Designing Ambient Musical Information Systems

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ABSTRACT

In this work we describe our initial explorations in building a musical instrument specifically for providing listeners with simple, but useful, ambient information. The term Ambient Musical Information Systems (AMIS) is proposed to describe this kind of research. Instruments like these differ from standard musical instruments in that they are to be perceived indirectly from outside one's primary focus of attention. We describe our rationale for creating such a device, a discussion on the appropriate qualities of sound for delivering ambient information, and a description of an instrument created for use in a series of experiments that we will use to test out ideas. We conclude with a discussion of our initial findings, and some further directions we wish to explore.

Keywords

Ambient Musical Information Systems, musical instruments, human computer interaction, Markov chain, probability, algorithmic composition

1. INTRODUCTION

In 1996 research conducted by Mark Weiser at Xerox PARC gave a new perspective on human-computer interaction. Weiser argued that the best technologies are those which are not experienced as technology at all, and pointed out that the designs that "encalm" and inform meet two human needs that are not usually met together [9]. For example, cell phones, news services, television, and pagers, provide useful information, but at the same time they control our attention, causing unnatural distractions, and ultimately leading to a state of informational overload. To address this conflict between people's need to be aware of a growing amount of information, and people's need to not be overwhelmed by it, Weiser proposed the development of *calm technologies*. In Weiser's vision, information can exist both at the center and the periphery of our awareness, moving smoothly back and forth between the two, so that information can be provided in such a way that it can be easily ignored when the observer has more pressing issues to address.

Over time, Weiser's conception of calm technology has compelled researchers to explore several novel methods of observing and interacting with information. One outcome of these explorations is a specific class of alternative displays that can provide useful information while blending naturally into the surrounding environment. These devices are distinguished from more common informational displays in that they are primarily intended to be perceivable from outside a person's direct focus of attention, and providing preattentive processing without being distracting. Technologies such as these are often embedded in existing environments, making use of unused physical and visual aspects of everyday objects to provide an information channel that can be easily ignored when there are more important matters that require ones attention [6].

2. AMBIENT INFORMATION SYSTEMS

While exploring these concepts, researchers have used a variety of different terms to describe their own implementations for this form of representing information. These terms include: peripheral displays, ubiquitous technology, informative art, everyday computing, glanceable displays, user notification systems, and slow technology. Partially because of this over proliferation of terminology, Pousman and Stasko [7] have proposed the term *ambient information system* (AIS) as a means to describe the collection of properties that are inherent in all such implementations. According to their definition, AIS is intended to describe all technologies that, display non critical information, move easily in and out of the periphery, focus on tangible representations, changes subtly to reflect changes, and have an emphasis on aesthetics.

Almost all existing AIS implementations make use of various visual elements such as: color, texture, shape, and motion, to produce subtle changes in their appearance and convey a specific piece of information. For example, one device which is commercially available is the *Ambient Orb*, from AmbientDevices.com. This device consists of a simple frosted glass sphere that contains an array of colored LEDs that can be powered in such a way as to allow the orb to display thousands of different colors (see Figure **??**, left). By using these changes in color, the orb can be configured to display several different channels of information, such as: stock price, weather forecast, traffic condition, and local air quality. For example, with stock pricing the orb

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may shift from green to red when a particular stock drops significantly in price. Another example of a visual ambient display is the *DataFountain* by Koert van Mensvoort. This display is comprised of three water jets that project water to different heights based upon the relative value of the Yen, Euro, and US Dollar.

One of the problems with the normal visual cues used in AIS is that they must be within the reader's field of vision. However, one of the primary advantages of this class of information technology is that one may perceive it while focusing directly on other tasks. This has lead us to believe that sound may be a preferable medium to use when developing this sort of system, although sound-based AIS has been largely left unexplored.

Unlike more traditional musical interfaces, which are designed to be directly observed in public performances, we need our instrument to have some subtlety and to perform in the periphery of the listener's awareness.

This paper describes an instrument designed to study music as a medium for delivering ambient information in the style of AIS. We begin by discussing our design rational for the development of the initial instrument, and follow with a description of its actual development and construction. Finally, we discuss some evaluations and the next stages in our research.

3. DESIGNING AN AMIS

Because of the lack of existing sound-based implementations, we sought to construct our own AIS that can convey a simple stream of information within a public setting. We are proposing the term Ambient Musical Information System (AMIS) for this type of research, based on Pousman and Stasko's definition of an Ambient Information System, but focused on audio-based delivery.

One type of information which is both important and useful, but not necessarily critical, is regarding how and when people are making use of public spaces (i.e., lounges, conference rooms, study halls, etc.). The particular situation we wished to experiment with is a system that can inform people in one location how much activity is taking place in a remote location. For example, if there are two separate lounges in a building it could be useful to know if a high level of activity is taking place in the other lounge so that one could choose to relocate to the area where most of their colleagues are. Alternatively, they could choose to relocate to the other lounge if less activity was taking place, and they needed a place to study, or have a private meeting.

This is one of the most important and difficult features of an AIS to design. We had to carefully consider different qualities of sound that might be appropriate for this sort of informational interface. The sound produced needs to situate the information being conveyed at the edge of the listener's perception, and fade in and out of their awareness depending on the level of information that is being presented. The idea that there could be an optimal kind of music for this sort of display has been the source of some debate within our group.

The need to focus on tangible representations required that we could not simply place audio speakers into the public space and provide the information as disembodied sound. Instead, we had to build a physical musical instrument that was capable of conveying musical information in a subtle manner. We decided to take our inspiration from Eric Singer's "League of Electronic Musical Urban Robots" and create a semi-autonomous automated musical instrument [8], which can be fed information regarding the activities in a remote location, and change its state accordingly.

Our musical interface has to be able to alter the music it was producing to inform listeners about different levels of activity in remote locations, but had to do so without forcing itself into the listener's primary focus of attention. We had to come up with a way to change the type of music being played such that it mapped to the remote level of activity, but without being distracting. To achieve this, our system makes use of Markov chains in a generative context. This is discussed further in Section 6.1.

To build a proper AIS we had to take the aesthetics of our instrument into careful consideration. Maintaining the instrument's perceptual subtlety requires that it blend smoothly into the environment so that people would not be overly engaged with it. This means that it could not be overly attractive or unattractive. In this case, we chose to make the instrument resemble a piece of generic artwork, akin to those that might be found in common waiting rooms or lobbies. For our sound emitting material, we made use of thin bars of slate stone which were tuned and could be played similarly to a xylophone or marimba. To keep the motion and electronics from drawing attention to the instrument, we hid all of the mechanisms that were operating the instrument internally. To the casual onlooker, it would appear that the instrument was nothing more than a simple, somewhat bland, wall-hanging piece of artwork.

4. MUSIC AS INFORMATION

As we have mentioned, there have been few explorations in AIS that make use of sound as an information channel, but the underlying concept of providing music as an additional information layer has some precedents. Perhaps the most pervasive example of music as information is Muzak. Used by 90 million people each day, this company's traditional products are designed specifically to be non-invasive, yet are subversively "made and programmed for business environments to reduce stress, combat fatigue, and enhance sales" [4, pp. 4] and in some cases has been used to increase worker productivity in factories by arranging songs in cycles of increasing tempo. [4, pp. 43–5]. Muzak is a good example of music that was developed to be perceived outside the direct focus of attention. The style of Muzak is produced such that it is deliberately tame ("easy listening"), and does not give cause for listeners to become overly interested in what is being played.

One of the continuing topics of discussion concerning our instrument is regarding the qualities of sound that are best suited for conveying ambient information. Of course we know what sound qualities are probably inappropriate (e.g. a fog horn, or drum set), but we believe that there may be other sound qualities (e.g. tone, timbre, resonance)may be best for delivering information in an ambient manner. In considering the construction of our instrument we felt that the right place to start was with a highly resonant, slowly changing, sound source.

5. IMPLEMENTATION

Our instrument consists of five tuned bars (sound elements) of slate stone mounted to a hollow wooden box with a hole beneath each bar to amplify the sound. Beneath each of the bars is a single solenoid that can be activated to strike the bar, producing sound. The solenoids are controlled programmatically by using an existing hardware platform called "Phidgets" [2]. This setup proved to be more complicated than we had anticipated. Individual components of our instrument are discussed below.

5.1 Physical Aspects

Upon acquiring our sound elements, we tested them on a standard xylophone mounting and found that the sound produced had a mellow quality, and decay rate similar to a marimba. To amplify the sound and contain the electronic components, a resonant box was constructed out of 1/4" thick particle board with 3" holes below each sound element. After mounting the sound elements we found that the density of the wood, and the mechanism used to mount the sound elements vertically, had an effect on the decay of the sound elements. We assumed that part of the problem was the thickness of the wood, so a second box was constructed from 1/8 inch wood stock. This improved the sound by increasing the overall decay rate, but the act of mounting the sound elements vertically still caused them to lose some resonance. In our second iteration on the instrument's construction, we designed a new mounting bracket that pinched the drilled mounting holes in the sound elements between two small pieces of foam not much larger than the holes themselves. This provided some improvement over the initial mounting. We are still experimenting with better ways to mount these sorts of sound elements vertically, so that they produce the same sound as when they are mounted horizontally.

5.2 Working with Solenoids and Phidgets

The primary difficulty in automating our instrument was in acquiring solenoids that would best suit our purposes. A solenoid is a device that can convert energy into a linear motion by making use of a simple electromagnet. Inside the electromagnet is a simple piston that is drawn in when power is passed through the magnetic coil. Solenoids can be categorized as either pull-type, or push-type (sometimes called thrust-type), depending on the motion they create. The push-type solenoids differ from the pull-type only in that another smaller piston is attached to the primary so that when the primary is drawn in, the other pushes out the opposite direction.

Solenoids like these are used for everything from controlling automated car locks, to operating soda vending machines. The companies that produce these devices will make custom orders to match the needs of a particular project, but these companies normally expect very large orders in order to do so. For someone doing a project like ours, were we need only 5 to 10 solenoids, purchases are likely going to be done through surplus retailers, and only the basic model will be available. A basic solenoid model will consist of only the plunger and the frame. If the plunger is placed half way into the frame, and power is applied, the plunger will quickly force itself into the stop position. Making this mechanism useful requires the additional construction of a return spring to move the plunger back to the start position when the power is turned off. Without access to specialized drilling machines, we attempted several less-than-optimal ways to create a functioning return spring for each of our solenoids. The final solution involved welding a small spring to the base of the plunger, and attach the opposite end of the spring to a cap which is fitted over the back of the solenoid. This solution worked well enough to make our solenoids functional, but the resulting assembly produces a bit of extra noise that lessens the overall effectiveness as an AIS device. Other researchers have proposed different strategies for dealing with solenoid problems, although some of these were not applicable in our case [3].

The Phidgets platform works very well as a means to control the solenoids we manufactured for our instrument. We were able to make use of the Phidget Interface Kit 8/8/8 [2] to control three *Dual Relay Boards* in combination with a 24 Volt power supply. The only drawback to using the Phidget Dual Relay Boards is that they produce some extra noise. Specifically, a "click" can be heard when the board switches between the on and off position. This had the effect of giving our instrument a sound that has some similarities to a pinball machine, which we are not completely certain is appropriate as an sound-based ambient information source. The company that developed the Phidgets platform has just released a new component that is similar to the Dual Relay Board, but this model makes use of a solid-state switch which operates silently, and that we believe will solve this problem.

6. MUSICAL CHARACTERISTICS

There are a number of musical factors that must be carefully considered when designing an ambient musical instrument. One strategy for building an ambient instrument could be to use specific melodies or well-known songs. However, the difficulty with this approach is that these kind of musical materials bring in a variety of distracting cultural and semantic associations, as can be seen in the current "ringtone" phenomenon with cellular phones, that we feel would bias our results. Instead, the approach used here has been to use somewhat non-descript musical materials, and to transmit information to the user using changes in global musical characteristics. For instance, changes in tempo, activity levels, repetitiveness of pitches or regularity of rhythm can be used to indicate changes in some aspect of the information that is being represented. Additionally, there is the need to supply musical materials over long periods of time, such as entire days or perhaps even weeks at a time.

However, music that is completely redundant, such as an endlessly repeating rising scale, can be extremely tiring for a listener. A chorus that is repeated multiple times may be acceptable within the confines of a three minute pop song, but is likely to be unacceptable for longer periods of time. Alternately, and as has been pointed out by other researchers [5], completely random music with no predictable attributes also has a tendency to be extremely tiring for a listener. This is perhaps in part because the only predictable attribute is that it is unpredictable. The long-term characteristics of the instrument must sit somewhere between these two extremes. The ideal music, for our purposes, should not carry recognizable cultural attributes, be able to transmit information through large changes in style, have a partial degree of redundancy, and be able to run continuously for extremely long periods of time.

6.1 Markov Chains

Discrete Markov chains have a long history in computer music and algorithmic composition [1], and are ideally suited to our purposes.

A discrete Markov chain is a discrete-time stochastic process that can be used to model a series of events, where each event is assumed to belong to one of a finite set of unique states. The entire process must always be in a single state at any one time, and will change state based on some kind of received information. One interesting aspect of Markov chains is the underlying *Markov property*, which assumes that future states only depend on the present state, and not on previous states.

$$P(X_{n+1}|X_0, X_1, X_2, X_3, ..., X_n) = P(X_{n+1}|X_n)$$

Each transition between states has a fixed probability, ranging from 0 to 1, and all outgoing probabilities from any state must sum to 1, forming a probability distribution. These probabilities can be learned from data, or can be assigned directly by some other means.

The transition probabilities for a Markov chain, for example a random walk procedure, can be indicated using a *transition matrix*, as in Figure 6.1.

$$S = \begin{bmatrix} & \text{a} & \text{b} & \text{c} & \text{d} \\ \text{a} & 0 & 1 & 0 & 0 \\ \text{b} & .5 & 0 & .5 & 0 \\ \text{c} & 0 & .5 & 0 & .5 \\ \text{d} & 0 & 0 & 0 & 1 \end{bmatrix}$$

Here, each element $S_{i,j}$ represents a particular transition probability, where i, the row, is the current state and j, the column, is a possible future state. One of the advantages of the matrix approach is the ease by which probabilities can be altered; for instance, adding a link from d to a is as simple as filling in a value at $S_{4,1}$ and normalizing the row.

Markov chains are ideal for our purposes, for two main reasons. First, they can be used to simulate various degrees of "stochasticity" including completely randomness (by setting all output transitions to the same amount) to completely predictable, and any degree between. Secondly, Markov chains have the ability to continuously generate a stream of data tokens. Normally, termination of the chain is set by either specifying an end state or a fixed number of tokens to generate. If neither of those conditions is set, the chain will continue to generate tokens without stopping. This is equivalent to simply repeating the state-selection process inside an infinite loop.

For this experiment we have used two Markov chains, one for controlling generation of new pitches and one for controlling durations, and encoding each separate pitch or duration as a separate state in each respective chain. Changes in the musical behavior are accomplished by loading new probabilities into the transition matrix, which immediately results in a change in instrument behavior. Additionally, a standard time unit (an eighth note) is specified in milliseconds, and duration states are specified as multiples or divisions of that. This is used to provide a way to globally alter tempo, without disturbing the other musical characteristics.

7. EVALUATION

Our current, implemented device is shown in Figure 1. While more-extensive listener studies are planned, we have already tested the instrument casually with a number of listeners. We have received a range of opinions that have proven valuable in both the planning of the experiment, as well as the next version of the instrument. The most prevalent feature that has been mentioned, and that we would like to introduce (besides fixing the aforementioned click problem) would be to have better control over the volume of individual notes, which is difficult with our present solenoid-based system. The present version has convinced us that we are moving in the right direction and that the AMIS concept shows much promise.

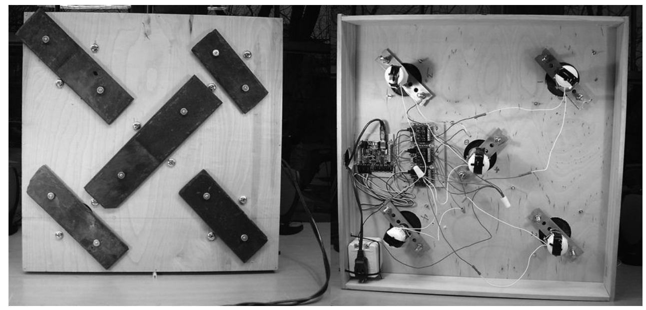

Figure 1: Current implementation, front and back

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