31st Annual International Conference of the IEEE EMBS
Minneapolis, Minnesota, USA, September 2-6, 2009

Design and Analysis of Ultrasonic Monaural Audio Guiding Device for the Visually Impaired

Keonwook Kim, *Member, IEEE*, Hyunjai Kim, Gihun Yun, and Myungsoo Kim

Abstract—**The novel Audio Guiding Device (AGD) based on the ultrasonic, which is named as SonicID, has been developed in order to localize point of interest for the visually impaired. The SonicID requires the infrastructure of the transmitters for broadcasting the location information over the ultrasonic carrier. The user with ultrasonic headset receives the information with variable amplitude upon the location and direction of the user due to the ultrasonic characteristic and modulation method. This paper proposes the monaural headset form factor of the SonicID which improves the daily life of the beneficiary compare to the previous version which uses the both ears. Experimental results from SonicID, Bluetooth, and audible sound show that the SonicID demonstrates comparable localization performance to the audible sound with silence to others.**

I. Introduction

HUMAN being collects significant amount of daily living information based on the visual sensors especially within the personal space perimeter. In particular, the mobility is the one of the important part living which considerably affected by human vision system. Therefore, the visually handicapped inevitably reduce their mobility due to the lack of visual cognition.

In order to develop the assistive technology for the visually impaired, the purpose of the technology must be specified since the vision information is translated into the broad spectrum of our lives. Numerous approaches have been exercised to reduce the difficulties of vision impairment in terms of mobility, context aware, reading, etc. Mowat sensor[1], laser cane[2] and Navbelt[3] are representative of the assistive devices. The other devices, MiniGuide[4] and UltraCane[5], became commercialized.

The mobility can be divided into long range navigation, short range navigation and obstacle avoidance which could be used all together or any combination of the factors. The long range navigation is the routing plan of the personal journey based on the map image information. The short range navigation is destination finding and orientation via personal sight information. Lastly, the obstacle avoidance is near range path planning for safe walking. The purpose of this research is to develop the assistive technology for the short range navigation based on the ultrasonic communication.

The ultrasonic communication is rarely used in the area of information exchange since the carrier is vulnerable to the airborne environment such as distance and Line of Sight (LoS). On the contrary to the drawback, the sensitivity to the distance and obstacles provides additional information to the communication users in order to find the source over the short range. Provided that the ultrasonic transmitter is properly located, the receiver discovers the transmitter's relative position with certain searching movement.

The previous research by author proposed the binaural headset for the short range navigation which uses the human capability of localization based on the Interaural Time Difference (ITD) and Interaural Level Difference (ILD)[6]. The device provides reliable performance to the visually impaired since the methods used are exact imitation of aural function with beyond audible sound, ultrasonic. However the field experiments and interview showed that the binaural headset decreases the quality of life due to the continuous blocking of both ears.

This paper proposes the monaural headset for the localization. The device employs single ear and mainly find the transmitter via the level difference over the head turn and human movement. Our experiments demonstrates that, within the conventional visible range, the subject find the transmitter with comparable performance over the audio signal experiments.

II. Methods

A. Conventional Method

Currently conventional Audio Guiding Device (AGD) has been in use for short range navigation and deployed over the public facilities such as subways, crosswalks on the streets in Korea[7]. Conventional AGD is organized as two parts: remote controller and voice guidance. When the operating button of the remote controller is pushed, the operating signal is wirelessly sent to the voice guidance. The voice guidance which received the signal transmits the audio information through the loudspeaker of the voice guidance. The user of conventional AGD is able to take location information by listening to the audio signal. In addition, the user is able to estimate relative position by using biological capability of human which localize sound source.

The localization is helpful to the visually handicapped

Manuscript received April 7, 2009. This work was supported by the Seoul Olympic Sports Promotion Foundation, Ministry of Culture, Sports and Tourism of Republic of Korea under Grant S07-2008-08.

K. Kim is with the Department of Information Technology, Dongguk University, Seoul 100-715 Republic of Korea (phone: +822-2260-3334; fax: +822-2263-5889; e-mail: kwkim@dongguk.edu).

H. Kim is with IESystems Co., Ilsan Kyunggi-do 410-904 Republic of Korea. (e-mail: matrixhj@iesystems.co.kr).

G. Yun and M. Kim are with the Department of Information Technology, Dongguk University, Seoul 100-715 Republic of Korea (e-mail: cha741@dongguk.edu and bluekimms@dongguk.edu, respectively).

who travels to an unfamiliar destination. In spite of the advantage, conventional AGD has not been well recognized by officials of the Ministry of Health and Welfare and visually impaired due to the following factors. Firstly, the audible signal creates perceptible interference to the passerby. Secondly, over the conventional situations, unfocused multi sound sources provide low performance in localization by human due to the superposition of acoustic waves.

B. SonicID

SonicID consists of number of transmitters, which are installed at points of interest as shown in Fig. 1, and user receiver. The spatially distributed transmitters continuously broadcast the unique information and the user with receiver autonomously recognizes the nearby spatial information. Since the transmitter sends message spontaneously, the user intervention, such as pushing the button, is not required in this scheme.

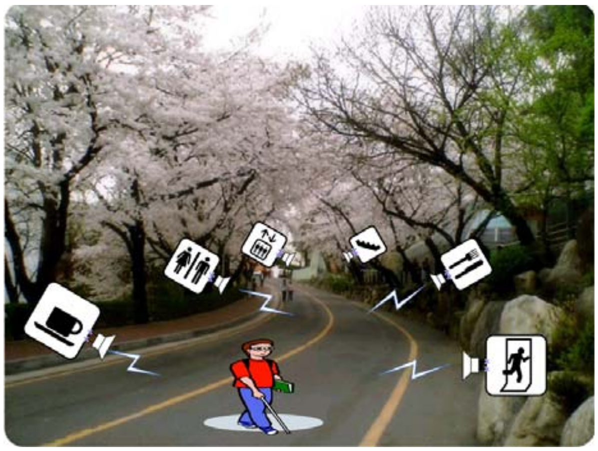

Fig. 1. Conceptual deployment of SonicID transmitters for the visually impaired.

SonicID utilizes ultrasonic wave as the medium of data transmission. The choice of ultrasonic spectrum is justified by the inaudibility, the propagation speed, and path loss of the frequency. The inaudibility provides the selectiveness of the communication between the transmitter and receivers. The relatively low speed of ultrasonic and high propagation loss simulate the acoustic waves over the air in order to localize the sound source by the user[6].

Amplitude Modulation (AM) is selected for the SonicID ultrasonic communication. Numerous modulation methods are available however the AM provides the sense of distance by producing the variable signal amplitude in terms of the Euclidian distance between the transmitter and receiver. Other methods such as Phase Modulation (PM), Frequency Modulation (FM), and digital modulations known as the better performance in Signal to Noise Ratio (SNR) generate the almost stationary output unless the system explicitly exploits the carrier strength to the signal[8]. The system configuration of transmitter and receiver is shown in Fig. 2 and note that the Envelop Detector (ED) is the demodulator for the AM.

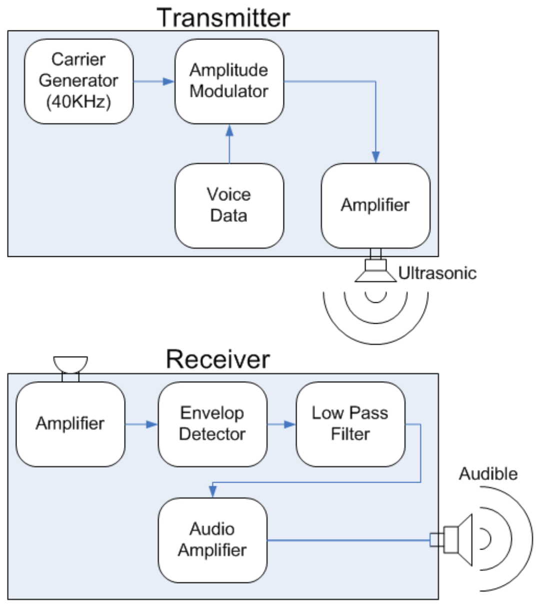

Fig. 2. System configuration of SonicID.

The human localizes the sound source by using interaural time & level difference and Head Related Transfer Function (HRTF) for the spectral cue[9]. The interaural factors are related to the both ears for resolving the azimuth of the sound source. The spectral queue is devised to overcome the ambiguity of the horizontal ear configuration in order to find the elevation of the source.

The proposing SonicID is for the single ear use only therefore the interaural factors cannot be applied for the localization. In addition, the HRTF is useless since the factor highly depends on the shape of ears & head and SonicID is add-on device to the ear and head. However, SonicID user finds the horizontal angle of the target by rotating head or body for searching purpose. The conventional single aperture radar performs identical motion for target detection. SonicID partially appreciates the aural system of the human however SonicID comes in a handy form for the visually impaired which create less attention. The actual SonicID system developed by the author is shown in below figure.

Fig. 3. Developed SonicID transmitter (above) and receiver (below)

III. EXPERIMENTS AND RESULTS

A. Hardware Performance

To analyze the hardware performance, the transmitter and receiver pair is evaluated in terms of signal strength over the distance and angle. In this experiment, the known signal 1 KHz is sent by the SonicID and the receiver with Oscilloscope measures the strength of the 1 KHz via the spectrum function. The results show that the aperture angle of the SonicID is ±10° which is preferable outcome. The small aperture provides the better resolution of the target detection with price of high sensitivity which creates frequent head movement. The perceptional distance of developed hardware is limited up to the 2 m by given experiment. The small functioning range is due to the use of low power ultrasonic transmitter and may increase the distance by improvement of the transmitter. However, provided that the SonicID user is within the 2 m range, the user easily localizes the transmitter since the exponential increase/decrease of the signal amplitude like conventional sound. Fig. 4 shows the signal strength over the distance between transmitter and receiver.

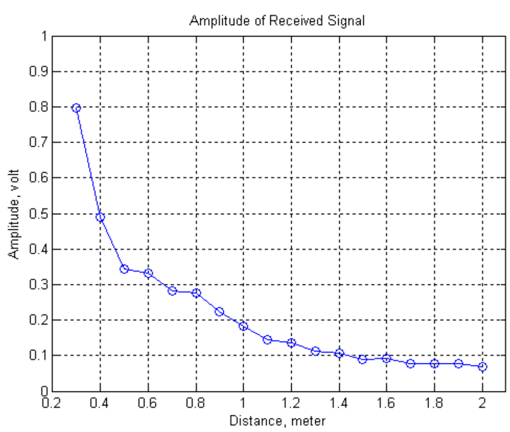

Fig. 4. Amplitude of the received signal over distance between transmitter and receiver.

B. Field Experiments

Over the six subjects who do not have visual handicap with blindfold, three experiments are performed to observe the comparable performance of the SonicID. In each experiment, the randomly and spatially distributed three transmitters, which broadcast different information respectively, should be identified by location and information. Three experiments are executed at indoor environment for SonicID, audio speaker, and Bluetooth correspondingly. Note that the localization is performed by human from the given audible information. The experiment is depicted in Fig. 5 below.

The experiment result shows that the Bluetooth (RF method) does not provide any localization information to the user. Within the certain range, the Bluetooth delivers the constant level of sound therefore the user lost the orientation to the target inevitably. The Radio Frequency (RF) demonstrates the exponential decreasing of the signal strength over the distance as well however the communication system automatically controls the gain and/or the modulation method is robust to the strength[10]. While the RF based SonicID is feasible, the ultrasonic is favorable due to the high uncertainty of the RF signal against the environments[11].

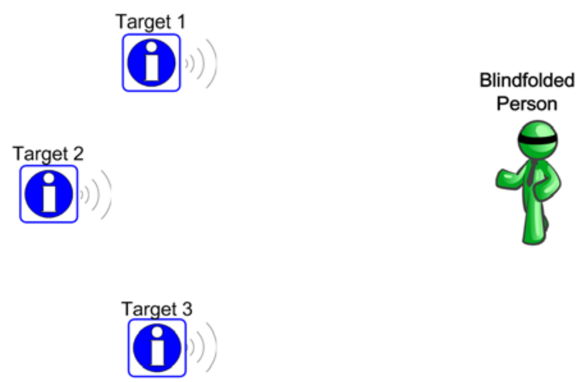

Fig. 5. Field experiments of hardware (SonicID, audio speaker, and Bluetooth)

TABLE I
FIELD TEST OF SONICID WITH OTHER DEVICES

Person #	SonicID	Speaker	Bluetooth
Subject 1	22.61	21.25	∞
Subject 2	27.14	15.14	∞
Subject 3	17.25	10.53	∞
Subject 4	19.84	8.33	∞
Subject 5	15.34	14.57	∞
Subject 6	24.62	25.97	∞
Average	21.13	15.94	N/A
Variance	4.49	6.64	N/A

∞ means not find target and unit in second

SonicID presents comparable performance to the audible speaker with 33% extra time to find the target. Furthermore, the SonicID results have less statistical distribution than speaker's one. Both consequences and motion analysis of the subject conclude that short working range of the SonicID increases the navigation time to arrive at the certain proximity but once within the range high directivity of the device decreases the time to reach the target.

One of the interesting facts from the experiments is that the SonicID is highly responsive to the obstacles. Any object located between the transmitter and receiver disturbs the information transfer which results in no communication at all. On the contrary, the audible signal from the speaker can be perceptible even with significant blockage of the path. This phenomenon of SonicID is due to the characteristics of the ultrasonic carrier which are high directivity and low diffraction than audible sound. This feature of the SonicID is desirable for the visually impaired to find any obstacle in-between the devices. Further study is required to analyze the communication capability of the SonicID in various situations. The actual experiment is shown as below.


Fig. 6. The actual SonicID experiment

IV. Conclusions

In this paper, novel device named SonicID is presented for visually impaired in order to localize and identify the transmitters located at point of interest. The proposing system utilizes the ultrasonic carrier for short range communication with variable signal strength over the distance. The localization is performed by human with monaural SonicID headset based on the given audio from the device which is equivalent to the human aural function does. The experiments show that the SonicID provides the comparable information to the human ear similar to the audio sound with small form factor creating less attention.

The assistive technology described in this paper present many opportunities for localization, identification, and context aware to the visually impaired and handicapped. The SonicID selectively provides localization information with multiple transmitters, thus improving the user mobility for in- and outdoor environment without creating the noise pollution to others. Furthermore, high LoS only communication of the system can increase the safety of the user by taking advantage of the ultrasound characteristic. Further work will involve analysis of more intricate localizations, including the obstacles and transmitter deployments. With the additional improvement of the SonicID transmitter over conventional AGD, assistive technology and services such as those described in this paper will be necessary to provide sufficient information to the visually impaired, the authors hope.

Acknowledgment

Special thanks go to Prof. Hyeseon Jeon from the Department of Physical Therapy at Yonsei University for many useful suggestions.

References

[1] N. Pressey, "Mowat sensor," *Focus*, vol. 11, no. 3, pp. 35-39, 1977.
[2] J. M. Benjamin, N. A. Ali, and A. F. Schepis, "A laser cane for the blind," *in Proc. San Diego Biomedical Symp.*, vol. 12, pp. 53-57, 1973.
[3] S. Shoval, J. Borenstein, and Y. Koren. "Auditory guidance with the Navbelt-a computerized travel aid for the blind," *Systems, Man, and Cybernetics, Part C: Applications and Reviews, IEEE Transactions on*, vol. 28, no. 3, pp. 459-467, August 1998.
[4] MiniGuide, GDP Research co., Available: http://www.gdp-research.com.au
[5] UltraCane, Sound Foresight Ltd., Available: http://www.batcane.com
[6] G. Yun, H. Kim, and K. Kim, "Audio Guiding Device based on Ultrasonic for Visually Handicapped," *RESNA 2008 Annual Conference*, Washington, D.C., USA, June 2008.
[7] Standard of Audio Guiding Device for Visually Handicapped, *Telecommunication Technology Association*, TTAS.KO-06.0046/R3, 2007.
[8] S. Haykin, *An introduction to analog and digital communications*, John Wiley & Sons, Inc., 1989.
[9] W. M. Hartmann, "HOW WE LOCALIZE SOUND," *Physics Today*, vol. 11, pp. 24-29, 1999.
[10] J. G. Proakis, and M. Salehi, *Communication Systems Engineering*, Prentice-Hall, 2002.
[11] E. Miluzzo, X. Zheng, K. Foder, and A. Campbell, "Radio Characterization of 802.15.4 and Its Impact on the Design of Mobile Sensor Networks," *EWSN 2008*, pp. 171-188, Bologna, Italy, January 2008.