Interactive Tactile Display System

– A Support System for the Visually Disabled to Recognize 3D Objects –

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Abstract

We have developed an interactive tactile display system for the visually disabled to actively recognize three-dimensional objects or environments. The display presents visual patterns by tactile pins arranged in two-dimensional format. The pin height can be set to several levels to increase the touch information and to display a three-dimensional surface shape. Also, each pin has a tact switch in the bottom for the user to make the system know the position by pushing it. This paper describes the hardware and software of the system.

Keywords
Tactile display, The visually disabled, Interactive interface, Stereo vision, 3D

Introduction

There has been a lot of research on supporting systems for the visually disabled in the world. However, most of them are for character recognition. There are only a few to recognize 2D figures and 3D objects [1]–[8].

We are developing a computer aided system for the visually disabled to get 3D visual information as well as sighted people by incorporating high-level image processing technology. It consists of three parts: input, transformation, and output of visual information (Fig. 1). The input part is a stereo vision system from which a variety of 3D geometric data are obtained without touching objects. In the transformation part, the data is transformed into tactile or auditory data. The output part consists of a tactile display and a 3D audio display. The 3D data obtained is not just raw image data. The image data is analyzed structurally and only the required visual information can be selected according to the user's demand. In this paper we introduce an interactive tactile display subsystem in the total supporting system.

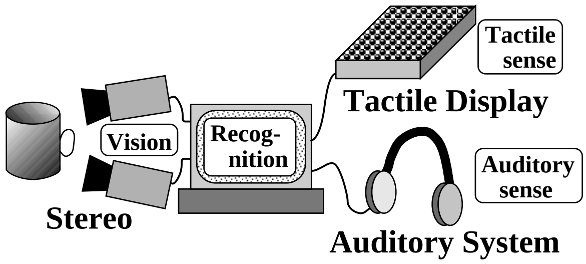

Figure 1: Conceptual diagram of the support system.

Tactile displays are useful for representing 2D or 3D information[1]–[8] and there exist some two-dimensional tactile display products [2]–[6]. For example, "Dot Matrix Display" of the German company "METEC" consists of 7,200 tactile dots arranged in an equally spaced matrix of 120 columns and 60 rows. The reading area is 372×186 mm and the dot elevation is 0.7 mm. The spatial resolution is very high and it is possible to display figures in detail. But the vertical resolution is only two levels. Kawai developed a tactile display with 8×8 pins with a vertical resolution of three levels[6]. The height of each pin is controlled by two solenoids. However, the vertical resolution of these displays is insufficient to represent 3D information.

Shinohara et al.[7],[8] have developed three dimensional tactile display with 64×64 pins, which are arranged in a triangular grid. The space between each pin is 3 mm, the diameter of each pin is 2.5 mm, and the height is variable between $0-10$ mm. Since this display has high vertical resolution it is easier to represent 3D shapes. However, the display is too large and prone to mechanical problems.

We have developed an interactive tactile display to help visually handicapped people to actively under-

Figure 2: System.

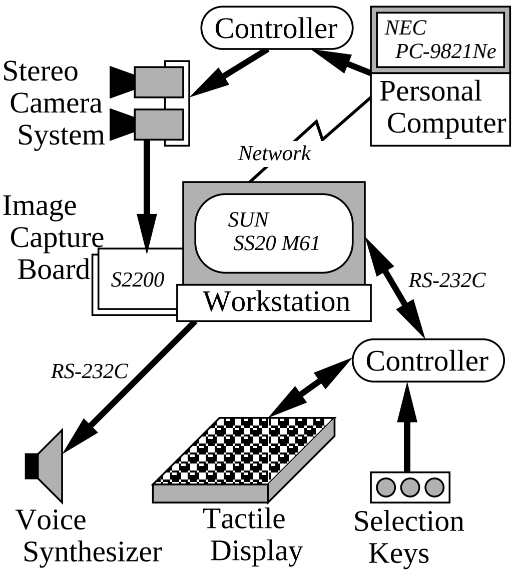

Figure 3: Composition of the interactive tactile display system.

stand three-dimensional objects/environments. The new tactile display is based on the concepts outlined by Kawai[6], and the hardware was constructed according to the technology by Shinohara[7],[8]. The major difference is the function of the digitizer. Using this function users are not only given tactile and auditory information but also they can select the required information from the system to make it easier to understand the 3D world.

In Section 2, the hardware for the interactive tactile display system is described. In Section 3 the stereo vision system is explained. In Section 4 the interface is described together with some examples. In Section 5 we discuss the operation of the system and conclusions are drawn in Section 6.

Tactile Display System

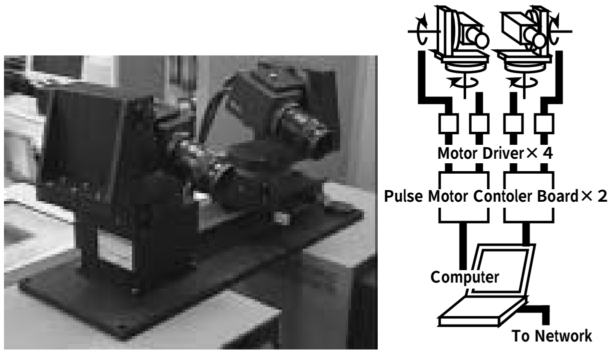

Figure 4: Stereo camera system.

In this section, the interactive tactile display system is described. The overview of the system is shown in Fig. 2 and the composition of the system in Fig. 3. The system is composed of three parts: a "Stereo Camera", a "Tactile Display", and a "Voice Synthesizer". Details of these parts are as follows.

Stereo Camera

The stereo camera system [10] is shown in Fig. 4. This system has two cameras, which are controlled by a personal computer. Each camera is panned and tilted by pulse motors with an angular speed of 50 degree/s. The speed is fast enough to track moving objects. The specification of each part is as follows: 3CCD camera (Sony, XC−007), frame grabber (Data Cell Limited, S2200), computer (NEC, PC−9800Ne), OS (Lynx (real time unix)).

The frame grabber is an s-bus board in a SUN SPARCstation. It inputs a 640 $\times$ 480 color image in 1/15 second.

Tactile Display

The tactile display (Fig. 5) represents visual patterns by tactile pins arranged in a two-dimensional lattice. The pin height can be set to several levels to increase the touch information and to represent a three-dimensional surface shape. Also, the display has three pushbutton keys for selecting the display mode. Both the tactile display and the selection keys are controlled through an exclusive controller.

The specifications of the tactile display are as follows. Pin arrangement: 16×16 pins; Pin area: 175×175 mm; Diameter of pin: 5 mm; Spacing between each pin: 10 mm; Height of pin: 0 − 6 mm; Drive: stepping motor; Sensor: tact switch; Size: $550(W) \times 530(L) \times 195(H)$ mm; Weight: 28 kg.

The pins are arranged both horizontally and vertically. The tactile display mechanism is shown in Fig. 6 in detail. The upper part of the figure is a picture of the

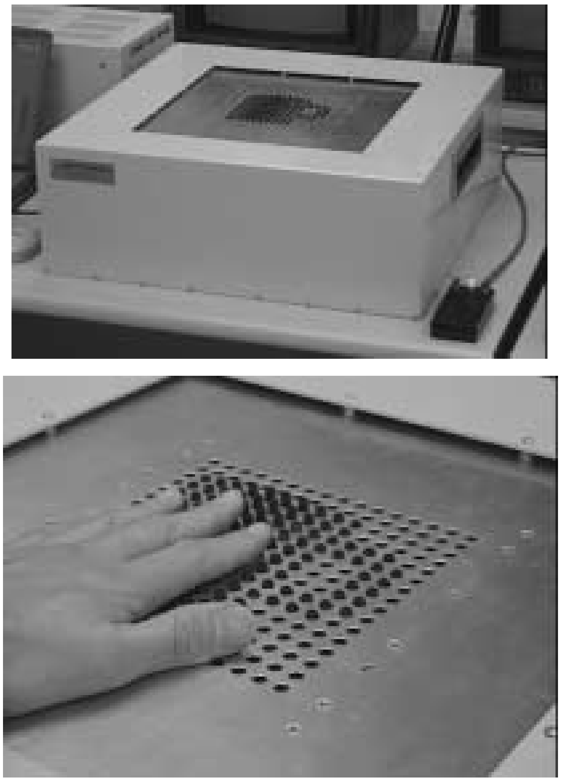

Figure 5: Tactile display.

inner part. There are 32 driver boards for stepping motors, with each board controlling two pins. The diameter of the motor used is 10 mm. The motors are sufficiently powerful to maintain the some height under finger pressure. As depicted in the lower part of the figure, the construction is in two layers to allow the pins to be positioned more closely together. The screw in the pin relates rotation to the vertical movement. Thus, the height is controlled by the number of pulses. A tact switch, similar to that used in card type calculators, at the bottom of each pin records which pins are pushed.

The selection key consists of three push buttons, and has a size similar to that of a computer mouse. It is used when the user wants to hear the voice message or change into another display mode (see Interface Section).

The controller of the tactile display, which uses a 16 bit CPU (16 MHz), is shown in Fig. 7. It is connected to the workstation by an RS-232C cable. This controller interprets the command strings from the computer and 1) sets the vertical position of each pin, 2) obtains the position of pushed pins, and 3) determines the state of the selection keys.

Voice Synthesizer
The voice synthesizer is used to add more information to the tactile display. We used a "VC-1" voice synthesizer made by the RICHO corporation, Japan. The specifications are as follows: synthetic method: LSP−CV; I/F: RS−232C (9600 bps); language: Japanese; voice: man & woman; size: 150 × 230 × 35 mm; weight: 1.0 kg.

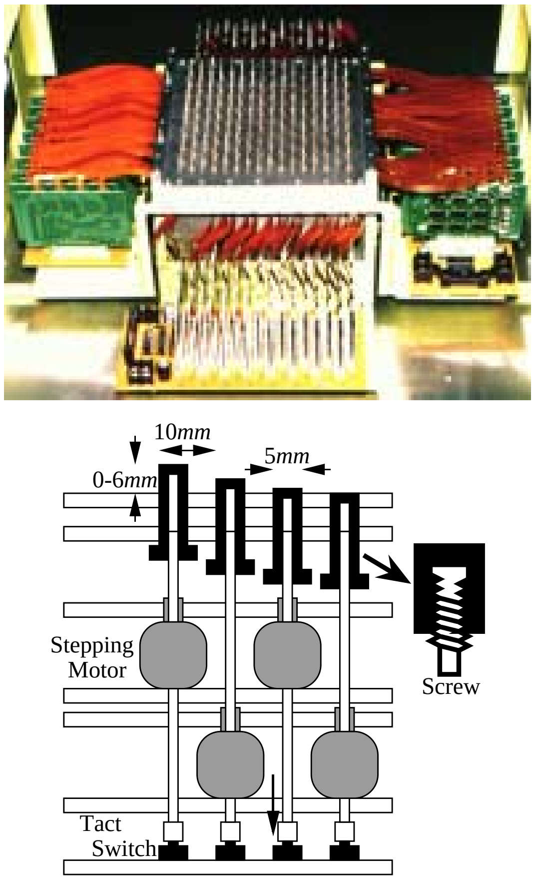

Figure 6: Tactile display mechanism.

Figure 7: Tactile display controller.

A library of strings is registered in the database by combining some phonemes in a transfer dictionary. These strings are sent from the VC−1 to the workstation

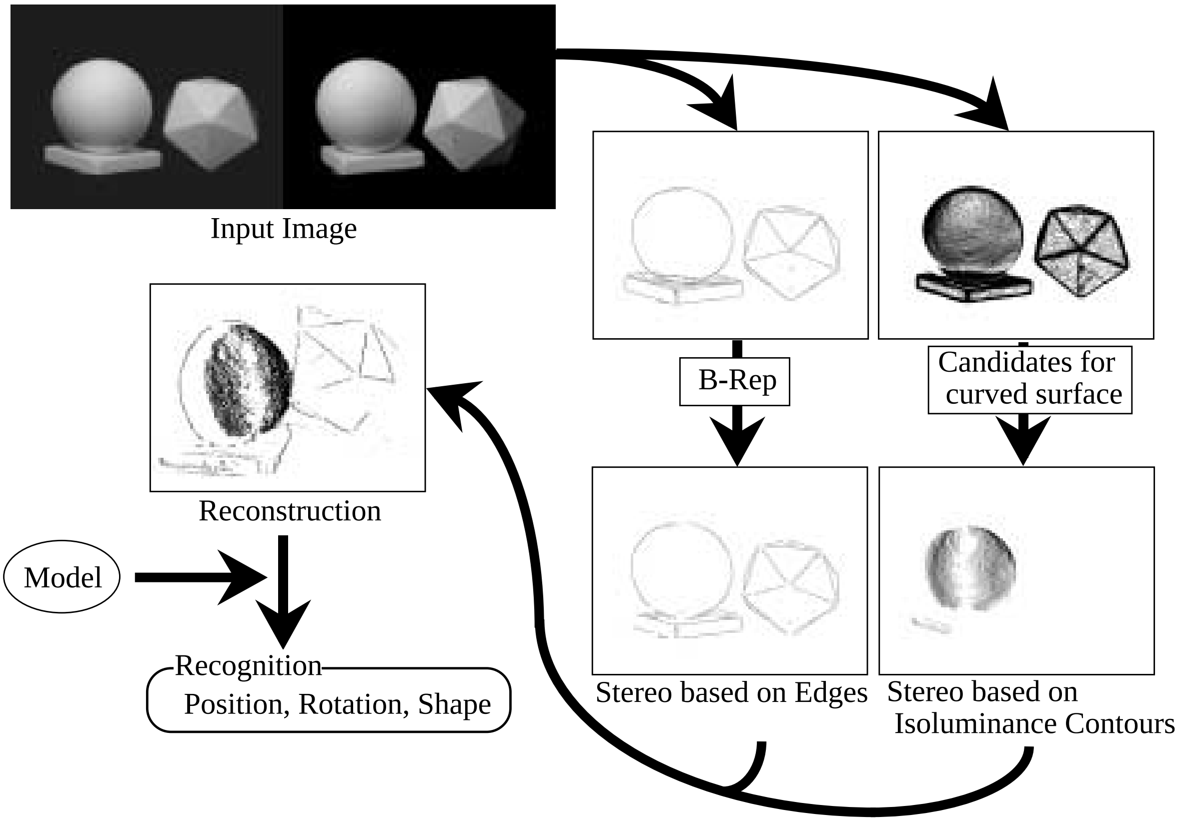

Figure 8: Stereo.

through the RS−232C and the synthetic voice is output from a speaker.

Stereo Vision

We use a stereo vision system to get 3D data of observed objects. One reason why we don't use a usual range-finder system is that it can detect only a limited distance. The main reason that we have developed a stereo vision system which can get 3D data as well as or better than range-finder systems is that the stereo vision system is more flexible and versatile. The two stereo cameras can be controlled by computer (see Stereo Camera Section). The process of stereo is shown in Fig. 8. Two methods are used to get 3D data of objects by stereo: an edge-based method [11] and an isoluminance-contour-based method [12]. The former gets 3D boundary data of objects and the latter the surface data of objects.

After getting 3D data by stereo, the process of object recognition follows. The 3D data is matched with object models in the database to know what objects exist and the position and the orientation of each object.

Interface

Since the resolution of the tactile display (16 × 16 pins) is not enough to represent a lot of information at the same time, we have developed a multi-level display mode (see Figs. 9 and 10): the position mode, the boundary shape mode and the surface shape mode. The interface is depicted in Fig. 9. In the position mode, the user can recognize the relative position of each object by indicating the object position with a single pin. By pushing the voice guide button, the user can hear an auditory explanation about the number of objects. Also the user can hear an auditory explanation about the name of the object by depressing the corresponding pin.

If the user wants to know its shape, the user pushes the information selection key to change the mode into the boundary mode or the surface shape mode. In these modes, the size and color of object are explained by voice, for example, "This is a cup with a grip. Its size is about 10 *cm* high and its color is white." In the boundary shape mode, the user can feel the wire-frame shape, and in the surface shape mode, scan the convex or concave shape. The user can select one of the three modes easily by pushing the information selection keys. The user can recognize objects by repeating these processes.

Discussion

Our new display system can represent more complex patterns than characters by making it possible to adjust the pin height more than conventional tactile display systems. The resolution of the tactile display may not be enough to represent complex shapes. However, a higher resolution display would be much more expensive to produce and maintain due to current technical limitations [8]. Thus, our concern is much more on how to use the tactile display effectively in the total supporting system than developing the tactile display itself.

Each of the three display modes of the interactive interface serves a specific purpose. The position mode is suited to know the relative position of each object. The surface shape mode is useful for perceiving the approximate 3D shape of an object. For example, a hemisphere is displayed as a smooth convex hemisphere. However, it might be difficult to know the exact shape because of the low resolution. The interface has another shape mode, the boundary shape mode. In this mode, the shape is represented by a wire frame. In both shape modes, it is possible to display objects from any viewpoint by using 3D models. At present, this interface is still at the prototype stage and we hope to further improve its function through more experimentation with visually impaired people. The first experiment we are going to do is object recognition by the user. We will check what presentation is better for the visually disabled to display only one object. After that we will examine the suitability of the position mode for position recognition of objects.

Conclusions

We have described the hardware and software of an interactive tactile display system. The tactile display presents visual patterns by tactile pins arranged in a two-dimensional format. The pin height can be set to several levels to increase the touch information and to display a three-dimensional surface shape. Also, it has a digitizer function by means of a tact switch in the bottom of each pin. It is possible for a user to communicate with this system.

This system will help the visually disabled recognize 3D objects and environments by themselves. We anticipate that this new tactile display system will also have more general uses such as for education on three-dimensional shapes in schools.

We have to develop and refine the system through experiments with some visually disabled people. In the future we hope to develop a tactile display with higher resolution, further enhance the interface and to include a 3D auditory system.

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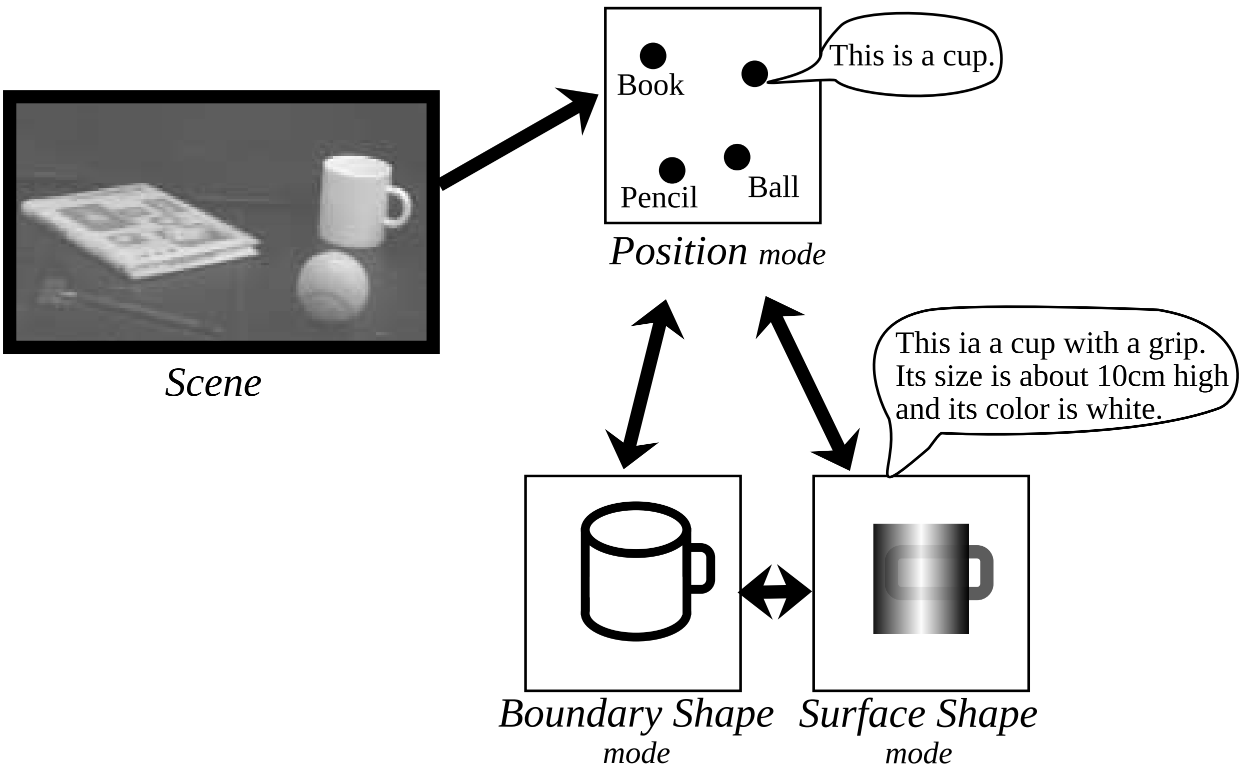

Figure 9: Interactive interface.

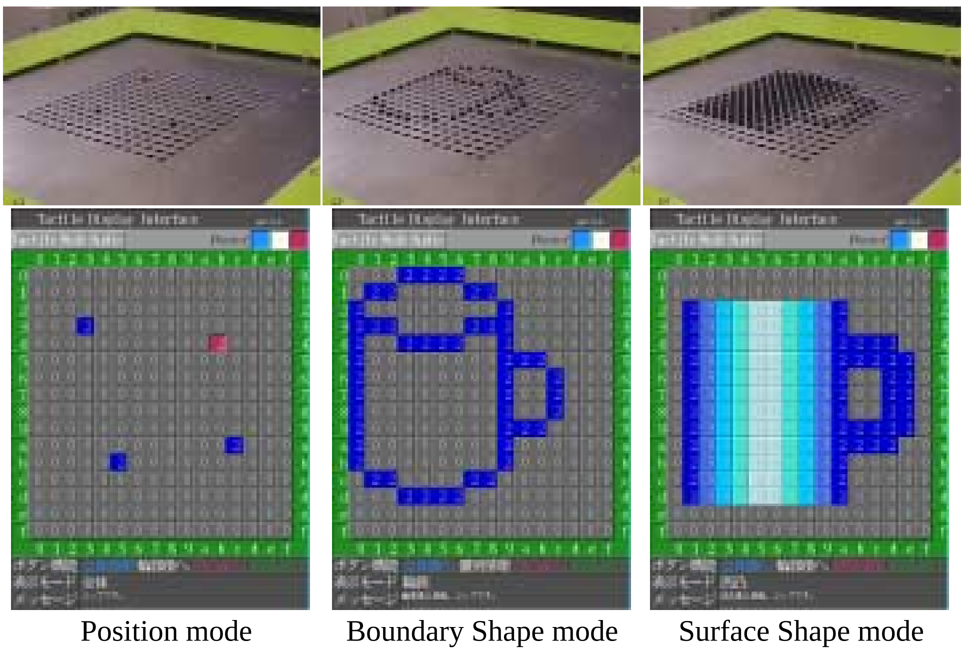

Figure 10: Examples of the three modes of the interface.