LINE: Interactive Sound and Light Installation

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ABSTRACT
LINE is an interactive installation that enables a synchronous expression of sound and light. Audiences can simultaneously control sound and a three-dimensional light object which appears in a cylindrical tank of water. By moving a hand-held control device in the air, audiences can experience a harmonious expression of sound and light.

Keywords
Sound and light relationships, three-dimensional light object, arm gestures, interactive installation.

1. INTRODUCTION
In the field of classical music, musical harmony has been researched on a systematic and theoretical basis. Here, certain aesthetic standards have been derived from the ratio in frequencies of sounds [1]. The first goal of this project is to link such harmony of sounds with visual harmony expressed by lights, colors, etc.

We aimed to create two types of expressions. The first is an interactive exhibit using integrated light and sound that have corresponding parameters. The other is an expression where the audiences can visually experience harmony of sounds.

On another note, in the field of Interactive Installation and Media Art, there have been various works with simultaneous audiovisual expression that use projectors. Previous works of interactive audiovisual installation that use projectors include the series of works by Golan Levin [4, 5], and "Piano – as image media" by Toshio Iwai [2].

However, since projectors themselves are originally made for the purpose of projecting images on a flat screen, such visual expressions naturally remain two-dimensional ones. Another goal of this project is to create a three-dimensional expression using a projector, which is generally versatile and easy to control.

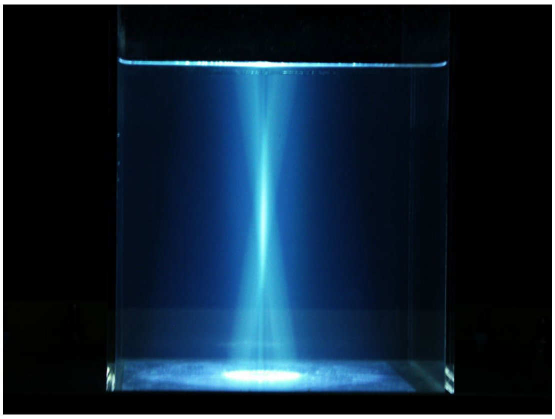

Figure 1. Three-dimensional Light Object

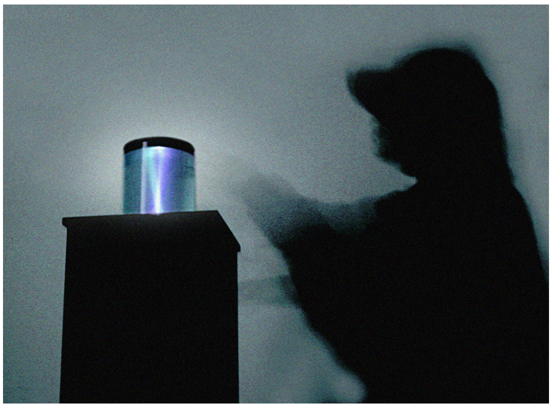

Figure 2. The sideview of LINE

Therefore, we examined and developed a set of original software and hardware: the LINE system. LINE's hardware enables the generation of a three-dimensional light object using two-dimensional images emitted by projectors (Figure 1). LINE's software processes the input from a hand-held control device, and then carries out sound synthesis and generation of two-dimensional images corresponding to the input. As result, this system enables an interaction with both sound and the three-dimensional light object (Figure 2 and Figure 3).

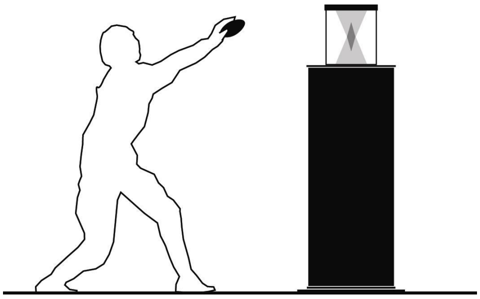

Figure 3. Audience operating LINE

2. HARDWARE IMPLEMENTATION

The LINE system outputs multiple light beams from an LCD projector that creates a three-dimensional light object. As shown in Figure 4, the space where the light beams intersect becomes relatively brighter, thus creating a light object. The light object appears to illuminate in space where the beams intersect, with light beams flaring vertically outward from its center.

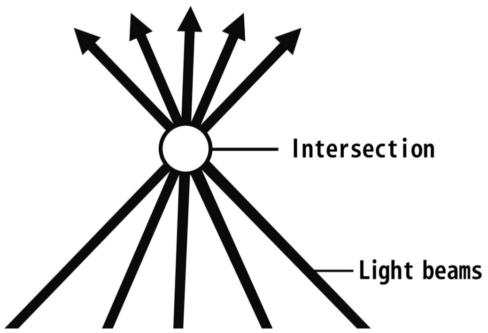

Figure 4. The basic concept of this system

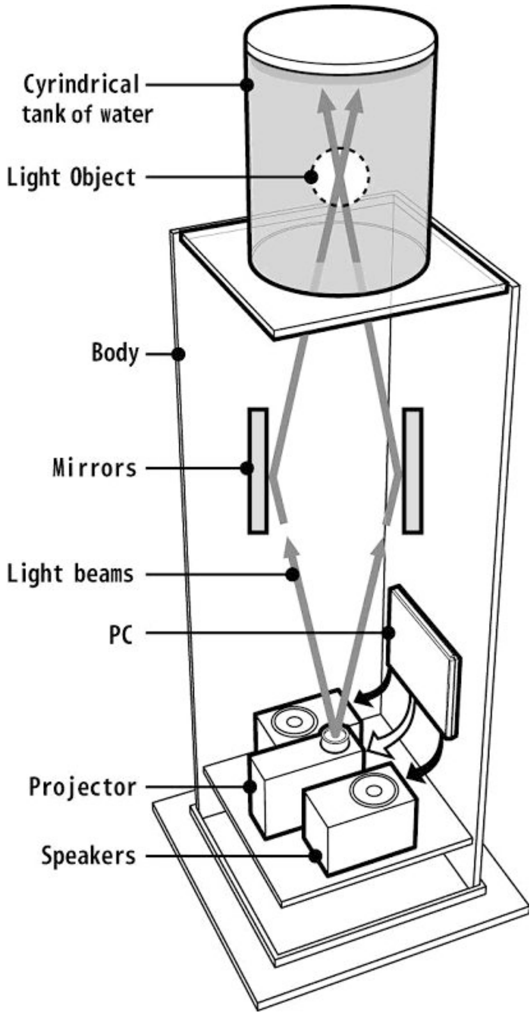

Figure 5. Hardware diagram

Figure 5 shows the hardware diagram of this system. The hardware consists of a body (450mm wide x 1200mm high), an LCD projector, mirrors, a cylindrical tank filled with water, a PC, and speakers. A SHARP PG-B10S projector is used.

The PC (a Windows machine) processes the input from the control device and outputs image data to the projector and sound data to the speakers. The projector is set at the bottom of the body with its lens pointing upward, projecting two-dimensional images that creates the light beams.

The courses of the beams are altered by the mirrors as they are projected upward. The beams intersect at a given space inside the water tank set on top of the body, creating a light object. Water soluble dye was mixed in the water to increase the visibility of the light object. Also, the two-dimensional images emitted from the projector can be manipulated to adjust each of the light beams, thus enabling the system to control the size, color, and position of the light object, as shown in Figure 6.

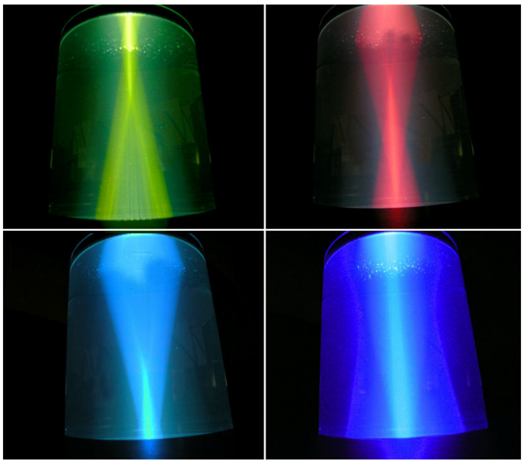

Figure 6. Variations of Light Object

3. SOFTWARE IMPLEMENTATION

Three main functions constitute the LINE's software:

The first function is that it processes the input from the control device. Audiences holding this control device can control the sound and the light object just by swinging their arm.

The second function is that it carries out sound synthesis. Every beam corresponds to 1 synthesizer. This synthesizer is a simple 2 operators FM synthesizer implemented using the real-time audio I/O C++ classes of Gary Scavone's RtAudio [6, 7], and its parameters can be modulated independently.

The third function is that it generates two-dimensional images. As shown in Figure 7, this system generates quite simple images, which are emitted using the projector as beams. Each source of the beams corresponds to 1 synthesizer, and their colors can be controlled individually.

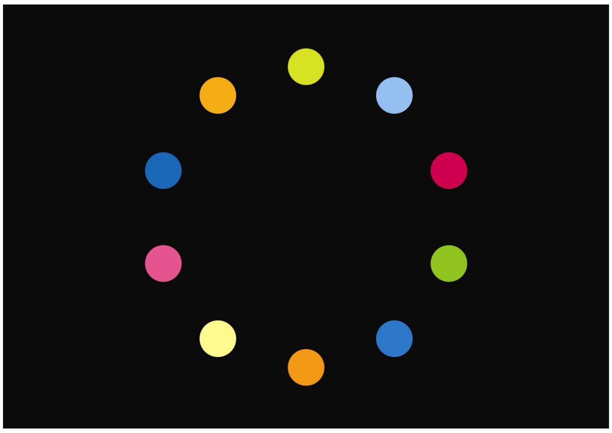

Figure 7. An image generated by LINE's software

3.1 Interaction using Arm Gestures

The control device uses a gyro-sensor and converts the input from the arm gestures to mouse pointer values, X and Y. The software measures the change in the values of X and Y in a given time, and carries out sound synthesis and image generation according to the mappings shown later.

When the audience holding the control device swings up his arm in a large and quick motion, the light object and sound emerges or vanishes, as with a lamp.

If the audience slowly moves his arm up and down when the light object is visible, the light object moves vertically along with the arm's motion. Likewise, a slow, horizontal motion of the control device changes the light object's size (See also Table 1 and Figure 8).

Table 1. Light Object and arm gestures correspondence

Light Object Properties	Arm Gestures Properties
position	vertical motion (Y axis)
size	horizontal motion (X axis)

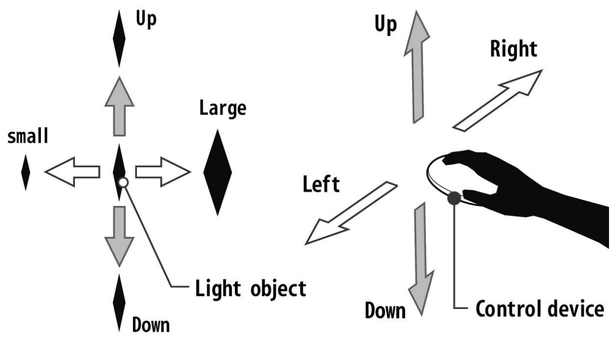

Figure 8. Light object is controlled by arm gestures

3.2 Mappings between Synthesizer and Beam

Mappings between synthesizer's parameters and beam's parameters are as given in Table 2.

Table 2. Mappings between Synthesizer and Beam

Synthesizer Properties	Beam Properties
frequency	color
harmonics	size
amplitude	brightness

The synthesizer's frequency corresponds to the beam's color. Using hue and saturation in terms of HSB color space [8], precise correspondence between frequency and color is represented in the following equation:

$$freq = 20 \times 2^{\lfloor 10s \rfloor + h}$$

where *freq* is frequency (in Hz),

s is saturation, $0 \leq s \leq 1.0$,

h is hue, $0 \leq h \leq 1.0$

The brackets surrounding 10*s* represents a floor function. Thus, if we increase the synthesizer's frequency from 100Hz to 1000Hz continuously, the beam's saturation increases while its hue returns to the same value as at 100Hz at the time of 200Hz, 400Hz and 800Hz.

Frequency is made to correspond to hue and saturation so that the harmony of sound and that of light can be attained simultaneously, using the similarities in the characteristics of visual and acoustic senses. When the frequency doubles, the resulting sound is recognized as being in the same "pitch class" as the original sound. At the same time, colors can be presented in a "hue circle", where colors moving across a spectrum circulate, eventually returning to its original color [8]. Also, by using saturation to express the general bandwidth of the frequency, we are able to avoid the colors at, for example, 100Hz and 200Hz from having exactly the same colors.

The synthesizer's harmonics correspond to the beam's size. If we increase the beam's size, we hear resonant sound derived from the increase in FM modulation index. Thus horizontal motion of the control device changes harmonics of sounds as with the size of light object made up by the beams.

The synthesizer's amplitude corresponds to the beam's brightness. If we increase the beam's brightness, the synthesizer's sound becomes louder.

3.3 Rule for Harmonious Sound

As time progresses, each synthesizer's frequency changes autonomously according to the following rule. Each synthesizer compares its frequency to that of a neighboring synthesizer. Unless the ratio of the two is in harmonious relationship, where the ratio of the frequencies is in simple integer such as 2 or 3, the synthesizer's frequency changes.

For instance, if this rule is applied to an initial state where each synthesizer's frequency is set at random, some of them that are in harmonious relationships are gradually collected together, until eventually every ratio of the synthesizer's frequencies is in harmonious relationship (See also Figure 9). Also, as the frequencies change, the beam's color changes according to the mapping mentioned above.

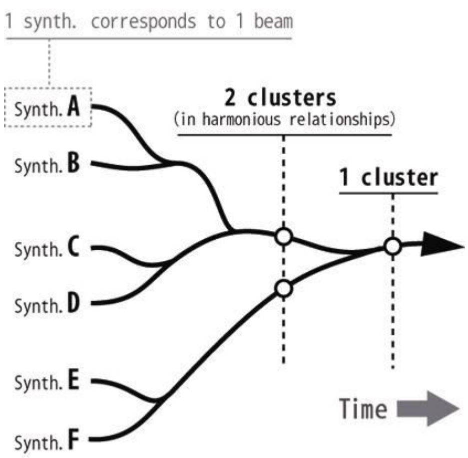

Figure 9. Clustering process

4. EXHIBITION

This installation was exhibited for 3 days during iii Exhibition 4 [3]. It was exhibited using a space approximately 2.5 meters x 2.5 meters surrounded by a curtain.

5. CONCLUSION

We present here an expressive installation that enables an audience to interact with integrated sound and light. We developed a hardware that generates a three-dimensional light object and a software that processes the control device's input to generate sound and light.

As for the relationship between sound and light, when the sounds were split into two or three clusters in frequencies, we were able to express the light in two or three clusters as well. As a result, we were able to express a mutually complementary relationship of auditory and visual experiences.

Although the light object only move vertically at the present time, it is possible that the light object will be able to move horizontally as well as three-dimensionally in theoretical.

In the future, we will further enhance the expression of this installation by adding horizontal and three-dimensional motion to the light object.

6. ACKNOWLEGEMENTS

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