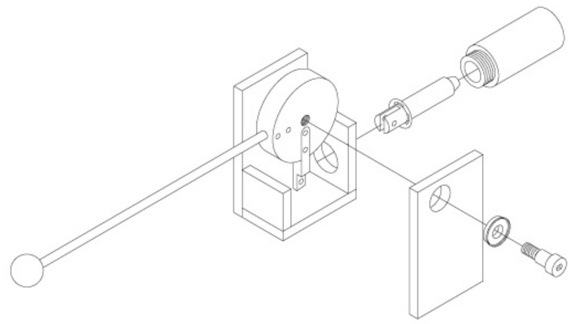

Figure 1 - Dartron: Robotic Drummer Design

4. ROBOTIC INSTRUMENTS

This section describes the robotic instruments built in the class and finally used in the Machine Orchestra. These instruments were custom built by students and faculty at CalArts. *Tammy*, *Raina*, *GanaPatiBot*, the *Robotic Reyong*, and *MahaDeviBot* are all described.

4.1 Tammy

Students of the Robotic Design class engineered three distinctive instruments making up Tammy’s body, including a handcrafted and tuned marimba, a self-plucking drone device, and five 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 and the 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 the Apex electronics junkyard and classrooms at the Institute, *Tammy* stands six feet tall with 14 actuators (and counting!).

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

4.2 Raina

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

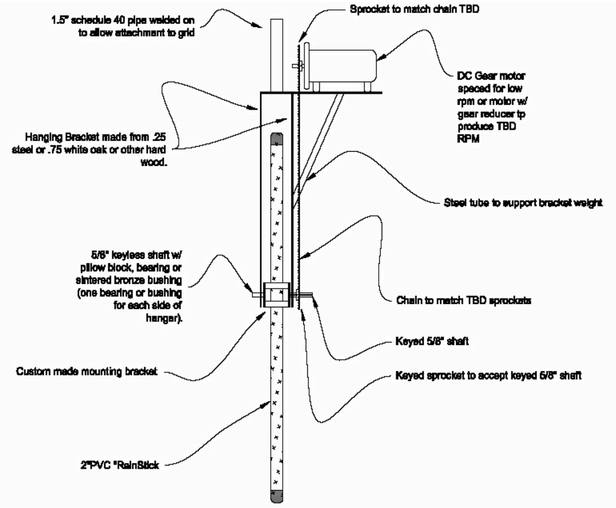

Figure 3 - Raina - Robotic Rainstick

4.3 GanaPatiBot

The *GanaPatiBot* is the re-engineered successor to the *MahaDeviBot* (described in section 4.5). 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.

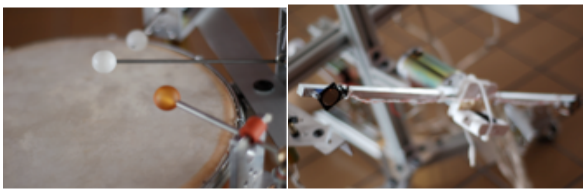

Figure 4 - GanaPatiBot Leslie Speaker (left), Tri-beating Drum (right)

4.4 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[2], we designed a 7-armed robot to perform a reyong using simple push solenoids.

Figure 5 - Robotic Reyong (left), Gamelan (right)

4.5 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 [11]. The *MahaDeviBot* was used in class as a proof of concept design to help inspire new ideas.

5. THE MACHINE ORCHESTRA

Influenced by PLorK and SLorK, our team endeavored to design our own "LorK" inspired laptop orchestra. Adding the pedagogical disciplines of "Lorks before us", our project focuses on training new computer musicians on other skills including: metal machining, mechanical engineering, interface design, and musical robotics. Once the robotic instruments are built in the course, they are moved to the Machine Orchestra rehearsal room for use in composition and performance.

The Machine Orchestra brings together custom-built robotic musical instruments and human performers with modified instruments, unique musical interfaces, and hemispherical speaker-pods. 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 to the orchestra, this project continues to mature and expand. Similarly, as new mechanical sculptures and robotic instruments are designed, new possibilities emerge.

Figure 6 - World Premiere of Machine Orchestra at REDCAT Walt Disney Hall, Los Angeles CA, Jan. 27, 2010.

[2] http://gamelatron.com/

6. PERFORMANCE SCENARIOS

This section describes a few performance scenarios, providing a small set of the composition capabilities of the Machine Orchestra.

The strong influence of North Indian Music at CalArts has led to a significant body of compositions using Indian classical theory. Ustad Aashish Khan has written a number of melodic lines specifically for the orchestra. Electronic musicians then take these melodies and write software that allows the robots to match these motifs. Harmonies and rhythmic structures are composed to complement the melodies, but are generally performed on custom interfaces designed by the students.

"Voices", a composition written for the machine orchestra, begins with each of the musicians exploring various aspects of vocal synthesis. One by one each musician introduces their "Voice", using their interface to impart unique gestural control. As the piece evolves, dialogs between different performers begin to emerge, until the composition morphs into a large conversation between everyone in the orchestra.

"Mechanique" is an orchestra piece in which each performer controls 2-3 arms of a robotic instrument. Inspired from a piece by Bjork's "Dancer in the Dark." This piece is very industrial, transforming physical gestures in to mechanical movement.

Finally, with the large presence of talent in Indonesian music at CalArts led by I. Nyoman Wenten, and a custom robotic reyong, a large body of work fuses live-electronics and gamelan. This presents unique challenges, such as keeping time with the robots while following all the changes in timing from a traditional gamelan orchestra. Additionally, the microtones within Indonesian music are extremely important; in order to ensure that these intricacies are not lost, care must be taken when designing sound scapes.

7. ACKNOWLEDGMENTS

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