Mimetic Dynamics

NATASHA BARRETT† and OYVIND HAMMER‡

† Avdeling for Kunstfag, Hogskolen I Tromso, 9005 Tromso, Norway
E-mail: natasha.barrett@notam.uio.no
‡ Paleontological Museum, University of Oslo, Sars gt. 1, 0317 Oslo, Norway
E-mail: ohammer@toyen.uio.no

The 'art' we produce today attempts to incorporate an increasing level of computer technology. There are many reasons for this trend, the most significant being a thirst for an exploration of the 'new', and the desire to parallel the increasing level of technology seeping into everyday life. However, when surveying recent developments we find an array of technology-related arts projects that instead of reaching forward into the previously unknown, often reproduce the past simply in a digital form, designed to appeal to our immediate senses but lacking in depth and substance. Likewise, it can be observed that in many cultures (ancient and modern), mimesis grows out of what seems to be a human reaction to technological change. Qualities familiar from past usage tend to be reproduced in new materials and with new techniques, regardless of appropriateness. This may have religious origins, or simply result from inertia, reworking concepts within the current paradigm. Parallels can be drawn from evolution, which can be observed to progress in a series of large advancements alternating with periods of extremely slow or zero development (Eldredge and Gould 1972), and from the progress of science, which seems to be similarly stepped (Kuhn 1962).

This paper describes *Mimetric Dynamics* – an audiovisual interactive installation exploring one of the many possible relationships between nature and technology. In this work, real and simulated fluid dynamics are presented simultaneously, allowing both artist and viewer to explore the relationship between 'digital' and 'analogue' media in both sound and visual dimensions. It gains insight from physical laws and time flows derived from the natural world, where digital technology is used to produce mathematical models simulating real physical attributes. In doing so we are able to harness qualities of the 'natural' and use their characteristics to control aspects of the 'artificial' (virtual).

1. INTRODUCTION AND ARTISTIC CONCEPT

Within the differences between what can be termed 'real' and 'virtual' lies the essence of *Mimetic Dynamics*. The term 'real' is here used to describe a situation where the display of defining characteristics is inseparable from the causal physical matter. The term 'virtual' is here used to describe an artificial environment where the set of displayed attributes is illusory and separable from the real cause. The use of physical matter displaying physical laws derived from the natural world constitutes the 'real', while the simultaneous display of a mathematical model constitutes the 'virtual'.

The differences between the real and virtual are brought to light through the superimposition of different media. The degree of detachment of the virtual from the real will exist in a continuum. At one extreme, due to the accuracy of computer simulation, the simultaneous presentation of 'real' audiovisual information and 'artificial' model are clearly mimetic such that a paradox is evoked through an ambiguity in the direction of the mimesis. Is the mathematical model mimicking the physical, or vice versa? Is the sound material provoking further visual development, or does the visual articulation determine the sound? This ambiguity entices the viewers/listeners to connect their immediate perception of the totality with their memory and imagination, and in doing so aims to stimulate an emotional and cognitive reaction to aspects which have become purely factual facets of both the natural and the modern world. At the opposite extreme, sound material which lacks any immediate association to the visual allows one's perception and understanding to explore aspects not superficially evident, and in doing so, explore further the realm of the 'aesthetical'.

The sound material and the computer program determining its articulation are used to prolong one's awareness of the visual-physical laws, such that the ear can dwell on structural relationships even when the visual information is less clear, or fleeting in its development. In other words, the totality of sound and vision heightens one's perceptual awareness of physical laws experienced every day. Perceptual awareness is further explored when designing the macro and micro relationships (large and small physical qualities, and long and short time-spans) between the different media of the project. Normally there are considered to be three main dimensions to a visual object. In time-based art, the addition of 'duration'

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provides a fourth dimension. In *Mimetic Dynamics* the design of sound and visual relationships adds a fifth perspective (although this cannot be called a fifth dimension) where changing synchronic relationships provide the audience with different 'windows' of material. Each window develops into a totality analogous to viewing every angle of a statue from a single point in time and space.

2. REALISATION AND TECHNICAL DESCRIPTION

The installation has four major components:

(1) *The 'real' aspect:* a system of computer-controlled valves releasing drops of oil that fall into a shallow, transparent tank suspended from the roof, producing complex, interfering wave patterns that cast shadows on the floor below. Other valves inject turbulent jets of oil into the same tank.
(2) *The 'virtual' aspect:* a mathematical model running in real time in the computer, simulating the real interfering surface waves produced by the falling drops. A visualisation of this simulation is projected onto the wall below the tank. The movements produced by the injected jets are similarly computed and visualised.
(3) *The 'sound' aspect:* a computer music system where preprepared sound materials are derived from, and synchronised with, the visual physical system. Playback is over four loudspeakers (even though the sound format is stereo). Soundfile triggering is determined by a set of rules extracted from the overall dynamics (sound and visual combined) and programmed into an interactive system.
(4) *The 'interactive' aspect:* the dynamics of the installation (activation and intensity of the falling drops, injected jets, computer graphics projection and sound) are under control of the computer program. In addition, the valves can be controlled by the audience through a user interface within the space (located away from the controlling computer). Interaction is linked directly to the visual information, and via a series of abstractions (determined by a set of rules) to the sound information.

2.1. The tank and the valve system

The tank is a transparent construction with dimensions 80 cm by 217.5 cm by 6 cm (the ratios are given by the mathematical constant 'e', the base for the natural logarithm) containing a layer of clear colourless oil (Mobil Oil Whiterex 309, which is also nonflammable) 5.5 cm deep, with a weight of around 70 kg. Oil has been chosen due to its viscosity properties damping the speed of the wave motion, while the clear, colourless properties paradoxically associate with water. A light source is placed above the tank, directed downwards, casting a shadow of the rippled surface on the floor below. The oil also has a higher refractive index than water, enhancing the brilliance of the shadows.

The tank is suspended by wires from the roof, just above arm's reach and close to one wall. About 1.5 m above the tank (depending on the height of the roof) a reservoir of about ten litres of oil is mounted. This reservoir supplies oil to five precision solenoid valves under computer control, from which drops or streams of oil fall into the tank at five positions. Also, from the same reservoir, two flexible plastic pipes descend and enter two sides of the tank through computer-controlled solenoid valves. Through these valves, oil can be injected into the layer at a pressure of about 0.1 atmosphere (atm). These streams of oil produce visually interesting currents disturbing the exact circular properties of the droplet-wave propagation. Most of this upper mechanical and electrical system is covered frontally such that it is initially transparent to the viewer, who only gains insight into this mechanism after moving closer.

An outlet 5 cm above the floor of the tank acts as an overflow to remove excess oil. A plastic pipe transports this into a 10 litre reservoir below the tank, from which an electric pump transports the oil back to the reservoir above the tank. Every half hour a timer starts the pump, which recirculates the used oil from the bottom to the top reservoir. A level switch is mounted on the bottom reservoir to stop the pump at low oil level. Overflow can never occur because of the limited amount of oil in the system.

The controlling computer is a Silicon Graphics O2, which is also used for the mathematical modelling, visualisation and audio. An eight-relay interface is connected to the serial port, controlling the seven valves and the pump, and also reading the seven buttons on the control panel for interactive use.

2.2. Simulation and visualisation of the fluid dynamics

The two-dimensional wave equation is solved in real time on the O2 computer. Drops fall into the mathematical model at the same positions and points in time that the real drops are released (corrected for the falling time), such that the moving wave patterns in the virtual tank should approximate the patterns in the real tank, synchronised in time. The wave equation is discretised and solved on a 2 cm grid, giving a grid size of 40 by 108 nodes. A staggered grid explicit method is utilised.

The modelled waves are visualised with three-dimensional graphics, using the Inventor library on

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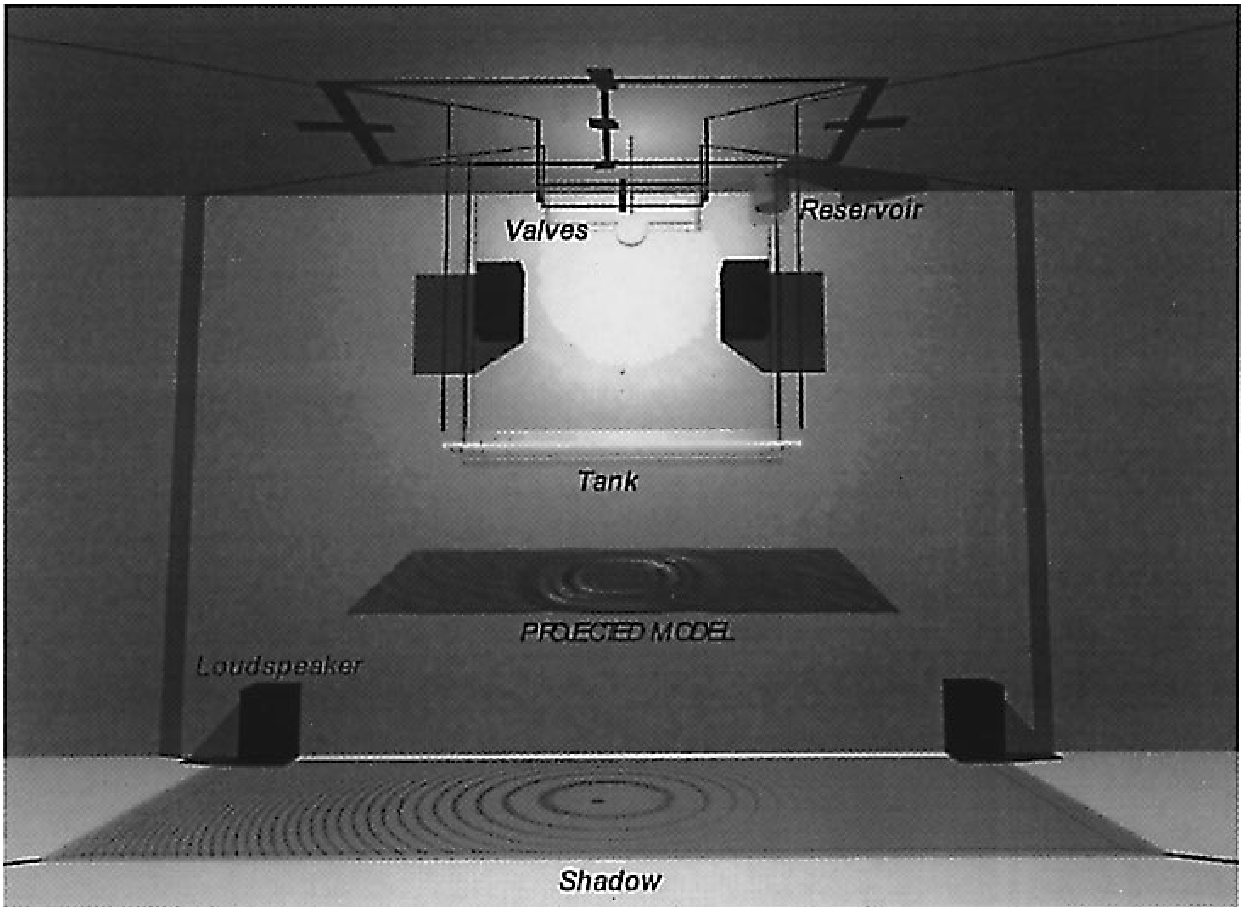

Figure 1. Overview of the *Mimetic Dynamics* installation.

the O2. The free-floating surface is projected in perspective on the wall below the tank, partially giving the impression that the real wave patterns are reflected in the modelled versions, though the two processes are totally separate except for the synchronised drops. This is illustrated in figure 2. (The mathematical solution of the wave equation and the visualisation on the O2 computer can be done with more than 60 percent CPU time to spare for the jet model, audio and control.)

The injected jets cannot be modelled adequately in real time because of the amount of computation involved. Therefore, the steady-state velocity field of the fluid in the tank is precomputed for the four possible combinations (on–off) of the two injection valves. This is done using a standard Navier–Stokes solver for incompressible fluids in two dimensions. From this velocity field, a simplified particle system animation can be produced and projected together with or separately from the wave model, on the same video projector.

The steady-state approximation does not reflect reality as accurately as the wave model, thus producing interesting discrepancies between the projection and the real tank.

2.3. Computer music and sound diffusion system

The sound material is of two origins:

(1) 'Live' sound produced by the open–close action of the valves (a gentle mechanical click, in part visually obscured), the pump (again, a quiet mechanical sound) and the sound of the oil droplets 'plopping' into the tank.
(2) Preprepared sound material stored on the computer, consisting of both 'raw' material and sound that has undergone computer transformation. The 'raw' (untreated) sounds consist of sources from the installation as well as other materials approximating in articulatory characteristics. Numerous different methods are used in the transformation process, including use of the CDP (Composer's Desktop Project) and Ircam Forum synthesis group. However, the most important transformation procedures are achieved through different time and frequency controls programmed in Csound.

Parameters derived from the computer simulation of the visual installation are mapped onto the sound transformation algorithms, such that viewers experience a clear correlation between their visual and aural

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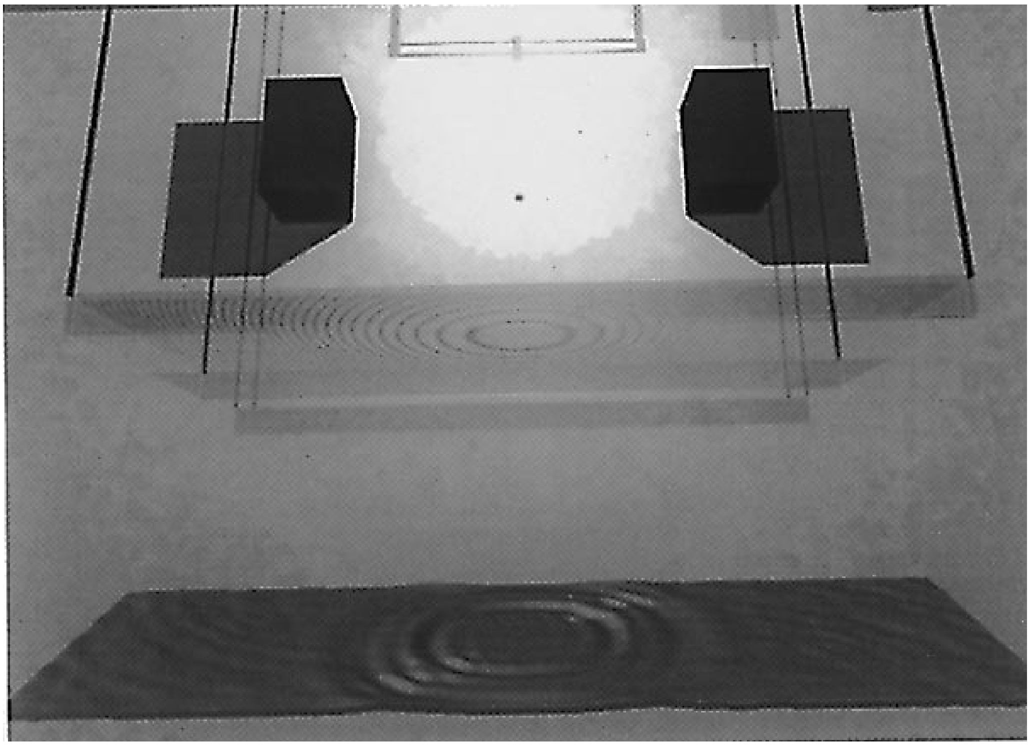

Figure 2. Close-up of the tank and video projection, showing the impression of reflection between the two.

senses. Data mainly extracted from the wave equation model of the system is used to control depth and rate of pitch transpositions, granulation (long and short time segments), filter parameters (Q, bandwidth, centre frequency), amplitude oscillations and spectral stretching. In some instances extracted numerical information is transformed (for example a change in the duration or amplitude parameters) before the sound transformation stage, achieving a nonexact visual correlation. Figure 3 is a time series taken from a single location in the wave model in which two droplets fall at an interval of four seconds. The attributes of this wave motion are then converted into a Csound score file, which is used in conjunction with an orchestra implementing pitch shifting, amplitude variation, and filtering techniques. In sound example 1(a) the reader can hear a raw source sound. In example 1(b) this sound is transformed through a time-varying pitch shift, varying in ratio between 0.5 and 2. The wave amplitude pattern shown in figure 2 is used to create the Csound score file. Similarly, sound example 1(d) demonstrates the same transformation procedure, but in this instance applied to the sound in example 1(c), that has already undergone filtering and reverberation transformations.

The sound activity forms a continuum between exact visual synchronisation and longer extensions through time. Greater time abstraction is correlated with greater sound transformation (abstraction from the original source). This transformation is of two types: abstraction from the real source and abstraction from any immediately recognisable real-world sound. With the latter, the listener forms mental 'constructs' or associations from the combined sound–visual gesture and energy flow. Sound example 2 illustrates how, at the same instant that droplets hit the surface of the oil in the tank, further sounds are triggered to create a layered texture of sound articulations.

2.4. Interaction

By interacting with the installation, the audience can discover how their human input can change the physical dynamics of the system. The interactive interface consists of a series of 'buttons', each connected to one of the seven valves which release drops or flows of oil into the tank. There are a number of rules determining the cause–effect relationship between the users triggering a valve and the nature of the played sound. The rules allow an infinite possible number of sound permutations while maintaining coherence. Playback occurs simultaneously with the drop or flow disturbing the surface of the oil. Through auditory and visual cues, the audience can unfold a lengthy aural–visual development. When there is no interactive activity, the computer begins to perform one of its preconstructed patterns.

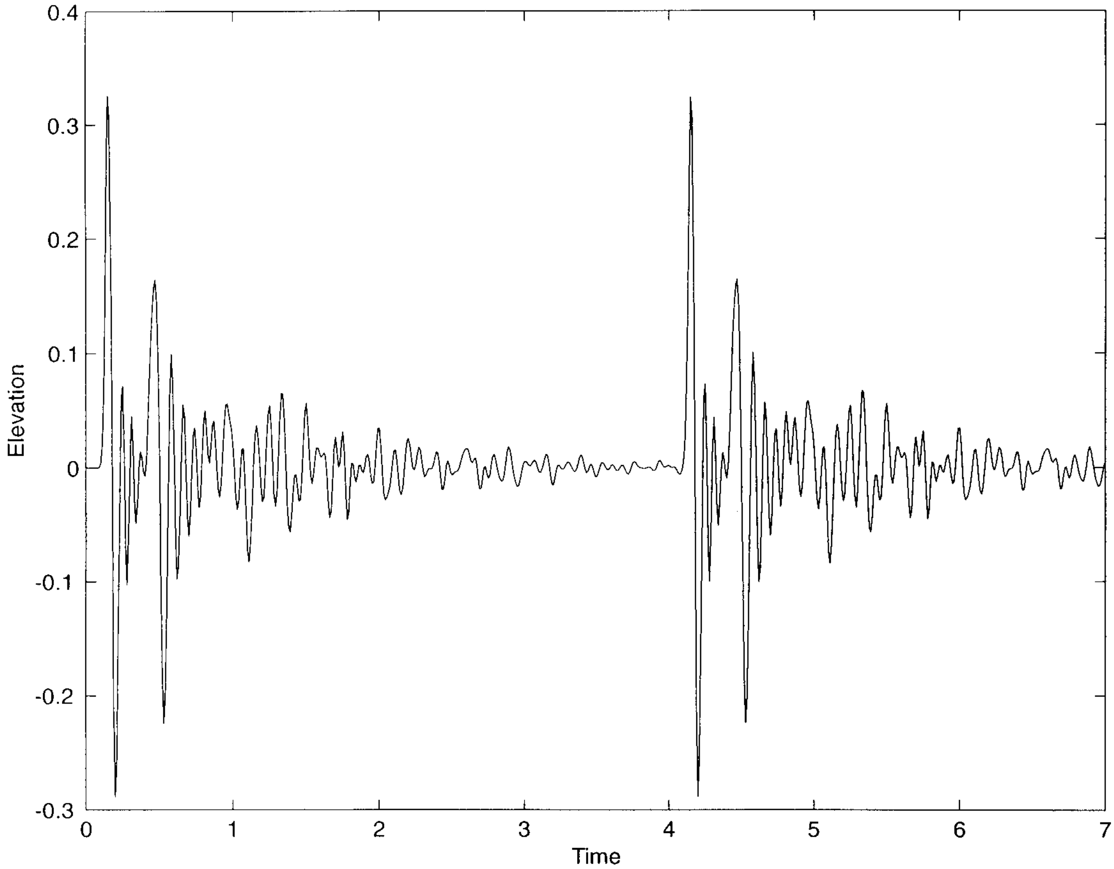

Figure 3. Plot of oil elevation at a specific location in the virtual tank. Two impacts of droplets are shown, with the complex patterns produced by interference and reflection from the walls.

3. SOUND AND VISUAL INTERRELATION

The relationships between fluid characteristics (wave motion and currents) are used to create structural relationships between the sounds materials. 'Micro' timescales are extracted from aspects such as the droplet-wave motion, midrange structures are formed by time abstractions, and macrostructures are derived from the flow of people interacting with the installation throughout the day.

To some extent the interactive aspect hands control over to the audience. However, different levels of control can be maintained by correlating sound and visual aspects such as drop rate, drop size, jet flow, levels of activity at certain times of the day and by considering the properties of materials performed in the immediate and distant past. All these considerations are programmed into the set of rules determining the soundfile selection.

3.1. The sound selection rules system

When designing the rules there were some technical restrictions that needed to be considered:

(1) The exact time delay betwen the drop being released and the drop hitting the liquid.
(2) The safe number of simultaneous sounds that the O2 could play at the same time as computing the wave and Navier–Stokes equations in real time.
(3) The fastest valve open–close speed.

When valve open messages are sent at different time intervals, the visual information gained from the combined motion of the oil in the tank, the computer visualisation and the shadows, will also change. These changes are associated with three different main classes of sounds called 'main pools':

- Main pool 1 consists of short, single articulations, which have been clearly transformed in time and frequency domains using information extracted from the main wave equation. These sounds are triggered when open-valve messages are greater than 0.7 s apart.
- Main pool 2 consists of small groups of articulations (not strictly textures) which are triggered when open-valve messages are between 0.7 and 0.3 s apart.
- Main pool 3 consists of lengthy sound textures, triggered when messages sent to the valve are less than 0.3 s apart.

In deciding from which main pool to trigger a sound, the computer program looks at the previous

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three time intervals and then takes the average time. This is necessary due to the unpredictability of the audience interaction preventing the computer program from anticipating the next time interval.

For each valve there is an associated subpool of soundfiles. Each of these subpools has certain characteristics concerning timbre. They are also spatialised, approximating to the location of the real droplet or flow in the physical system. When two adjacent valves are triggered simultaneously, a further subpool of sounds are accessed (a delay of 100 ms is allowed between messages to be classed as a simultaneous action). However, if a flow valve is currently active, any neighbouring valve-open message occurring within five seconds of this flow valve opening will be classed as a simultaneous occurrence, and will access the associated subpool of sounds. There are seven combined subpools in addition to those associated with single valves, giving a total of fourteen subpools overall.

In all 'pools', many of the soundfiles are labelled with letters. If a sound of one letter class has just been played, when a trigger message moves *across* subpools or main pools then a sound of the *same* class will be played from this next pool. This will mean that we can control to some extent the resulting soundfile mix, while leaving the specific sound selection to a combination of chance and user interaction.

Finally, each of the 870 sound files used in the system has its own specific rule. These consist of one or a combination of the following:

(1) A specified time delay before playing the next sound (used especially in main pool three to avoid exhausting the maximum number of audio channels).
(2) If the time interval is constant (+/− a certain duration), specified soundfiles are looped until otherwise. This is to approximate a constant visual image with a repeating sound, and vice versa.
(3) If the time delay is greater or less than a specified duration, the system skips to a specified sound in the list. This again helps to maintain correlation between visual and aural intensities.

In the day-to-day running of the system, there are a number of premade sequences that are automatically activated after two minutes of no interaction. When a user sends a valve-open message, the premade is interrupted so that interaction can begin.

Sound example 3 is a 3′18″ extract from a sound collage created via realtime triggering at the user interface. In this example the listener can hear short and long transformations of clear and ambiguous implication. Only the surface 'layer' of the sound composition is synchronised with the realtime fluid dynamics, to which the density of this sound layer will correlate exactly. Sound developments that are abstracted from the realtime aspects of the installation are designed to also show a similar correlation. In other words, the algorithm used to select which 'nonsynchronous' sound is to be triggered by the computer is also correlated to the realtime activity in the fluid dynamics.

3.2. Sound and Visual Space

The sound is projected over four high-quality loudspeakers: one pair located above the installation, the second pair located towards the rear on the floor, angled slightly upwards. The speaker positioning changes depending on the space used, with the effect of surrounding the audience with sound once they step into the installation space. The sound exists in real (listener) space through the placement of loudspeakers; virtual (illusion of) space through the use of reverberation and filtering signal processing effects, correlating appropriately to the virtual aspect of the projected visual model; and nonreal (imaginative) space through implication, such as the layering of different degrees of sound detail. The relationship between spatial motion in the sound and spatial motion in the visual is one of 'amplification': sound amplifying the visual motion (in all aspects of space) heightening the viewer's perception. In real space the sounds are spatialised with respect to the valve locations (while occupying a wider stereo image). In the imaginative space, 'spatialisation' is most effective because the mapping will exist at various levels of abstraction, avoiding any mimicry.

Visually, the front of the installation aligns perspectives of the tank, shadow and projection, and provides a balanced aural image. As the viewer–listener moves around the installation, perspectives change in a way highlighting the detachment of virtual from real. Figures 4 and 5 illustrate this visual shift in perspective.

4. DISCUSSION

Mimetic Dynamics is the first in a series of potential projects exploring the physical world around us, and our use of computer technology. We attempted to evoke a greater depth of awareness, perception and reaction to an everyday aspect of the natural world. *Mimetic Dynamics* was fully realised and exhibited for the period of a month and seamlessly integrated the computer model with the physical subject from which it derives its character; overcoming the barrier that the technology sometimes sets up between the viewer and the work.

While realising the work, some of the original concepts were modified due to technical considerations:

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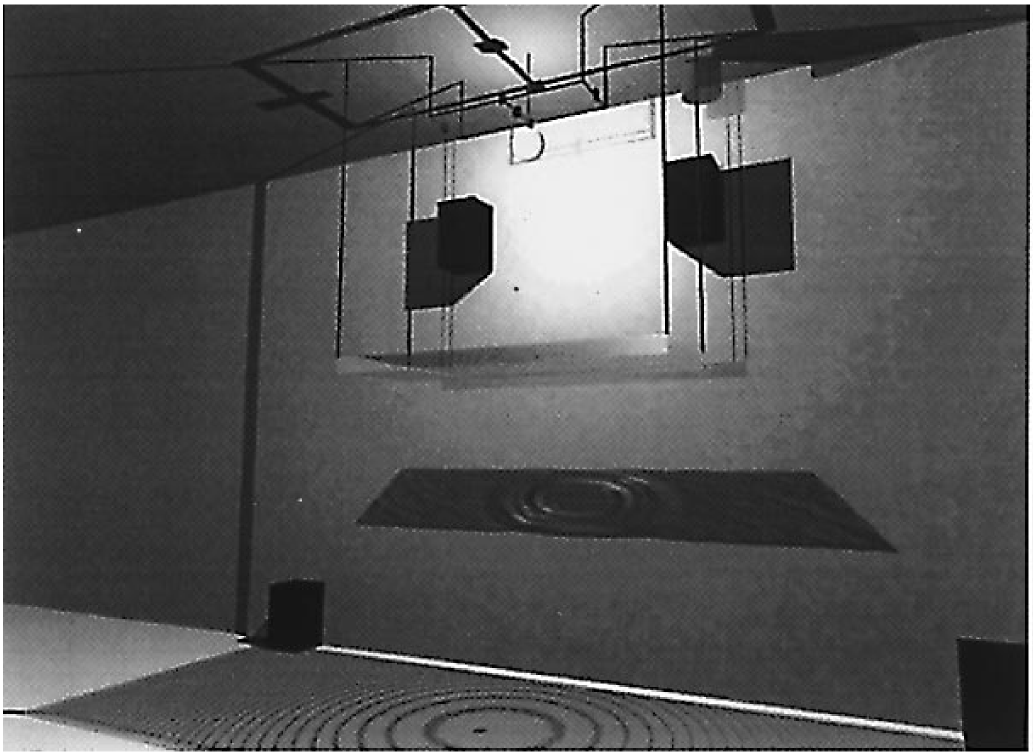

Figure 4. Oblique view of the installation, showing paradoxical distortion of perspective.

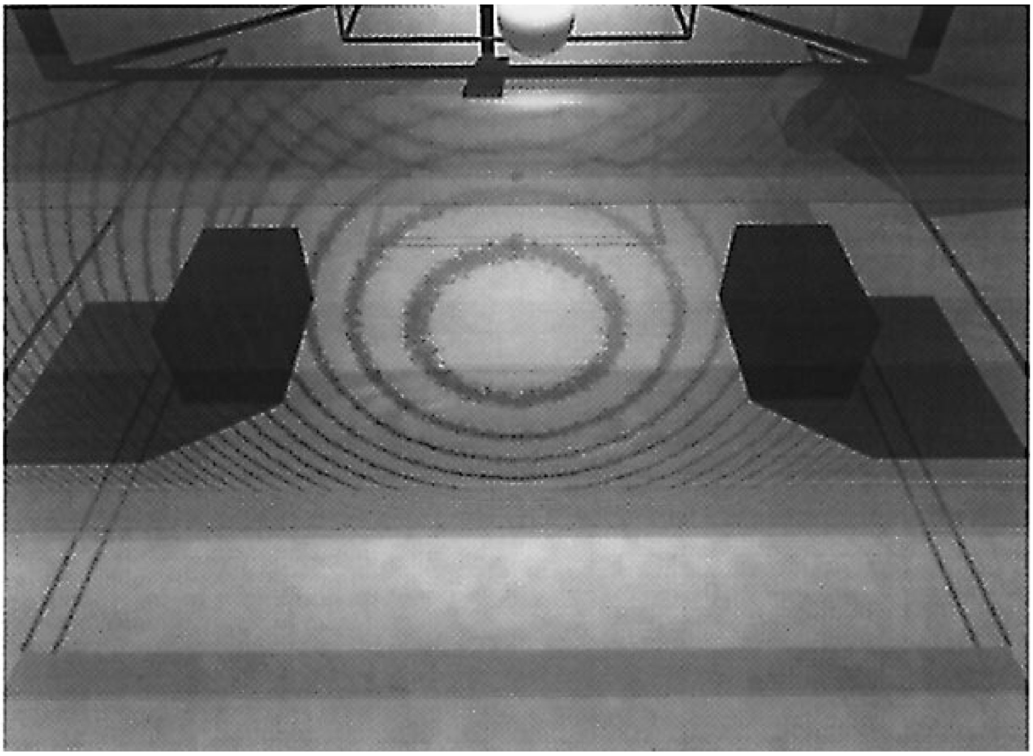

Figure 5. Oil tank viewed from below.

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(1) The sound aspect originally included collecting materials from the space via contact microphones. These materials were then to be transformed in real time, using the same algorithms as those applied to the preprepared material. However, this task proved computationally expensive to run simultaneously with the mathematical model on the same computer.
(2) The ceiling of the exhibition space was unsuitable for suspending the tank and so scaffolding was used, which was covered in white cloth so as to blend in with the walls and floor of the space.

Many visitors to the installation would stay for sometimes an hour, interacting or simply absorbing the environment.

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