Gemotion Screen: A Generative, Emotional, Interactive 3D Display

Ryuma Niiyama/Graduate School of Interdisciplinary Information Studies, The University of Tokyo,
Yoichiro Kawaguchi/Interfaculty Initiative in Information Studies, The University of Tokyo.
niiyama@isi.imi.i.u-tokyo.ac.jp[1], yoichiro@iii.u-tokyo.ac.jp[2]

Abstract: One of the major goals of information display devices is to re-create, in addition to video and audio, three-dimensional (3D) worlds containing 3D shapes. In this study, we propose a 3D display system, which we call “Gemotion Screen” for presenting 3D worlds not simply as visual illusions, but as material that can be touched. A Gemotion Screen can be realized by the projection of high-definition images on a screen of varying shape. The features of such a device are the ability to dynamically depict 3D worlds, suitability for application to large screens, and the potential for physical interactions. The display can be used for cinema screens and even architectural applications. In this report we verify the potential of such screens as a new device capable of expressing the “presence” of objects and the natural “animacy” of living things.

Keywords: Haptic Interaction, 3D User Interfaces, Virtual Reality, Digital Cinema, Pneumatic Actuator Array

1. Introduction

In this study, we outline the basic concept of a 3D video display device for presenting 3D worlds. The proposed and developed display can present spatial shapes and video dynamically. This technology can be described as a new media that realizes multimodal communication, including visual and physical interaction with viewers. Such a display can also be viewed simultaneously by multiple people, making it suitable for large screen applications.

Large numbers of haptic devices and tactile displays have been proposed and commercialized. However, the only objective in these previous studies was to display local shapes without color textures[Bosscher03, Nakatani03]. In order to generate shapes precisely, it was necessary to position actuators very densely[Iwata01, Iwata07], or interactions with objects are limited to points[Massie94]. A related study have been done on the development of a moving billboard [JapanCreation07] and moving wall “Aegis Hyposurface" for architecture[Parrella00].

A “Gemotion” [Kawaguchi00] was a pioneering project that combine an interactive 3D display with color texture. The Gemotion enables the display of video, as well as simple shapes corresponding to the video as shown in Fig.1. It is an interactive 3D display device that responds to the touch of a viewer.

The major aim of this study is further develop the Gemotion project, and to produce a large display that can recreate the colors and shapes of the objects and scenery in both the real world and virtual world. We expect the birth of a new meda that is capable of displaying the “presence” of objects and the natural “animacy” of living things.

Figure 1: “Gemoion” (gemotion = growth, gene + emotion). [Kawaguchi00, Kawaguchi01]

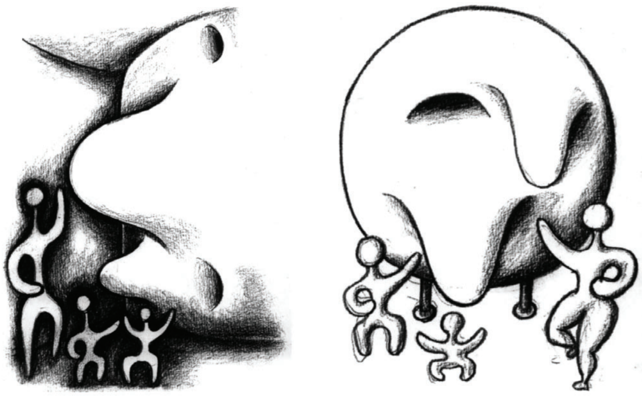

Figure 2: Sketch of Gemotion Screen. (Drawing by Yoichiro Kawaguchi)

2. Basic Concept of Gemotion Screen

What we are proposing here is a 3D display that can re-create the shapes of all kinds of 3D objects on a screen—that is, a technology capable of presenting viewers with the appearance of real worlds and virtual worlds, including depth. Fig.2 shows sketches describing this concept. The application of such technology would not be limited to conventional home TV displays. Rather, we envision the display eventually working by projection of images on spaces such as floors, walls, and ceilings. The “Gemotion Screen” we are proposing is a new media that can be regarded as an extension of the classic photographs and the 2D televisions.

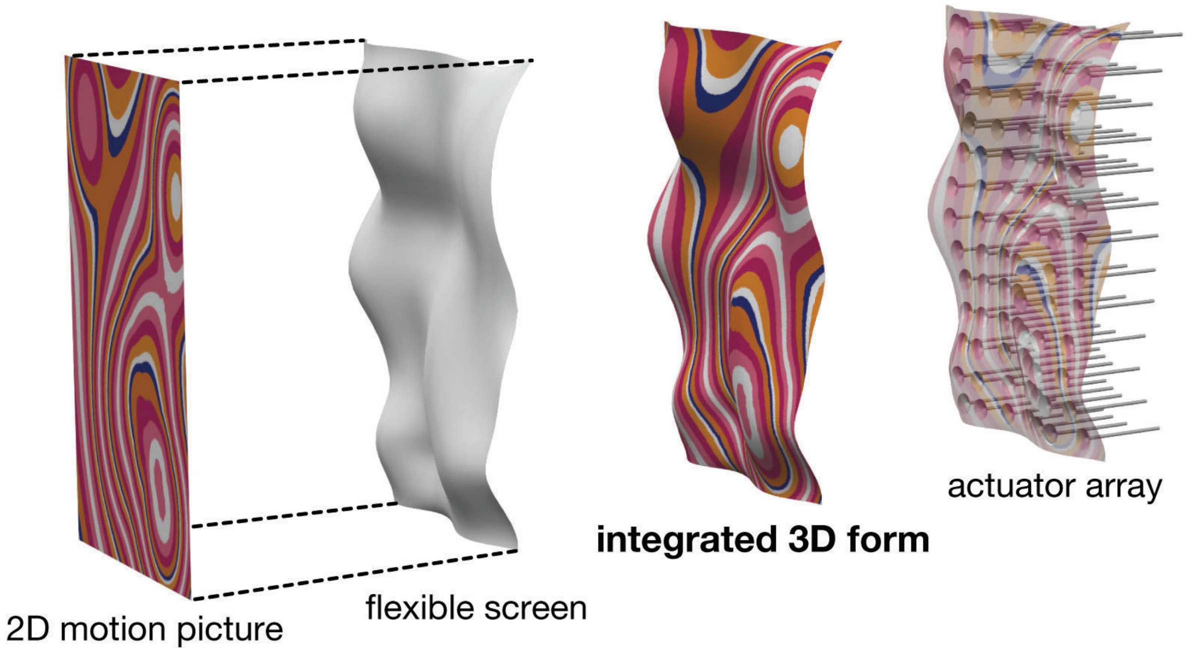

Figure 3: Basic concept of Gemotion Screen.

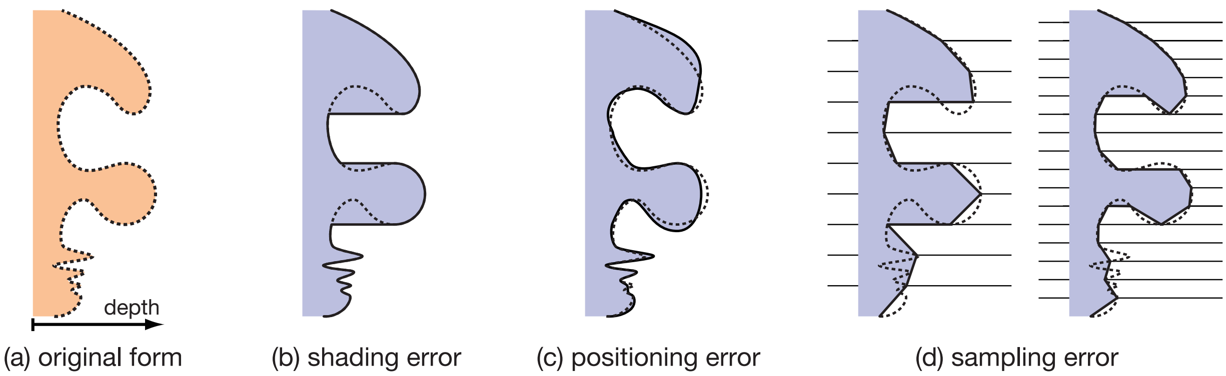

Figure 4: Three types of approximation errors.

In order to realize such a display, we are proposing a flexible screen that re-creates 3D shapes at high speed and projects high-definition images onto a screen (Fig.3). Another method of re-creating a 3D-shapes display based on the same idea is to very densely layout a fine video display on a flexible screen.

3. Technologies

3.1. Recognition of Depth

Our proposed method of using a flexible screen is a means to present a mixture of multiple kinds of sensory information, such as shapes and video. This makes it possible to achieve complementary effects that are not possible with single kinds of information. This is because humans use cues from multiple senses in constructing their 3D perceptual worlds. Using texture mapping to 3D objects of minimum polygons is the widely used technique in computer graphics. Other cues used by humans to perceive the distance and shapes of objects from a screen include perspective, shade/shadows, the coarseness/fineness of textures, the parallax effect of viewing with two eyes, and previous knowledge of objects.

3.2. Approximation of shapes

Objects in the real world are solid, and the optical characteristics of their surfaces cannot be separated from the materials they are made of. However, in the re-creation of objects on a display, 3D images can be decomposed into textures and shapes. When the textures and shapes contained in 3D video are played on a display, they are degraded due to the approximation errors (Fig.4).

Here, the 3D video shape information is realized in terms of the depth at each point on the screen surface. Therefore,

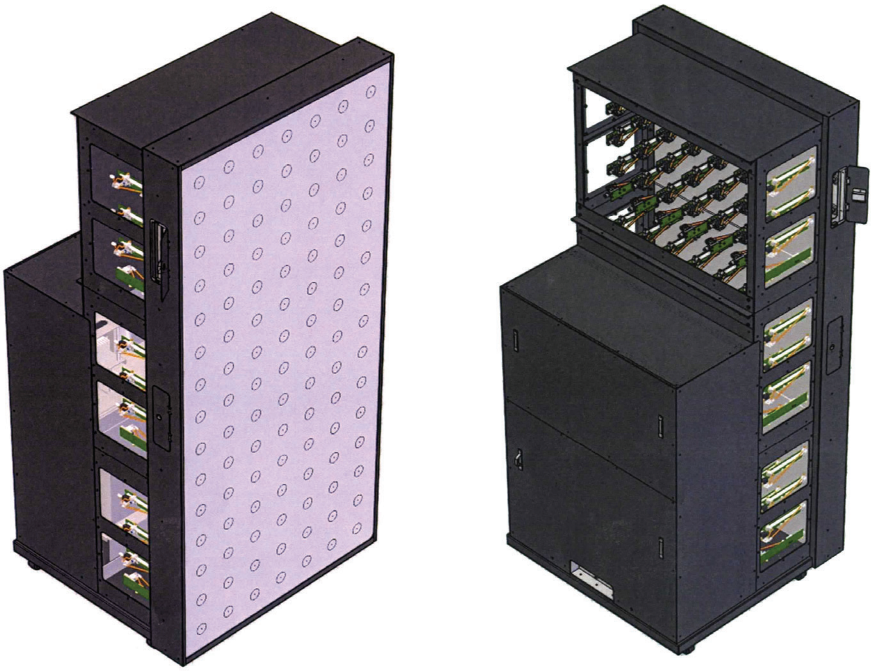

Figure 6: CAD drawing of the Gemotion Screen.

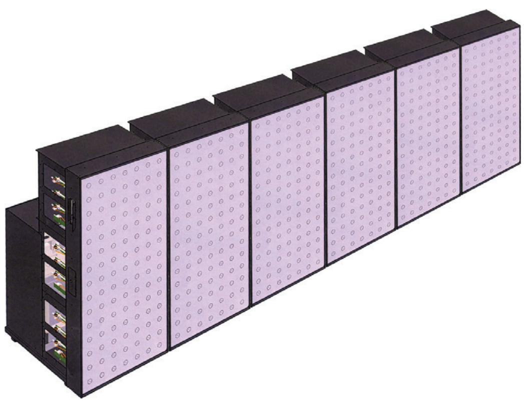

Figure 7: Tiling of the multiple screens.

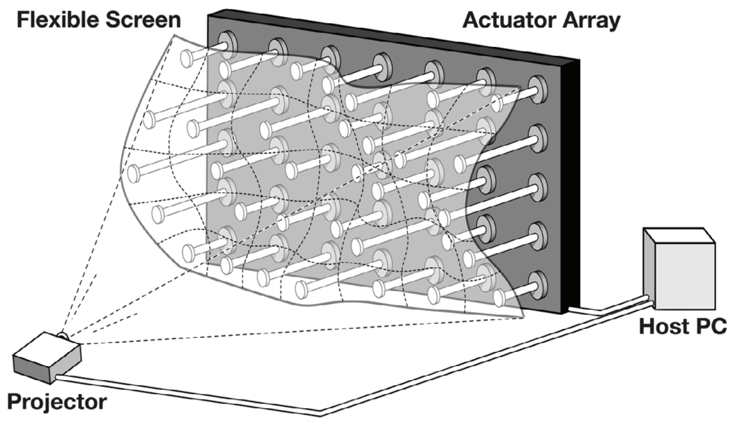

Figure 8: System overview.

just like a relief carving, whatever is hidden and diffracted is ignored. Furthermore, since shapes must be approximated using a limited number of actuators, it is not possible to playback the high-frequency components of the shape.

4. Gemotion Screen

4.1. General Outline

The Gemotion Screen is pictured in Fig.6. The screen size was 0.9m×1.8m (width × height), with a depth of 0.9 m. The actuators are arranged in an array of 7×15 (= 105 points), with an interval of 0.12m between points. In order to construct a single large display that combines multiple screens vertically and horizontally, the dimensions of the screen frame are carefully determined. Figure 7 shows an example of combining three screens.

4.2. System Overview

The construction of the system is illustrated in Fig.8. A host PC generates, in real time, texture information and shape information that are perfectly synchronized. The advantage of drawing 3D video images from moment to moment is that the video can be interactively changed according to the inputs of viewers. Of course, the system can also play back 3D video sequences created in advance.

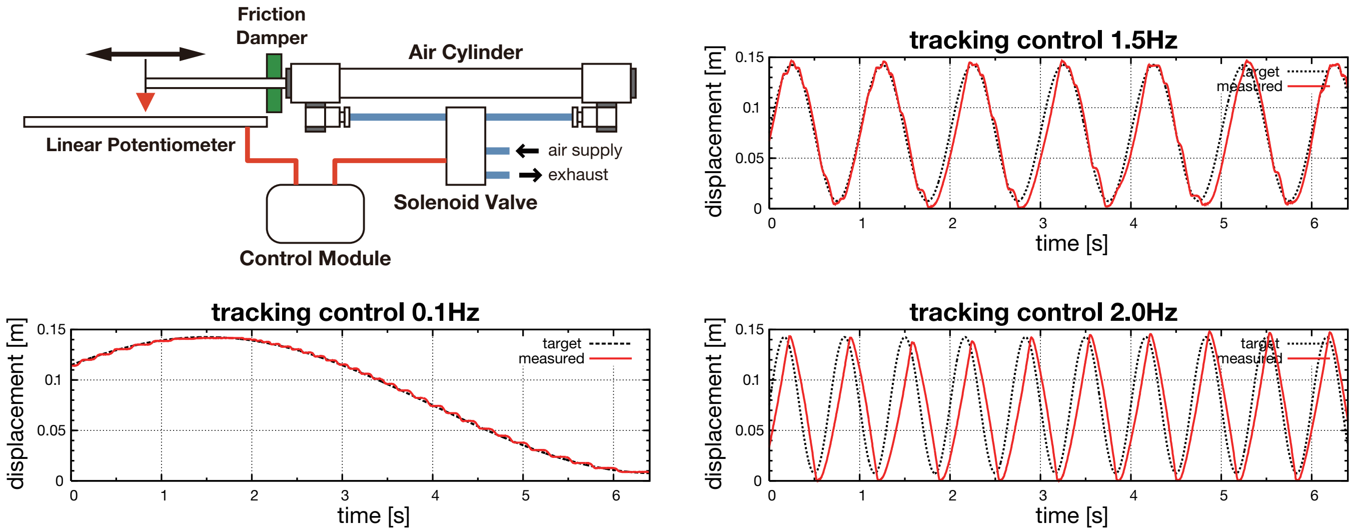

Figure 9: Tracking control of the drive module. The target frequencies are 0.1Hz, 1.5Hz and 2.0Hz.

Texture information is sent to a carefully positioned high-definition projector, and projected onto the screen. At the same time, a signal distribution device extracts depth information for each point on the screen using shape information for the entire screen. Next, a group of actuators drive the flexible screen according to the depth information, at the video rate.

4.3. Generation and Transmission of 3D Video

Artistic and abstract virtual world scenery created using 3D computer graphics is used as content for this system. This is because for now it remains difficult to acquire 3D information simultaneously when capturing video using a video camera.

The 3D content for our system was created in real time using the host PC. The information output by the PC is divided into two channels—the 2D video and the shape information. The 2D video is transmitted directly to the projector. The shape information is converted to gray scale and input to the Gemotion Screen as a 2D video signal. Since the system does not use any special video format, anybody can create content for it.

4.4. Control of Flexible Screen

The flexible screen uses a special stretch fabric that freely expands and contracts and on which video can be projected. The cloth of the screen is white and highly extendable in all directions. In order to control the shape of the flexible screen, we set up an actuator array consisting of a large number of telescopic drive modules. We adopted a pneumatic cylinder having a large stroke, compliance, and high-speed operation. The stroke is 0.15 m, which corresponds to a movement of ±0.075m from the neutral position. The cylinder speed is rated at 0.45m/s.

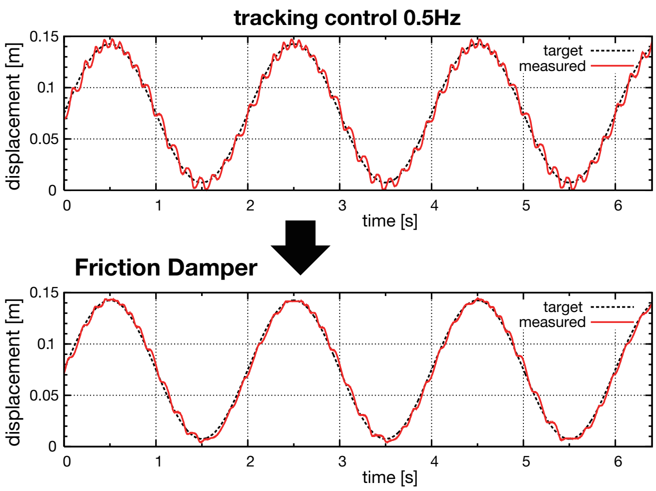

Figure 10: Reduce the positioning error using friction damper.

When the flexible screen is driven by limited number of actuators, the surface becomes polyhedral. It means the addition of high-frequency components that were not included in the original shape. In order to smoothly interpolate surfaces, we attach an elastic disc to the end of the cylinder rod.

The use of pneumatic actuator enables high-speed movement, light weight, reduced cost, and improved reliability. The disadvantage of air cylinders is the low precision in positioning, but our experimental results shows good positioning accuracy using feedback control and friction damper (Fig.10). We also obtain acceptable low error in follow-up control as shown in Fig.9. The position of the rod end is controlled in accordance with the sine wave.

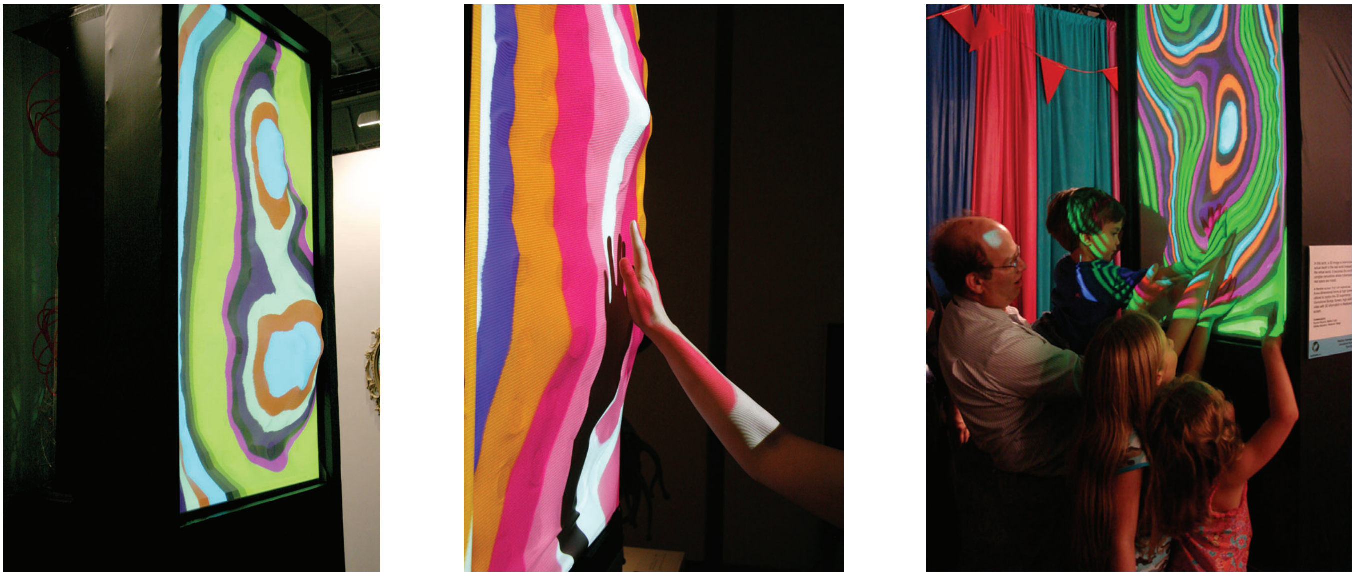

Figure 11: Demonstration of the prototype “Gemotional Bumpy Screen” at SIGGRAPH 2006 Art Gallery. The size of the screen was 0.6m×1.0 m (width × height). The actuator array was 6×12 (= 72 points), with an interval of 0.075m between points.

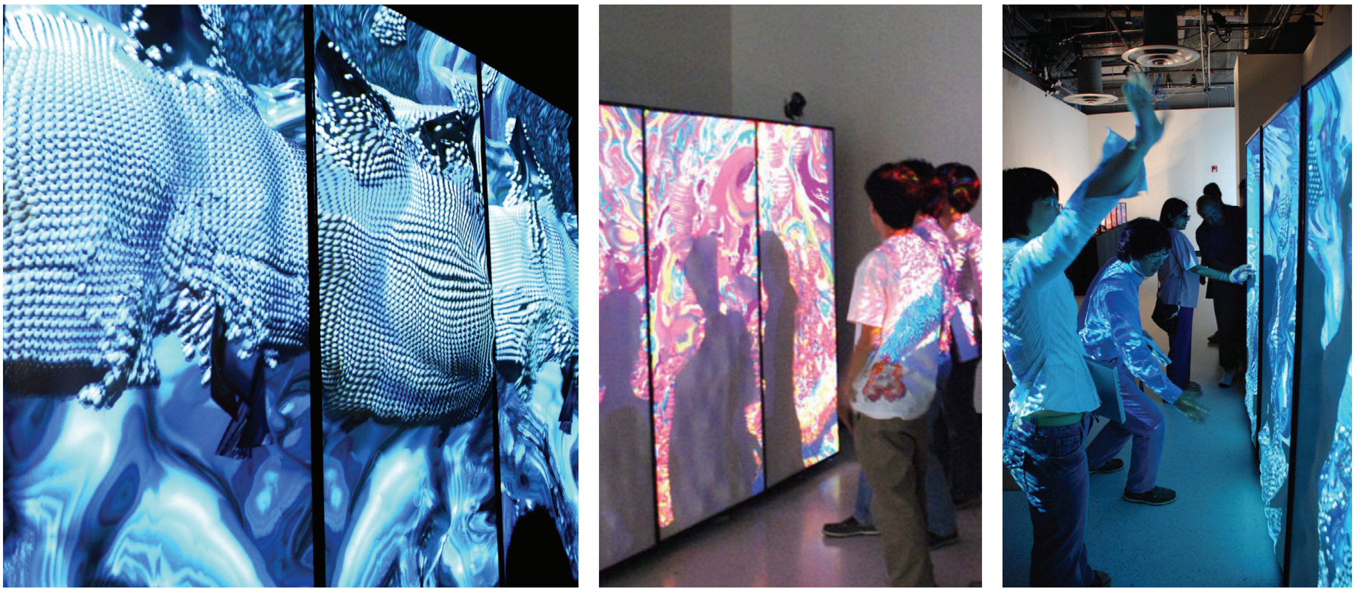

Figure 12: Gemotion Screen with “Hydrodynamics Ocean” at SIGGRAPH 2007 Art Gallery. The screen size was increased to 0.9m×1.8m (width × height), with a depth of 0.9 m. The actuators are arranged in an array of 7×15×3 (= 105×3 points), with an interval of 0.12m between points.

The drive modules are made up of air cylinders and control circuits, and feedback control is conducted within the module. The control processing load is distributed by means of modularization, resulting in improved productivity and maintenance.

5. Demonstration

Trial operations of prototype and demonstrations of the developed Gemotion Screen were conducted at SIGGRAPH Art Gallery. The name of the exhibit was “Gemotional Bumpy Screen” and “Hydrodynamics Ocean”. We constructed one large screen by lining up three screens horizontally. We displayed interactive content that reacts to the movements of viewers. Fig.11 and Fig.12 shows the scene of the exhibition and visitors interacting with the system.

We found that when looking from a distance, at a position directly in front of the screen, the parallax effect is low, making it difficult to perceive the form of the screen. The visitors experienced the objects of the virtual world via their bodies, through physical interactions. The advantage of the Gemotion Screen relative to the many other kinds of 3D display systems, which are only for viewing, is that viewers can actually touch and interact with the display.

6. Conclusion

In this study, we propose a basic concept for "Gemotion Screen", a brand-new 3D display device. By overcoming various technical challenges we developed a working version of the screen. The proposed and developed Gemotion Screen enables the dynamic expression of 3D worlds not simply as visual illusions, but as physical object that can be touched. Furthermore, multiple people can view the display at the same time, and the system can be applied to large-screen applications.

Here we proposed a flexible screen controlled by the actuator array, and projection of the high-definition video onto the screen. We selected a stretch material for the flexible screen and newly developed and evaluate actuator array and a control system to drive the screen. At SIGGRAPH Art Gallery, we exhibited and demonstrated the system to many visitors, and verified that Gemotion Screen enables the display of 3D shapes and physical interactions.

Looking ahead, one of our next challenges is to improve the performance of the system. Our next goal is to expand applicability from the flat screens we are currently using to curved screens and apply to the walls and floors of architecture. Using the technology of Gemotion Screen, we are hoping to make a connection between virtual worlds and the real world, and to realize a new kind of interactive media.

Acknowledgement

This work is supported by JST CREST and by the Ministry of Education, Science, Sports and Culture, Grant-in-Aid for Scientific Research (A), 17200005.

Finally, we would like to express thanks to Akihiko Miyadera and Mariko Fujita, an engineer who helped build the prototype of Gemotion Screen. We also extend deep gratitude to Shuhei Tsuruoka and Tomohiro Akagawa, the programmer who created the video source for the Gemotion Screen.

References

Hiro-o Iwata, Hiroaki Yano, Fumitaka Nakaizumi, Ryo Kawamura, 2001. Project FEELEX: Adding Haptic Surface to Graphics. In *Proc. of SIGGRAPH2001*.

Hiro-o Iwata, 2007. Palparable Graphics – Research into haptic/visual display. In *Proc. of ASIAGRAPH2007*, pp.37–42.

JFW Japan Creation, 2007. *TOKYO FIBER'07 SENSEWARE*, The Asahi Shimbun Company. Tokyo.

Masashi Nakatani, Hiroyuki Kajimoto, Dairoku Sekiguchi, Naoki Kawakami, Susumu Tachi, 2003. 3D Form Display with Shape Memory Alloy. In *Proc. of the 13th Int. Conf. on Artificial Reality and Telexistence (ICAT 2003)*.

Paul Bosscher, Imme Ebert-Uphoff, 2003. Digital Clay: Architecture Designs for Shape-Generating Mechanisms. In *Proc. of the IEEE Int. Conf. on Robotics & Automation (ICRA03)*, pp.834–841.

Stephen Parrella, 2000. *Hypersurface Architecture II*, John Wiley & Sons. New York.

Thomas H. Massie and J. K. Salisbury, 1994. The PHANTOM haptic interface: A device for probing virtual objects. *In Proc. of the ASME Winter Annual Meeting, Symposium on Haptic Interfaces for Virtual Environment and Teleoperator Systems*.

Yoichiro Kawaguchi, 2000. "Gemotion". In *3D@Virtual 2000: Exhibition at Tokyo Metropolitan Museum of Photography.*

Yoichiro Kawaguchi, 2001. "Gemotion". In *SIGGRAPH2001: Electronic Art and Animation Catalog*, p.129.