A Proposal for a Display Method of a Walking Support System for the Blind

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Abstract: We would like to propose a display method of a walking support system for the blind that detects obstacles. Our system, resembling a pair of glasses, would present tactile stimulation to the face. This paper will describe basic experiments which we have conducted where such stimulation was presented to the face. The results of these tests provide evidence that such a system is in fact practical.

1. INTRODUCTION

Numerous studies of a device that can inform the blind of obstacle location have been conducted since the 1970's. As a result, some devices, such as the Mowattsensor and the Lasercane, were developed and have appeared on the market. However, those devices are rarely used in Japan due to their impracticality. Therefore, many researchers are attempting to improve such devices. It is with this view in mind that we have also embarked on such developmental research. As a first step in this process, we have examined the problems of the conventional devices from a user's point of view. Next, our basic experiments have enabled us to propose a new and alternative assistive method for the blind.

2. CONVENTIONAL DEVICES VERSUS OUR PROPOSED DEVICE

Some of the problems of conventional devices are as follows:

a) Using both hands

In general, the blind use a white cane while walking. However, if they use some hand-operated conventional devices in addition to a white cane, it is difficult for them to open a door, pick up something, use an umbrella and so on.

b) Using auditory feedback

Sound information regarding one's surroundings is of great benefit to the blind. For example, they may be able to estimate the size of a room. They can also sense the presence of walls from the change in the frequency and strength of environmental sounds. However, some devices use sound to inform the blind of the location of obstacles. As a result, sound emanating from such a device may interrupt their ability to decipher other important sound information.

c) Variance in obstacle detection range

The obstacle detection range varies with conventional devices. For example, one conventional device informs the user of objects that lie within a distance of 5 meters, whereas another performs the same function within a 1 meter range. In the former case, by detecting objects as far away as 5 meters, the blind will continuously receive unnecessary obstacle information such as the location of the walls of buildings. Specifically, it would be more beneficial for the blind to only detect closer obstacles which may constitute a safety threat.

d) A complicated display method

Such an assistive device should not only inform the blind of the distance to an obstacle but the object's direction as well. Unfortunately, this directional information is not provided by conventional devices. A related fact worth mentioning at this point is that when the blind are about to touch or grasp an object, they first tend to move their faces in such a way as to center the objects in their visual field. This fact suggests that the direction of the face may serve as an aid to obstacle detection.

3. CONCEPTUALIZATION OF OUR DEVICE

In order for blind people to know where to turn their heads, it is necessary to present them with some form of tactile stimulation, such as vibrations. The possible areas of stimulation could be the ears, the neck, the forehead, the hair on the head, the front of the face and so on. However, in choosing which area to stimulate, we considered the front of the face to be the ideal choice to facilitate object perception. Our reason for this choice is that the blind often express concern about their appearance and explain that they would prefer not to use a device that attracts attention by making them appear strange or unusual. With this in mind, we concluded that a device resembling a pair of glasses would be the least conspicuous. Figure 1 indicates the outline of our proposed device, while Figure 2 shows the imaginary device when tactile stimulation is presented. The distance and direction from the proposed device to an obstacle would be measured by obstacle detection sensors and would be calculated by means of a signal processing unit, as shown in Figure 1. The tactile display, resembling a pair of glasses, would present tactile stimulation to the face according to the measurement results. Specifically, the tactile stimulation would be presented from the right part of the tactile display (shown with an asterisk) if the obstacle appeared to the right of the user, as shown in the left portion of Figure 2. Using this approach, the user would naturally turn his or her head toward the object, such that the area of tactile stimulation would then shift to the center of the user's face (right side of Figure 2). The distance to the obstacle would be indicated by the intensity of tactile stimulation, as in the case of conventional devices. However, in the special case of a blind person looking down at the floor, it would be more convenient if the intensity of stimulation was maintained, based on the distance between each user's face and the floor.

Incidentally, vibration is often used as the form of tactile stimulation because it provides good controllability. However, since vibrators must always maintain contact with the skin, they may cause some discomfort to the user. Moreover, it would be difficult to stick vibrators on the face, since a person's face has an irregular surface. Considering these factors, we came upon the idea of using a breeze consisting of mild but short air currents, since a breeze would not make people feel uncomfortable, nor would it be necessary to be concerned about the distance between the stimulator and the skin. In fact, we decided that an appropriate name for such an approach would be *breeze stimulation*. There is in fact some research indicating that such information regarding obstacle distance could be presented by a breeze [Tanaka 95]. However, no research includes information on obstacle direction presented by a breeze. In particular, there hasn't been any research dealing with the presentation of an obstacle's vertical location, though it has been possible to inform users of the horizontal direction of obstacles by using vibrators attached to the waist [Yamamoto 02]. In short, the objective of this paper will be to consider whether or not the perception of obstacle direction is possible by means of breeze stimulation to the face.

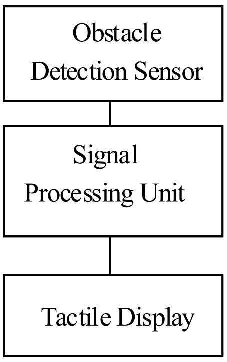

Figure 1 Blockdiagram of our device

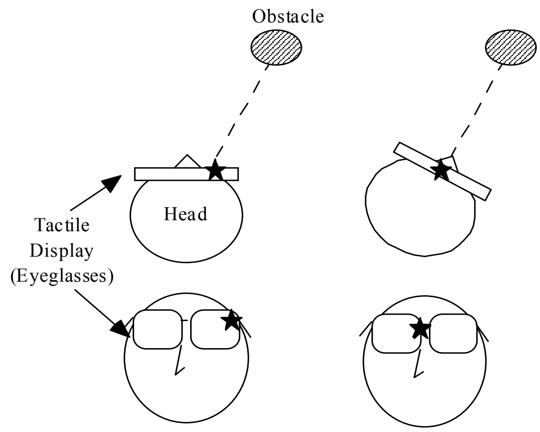

Figure 2 Outline of our device

4. EXPERIMENTS

4.1 Deciding the number of stimulation points

Our display method consists of breeze stimulation points placed across the forehead. By using such an approach, it would therefore be necessary to determine the optimal spatial resolution of the stimulation points. This spatial resolution is called the *successive spatial threshold*. According to Weinstein [Weinstein 68], this threshold is roughly 4mm when using a pin stimulator applied to the forehead. However, since our approach differs, the spatial resolution threshold should change. With this in mind, we measured successive spatial thresholds in order to determine the appropriate number of stimulation points to arrange across the forehead.

4.1.1 Experimental setup and method

Figure 3 shows the block diagram of the experimental setup. The breeze stimulation was presented by a 2mm diameter vinyl tube and was controlled by a computer and electric valve. The tubes were arranged on a board. The subject sat on a chair with his/her head in a fixed position, and the board was placed 1cm in front of the face.

Successive spatial thresholds were measured at points *a, b,* and *c,* as shown in Figure 4. Two breeze stimuli from two tubes were presented to the forehead at specific time intervals. The distance between the two breeze stimuli was then changed. Next, the subjects were asked whether or not they sensed the two stimuli separately or as one single sensation. We then measured the border at which the subjects sensed a difference between the two stimuli. The average distance of the border was then defined as the successive spatial threshold. Needless to say, the time difference between two stimuli influences the successive spatial threshold. The time difference was decided as follows: By analyzing a video of the subjects walking, we found that it took about 0.5 sec for both the blind and the non-impaired subjects to take a step. That is to say, each subject moved one leg every 0.5 seconds. Since the aim of our device was to avoid obstacles while walking, we thought that information about nearby obstacles should be presented to the blind user every 0.5 seconds. Thus, the time difference between the two stimuli was set at 0.5 seconds. In our investigation, the first breeze stimulation was called a *referential stimulation*, while the second stimulation was called a *comparative stimulation*. Stated more specifically, one puff of air lasted for 0.25 seconds and the interval between a referential and a comparative stimulation was 0.25 seconds. Five currents of air were used at a pressure of 0.04-0.08MPa. The measurements were conducted by using the method of limits

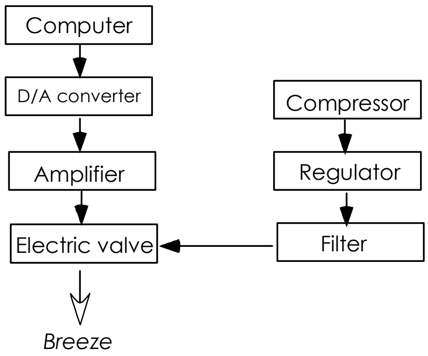

Figure 3 Block diagram of experimental setup

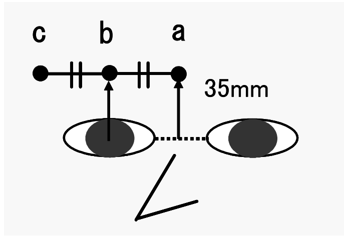

Figure 4 Location of stimuli

and each subject was given 5 trials. The subjects included four non-impaired people ranging in age from 23 to 29 years.

4.1.2 Results and discussion

Figure 5 shows the relation between pressure and the successive spatial thresholds. The threshold increased as the stimulation point moved away from the center of the forehead. It was necessary for the spatial interval between two stimuli to be greater than the successive spatial thresholds so that a blind person could know the positional change of the stimuli. However, there was little relation between the successive spatial thresholds and the pressure. The standard deviation of the successive spatial thresholds at point *a* was 10 mm. This meant that the subjects could tell the difference between two breeze stimulations if the two stimulations were presented with more than a 10 mm interval at point a. In other words, the interval between two stimulation points should be at least 10 mm at the center of the forehead. On the other hand, the stimulation interval should be at least 15 mm at the edge of the forehead because the standard deviation of the successive spatial thresholds at point c was 15 mm. In consideration of these standard deviations, we were able to arrange thirteen simulation points across the forehead, based on the average width of a person's forehead.

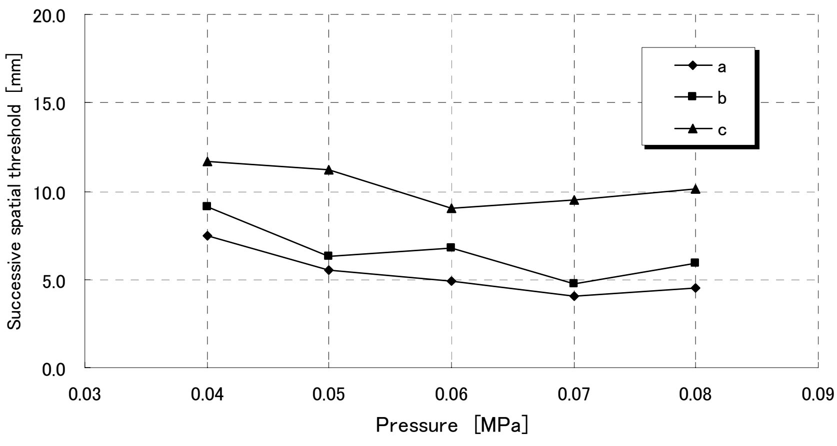

Figure 5 Relationship between pressure and successive spatial threshold

4.2 Determining facial direction

Next, the subject's facial direction was determined. Figure 6 shows the outline of the experimental setup. It was shown that the direction of a person's face passes through the area between the eyes. Therefore, the first positioning sensor was attached to the face at the point between the eyes. This sensor was called sensor 1. This positioning sensor system measured spatial distance by magnetism (Fastrak, Polhemus inc.).

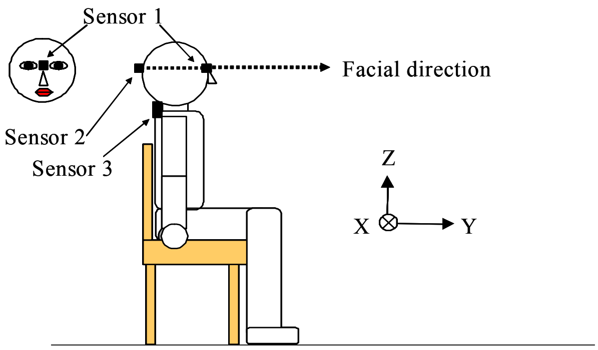

Figure 6 Experimental setup for deciding facial direction

4.2.1 Experimental method

The subjects were asked to sit down with their eyes closed, to move their face to the front and to keep still. Positioning sensor 2 was attached to the back of the head so that the values of the x and z coordinates of sensor 1 and the values of the x and z coordinates of sensor 2 would be almost identical. Positioning sensor 3 was attached to the base of the neck in order to measure the body's sway. Under this condition, the subjects were asked to turn their heads in the direction they perceived the object to be. During this time, the subjects were also told to close their eyes so that they would not be able to use their ocular motor function. The subjects included three non-visually handicapped who were using eye masks and earplugs. Seventy five trials were conducted with each subject.

4.2.2 Experimental results

The values of the x and z coordinates of sensors 1 and 2 were measured after the subjects had returned their faces to the frontal position. Figure 7 shows one example of the results. For the x coordinate of sensor 1, the graph shows a high frequency between 10-10.9cm, while in

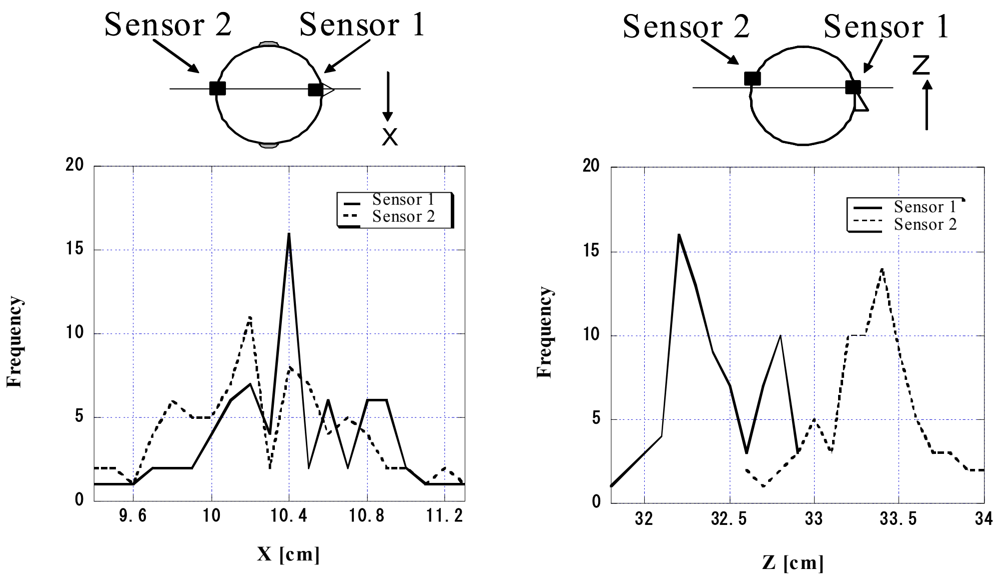

Figure 7 Definition of facial direction

the case of sensor 2, it shows a high frequency between 9.7-10.7cm. If the graph of sensor 2 is moved by 0.3mm, it becomes almost identical to the graph of sensor 1. If the graph of sensor 2 is moved by -0.9mm, it becomes almost identical to the graph of sensor 1 for the z coordinate. After sensor 2 is moved, the straight line that connects sensor 1 and sensor 2 indicates the facial direction. Each subject repeated this experimental procedure in an attempt to determine the correct facial direction. The next experiment was done without detaching the sensors.

4.3 Sense of direction indicated by breeze stimulation

4.3.1 Experimental setup and method

Measurements were taken of how breeze stimulation caused the sense of direction to shift from the expected direction, when facial direction was used as a criterion. The sense of direction caused by breeze stimulation was termed the *subjective obstacle direction*, as shown in Figure 8.

Figure 9 shows the outline of the experimental setup. The subject sat on a chair with his/her head in a fixed position. A plane board was set up such that the distance between the subject and the board equaled 70% of the person's arm length. The movement of the head and the arm was measured by the Fastrak. The breeze stimulation device (described in 4.1.1) was placed 1cm in front of the forehead.

The subject's hand position was used to subjectively indicate the obstacle's direction. After a breeze stimulated the foreheads of the subjects, they were asked to imagine the presence of an object. Next, they were asked to grasp the virtual object with their right hands. Sensor 3 was attached to the palm of each subject's right hand. The subjects included three non-impaired people wearing eye masks. The pressure of the breeze stimulation was 0.05MPa, with each subject undergoing 10 trials.

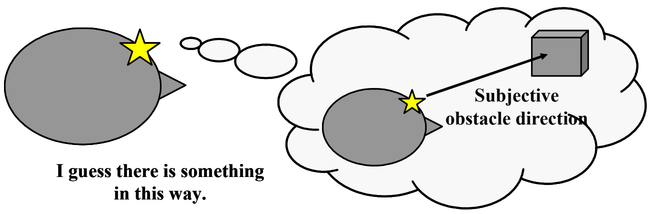

Figure 8 Subjective obstacle direction

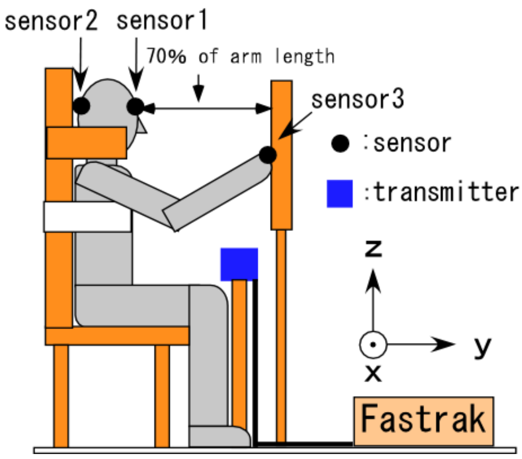

Figure 9 Experimental setup

4.3.2 Results and discussion

Figure 10 shows the coordinate system. In this coordinate system, the zero point corresponds to the center of the head, which was assumed to be halfway between sensors 1 and 2.

Figure 11, showing the results for one subject, represents the experimental setup shown in Figure 9 but from a downward looking view of the head and the plane board. In Figure 11, the reader can see that the subject pointed to the black dot on the board when the breeze stimulation was presented to the stimulation point of the forehead. For instance, a diagonally straight line shows that the subject pointed to R4 with his hand when the breeze stimulation was presented at the r4 point on the forehead. Here, r4 refers to a stimulating point while R4 means a point indicated by the subject. The angle between the indicating point and the facial direction was defined as θ, whereas the angle between the stimulating point and the facial direction was defined as angle α.

Figure 12 shows the relation between θ and α. The horizontal axis shows angle α and the vertical axis shows angle θ. The dot equals the average value, while the stick represents the standard deviation. The tendency was almost the same for all subjects. Moreover, by considering the standard deviation, we thought the value was almost the same for all subjects. Judging from our results, if the obstacle exists at a position 30 degrees in front of the subject, the breeze stimulation should be presented at a corrresponding 30 degree position on the forehead. In this way, the subject could imagine the location of an obstacle in order to avoid it.

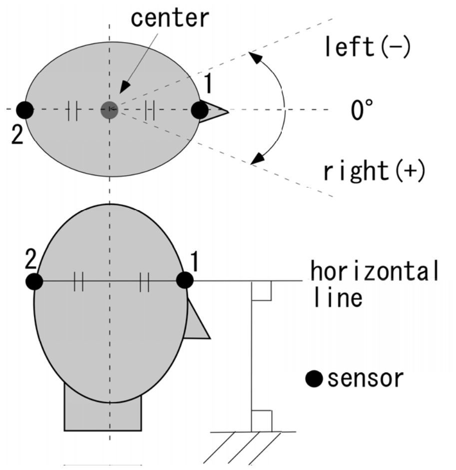

Figure 10 Head-centered coordinate system

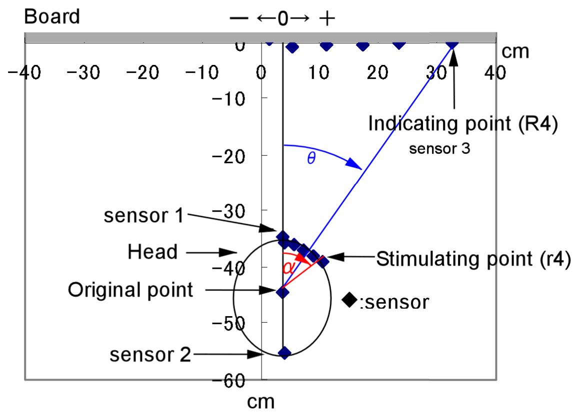

Figure 11 Relationship between tactile stimuli and response of indication (results of one subject)

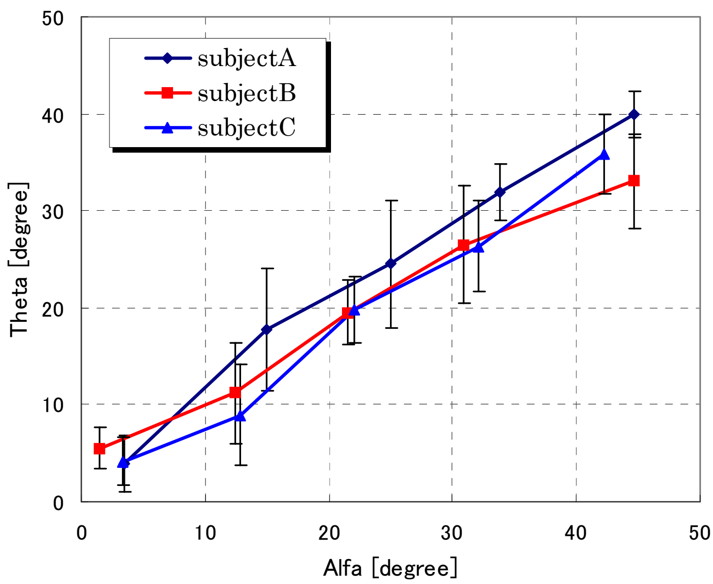

Figure 12 Relationship between tactile stimuli and response of indication (results of all subjects)

5. CONCLUSIONS AND FUTURE STUDY

First, a comparison was made of the problems of conventional devices and our proposed device. Second, the number of stimulation points was decided. Third, each subject's facial direction was determined in order to measure the degree to which the facial direction corresponded to the subjective direction of an object. Lastly, we examined how well the subjective obstacle direction corresponded to the breeze stimulation applied to the forehead. Our findings suggest that the obstacle direction was indeed perceived through breeze stimulation on the forehead.

Future studies are as follows.

- To investigate the vertical subjective obstacle direction
- To make a breeze stimulation device which resembles a pair of glasses
- To confirm that the blind can actually avoid obstacles by using our device

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