UNTITLEd
AN INTERACTIVE INSTALLATION
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ABSTRACT

Untitled is an installation that translates movement into sound. The hardware and software that comprise the piece are described, and the manner of presentation of the piece is discussed. Three different methods of detecting movement with ultrasound are presented together with a simple 'harmony-pass' filter algorithm. The installation form is described through specific works by Tudor and Rauschenberg and the problems peculiar to interactive installations are addressed.

1. INTRODUCTION

Untitled uses ultrasonic motion sensing and simple signal processing algorithms to translate movement into sound. The piece is presented as a gallery installation where any spectator can choose to become a performer by approaching the computer. Movement determines the timbre which articulate computer determined harmonies. A control program selects new harmonies and, in the absence of movement, gradually cross-fades from the currently active harmony to the new one it has selected. This paper describes the technical apparatus of Untitled and, framed by a few remarks on installations by Tudor and Rauschenberg, discusses the way the installation is presented.

The following diagram provides a simple flow chart of Untitled.

2. MOTION AND POSITION SENSING

Ultrasound is commonly used to both detect motion and determine position. Ranging systems, such as those marketed by Polaroid and Harris Products, emit a toneburst and measure the time until the first reflection returns to the transmitter. This can provide a very accurate estimate of the distance from the transmitter to one other object. However, this limits it to avoiding a single user. Also, if one transmitter is used to both transmit and receive, the system must wait for the return reflection before initiating another transmission. This, combined with mechanical considerations such as transducer ringing, limits the update rate to below 30 hertz. This rate is too slow to provide an accurate estimate of rapid gestures.

In Untitled, motion sensing was effected with doppler sonar. In this section, a 40 kilohertz tone is broadcast into a room through an appropriate loudspeaker. Any movement in the room gives rise to doppler-shifted reflections of the original tone. The velocity of movement relative to the sound source determines the amount of doppler-shift. (This assumes that the sound source and microphone are not moving with respect to one another.) If the movement is directly towards (or away from) the sound source, the relationship of velocity to shift is

velocity/wavelength=dopplershift (in hertz).

For 40 kilohertz, one produces 3 hertz of doppler shift for each inch per second of velocity. Most human movements will produce shifts ranging from 1 hertz to 400 hertz. Both shifted and unshifted reflections of the original tone mix in the air, producing beating patterns in the same frequency range. The beating patterns themselves are the signal of interest. They can be detected and translated into a low frequency audio signal with a microphone, a preamplifier, and a fast envelope follower. A significant advantage of this method is that it can detect several different movements simultaneously; however, it is not well suited to determining relative position, limiting its general usefulness.

In an alternative approach to the problem is currently under study. The proposed technique would determine the position of the loudspeaker yielding a three dimensional 'house' that could be used to sense human movements for music or graphics. Its range of application is sufficiently large to merit a brief discussion. If the loudspeaker in diagram 1 emits a sound, mic 0 will receive it because the angle 80 is less than 81. The time difference will be .01764 sec, where r is the distance of the sound emitted in a 40 kilohertz tone, mic 0 will receive 40,000 cycles before mic 1 receives any. Consequently, the up/down counter will count up to the integer part of 40,000 times and oscillate between this value and one less as it receives up and down pulses from the two microphones. The computer is actually providing the absolute phase difference (divided by 2pi and truncated) between the sound arriving at mic 0 and mic 1. This value, (40,000)x(2pi)/(2x3.14) is the difference between the distances from the

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speaker to mic 1 and to mic 0 expressed in wave-lengths of the 40 kluminous tone. It locates the speaker on a hyperboloid: the arrangement of microphones in diagram 1 can provide the additional information needed to locate the speaker without any ambiguity. The distance ranging methode the distance estimate provided is automatically updated 40,000 times a second.

**THREE DIMENSIONAL MODEL**

**diagram 1:**

```
+---+    +---+
|   | 0  |   |
+---+    +---+ 45
  \  /    \  /  Up
   \|     \|
  | up |     | down |
  |    |     |      |
  +---+     +---+
```

**diagram 2:**

```
\___\     \___\  X mic 2
|     |   |     | 0 speaker
|     |   |     | mic 1
\___\     \___\  X mic 3
```

3. **HARMONIC BAND FILTERING**

The sounds generated by double sonor motion sensing dimensional immeasurable low frequency dissonance unless the movements are constantly and regularly repeating (i.e., mechanical) or highly differentiated and articulated (i.e., dance). Greater apparent sensitivity can be obtained by using a computer either to process or to analyze the low frequency sounds produced. In building the computer implements a simple comb filter that quantizes each low frequency glissando into a discrete series of pitches found within one harmonic series. This makes it significantly easier to distinguish different movements made by oscillators. This is apparent sensitivity of the installation.

The basis filter algorithm is:

```
on interupt: SAMPLE(1)=1-Q*INPUT + r*SAMPLE OUTPUT=SAMPLE(1)
[=1=1] NOAA 156 RETURN
```

Where INPUT is an ATG converter, OUTPUT is a GTO converter, and r lies strictly between 0 and 1. It is interesting to note that if INPUT and OUTPUT are set equal to one another (i.e. feeding the filter itself), the filter reduces to a version of the Karplus-Strong plucked string algorithm in decay mode. In this case, the filter is used in the delay line that averages its output with its input. Frequencies that are equal to some multiple of 1/DELAY time are "in time" and will build up in the array SAMPLE(1); other pitches will tend to be cancelled out by the averaging operation. Thus, the filter has resonant peaks at the first 128 harmonics of the input clock frequency divided by 256, and the constant, Q, determines the selectivity of the filter. The GTO microprocessor is far too slow to implement the averaging operation with a bona-fide multiplication. By setting r=0.78 it was possible to implement the multiplication with shift and subtraction.

4. **SYNTHESIZER AND OUTPUT**

The output of the filter is transmitted to a more psychoacoustically appropriate range with a modest digital synthesizer. Called the Mountain Hardware Music System, the device implements 16 oscillators with 256 byte waveform tables. Three control parameters are provided for each oscillator: an 8-bit amplitude control, an 8-bit waveform selector, and a 16-bit frequency control word. The waveform selector is multiplied by 256 to determine the base address of the desired waveform in the table. These tables can lie anywhere in the Apple's 64K address space. The pitch determined by the frequency control word is:

```
F(CV)=VC(M(31,256/65,536))
```

Thus all the pitches produced by the synthesizer lie in the harmonic series of a pitch a little below 1/256TH of the pitch 1 and the value of the CV corresponds to the harmonic number of the specified pitch.

In order to efficiently implement transposition, the array SAMPLE(1) is actually moved in the waveform buffer used by the synthesizer. There is a potential discontinuity between the sample most recently updated by the filter and the next sample to be updated. Since the synthesizer and filter must run asynchronously the pitch in the waveform. The value of Q selected prevents this glitch but it reduces the effect. In this way that movement creates a sound that defines and dynamically-gives the waveforms being used by the synthesizer and spectators can control the amplitude and phase of the sounds they hear.

The synthesizer steaks every other clock cycle from the CPU in order to update the oscillators, and the filtering program must run at least 600 times a second. That little CPU time is left is used by a simple control program. The program has two modes of operation. The main mode determines three or four parameters from a predefined table and slowly cross-fades from the current harmony to the one it has selected. If the computer senses sufficient movement it will freeze the cross-fade at whatever harmonic is found to be, allowing the spectator to examine the resultant harmony more closely. The harmonics themselves are deformations of vocal formant structures. At different intervals the control program goes into a second mode where it "improvises" melodies on the harmonic series. The tempo of the improvisation is determined by the spectral content of the waveform table which are determined by the velocity of people's movements. The peak to peak amplitude of the waveform table determines the overall register of the melodies, providing spectators with another level of control.

5. **PRESENTATION**

Unlike concert rafters, galleries allow spectators to change their positions in relative to the sights they are seeing and the sounds they are hearing. Certain
pieces have been composed which require this freedom, notably David Tudor’s Rainforest IV. Interac-
tive installations most exacerbate the added complic-
tions of performers with unknown backgrounds and
gains. Finding strategies to ensure ‘good perform-
ance’ by strangers was a major preoccupation in
composing Rainforest. Robert Rauschenberg’s bouncing
sends some light on this problem.

David Tudor’s Rainforest IV is based on a radical
reformulation of a very basic assumption of most
electronic music. Most audio technology requires
that microphones, speakers, and amplifiers be neu-
tral conduits from the air. Given microphones we
hear to the electronic signal we can store and
manipulate. This is clearly necessary for sound
recording and extremely powerful in electronic
music, but it is by no means perfect. We know that
the speaker with perfectly flat frequency response
and well-defined spatial characteristics replaying
a perfect recording of the piano will fail to sound
exactly like the piano precisely because the piano
falls to have those neutral patterns of dispersion.
In Rainforest, Tudor collapses synthesis and trans-
duction into a single process of transformation.
The highly prized neutrality of speakers is set
aside in favor of a highly differentiated collection
of extremely ‘low fidelity’ speakers with complex
spatial characteristics. This is not an unfamiliar
project: we do not prize the violin because it per-
fectly amplifies that many ramp have produced by
shaping a bow across a string. The development of
the piece can be seen as the inspiration of a ‘musical
technology’ that prizes inaccuracy over regularity.
It does not reject technology; neither it extends it
in directions it would never go within the engineer-
ing ‘discourse’. The speakers, the sounds they pro-
duce, and the spatial distribution of those sounds
are all of interest. Spectators can encounter the
piece as both a concert and an exhibition of ‘sing-
ing sculptures’. The idea underlying this piece
requires a drastic revision of the concert format;
it literally demands to be presented as an instal-
lion. The piece also raises questions about the
relationships of technological thinking to cre-
ative endeavor in the context of technology. The
thoughts provide another example of this problematic.
Earlier, three different methods of sensing motion
with ultrasound were discussed. The two aspects
that provide salience information and consequently
are of general interest could not have been used to
make ‘Rauschenberg in Rainforest’.

In Robert Rauschenberg’s bouncing a one-way mirror
sides an elaborate construction of hanging chains
form view. Sounds in the gallery trigger lights
that reveal the sculpture hiding behind the mirror.
These sounds may be accidental or involuntary at
first, but spectators quickly recognize the struc-
ture of the situation and merely to ‘play’ the in-
stallation. These ‘performers’ do not need more than
illuminate Rauschenberg’s hanging chains for in any other
situation they would represent a breach of gallery
etiquette. By encouraging, in fact demanding, these
actions the piece directs attention to its social
context. If it were not for its visual interest
the piece would merely turn the gallery where it is
placed into a fun house. While spectator’s ac-
tions may amuse or irritate, the visual imprint
that leave on the piece is always interesting.
Details of anyone’s actions are confined to the
social and auditory environment of the sculpture.

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de can always turn away and see what Rauschenberg
has done. The sculpture accommodates performance
by limiting its scope. This structure is envisioned in
Rauschenberg sculptures ‘illuminate’ programmed
sound structures with their movement.

In presenting ‘Rauschenberg in Rainforest’ I sought to design a visual
setting that, together with the tiling of the elec-
tronics, would encourage careful, attentive perform-
ances. The motion-sensing was made most sensitive to the slow, steady movements that anyone can ex-
cute gracefully while continuing to listen. Harm-
onic changes are triggered by the presence of move-
ment, encouraging one to stop and to listen. The
setting of the piece is illuminated by a single
light source that is focused on the area where the
installation is most sensitive to movement. A bar-
rier of broken glass prevents spectators from look-
ing into the box to the computer. The light reflects
of the glass, casting a tattered light throughout the
space. Approaching the computer, the shadow
and cast illusion is reflected, upside down, in this light. This
drastic, and unexpected, change in light level
combines with the implied threat of the broken glass to create a space where one must proceed with cau-
tion. The broken glass is also in sympathy with the
use of sounds that are fragments, or tattered
remnants, of a concert piece entitled ‘Minute Dis-
terences’. Close Guarded.