GEER HEAD

by David Geer

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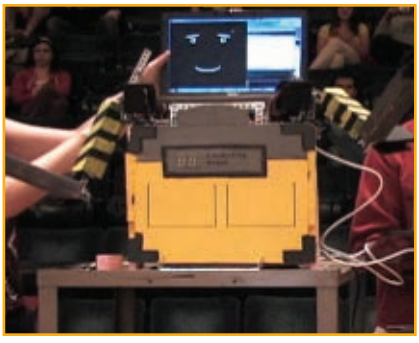
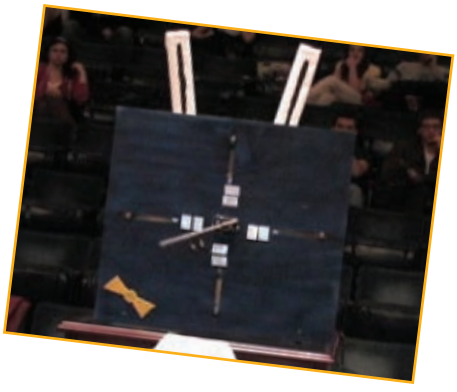
Baton-Wielding Bots Command and Control Orchestrated Wonders!





The College of New Jersey in Ewing received an award of $359,477 in March '09 from the National Science Foundation (NSF) to support the Conducting Robots class for three years. The class brings together students from four disciplines — Computer Science, Mechanical Engineering, Interactive Multimedia, and Music — to design, build, and program robots capable of conducting orchestras. The class culminates in a performance where the robot conducts the TCNJ orchestra on brief musical pieces.

Under the NSF's CreativeIT Program, the college receives funding to explore synergistic cross-disciplinary research combining computer science and creativity. The course teams students from the varying disciplines to pool their resources and come up with robotic systems that conduct the orchestra. The systems include multimedia displays. "In essence, the students will create a robotic maestro that mimics the arm movements and facial expressions of a human conductor at work," according to a TCNJ media release. The robotic system is a mode for teaching the students not only about their own areas of expertise but how to cooperate technically with other disciplines in order to awaken or enhance their creativity.

During a recent semester, students in the Conducting Robots course constructed three robots. Chris Ault, associate professor of Interactive Multimedia; Dr. Teresa Nakra, associate professor of Music; Dr. Andrea Salgian, assistant professor of Computer Science; and Dr. Jennifer Wang, associate professor of Mechanical Engineering taught the class. Seventeen students took the course and made up three teams of roboticists.

Requirements included that the robots use both visualization and mechanical motion to communicate cues and instructions on tempo, dynamics, and articulation to the orchestra.

There has been little attempt by roboticists to date to create robots to conduct orchestras. A couple exceptions were Honda's ASIMO robot conducting the Detroit Symphony in 2008, and Honda's QRIO that conducted the Tokyo Philharmonic Orchestra for 90 seconds in March '04. However, the robot's pre-coded activity did not include true interaction with the musicians in the orchestra.

The TCNJ students were provided with the input from MIDI files. This and visual analysis helped to give the robots more human-like gestures. The robots were able to convey more information than ASIMO.

ACRE Robot

The ACRE or Automated Conducting Robot Experience robot is a human size robot. The team built it with an upper frame and a lower frame to simulate the human torso and legs, respectively. The upper frame consists of three plates used to accommodate a laptop, a monitor (to simulate the conductor's face), and other necessary equipment. The arms were connected to the top plate, or shoulder plate. The team made the frame of aluminum 6061 for its strength, rigidity, and ease of use.

Since the robot's right arm keeps the tempo, its movement is on a fixed path that can be achieved with only three degrees of freedom: two in the shoulder joint and one in the elbow joint. There is a gripper at the end of the right arm for a hand.

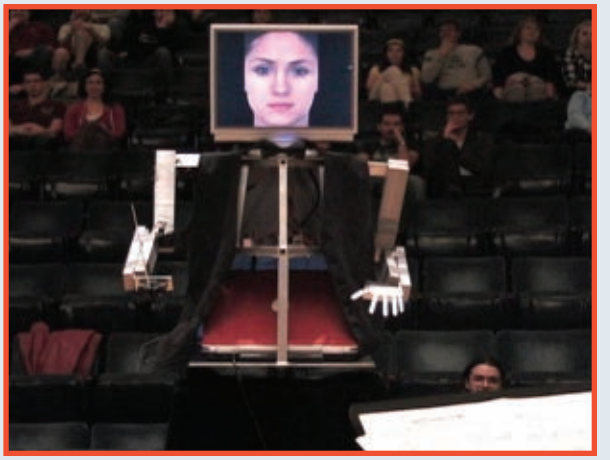
The left arm has two degrees of freedom (more can be added) and is used to indicate cueing and volume control to the orchestra.

Each arm motor is a Hitec HSR-5990TG servo motor. The team selected this motor because it provided enough torque to enable the necessary arm capabilities given the arm's weight and other factors. The gripper is a Lynxmotion Little Grip servo motor.

An Arduino Duemilanove was used for the arm's motor controller. The team chose it for its open source platform which made it easy for team members to select and write code for the necessary functions. The Arduino was programmed in Processing — a programming language that is an extension of the Java language.

The lower body is a rectangular frame design with four

ACRE



At the recent performance of the TCNJ robot builds, the ACRE robot led a portion of music from West Side Story (written by Leonard Bernstein). The goal of this robotic project is to imbue the necessary traits of a human conductor so that it leads an orchestra through a given piece of music. The robot's aesthetics bridge the gap between the human and robotic worlds, combining human and robotic features, according to the roboticists at TCNJ.

The robot proffers visible, physical cues from which the orchestra takes its lead. According to the students, this robot's functions and communication modes include:

- A right arm that conducts the beat pattern.
- A left arm that indicates to each section of the orchestra when to start, stop, and increase or lower volume, and by how much.
- The robot uses simulated knee bends, actuated by a linear actuator in its lower body.
- A Hilaire-type mobile robot configuration enables hip rotation so the bot can turn in place to face different sections
- The team endowed the robot with facial expressions displayed on a flat panel monitor to indicate changes in emotion.

Resources

The College of New Jersey
www.tcnj.edu

Videos of the robotic conductors
http://creativeit.immtcnj.com/video

Grant aids Conducting Robots Course
www.tcnj.edu/~pa/news/2009/creativeitgrant.htm

corners and a divider in the middle. The designers built in ample space for components such as batteries and microcontrollers. From there, they designed the robot to be able to "bend at the waist" which is between this lower frame and the upper torso.

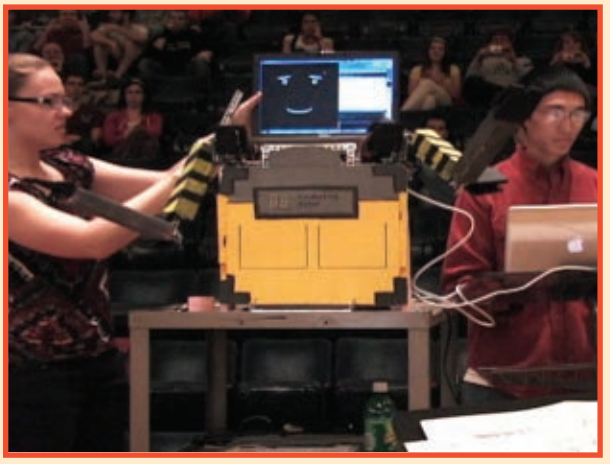
To simulate bending at the waist, the team designed the robot to make a vertical movement of up to six inches while still supporting the upper torso and mechanics. The technology used to create the movement was a linear actuator; specifically a Thompson Electrak Pro Series linear actuator.

The team housed the actuator for the waist bending system in the lower frame using two pieces of aluminum plating bolted to two pieces of angle iron, secured to the bottom of the lower frame's top plate. A bolt running through both plates beneath the actuator holds it in place. The team covered the non-moving areas of the actuator with noise canceling foam to keep sound from spreading and reverberating in the auditorium.

The robot's facial expressions consist of six images taken from the Bosphorus 3D Face Database and display on the monitor to indicate emotional changes. The team altered the images for brightness, background consistency (black), and facial consistency (no blemishes) so the orchestra could clearly understand and interpret the facial cues.

The robot learned the conducting movements by analyzing a video sequence of one of the students conducting the same piece of music. A video tracking system previously developed by Dr. Salgian's students was used to extract the locations of the conductor's hands. From here, the students were able to compute the required joint locations using inverse kinematics.

C4



C4 conducted a fragment from Hungarian Dance #5 by Johannes Brahms.

The C4 robot uses two humanoid robotic arms, each with three degrees of freedom. The left arm points to the particular sections of instruments in the orchestra when it was time for them to take up their parts.

The two arms indicate the beat pattern and tempo. The robot would raise and lower its left arm and increase the breadth of the movement of its right arm to indicate changes in dynamics.

The student roboticists used a software program to convert a MIDI-based musical score into something the robot could follow to guide its own movements. The robot uses a real-time audio processing capability to listen to the orchestra and respond to its efforts. "If the orchestra was performing differently than the robot was conducting, the system sent interrupts to the microprocessor to change the robotic motion to adjust the orchestra," the students said.

The robot's head was a display with a smiley face that smiled when the orchestra played well, and took on a serious or sad face if the orchestra was not performing at its best.

C4 Robot

This robot — a comparable three degrees of freedom two arm robot — is half human size and was built using the VEX robotics kit. It is also controlled by the Arduino microcontroller.

Two-dimensional cartoon faces represent the robot's facial expressions. The team selected cartoon faces for their simplicity, familiarity and because they would not seem too human for a robot, thus avoiding the uncanny valley phenomenon (**www.popularmechanics.com/technology/engineering/robots/4343054**).

The team covered the arms and body with yellow and gray foam to beef up the body and ensure its visibility.

Instead of video analysis, this robot used annotated MIDI files and a set of standard conducting gestures to learn how to conduct a given musical piece.

C4 is the only one of the three robots that can get feedback from the orchestra. It uses ChucK — an audio programming language for real-time performance and analysis — to verify if the dynamics and tempo of the music played by the orchestra matches the one conducted.

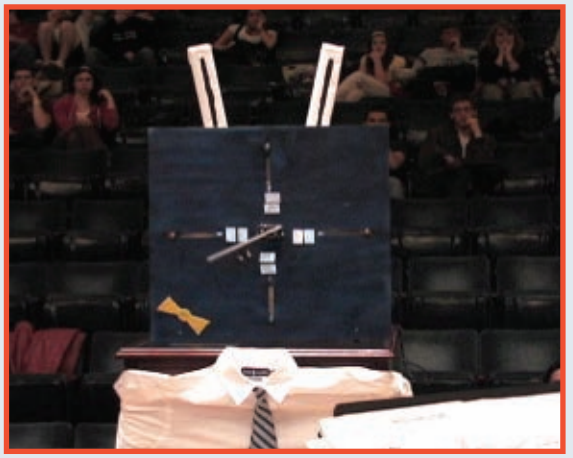
SuperConductor Robot

This conducting robot is decidedly non-human. A square, black board with a rotating baton in the center and four consecutively lighting LEDs that move away from and back to the center of the board comprise this bot.

The robot employs two motors and a circuit board to actuate the baton and lights. The board is a BASIC Stamp. A bicycle hub and lever attached to one of the motors actuates the four levers attached to the LED lights.

The motors are a Parallax standard servo and a continuous servo.

SuperConductor



SuperConductor directed an original piece titled SuperPiece, composed by Brett Taylor — one of the students on the SuperConductor team.

This non-humanoid conducting robot is a square board with four LED lights. The conductor's baton lies in the center of the board. The baton rotates clockwise around the face of the board. The LEDs light up as the baton passes a metallic fabric across their circuits in order, temporarily completing each of those electric circuits.

A four-armed contraption rotates independent of the LED lights behind the conductor's face. As the arms rotate, the LEDs move closer to and then farther away from the center of the board. All the movements correspond to the tempo changes and dynamics of the music.

Final Notes

The students involved in the Conducting Robots course truly orchestrated three original builds, all accomplishing the task at hand. It is amazing how students from different disciplines can come together to innovate. Truly music to the future's ears.

The robots conducted their pieces in April of this year. **SV**