LaneMate: Car Sensing System for the Deaf

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Abstract
Recently, while many assistive technology systems for the disabled have emerged with the advancement of the Information Technology (IT), there are not many solutions for people with hearing impairment. This study aims to design and develop an assistive technology system to help the deaf adopting the process of human-centered design. First of all, we conducted an interview with people with hearing impairment to find their needs in daily situations, and one of the core problems was related to their walking in the street with cars approaching behind them. To resolve this problem, we developed a prototype of the car sensing system called *LaneMate* using Arduino platform. We tested the prototype with four subjects, and the responses were mostly positive. Overall, this research suggests the possibility of developing an affordable assistive technology system that helps the daily activities of people with hearing impairment.

Author Keywords
Deaf; Hearing Impaired; Assistive Technology; Arduino; Mobility; Car Detection; User Testing.

ACM Classification Keywords
H.5.2. Information interfaces and presentation (e.g., HCI): User Interfaces;

Introduction

With the development of IT and the improvement of the public awareness of people with disabilities, the life of many disabled people have improved greatly. Despite such improvement, assistive technology systems for people with hearing impairment are relatively lacking compared to the solutions for the blind people. With a broad aim to develop an "assistant devices for the deaf", we conducted an interview with two deaf people, and found the need of assistive systems supporting them walking safely along a street due to poor road conditions in Korea.

Seoul street statistics [3] indicate that 39.8 % of the street is a one-lane narrow road and most of them are side streets that do not have a clear distinction between a sidewalk and a street. On such a street, pedestrians should be careful about cars at all times. However, there are a lot of accidents because of the nature of streets in Korea. According to the Korean Road Traffic Authority's statistics [2], 35 % of traffic accidents happened on roads with no distinction between a sidewalk and a street, which have widths less than 6 m. This specific traffic condition in Korea endangers people with hearing impairment who cannot detect car movement when it is out of sight.

Most deaf people feel discomfort walking along a road that coexists with a street since they cannot recognize the car at the rear rapidly, which causing even physical, and psychological pains. Focusing on this problem, we aim to suggest a technological solution that recognizes a car at the rear fast.

The purpose of this research is two-fold. The first goal is to develop an assistive technology system for the deaf through the process of human-centered design. The second goal is to design an affordable assistive technology system that can be easily distributed and used by people with hearing impairment.

Related Work

In this section, we present and discuss four research studies that focus on assistive technology systems for people with visual impairment and hearing impairment. They have similar conceptual factors with our research.

One research uses a 3D Time-of-Flight (TOF) camera to make an Object Detection System for the blind. The camera gets the depth information of the objects and transmits it to the blind using a 2D diaphragm. This research shows the potential of TOF technology used for assistant systems, but not considering the usability and mobility issues [7]. Another research uses an ultrasonic sensor hung on the waist of a vest to sense objects, and from the measurements the location of objects can be transmitted to the bind with a Bone Conduction Headphone. Even though the system partly considers users' convenience, it is hard to use in real life because of the weight of the device [5].

There is also a study that calculates the detection range of an ultrasonic sensor, and finds the best arrangement to detect all objects with 8 ultrasonic sensors. Using both vibration and sound, this paper focuses on the process of telling the direction of where to go rather than the location of the objects. Also, the function notifying the direction of the destination using GPS (Global Positioning System) makes visual impaired people walk outside by themselves [6].

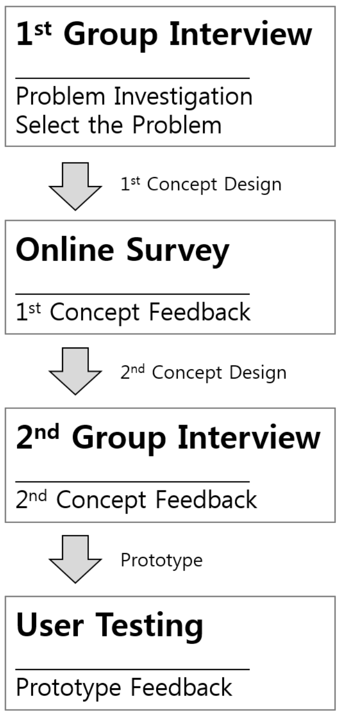

Figure 1: Methodology Overview

The last relevant study produced a handheld device for the blind and the deaf. This device gives auditory and tactile feedback when a front ultrasonic sensor detects an object. However, since it should be held by a hand consistently, the usability worsens [1].

Methodology

By adopting the process of human-centered design [4], we put a high emphasis on identifying users' needs and on receiving feedback from them in iterative ways. Figure 1 presents the overall research process from problem identification to user testing. The first group interview focused on finding the needs for people with hearing impairment. The research theme, "Car Sensing System for the Deaf" emerged from this interview. Hearing impaired people do not have the ability to detect the car's presence when it is behind them, since they cannot hear the sound of the car. To solve such an inconvenience in their daily situations, we sketched a simple concept design.

The online survey was conducted to gather more information about the inconvenience and feedback for the first concept design. We made the second concept design based on the feedback from the online survey. In the second group interview, the subjects gave feedback for the second concept design and discussed the functionality and usability of our product. Then, the prototype for the final design was made with feedback from the user testing with four deaf people.

First Group Interview: Problem Identification

For the first group interview, we visited the Pohang Association of the deaf and had unstructured interviews with two deaf people to openly find any problems that they encounter in daily situations. One interviewee was a 35-year-old man, and the other was 45-year-old woman. They mainly talked about the inconvenience from the lack of the ability to detect background information. From the interview data, we categorized the type of the inconvenience to (a) the discomfort from the internal environment and (b) the discomfort from the external environment. The former usually occurred in the house setting and was caused by the signal from familiar people or machines such as a baby crying and alarm sounds. The latter usually occurred on unfamiliar streets and was caused by unpredictable signals or anything beyond one's ken such as vehicles, pedestrian signs, car horns, and auditory signals from public transportation.

For the former problem, there are already various preinstalled assistance systems for hearing impaired people to notice such signals in the house settings. On the other hand, there is no popular, well-used aid for the latter problem. Therefore, we decided to solve problems in the external environment and set up the goal suggesting a solution concerning hearing impaired people not being able to detect cars.

First Concept Design

A car is an unfamiliar and unpredictable factor from the external environment. For the first concept design, we considered a mobile device that can be carried around by deaf users. For the mobility of the device, we tried to make the concept design with minimum components specialized to "Car Sensing". The device has two parts, "Car Detection" and "Feedback." (Figure 2, 3)

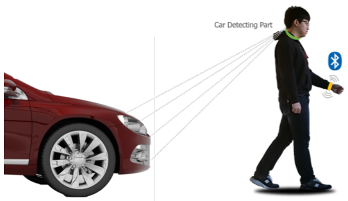

Figure 2: The First Concept Design

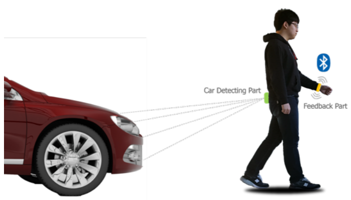

Figure 3: The Second Concept Design

Car Detecting Part

The Car Detecting Part is composed of ultrasonic proximity sensors, a sound analog sensor, Bluetooth modules, a microprocessor, and a case. The Car Detecting Part is placed on the user's shoulder with sensors facing the rear. The ultrasonic sensor measures the distance between the user and the object, and the sound sensor measures the loudness of the ambient sounds. The microprocessor checks two conditions to recognize the presence of the car at the rear. The first condition is that the measurement by the sound analog sensor is larger than a specific value. This is the situation when a loud noise like a car horn is made around the user. When the first condition is satisfied, the microprocessor checks the second condition, which is whether the value measured by the ultrasonic proximity sensor is in a range of 30 cm to 200 cm. If the two conditions are satisfied, we can infer that a car is behind the user, so the microprocessor sends the signal to the Feedback Part through the Bluetooth.

Feedback Part

The Feedback Part is composed of vibration motors, a Bluetooth module, a microprocessor, and a case. This part is worn on one's wrist. When the Bluetooth module receives a signal, the microprocessor runs vibration motors. With the vibration from motors, the user can notice and avoid a car.

Initial User Feedback

We contacted the deaf student society in Daegu University in South Korea to gather initial feedback for the first concept design. We conducted the online survey using the Google form, and 6 deaf students completed the survey. Overall, the students preferred tactile feedback to visual feedback. For the Car Detecting Part, they were skeptical that it was located on the neck of the user because of the wearing discomfort. For the Feedback Part, that is the body part to get feedback, they preferred the wrist. Also, one of them gave the opinion that it would be better if the directional information of a car could be informed.

Second Concept Design

Through the result of the online survey, we redesigned the Car Detecting Part into a semi-permanent form attached to a bag, not a separate form worn on the neck. The condition that the microprocessor detects a car also changed. Through an experiment where the sound of the car horn was measured with a sound analog sensor, we could observe that the measurement for the car horn shows constant high decibel for a long time. Based on the result, we changed the condition to sound that is larger than a specific value and is kept constant for a specific interval.

Formative Feedback Session

We proceeded to have the formative feedback session through the second group interview with six deaf students in the deaf society and listened to their opinions about the second concept design and experiences they actually had. For the bag-attached-form, they were skeptical about the form and functions since they do not always carry a bag. They suggested a clip form that can be attached anywhere and is detachable.

We also considered detecting the direction of a car with several ultrasonic sensors arranged horizontally, even though the size could get larger. However, the students said it did not have to be bigger for the additional function. If they could only know whether the car is

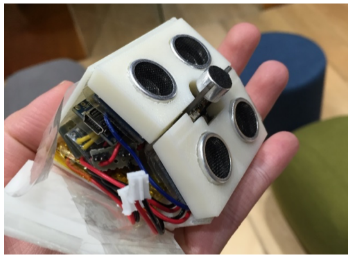

Figure 4: The Prototype for Car Detecting Part

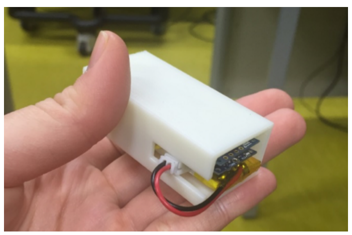

Figure 5: The Prototype for Feedback Part

Figure 6: User Testing with a Car Model

behind them or not, they would turn around and know the direction of the car. Additionally, one of them said the condition we set was insufficient since there were many situations where a car did not ring a horn and instead waiting for pedestrians to notice the car and step aside.

Prototyping

Based on the opinion of the deaf, we decided not to make the supporting part attached to a bag. However, with the change of the design to clip form, the Car Detecting Part could not be fixed perfectly. Moreover, it was difficult to get reasonable values from an ultrasonic sensor when the angles between each sensor warped a little. Therefore, we changed the design to increase the operation range with the vertical arrangement of two ultrasonic proximity sensors and made the case based on the design. Additionally, the condition in the algorithm changed. Based on the interview, a new condition that an object behind the user for a long time with a constant distance was added. Therefore, even when a car without a horn waited behind the user, the user could notice the presence of a car. We used Arduino to design the circuit, and with the 3D printer, we made the external case and covered it. (Figure 4, 5) Figure 7 and Figure 8 show the flow charts of the device.

User Testing

We produced the prototype with Arduino, and conducted user testing with four deaf students at Daegu University. We used a car model, not a real car for safety reasons to make users understand the functionality and the usability of the prototype. The model was made of the foam board in a size similar to a real car as shown in Figure 6. The participants, in general, showed positive responses about the functionality of the device, and gave feedback for the improvement of the device.

For the Feedback Part, there was an opinion that the part was a little heavy to wear. There was some feedback for the time taken and detected distance. Specifically, it took a long time for detecting and signaling to the Feedback Part, and it gave the signal when the car model was too close. We modified some initial values of the code to solve this problem. There were also some opinions about the vibration. Some students said the vibration was too weak because of the gap between the vibration motor and the case. Others said it would be better if the intensity of the vibration could be modified by the users. For the size of the device, most participants said the Car Detecting Part was appropriate, but the Feedback Part was too large for be worn on the wrist. The feedback was taken for further research.

Conclusion

The goal of this research was to help people with hearing impairment to walk safely on the street, considering the poor road conditions in Korea. We designed the car sensing system called *LaneMate* that can solve the problem, and improved it with consideration of the convenience and usability through iterative processes. Even though the prototype was not made with the perfect form factors, users were satisfied with the device concerning the factor of its functionality, and this made us confident that the improved device would help the deaf walk safely in an external environment.

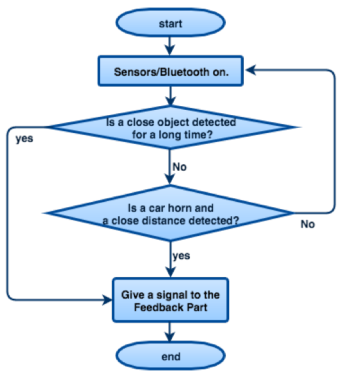

Figure 7: Flow Chart of Car Detecting Part

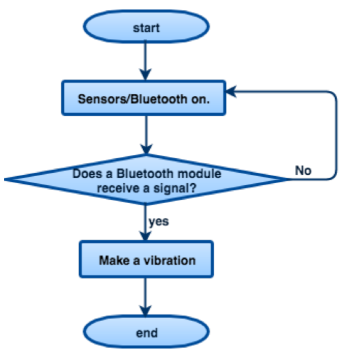

Figure 8: Flow Chart of Feedback Part

For further research, there is a need to design a product with better sensing parts and a design considering convenience. Also, the error rates for sensing should be corrected with more testing, and additional research is needed to prove the functionality of the proposed system. In the near future, with the development of the depth camera technology, the size of the depth camera will become small enough to be carried. Then, we plan to incorporate the research for receiving additional information about the approaching object, and replacing ultrasonic proximity sensors with a camera for further improvement of the proposed system.

The limitation of our research should be noted. First, we made the product using the Arduino and the Printed Circuit Board (PCB) for prototyping, but this might have provided with less efficiency, safety, and mobility. This can be solved by using dedicated processors and the PCB. Another limitation of the research is the lack of reliability testing. Since this device is directly related to the safety of users, a reliability testing should be done strictly with the control of variables. However, using a real car and meeting the deaf frequently are not easy, so it is challenging to do reliability tests in real contexts. Nonetheless, we believe that this study has demonstrated the possibility of developing an affordable assistive technology system for people with hearing impairment, which can help their safely in daily life.

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Reference

1. Mahdi Safaa A., Muhsin Asaad H. and Al-Mosawi Ali I. 2012. Using Ultrasonic Sensor for Blind and Deaf persons Combines Voice Alert and Vibration Properties. *Research Journal of Recent Sciences*, 1(11), 50-52 (2012)
2. Korean Road Traffic Authority, Traffic Accident Statistics
3. Seoul Metropolitan Government. Statistical Yearbook of Road Counts, 2014.
4. IDEO.org. 2015. The Field Guide to Human-Centered Design (1st. ed.)
5. Chang-Gul Kim and Byung-Seop Song. 2007. Design of a wearable walking-guide system for the blind. In *Proceedings of the 1st international convention on Rehabilitation engineering & assistive technology: in conjunction with 1st Tan Tock Seng Hospital Neurorehabilitation Meeting* (i-CREATe'07). ACM, New York, NY, USA, 118-122. DOI=http://dx.doi.org/10.1145/1328491.1328523
6. Jin-Hee Lee, Sukhyun Lim, Eun-Seok Lee, and Byeong-Seok Shin. 2009. An Outdoor Navigation System for the Visually Impaired Persons Incorporating GPS and Ultrasonic Sensors. *Journal of KISS :Software and Applications* 36.6 (2009): 462-470.
7. Limin Zeng. 2012. Non-visual 2D representation of obstacles. SIGACCESS Access. Comput. 102 (January 2012), 49-54. DOI=http://dx.doi.org/10.1145/2140446.2140457