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Care4HIP: an embedded system design for discerning hear-impaired people in traffic

Care4HIP: trafikte duyma engelli kişileri fark etmek için gömülü bir sistem tasarımı

Yazar(lar) (Author(s)): *Kemal AKYOL[1], Abdulkadir KARACI[2], Muhammet Emin TİFTİKÇİ[3]*

ORCID[1]: 0000-0002-2272-5243

ORCID[2]: 0000-0002-2430-1372

ORCID[3]: 0000-0001-7954-0816

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Care4HIP: An Embedded System Design for Discerning Hear-Impaired People in Traffic

Care4HIP: Trafikte Duyma Engelli Kişileri Fark Etmek İçin Gömülü Bir Sistem Tasarımı

Highlights

- *Care4HIP consists of three main modules including the server, mobile and embedded system.*
- *Haversine Formula presents the positional distance between the embedded system and the hearing-impaired person.*
- *Care4HIP detects the hear-impaired people in traffic.*
- *Care4HIP finds the direction of the hear-impaired person with respect to the vehicle.*

Graphical Abstract

This study focuses on discerning the hear-impaired people in traffic. The proposed system in this study provides a safe environment for the hear-impaired people living in big cities and thus facilitate their lives.

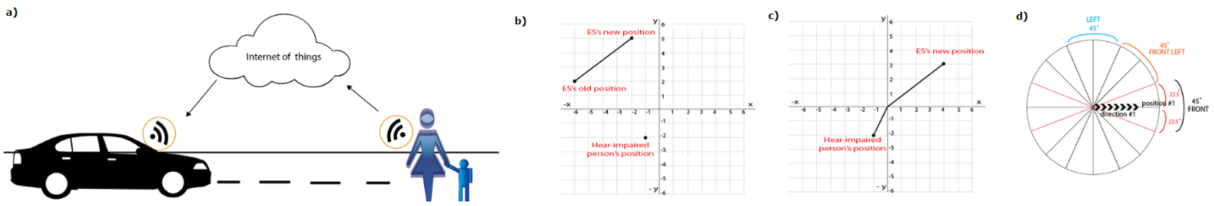

Figure. a) Overview of the proposed study b) The angular difference between the new and old position of the embedded system, b) the angular difference between the new position of the embedded system and the position of the hear-impaired person c) Determining the position of the hear-impaired person relative to the embedded system.

Aim

The aim of this study is to present an embedded system that discerns hear-impaired people living in big cities and thus facilitate their lives.

Design & Methodology

There are three main modules in the proposed system; One is the embedded system side which sends its location information to the server. The second one is the mobile side which sends the location information of the hear-impaired person to the server. The other one is the server side that calculates the distance between the vehicle and the hear-impaired person, and also finds the direction of the hear-impaired person with respect to the vehicle.

Originality

By considering the literature, it is obviously seen that there is no study aiming to eliminate the negativities faced the hear-impaired people in streets where there is heavy traffic. At this point, the Care4HIP offers an original and practical solution.

Findings

The experimental tests carried out on the 8 directions show that the Care4HIP successfully runs with 100% accurate detection.

Conclusion

This study focuses on the problem which detects the hear-impaired people in traffic. Experiments show that Care4HIP is reliable. Besides, the survey results indicate that Care4HIP is a valuable system.

Declaration of Ethical Standards

The author(s) of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

Care4HIP: An Embedded System Design for Discerning Hear-Impaired People in Traffic

Araştırma Makalesi / Research Article

Kemal AKYOL[1*], Abdulkadir KARACI[1], Muhammet Emin TİTİKÇİ[2]

[1]Kastamonu University, Department of Computer Engineering, Kastamonu, 37150, Turkey

[2]Resital Bilgisayar Eğitim, Turizm, Gıda, Tekstil Sanayi ve Ticaret Ltd. Şti., Kastamonu, 37210, Turkey

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ABSTRACT

Embedded systems are designed for many different applications including navigation, thief warning, smart home, tracking. We designed an embedded system, Care4HIP, Care for Hearing Impaired People, which presents a solution for discerning the hear-impaired people in traffic. Our solution aims that drivers will be able to notice the hear-impaired people. Care4HIP calculates the locational information of these people which close to the vehicle and determines the direction of these people with respect to the vehicle. Location information refers to the latitude and longitude data of each person's location. The proposed system involves server, mobile and embedded system based applications. We think that Care4HIP offers an original and practical solution with minimal overhead for hear-impaired people.

Keywords: Hearing-impaired people, traffic, embedded system, Raspberry Pi 3+.

Care4HIP: Trafikte Duyma Engelli Kişileri Fark Etmek İçin Gömülü Bir Sistem Tasarımı

ÖZ

Gömülü sistemler, navigasyon, hırsız uyarısı, akıllı ev, izleme gibi birçok farklı uygulama için tasarlanmıştır. Trafikte işitme engelli kişileri ayırt etmek için bir çözüm sunan Care4HIP, İşitme Engelli İnsanlar İçin Dikkat, gömülü sistemini tasarladık. Çözümümüz, sürücülerin işitme engelli insanları fark edebilmesini hedeflemektedir. Care4HIP, araca yakın olan bu kişilerden gelen konum bilgilerini hesaplar ve bu kişilerin araca göre yönünü belirler. Konum bilgisi, her bir kişinin bulunduğu konumun enlem ve boylam verilerini ifade eder. Önerilen sistem sunucu, mobil ve gömülü sistem tabanlı uygulamaları içerir. Care4HIP'in duyma engelli kişiler için minimum ek yüke sahip yeni ve pratik bir çözüm sunduğunu düşünmekteyiz.

Anahtar Kelimeler: İşitme engelli bireyler, trafik, gömülü sistem, Raspberry Pi 3+.

1. INTRODUCTION

Hearing impairment or disability is a global health problem [1]. Hearing disability is an individual's inability to use verbal language functionally in daily life due to a problem in the hearing system [2]. According to the World Health Organization (WHO), hearing loss is one of the major diseases that increase the global disease burden. In general, this situation is becoming more important than ever in society. Hearing loss is not only due to the aging of the population, but also because young people are increasingly spending time in activities that expose them to excessive noise in their free time [3]. According to the WHO 2019 data [4], 6.1% (466 million people) of the world population suffer from hearing loss. 93% (432 million) of them are adults and 7% (34 million) are children. In addition, the number of hearing impaired people is estimated to increase to 630 million in 2030 and 900 million in 2050. According to TurkStat, Turkey Disability Survey in 2002, the proportion of disabled hear-impaired population in Turkey is 0.4%. A survey on problems and expectations of disabled people which performed in 2010 by TurkStat showed that 26.8% of the hearing impaired people aged 15 years and over are from working class [5].

People with disabilities face many difficulties in business and social life [6]. Similarly, the hear-impaired or deaf people try to overcome these difficulties in social life. Hear-impaired people face the difficulties of life, especially in big cities. One of these difficulties is that they cannot discern the vehicle behind them while walking on the street and therefore deadly accidents occur.

When the literature is examined, there are few studies aiming at developing tools to contribute to the social life of the hear-impaired people. For example, Ando et al. [7] developed a system which detects the sounds coming from people and objects around hearing impaired people using Raspberry Pi and USB microphone, and that sends them to their mobile phones in writing. The system operates with 100% accuracy for applause and intercom, while it is with 80% accuracy for door sound. Furuhashi et al. [8] developed a wheeled robot that gives tactile warning in case of emergency for the hearing impaired people. The developed robot recognizes sounds such as fire alarms and gives tactile warning by hitting the

*Sorumlu Yazar (Corresponding Author)
e-posta : kakyol@kastamonu.edu.tr

hearing impaired person. Landicho [9] developed a mobile messaging application for visually and hearing impaired people to communicate with each other. In the developed application, the sound was converted to text or vice versa according to the obstacle situation of the user. Ertzgaarda et al. conducted a study on the prevalence and etiology of hearing impairment among primary school children in Tanzanian. They examined 403 children and screened those for hearing loss, and also they used otoscopy images on the children who failed the screening [10]. De Oliveira et al. evaluated the performance of adults having sensorineural hearing loss which is associated with speech perception [11]. Peddie and Kelly-Campbell investigated the hearing-impaired people in New Zealand whether and how used the internet to find hearing-related information with 11 participants having hearing impairment with various degrees [12]. Karmel et al. conducted an IoT based device for deaf, dumb and blind people using a Google API and Raspberry Pi embedded system. This system which has text to speech and speech to text modules provides an image to text conversion and speech synthesis [13]. Kim et al. examined the depression risk of the peoples in all age groups having hear-impairment. Hearing-impairment was conducted with Cox-proportional hazard model [14]. In addition, the studies in [15-17] focused on the appropriateness of educational contents, and the role of information technologies in the education of the hearing impaired or deaf people.

Unlike these studies, this paper proposed a solution for hearing-impaired people (HIP) in traffic. This solution is a simple and reasonable approach to recognize these people. The proposed study eliminates the negativities that may be encountered in the streets where there is heavy traffic, which is one of their many problems faced in social life. The main focus of the study is to determine the HIP in traffic and to contribute to the prevention of risky situations. For this purpose, an embedded system was designed for vehicles in traffic. The developed system can be explained as the calculation of the locational information coming from the hear-impaired person and the embedded system, and the activate the real time warning system considering the threshold limit value. It is thought that this system will be especially beneficial for the hear-impaired people and drivers in big cities. The hosting of information of the HIP in a centralized system, and accessing this information by the embedded system through the internet of things are the main procedures carried out in this study.

The rest of the paper is organized as follows; Section 2 presents the problem statement and its workflow process. After giving an overview of the proposed study, each procedure is explained in the sub-sections. Section 3 presents an experimental evaluation of the proposed study. Finally, Section 4 addresses the conclusion and future works.

2. EXPERIMENTAL DESIGN

HIP detecting system can be used by the related people with daily activities in city center, specifically. For this reason, we offer an embedded system design having a new technological infrastructure in order to carry out detection of hear-impaired people and feedback to driver in this study. There are three modules in this system; the one is the embedded system side which sends the location information to the server. The second one is the mobile side which sends the location information of the hear-impaired person to the server. The other one is the server side that calculates the distance and angle between the embedded system and the hear-impaired person.

In this section, we explain how to design the system, hereafter Care4HIP, step by step. Overview of the study, the connection schema of the embedded system, and the

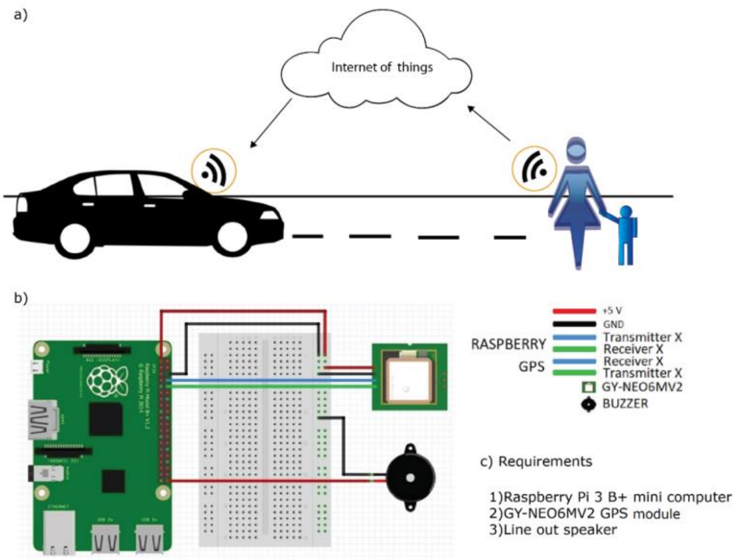


Figure 1. a) Overview of the proposed study b) Raspberry Pi 3+, GPS module and Buzzer connection schema, c) Requirements

requirements of the Care4HIP are illustrated in Figure 1. Each of the main steps is described in the following sub-sections, in detail.

2.1. System Design

The schematic design of the proposed study is introduced in Figure 2. According to this schema;

1) The embedded system connects to the server over an HTTP connection to send its location information (Figure 2, arrow 1).
2) The hear-impaired person connects to the server over an HTTP connection via mobile phone to send his/her location information. (Figure 2, arrow 2).
3) The server-side application detects the hear-impaired person who close to the vehicle and triggers the embedded system to alert (Figure 2, arrow 3).
4) The android programming was used to send the hear-impaired person's locational information while Python was used for both server side and embedded system side.

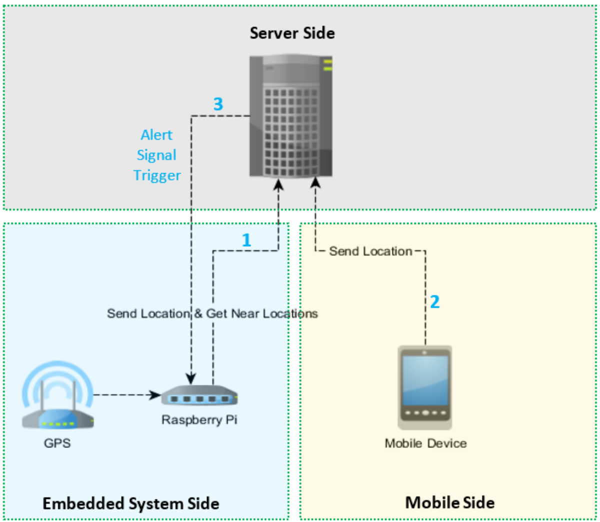


Figure 2. The schematic design of the proposed study.

In this system;

a) Positional information includes a latitude and longitude data (e.g., 41.99393, 34.92023).
b) All requests are performed with HTTP URL.

To initialize the system, first, the socket server application is started via port number 37037. Location information from the embedded system and mobile application are then sent to the server in every second.

2.2. Server Side

In this sub-secion, we explain the calculation process of positions retrieved from person's smart phone and the embedded system. The server side has three main tasks:

1) The server stores and updates the location and time information of the HIP continuosly.
2) The HIP who is close to the vehicle is ignored if the difference between the sending times of last position and previous position is less than the 5 seconds waiting time that is defined in the system settings. The reason for this is to prevent the system gives alert repeatedly for the same person.
3) When the location of any vehicle is sent to the system, the server sends the direction information of the HIP located near this vehicle to the embedded system.

Server-side socket programming was carried out with Python. The server queries if there are any hear-impaired individuals near of any vehicle. Figure 3 shows a list of locations of the HIP near the embedded system. Server side module checks the distance between the HIP and embedded systems by using the location information of both of them, and triggers the embedded system by performing the following two steps, respectively.

Step 1: Calculation of the distance of hearing-impaired person to the vehicle: Positional distance between the embedded system and hearing-impaired person was calculated using the latitude and longitude values of them on earth with the help of ***Haversine*** Formula coined by James Inman in 1835 [**18, 19]**. This formula is given in Pseudo Code 1.

Pseudo Code I. Convert the distance to the meter

begin
Input: latitude_1, longitude_1, latitude_2, longitude_2
R = 6378.137 // The radius of the world
distanceLatitude = latitude_2 x π/180 - latitude_1 x π/180
distanceLongitude = longitude_2 x π/180 - longitude_1 x π/180
a = sin(distanceLatitude/2) x sin(distanceLatitude/2) + cos(latitude_1 x π/180) x cos(latitude_2 x π/180) x sin(distanceLongitude/2) x sin(distanceLongitude/2)
c = 2 x atan2(sqrt(a), sqrt(1 - a))
d = R x c
return d x 1000 // meter value
end

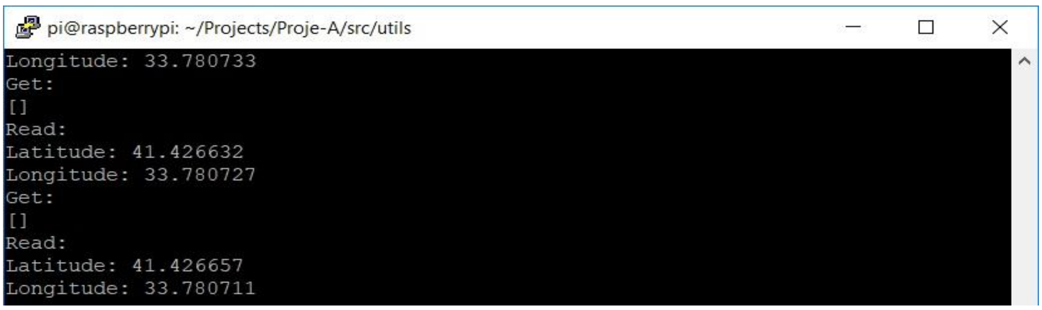
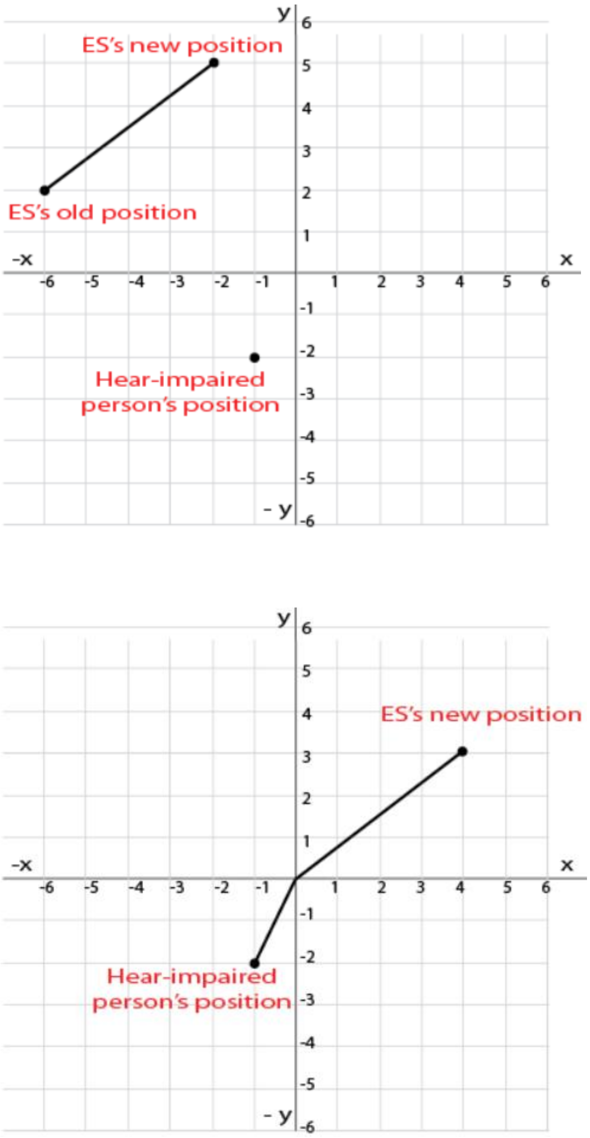


Figure 3. List of locations of the HIP near the Raspberry Pi 3+ embedded system.

Step 2: Calculation of the position of hearing-impaired person to the vehicle: First, the angular difference of the previous and last position of the GPS module, which was obtained at one second intervals, is calculated using Equation 1 (see Figure 4a). Then, the embedded system is moved to the plane of origin 0 for each calculation.The angular difference of the hear-impaired person to the new position of the embedded system is then calculated using Equation 2 (see Figure 4b)

radians, the values in degrees are obtained by multiplying the angle values with (180 / π). For example, the angles of the embedded system and the hear-impaired person in Figure 4 were calculated as 45° and -108.43°, respectively. Then, the angular difference of the hear-impaired person to the embedded system was calculated by taking the difference of these two angles as seen in Equation 3.

$$\text{Hear} - \text{impaired\_person} - \text{the embedded system} = -108{,}43 - 45 = -153{,}43° \quad (3)$$



$$\boldsymbol{The\ angular\ difference\left(ES_{new_{position}}, ES_{old_{position}}\right)} = atan2\left(ES_{new_{position}}{}_x - ES_{old_{position}}{}_x, ES_{new_{position}}{}_y - ES_{old_{position}}{}_y\right) * \left(\frac{180}{\pi}\right)$$

(1)

Example:

$$The\ angular\ difference\left(ES_{new_{position}}, ES_{old_{position}}\right) = \text{atan2}(-2-(-6), 5-(2)) * \left(\frac{180}{\pi}\right) = 45°$$

$$\boldsymbol{The\ angular\ difference\left(Hear - impaired\_person, ES_{new_{position}}\right)} = atan2(Hear - impaired\_person\_x - ES_{new_{position}}\_x,\ Hear - impaired\_person\_y - ES_{new_{position}}\_y) * \left(\frac{180}{\pi}\right)$$

(2)

Example: $The\ angular\ difference\left(Hear - impaired\_person, ES_{new_{position}}\right) = \text{atan2}(-1-(4), -2-(3)) * \left(\frac{180}{\pi}\right) = -108{,}43°$

Figure 4. a) The angle difference between the new and old position of the embedded system, b) the angle difference between the new position of the embedded system and hear-impaired person's position.

The angular values that belong to these positions are calculated using the ***atan2*** function which is based on a mathematical calculation. The atan2 function calculates the angle of the given point from the polar arctan(y/x). This function is widely used in digital image processing applications **[20].** Since this function gives a value in

In cases where the angular difference is negative, 360° is added to this value and the angular difference is moved to the positive plane. Therefore, for this example, the angular difference is -153,43 + 360 = 206.57°. The direction determination of the hear-impaired person according to the embedded system was carried out via this angular difference. For this purpose, the calculations were made on 8 bows of 45° in the analytical plane. 22.5° tolerance was used to provide the required precision in these bows. After the distance and direction calculations, in case of the hear-impaired person exceeding the specified distance limit, the embedded system gives a warning sound with buzzer. In addition, the server sends the direction information of the HIP to the driver, such as 'FORWARD', 'FORWARD_LEFT', and also the embedded system notifies the driver by a sound in wav format. In Figure 5, it is assumed that the vehicle is in the center of the circle, and also it is moving in direction #1. The direction of the hear-impaired person in position #1 relative to the vehicle is "FRONT".

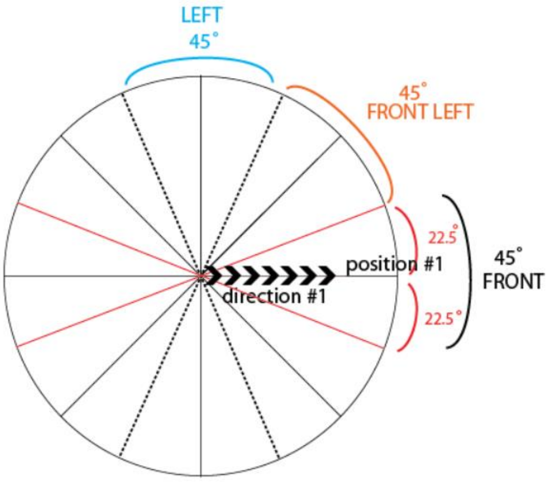


Figure 5. Chart showing the position of the hear-impaired person relative to the embedded system.

2.3. Mobile Application Side

As seen in Figure 6, in this module, which is developed with Java language in Android studio platform, after entering the user name and password, 'Start' button is pressed and user information and location information are continuously sent to the server every second. Figure 7 shows the location information sending from the mobile application to the server

2.4. Embedded System Side

The embedded system is located in the moving vehicle. This system consists of Raspberry Pi 3+, GY-NEO6MV2 GPS module and buzzer components. Raspberry Pi is a Linux-based, small-sized, low-cost device that can be used as a personal computer [**21**]. The GY-NEO6MV2 GPS module is used for location control and tracking in many applications, especially flight control systems. This module, which has high quality and sensitivity, is frequently used in applications requiring location information with GPS. It has a sensitivity of approximately 5 meters [**22**].

The application was developed with Python language in this study. The communication between the Raspberry Pi 3+ and the GPS module is carried out via serial connections on the RX and TX pins. To ensure this communication, these pins are mutually cross-linked. The current location information received from the GPS module and the associated embedded system ID's user name and password are sent to the server over the internet connection by embedded system.

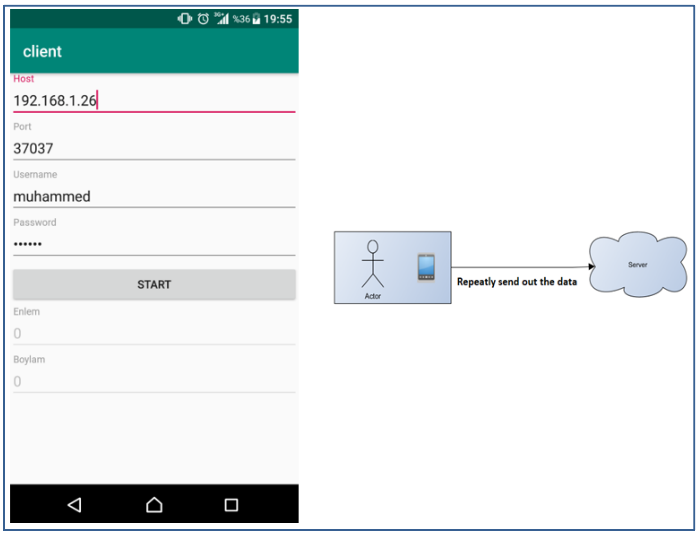


Figure 6. Launch screen for location sending in the mobile application.

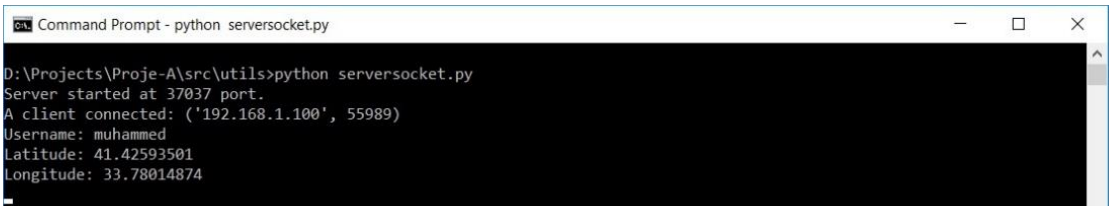


Figure 7. Listing the location information sent from the mobile application on the server.

3. EXPERIMENTAL EVALUATION

Assuming that the city inner speed limit is 60 km/h, the distance taken by the vehicle per second will rise to approximately 17 meters. Taking this information into consideration, it is ensured that the embedded system in the vehicle gives warning between 80 and 100 meters away. Under these conditions, the performance of the Care4HIP was tested with the 8 directions. The test results are shown in Table 1. The server calculated the distance and correctly determined the direction. The embedded system triggered the alarm circuit and also gave direction information in wav format from the speaker. When the actual and calculated direction information is examined, it can be said that the Care4HIP system runs successfully with 100% accurate detection.

Overall, it was accepted that this system operated under criteria below:

a) The mobile application was installed in the smart phones of the hear-impaired people and these people known use the program.

b) Vehicles have embedded system.

c) Drivers followed the speed rules and have a smooth internet connection.

In addition, we offered a questionnaire form based on the evaluation of the designed system. This form consists of 5 questions and it is 'Likert' scale type; Strongly Agree (5 scores), Agree (4 scores), Neutral (3 scores), Disagree (2 scores), Strongly disagree (1 scores). A questionnaire form was applied to 22 participators to evaluate the ***Care4HIP***. The average scores obtained from each participant's answers given to the questions are shown in Figure 8. As can be seen in this figure, 15 participants gave a positive opinion while 4 participants gave a negative opinion. In addition, the number of people who gave a neutral opinion about the designed system is 3. According to these evaluations, the majority of the participants had positive opinions about the overall Care4HIP system, while only a few of them had negative opinions

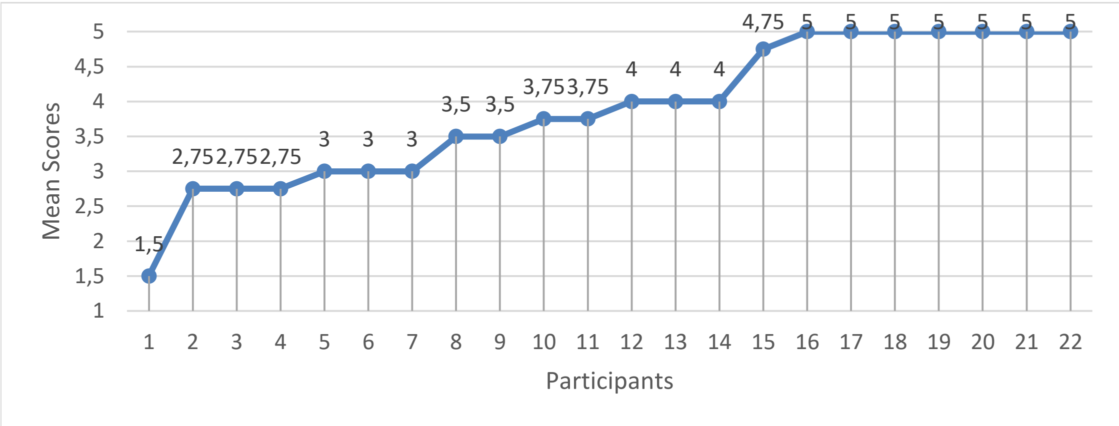


Figure 8. Mean survey score of the participants

Table 1. Calculations on the sample syntetic data

Tests	Distance	The first position of embedded system (latitude and longitude)	The last position of embedded system (latitude and longitude)	The position of hear-impaired person (latitude and longitude)	The angle of embedded system	The direction of embedded system	The angle of hear-impaired person	The angle between the hear-impaired person and the embedded system	Calculated direction	Actual direction
# 1	91.07177430876409	41.376605, 33.777010	41.37752517331584, 33.776200381633465	41.37671406927994, 33.776342777221075	-41.343069310199844	FORWARD_RIGHT	170.0427511237337	211.38582043393353	BEHIND_RIGHT	BEHIND_RIGHT
# 2	85.70187546057214	41.376605, 33.777010	41.37636188846356, 33.777308673314764	41.37673430627457, 33.77820661934061	129.14460373260013	BEHIND_LEFT	67.47405921151093	298.3294554789108	FORWARD_RIGHT	FORWARD_RIGHT
# 3	90.92476092121774	41.376605, 33.777010	41.37708821568443, 33.77611478622242	41.377560431182125, 33.77700294932325	-61.64085306415019	FORWARD_RIGHT	62.001468542648404	123.64232160679859	BEHIND_LEFT	BEHIND_LEFT
# 4	93.41053278488113	41.376605, 33.777010	41.37722518715341, 33.77756392297327	41.376430258841005, 33.777205803535324	41.769779609133494	FORWARD_LEFT	-155.7481818922849	162.48203849858163	BEHIND	BEHIND
# 5	99.26374153533541	41.376605, 33.777010	41.377334806424194, 33.77789823552199	41.377888709962335, 33.778829510862224	50.592238084682975	FORWARD_LEFT	59.25668325841786	8.664445173734883	FORWARD	FORWARD
# 6	93.50544380169437	41.376605, 33.777010	41.37659421803862, 33.7775991378127	41.37743413617591, 33.7776120121981	91.04846762898472	LEFT	0.8781691356589164	269.8297015066742	RIGHT	RIGHT
# 7	89.62601271551928	41.376605, 33.777010	41.37716222489058, 33.777331207937294	41.376599942785774, 33.778099154036525	29.96096290818471	FORWARD_LEFT	126.21119828016124	96.25023537197653	LEFT	LEFT
# 8	99.35525826192627	41.376605, 33.777010	41.37645947414782, 33.77692366280222	41.37595877691156, 33.7759390347071	-149.3203021334509	BEHIND_RIGHT	-116.95397669208361	32.36632544136728	FORWARD_LEFT	FORWARD_LEFT

# indicates the number of test.

Also, Figure 9 shows the frequency of responses of all participants to each questionnaire form. The first survey item asks whether the Care4HIP system is easy to use. When the answers given to this question are examined; while 12 participants stated that the Care4HIP was easy to use, only 5 participants expressed negative opinion and 5 participants expressed neutral opinion. In other words, more than half of the participants think that this system is easy to use. The second survey item asks whether it is quick to learn how to use the Care4HIP system. 12 participants gave positive opinion, 4 participants gave negative opinion and 6 participants gave neutral opinion. That is, more than 50% of the participants learned the use of the Care4HIP system quickly. The third survey item asks whether the Care4HIP system is useful. While 13 of the participants thought that this system was useful, only 1 participant thought that the system was not useful. The number of people who expressed neutral opinion is eight. That is, approximately 60% of respondents think that the Care4HIP system is useful, while only about 4.5% think it is not useful. The fourth survey item asks whether participants are satisfied with the Care4HIP system. While 15 of the participants expressed positive opinion, 2 of them expressed negative opinion and 5 of them expressed neutral opinion. In other words, nearly 70% of the participants are pleased to use the Care4HIP system. Only 9% are not happy with this system. The last survey item is about whether or not the participants would recommend Care4HIP to their friends. While 14 (more than 60%) of the participants stated that they could recommend this system to their friends, 1 (approximately 4.5%) of them could not recommend it, and 7 of them stated as neutral.

As seen in this table, there is a middle-level positive relationship (r = 0.674) between the answers of the participants to the items Q1 and Q4. There is a strong and positive correlation between all answers to other items (r> 0.70). These correlation values can be interpreted as an indication that the participants' answers to the questionnaire items are not random.

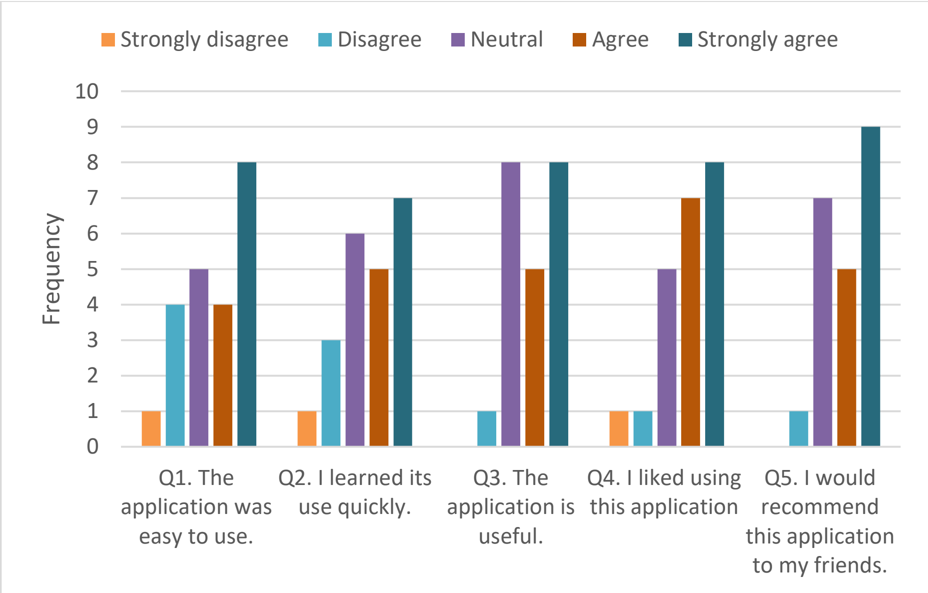


Figure 9. Feedback from the hear-impaired people

4. CONCLUSION AND FUTURE WORKS

This study focuses on detects the hear-impaired people in traffic. It is aimed to develop an embedded system that will contribute to the providing a safe environment

Table 2. Correlation analysis results between the answers given by the participants to the questions.

Items	Q1	Q2	Q3	Q4	Q5
Q1	1	.941**	.807**	.674**	.830**
Q2	.941**	1	,897**	.821**	.882**
Q3	.807**	.897**	1	.876**	.854**
Q4	.674**	.821**	,876**	1	.924**
Q5	.830**	.882**	,854**	.924**	1

** p< 0.01

especially for the hear-impaired people living in big cities and thus facilitate their lives. In this context, we designed three main modules in the proposed study: a) the server, which is the core beneficiary, calculates the distance and angle between an embedded system and hear-impaired person b) the mobile application, which sends the coordinate information of hear-impaired people to the server in traffic and c) the embedded system which sends its location information and also warns the driver according to the trigger information from the server. Therefore, in addition to making the driver of the vehicle more careful, it is very vital for the hear-impaired people. Care4HIP is quite important in terms of having a protective effect on the hear-impaired people's life, considering that 6.1% of the world population suffers from hearing loss and these people cause various traffic accidents.

Experimental results show that the system is reliable. In addition, the survey results show that the Care4HIP is a valuable system. More than half of the participants stated that Care4HIP is easy to use and quick to learn; More than 60% stated that this system is useful, and they are satisfied with the use of the system and can recommend it to their friends.

As future improvement, we intend to develop new functionalities and to adapt the application to new requirements best fitting for the hear-impaired people. A system that has stimulating signal to self via an electrode attached to the wrist to the person is among our aims in the future.

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DECLARATION OF ETHICAL STANDARDS

The author(s) of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

AUTHORS' CONTRIBUTIONS

Kemal AKYOL: Conceptualization, Validation, Writing - Review & Editing, Supervision, Project administration.

Abdulkadir KARACI: Conceptualization, Validation, Writing - Review & Editing.

Muhammed Emin TİFTİKÇİ: Software, Formal analysis, Resources, Data Curation

CONFLICT OF INTEREST

There is no conflict of interest in this study.

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