

A Large-Scale Networked Robotic Musical Instrument Installation

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ABSTRACT

This paper describes an installation created by LEMUR (League of Electronic Musical Urban Robots) in January, 2005. The installation included over 30 robotic musical instruments and a multi-projector real-time video projection and was controllable and programmable over a MIDI network. The installation was also controllable remotely via the Internet and could be heard and viewed via room mics and a robotic web cam connected to a streaming server.

Keywords

Robotics, music, instruments, MIDI, video, interactive, networked, streaming.

1. INTRODUCTION

In 2004, LEMUR (League of Electronic Musical Urban Robots) was invited to create an installation at the Beall Center for Art and Technology at the University of California at Irvine. In January of 2005, we installed and opened a site-specific installation at the Beall comprised of over 30 robotic musical instruments.

2. INSTALLATION TOPOGRAPHY

The Beall gallery space where LEMUR's show was installed is a large open room, 43'x 59', with a clear height of 16' to a ceiling pipe and support grid. To facilitate interactive installations, the room is laid out with power outlets and CAT-5 data ports in an approximately 8' grid in the floor and 6' grid in the ceiling.

The installed instruments included five ForestBot units, TibetBot and approximately 30 ModBots in a wide variety of forms and functions (Figure 6). The ForestBot units were distributed around the outside of the floor space to facilitate their wide span of movement. The ModBots were arrayed around the space, mounted either on pipes coming up from the floor or suspended from or attached to the ceiling grid. TibetBot was also mounted from the ceiling grid. All instruments were controlled using MIDI via a custom, distributed MIDI network.

The installation's video component consisted of a large

continuous space generated in Jitter and displayed in the center of the gallery floor using four ceiling-mounted projectors. For aesthetic visual interest, the projector images were tiled and rotated in a non-rectangular arrangement. Through creative Jitter programming, the space was rendered to appear continuous.

The installation was controlled from three Macintosh computers running Max/MSP/Jitter. One machine was dedicated to MIDI, another to video and the third to streaming and camera control. The computers were interconnected via Ethernet, and communication was accomplished using the net.udp.send and net.udp.recv facilities of the mxj object.

2.1 MIDI network

The MIDI machine had two 8-port USB MIDI interfaces for sending and receiving MIDI. As the computers were located in a machine room separate from the gallery space, we created a custom MIDI network to connect to the robots over the Beall's CAT-5 wiring grid.

A patch bay in the machine room allowed access to all connection points in the gallery grid with no intervening electronic equipment (e.g. hubs or routers). To translate MIDI across the grid, we defined an interconnection scheme for MIDI to CAT-5 conductors and spliced together MIDI and CAT-5 cables according to this scheme. Owing to the MIDI standard's hardware implementation being a current loop, MIDI in one cable end emerged as MIDI out the other end, with no electrical problems encountered.

One MIDI interface was dedicated to the ModBots and the other to the ForestBot units. On the ModBots interface, the same MIDI information was sent to all eight ports. From there, it was distributed to numerous points on the grid, either directly from the interface ports, or in some cases, via custom 1x6 MIDI distributor boards (one MIDI In port reflected to six MIDI Thru ports). Also, when emerging from some of the grid ports, MIDI was further distributed using the 1x6 boards.

By distributing the ModBots MIDI signal in this manner, we were subsequently able to connect instruments to any point in our network. This facilitated flexibility in instrument location and redundancy in case of cable or board failure, as instruments could quickly be relocated to any other point in the network.

The ForestBot units, which required both MIDI In and Out signals, were connected over the CAT-5 grid to the ForestBot interface. Using additional CAT-5 conductors, the ForestBot cables had both MIDI In and Out ends over a single CAT-5 connection. Each unit was then connected to an input/output port pair on the MIDI interface.

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2.2 Video projection

The video machine generated a continuous video space which was then divided and rendered into four tiled, rotated subspaces. The subspaces were sent out of the machine using two 2-head video cards, resulting in four VGA outputs. VGA signals were sent to the four video projectors over the CAT-5 grid using VGA-to-CAT-5 converter boxes.

3. INSTRUMENTS

The installed instruments included five ForestBot units, a large variety of ModBots, and TibetBot. Most instruments were created especially for this work.

3.1 ForestBot

ForestBot (Figure 5) consists of a collection of stalks which arc up from bases on the ground. Each stalk has an egg-shaped rattle mounted at the free end and a small aluminum armature affixed near the base. The armature supports a motor with an asymmetrical counterweight which, when spun by the motor, vibrates the entire stalk and thus causes the rattle to shake.

The stalks are in clusters, with 5 sharing a single base. The robot's five bases can be arranged such that a person is entirely surrounded by the stalks, with the rattles dispersed in the air just above head level.

The rods are made of fiberglass, 10 feet long by 1/4" inch in diameter and exhibit a slow and gentle fundamental movement when the rattles are attached. The rattles themselves are *Rhythm Tech Eggz* brand plastic egg shakers epoxied to suction cups.

Each armature consists of a custom-formed piece of aluminum approximately seven inches long that provides a mechanism for attaching to the rod; a simple mounting for the small DC motor; and a Delrin counterweight shaped like a thickened checkmark. Soldered to the underside of each motor is a simple circuit consisting of a resistor, capacitor and LED such that the LED illuminates in proportion to the motor's speed when the motor is activated.

When mounting the stalks, a small deviation from vertical causes them to lean to one side. Slight changes in that deviation cause the rattles on the end of the stalks – essentially sprung weights – to bob and sway in a dramatic fashion. When groups of stalks are moved together, the rattles engage in a highly animated kind of flocking behavior. The resulting robotic choreography is both visually engaging and has the effect of moving dozens of sound sources semi-independently through three-dimensional space.

For this installation, the ForestBot bases, which were originally fixed, were redesigned to allow for the type of behavior described above. The new bases consist of two segments. A lower segment houses the power supply, digital electronics, and two powerful linear actuators. The stalks are mounted to a smaller, upper segment. The two parts are joined by a flexible, two-way joint constructed from layers of industrial rubber surrounding a central rigid rod. The joint has a channel built into it allowing for electrical connections between the two segments.

The actuators in the lower segment are connected to the upper segment by short sections of reinforced PVC tubing that allow them to push and pull on the upper segment, thereby tilting it. Linear potentiometers provide position feedback for each actuator, and hardware limit switches provide a software-

independent means of preventing the actuators from being driven beyond acceptable ranges.

3.2 ModBots

ModBots are miniature, modular percussive, idiophonic and melodic instruments. The devices usually have a single electromechanical mechanism (DC servo motor, stepper motor or solenoid) and a single custom PIC MIDI/driver board. They are designed to affix to virtually any structure, thereby allowing musical control of anything from a battery of specially designed instruments to structural surfaces within pre-existing architectural space.

For this installation, we created a large range of custom instruments and mechanisms, including BeaterBots, SpinnerBots, SistrumBots and RecoBots.

BeaterBots (Figure 1) are solenoid-driven beater mechanisms that can be fitted with any striking device to play loud or soft with a speed and consistency unavailable to human percussionists. BeaterBot instruments included a variety of metal, plastic and wooden boxes, buckets and surfaces, as well as specially modified and distressed cymbals.

SpinnerBots (Figure 2) apply friction to a circumference in much the same manner as rubbing one's finger on the rim of a wine glass. These were fitted with round telephone bells, causing them to sing with a high-frequency warbling sound.

RaycoBots (Figure 3) use a stepper motor to move a scraper back and forth along an attached surface with precise control over position and speed. In this installation, Rayco instruments consisted of springs lightly stretched over metal resonating boxes.

SistrumBots (Figure 4) use a DC motor and cam mechanism to shake a rattle or jingler back and forth. Two magnets and two Hall Effect sensors sense when the mechanism has reached the left and right extremes, therefore enabling timed shaking of the rattle. Rattles consisted of a variety of small boxes and tubes filled with ball bearings, beads, rice and other sounding materials.

3.3 TibetBot

TibetBot is designed around three Tibetan singing bowls, with six robotic arms which strike the bowls to elicit a variety of tones. Bowls are constructed from seven different metals formed into a distinctive dome shape. The combination and density of these metals produces the distinct tonal quality of the instrument, a ringing drone combining the high, low and harmonic tones depending of the area of the bowl struck.

Of TibetBot's six aluminum arms, one arm per bowl is raw aluminum bar, producing a high pitch tone when striking the bowl. The other arm has a soft rubber end, producing a low tone. The arms are controlled by solenoids, triggered by MIDI note commands.

4. MIDI CONTROL AND PROGRAMMING

All instruments are played by MIDI using simple, standard MIDI commands (usually note and controller messages). Each instrument is assigned an identifier by means of a pitch or controller number or in some cases, the MIDI channel.

For example, ModBots with triggered mechanisms, such as BeaterBots, use Note On messages to cause the trigger, with pitch identifying which instrument to be played and velocity controlling gate time (which provides control over hit

strength). ModBots with speed controlled mechanisms, such as SpinnerBots and SistrumBots, are played with continuous controller messages, with control number identifying the instrument and value controlling speed.

Each instrument's firmware program has a number of programmable parameters. These vary from instrument to instrument and include parameters such as gate time range, speed range, step size, etc. These parameters are programmable using custom sysex strings which include the instrument ID number, parameter number and parameter value. By using sysex, we were able to reprogram these parameters at any time by sending MIDI strings over the MIDI network.

The installation was driven by means of Max-based algorithmic pattern and rhythm generators. These generators sent pre-recorded and generated beats to the ModBots and TibetBot, as well as behavior-pattern generation to control the ForestBot rattling and X-Y articulation.

5. INTERNET CONTROL AND STREAMING

The installation was designed to be fully remotely controllable via the Internet, as well as viewable and audible by means of a robotic web cam and streaming video server. Streaming was accomplished using Apple's Darwin Streaming Server and QuickTime Broadcaster. The web cam was controllable from a Max patch, which received camera position information via UDP and controlled an Elmo robotic pan-tilt-zoom camera via RS232 serial.

For updating, maintenance and remote demonstrations, we connected to the machines using Apple Remote Desktop (ARD) software. This enabled total control of each machine, effectively taking them over as if one were standing at the machines. We also implemented Max patches with networking to enable remote playing of the instruments with lower network overhead than ARD.

During the installation run, we released a composer's interface to enable remote users to compose for the installed instruments. This consisted of the MIDI control specification for the installation and a network interface application created as a Max standalone (Figure 7). The application enabled users to upload a standard MIDI file to our MIDI machine and then control, play back and loop the file to play the instruments in real time, viewing and hearing the performance via streaming. By encoding program change messages with instrument IDs in the sequence, users could move the camera to show particular instruments and views.

6. INTERACTION

We are in the process of developing interaction stations and software for planned future versions of the installation. The interactive hardware consists of two interaction stations to be placed adjacent to the edges of the video projection. Each interaction station consists of pedestal with two piezo-sensor drum pads and a 3" video game style trackball. The piezo sensors are connected to an amplifier circuit, then to a custom PIC microcontroller board, which converts and sends beats as MIDI Note On messages with velocity corresponding to hit strength.

The trackball generates two channels of 2-bit quadrature code, for X and Y spin data, respectively. These signals are sent to the PIC board, where X/Y information is sampled and sent as X/Y velocity via continuous controller messages. Sending

velocity information enables us to track the user's spin velocity and also to integrate this data to generate X/Y position.

The stations allow users to navigate through the robotic space, assisted by the video projection, and play the various robots. Playing is recorded using a quantizing, looping algorithm, allowing users to create layered patterns among the instruments.

When a user begins interaction at either station, the control software switches out of stand-alone mode and into interaction mode. In this mode, a metronomic beat is played back on a small subset of ModBots. The user can then use the trackball to navigate an avatar through the robotic space as represented in the video projection. Icons in the projection represent the instruments and are arranged in the video space analogous to their placement in the physical space.

The video machine tracks avatar and position information and communicates this information back to the MIDI machine. The MIDI machine uses this information to control which robot is being played by the user.

When the avatar is close to a robot icon, it is "pulled in" using a simulated gravity effect. The user can then use the drum pads to play the selected instrument. User beats are accumulated into a sequencing patch and played back in a loop, with quantization and latency correction applied.

To avoid accumulated chaos, beats are selectively removed from the loop player over time using an aging algorithm. As the time since a particular robot was played increases, beats to that robot are selected at random and removed from its stored loop. As time increases, more and more beats are removed until the robot stops playing. This yields a thinning effect based on the age of entered beat.

Beat playback and user interaction is also reflected in the video interface. The MIDI machine communicates beat playback information to the video machine, which uses this to control movement, color and video effects applied to the avatar, icons and background video.

7. ACKNOWLEDGMENTS

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More information on LEMUR is available at <http://lemurbots.org>.

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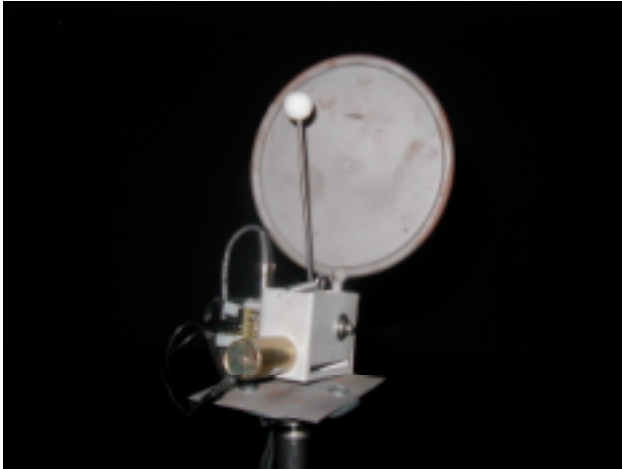


Figure 1: BeaterBot

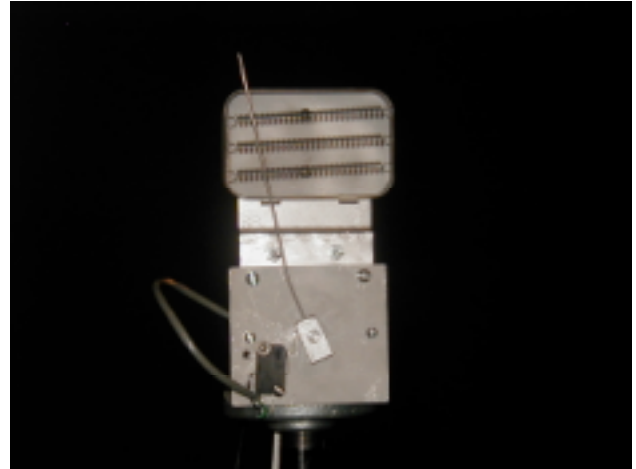


Figure 3: RaycoBot



Figure 2: SpinnerBot



Figure 4: SistrumBot



Figure 5: ForestBots and Installation View

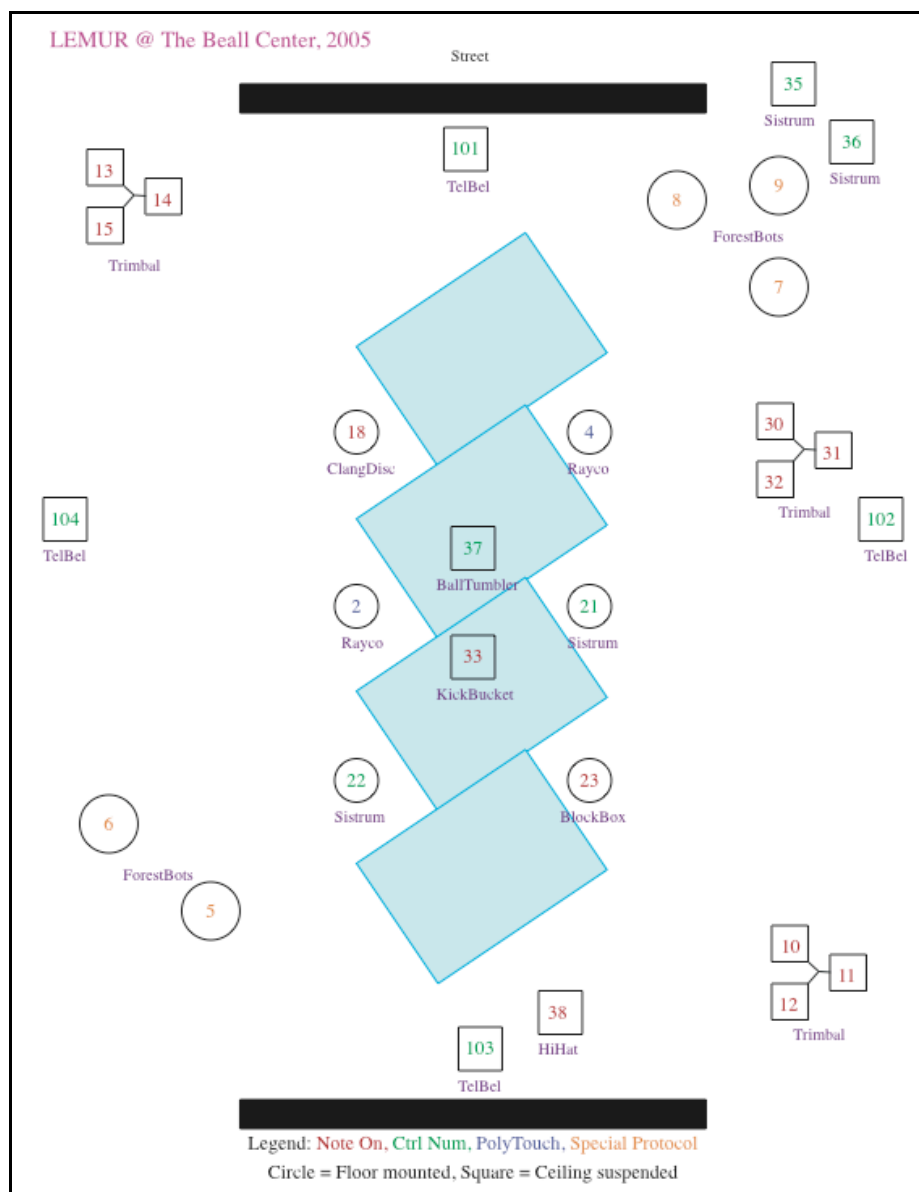


Figure 6: Installation Topography

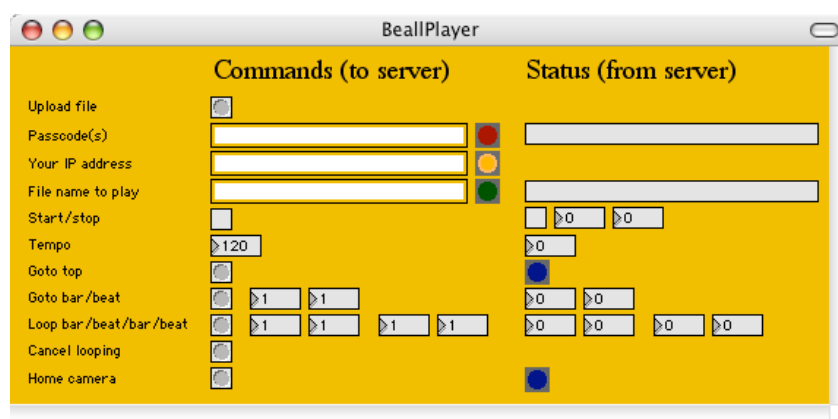


Figure 7: Composer Interface