# Design of a Wearable Walking-Guide System for the Blind

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## ABSTRACT
A wearable walking-guide system for blind people or visually handicapped is investigated and designed. The acoustic signal interface is employed for notifying the obstacle information to the user. For easy understanding, the front direction of user is divided to ten sectors and the system notifies the user to the sector in which the closest obstacle located. As a controller, the system has a microprocessor and a PDA. All of the information about obstacle in front of user is checked by three ultrasound sensor pairs and delivered to the microprocessor which analyzes the information and generates the acoustic signal for alarm. In order to avoid interference occurring by the alarm sound, the bone conduction(BC) headphone is used. It because it is set up behind ear and ear canal remained vacant to hear the environmental sound which the blind people use as one of essential signal for walking. In addition to the alarm signal, the system provides the user with guide voice using the PDA which has the text-to-speech (TTS) program for easy and safe guidance. Generally, almost of people who are blind has inclination to hide their disability, they reluctant to use the assistive device which reveals their disability. Therefore, we designed the wearable type of system and almost of the system are concealed in the clothes. We expect that blind people will use this system without any hesitation. According to the design concept, a prototype of the system was implemented and some experiments were carried out.

## Keywords
Walking-guide system, the blind, bone conduction, wearable system

## 1. INTRODUCTION
There are over than 180 thousands visually impaired or blind people in Korea and the number of these people is growing every year [1]. Although there are some differences, almost of the blind have serious trouble to walking and most of them use the white cane as an assistive device to help their walking. Some of people who are blind rely on the Guide Dog or other assistant device. But these assistive methods have some problems each and cannot be certain solution about the handicap.

Recently, with advanced electronic technology, new assistive devices for walking known as electronic travel aids (ETAs) were introduced. It is a NavBelt, Guidecane, VA-PAMAID, Laser cane, Guide Dog Robot, Mowat sensor, Sonicguide, KASPA, etc [2]-[8]. These devices import advanced control and measurement technologies such as robot, radar, ultrasonic scan, and so on. The core principles of these devices are detecting the obstacles which are the front direction of user with ultrasonic or laser scan and sending the guide information to the user for safe and correct moving.

The newly introduced devices are classified two groups; a handheld device and robot system. The handheld device such as Mowat sensor, Sonicguide, KASPA can be used with white cane and it helps the blind people's walking. The robot systems such as Guidecane, VA-PAMAID, Laser cane, Guide Dog Robot navigate by itself with motors and battery power. The user only follows the robot system to go somewhere and it is more convenient.[6]-[8]

Most of the electronic assistive devices, the acoustic signal or tactile stimulation is commonly used as information sending method[5]-[10]. The direction, distance from the obstacles are modulated as frequency, volume of the sound or stimulation signal. In case of the NavBelt developed by University of Michigan's Mobile Robotics Laboratory in USA uses the vector field histogram (VFH) and provides the user with a virtual acoustic panoramic image. It is reported that the acoustic image method is very effective and reduce misunderstanding rate[5][6]. But in place of the blind people, it is very hard to accommodate themselves to the acoustic image method. Because the headphone/earphone which delivers the acoustic signal blocks up their hearing for the environmental sound which is one of essential cues to go somewhere for the blind. Therefore, they are obliged to decide the surroundings only with the acoustic image.

Although many benefits from the devices, most of the Korean people who are blind or visually handicapped do not know about the electronic assistive devices or are reluctant to use it. The major reasons of that are the price, performance, inconveniency and discordance in Korean environment. In case of robot system, it may not work properly in Korea road situation. There are too many obstacles in the roadside and even though powered wheelchair can't go anywhere freely. Therefore, the robot system can be used in very limited area. In addition, it is very hard for the blind people to adapt to the new equipment. Most of the blind people are highly rely on the accustomed white cane for walking and they don't attempt to use any other new assistive devices.

Generally, the disabled people have an inclination to hide their disability because of a prejudice about disabled person. And they think that the use of assistive device will reveal their disability to others and it is very important reason why the blind dislike the use of new assistive device that anyone can see with curiosity.

Therefore, we have investigated the most appropriate electronic guide device which is suitable to the demand of blind people in Korea. We introduce a wearable walking-guide system which have both advantages of handheld and robot system. It can be used with the white cane together and the user will acquire more information from the device for safe and correct walking. We adopted a vest type of wearable guide system in which all the components of system located as shown in Figure 1. The proposed type is very convenient because the user get the benefit only wearing the vast. Moreover, all of the components are concealed in the garment and nobody knows their disability, we expect that they easily use the device with any hesitation. Basically, we use virtual acoustic image method as the user interface but we apply the bone conduction headphone which doesn't block the ear and the user can hear the environmental sound. For the convenient user interface, TTS technique is imported and voice guide is offered.

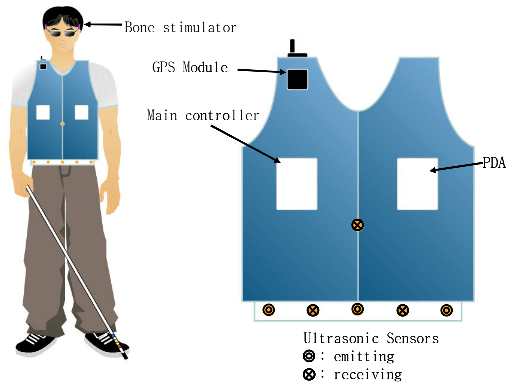


**Figure 1. The schematic diagram of the proposed vest type walking guide system.**

# 2. METHODS

## 2.1 System Design

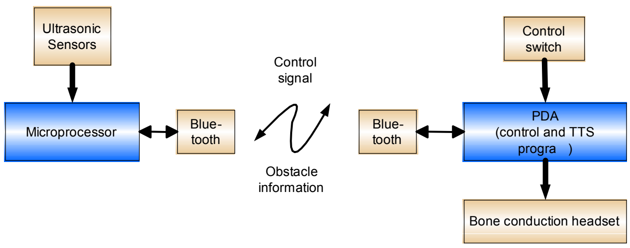


**Figure 2. The block diagram of the proposed system**

The wearable walking-guide system consists of four units such as ultrasonic sensors for detecting the obstacles, a small micro processor for controlling and analyzing information from sensors, A PDA in which system software is installed for generating the acoustic signal and the user interfacing and a bone conduction headset for delivering the acoustic signal. A Bluetooth module is set up at the microprocessor and the PDA for the data delivering respectively. The analyzed obstacles information at micro-processor and the control signal at PDA are communicated reciprocally. The block diagram of proposed wearable walking-guide system is shown in Figure 2.

## 2.2 Detecting obstacles

Generally, in previous ETA system, ultrasonic sensors scan 180˚ range about front direction. But people who are blind need the obstacle information in more narrow range for walking. Especially, at indoor situation, only small range of scan is required. At indoor place, if the user keep near distance with the wall, it is impossible to detect another necessary obstacle because the system always detects only the left/right wall by 180˚ range scanning. Therefore, we set up the scan angle to 125˚ at outdoor mode and 45˚ at indoor mode. The system was programmed that the user can choose the operating mode.

### 2.2.1 Area division

For user's easy understanding about obstacle location, we divide the front direction into ten areas– five areas in azimuth and two areas elevation as shown in Figure 3. Actually, the required obstacle information is the closest one. The system indicates the area where the closest obstacle is.

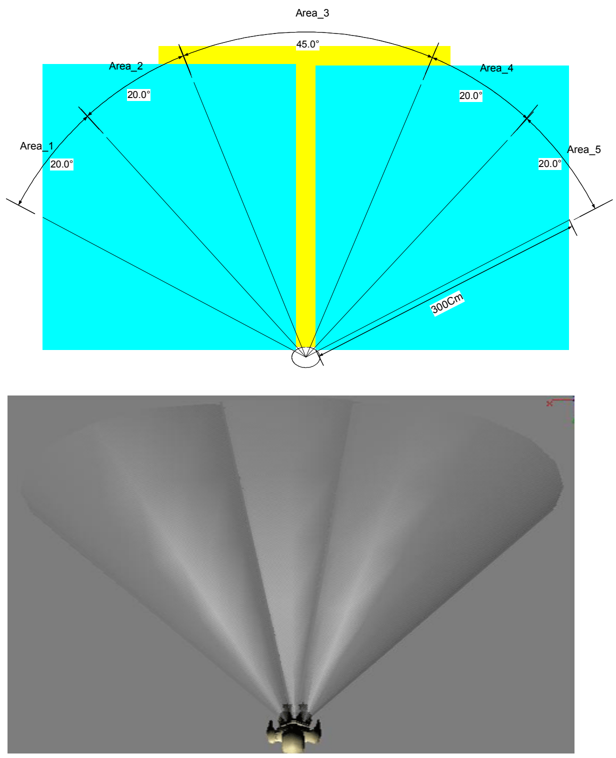


**Figure 3. Area division and ultrasonic sensors field**

### 2.2.2 Ultrasonic detection

As in Figure 3, three ultrasonic signal transmitters and receivers are used for detecting the obstacles in this system. Ultrasonic sensors are located at the front part of vest in Figure 1. One of receiving sensor is located at center side of the vast in order to calculate the elevation of the obstacle. All of transmitters emit the ultrasonic wave simultaneously and the receivers get the reflected wave. From the wave the only closest obstacle is calculated using TOF (time of flight) and ITD (inter-aural time difference) method. The detecting range and angle of each ultrasonic sensor(SRF10, Robot electronics) are 0.1 – 6 meters and 60˚ (azimuth and elevation) respectively.

### 2.2.3 User Interface

As a user interface, the stereo BC method is employed. Therefore, the warning and guide sound are transmitted to the user by BC vibrator which located at the behind ear. Because the ear canal of user is vacant, he/she can hear the environmental sound well not interfered by guide or alarm sound.

### 2.2.4 Stereo bone conduction test

When the audible frequency of vibration of skull is delivered into cochlea, human feels it as sound and we call this mechanism to BC sound. The volume of BC sound is depends on the stimulation amplitude regardless of stimulation position on the skull. Therefore, if the same vibration is stimulated anywhere on the skull, human feels the same sound pressure level. It means that human can't feel the stereo BC sound. But, practically, human feels the stereo BC sound. When the different amplitude of vibration with equal frequency are provided to the right and left cochlea simultaneously, human can distinguish the difference. Accordingly, the system uses the stereo BC sound for notifying the obstacle information.

To use the BC sound to the system we investigated the threshold of stereo BC recognition. The difference perception audiometry experiment was carried out with 6 person include 3 blind people with normal hearing. First, we carried out general pure tone audiometry and BC threshold test to confirm the hearing ability. And then we test the distinguish ability from the stereo BC stimulation.

In general audiometry, only one side of BC threshold test is executed. But we need both side of BC threshold and find out the minimum difference perception about stereo BC. So we carried out the experiment using two same kinds of audiometers as shown in Figure 4. We used two GSI61 diagnostic audiometers manufactured by Grason-Stadler Inc, USA.

**Figure 4. The stereo BC recognition audiometry experiment**

As the Table 1, people who take part in the experiment have the normal hearing. And average threshold of the perception the stereo BC is under 3dB. Therefore, we set up the difference of BC stimulation of both side of headphone to 5dB so as to display the direction of the obstacle.

**Table 1. The results of experiment for measuring the stereo BC recognition threshold**

| Frequency(kHz) | 0.025 | 0.5 | 1 | 2 | 4 |
|---|---|---|---|---|---|
| Average BC threshold (dB) | 10.8 | 16.5 | 13.8 | 22.8 | 18.3 |
| Average perception threshold for stereo bone stimulation (dB) | 1.5 | 1.7 | 2 | 2.8 | 2.8 |

### 2.2.5 Warning and Guiding Sound

The system represents the location of obstacle to BC sound. The distance, elevation and direction of the obstacle are expressed by frequency, interval and stereo BC sound volume respectively. For easy user understanding, the distance and elevation divided only two fields by 1.5meter and 1meter basis respectively. The frequency of BC sound is set to 0.5 kHz when the distance from obstacle is more than 1.5 meter. But the distance is closer than 1.5 meters, 1kHz of the BC sound is delivered. The interval of BC sound is set to 0.2 second when the elevation of obstacle is less than 1 meter. When the elevation is more than 1 meter, 0.5 second interval BC sound is generated.

We designed that the bone vibrator of obstacle's direction generates louder beep BC sound and the user become aware of the obstacle's direction only compare the left and right sound intensity. The volume of stereo BC sound for alarm is set up on the basis of the results of the stereo BC recognition audiometry experiments. Each BC stimulator in headset delivers 50 dB sounds according to the obstacle location as Table 2. Because the average stereo BC recognition threshold is less than 3 dB, we set up 5 dB sound differences are represented when the obstacle located in area 2 or 4.

**Table 2. The stimulation volume according to the obstacle location**

| Sector | | Area 1 | Area 2 | Area 3 | Area 4 | Area 5 |
|---|---|---|---|---|---|---|
| Angle (˚ ) | | 20 | 20 | 45 | 20 | 20 |
| BC stimulation (dB) | Left | 50 | 50 | 50 | 45 | 0 |
| | Right | 0 | 45 | 50 | 50 | 50 |

We tested the recognition of the 5dB sound difference in laboratory with 55 dB sound noise environment for 5 normal hearing persons. The result showed that they judged more than 95% correct score.

For more exact and convenient guide, the direction of obstacle is notified to the user by voice sound using text-to-speech (TTS) program concurrently.

## 3. IMPLEMENTATION and EXPERIMENT

### 3.1 Implementation of the system

According to the design specifications, a prototype system was implemented as shown in Figure 5. Three pairs of ultrasonic sensors are fixed in front part of a vest and a PDA and electric circuit including the microprocessor is keep in front pocket. All of electric wires are concealed in the lining of clothes. There isn't something particular in the external appearance; it may be difficult for someone to find out the concealed device.

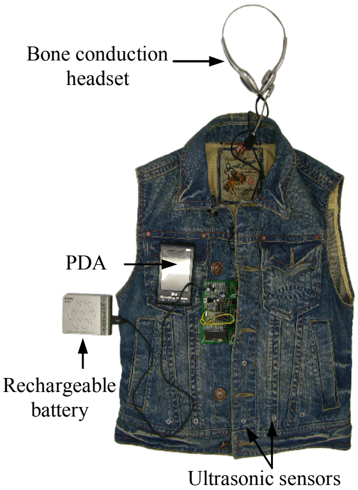


**Figure 5. The implemented prototype wearable walking-guide system**

Total weight including a vest is 1.76 kg and the user may feel that it isn't heavy. The current consumption of the circuit excluding a PDA is 65mA and it can be used for 147 hours with 9.6AH rechargeable battery. The PDA can be used for 2.5hours continuously; the continuous using time of the system depends on the PDA. Table 3 shows the specification of the implemented prototype system.

**Table 3. The specification of the implemented prototype system.**

| | | |
|---|---|---|
| Detecting Range | Distance | 300cm |
| | azimuth angle | 125° |
| | Elevation angle | 60° |
| Total weight | 1.57kg (including a 800g vest) | |
| Current consumption | 65mA | |
| battery | 7.9Ah, 12V (Enin Universal Lithium Battery, LG) | |
| Continuous using time | 147 Hour | |

## 3.2 Experiment

Using the prototype system, we carried out the detecting the obstacle. The prototype was worn to torso mannequin and one or two objects were located the front direction as shown in Figure 6. We tested that the prototype correctly judged the direction of the object.

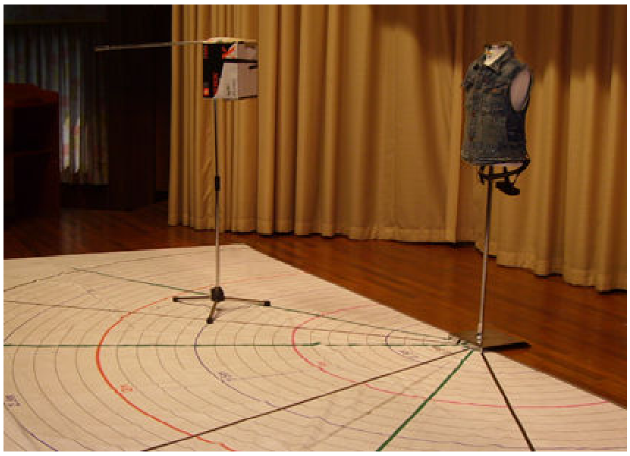

**Figure 6. The picture of object detecting experiment.**

When two objects were located in front of the mannequin, we examined that the prototype detecting the closest object. The results of the experiments are shown in Figure 7.

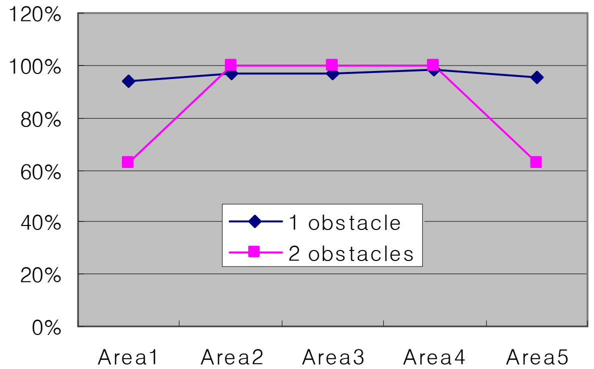


**Figure 7. The correct detecting rate from object detecting test**

From the results of test, we confirmed that the prototype has expected performance. The correct detecting rate was over than 95% when only one object is located. When two objects are in front of the system, the correct detecting rate about Area 1 and 5 become conspicuously low. We think one of receiving sensor which is located in opposite direction from the object couldn't detect the reflected wave and detecting error was occurred. If ultrasonic sensors are added, the error detecting should be disappeared. The prototype perfectly detected the object which is located at center position. Therefore, this system will be very effective at indoor situation.

## 4. DISCUSSION and CONCLUSION

A wearable walking-guide system for people who are blind or visually impaired is designed and implemented. Although some modification is required, the implemented prototype was showed very good performance through several experiments. After some modification of the system, the road test will be carried with people who are blind in near future. We have a plan to use the virtual acoustic image in the system and we expect that the user will acquire the obstacle information more effectively. And we will import the voice recognition method for convenient ordering.

The most required technique to this system is the GPS which permits the confirmation of the user location and navigation.

## 5. ACKNOWLEDGMENTS

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