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Design and Implementation of Application for Mobile Accessibility of Hearing-Impaired Persons

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Abstract: *Thanks to the convenience of the mobility and portability of mobile device, the paradigm of ICT has been changed leading to the shift from the era of PC to the era of mobiles. Most people use mobile devices and diverse services provided by mobile devices are used not only for business but also for convenience of life. Therefore, the development of applications that support accessibility so that everybody can use the services provided by mobiles is important. In this respect, in the present study, the actual conditions of use of mobiles by hearing-impaired persons that have been a little away from the targets of interest for accessibility were investigated, the elements of development of applications to support hearing-impaired persons' accessibility were examined, and an application was designed and implemented based on the results of the foregoing. The application implemented in the present study is expected to be helpful for hearing-impaired persons' mobile accessibility because it is composed of functions that are the most basic for hearing-impaired persons' use of mobile applications.*

Keywords: *Web Accessibility, Mobile Accessibility, HCI, UI Design, Evaluation of Accessibility, Universal Design*

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I. Introduction

As the ICT trend has been switched to mobiles, smart devices including mobile phones have been swiftly changed into devices with new shapes and performances [1][2].The current smart devices have broken away from devices simply guarantee mobility and are used in the daily life in the contemporary times as smart devices that take care of cultural life, shopping, information retrieval, and public administration services. Therefore, applications for diverse purposes have been developed and used. According to the '2017 smartphone app use behavior', the degree of use of smartphone is very high to the extent that almost all smartphone users had downloaded applications within the last six months [3]. However, mobile devices including smartphones have characteristics such as small screen sizes and gesture based inputs, which approach disabled persons as larger constraints than those constraints that they experience when they use PC [4][5]. Therefore, when developing smartphone applications, which would be used by many people, the consideration of accessibility can be said to an important element.

Mobileaccessibility is an expansion of the concept of webaccessibility and refers to the way of provision of services and content that enables all people including disabled persons and the aged to utilize the services and content[6][7]. Currently, not only non-disabled persons but also disabled person use mobile devices as an important element for convenience in daily life. Ordinary persons use web or mobile services using their vision and hearing. However, disabled persons with impaired vision, hearing, or limbs become to use such services using means of assistance. Persons with physical disabilities use assistive devices, visually impaired persons use their residual vision and hearing, and hearing-impaired persons use their vision to use such services. Therefore, when content is produced, devices equipped with elements that support accessibility should be developed so that disabled persons can use the content.

However, most mobile applications currently provided in open markets do not support disabled persons' accessibility so that most disabled persons cannot use those mobile applications [2]. In addition, even when content that observes the requirement for accessibility is produced, such production focuses on vision that accounts for the largest part of information acquisition. Those web accessibility guidelines such as WCAG (Web Content Accessibility Guideline) and KWCAG (Korean Web Content Accessibility Guideline) also mention guidelines for the provision of alternative texts for visually impaired persons first [8]. Therefore, among disabled persons' abilities to use smartphones by type of disabilities, hearing-impaired persons' ability to use smartphones is much poorer compared to persons with other types of disabilities. Smartphones cannot be communication tools that can be conveniently used by hearing-impaired persons, who have difficulties in voice communication, which is the most basic function of smartphones [9].

Therefore, in the present study, to relieve the inconvenience of hearing-impaired person, who have difficulties in communication and information exchanges in daily life at least slightly, an application considering hearing-impaired persons' accessibility was designed and implemented. The applicationdesigned and implemented in the present study includes a function to search for sign language and deliver messages in sign language, a function to deliver voices as texts, and an alarm function that generates vibrations for hearing-impaired persons, who cannot hear sounds. In addition, an SOS function to be prepared for cases where voices cannot be used in an emergency, a surrogate ordering function, and a function to guide to welfare facilities were added for added convenience. This author hopes that the use of the applicationdesigned and developed in the present study will be helpful for hearing-impaired persons' communication at least slightly.

The composition of the present paper is as follows. In Chapter 2, the concept of mobile accessibility was introduced with related works and the actual conditions of hearing-impaired persons' use of the Internet, elements that support hearing-impaired persons'accessibility to applications, and previous studies were described. In Chapter 3, the details of the needs assessment for the applicationdesigned and implemented in the present study were described. Chapter 4 is a part for design and the DFD structure diagram and functiondesign were described. Chapter 5 is a part for implementation and the screens implemented according to defined functions were described. Chapter 6 is a part for conclusions.

II. Relatedresearch

The information provided on the Web or mobiles is recognized using the vision in most cases. Therefore, studies on the accessibility of disabled persons conducted thus far mostly considered visually impaired persons, who cannot use the vision. However, on reviewing the actual use of mobile devices, it was found out that the use of mobile devices by disabled persons with hearing impairment or speech impediment was much lower than that of other types of disabled persons.

2.1 Mobile Accessibility

Mobileaccessibility refers to enabling even users with disabilities to easily access websites and applications when they use mobile phones or diverse mobile devices [10]. Mobile accessibility should guarantee both the accessibility supported by the mobile devices per se and the accessibility provided by the services or contents provided by the mobile devices [7]. The government is making diverse efforts to improve the mobile accessibility such as conducting surveys of actual states of disabled persons' accessibility to mobile apps and by specifying guidelines for mobile application accessibility. The government officially announced the 'Guidelines for Mobile Application Accessibility' in September 2011, as a notification of the Ministry of Public Administration and Security (no. 2011-38) so that the guidelines are applied when mobile applications are developed. The Guidelines for Mobile Application Accessibilityconsist of seven matters that must be mandatorily observed for accessibility when mobile applications are developed and eight recommendations that are recommended to be observed.

The following is a table that shows the seven matters that must be mandatorily observed as specified by the Guidelines for Mobile Application Accessibility [5].

Table 1.Mobile Application Accessibility Guideline

Guideline	Main Target	Notes
Provide alternative text	Blind people	Obedience
Provide focus	Blind people, Phisically challenged people	Obedience
Support accesiibility function of operating system	All challenged people	Obedience
Support 'push' action	Blind people, Phisically challenged people	Obedience
Provide realization disrelated to color	Color vision defectives	Obedience
Provide brightness contrast	Low vision people	Obedience
Provide subtitle, sign language, etc.	Hearing-impaired people	Obedience

2.2 Mobile Use of Hearing-Impaired Person

When using a mobile device, ordinary persons use the vision to recognize the content on the screen, use the hearing to hear the sounds, and use touches or gestures to input messages. However, since hearing-impaired persons cannot hear sounds, they have difficulties in telephone conversations, which are the basic function of smartphones. Furthermore, they cannot use diverse services provided by smartphones in sounds. However, studies on accessibility conducted thus far have focused on visually impaired persons considering the vision,

which is the hub of human ability to perceive information[11]. On reviewing the content of the Guidelines for Mobile Application Accessibility, it can be seen that matters related to visually impaired persons are much larger in number than matters related to other types of disabled persons as the number of matters to be observed in relation to visual impairment is 5, the number of matters to be observed in relation to hearing-impaired persons is 1, and the number of matters to be observed in relation to all disabled persons is 1. In addition, both of the first guidelines of WCAG and KWCAG, the basics of webaccessibility, which is the basis of mobile accessibility, are related to the provision of alternative texts considering visually impaired persons [12][13]. The homepage 'www.wah.or.kr' of the Web Accessibility Laboratory in South Korea, which introduces webaccessibility, introduces only how visually impaired persons can utilize computers. Unlike physically disabled persons, who should use assistive devices, for the accessibility of visually impaired persons and hearing-impaired persons, the content should provide accessibility supporting elements. Whereas interest in and studies of accessibility for visually impaired persons have been continued, not so many studies of accessibility for hearing-impaired person have been conducted. In fact, on reviewing the results of the '2016 survey of actual states of the digital divide', it can be seen that among the mobile device use rates by type of disabilities, the mobile device use rate of disabled persons with hearing impairment or speech impediment was much lower than that of other types of disabled persons[14].

Figure1 below shows the mobile device use rates by type of disabilities as of 2016 as a graph.

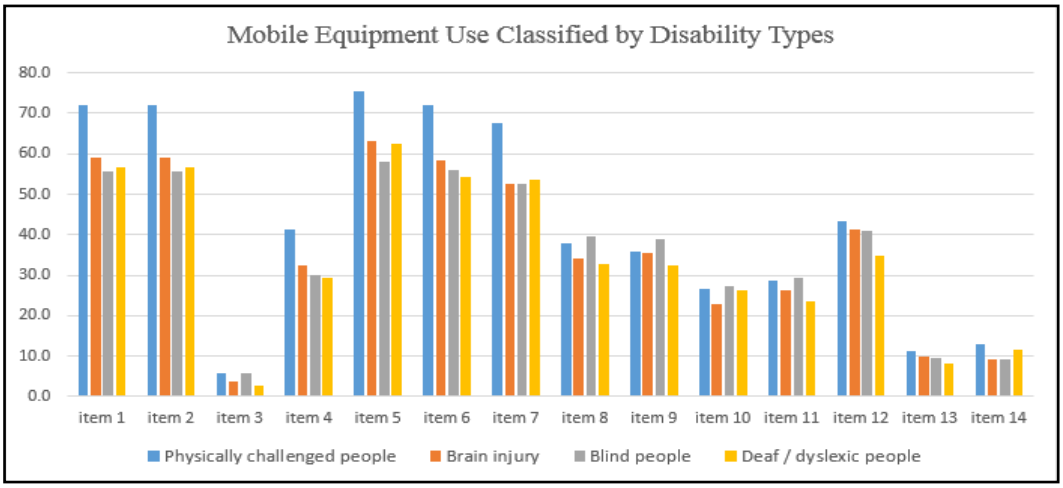

Fig.1. Mobile Equipment Use Classified by Disability Types(2016 standard)

On reviewing the mobile device use rates by type of disabilities, it could be seen that physically disabled persons showed the highest mobile device use rate followed by visually impaired persons, persons with brain lesions, and disabled persons with hearing impairment or speech impediment in order of precedence. It can be seen that the mobile device use rate of visually impaired persons, who cannot use the vision, was much higher than that of hearing-impaired persons. Table 2 shows the use rates arranged by giving number 1 to the highest use rate and number 4 to the lowest use rate.

Table 2. Utilization Comparison Chart according to Usage Rank(measure: unit)

Usage Rank / Disability Type	1	2	3	4
Physically challenged people	10	4	0	0
Brain injury	0	7	5	2
Blind people	4	1	6	3
Deaf / Dyslexic people	0	2	4	8

Among the 14 surveyed items, hearing-impaired persons were shown to have the lowest use rate for eight items.

Table 3 shows the items used in the survey of the mobile device use rates by type of disabilities.

Table 3. Mobile Use ItemsClassified by Disability Types

Item Number	Content
1	Mobile equipment(smart phone) possession rate
2	Whether internet is enabled or disabled in house
3	PC using ability(use well)
4	Mobile using ability
5	Whether internet is enabled or disabled
6	Use internet in recent one week
7	Number of every day internet usage using smart phone curing recent one month
8	Search, e-mail, and contents service using mobile equipment
9	SNS service usage by mobile
10	Life service use
11	Information production or sharing activity
12	Online network activity
13	Online social participation activity
14	Online economic activity

2.3 Prior Research for Accessibility of Hearing-Impaired Persons

For the accessibility of hearing-impaired persons, voices should be converted into data that can be perceived by other organs than the auditory organ. To this end, methods to convert auditory information into visual information are used [15]. The most frequently used method is providing voice conversations as visual information such as sign language or characters.

Previous studies on the accessibility of applications for hearing-impaired persons are as follows.

In the 'survey of users' needs for the development of cultural facility apps considering hearing-impaired person', Kim Gi-Won and KohYeong-Jun have identified user requirements that must be considered when applications are developed through user evaluation in order to relieve the inconvenience of hearing-impaired persons felt when they use cultural facilities. Through the study these researchers understood that explanations in the form of texts should be added for hearing-impaired persons, who do not know sign language,and the complicated structure should be simplified [16].

In a study titled 'Pronunciation correction mobile app-See&Speech for hearing-impaired persons', LeeYeong-Ju et al. designed and implemented an application capable of providing pronunciation corrective training for hearing-impaired persons[17].

In a study titled 'Sign language interpretation app GUI guidelines made through a user needs survey with hearing-impaired persons-centering on Seoul Seodaemun Rehabilitation Center for the Deaf', JeongEun-Ah and Kim Bo-Yeonsurveyed user needs for the development of an app that would interpret motions into texts in real time. These researchers surveyed inconveniences felt by hearing-impaired persons when they communicate with non-hearingimpaired persons and conducted usability tests to find improvement points of the app.

III. Requirement Analysis

Questionnaire surveys were conducted for the development of the 'application for the mobile accessibility of hearing-impaired persons' to be implemented in the present study to examine the functions that must be provided by the application and the strengths of the application were examined through SWOT analyses.

3.1 Questionnaire survey

A preliminary questionnaire survey was conducted for the development of an 'application for the mobile accessibility of hearing-impaired persons.' The purpose of the present study was to develop an application to improve the accessibility of hearing-impaired persons and a questionnaire survey was conducted on the provision of voice data converted into sign language, which is visual data. The questionnaire survey was conducted through online from October 1 to 6, 2016. A total of 96 persons participated in the survey. Figures 2-4 show significant results out of the results of questionnaire survey as graphs.

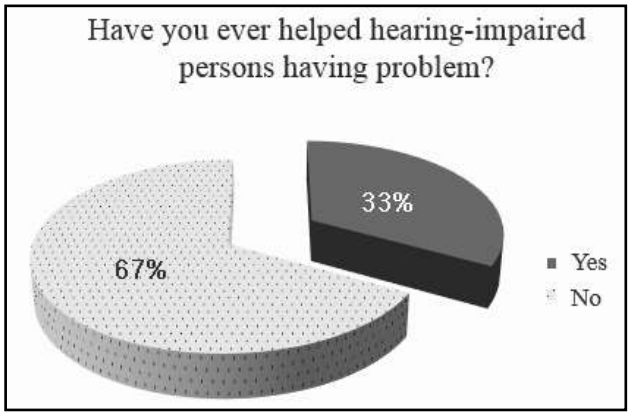

Fig.2. Survey1

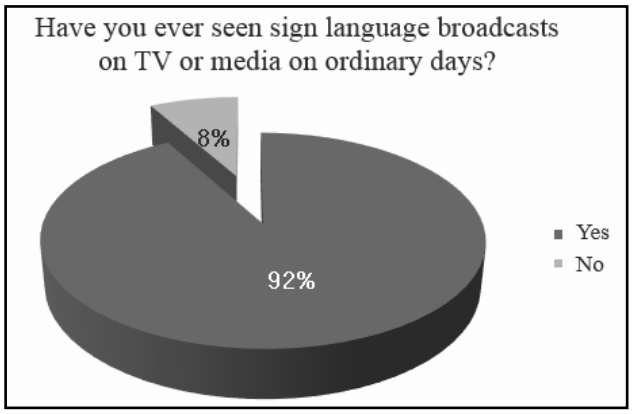

Fig.3. Survey2

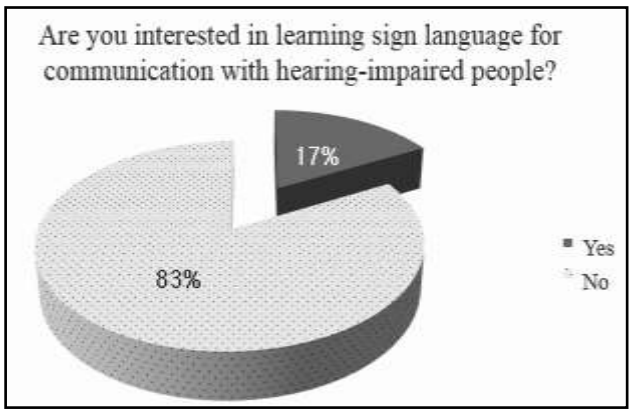

Fig.4. Survey3

Based on the results of the survey, 67% of the respondents did not help hearing-impaired persons when they saw hearing-impaired persons having difficulties, 92% of the respondents had experience in watching sign language broadcasts on TV and other media on ordinary days, and 17% of the respondents were willing to learn sign language to communicate with hearing-impaired persons.

Based on the results of the survey, the respondents saw hearing-impaired persons having difficulties in communication but could not help the hearing-impaired persons because they could not communicate with the hearing-impaired persons in many cases. Although non-disabled persons frequently saw sign language but did not want to learn sign language for communication with hearing-impaired persons in many cases. Therefore, for communication of hearing-impaired persons, their accessibility should be supported without fail using visual data such as sign language.

3.2 SWOTAnalysis

Figure 5 shows the SWOT analysis for the application to be developed in the present study. With regard to the application to be developed in present study, there may be cases where devices do not supportaccessibility despite that the application supports accessibility due to the characteristics of the application. However, since interest in accessibility has continuously increased recently, applications that support accessibility should have diverse values.

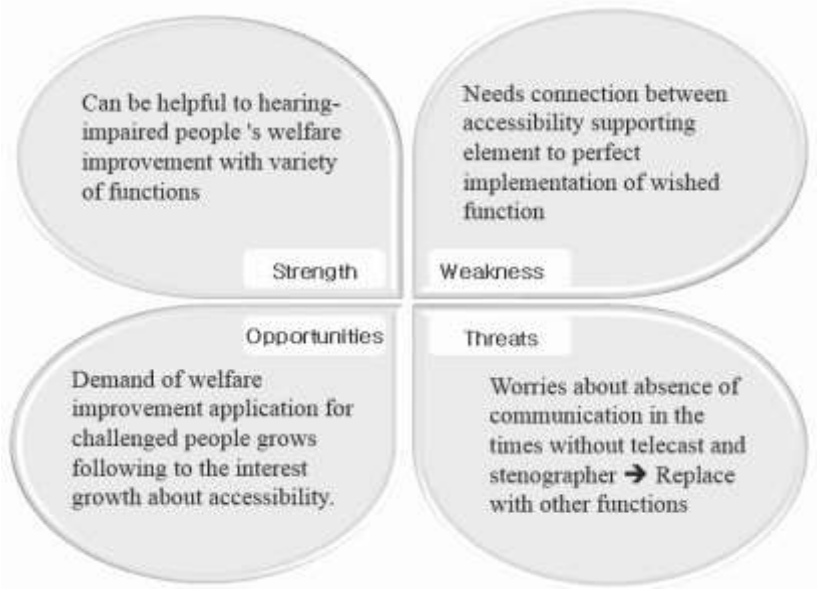

Fig.5. SWOT Analysis

IV. Design

These are the DFD design and function design for the 'application for the mobile accessibility of hearing-impaired persons.'

4.1 DFD Design

The functions of the application developed in the present study can be largely divided into six functions; 'sign language search', 'voice translation', 'vibration alarm', 'SOS', 'surrogate ordering', and 'guide to welfare facilities.' Figure 6 shows the DFD structure diagram for the six functions. Recent smartphones have focused on providing sign language, which is another tool for communication, by providing the function to change voices into texts on the device per se.

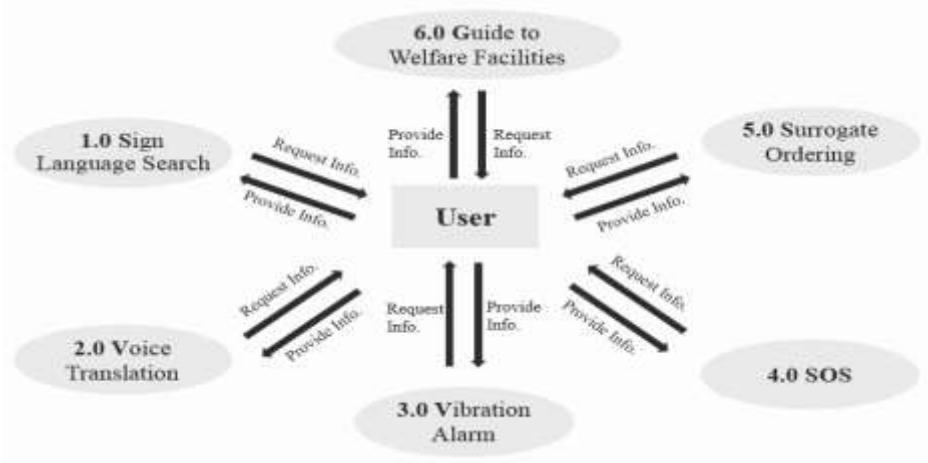

Fig.6. DFD Diagram

4.2 Function Design

When a hearing-impaired person searches a sign language word to be delivered, the 'sign language search' function retrieves the sign language word in the homepage of the Korean Sign Language Dictionary and output the sign language video. When necessary, this function enables video calls with sign language experts.

When the user has clicked the mike button and inputted voices, the 'voice translation' function outputs the voices as texts. This function enables communication with non-disabled persons, who do not know sign language.

The 'vibration alarm' function issues alarms with vibrations for hearing-impaired persons who cannot hear sounds. This function was defined so that vibration alarms are generated at the time, date, etc., designated by the user.

The 'SOS' function notifies cases where hearing-impaired persons who cannot speak is in an emergency to surrounding people. If 119 or desired numbers are stored, messages notifying the situation are transmitted to the stored numbers in an emergency situation and siren sounds are generated so that surrounding people can hear the sounds.

The 'surrogate ordering' function helps hearing-impaired persons, who cannot make phone calls, place orders using messages. If numbers are stored in the 'Favorites', ordering messages can be immediately sent.

The 'guide to welfare facilities' function directly connects the user to welfare facilities or professional social workers to whom disabled persons can request for help.

V. Implementation

The application in the present study was implemented maximally reflecting the needs assessment and the design part. Since hearing-impaired persons access devices by converting voices into visual data, the application was implemented so that no sound would be generated without any input operation considering cases where background music is converted into sign language or texts. The application in the present study was implemented using Android Studio.

Figure 7 shows the subscription screen and the implemented screen normally logged in. When a normal login has been made, the main screen is displayed as shown in Figure 7 and the implemented functions can be used.

Fig.7.'Sign up' and 'Login' Implementation

Figure 8 shows the screen on which the 'sign language search' function has been implemented. When the 'Sign Language Dictionary' has been selected, the user is connected to the Korean Sign Language Dictionary site. The user may enter desired sign language words to search the words at the connected Korean Sign Language Dictionary site. If a sign language word has been clicked, a video of the clicked sign language word will be played.

Fig.8.'Sign Language DictionaryImplementation

Figure 9 shows the screen on which the 'voice translation' function has been implemented. This screen is displayed when the voice translation icon has been clicked on the main screen. Click the mike and input the content desired to be outputted. When the input has been completed, the inputted voices converted into texts are outputted on the TextView below the mike.

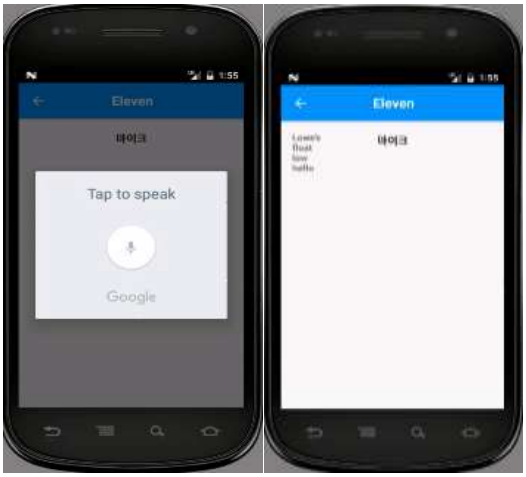

Fig. 9.'VoiceTranslation'Implementation

Figure 10 shows the function to register phone numbers in the 'Favorites.'

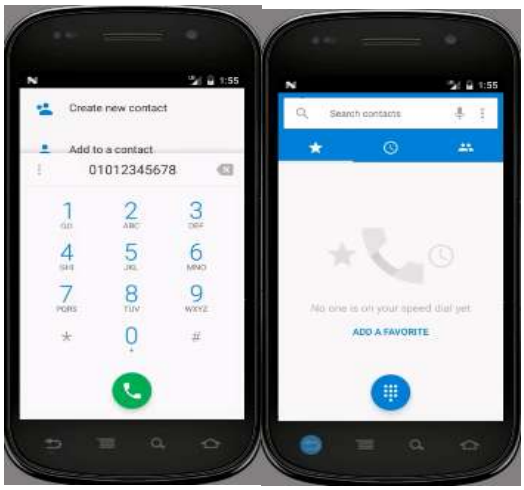

Fig. 10.'Favorites'Implementation

Figure 11 shows the screen on which the 'alarm generation' function has been implemented. Alarms will be generated if the 'set' button is clicked after selecting a date and time and the generated alarms are issued as vibrations for the accessibility of hearing-impaired persons. The 'IoTalarm' is a function to set the alarm currently set on other connected devices too.

Fig.11.'Alarm Generation' Implementation

Figure 12 shows the screens on which the 'SOS' function and the 'surrogate ordering' function have been implemented. When the 'SOS' function has been clicked in an emergency situation, the texts notifying the emergency situation are transmitted to numbers designated in advance. The 'surrogate ordering' screen is opened when the 'surrogate ordering' icon has been clicked on the main screen.

Fig.12. 'SOS' and'SurrogateOrdering'

VI. Conclusion

As the modern society has been moved into the smart information society by the mobile revolution, many parts of daily life are handled using mobile devices. Therefore, to relieve the digital divide, the target of interest for accessibility has been rapidly shifted from web accessibility to mobile accessibility. Thus far, elements for visually impaired persons have been considered the most for improvement of the accessibility of disabled persons. However, surveys indicated that the mobile use rate of hearing-impaired persons, who have been regarded to have not so much inconvenience in using mobiles as were though to be able to recognize most web or mobile information except for auditory elements, was the lowest among the mobile use rates of various types of disabled persons.

Therefore, in the present study, an application was designed and implemented considering those functions that are helpful for the accessibility of the hearing-impaired persons. In the present study, 'application for mobile accessibility of hearing-impaired person' is not implemented as an application having a specific function but hearing-impaired person considering the specificity of hearing-impaired person in order to increase accessibility of hearing- I designed and implemented the necessary functions for the impaired person. Therefore,

we used a method of linking web sites that can provide sign language without constructing a separate DB for functions such as "sign language search" as a communication means of hearing-impaired persons. The 'application for the mobileaccessibility of hearing-impaired persons' implemented in the present study was not implemented as an application that has a certain function but was implemented by designing and implementing functions necessary for hearing-impaired persons considering the special characteristics of hearing-impaired persons in order to enhance the accessibility of hearing-impaired persons. Therefore, the relevant functions such as the 'sign language search' function were implemented not by separately constructing a DB but by connecting the application to websites that can provide sign language.

To improve mobile accessibility along with webaccessibility, the government and developers should have continuous interest and will to improve the accessibility. It is considered necessary to provide content that observes the requirements for accessibility to disabled persons that have difficulties in daily life due to their disabilities in order to reduce the digital divide and ensure that the disabled persons are guaranteed for the same opportunities as non-disabled persons.

Acknowledgements

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