Smart Block-based Route Guidence Technology for the Visually Impaired

J.G.Hwang, D.J.Lee, H.Y.Choi, B.H.Lee
Korea Railroad Research Institute
Uiwang-si, Gyeonggi-do, Korea
jghwang@krri.re.kr

C.G.Yu, S.C.Kim
Bluemobile Co. Ltd. , Seoul, Korea

blue@bluenmobile.com

***Abstract*—**The visually impaired are complaining of much inconveniences in moving at indoor area like metro station due to the restricted behavior and lack of guidance information. There are several route guidance services for the visually impaired through smartphone using the GPS signal, but these mobile apps cannot be used indoor areas because GPS signal can't used. The smart block-based indoor route guidance technology was presented to improve the mobility of the visually impaired in indoor areas in this paper. The smart block is designed to check the location of the user indoors and installed on the floor. User positioning algorithm is performed on their smartphone using the location signal from smart block. In this paper, the proposed smart block, route guidance technology using it, and the results of empirical tests in actual railway stations are also represented. The smart block-based route guidance technology is expected to contribute greatly to the improvement of mobility of the visually impaired in indoor areas including railway stations.

Keywords—The visually impaired, Route guidance, Smart block, Indoor positioning

I. INTRODUCTION

The mobility handicapped who have temporary or continuous movement restrictions when using public transportation facilities such as subway, city bus etc. These population is expected to reach 25% of the total population as of 2017 in Korea. Among them, especially the visually impaired people complain of serious difficulties in mobility in railway stations, and it is difficult for the visually impaired to safely escape through various types of emergency evacuation information and escape systems in case of emergency situations such as fires in railway stations, so it has potential safety problems for them. So, it is urgent to come up with countermeasures.

Recently, several walking assistance technologies for the visually impaired using GPS signal have been introduced, helping them in their outdoor activities. However, since GPS signal cannot be used in indoor areas such as railway stations, so most of them that have been introduced recently cannot be out of use by the visually impaired.

According to a survey report by the Ministry of Land, Infrastructure and Transport in Korea[1], as shown in Table 1, it is identified that the level of user satisfaction of the mobility handicapped including the visually impaired is 10-20% lower than that of the general public at railway station and bus terminal[1]-[3],[11][12].

TABLE I. USABILITY EVALUATION RESULTS FOR EACH THE MOBILITY HANDICAPPED[1]

Division	Sum	Very satisfaction	Satisfaction	Normal	Unsatisfaction	Very unsatisfaction	No use	User satisfaction
Physically disabled	156	3	7	91	35	20	22	52
Visually disabled	69	0	7	42	13	7	5	54
Hearing disabled	63	3	3	42	12	3	9	57
Complex disabled	68	3	4	38	17	3	8	56
Pregnant	93	6	24	43	20	0	17	63
Older	374	45	105	165	50	9	83	67
Ordinary	430	68	188	160	11	3	63	72

In order to increase the satisfaction ratio for the physical disabled, large-scale hardware investment such as the installation of elevators and improvement of facilities such as application of BF(Barrier Free) design is necessary. But the providing information such as pathway or safety alarm is more important for the visually impaired to improve mobility indoors. That is, various mobility assistance facilities for the visually impaired in indoor areas are continuously installed, but their satisfaction ratio is not improving as the facilities installation rate increases. Accordingly, although it is important to install hardware-based mobile convenience facilities, measures to improve the user satisfaction in view of software are required.

In order to solve these problems, various technologies for supporting independent walking for the visually impaired are being introduced and developed in many countries and institutes (see Table 2). It is confirmed that these various technologies are having difficulty in practical use in terms of usability, such as electronic sticks like NAVIWALK[4]-[10] or still in the early stages of technology development. In particular, most of these are technologies for outdoor application, and except for some, it is analyzed that indoor technology is still in the early stages of development.

TABLE II. EXAMPLES OF TECHNOLOGY DEVELOPMENT RESEARCH AND COMMERCIALIZATION [4]-[10]

Class	Nation	Project	Remark
The visually impaired	Korea	Bus Information Terminal (BIT)	LOGISYS
		Passage assist technology for the visually impaired (NAVIWALK)	NAVIWORKS
		Passage assist technology for the visually	PRIMPO, ISONIC

		impaired	
		Passage assist technology for the visually impaired (Destination Guide Cane)	Daegu University
		Smart-walk technology for the visually impaired	Daegu University
		Voice guidance system for the visually impaired	Nowon-gu Office
		Passage assist technology for the visually impaired (only navigation for the visually impaired)	HIMS International
		A sound signal device for the visually impaired using GPS	Road Traffic Authority
	USA	Wireless Pedestrian Navigation System (Drishti)	University of Florida
		Trinetra Project (the third eye)	Carnegie Mellon University
		Seeign AI	Microsoft
		Access program	Go-Metro
		Drone System that helps visually impaired people to exercise	University of Nevada
		Accessible Pedestrian Signals (APS)	USA Government
	Europe	GuideCane	Wormald International Sensory Aids
		Brumel navigation system	Brunel University
		Walking guidance technology using Bluetooth-based beacon	Wayfindr
		OnTheBus System Project	UAB Barcelona
		GPS-based navigation app for the visually impaired (Blindsquare)	Scandinavia

Recently, the use of smartphones has become common among visually impaired people in external activities in Korea. Accordingly, in this paper, a technology for supporting mobility in indoor spaces of the visually impaired people based on smartphones that do not require large-scale facilities was presented and its applicability was verified. That is, smart block-based route guidance technology that can improve the satisfaction of the visually impaired in indoor space through smartphone-based technology and user satisfaction evaluation results was represented.

Fig. 1. Configuration of IoT-based route guidance technology for the visually impaired

II. SMART BLOCK-BASED ROUTE GUIDANCE TECHNOLOGY FOR THE VISUALLY IMPAIRED

The visually impaired people have a lot of difficulties due to their visual limitations when moving outside. However, recently, various route guidance support systems using GPS signals have been developed and introduced to help them find their destination, but there are still many difficulties in mobility in underground and indoor areas such as railway stations where GPS signals cannot be used. Several technologies that can use location information in this indoor area are being developed, but most of them require the construction of many infrastructure facilities, and at the same time, users must have a dedicated terminal or additional device to use these services, etc. Therefore, it is difficult to put it into practical use. In this paper, to increase practicality through the analysis of these existing studies, smart block-based route guidance technology was designed through positioning in the indoor space so that the user installs only the smartphone app and minimizes the construction of infrastructure facilities is minimized.

A. *Overview of Proposed Technology*

Braille blocks for the visually impaired are installed on the floor of most indoor areas, including railway stations, and rounded type is installed on the path of the braille blocks, and linear type is installed at junctions or end points to help the visually impaired. In this paper, the smart block which is braille block with built-in IoT sensor is installed on the floor, and the mobile app determines the user's location and calculates the route to their destination based on the signal from the sensor. User's current location and desired route, route information is guided through voice and screen of the mobile terminal. Fig. 1 shows the outline of the route guidance technology in the indoor area proposed in this paper and the application screen of the mobile terminal.

The app screen is used by the visually impaired, not the general public, and must be designed in accordance with the national app accessibility standard, and must also be certified by an authorized agency. The app developed in this paper is designed and certified according to this standard. When the user's location information in the indoor area is confirmed, a route guidance service to the desired place is possible, and additionally, information on major facilities around the moving route and risk information can be provided. In other words, until now, it was impossible to provide various information to improve mobility as GPS signals were not available in indoor areas. However, through the location information through the smart block proposed in this paper, it is possible to apply various services for the visually impaired to support movement in indoor spaces. Fig. 1 shows an overview of route guidance technology for the visually impaired.

B. *Data Structure of Smart Block*

The smart block installed on the floor to identify the user's location in the indoor area is a BLE(Bluetooth Low Energy), and this IoT sensor is based on the MAP of the indoor area that provides the route guidance service. As a result, the mapping for smart block mapping was done through the following appropriate zone design for each sensor.

- Zoning so that travel routes do not overlap

- Zoning by equalizing the installation interval of the sensor

- Mapping of direction information for each zone to provide user movement direction information

- Mapping with POIs (Points of Interest) management information by establishing standard identification code of sensor

After zoning on the map of the indoor area for location-based service in this way, the smart block was mapped for each zone, and then each identifier code system for each mapped sensor was designed. In this paper, the BLE sensor standard data structure(in Fig. 2) was applied in consideration of service scalability and terminal(android and iOS) compatibility with the smart block. It was designed to use the identifier for classifying route guidance services for the visually impaired in the UUID(Universally Unique IDentifier) field of the data structure, the local information identifier for the area where the indoor area is located in the Major field, and the facility information identifier of the indoor area in the Minor field

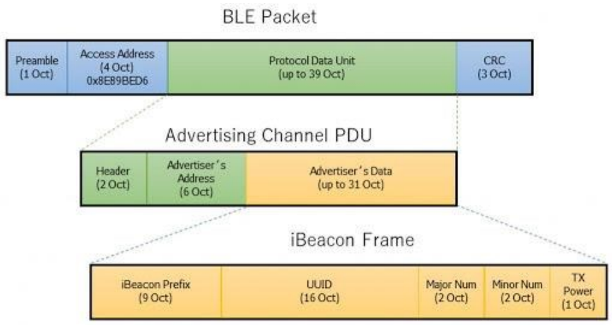


Fig. 2. BLE data structure

The information in these two fields is configured differently depending on the characteristics of indoor areas such as railway stations, underground shopping malls, and buildings. Each smart block having information by such a standard identification code emits an RF signal having physical location information by allocating it to each zone in the indoor area map. Table 2 shows an example of designing an identifier code for the Major and Minor fields when the indoor area to be serviced is a metro station. If the area to be serviced is not a railway station, but a different area such as an underground shopping mall, the structure of the Major and Minor fields will be adjusted according to the characteristics of the target area.

TABLE III. EXAMPLE FOR BEACON IDENTIFIER CODE IN CASE METRO STATION

	Major	Minor
Structure	[J1] [J2] [J3] [J4] [J5]	[M1] [M2] [M3] [M4] [M5]
Allocation range	[J1] : 0~5, [J2] : 0~9 [J3] : 0~9, [J4] : 0~9 [J5] : 0~9	[M1] : 0~5, [M2] : 0~9 [M3] : 0~9, [M4] : 0~9 [M5] : 0~9
Code allocation	[J1][J2][J3] : Station Code(000~599) [J4][J5] : Region/Line Classifcation(00~99) *Region/Line Classification 00~29 : Seoul area, 30~39 : spare 40~49 : Busan, 50~59 : Daegu, ...	[M1][M2] : Consecutive numbers(00~59) [M3][M4] : Use classification(00~99) [M5] : Classification of floors *classifications of floors 0 : top 4th floor, 1 : top 3th floor 2 : top 2th floor, 3 : top 1th floor 5 : bottom 4th floor, ...
Examples	[09801]Seoul area/line 1/Seoul station [02906]Seoul area/line 6/Bugok station, ...	[01014] : Platform Up/bottom 1th floor [01353] : Transfer parking/top 1th floor, ...

C. Design of smart block

A smart block is a block with a built-in BLE sensor inside a braille block on the floor or a regular block[11][12]. Therefore, it must be a structure that can withstand an impact or strength equal to or greater than that of a conventional block. In addition, the case of the built-in sensor should have a structure that can be maintained such as replacement of power, and at the same time, the material and structure that consider the RF characteristics of the sensor.

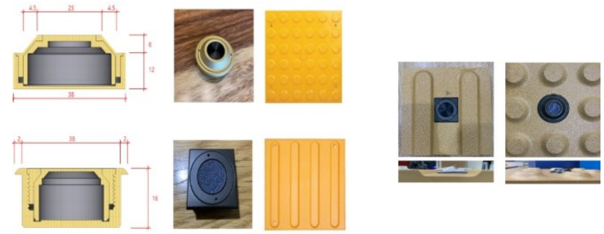


Fig. 3. Smart blocks based on braille blocks with button cell battery

In this paper, structures and materials were designed and produced through RF characteristics analysis of smart blocks. In particular, the smart block for braille block was designed to have the same appearance as before so as not to interfere with the walking of the visually impaired, and was designed and manufactured in two structures in consideration of the shape of the internal battery(see Fig.3 & Fig.4). It is designed in a structure that allows visually impaired people to receive guidance in braille blocks and general blocks.

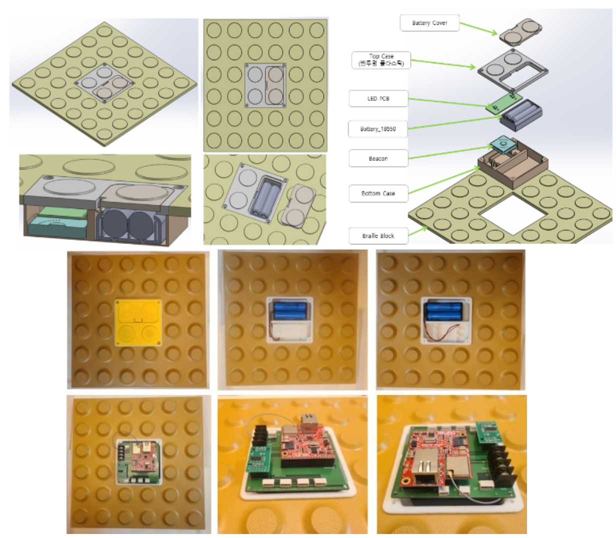


Fig. 4. Smart blocks based on braille blocks with coin type battery

D. Smart block-based positioning algorithm in indoor area

In this paper, the user's location in the indoor area is confirmed based on the smart block with the data structure presented in section 2.3. Although the user's location is identified based on a RSSI(Receiver Signal Strength Indicator) signal from a smart block installed on the floor, sensor signals of adjacent sections can be received at the same time, so a method of determining in which section the user is actually located is required. In addition, in order to increase the accuracy of the route guidance information, even if the area of the sensor where the user is located is determined, it is necessary to monitor how far away from the sensor and whether the user deviates from the set route while moving.

To measure the user's moving direction and distance from the sensor, a hybrid positioning algorithm is applied through PDR(Pedestrian Dead Reckoning) technology, which corrects the position through various sensors built into the mobile terminal. PDR is a technique for estimating the relative position change from the previous position through detection of a pedestrian's steps, estimation of the stride length to determine the distance traveled, and estimation of the direction to determine the direction of walking by using the measurement values of three sensors in the IMU(Inertial Measurement Unit) built into the smartphone. For positioning error correction, KF(Kalman filter) was applied to remove the error included in the RSSI value measured by the inertial sensor of the mobile terminal, and an algorithm for correcting the accumulated error of the inertial sensor of the smartphone was applied. During positioning, error correction and algorithms are applied according to the situation such as the position of terminal, stride length, and speed. The user's current location, movement direction, and movement distance are determined using map information based on the link information between nodes of the smart block mapped to the indoor area map and a hybrid positioning algorithm.

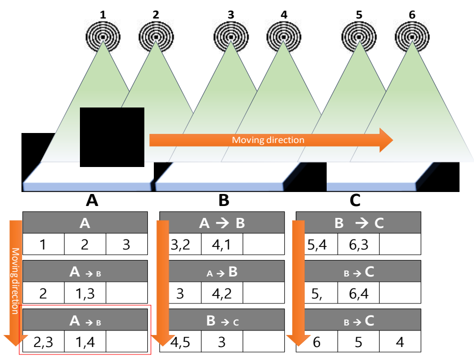


Fig. 5. Concept of smart block based tracking information

The overview of user tracking algorithm through smart block signal is shown in Fig. 5. It shows the concept of tracking information and area determination when a user enters area A and then moves to area C via area B. Multiple smart block signals are simultaneously received at the user's current location, in consideration of the magnitude of these signals and the magnitude of the received signa l of each signal in the previous position, the user's moving position is estimated and which current sensor zone the user is in is determined. When the user enters area A and exits area C through area B, multiple smart block signals may be received by the user's terminal, and some signals may be within the error range. The current user location is estimated in consideration of the strength of the received smart block signals, the mapped link information between the sensors, and area information from the previous location.

It is estimated which area the user is in now or from which area the user is moving to which area. In the figure, ‘A→B’ means that, although it is estimated that the user is moving from area A to area B, the user is currently in area A. The part shown in the Another case that the signals of sensor No.2 of A and No.3 sensor of B, and the signals of sensor No.1 of A and No.4 sensor of B are received within the error range respectively, although it is ambiguous to determine where the signal is in A or B area from only this received signal, since the previous position is in area A, in this algorithm, it is determined that the user is moving to area B while he is in region A.

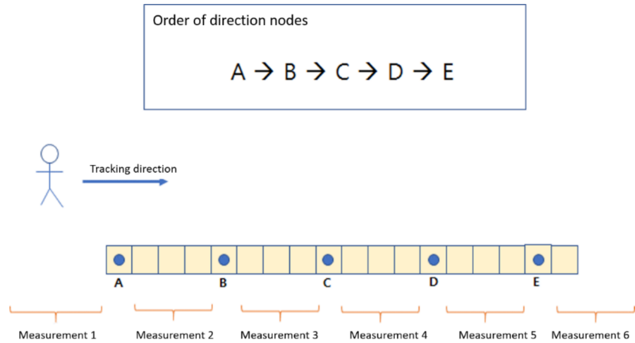


Fig. 6. Node link of sensors when the desired route is straight line

As described above, after estimating the user's location as a zone first, which sensor the user is located in is estimated in detail by the method shown in Fig. 7 It is checked whether the sensor signal received from the terminal is a signal from a valid sensor, and if it is a valid signal, it is determined as the first priority signal of the user's current location based on the received RSSI value through the above-described location correction algorithm. In addition, the sensor after ranking correction is compared with the previous tracking information to check whether there is a change, and finally the user's tracking information is updated.

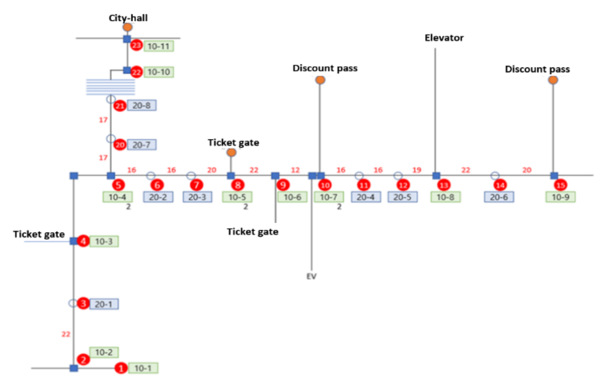


Fig. 7. Mapping of smart block in case Busan City Hall station

It is checked whether the smart block signal received from the mobile phone is a valid smart block signal, and if it is a valid signal, it is determined as the first priority signal of the user's current location based on the received RSSI value through the above-described location correction algorithm. In addition, the smart block after ranking correction is compared with the previous tracking information to check whether there is a change, and finally the user's tracking information is updated. That is, the smart block signal processing order for user tracking is processed according to the following order.

For route guidance in an indoor area, the criteria for continuous route guidance are divided into one unit through a smart block, and separate map node information is stored in the server for each divided unit. And when the user arrives at a location where route guidance is possible, the map node information of the corresponding unit is designed to be downloaded from the server to the mobile terminal. When the user's mobile terminal detects the sensor of the smart braille block, the current location is provided to the user by voice, and basic information and brief usage of the app are provided by voice. A list of facilities for a destination reachable from the current location is provided, and when the user selects a facility corresponding to the destination, route information is set up to that facility, and route guidance information can be provided in image and voice according to the user's movement.

III. On-site Demonstration Test Results

For route guidance in an indoor area, the criteria for continuous route guidance are divided into one unit through a smart braille block with built-in IoT sensors, and separate map node information is stored in the server for each divided unit. And when the user arrives at a location where route guidance is possible, the map node information of the corresponding unit is designed to be downloaded from the server to the mobile terminal. When the user's mobile terminal detects the sensor of the smart braille block, the current location is provided to the user by voice, and basic information and brief usage of the app are provided by voice. A list of facilities for a destination reachable from the current location is provided, and when the user selects a facility corresponding to the destination, route information is set up to that facility, and route guidance information can be provided in image and voice according to the user's movement.

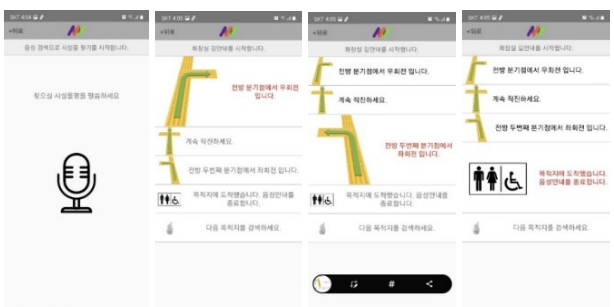
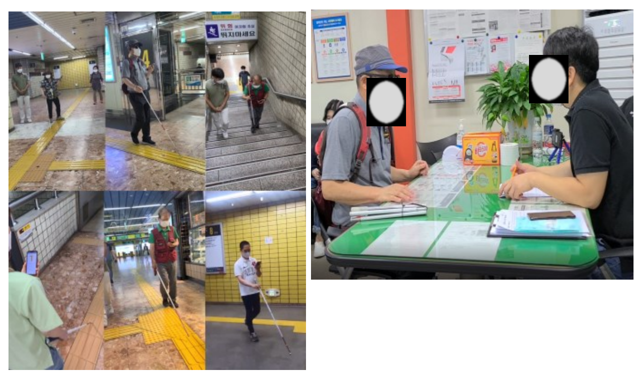


Fig. 8. Developed mobile app windows (in Korean)

Fig. 8 shows some part of the screen of the mobile app produced. The left first screen is the initial screen displayed when the user runs the app after arriving at the location of major facilities in the station, through voice recognition, the visually impaired people can easily select the destination they want to go to. Furthermore, it was also produced to provide a UI that allows users to select and set destinations through screen touch rather than voice recognition. When a destination is selected through voice recognition or screen touch, the route is set by linking the sensor nodes as shown in Fig. 7 to the destination route, and the route to the destination is sequentially guided as shown in the middle two screens in Fig. 8. In this case, route information is sequentially provided to the visually impaired through the voice displayed in red as well as the image to be guided, and when they finally arrive at the destination, the voice guidance is terminated.

The design of the questionnaire is important in the user satisfaction survey according to the use of the development system. In this paper, the basic survey items were applied mutatis mutandis by reviewing the "2017 Transportation Convenience Survey Study" conducted annually by the Ministry of Land, Infrastructure and Transport for the system use satisfaction survey for the test subjects. In order to understand the user satisfaction and the effect of the system on route movement, the NASA-TLX survey items were reflected as items for the satisfaction survey through the review of experts in related fields. Fig. 9 is a photograph of demonstration test and user satisfaction survey conducted by the Busan Blind Union for the 33 visually impaired persons, and Fig. 10 shows the results of the user satisfaction survey before and after the application of the development system of this paper. As shown in the figure, the user satisfaction ratio before application of the development system was 6.81 out of 10, but after using it, it was analyzed to be 8.81, which was an improvement of about 19.4%, confirming that the application effect of the proposed system was very good. In addition, the visually impaired people were reluctant to use railroad stations due to difficulties in finding routes when using them, but if the system of this paper is applied to the field, a majority opinion that it would be very useful and helpful when moving at an actual station through a simulation walking through this app before going to the station, were suggested.



(a) Status of demonstration tests (b) User satisfaction ratio survey photo

Fig. 9. Configuration of demonstration test

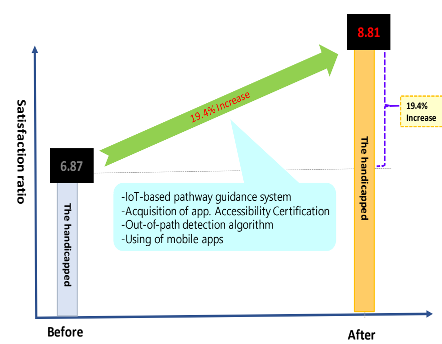


Fig. 10. Results of the satisfaction ratio survey

In order to improve the mobility of the visually impaired in indoor area, a smart block-based route guidance technology was designed and presented in this paper. To this end, a system was developed, such as smart block -based user positioning algorithm and a mobile app that reflects the UI according to the app accessibility guidelines that reflect the user's convenience. For the evaluation of the developed technology, the smart block map was mapped for the urban railway station, which is one of the representative indoor areas, and the app for the simulation test was additionally produced, and the user satisfaction level of the application of this developed system for the visually impaired was investigated. As a result of the user satisfaction survey, it was confirmed that the user satisfaction improved significantly compared to before the application of this developed system. In addition, with just the app for the simulation test the visually impaired people who participated in the simulation test could check the station and the route to destination before going out in advance, and experience the route to the station they wanted to go, so it was possible to confirm the utility of the technology proposed in this paper, such as many opinions were suggested that it can be usefully used. Moreover, if the improvement of the voice recognition rate specialized for the relevant indoor area, such as a railway station, is supplemented, it is expected that it will be possible to dramatically improve the mobility support of the visually impaired and user satisfaction through the minimum hardware installation in the indoor area and software technology.

Identify applicable sponsor/s here. If no sponsors, delete this text box (*sponsors).*

REFERENCES

[1] Ministry of Land, Infrastructure and Transport, "In year 2017 – A Study on the Actual Condition of Movement of the Traffic Handicapped", 2018. (in Korean)

[2] S.B.Jung and S.O.Lee, " A Regression Analysis Study on Customer Satisfaction Considering the Mediation Effect of Safety of Operation – Focusing on Subway Line 9", Journal of the Korean Society for Railway, vol.20(6), 2017, pp.853-865.

[3] KRRI Research Report, "Development in Interactive Route Guidance and Supporting System Technology for Mobility Handicapped in Railway Station", KRRI, 2021.

[4] Tengqinging Ge., "Indoor Positioning System Based on BLE for Blind or Visually Impaired[thesis]", KTH Royal Institute of Technology, 2015.

[5] S.Sgoval, I.Ulrich, J.Borenstein, "NavBelt and the Guide-Cane [obstacle-avoidance systems for the blind and visually impaired", IEEE Robotics & Automation Magazine, vol.10(1), 2008, pp.9-20.

[6] Md. Atikur Rahman and et al., "Design and Development of Navigation Guide for Visually Impaired People", Proceeding of IEEE International Conference on Biomedical Engineering, Computer and Information Technology for Health, 2010, pp.28-30.

[7] R. Kasthuri, B. Nivetha and et al., "Smart device for visually impaired people", Proceedings of International Conference on Science Technology Engineering & Management(ICONSTEM), 2017.

[8] iSONIC Hompage, http://www.primpo.com/kr/index.html, last accessed 2022/05/02.

[9] Google's HearHere Project Hompage, https://folio.openknowl.com/project/7950, last accessed 2022/05/02.