# Virtual Sand Box : A development of an application of virtual environment for the clinical medicine

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ABSTRACT : The Sand Play Technique (Sandspiel) has often been used in psychological treatments. The primary purpose of this study was to construct a practical virtual environment to support the application of this technique with computers. The prototype application called "Virtual Sand Box" was developed to test the Sand Play Technique in the diagnosis and treatment of autism patients. The display system and input device are discussed. A detailed description is also provided for how a virtual environment was constructed to cater input systems into output systems in order to facilitate manipulation tasks for the user. Experimental results gave insight into the feasibility and advantages of applying Virtual Reality technology to clinical medicine; particularly with respect to the diagnosis of autism patients.

KEYWORDS: Artificial Reality, Virtual Environments, Medical Applications, Therapy, Psychology, Motion Input, Sandplay Technique

Category: Artificial Reality / Virtual Reality

## 1: Introduction

Artificial Reality technology has recently attracted much attention and curiousity. In this paper, despite the fact that few practical applications of virtual environments currently exist, the "Virtual Sand Box" is proposed as a practical application of a virtual environment to clinical medicine. The Sand Play Technique is a psychotherapy technique that has been applied to diagnose and treat patients with psychological sicknesses such as autism. As mental patients generally dislike interacting with medical personnel, they are asked to play with a sand box and various figures to create landscapes. These created landscapes are then carefully analyzed by doctors and therapists to identify the patients' mental problems. The objective of this study was to develop a virtual environment for the application of this Sand Play Technique.

Presently, virtual environments and the technologies associated with them are still far from mature. Furthermore, it is natural that difficulties will arise when dealing with patients who are uncomfortable with using unfamiliar devices such as a data glove. To address this situation, careful selection and development of suitable devices to be used for a virtual environment was conducted. A large projection display instead of a full sight display using an HMD (Head Mounted Display) and position/orientation sensor was used. In addition , a simple 3D mouse instead of a data glove type input device capable of sensing many degrees of freedom was implemented. The motivation for applying somewhat older more simplified technology was to provide an enivronment where subjects could feel more comfortable in performing Sand Box tasks with less stress.

First, a usable virtual environment and virtual sand box was constructed. Second, experiments were performed with various subjects. Students from both elementary school and unviversity (both both mental patients as well as normal people) were asked to use this system. Since "Virtual Sand Play" is different from traditional sand play, this investigation observed whether or not the method for virtual sand play could be applied for traditional sand play.

## 2: The Sand Play Technique

The sand play technique has long been used in psychotherapy. It was first developed in England by M. Lowenfeld back in 1929, and further expanded by D. Kalff and various other researchers. Since 1965, application of this technique in Japan has been growing. The landscape is created as an expression by the patient. A sand box and various figures on a toy shelf are provided. The patient can then shape the sand in the box and place figures on the sand. In most studies, the inner size of the sand box is 52cmx72cmx7cm in order to be easly seen at a glance (ie. without having to look around). The inner bottom is painted blue in order to simulate water. Prepared figures include people, animals, trees, flowers, houses, buildings, bridges, fences, stones, monsters, etc.

## 3: Design of the Virtual Sand Box

The artificial reality system called "Vis-Age"[2][3] was developed using an HMD sub-system and data glove type motion input device. Up until now, many problems have existed with such devices in the way that the general user has felt uncomfortable using such virtual systems. In the case of this study, with mental patients and children as subjects, the need to minimize the difficulties and stresses associated with operating in a virtual environment had to be addressed. In this section, the problems of typical virtual reality systems are identified and the proposed alternatives discussed in detail. In addition, the spacial assignment between display systems and input system is explained ( a problem when a large projection display is used).

### 3-1 The Display System

The following factors were considered important in creating a virtual environment with a high degree of presence: wide view angle, high resolution of display, stereoscopy, and natural motion input. An HMD system with a 6 degrees of freedom sensor (used for a typical AR system), appeared to have following problems: 1) time delay derived from the 6D sensor and from generating graphics 2) heavy weight 3) low resolution 4) giving the operator a sense of closed surroundings.

The problems associated with time delay are a significant issue.
Some predictive filters[4][5] have recently been developed in order to decrease the time delay of the 6D sensor and show much promise for future applications. However, presently they still have many performance limitations.

Although the weight of the HMD is negligible for normal adults, it is a serious problem for children and some patients. Some light weight HMD's have been developed, but are currently not sold on the market.

Stereoscopy is one of the HMD system's merits, but because of low resolution, the typical HMD can only provide parallax within about one meter of the user. Due to this and the above reasons, it was decided that the merits of the HMD system did not outweigh its limitations. Furthermore, a fixed display system was capable of providing high resolution with less time delay. Moreover, a projection display could provide a large static field of view which was important for creating a better presence for the user.

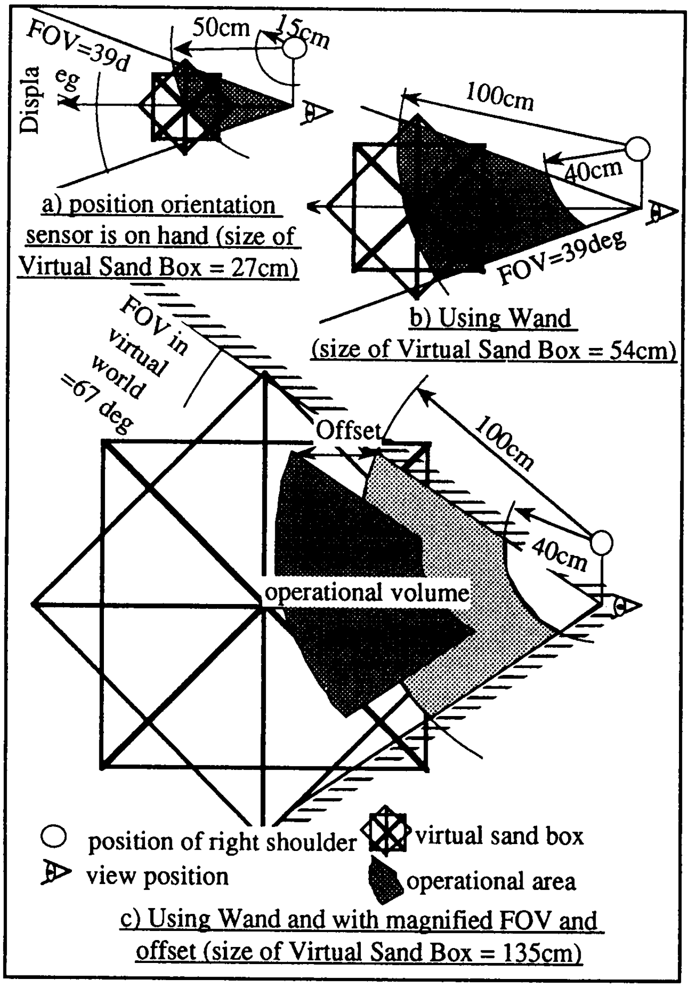
For the above reasons, a large projection display was selected for the development of the Virtual Sand Box prototype system. The negative aspect of using a projection display was that it could not provide a full dynamic field of view as in the case of the HMD. To compensate for this limitation, a joystick type device was implemented. This allowed the user to change his/her viewing direction without turning his/her head. The freedom of eye line direction was restricted to the center of the object because the joystick type device had less degrees of freedom compared with the 6D sensor.

## 3-2: Assignment of Operational Space to Real Space

Another limitation associated with using a large fixed display concerned user dexterity. Currently, the user's dexterity in virtual environments is lower than that in real environments because of the effects of sensing noise and time delay; caused from the sensor, from calculations, and from generating graphics. To improve dexterity in the virtual environment, a sort of distortion was added to the assignment. The distortion was: 1) to magnify the field of view of the (virtual) camera model 2) to offset the operational space forward 3) to magnify real operational space using "Wand" ( Wand is detailed in section 3-3).

Generally, the position of the effector in virtual environments is assigned to bodily sense of position. Namely, the virtual body model is similar to the real body of the operator. When distortion is added, the benefit of having similarity between virtual and real is lost in exchange for the benefit of better dexterity. For a virtual environment which uses a large fixed display, having better dextrality was considered more important than having similarity between virtual and real for the purposes of our investigation.

Another reason for adding distortion was that the operating space was too small. The operating space is defined as the mutual volume shared by the viewing volume from the user's eye point to the screen and the reach volume between the user's inner and outer limits of his reach in terms of his effector (see Figure 1). The environment constructed allowed about 30 degrees for a horizontal field of view . Due to this restricted field of view, the operating space was too small. In order to add distortion and allow effective use of the "Wand", the operating space was sufficiently magnified.




[Fig.1 Operational volume and the size of Virtual Sand Box]

## 3-3: Motion Input System: "Wand"

The data glove type motion input device is used for typical virtual environments. Such devices are capable of sensing many degrees of freedom simultaneously and allow the system and user to interpret some vague meaning of human motion. However, current interpretation technology for vague motion input is not yet mature. In fact, the results of human motion input often differ from the operator's intentions. The operator is also frequently confused by such uncertainties; especially when there is time delay contained in the feedback loop. Consequently, if there does not exist a complete interpretation technique, motion input should be definite and the assignment from motion to meaning should also be definite (for the purposes of this particular study).

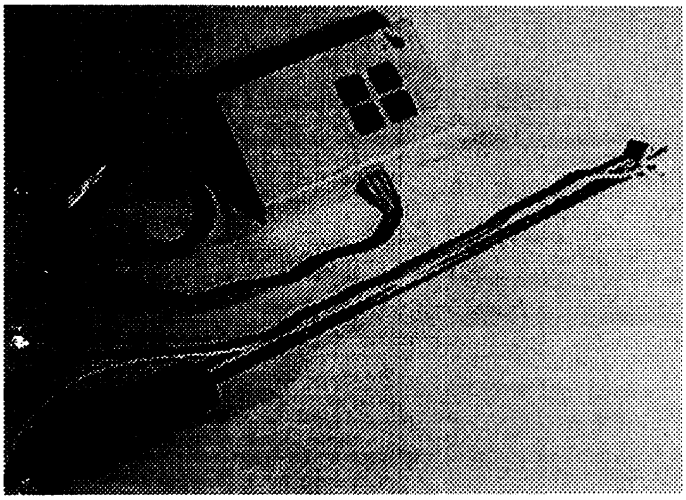
Button type input devices cause a definite action and also permit the operator to accurately recognize what he is doing to the system; because he can immediately feel the click feedback upon pushing a button. The existence of direct tactile feedback in addition to the main system feedback loop (motion input ==> sensor ==> system ==> calculation ==> display ==> operator) will help the user to generate mental models of the system's behavior.

To provide both clearly defined capabilities and direct tactile feedback to the user, a rod shaped input device called "Wand" with a position/orientation sensor was developed [see Figure 2]. Wand was equipped with a 6D sensor at the far tip and 2 buttons at the handle. Another motivation for developing Wand was to magnify the operational space as a physical extension of the user's real hand. The distance from the operator's shoulder to the center of his hand during operating motion is between 15 cm to 50cm. When using Wand, this distance is increased to allow a 40cm to 100cm range [see Figure 1].

Two Wands were used during experimentation to provide two main functions. Wand One was used for changing the shape of the land and Wand Two was used to place figures in the landscape. Two Wands were necessary because it was believed that switching between Wands would be easier for the user to understand than trying to understand and use a more complicated device which incorporated the functions of both Wands.

The system components were comprised in the following way:

Wand <---> Interface Box <---> PC <---> Graphics Workstation

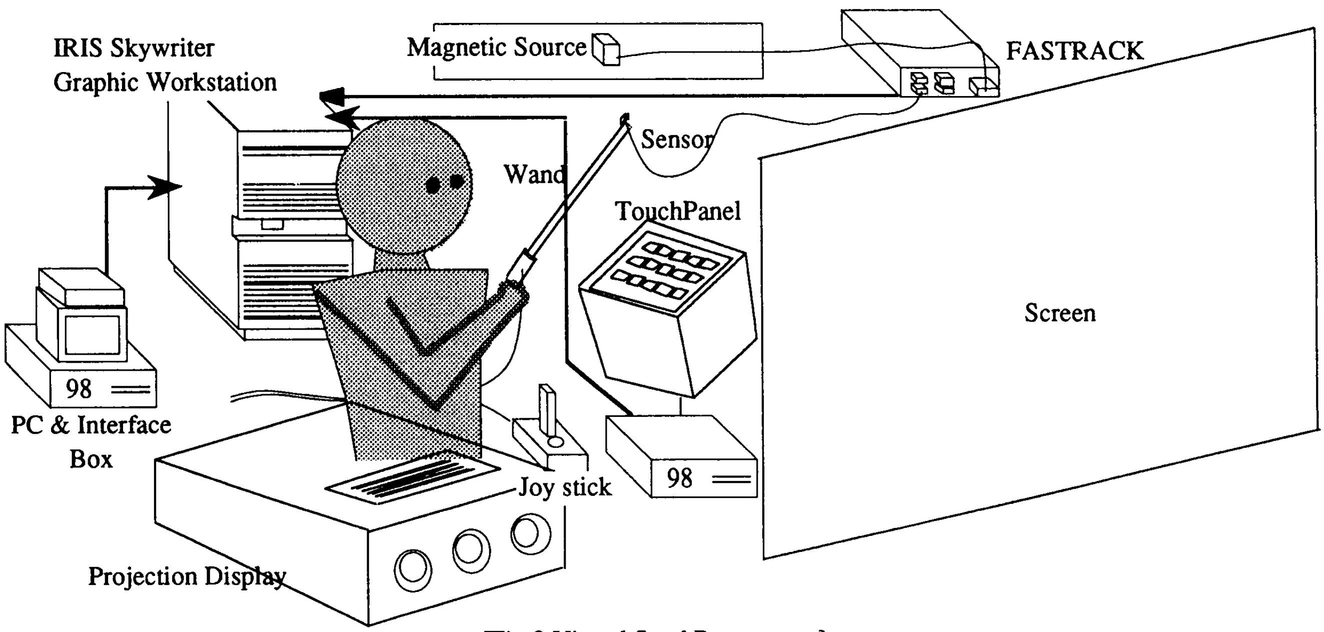


[Fig.2 Wand and its interface box]

## 3-4: System Design and Implementation

(1) System Structure.

Figure 3 and Figure 4 show the appearance and structure of the Virtual Sand Box prototype. An




[Fig.3 Virtual Sand Box system]

RGB projector and screen were used as a display. Two Wands were used as input devices in addition to a joystick and a touch panel. The touch panel was used for choosing color or figure type. The joystick was used for changing view position and view direction. An IRIS SkyWriter workstation was used to generate graphics and perform calculations. Two PCs were used to communicate with the joystick, Wands, and touch panel.

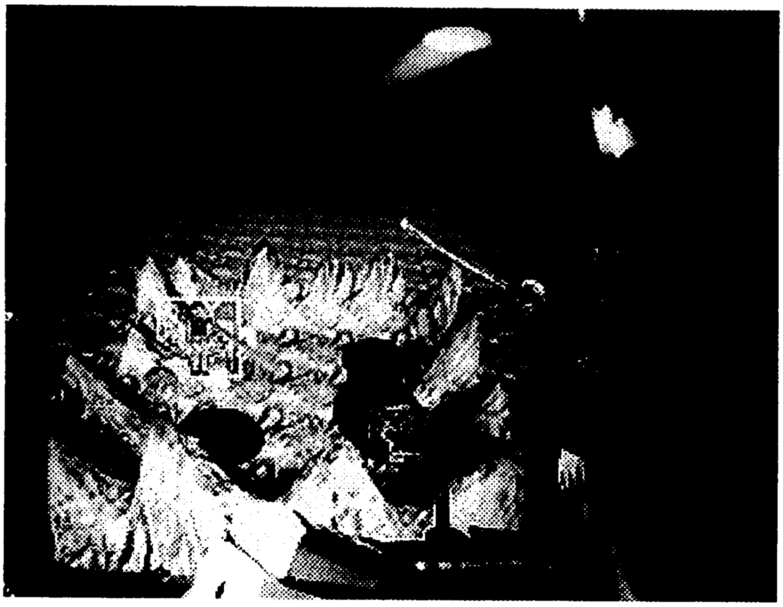
(2) Software Structure

This application was developed on a library called "vis-age" for our virtual reality system "Vis-Age". The "vis-age" library enabled the kernel to generate and manage virtual objects.

The modeling of the figures and their respective shapes appeared very expensive in terms of labor. As well, detailed modeling would tend to reduce the refresh rate during drawing. A technique called transparent texture mapping was applied to reduce the cost of modeling. One texture mapped rectangle was generated for each figure. The texture had an alpha plane with maximum value in the area where the picture existed and had a value of zero in the surrounding areas. To display the figures correctly (two dimensional pictures), a requirement was established so that figures would always faced toward the user when appearing on the screen.

(3) Functions

The executable tasks in the Virtual Sand Box system enabled the user to shape the land and also to choose and place figures on it. The number of functions was minimized so that the Virtual Sand Box would be easy to use and understand. The system was designed to automatically record all the executed Virtual Sand Box operations. This task recording capability was extremely useful for purposes of patient analysis. After the experiments, therapists could carefully observe and examine patients behavior by virtually re-experiencing the sand box created by each patient. This replay of the work allowed therapists to see what the patients themselves were seeing during the creation of the virtual sandboxes. In contrast, therapists had to take manual notes in the case of real sand box



[Fig.4 Appearance of Virtual Sand Box]

| | | |
|---|---|---|
| Wand1 | BUTTON A | Grasp/release a point on land |
| | BUTTON B | Smoothing function for land |
| Wand2 | BUTTON A | Generating/Grasping/Reseasing figure |
| | BUTTON B | Changing the size of figure |

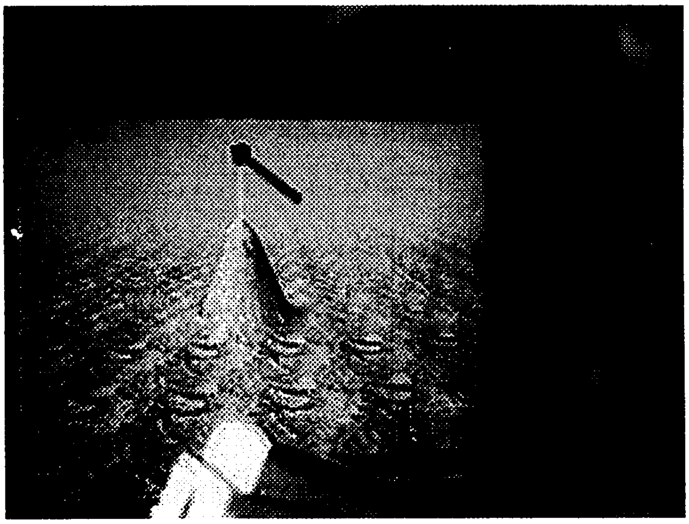
[ able 1 Function and assignment]

experiments.

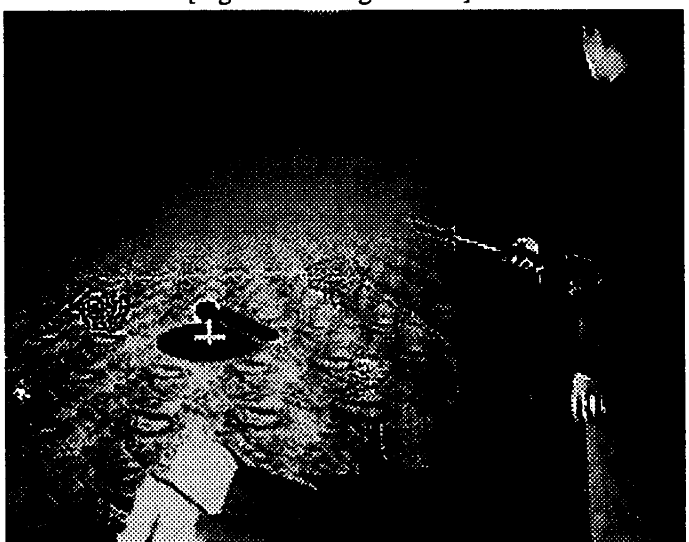
(3.1) Choosing Texture and Material for the Land

Before the execution of any other tasks, the subjects were asked to choose their desired texture and material for their sandbox land. Provided choices were a brown terrain, a green grassy field, a brown sand field, and a bluish white snow field.

(3.2) Shaping the Land



[Fig.5-1 Creating the land]



[Fig.5-2 Creating the land (the appearance of the water)]

The operational area of sandbox land was an arbitrary area of 30x30 mesh which was shaded smoothly. This area was marked by boundary lines and surrounded by exterior land which could not be shaped or changed (see Figure 7).

Using the Wand, the user could grasp a desired point anywhere within the arbitrary land. The height of the selected point would then change accordingly with the height of the tip of the Wand. A cross mark was always shown on the land as a shadow marker to indicate over which area of the land the tip of the Wand was located. The previous prototype system did not show such a shadow marker to indicate Wand tip position and caused considerable difficulty among the users when they were trying to grasp a particular point on the land.

The area around the grasped point could be transformed quite easily (e.g. lifted and raised into a small hill or large mountain (see Figure 5)). Grasped points could also be pushed down below the level surface to create ponds, lakes, and/or rivers. This level surface represented a type of sea level, so that any land depressed below it would contain water. Water was a texture mapped rectangle slightly under the land. Selected points and the nearby surrounding areas could also be flattened if they had been already raised or pushed down.

For this simulation, a more simple and efficient method was used instead of a more sophisticated and complex method such as a finite element method. This method was found to provide sufficient natural transformation operations for the purposes of this study.

(3.2.1) Transformation Algorithms

The height transformation values $\Delta h(x)$ around the grasped point were calculated as a product of the controlling value $\Delta h(0)$ at the grasped point and F(x) from the effect function distribution table (see Figure 6).

$$\Delta h(x) = F(x)\Delta h(0)$$

$\Delta h(x)$: height transformation value around the grasped point (in centimeters)

$\Delta h(0)$: controlling value at grasped point (in centimeters)

F(x) : effect function distribution table (in centimeters)

x : distance from grasped point to controlling point (in centimeters)

The effect function distribution is defined as:

$$F(x) = S(d)\frac{1}{p^{k_0 x^2}}$$

S(d) : a function representing the effect of boundary line d : distance from controlling point to the boundary line of the operational area of land

P : parameter controlling the reduction ratio of effect

ko : constant to fit this model to the size of constructed land (ko = 25)

The effect of the boundary line is defined as:

S(d) = d/do if (d<do)
1 if (d>do)

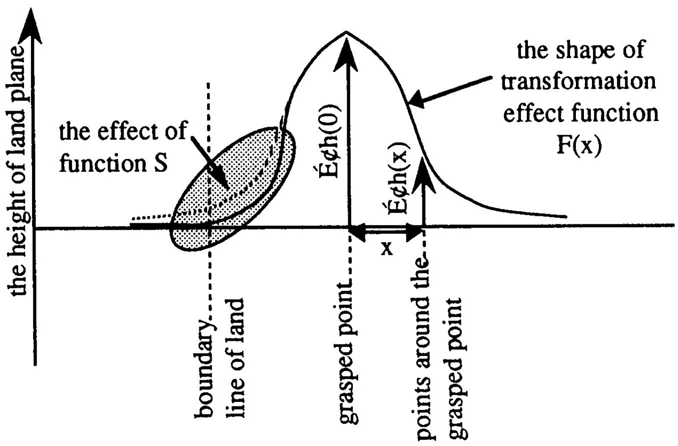
d : minimum distance from controlled point to boundary line (in centimeters)

do : constant which express the limit distance of the effect of boundary line (in centimeters)

When the parameter p becomes a small value, the effect flows to a large area and the land shape becomes smooth. Conversely, when p is large, the effect is limited to within the smaller area around the grasping point and more rugged shaped land is created. An additional function to control the parameter p made the system too difficult to be easily understood. Consequently, the parameter was set for somewhat sharper transformations (a value of p = 1.2 was used) and another function of the smoothing effect was added.

The smoothing effect had the same effect area as function F and only the area nearby, around the tip of Wand was smoothed.

The parameter S represented the boundary effect. The area located on the boundary lines had fixed attributes in terms of height (i.e. they could not be raised or depressed (see Figure 6)).




[Figure 6 the transformation function of land]
(In case the height of land constantly zero and pulling the point near boundary line of land)

(3.2.2) System Operation

- Choosing, generating, changing the size of, and removing figures

Subjects chose their preferred type of figure and then selected the desired color using a touch panel. 15 pictures of figures were shown for each page on the touch panel display along with a page button to display other pages (see Figure 7). In total, there were 6 pages, giving 15x6 = 90 types of figures to choose from. After subjects would choose their desired figure by touching it on the touch panel display, the display changed to show 8 colors. After color selection and the figure type were selected, the color of Wand would change to the selected color and the Wand would blink to inform the subject that he/she could then place and generate the figure in a desired location. By pushing the A button of the Wand, the figure would appear and the virtual Wand would stop blinking.

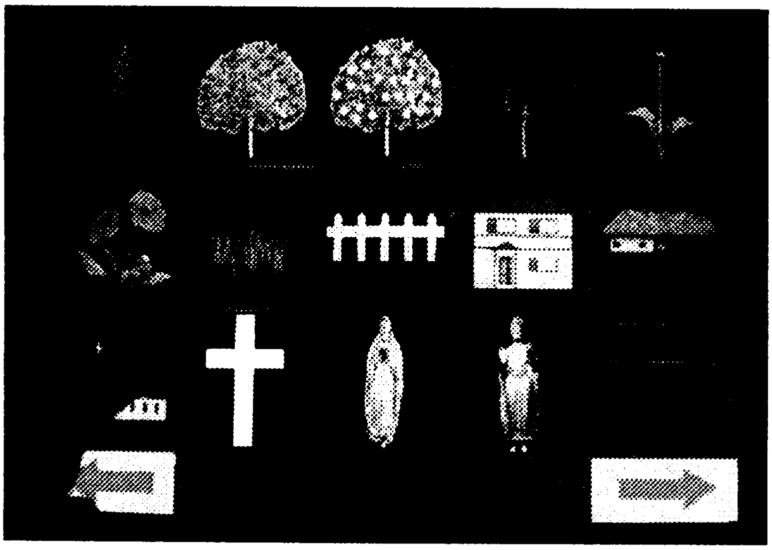
During sandbox playing, if there was a figure placed near the position of the virtual Wand, the figure would be highlighted to indicate that it was capable of being manipulated. In the case of many figures being located near the tip of the virtual Wand, the closet figure would be highlighted.

The functions involved were grasping, moving, and changing the size of figures. To change the size of a figure, the subject pushed the B button of the Wand which would then cause the size of figure to continuously grow and shrink gradually. By pushing the B button again, the size of the growing and shrinking figure at that given moment would become fixed.

If a figure was placed out of the operational land area, it would disappear and be removed from the sandbox. The system always detected collisions between the grasped figure and land in order to prevent the placing of figures under the land.

- Changing the View Position and Direction

A joystick was used for changing view point and direction. The joy stick contained only 2 degrees of freedom while the eye has 6 degrees of freedom. Consequently, some arbitrary assignments



[Fig.7 Touch panel and figures displayerd] were necessary for controlling degrees of freedom. In the prototype system, two methods of assignment were implemented: 1) Forward, backward, and rotational movement around a vertical axis was enabled at a constant height (an analogy of a military tank moving in a Cartesian coordinate system) 2) Rotational movement about both a vertical axis and a horizontal axis. The view point was always on the spherical plane with a constant distance from one point (Spherical coordinate system).

1) was found to be suitable for operation in relatively a large space. The subject could select an object to be manipulated by looking around him and moving near the object before handling it. In this way, the subjects could move easily through the virtual landscape.

2) was found to be suitable for tasks where the space involved was relatively small and objects to be manipulated were already determined.

The second method appeared to be easier to understand on the previous prototype system. Therefore, the authors favored the second method over free movement for operating in the virtual land. The land was placed at the center of the spherical surface.

## 4: Experiment

Over 40 people, including both patients and normal people, participated in the Virtual Sand Box study. Children for this study were from the senior grades of elementary school. Adults who took part were from age18 to their late 20s. Before the actual Virtual Sand Box experiment, the subjects were given brief explanations on how to operate the system. No suggestion was given about task time, the aim of the experiment, or what they should create. This encouraged the subjects to behave freely when playing in the Virtual Sand Box.

Typical play times to complete landscapes ranged between 30 minutes and one hour. Subjects who played for more than one hour were interrupted and asked to stop.

### 4-1: Understanding the Functions and the Operations

Most subjects were interested in shaping land and created landscapes naturally. Although the simple hill or valley created by one operation was simply the result of the effect function, subjects often created complicated shapes of land by repeated operations. The smoothing function was not used often.

Some people became confused when they manipulated figures because the system's reaction time was slow. Occasionally, subjects would push buttons repeatedly and become confused and lose sense of the relation between operation and reaction.

No hints or explanations were provided to the subjects about how to remove figures. In fact, subjects were not informed at all of existence of the remove function. Most subjects naturally discovered this function by themselves through experimentation and learned to use it.

The subjects could naturally change their view point and direction.

The cue provided to the subjects regarding depth was not sufficient. Subjects often noticed that a placed figure would not be placed accurately at the point they intended. They then learned to use motion parallax to confirm the position of figures.

The effective improvements for the experimental system (after testing with the first prototype system) were: 1) displaying a shadow icon for the tip of the Wand on the land 2) collision detection between figures and the land 3) highlighting of the figure closest to the Wand.

### 4-2: Experimental Results

Figures 7 are pictures of some of the landscapes created by subjects. The capacity of the Virtual Sand Box system in terms of allowing subjects to express themselves was quite adequate and there appears to be a strong possibility to applying the Virtual Sand Box to practical clinical medicine by further correcting and analyzing more examples.

## 5: Conclusion

A virtual environment was developed to support study of the Sand Play Technique which has had wide application in clinical medicine. The Virtual Sand Box system was developed and enabled users to create virtual landscapes containing various objects and figures. Experiments were conducted with over 40 subjects to analyze the effectiveness of using the Virtual Sand Box system to aid both patients and therapists in treating autism patients. Results of the study supported the belief that Virtual Reality technology can find practical application in clinical medicine.

## 6: Acknowledgment

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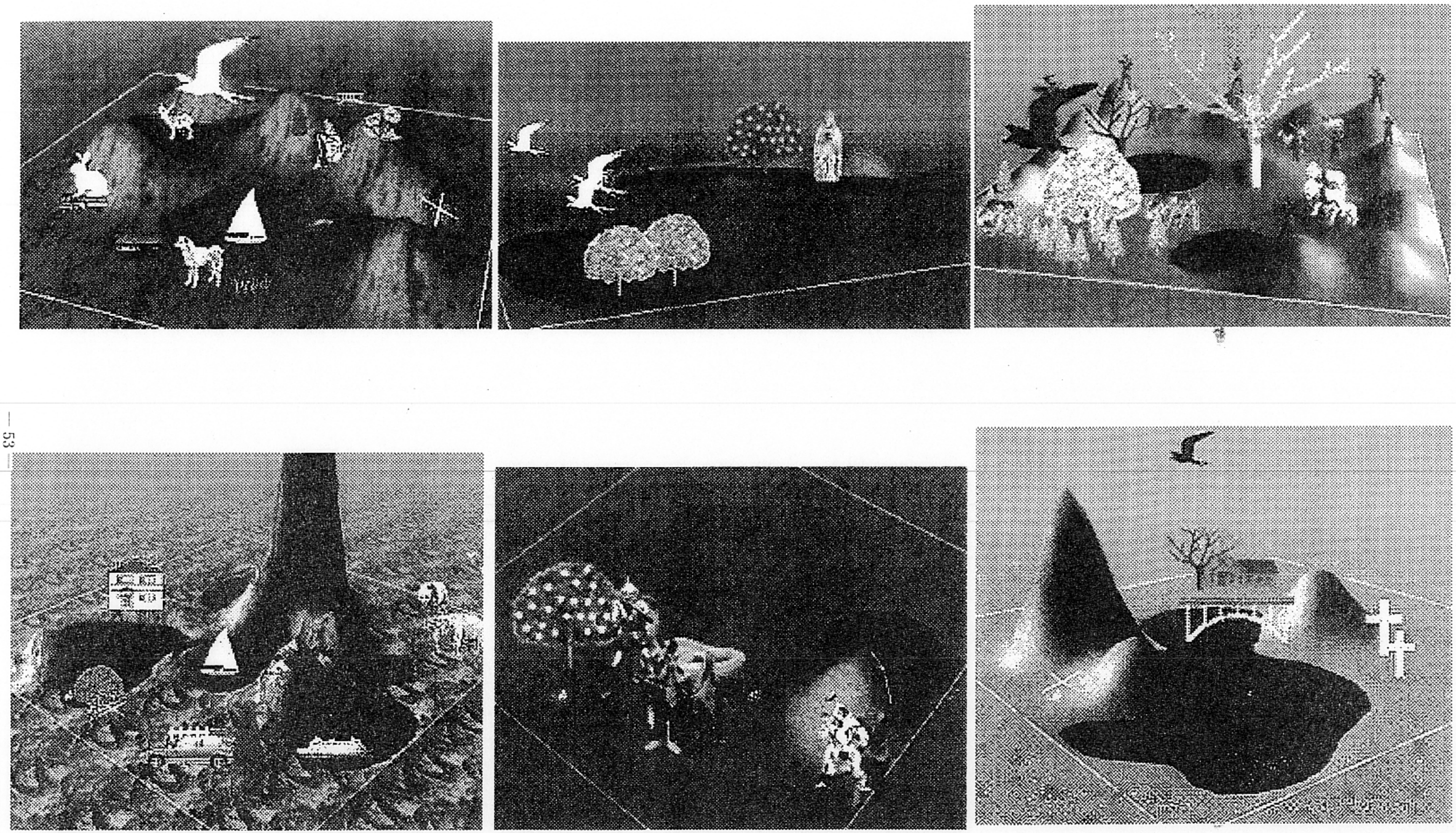

[Fig.8-1～8.6 Examples of the subject's work]