# A "Ballet mécanique" for the 21st Century: Performing George Antheil's Dadaist Masterpiece with Robots

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## ABSTRACT

An installation to perform *Ballet mécanique*, one of the most notorious works of the early 20th century, using acoustic instruments entirely under computer control, was constructed at the National Gallery of Art in Washington, DC to accompany a major exhibit on Dadaist art.

## Keywords

Robotics, computer control, MIDI, player pianos, mechanical music, percussion, sound effects, Dadaism.

## 1 INTRODUCTION

George Antheil's 1924 *Ballet mécanique* for percussion orchestra, sound effects, and multiple player pianos, a composition which was never heard in its original orchestration until 75 years after its creation, is considered one of the major "lost" works of the early 20th century. The National Gallery of Art presented an opportunity to bring *Ballet mécanique* into the 21st century by inviting the authors to install a completely computer-driven orchestra to perform the piece, as part of a major exhibit on Dadaist art.

## 2 HISTORY OF *BALLET MÉCANIQUE*

*Ballet mécanique* was composed in 1924 by George Antheil, a young American composer and pianist living among the literary and artistic elite of Paris. His most outrageous work, *Ballet mécanique,* called for an orchestra of three xylophones, four bass drums, two pianists, a tam-tam, a set of electric bells, a siren, and three airplane propellors, as well as 16 synchronized player pianos.[1]

But the technology to perform the piece, and to link it to the film, actually didn't exist at the time, and so when it was performed, it was in a reduced version.

In the early 1990s, New York music publisher G. Schirmer, enlisted the aid of current author Lehrman to convert the player-piano parts in Antheil's score to a multitrack MIDI file, which could be played from a standard sequencer on MIDI-compatible player pianos.[2] In this form, the piece had its premiere in 1999, and has since been performed over 20 times in North America and Europe. It was published by Schirmer, with the MIDI files on CD-ROM, in 2003.[3]



## 3 DADA AT THE NATIONAL GALLERY

From 19 February to 14 May 2006 the National Gallery of Art was host to "the most comprehensive museum exhibition of Dada art ever mounted in the United States,."[4] Prior to coming to Washington, the exhibit appeared at the Musée national d'art moderne, Centre Pompidou, Paris, and after Washington it was scheduled to go to the Museum of Modern Art in New York City.

Stephen Ackert, head of the music department at the National Gallery, originated the idea of incorporating *Ballet mécanique* into the exhibit in Washington. His initial concept was for both an automated installation and a performance of the piece with a live orchestra. Unfortunately, it became apparent that the logistics of doing a live performance would be too complex, and so efforts were concentrated on the installation.[5]

## 4 CREATING THE INSTALLATION

Ackert and his design team scheduled the *Ballet mécanique* installation to be on view March 12-29. The location was the mezzanine lobby of the East Wing building, one flight above street level, directly outside the gallery hall in which the Dada exhibition took place (Figures 1 and 2).

### 4.1 Pianos

The score for *Ballet mécanique* has four separate player-piano parts, each of which is designated to be played on four instruments, for a total of 16. However, the piece can be (and has been) played on fewer instruments, as long as the number is a multiple of four.

Most previous performances utilized Yamaha *Disklaviers*, but Yamaha Corporation elected not to participate in the installation. Instead, QRS Music Technologies loaned 16 Gulbransen baby-grand pianos equipped with their *Pianomation* MIDI-controllable player system. The company also sent an identical


**Fig. 1—End view of the Ballet mécanique installation at the National Gallery of Art.**

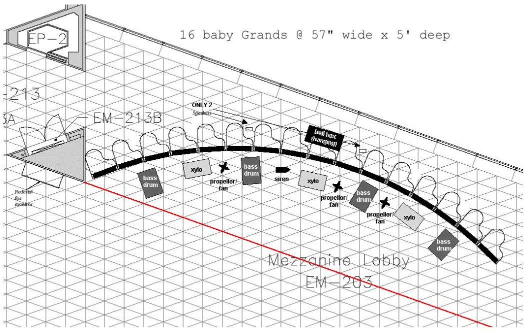


**Fig. 2—Schematic diagram of installation. The entryway to the right of the pianos leads into the Dadaist art exhibition hall.**

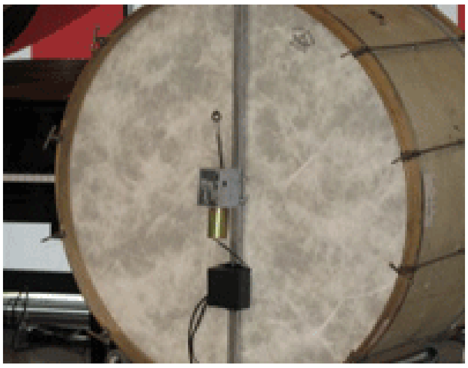

**Fig. 3—Bass drum with BeaterBot.**

instrument to Lehrman's home for for six weeks prior to the exhibition, to allow him to test and modify the sequence file, since the *Pianomation* system responds to MIDI slightly differently from the *Disklaviers*.

The two human pianists' parts were performed using two Kurzweil *MicroPiano* MIDI-controlled modules, amplified through JBL powered speakers. In order to blend the tone of the electronic and acoustic pianos as well as possible, Lehrman copied some of the human pianists' parts to the player piano tracks, taking care not to allow the parts to overlap (i.e., doubling notes) on a single instrument.

## 4.2 Other instruments

The Gallery's original concept was for the percussion and sound effects parts in *Ballet mécanique* to be provided by recordings, or by MIDI synthesizers or samplers, synchronized with the player pianos. But when Lehrman met with Ackert and the Gallery staff in Washington for the first time in October, 2005, he recalled seeing the work of current author Singer at NIME05,[6] and proposed that those parts be performed on real percussion instruments and mechanical noisemakers, played by MIDI-controlled robots.

Lehrman contacted Singer, who enthusiastically agreed to enlist his group LEMUR (League of Electronic Musical Urban Robots) to design and build the robotic players, installing them on rented percussion instruments.

### *4.2.1 Percussion*

Most of the instrument mechanisms LEMUR constructed for this installation were based on the "BeaterBot" mechanism developed for LEMUR's ModBots. This is a microprocessor-controlled solenoid and lever mechanism used to move a beater at high velocity to strike a drum surface. The mechanism was used more or less directly for the bass drums and tam-tam, and adapted for use with the xylophones and propellors.

For the bass drums, they devised a cross-bar bracket to span one side of each drum. A BeaterBot mechanism was mounted on the bracket and fitted with a steel ball for a striker; steel was chosen because it produced a better attack transient than other materials tested, improving the audibility of the drums (Figure 3). Similarly for the tam-tam, a bracket arm fitted with a BeaterBot mechanism was mounted to the tam-tam stand, and a steel cylinder wrapped in suede was used as a striker. These materials produced the best combination of transient response and a sustained "blooming" of sound (produced by multiple strikes) that is an important part of a tam-tam's timbre.

LEMUR designed and constructed new robotic mechanisms to play the xylophones. They first considered a design using a small number of beaters which could move around to play different keys on each instrument. However, to achieve the playing speeds required by the score, they decided to use a separate beater for each key. This required 44 beaters per instrument (Figures 4 and 5).

To simplify construction of a large number of beater mechanisms, beaters were divided into sets. Each instrument had four sets of beaters, with two sets of 13 beaters each on the diatonic side and two sets of 9 beaters on the chromatic side.

Each beater within the set had an individual solenoid, pivot mechanism, and beater rod, with the pivot bars in the set mounted on a common shaft. The solenoids pull down on the pivot on the same side as the beater. This is in contrast to the original BeaterBot mechanism, in which the solenoid pulls from the opposite side in a standard lever fashion. This design modification was done for aesthetic reasons, so that the solenoids would hang below the keys, not stick up above.

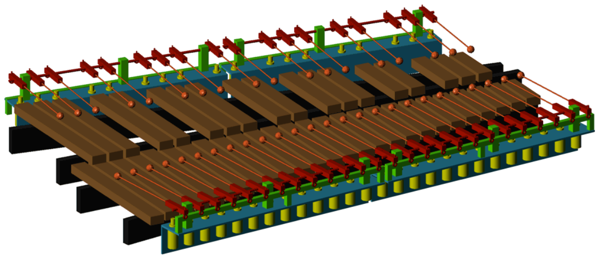

**Fig. 4—Schematic drawing of XyloBot mechanisms.**

The beaters are fitted with 3/4" Delrin® balls. This was found to produce the best tone out of several materials tested (e.g., other plastics, hard rubber), without damaging the wooden bars.

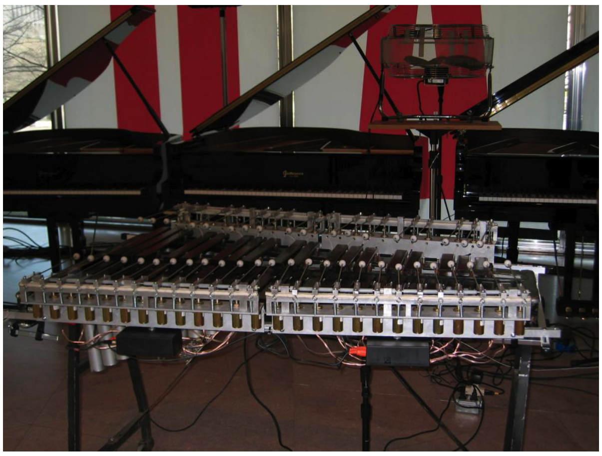

**Fig. 5—XyloBot mechanisms on a concert xylophone. Propellor mechanism is in the background.**

Each set of beaters is controlled from a custom PIC microcontroller-based circuit which receives MIDI note commands, maps them and converts them to timed signals to fire the solenoids. Velocity control is effected by controlling the gate time of the solenoids: within a certain set range of gate times, the shortest time will yield the minimum achievable strike velocity and the longest will yield the maximum. This range of gate times is determined experimentally. Firmware parameters are then stored in EEPROM which map note velocities 1-127 to this time range.

### 4.2.2 Propellors

As they were in Antheil's original performances, propellors are simulated using industrial fans. To create an appropriate sound, a piece of flexible material was inserted into the spinning fan blades—the "baseball card in the bicycle wheel" effect—at specific points in the score. Since the propellor sounds need to start and stop quite quickly, this was deemed more practical than using a fixed piece of material and turning the fans on and off.

To accomplish this, the team used a push-type solenoid mechanism fitted with a crossbar holding four .04" thick, 1-inch-wide strips of MDS-filled nylon (chosen for flexibility, durability and sound quality). When energized, the solenoid pushes the bar down, moving the nylon strips into the spinning blades. Again, several materials in various thicknesses were auditioned, with the final choice based on maximum volume of the mechanism and longevity of the strips.

The propellor parts call for notes to be held for long periods. Therefore, the intermittent-duty solenoid normally used in the mechanism was replaced with a continuous-duty model. A continuous-duty solenoid operates with a lower force (which is not an issue in this case) but may be energized for long periods of time without heat build-up and consequential damage to the solenoid.

### 4.2.3 Siren

The siren is an electric fire-engine-type wailing siren, running on 117 volts AC. It is controlled using a Mediamation LM-4 MIDI-controlled light dimmer. The three remaining outlets on the LM-4 are used to switch the propellor-fan motors, so they run only when called for in the score.

### 4.2.4 Bells

The score for *Ballet mécanique* is ambiguous about how many electric bells are required, but when Lehrman was preparing the files for Schirmer, they decided to make the number seven. For the Lowell premiere, with the help of engineer Coleman Rogers, Lehrman built a plywood "Bell Box" (Figure 6).

It is equipped with bells from 2" to 10" in diameter, obtained from various sources, with the largest being an old Radio Shack alarm bell, similar in appearance and tone to that found in schools and other public buildings.

Originally Lehrman intended to mount all of the bells on the front surface of the Bell Box, but he found when he did that all of the bells (except the largest, which has its own shock mount) sounded more like buzzers, as the plywood resonated louder than the bell gongs. The solution was to suspend the bells in free air: each bell was attached to a small piece of dense butcher-block wood, which was in turn hung using short chains from a pair of hooks at the bottom of the Bell Box.

Since the Lowell premiere, the Bell Box has been used for several other performances of *Ballet mécanique*, and there was no question it would be used in the Washington installation. Gallery personnel suspended it from the mezzanine ceiling with

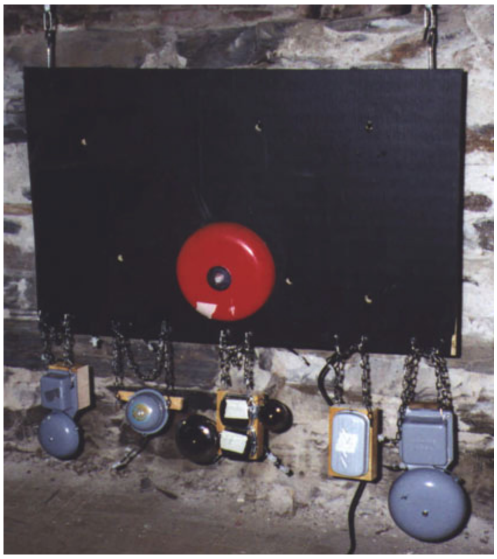

**Fig. 6—MIDI-controlled Bell Box**

aircraft cable. It was noted that the ringing bell mechanisms produced very large transient voltages, which were damaging the DC power supplies originally used. Singer therefore rewired the unit, driving the bells with individual AC transfomers to improve reliability.

### 4.3 MIDI Control and Networking

*Ballet mécanique* was performed by a Macintosh G5 computer running Mark of the Unicorn's *Digital Performer* software. The MIDI streams were generated by a Mark of the Unicorn *MIDI Time Piece USB*. Because of the density of the MIDI data, each group of pianos was assigned a separate MIDI cable, and the signal was daisy-chained within each group. The XyloBots all shared a single MIDI output from the *MIDI Time Piece*, with the MIDI signal being distributed via custom MIDI splitters and MIDI thru chains and each XyloBot responding to a different MIDI channel. Similarly, signals were distributed from other outputs to the other MIDI robotics, with each instrument responding to a specific MIDI note (Figure 7).

A Mark of the Unicorn *828 Mk II* audio interface (see below) supplied one extra MIDI output, which was used to drive the Kurzweil *MicroPiano* modules.

MIDI control of the Bell Box is effected by a MIDI Solutions R8 MIDI-controlled Relay Array. The low-current relays in the R8 are not sturdy enough to withstand the heavy currents drawn by the bells, so a secondary tier of relays was necessary.

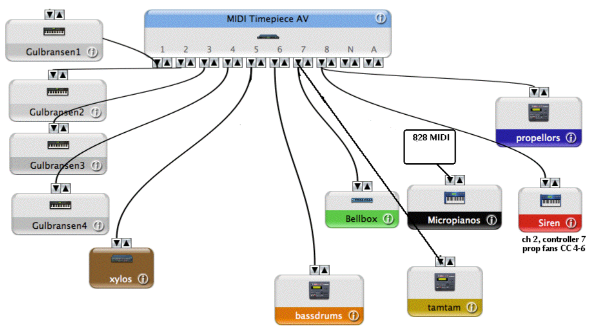


**Fig. 7—MIDI network for the Ballet mécanique (Apple AudioMIDI Setup)**

### *4.4 Testing and Modifying the Files*

A complete performance of *Ballet mécanique* is 25-30 minutes long (depending on the tempo), but the National Gallery requested that each performance there be no more than ten minutes, so as not to frighten too many patrons. As Lehrman had edited the piece a number of times for several applications with the full cooperation of the publisher and the composer's estate, he was given a free hand to decide where the score would be trimmed.

Before any editing was done, it was necessary to determine how fast the piece was going to be played. Antheil's tempo markings are ambiguous, but the best interpretation says that he intended it to be played at about 150 beats per minute (bpm). However, this tempo is far beyond the capabilities of any live performers, and the fastest performance to date has been at 120 bpm. Absent the human beings, on the other hand, the limiting factor becomes the mechanical instruments, specifically the player pianos, which have the most complex mechanisms.

In empirical testing when he was preparing the original MIDI sequence for the Lowell performance, Lehrman determined that Yamaha *Disklaviers* could play the piece at 133 bpm, but at any faster tempo repeated notes would start to be skipped. Even to get the instruments to play at this tempo, the MIDI data had to be carefully massaged, with certain counterintuitive changes made to velocities and durations in order to get the desired response.

Lehrman's tests on the Gulbransen piano in his home showed that it could play the piece slightly faster—138 bpm—without a great deal of customization of the sequences, and so that was the tempo chosen. Note velocities in the sequence were set to a constant value of 100, and an initial Controller 7 (volume) command with a value of 127 was sent on each track. Lehrman then edited the score to the requested length, while attempting to preserve all of the thematic and orchestral elements that make the piece unique. Similar to the *Disklaviers*, the Gulbransen pianos have a built-in delay of 500 ms after receiving a MIDI command, so those tracks needed to be advanced by 500 ms.

After editing the sequence, Lehrman sent it to Singer, who tested the appropriate tracks on his instruments, He found that the solenoid instruments responded the best within a small range of velocity values, and although each instrument had its own optimum range, the best velocity for fast, repeated strokes was consistently 30% lower than for individual strokes. Lehrman modified the tracks to accomodate this. Singer also determined that the latencies in his instruments were insignificant and so no track offsets were required.

### *4.5 Amplification*

As the installation was being completed on site, it became apparent that the airplane propellors and xylophones could not compete in terms of volume with the 16 grand pianos—especially with the latter's lids fully open, which is how the Gallery preferred to set them up. The Gallery was able to supply amplification, in the form of Shure SM57 microphones and JBL EON powered speakers, for these instruments. We were able to take advantage of the built-in mixing capabilities of the EONs, accomodating all of the necessary inputs while using only five speakers.

One unanticipated problem was that the noise from the fans when they were spinning would now be amplified even when they were not making the propellor sounds. Since the fans required a spin-up time of at least five seconds before each cue, amplifying their sound prematurely would significantly lessen their dramatic effect. This problem was solved using a Mark of the Unicorn *828 Mark II* audio interface and a Shure mic preamp. The signals from those microphones were sent to the 828's inputs, and in turn routed into audio channels within *Digital Performer*. Those channels were record-enabled with "full-time" monitoring, thus allowing the software to control the level of the signals passing through the *828*. Three audio tracks were added to the sequence which contained nothing but fader moves, timed to the start and end of each of the propellor cues. The signals from these tracks were sent to three outputs on the *828*, and from there to the JBL speakers.

## 6 CONCLUSIONS

The *Ballet mécanique* installation at the National Gallery of Art proved to be one of the most popular exhibits in that institution's history. Hundreds of listeners gathered for the twice-daily performances, and the *Washington Post*, in a highly laudatory review, deemed it "the best ten minutes of free fun in Washington."[7] Although the life of the installation was originally supposed to be 17 days, soon after the opening, the Gallery extended its run an extra six weeks, through May 7th.

We were delighted to have been asked to participate in this monumental undertaking. We believe that the spirit of the installation was faithful to the composer's intentions, extending and modernizing them in a way he would have been most approving of. Charles Amirkhanian, executor of the Antheil estate, flew in from San Francisco just to hear the opening-day performance, and pronounced it "Perfect." In addition, we were pleased to be able to bring this unsung composer's music to thousands of people who would otherwise have never experienced his unique vision.

## 7 ACKNOWLEDGMENTS

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