murmur

kinetic relief sculpture
multi-sensory display
listening machine

Aimee Rydarowski

Towards partial fulfillment of the requirements for the degree:
Masters of Science in Digital Media

School of Literature, Communication and Culture
Ivan Allen College
Georgia Institute of Technology
May 2007

Committee Members

Ali Mazalek chair
Jay Bolter advisor
Sara Hornbacher advisor
# Table of Contents

Abstract................................................................................................................. 3
Introduction........................................................................................................... 6
Premise................................................................................................................... 7

Object

*Defining the Structure* ....................................................................................... 11
*Conceptual Approach* ......................................................................................... 15
*Methodology* ........................................................................................................ 18
*Related Work* ....................................................................................................... 19

Interaction

*Listening Machines Installation* ........................................................................ 23
*Observations and Feedback* ............................................................................... 27
*Possibility Space* ............................................................................................... 28

Design

*Research History* ............................................................................................... 29
*Components and Construction* ...................................................................... 34

References............................................................................................................. 36
Appendices............................................................................................................ 37
Abstract

Today, increasingly varied modes of data representation, coupled with accessible technological resources, have democratized the field of information visualization and opened computing to new user groups. This environment has created a critical mass of consumer-creators who serve up information baked, sautéed, flambéed, stuffed, roasted, pureed, boiled, braised, steamed and flash fried to audiences with discerning pallets. By thoughtfully varying data representation, we can increase opportunities for information to be thoroughly digested.

Many educators and cognition researchers maintain the existence of multiple intelligences (as originally proposed by Howard Gardner), each benefiting from different modes of information abstraction and corresponding with a particular learning style. Although many would consider themselves to be multi-modal (having more than one strong learning style) it is clear that people employ individualized stratagems for learning and understanding (meta-cognition) that is more indicative of one style or group of styles over another. Bringing this concept out of the classroom and out of the journal is an important step in the creation of a working model for information design and display as well as making the tools of digital representation more accessible.

Object-oriented programming environments such as Cycling 74’s Max/MSP/Jitter package, Reas/Fry’s Processing, as well as CAD (computer-aided design) and other graphic interfaces, have encouraged visual modal types to become progressively more involved in the act of creation through digital representation by speaking to them in their language, or as Gardner would describe, their mode. By providing the appropriate method of abstraction in an interface designed for interaction with a data processor, designers with logical/mathematical and visual/spatial proficiency can make use of these tools and help to further the design of interfaces for those of similar cognitive adeptness. The appeal of these environments to many artists, architects, engineers, musicians and scientists lies in their ability to support the creation and modeling of and control of, multi-sensory devices and structures in the physical world.
Many of these projects could not be created as easily without the computational assistance of digital processors. Without the ability to produce complex graphical information visualizations projects such as the Human Genome Project, for example, would be rendered impossible. Works created for or in reference to this physical realm can help to convey information through form and structural relationships that promote new opportunities for understanding and schemas for cognition.

The Five Senses. Makert

The intrinsic design of biological organisms allows for multi-dimensional communication. Research in the areas of cognition and perception indicates that the more dimensions of information present in a signal the more memorable and distinguishable it becomes. By employing the sensorium one can more easily determine the state or condition of something else, which has corresponding elements that appeal to those same senses. Although one can see that the appropriate element-to-sense mapping is crucial in conveying information, trans-modal mapping of element-to-sense, i.e., triggering a secondary perception such as those experienced in synesthesia, has been found to be more memorable.

In parallel with a general trend towards gestalt methodologies based on recent neurological research, multi-sensory displays make use of the evidence for multimodal integration (perception based on the sum of the senses) by providing multiple perceptual channels by which to
communicate. Each sense that is catered to presents a unique design problem, which must be considered in respect to both the part and the sum of the parts as a whole. Multi-modal integration must take into account the general sensory anthropology and perceptual ecology of the intended audience. Currently, there are few guidelines, such as the MS-Guidelines (Nesbitt), for multi-sensory designers to follow in the creation of multi-sensory displays. This makes for challenging work, but is worth the effort when a creation’s form and function serendipitously reverberate into one another.

Close up of Murmur’s reactive surface at the Listening Machines exhibit at Eyedrum in Atlanta, GA
**Introduction**

*Murmur* is a multi-sensory display, an interactive kinetic relief sculpture and listening machine. The design intention is to balance these elements so they enhance one another and are still compelling when considered separately.

*Murmur* experiences the world through its 'ears' and 'speaks' through motion. In essence, *Murmur* is designed to represent aural information through the movement of DC-driven fans acting on a reactive surface. When fitted with different sensors *Murmur* can represent many different types of information. Although there are multiple possibilities for data representation, the current mapping of aural information to fan movement in wave patterns was chosen for its unity of form and will be discussed in detail in another section.

The aural information that *Murmur* presently displays is representative of the combination of environmental as well as self-produced sounds picked up by its sensors. Microphones are situated externally and monitor the surrounding sonic environment. The software processing this incoming data analyzes the sound over time and can be modified to average various elements such as pitch, amplitude, direction and timbre to influence the future movement of the fans. The result is stimulation of the display surface.

The sonic element(s) suited for visualization should be determined by analyzing the acoustic space where Murmur is to be installed including the space's function and resultant nature of movement within that space. For the first installation of Murmur in the *Listening Machines* show at Eyedrum Gallery in Atlanta, the sonic elements (variables) and method of handling those variables (software and hardware) were customized for the environment and were further manipulated *in situ* to enhance responsiveness.
**Premise**

**Physical Space**

The ideal environment for the work in its present form is one where the 2.5 by 10 foot wide object is hanging on a white wall in order to reduce the contrast between the environment and Murmur’s current minimalist white façade. By reducing the contrast with its surroundings, focus falls on the motion of the display surface. This motion is synonymous with aural information. Part of Murmur’s functional minimalist aesthetic is the elimination of unnecessary visual information.

Without sufficient input, a rippling wave-like motion is created by the fans moves across the entire length of the surface. This can be considered the steady state of the system. As the microphone sensors pick up aural information that falls outside of the normal range, the wave patterns begin to fluctuate in acknowledgement of this new data. The viewer/participant may observe the correlation between the sonic input and emergent response.

**Senses**

The particular nature of the reactive surface will give rise to various types of sensory communication. The following designs illustrate a sampling of the various sensory interaction and visual effects possible through this interface.

![Image of grid surface with X cuts into material centered over each fan. Left to right motion is shown.](image)

In this design, the modulated air pressure produced by the fans forces open the material in front of each fan, changing the black to white ratio of the surface (the surface material being white and the fans dark grey). In this method, the modulation of the fan’s speed will open the surface material to a
greater or lesser degree with the resultant effect producing halftones across the surface. Visual, aural, tactile and thermoception (temperature change) senses are stimulated.

*Fans behind semi-transparent material with backlighting or without display surface.*

In the above illustrations the fans can be left exposed or silhouetted behind semi-transparent windows and modulated at different speeds to create various effects, and at times produce a stroboscopic effect as they speed up or slow down.

*Flaps hinged from the top catch light as fans blow them open and up. Left to right motion is shown.*

As in the first design, the openings in the display surface depicted in *Figure 4* allow for the stimulation of the visual, aural, tactile, and thermoception senses. If a light source is positioned at the top and directed down across the surface, the flaps, opening at various degrees, much like the effect produced
in Daniel Rozin’s *The Wooden Mirror*, will create patterns in light and shadow. This design was chosen for Murmur’s installation in the recent *Listening Machines* show.

**Components and Mechanics of the Structure: Overview**

![Internal component layout.](image)

1a, 1b: microphones  
2: PreSonus FirePod pre-amplifier  
3: computer running Max/MSP with custom patch  
4: Wiring wiring board/microcontroller with custom program  
5: control circuit board for fan array  
6: power supplies (12V, 8.9V)

The diagram above illustrates the component placement inside the structure. Left and right microphone sensors (1a, 1b) pick up sonic data from the environment. The incoming signals are then amplified by a PreSonus FirePod (2) via XLR inputs and travels to a computer running Max/MSP (3) via a Firewire out. Here the signals are analyzed and variables created having to do with various aspects of the sound. For the *Listening Machines* exhibition amplitude data was the primary variable source. Once the variables have been established they are sent via serial/USB to the wiring board (4) where a custom program written in Wiring and uploaded to the microcontroller, handles strings of variables, which are plugged into equations that dictate how the fans should be turned on and off to reflect the signal data. The binary voltage control signals (5V) are transmitted to the circuit
board (5) by way of 20 I/O pins on the wiring board, which correspond to Murmur's 20 columns of fans. Twenty H-bridge rows arranged in groups of five on the circuit board receive signals from the wiring board and bus the signal to the
next four H-bridges in the row. These components act as switches, turning the fans on and off by
opening and closing the path to the fan's source of power when a 5V signal is received from the wiring
board.
Object

Defining the Structure

Listening Machine

*Murmur* responds to its environment through microphone sensors. Generally, listening machines analyze sound sources, most with the intention to isolate, identify and characterize discreet sound sources within a sonic environment. Pattern recognition and machine learning are employed to model a listening system that can perform these tasks to a degree found only in the extended auditory system of highly developed biological species. My initial objective with *Murmur* was to develop a machine that would create dynamic sound visualizations. It wasn’t until the opportunity to show the piece at the *Listening Machines* event at Eyedrum, presented by the Georgia Tech Music Technology Group that I realized that *Murmur* could be considered a listening machine. *Murmur* seeks to analyze environmental sounds and acknowledge various elements of this data through fan motion and surface effects.
Ambient Display

According to Wikipedia, ambient devices and displays are used to visualize information that can be perceived at a glance, with minimal cognitive effort. The Ambient Orb, hallmark creation of company Ambient Devices is one of the most recognizable consumer ambient displays.

The Ambient Orb is essentially a glowing ball of diffused light that changes color to represent a change or trend in specified information it receives on a wireless network. Research into this concept began at Xerox Parc and originated in a paper titled, Calm Computing, written by Mark Weiser and John Seely Brown. Since 2002, Ambient Devices has expanded its line of datacast receivable objects to include weather and time devices. Other information, such as stock data and traffic congestion can be subscribed to online and delivered wirelessly to the ambient device. The extent to which Murmur can be considered an ambient device/display is based on the extent to which the object’s mapping of sensors and actuators reflect environmental information and conditions, both sonic and social, in a way that is passively perceivable. Because Murmur produces a primarily visual and tactile representation of sonic information produced by activity in its environments, one can perceive this information without having to hear it. Murmur’s function as an ambient device is a residual effect of this interaction.

Information Visualization

The area of information visualization, with respect to computer science, combines areas of information design, human-computer interaction, computer graphics and cognitive science. It utilizes visual design theory and aesthetic principles to assist in the representation of abstract information in a way that reinforces cognition and promotes observation-based hypothesis. These representations appeal to the senses and are in many instances, interactive in nature. Transforming and re-contextualizing environmentally-derived data provides opportunities for learning and exploration that extend beyond verbal description. Data visualization is an integral part of the increasingly relevant science of Imaging.

Although one can become preoccupied with visual stimuli and describe non-visual sensory input in visual terms, other-sensory perception should not be overlooked when considering schemas for learning and understanding. Therefore, it is to our benefit to transduce data from one mode to another and observe it in different ways through multi-sensory experiences or through a concentrated, isolated trans-sensory event. One cannot overstate the importance of cultivating the sensibilities needed for
direct observation of the environmental phenomena to be described through data when creating information visualizations, as they can at times be a direct reflection of these sensibilities.

Interactive Art

Interactive art requires an interaction with a stimulus apart from the work in order for the work to be complete. This definition places generative art in a separate category. In order to promote interaction the design of the piece is structured to give the spectator agency to some degree. Thus, the piece can be described to afford interaction and a dialogue arises from this interaction, which in turn helps to create meaning for the interactor.

Generally, the artist structures the method of interaction to direct the type of dialogue that is befitting of the message to be communicated. Through the process of interaction the intention of the artist becomes manifest. At times the artist’s intention is to create a situation where a participant’s interaction is exploratory and the message of the piece is open. In other instances, the artist’s intention is to lead the participant towards a particular understanding or insight and interaction is scripted as such.

Interactive art can further be distinguished from Generative art, Electronic art and Immersive art in that Interactive art sets up a dialogue, rather than a monologue. The interaction afforded by Murmur is more passive in that it doesn’t require interaction in order to be experienced, but if a viewer/participant decides to influence the piece by providing input through the microphone sensors, they may observe a response to their interaction in combination with other stimuli present in the environment. They can then move towards an understanding of how their input into Murmur, in combination with other inputs, are interpreted by watching the output. In this sense, Murmur is a black box inviting elucidation.

Mechatronic Art

This emerging field has been described as “A systems based approach to design and fabrication of functional experimental art devices... (which) Combines principles of mechanical, electronic, electrical, software engineering, robotics, motion control, sensors, actuators, and other control devices.” Mechatronic Art is indicative of Intermedia art of the 1960s in that it is a truly inter-disciplinary endeavor. This mixed breed is now advanced by the availability of resources afforded by the Internet as it often requires a broad knowledge base. Mechatronic art is also indicative of DIY (“do-it-yourself”)
subculture in that out-of-the-box resources are discouraged in order to achieve new forms not afforded by pre-packaged tools. *Murmur* maintains its position as a mechatronic art object in its hybrid fabric, form and function, which spans the aforementioned areas.
**Conceptual Approach**

*Initial concept sketch. Illustration by Ozge Samanci for Ali Mazalek’s 2006 Experimental Media class.*

Initial construction of *Murmur*, formerly titled *Grillwork*, began in an Experimental Media course taught by Alexandra Mazalek in the spring of 2006. As part of the course of study the class broke into groups to create experimental media/tangible media objects and applications. I proposed an ambient display made of fans as a potential project idea, one that I had been wanting to create for several years prior, and found two students who were interested in working with me. Ozge Samanci and Ayoke Chinzeria, Digital Media PhD students with both with backgrounds and interests in aesthetic applications of digital media collaborated at the early stages of conceptual development and physical construction. Together we discussed what we liked about appropriating computer fans as a medium for information delivery. I described a project I had done in my undergraduate study that involved creating a relief sculpture out of modular paper units whose edges would form patterns when one directed a light across the surface. It was my hope to create a surface that would change dynamically, catching light and throwing shadow as it moved. My undergraduate project was a 10 X 10 square of sculpted paper units, so in the initial concept sketches, *Murmur* is depicted as a 10 X 10 array of fans.
Initial concept sketch of fans acting on a reactive surface of similarly modulated shapes to a project from my undergraduate study at the Atlanta College of Art. Illustrations by Ozge Samanci for Ali Mazalek's 2006 Experimental Media class.

In the early stages of development, we discussed various methods for sensor-based interaction. Vibration sensors, bend sensors, microphones, trip wire and heat sensors were all considered as a means by which to activate the fans. Realizing that the work would be more cohesive if the sensors were integrated in the object instead of located near the object, we dismissed any idea that required a secondary object apart from the installation itself. This constraint helped us to narrow down the list of sensors used for interaction. Throughout the conceptual development, I kept coming back to the idea of using of vibration sensors or microphone sensors to monitor wave-like structures in the environment. Using the fans to create patterns in waves in response to other types of waves (such as
sound waves) made sense in their unity of form. It was very important to me that all of the conceptual aspects of the project, from form and materials to function, related to each other and were balanced. It was at this time that I decided to change the aspect ratio from 1:1 to 1:4 (five fans high and twenty fans long) in order to place emphasis on the movement across the surface and to better size the work into the area of peripheral vision when standing in front of the piece. This aspect ratio served us well on several levels. Not only did it evoke the idea of a landscape (as it would sense its environmental audio/vibration landscape), as a bit of luck, it accommodated circuit constraints that were later discovered. Throughout this process we discussed the affordances of using fans, beyond their ability to create wind pressure that would act upon the surface. It was apparent that Murmur was to be a multi-sensory display, as it appealed to at least four senses.

Once we had a good idea of what we envisioned the interaction to be, one hundred fans were ordered, circuit testing began using similar CPU fans and materials for the structure and surface were researched and tested. We were attracted to several design concepts that influenced our choices in materials. Since fans generally serve industrial purposes, CPU fans purpose being to cool the internal components of a computer, it became an appealing notion to use them for a non-industrial function. Knowing that one-hundred dark-grey plastic fans in a grid would look very heavy and industrial, it also became our purpose to contrast these machined materials and forms with softer, more natural and pliable materials such as wood and paper.
Methodology

As the project developed, from its beginning in Mazalek’s Experimental Media class and in the months afterward, the most interesting and challenging aspect of the work lay in the balance and integration of the functional aspects of the work as information visualization and ambient display with Murmurs aesthetic pursuit. At every stage of development and with practically every decision that was made this balance was upheld. Several aesthetic practices were chosen as guidelines for design decisions:

Minimalism
Industrial Design
Truth in Materials
Unism

Unism refers to “the unity of a work of art with the place in which it arises, or with the natural conditions that had already existed before the work of art was made.” A research group from the University of Illinois recently published a paper describing what they term to be Virtual Unism. Modifying the initial term, Virtual Unism includes body movements in a space and how these movements define the space while being influenced by the space. A work of Virtual Unism will help identify and describe the reflexive nature of this union. It is in this way that Murmurs can at once be an ambient display and interactive art object as the nature of information it is describing is in essence the same information that can be transduced from interaction with and within the space. They are one in the same. The very nature of the space in which Murmurs resides helps to dictate movement and interaction of people within it. Even the structural aspects of the space influence the sonic data that is picked up by the microphone sensors as they combine to create its acoustic space. As Murmurs is focused on social and acoustic aspects of a space (which is in many dictated by architectural aspects), it can be unified with many different types of spaces, although some will be more suited than others in accentuating relevant variable mapping.
. Related Work

Several sculptural and new media works informed the conceptual and aesthetic nature of Murmur. Initial inspiration came from the desire to create a dynamically changing surface that would convey information through light and shadow. As mentioned previously, this idea was taken from a visual design exercise in a class taught by Martin Emmanuel at the Atlanta College of Art in the spring of 2001. In this project, it was our task to create a form out of scored and molded paper that when repeated, would create interesting edge patterns when lit across the surface. I was so intrigued by the ability of light to convey information it became my hope to one day create a similar piece with a dynamically changing surface, using light again to convey information about the changing nature of something.

Another past project I took inspiration from was a series of sound visualizations I created with fellow artist Aaron Miller in the summer of 2004 while attending a residency at the Experimental Television Center in Owego, NY. Visualizing sound has always been of interest to me. In this project, an audio source was passed into a + -5 voltage controlled oscillator to create detailed acoustic waveforms. The “picture” of the sound was then wrapped around simple Open-GL geometric shapes in Max/MSP. These geometries were then fit into equations and the resulting shape was amplified around 2000x until the screen view was in the center of these smashed-together shapes. In-world camera paths and color filters were applied and the result became an exploration of the newly created audio landscape. The skin of the landscape’s geometry was in essence the sound itself, and the movement on the surface would expand and contract the nodes in three-dimensions. The general effect was a landscape whose every detailed movement described and was inseparable from the audio that was playing. We experimented with different geometries and applied equations and filters to match the mood of the audio sources, which consisted of original tracks Aaron and I had brought with us to the residency. I liken Murmur’s reactive display to this body of work.

Sculptural installations such as Daniel Rozin’s Wooden Mirror and Aram Bartholl’s Random Screen influenced, to a certain degree, Murmur’s structural aesthetics. I appreciate these works in their simplicity of form and ease of integration into a gallery environment.
Rozin’s *Wooden Mirror* consists of a display grid of wooden squares with a camera situated in the middle. The work is designed to hang on a wall at eye-level, much like one would hang a mirror in which to look at one’s reflection. When the mirror is approached, the small camera in the middle of the grid captures the image of the person approaching and sends the image to be analyzed by custom software on a processor hidden behind the surface. The image broken down into a grid of identical units to the wooden chips on the display surface and each unit averaged for luminosity value. These values are apparently translated into a range of available degrees of luminosity, which can be reflected in the position of the wooden chips in relation to a strategically positioned light source. The chips are individually rotated to reflect the amount of light of the averaged luminosity value of the image unit to which it relates.

Part of the success of *Wooden Mirror* is the lack of apparent technology, creative use of natural materials, simple elegance and engaging interaction. Although the mechanics of the apparatus is quite complex, it is hidden behind an unassuming façade of wood squares. The whole structure feels at home hanging on a wall and could add aesthetic appeal to a variety of spaces.

*Daniel Rozin’s Wooden Mirror on display at the Israel Museum*
Aram Bartholl’s Random Screen differs from the Wooden Mirror in that the apparent effect is produced by non-electronic methods. Candles situated in recycled beer bottles spin a beer-can-turned-fan attachment around as the heat rises from the candles. This causes a flickering of light inside individual cubes in which they are situated. The entire piece looks like giant pixels lit in random ways which change over time as the candles burn down, hence the title Random Screen. I enjoy the simplicity of this piece both in concept and construction. Although the mechanics behind the screen is analog, the cubed grid, which houses the candles helps to create a digital effect. Random Screen and Wooden Mirror are similar in the way they use a grid for information abstraction.

While not necessarily a source of inspiration, Pinwheels, an info-vis from MIT’s Medialab, also uses fan-like objects in an architectural way to display information. Pinwheels employs 40 computer-controlled pinwheels in arrays of 5. Information such as people’s movement in physical space or cyber space can be mapped to the fans’ movement via pulse-width-modulation to control the speed of the fans. Each fan houses a circuit board, which is sent instructions by a Java-based program. In this way, the installation is modular and can be expanded to fit the demands of different architectural spaces. Pinwheels is described as using “a wind of bits” to display the mapping of information and the physical movement of the fans.
Pinwheels Installation: MIT Media Lab’s Tangible Media Group, Hiroshi Ishii, Sandia Ren, Phil Frei
Interaction

*Listening Machines Installation*

In observing audience interaction with the installation of *Murmur* at the *Listening Machines* event at Eyedrum Gallery, several points have come to my attention and can be broken down to several areas:

- Sound Environment
- Variable Mapping and Response Time
- Initial Interaction
- Questions and Feedback

The **sound environment** at the *Listening Machines* show could be described as similar to a crowded gallery opening. At its apex, about 150 to 200 people were simultaneously present in the space(s) directly surrounding the installation. Audio from other installations mixed with the chatter of conversation and reverberated from concrete floors and hollow walls. The general response of *Murmur* to this environment fluctuated little as the sonic elements in the environment remained relatively uniform. Generally, the motion started near the middle of the work and moved towards the direction of the microphone with the highest incoming amplitude. The waves usually fluctuated between 5 and 14 columns as the overall amplitude increased and decreased.

The **variable mapping** for this particular night was based on the anticipation of a certain type of sonic environment I expected to be present. A major challenge in machine listening is attributing discreet sound events to categories and source identities as well as pattern recognition. With more research and sophisticated programming, *Murmur* can one day respond to these events with recognizable accuracy. Attempting to respond to these types of events is outside my initial realization of *Murmur* as well as my current abilities. In order to produce an installation that would be responsive to its environment and appreciated through interaction and observation during the exhibit opening, working within the possibility space became imperative. The creation of a discernable response to environmental variables was necessary for the success of *Murmur's Listening Machines*. 
installation. To help facilitate an observable mapping of input to response, I decided to forgo complex variables such as pitch and spectral averaging which are not easily discernable in a cacophonous setting. Amplitude comparison seemed to be the most fitting sonic variable to create an understandable mapping for a mixed audience in a loud space. The incoming amplitude data was broken down in Max/MSP into three variables and resultant mapping of fan motion:

V1: Difference between amplitude of left and right microphone $\rightarrow$ where to start the wave. The smaller the difference the more towards the middle of the 20 columns.

V2: Highest average over time, of amplitude data contained in the buffer $\rightarrow$ the wave travels in the direction toward the microphone with the highest averaged amplitude since the last time the buffer was cleared.

V3: Overall amplitude $\rightarrow$ the value of the average of the microphone with the highest amplitude determined how long the wave is, particularly, where the wave will end.

The incoming amplitude data was amplified in situ to cater to the specific sonic environment and pre-coded variable ranges once the installation was in place. The responses to the variables described above approximated logarithmic spacing in the Wiring code. For instance, the range of values that were most likely to occur in the environment made up most of the response mapping that can be described as:

- If value = x then start at fan column y for V1
- If value = x then continue in the direction of fan column y for V2
- If value = x then end at fan column y for V3

It was pre-determined that the incoming amplitude would exist in a 50-decibel range starting at 25 dB and ending at 75 dB. In order to balance variance in response with the notion that longer waves would generally be more interesting to watch than shorter ones, the incoming signal from the microphones was amplified in Max/MSP to an average that would produce a wave of 6-10 columns long which resided in the 65-70 dB range. Any amplitude average at or above 75 dB would produce a maximum of a
20-column wave. Because Murmur was located on a wall in the gallery space that only slightly biased the right microphone, the difference between the right and left microphone was small and the wave generally started in the middle 5 (out of 20) columns and proceeded to move to one side or another. Also, because the right microphone was in a location slightly biased to receive higher amplitude data, the majority of the waves also moved in the direction of the right microphone. This was generally the case when the event gallery space was most crowded. After realizing this bias, the amplification of the left microphone was adjusted so as to balance the input with the right microphone, which helped to vary the direction of the wave. This modification helped (in this situation) to create a more direct response when the gallery participants involved themselves in interacting with Murmur.

Based on observation of audience interaction with Murmur I noticed that the initial action of an interactor was to clap or yell into one of the microphones and directly look to the display surface in anticipation of an immediate response, not knowing that the amplitude data was averaged over time (generally between 5-10 seconds). A lack of immediate response to their input qualified explanation in my part and I sought to explain the mapping to the interactor after observing the resultant confusion as to what Murmur was responding to. I believe that this dilemma can be partly attributed to the exposure of the microphones as well as the type of microphones used. Murmur is equipped with two dynamic stage microphones, needed for their XLR inputs to the
FirePod pre-amplifier. Although the exposure of these rather large microphones helped in illustrating the nature of *Murmur's* response, because these types of microphones are designed to be held in the hand or used to mic an individual person or instrument, it lead people to believe that the same was true in this situation.
Feedback

The week following the Listening Machines event, I presented Murmur at a Dorkbot meeting in the Music Department at Tech. Dorkbot is a monthly gathering of “people doing strange things with electricity” with chapters in many major cities. Several people at the meeting were also at the Eyedrum event, so it was a good opportunity to get feedback and discuss Murmur at length. Several comments were made in regard to my choice of reactive surface and Daniel Rozin’s wooden mirror was mentioned as a work with aesthetic similarities to Murmur. Two people who had seen the Eyedrum installation suggested that the work might have been more dynamic had I left the reactive surface off all together as illustrated in Figure 3. They reasoned that fans are a unique method for information delivery, and in covering them up, the affordances of using them for their tactile and thermoception sensation are reduced, instead of emphasizing the visual aspects of its communication. I agreed with this point, and went on to describe alternative designs proposed for Murmur’s surface, including the absence of any surface of the fans. For the initial design space of the Listening Machines event, emphasis was placed on the situational aspects of Murmur existing within a gallery context, focusing on its integration into a typical white-walled gallery environment.

It was my intention to highlight the features of Murmur as prototype of information architecture in the physical, as well as, the figurative sense. By integrating an interactive/reactive surface into the fundamental architecture of a space, new dimensions of communication emerge between the space’s physical and the social fabric present in the space at the time. As described in the introduction the minimalist white surface and casing help to direct focus to the subtle surface changes as the fans blow open flaps, which catch light and cast shadow. Although this surface effect is similar to one employed in The Wooden Mirror, the idea of using changes in light across a surface to convey information is an archaic practice used in Kabuki Theater, magic lanterns displays and shadow plays and is a basic consideration when creating relief sculpture.
Possibility Space

In addition to Murmur’s current status, I also conceived of it as a prototype for an architectural feature in a public space as well as an art object. I envision an entire wall made up of these fans reacting to sound generated by human movement. This arrangement will help unify the object as it is integrated in an architectural space and the social landscape.

It is also my intention that a future version of Murmur will incorporate a thermochromic display surface. Thermochromic materials such as plastic pellets used for injection molding, paints and inks, are becoming increasingly accessible. These materials would take advantage of the cooling effect the fans have on a surface. The temperature change can be specified to occur within a wide range of temperature to produce a change in color. The cooling effect could be tuned to hover around the region of the thermochromically-induced color conversion.

*Thermochromism is a color change by means of temperature change that can be afforded by specific properties of liquid crystals. Thermochromic injection molding or paint applied to back of clear acrylic is illustrated below.*

---

*Aimee Rydarowski Master’s Project Thesis Murmur Georgia Institute of Technology, May 2007*
Design

Research History

Experimental Media 2006

As mentioned before, I began construction of Marmur in Ali Mazalek’s spring 2006 Experimental Media class. I came in never having built a circuit, but very excited about the opportunity to create an interactive art object. In the first few weeks of class we went through basic circuit building exercises, were introduced to the Architecture Design Lab and electronics suppliers around town and online and familiarized ourselves with basic sensors and components. Physical Computing, our class textbook, proved to be a wonderful resource. We were also introduced to the Wiring coding environment and Wiring board. I continued to use this board for Marmur after comparing it to the Teleo, Making Things and Arduino boards because of the multiple 40 I/O pins. Finally, we familiarized ourselves with basic prototyping equipment such as breadboards, multi meters and soldering stations.

Transistor Circuit integrated in switching matrix to enable individual fan control with a limited number of signals.

After solidifying my project idea I began researching control circuits for the fans. Initially I decided to try and build the project out of entirely analog components in order to better integrate everything into
the structure itself, including sound processing components. After a bit of research into analog circuits for DC motor control, I learned I could use a transistor as a switch. By sending a low signal voltage (usually 5V) to the base of the transistor, a connection is made between the ground and power, which completes the circuit and turns on the fan’s motor.

Problem Space 1: Individual Fan Control

The first problem I encountered was how to control 100 fans individually with only 40 I/O pins. Through research I cam up with several possible solutions:

1. Daisy chain multiple wiring boards using I2C output of board.
2. Build a power control matrix to bus signal, giving each fan a row/column address.
3. Bus a signal to a row of 5 fans, circumventing the problem because only 20 I/O pins are needed
4. USB hub with multiple wiring boards.

After a bit of research and testing, I threw out the last option as it was the most cumbersome and required me to purchase two more wiring boards, which seemed excessive.

The first option is actually the most recent and also the most advanced. If I ever build another structure with multiple components I will definitely look into this. In the course of researching Murmur, I came upon I2C control (wiring boards with designated Master/Slave relationships) too late to test it out and was already involved with realizing option 2.

The idea for the second option, building a control matrix, came to me the summer after taking Ali Mazalek’s Experimental Media class. I was recalling a conversation about LCD circuits and figured I could apply a similar concept to control Murmur. At this point I began researching these types of circuits by spending hours in the Electrical Engineering section of the Tech bookstore and spending more hours trying to decipher complex circuits online. Seeking out someone with an EE background would have been too easy. I figured I would learn a lot more by doing the research myself. There came a point when designing the analog circuit became a task too large without having any background in the subject. I tested several types of transistors, usually MOSFET, and NPN style transistors. While testing, I bought some introductory books on circuits to better understand the mechanics of the components I was working with, which included diodes, resistors and DC motors.
I learned that when choosing a transistor, the transistor's minimum collector current (Ic max) should be greater than the load current:

\[ I_c \rightarrow \text{choose } I_c \text{ max } > I_c \]

We know that \( I_c = \text{supply voltage/load resistance} = \frac{V_S}{R_2} \) (0.2 Amps for the fans)

Also, the transistors minimum current gain should be at least 5X (some say 30% is enough) the load current over the maximum current output of the chip (for most microcontrollers this is ~0.02 Amps).

\[ \rightarrow \text{HFE} > 5 \times \text{load current/base current} = 5 \times \frac{I_c}{I_b} - 5 \times 0.2 / 0.02 = 50 \]

or

\[ \rightarrow \text{HFE} > 1.3 \text{ (add extra current to make sure that the transistor switch is always saturated) } \times \frac{I_c}{I_b} = 1.3 \]

\[ 0.2 / 0.02 = 13 \]

Using this equation, I began by looking for NPN transistors where the HFE >50 (or 13) and the Ic max>.2a. Now, this is no problem when working with a single fan, but I had 100 fans. I learned that I would have to get harder components to handle 20amps (.2 * 100) if all fans would be on at once. I moved to testing Darlington and n-channel enhancement MOSFET transistors as well as relays, which are made to switch higher AC voltages.

Late in the summer of 2006, a bookstore employee and electronics hobbyist recommended a book entitled *Bebop to the Boolean Boogie* by Max, which introduced me to the world of digital logic. Based on this new information, I switched out all the transistor circuits for switching the fans and replaced them with AND logic gates. Logic gates are digital components that take one or more inputs, apply (generally) a Boolean conditional statement and produce a single logic output. AND gates apply the logic if \( A \text{ and } B \text{ are true} \rightarrow \text{output signal.} \)
Problem Space 2: Simplifying the Circuit

With a newfound appreciation for digital circuitry, I sought out digital components to take the place of the analog components. Early in the fall of 2006 I came across H-bridges while flipping through the back of my Physical Computing book. These components are very helpful in controlling DC motors, servos, and stepper motors. By integrating a more complex transistor circuit into a manageable package, not only do they simplify a circuit, but allow for a range of control including backwards motion to help instantly stop the fans. I used the L293 to replace all my fan circuits.

Although these components simplified the circuit and made the breadboard test circuits much more manageable, they restricted the amount of current and consequently, the amount of fans that could run at once. The L293 bridges maxed out at around 2 amps, allowing me to run up to ten fans at once. Seeing no difference in running ten fans or five fans (one column) at once, I decided to not run the components at maximum capacity and just turn on one column at a time. Thinking back, my design decision to move from the ten by ten fan matrix to a five by twenty one allowed me to use these new digital components. During the fall semester of 2006 I tested the new digital circuit.

Problem Space 3: PCB (Printed Circuit Board) Design and Circuit Modifications

*Gate matrix diagram for individual fan control. Designed to prevent extraneous fans from turning on.*
Once the new components arrived, I created a scheme to switch the fans that would prevent other fans from turning on when they weren’t supposed to. The diagram above illustrates one such scheme. Each fan is targeted with a row and column number through the AND gate. For instance, fan 1 (top right) is targeted by sending a signal to column 10 and row 11. The AND gate associated with that position gets two positive 5V signals and outputs a 5V signal to the associated H-bridge which in turn opens the fan’s connection to the 12V power source, running the fan. Even though I could still only run five to ten fans at a time, this design would allow me to make diagonal waves across the surface.

While designing the printed circuit board in Protel 98*, I performed more test circuits with the design above. After getting mixed results (it would work at times and at other times there seemed to be a current leak), I decided to reformulate my plan. It was too late in the semester to continue testing and I had to finish the PCB. The current leak could be coming from anywhere, as I was without proper circuit testing equipment- using multiple breadboards and hundreds of wires...any of which could be loose. A breadboard might be defective and I wouldn’t know without hours upon hours of troubleshooting. My objective was to have Murmur finished in time to install it in the Listening Machines event at Eyedrum and the date was fast approaching. I decided to go with what I knew would work...getting rid of the AND gates and bouncing the control signal to a column of fans so that all fans in that column would turn on at the same time. After receiving the PCB, I proceeded to solder on all the components and plug in the fans with Hirose snap connectors. These connectors would allow me to unplug the fans from the circuit board so different types of circuits could be designed for the display and changed out at will.
Components and Construction

Constraints:

**Fans:** I began thinking about the affordances of using fans and thinking about designing around these affordances.
- built in smoothing
- tactile sensation
- uses air as medium
- can be used for a temperature change
- creates sound through movement (by itself or with attachment)
- works well with sound-wave analogy
- creates disconnect between actuator (fan) and secondary sensor (reactive surface)

I considered how I could make a representation of sound out of 100 elements, or in this first step, the movement of rows of 5 fans at a time, 20 units long that would be engaging, recognizable, understandable and most important, inherently synonymous with what it is representing.

**Components: Hardware**

100 DC fans
Electrical wire
Connectors for fans and wiring board
Circuit board: array of drivers for fans
Wiring board
Dynamic microphones (4)
PreSonus FirePod mic pre amp
Multi-media computer
USB serial from computer to wiring board
Components: Software

Wiring/Processing (Processing just in R&D)
MAX/MSP
Protel 98
Corel Draw
Rhino CAD

Construction:

Aluminum lengths
Cord ties
Pine box frame that mounts to wall
Mounting hardware

Fabrication Locations and Techniques:

Design Lab (Architecture)
Digital Media PhD lab
GVU #333
GVU laser cutter
Advanced Wood Products Laboratory (AWPL)
Garage space

Compressed image of CAD drawing that was used to cut out the display surface from styrene material in the Advanced Wood Products Laboratory (AWPL).


Web Sources:

http://www.datenform.de/rscreeneng.html
http://www.smoothware.com/danny/woodenmirror.html
http://www.evl.uic.edu/virtualunism/VirtualUnismFinalPR10-12-05.doc
Schematic of NPN transistor circuit to switch fan's connection to power and ground.

Left: close up of the control circuit before the fans are plugged in. Right: diagram of H-bridge.
Diagram of L293, a dual bridge motor driver.
Sketches and notes on construction of the fan casing.
PCB layout (left) and schematic (right) in Protel 98'

Printed circuit board with components connected.
Initial Flow

WB

CB

motion left and right

Grillwork Fan Display

microphones

Max/ MSP sends variables to WB

Regular Routine

WB

serial

I/O

CB

motion left and right

Grillwork Fan Display

microphones

Max/ MSP receives signal

sends new variables to WB

collects mic data into variable sets to be averaged over time

Signal flow