The Brain Opera Technology: New Instruments and Gestural Sensors for Musical Interaction and Performance

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Keywords: Brain Opera, human-computer interface, multimodal input devices, electronic music interfaces, interactive music systems, percussion interfaces, interactive dance, electric field sensing, capacitive sensing

ABSTRACT

This paper describes the array of new musical instruments and interactive installations developed for the Brain Opera, a large, touring multimedia production, where the audience first explores a set of musical modes at a variety of novel, interactive stations before experiencing them in an actual performance. Most of the Brain Opera's installations were intended for the general public, employing different gestural measurements and mappings that allow an untrained audience to intuitively interact with music and graphics at various levels of complexity. Another set of instruments was designed for a trio of trained musicians, who used more deliberate technique to perform the composed music. This paper outlines the hardware and sensor systems behind these devices: the electric field sensors of the Gesture Wall and Sensor Chair, the smart piezoelectric touchpads of the Rhythm Tree, the instrumented springs in Harmonic Driving, the pressure-sensitive touch screens of the Melody Easels, and the multimodal Digital Baton, containing a tactile interface, inertial sensors, and precise optical tracker. Also discussed are a set of controllers developed for the Brain Opera, but not currently touring with the production, including the Magic Carpet (immersive body sensing with a smart floor and Doppler radar) and an 8-channel MIDI-controlled sonar rangefinder.

Figure 1: Overhead view of the Brain Opera Lobby truss structure, as being assembled before a Tokyo run in November 1996. All electronics are mounted atop the truss, leaving only the interactive interfaces (such as the Rhythm Tree bags at lower right) visible to the participants

1) Introduction

New sensing technologies and the steadily increasing power of embedded computation, PC's, and workstations have recently enabled sophisticated, large-scale experiments in interactive music to be conducted with the general public. Although most (e.g., Ulyate 1998) have been one-time occasions, the Brain Opera is the largest touring participatory electronic musical installation to have been thusfar constructed. The interactive section alone, termed the “Mind Forest” or "Lobby" (named after the Juilliard Theater's Marble Lobby where it opened in July, 1996 at the first Lincoln Center Festival), is composed of 29 separate installations, run by an array of circa 40 networked PC's and workstations. Figure 1 shows an overhead view of the Lobby electronics being deployed atop its supporting truss structure, indicating the large physical scale. During a Brain Opera run, these interactive stations are open to the general public, who wander through them freely, in any desired order. The stations are of 5 types, each creating a different experience and exploiting various gestural sensing and multimedia mapping modalities, as described in the following section. Some of these stations allow manipulation of sound structures, others acquire voice samples from the users, and others enable parametric manipulation of various Brain Opera themes. After about an hour of Lobby experience, the audience is conducted into a theater space, where a trio of musicians performs the entire Brain Opera composition on a set of "hyperinstruments" (Machover 1991), similar in style and technology to those previously experienced in the Lobby.

The Brain Opera, conceived and directed by Tod Machover, was designed and constructed by a highly interdisciplinary team at the MIT Media Laboratory during an intensive effort from the fall of 1995 through summer of 1996. A major artistic goal of this project was to integrate diverse, often unconnected control inputs and sound sources from the different Lobby participants into a coherent artistic experience that is "more than the sum of its parts", inspired by the way our minds congeal fragmented experiences into rational thought (Machover 1996). This congealing process was anticipated to culminate in the Brain Opera performance, where the diverse themes and activities experienced in the Lobby were actively sculpted into a succinct musical piece. Such analogies to brains and the thought process, particularly as interpreted by artificial intelligence pioneer Marvin Minsky (Minsky 1988), drove much of the initial Brain Opera inspiration, from the use of uncorrelated, essentially stochastic audience input (emulating neural stimulation) to the somewhat "biological" appearance of the physical set. More generally, the Brain Opera attempts to make a strong statement about actively involving non-specialized audiences in artistic environments, confronting many questions about interactive music to which ready answers are currently lacking (Machover 1996).

The overall design of the Brain Opera as an interactive installation is described in (Orth 1997), and its artistic motivation and goals have been discussed in many articles; e.g., (Machover 1996), (Rothstein 1996), (Wilkinson 1997). This paper, in contrast, concentrates on the many different instruments and interactive stations developed for this project, describing their technical design, sensor architectures, and functional performance.

The Brain Opera is by no means a fixed or purely experimental installation; it had to operate in many real-world environments (already having appeared at 7 international venues), and function with people of all sizes, ages, cultures, and experience levels. As a result, the interface technologies were chosen for their intuitiveness, overall robustness and lack of sensitivity to changing background conditions, noise, and clutter. This tended to rule out computation-intensive approaches, such as computer vision (e.g., Wren *et. al.* 1997), which, although improving in performance, would be unable to function adequately in the very dense and dynamic Brain Opera environment.

Most of the Brain Opera's software is run on IBM PCs under Windows 95 or NT using ROGUS (Denckla and Pelletier 1996), a C++ MIDI utility library developed for this project, although some of the performance instruments are based around Apple Macintoshes running vintage code written in Hyperlisp (Chung 1988). Most of the musical

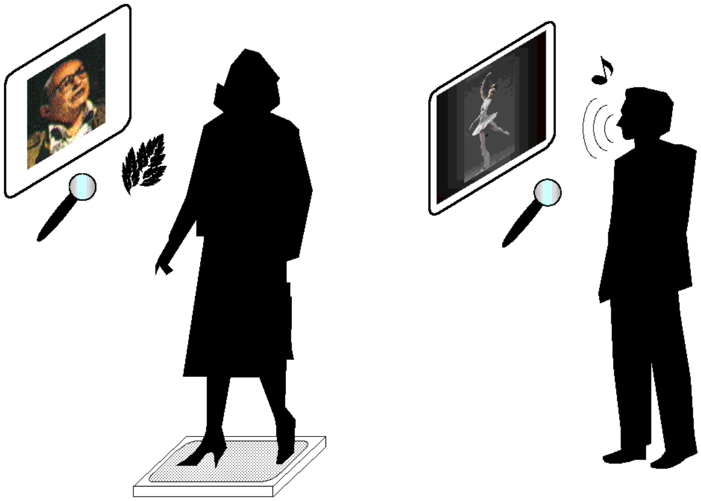

Figure 2: Schematic of the Speaking and Singing Trees

interfaces described in this paper were designed to communicate via MIDI. In order to limit data rates, continuous controllers were polled; i.e., an interface waits for a poll command (in this case, a MIDI program change directed to the appropriate channel), then responds with its latest data. All of the custom-designed interfaces employed a 68HC11-based circuit as their MIDI engine, incorporated as either a "Fish" for electric-field and capacitive sensing (Paradiso and Gershenfeld 1997) or "FishBrain" card. The latter is essentially a Fish without the capacitive sensing electronics; a 68HC11 with 4 raw analog inputs, 4 adjustable (gain/bias) analog inputs, 4 digital inputs, 8 digital outputs, and MIDI plus RS-232 input/output. The FishBrain is used as a general-purpose MIDI interface to analog sensors. With minor modification, the same embedded 68HC11 code is run on nearly all the Brain Opera devices.

2) The Lobby Installations

The simplest and most plentiful Lobby stations were the Speaking Trees. As depicted in Fig. 2 and shown in Fig. 3, these interfaces feature a dedicated PC, pair of headphones, microphone, 10" color LCD screen, and a modified ProPoint mouse from Interlink Electronics (*http://www.interlinkelec.com/*). The ProPoint is a handheld device that allows the thumb to navigate the cursor by adjusting the center of pressure atop a fingertip-sized, force-sensitive resistor array; the "clicks" are still determined by a pushbutton (mounted for forefinger access). In order to accommodate the "organic" look of the Brain Opera, the ProPoint circuit cards were removed from their dull plastic housings and potted into a somewhat elastic, leaf-shaped mold. As seen in Fig. 3, these

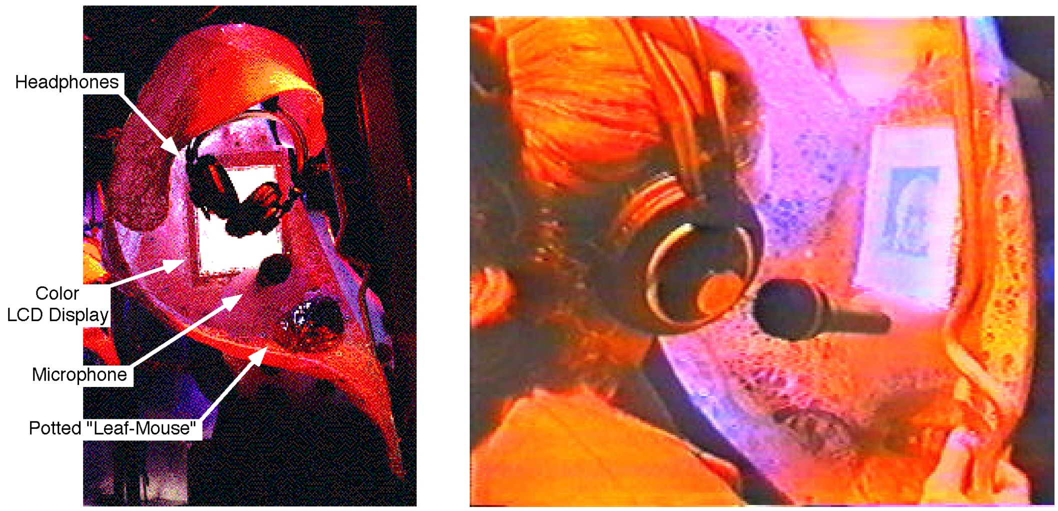

Figure 3: Layout and photograph of a Speaking Tree

components were all mounted onto an adjustable-height polypropylene frame that fit over the head, nicely encapsulating the user in a somewhat private and isolated environment. A simple 17" x 23" switchmat is mounted under the carpet beneath each speaking tree. When an occupant steps under the tree, the switchmat closes, bridging a set of polling lines on the PC serial port. When this event is detected, a MacroMind Director sequence starts up, featuring video clips of Marvin Minsky, whose *Society of Mind* (Minsky 1985) inspired the libretto and overall concept of the Brain Opera. Throughout the dialog, the image of Minsky asks the user several questions; their answers are recorded and indexed on the host PC, then subsequently transferred over the network to a bank of samplers in the theater for playback during following performances. There are a total of 15 Speaking Trees in the Brain Opera, 12 of which run different Director sequences. Although the dialog with Minsky can be interesting and amusing, it's only one simple application of the facilities available at each Tree; several other, more engaging experiences are now being developed. More detail on the Speaking Trees can be found in (Orth 1997).

Similar in construction are the Singing Trees, schematically shown at right in Fig. 2. Lacking a tactile interface, they respond solely to the singing voice, which they analyze into 10 dynamic features. These parameters drive an algorithmic composition engine, which effectively resynthesizes the participant's voice on a Kurzweil K2500 synthesizer. The Singing Trees look for consistency in the singing voice at a single pitch; the longer the pitch is held, the more tonal and "pleasing" the resynthesis becomes. The derived quality factors are also used to drive an animation playing on the LCD screen (Daniel 1996); as the pitch is held longer, the animation propagates forward and becomes more engaging (e.g., a ballerina appears and begins to dance, as in Fig. 2). When the voice falters, the animation

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