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An Application on Visual Cognitive Assistance system for Braille Block Recognition Based on Raspberry Pi System

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Abstract— **There are many visually impaired people living their lives throughout the world. As of now, the only realistic tools available for these people are white sticks and guide dogs. However, these visual aids are insufficient for handling unexpected obstacles in various environments. Accidents tend to occur frequently, and these aids are very costly, thus limiting their usefulness for the visually impaired. This paper aims to develop a visual aid cognitive system and explores the possibility of practical performance. The overall system configuration uses the Raspberry Pi and OpenCV in real-time to capture braille block images and recognize the braille blocks' pattern. It also gathers information about the surrounding environment before conveying the information to the user. In the first phase, the Go/Stop signal is determined by the linear or circular braille block according to the type of braille block. In the second phase, the visual aid system equipped with an ultrasonic sensor warns the user when encountering an obstacle so that the user can walk safely. We implemented a text recognition system based on a Text-to-Speech converter that transmits the text recognition information to the visually impaired and tested TTS function to read various street signs with various fonts. We lastly discuss the future possibility for our auxiliary system in various road environments and how it can be improved to help visually impaired people.**

Keywords— **Braille block; obstacle detection; Raspberry Pi; visual cognitive assistance system; visually impaired.**

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I. INTRODUCTION

A large number of people deal with blindness worldwide. In reality, these visually impaired people must navigate through daily life using various aids such as white canes and guide dogs [1]. However, these aids are limited in their usage to prevent accidents when encountering unexpected obstacles. They are also very expensive with limited availability.

Braille blocks are the most common form of aid for the visually impaired [2]. Braille blocks transmit cognitive information to the user through the tactile sense [3-5]. There are linear and circular types of braille blocks installed in Korea, and the installation rate is reported to be about 50.6% [6]. Linear braille blocks contain four lines that indicate the direction of the pedestrian crossing. On the other hand, circular braille blocks indicate the start and endpoints of bus stops, overpasses, and stairs. The position of these braille blocks is sensed by the touch of the soles or the tip of the cane and walks on the road [7].

The overall system configuration consists of two phases which are the visual cognitive part and the text-to-speech part. The visual cognitive assistance system implemented in this paper is implemented through OpenCV based on Raspberry Pi. In the first phase, the Go/Stop signal is determined by the linear or circular braille block according to the type of braille block. In the second phase, the visual aid system gives a warning to the user when encountering an obstacle so that the user can walk safely. We also implemented a text recognition system based on TTS (Text-to-Speech) converter that transmits the text recognition information to the visually impaired. Furthermore, we examined various character types to recognize road sign characters on the road and presented a possibility that may be applicable to our final development.

The rest of this paper is organized as follows. In section 2, we review the character recognition system and braille block recognition systems. Section 3 discusses proposed system architecture and experimental results, and Section 4 concludes the paper with future works and other possible solutions.

II. MATERIALS AND METHOD

A. Visual Cognitive Assistive System

People with visual disabilities have difficulty in recognizing their surroundings which leads to difficulty in walking. The information provided by text may be helpful to the visually impaired by applying an auxiliary cognitive system. This text information recognition system is developed by applying the MSER method [8, 9]. It delivers text information of documents or surrounding environment to the visually impaired through various text recognition engines [10-13]. Table 1 summarizes the various research related to the visual aid cognitive system [14-21].

As the number of people with visual disabilities increases, many systems for the blind is being developed. The braille block system using camera-based mobility aid and detection of immovable objects and gait-assistance system which combines RFID and braille block are examples of systems being developed [22-26]. The Braille block system uses image processing to collect images by attaching a Raspberry Pi camera to a white cane which then recognizes a braille block to inform the user with a vibrating motor. Since the system only requires a white cane with no additional tools, it is easy to use for the visually impaired [27]. Yoshida *et al.* [28] proposed a method for recognizing braille blocks using an automated mobile robot navigation device. This method uses a CCD camera and a laser fan beam projector as sensors to recognize bumps or road surfaces. The pedestrian aid system combines preinstalled RFID tags in braille blocks, an antenna in the braille block to store information about the current position, and a reader which reads the information on the white stick used by the user. The advantage of this system is that the current location is spoken out loud for the user [29]. However, this system has a disadvantage because it requires inserting an RFID tag and an antenna in every braille block.

B. Proposed System Architecture

The user can use Raspberry Pi [30] to walk safely on braille blocks in our implemented work. The system reads the surrounding environment and braille blocks in real-time by connecting a port to the Raspberry Pi to communicate with the Pi camera. It will also inform the user of impending dangers using an ultrasonic sensor that is connected to Raspberry Pi. The overall system flow diagram shows in Figure 1.

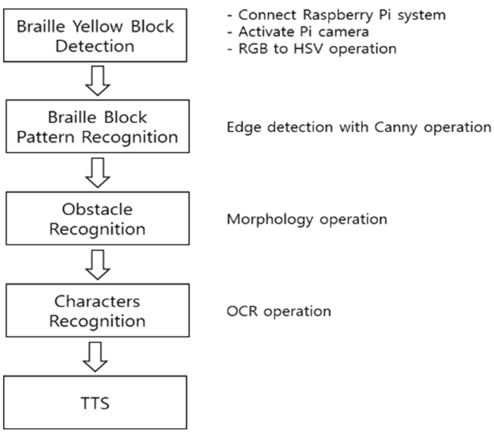

Fig. 1 The overall system flow diagram

TABLE I
VISUAL AID COGNITIVE SYSTEM RELATED WORKS

Related Work	Characteristics
[14]	The system is designed to help the visually impaired when navigating indoor environments. It transmits information through vibration sensors.
[15, 16]	The system allows the visually impaired to walk indoors by measuring the distance of objects from the user by analyzing images taken by the camera.
[17, 18]	The glasses are equipped with a microscopic camera that when the user points towards a specific object, the camera recognizes it and gives related information out aloud.
[19, 20]	Utilize artificial intelligence (AI) and computer vision technology to instantly read text for the visually impaired.
[21]	Developed a voice navigation system that can be used to navigate by receiving information from the smartphone.

1) H/W Configuration: The braille block cognitive assistance system consists of Raspberry Pi, camera module, and sensor parts. The user's video taken in real-time while walking requires communication between the Raspberry Pi 3 Module and the Pi camera module. In addition, an ultrasonic sensor (HC-SR04) [31] was connected to the Raspberry Pi 3 Model to communicate safely with the user. The device is connected via Bluetooth / Wi-Fi built into the Raspberry Pi 3 model. Figure 2 shows the configuration of H/W used by the user. The system will detect braille blocks, recognize various signs, and read-aloud for the user, which will help relieve invisible fears.

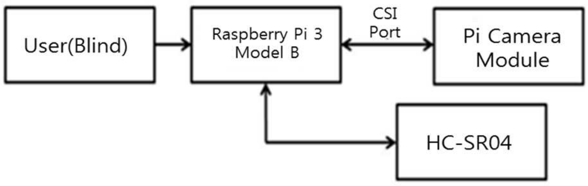

Fig. 2 The general H/W configuration

2) S/W Operation: To implement proposed system, OpenCV [32] library and Python programming language [33] were used. The system takes images of braille blocks in real-time with the Pi Camera and helps the user walk safely using voice guidance when braille blocks are unavailable. TTS technology in the cognitive system gives the user Go/Stop messages by reading braille blocks and informs the user of the right direction when there is not braille blocks available. Figure 3 is the S/W configuration of the braille block system.

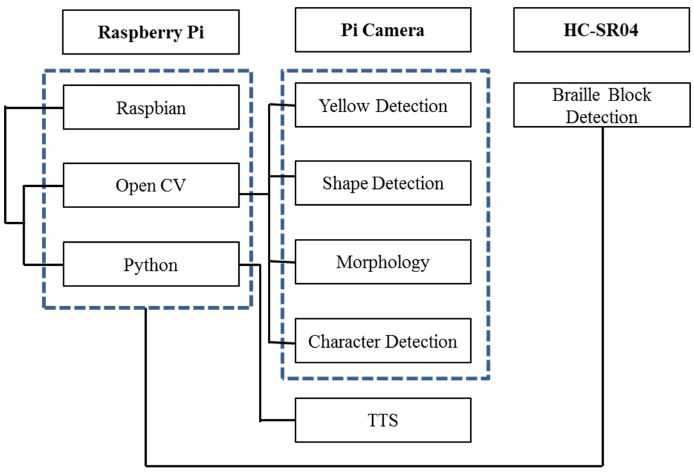

Fig. 3 S/W configuration for braille block recognition system

III. RESULTS AND DISCUSSION

This paper aims to develop a cost-effective and practical visual aid system. Figure 4 shows a prototype for the experiment. The prototype consists of a Raspberry Pi module, a Pi camera module, an ultrasonic sensor, an auxiliary battery, a TTS speaker (earphone), and a monitor to assist with each function.

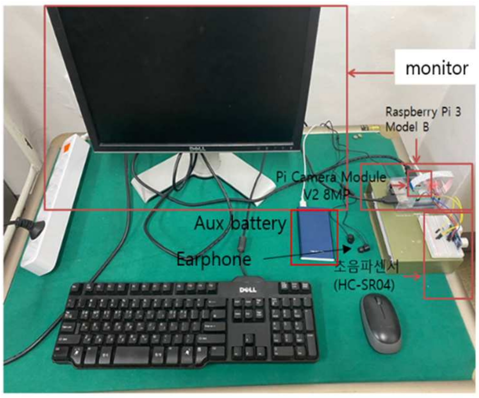

Fig. 4 The experimental H/W system configuration with auxiliary battery and earphone for TTS output

A. *Braille Block Extraction*

The most prominent H/W parts of the visual aid are the ultrasonic sensors and Pi camera modules. The camera module must detect the braille block part of the image detected in real-time. The most standard detection method is to transform an RGB image into a HSV color model to detect a braille block image made in yellow. During the first stage, to detect yellow, a mask that extracts an object of a specific color according to a range of colors must be created. In the second stage, the RGB image is converted to HSV, making it easy to classify colors because Hue has pure color information with a certain range in the HSV image. Figure 5 shows the braille block original image used in this study, yellow color detection, and HSV conversion. In Figure 6, pseudo-code describes the standard method of converting RGB to HSV.

(a) (b) (c)

Fig. 5 Braille yellow block recognition. (a) tested braille block image (b) extracted yellow area (c) transformed the black and white area.

As a preliminary step for recognizing the pattern of the braille block and delivering the type of pattern to the user, the shape of the braille block must be detected accurately. The Canny Edge algorithm [34, 35] was to detect the boundary of the braille block with three criteria:

- Detection: A low error rate. The algorithms do not dismiss occurring image edges.
- Localization: Well localized edges, being on the same position as the occurring edges.
- Minimal response: One given edge is marked once, and image noise does not create false edges.

Figure 7 shows results for braille block pattern recognition with edge detection. Figure 7 - (a) and (b) show linear type block shape and its Go signal. Figure 7 - (c) and (d) show circular type block shape and its Stop signal.

Read RGB image

Compute normalized RGB and parameters

$$R' = \frac{R}{255},\ G' = \frac{G}{255},\ B' = \frac{B}{255},$$

$$Cmax = max(R', G', B')$$

$$Cmin = min(R', G', B')$$

$$\Delta = Cmax - Cmin$$

Compute H, S, V

$$H = \begin{cases} 0^\circ & \Delta = 0 \\ 60^\circ \times (\frac{G' - B'}{\Delta} mod\ 6), & C_{max} = R' \\ 60^\circ \times (\frac{B' - R'}{\Delta} + 2), & C_{max} = G' \\ 60^\circ \times (\frac{R' - G'}{\Delta} + 4), & C_{max} = B' \end{cases}$$

$$S = \begin{cases} 0, & C_{max} = 0 \\ \frac{\Delta}{C_{max}}, & C_{max} \neq 0 \end{cases}$$

$$V = C_{max}$$

Fig. 6 Pseudo-code for conversion from RGB to HSV

B. *Obstacle Recognition*

The obstacle detection experiment was done in two parts to anticipate when the user walks on a braille block and encounters an unexpected obstacle. If there was an obstacle on the braille block, the ultrasonic sensor warns the user of an obstacle within 50 [cm], and if the braille block is broken, an algorithm for expanding the morphology calculation is used [36]. There are two morphology operations, erosion, and expansion. The erosion operation can darken the pixels in the effective area of the mask, removing unwanted noise in the image. In contrast to the erosion operation, the expansion we used in this study brightens the pixels so that they can fill the pixels in the image.

1) In case of an obstacle on the braille block: Ultrasonic sensors are used to detect an obstacle on the braille block. The sensor can measure up to 15 degrees up, down, left, right, and up to 5 [m] in all directions. The HC-SR04 ultrasonic sensor module is usually used for measuring the distance between the user and the obstacle. If the distance between the user and the obstacle is greater than 50 [cm], the system alerts the user that an obstacle exists but is currently "out of range" and a warning message was given only when the obstacle was measured to be within 50 [cm] of the user.

2) In case of damaged braille block: When the braille block is damaged or no longer detected, the dilation operation is used in the morphology calculation. Figure 8 describes the morphology expansion in real-time on the road. For exploring the morphological operation, a test image has been made by an artificial damaged part. Although it was not fully expanded, it can be seen that the extent of the expansion is actually less than the size of the obstacle.

C. Character Recognition

The optical character recognition function must be tested for the system to be properly tested while walking down the street. Test results show some fonts in which the capital and lowercase letters of English are only partially identified. This problem occurs because the recognition rate varies depending on the resolution or quality of the image. In this research, we applied Microsoft Speech API's speech-to-text functionality to consider efficient aspects [37].

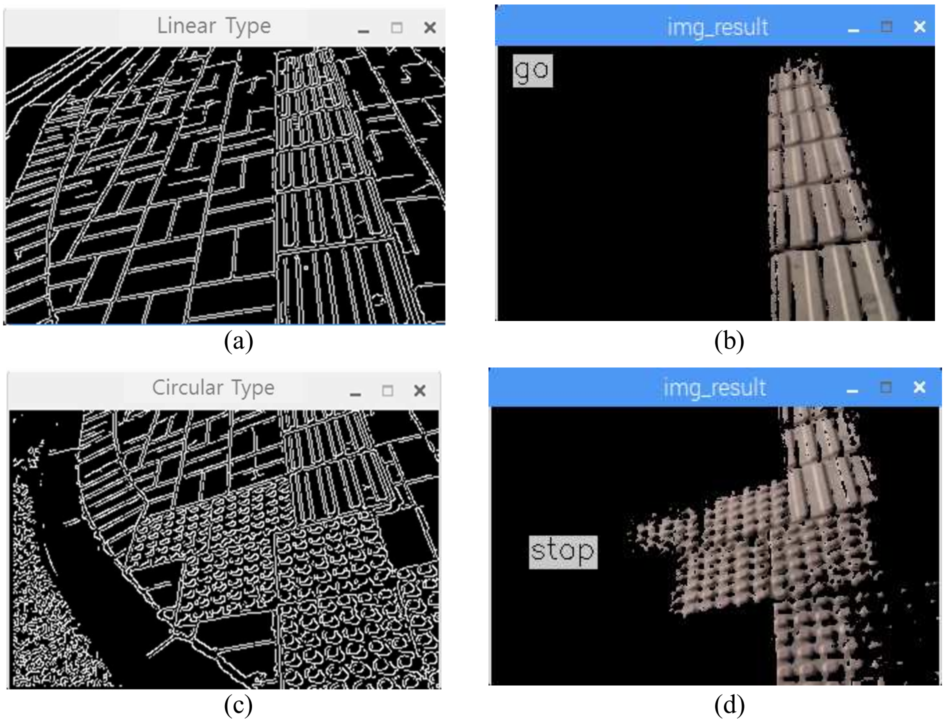

Fig. 7 Results for braille block pattern recognition with edge detection. (a) edge image with linear type, (b) detected go signal braille block, (c) edge image with circular type, (d) detected stop signal braille block

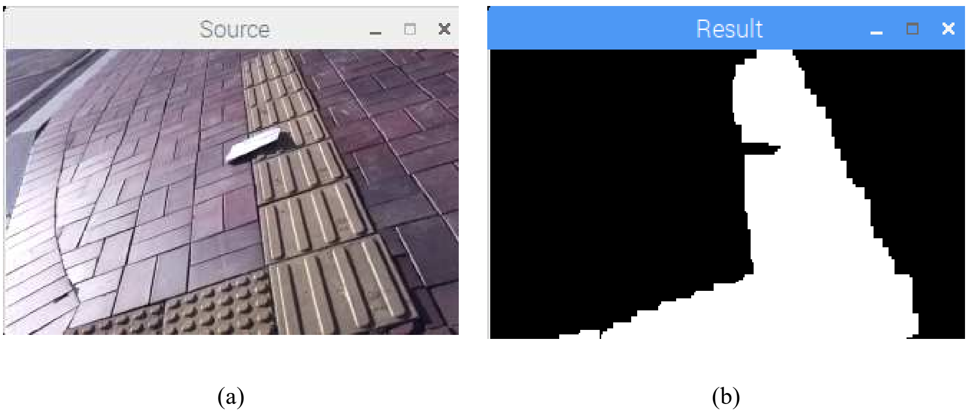

Fig. 8 Morphological operation result for test image in real-time

1) On various fonts: Although there are various fonts used all over the world, this paper tested three fonts from Hancom Office Hangul (HY 엽서 M, HY 목판 L, 양재난초) software and Times Roman font from Microsoft Word. Table 2 shows the experimental results of several font types and words, including Times Roman font. In this experiment, we used arbitrary word sets. As a result of the test, HY 엽서 M and Times Roman font showed a better recognition rate compared to the other Korean built-in fonts from Hancom Office due to odd shaped characters. Figure 9 shows the result of experimenting with the letters when the background is colored. The red background was chosen specifically due to STOP signs having red backgrounds. As a result, the system recognized the letters correctly except ambiguous I and J letters even when the letters had a different background color.

Fig. 9 Result with colored background

2) *On special symbol*: In the experiment using the image of a real-life building sign, the letters were recognized correctly, but the apostrophe symbol was not recognized. Various signs were tested, but the system was unable to recognize all the letters and symbols. Figure 10 shows the result of letter recognition using the image of a building sign with an apostrophe symbol.

Fig. 10 Result of character recognition using image of a building sign with apostrophe symbol

D. Text-to-Speech Operation

TTS is a function that scans various signs on buildings/sidewalks and then reads them out loud for the user. Figure 11 shows a simplified flow block diagram for TTS function, recognizes STOP from the input by the camera, reads STOP, and informs the user by sound while showing the result on the screen.

Fig. 11 The block diagram for text-to-speech process. (a) a test image, (b) captured letters on notepad, and (c) speech out with text.txt file

TABLE II
THE RESULT OF OPTICAL CHARACTER RECOGNITION WITH VARIOUS FONT TYPES

Font Type	Character Set	Test Result
HY 엽서 M [1]	STOP Stop Go go EXIT umbrella UMBRELLA ORANGE orange EGG Egg YELLOW Yellow GOOD JOB good job	pi@raspberrypi:~ $ sudo nano opencv_test3.py pi@raspberrypi:~ $ python opencv_test3.py STOP stop Go go EXIT umbrella UMBRELLA ORANGE orange EGG egg YELLOW yellow GOOD JOB good job
HY 목판 [2]	STOP Stop Go go EXIT umbrella UMBRELLA ORANGE orange EGG Egg YELLOW Yellow GOOD JOB good job	pi@raspberrypi:~ $ sudo nano opencv_test3.py pi@raspberrypi:~ $ python opencv_test3.py sSTor stop Go o EXIT uambrella OMBRELLA ORANGE srange Eao egg JELLOW gellow Goob JoB good job
양재난초 [3]	STOP stop Go go EXIT umbrella UMBRELLA ORANGE orange EGG egg YELLOW yellow GOOD JOB good job	pi@raspberrypi:~ $ sudo nano opencv_test3.py pi@raspberrypi:~ $ python opencv_test3.py sTtoP stop Go so exit wmbralla UMBRELL A ORANGE crange ceaa =o9 yerLLow yallow GooD JOoB good job

Times_Roman	STOP stop Go go EXIT Umbrella UMBRELLA ORANGE orange EGG egg YELLOW yellow GOOD JOB good job	pi@raspberrypi:~ $ python opencv_test3.py STOP stop Go go EXIT Umbrella UMBRELLA ORANGE orange EGG egg YELLOW yellow GOODJOB good job

[1,2,3] These indicate some samples of Korean built-in fonts from Hancom Office software.

IV. Conclusion

This paper proposed a system to aid visually impaired people by combining image recognition of braille blocks and obstacle recognition. That combines an image with an existing braille block in real-time. It also includes TTS function in order to read various street signs. There are several differences between the proposed system and existing assistive devices. First, the Pi camera module enables the system to take images in real-time. Second, while the white cane must make direct contact with an obstacle, the system will sound a warning if there is an obstacle. Third, the system informs users of various street signs scanned by the Pi camera module by sound. With these features, people with visual disabilities will be able to walk more safely. Moreover, because they can “read” various street signs while walking, they have the advantage of roughly knowing their position. However, as a result of testing, letter recognition must be improved.

The end goal is to develop an app that can easily and flexibly utilize the Internet of Things (IoT) infrastructure such as smart city/traffic/energy at a national level. By studying character recognition systems using deep learning, we can also improve the quality of wearable assistive aids using IoT-based road guidance service application technology and behavior pattern analysis technology of the visually impaired. The design and development of the devices are intended to expand the size of the auxiliary equipment market by being affordable and easy to use. However, to develop an efficient auxiliary system, the system must be reduced to a lighter, simpler form. In addition, scenarios such as using stairs and pedestrian crossings must also be considered.

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References

[1] Assistive products for blind and vision-impaired persons - Tactile walking surface indicators, ISO 23599, 2012.

[2] Braille Blocks for the Visually Impaired, KS F 4561, Korean Agency for Technology and Standard, 2013.

[3] M. C. Ghilardi, R. C. Macedo, I. H. Manssour, “A new Approach for Automatic Detection of Tactile Paving Surfaces in Sidewalks,” *Procedia Computer Science*, vol. 80, pp. 662–672, Jun. 2016.

[4] K. Zhou, C, Hu, H. Zhang, Y. Hu, B. Xie, “Why do we hardly see people with visual impairments in the street? A case study of Changsha, China,” *Applied Geography*, vol. 110, article 102043, Sep. 2019.

[5] D. Kanoulas, N. G. Tsagarakis, M. Vona, “Curved patch mapping and tracking for irregular terrain modeling: Application to bipedal robot foot placement,” *Robotics and Autonomous Systems*, vol. 119, pp. 13-30, Sep. 2019.

[6] Infrastructure and Transport, Actual Condition Survey on Mobility Conveniences for Transportation Poor, Ministry of Land, South Korea, 2013.

[7] V. Tink S. Porritt, D. Allinson, D. Loveday, “Measuring and mitigating overheating risk in solid wall dwellings retrofitted with internal wall insulation,” *Building and Environment*, vol. 141, pp. 247-261, Aug. 2018.

[8] M. Lee, I. Park, “Performance evaluation of local descriptors for maximally stable extremal regions,” *Journal of Visual Communication and Image Representation*, vol. 47, pp. 62-72, Aug. 2017.

[9] L. M. Dang, S. I. Hassan, S. Im, I. Mehmood, H. Moon, “Utilizing text recognition for the defects extraction in sewers CCTV inspection videos,” *Computers in Industry*, vol. 99, pp. 96-109, Aug. 2018.

[10] G. A. Robby, A. Tandra, I. Susanto, J. Harefa, A. Chowand, “Implementation of Optical Character Recognition using Tesseract with the Javanese Script Target in Android Application,” *Procedia Computer Science*, vol. 157, pp. 499-505, Oct. 2019, DOI: 10.1016/j.procs.2019.09.006, [Online].

[11] C. Clausner, S. Pletschacher, A. Antonacopoulos, “Flexible character accuracy measure for reading-order-independent evaluation,” *Pattern Recognition Letters*, vol. 131, pp. 390-397, Mar. 2020, DOI: /10.1016/j.patrec.2020.02.003, [Online].

[12] S. Yousfi, S. Berrani, C. Garcia, “Contribution of recurrent connectionist language models in improving LSTM-based Arabic text recognition in videos,” *Pattern Recognition*, vol. 64, pp. 245-254, Apr. 2017.

[13] V. C. Kieu, F. Cloppet, N. Vincent, “Adaptive fuzzy model for blur estimation on document images,” *Pattern Recognition Letters*, vol. 86, pp. 42-48, Jan. 2017.

[14] T. Froneman, D. Heever, Kiran Dellimore, “Development of a wearable support system to aid the visually impaired in independent mobilization and navigation”, in *Proc. IEEE EMBC*, Jeju Island, Korea, 2017, pp. 783-786.

[15] K. Y. Chan, U. Engelke, N. Abhayasinghe, “An edge detection framework conjoining with IMU data for assisting indoor navigation of visually impaired persons,” *Expert Systems with Applications*, vol. 67, pp. 272-284, Jan. 2017.

[16] R. Tapu, B. Mocanu, T. Zaharia, “Wearable assistive devices for visually impaired: A state of the art survey,” *Pattern Recognition Letters*, vol. 137, pp. 37-52, Sep. 2020.

[17] A. P. Finn, F. Tripp, D. Whitaker, L. Vajzovic, “Synergistic Visual Gains Attained using Argus II Retinal Prosthesis with OrCam MyEye,” *Ophthalmology Retina*, vol. 2, pp. 382-384, Apr. 2018.

[18] N. Niknejad, W. B. Ismail, A. Mardani, H. Liao, I. Ghani, “A comprehensive overview of smart wearables: The state of the art literature, recent advances, and future challenges,” *Engineering Applications of Artificial Intelligence*, vol. 90, article 103529, Apr. 2020.

[19] MIT News, “Wearable system helps visually impaired users navigate”, May, 2017. [Online]. Available: http://news.mit.edu/2017/wearable-visually-impaired-users-navigate-0531.

[20] M. C. Rodriguez-Sanchez, J. Martinez-Romo, “GAWA – Manager for accessibility Wayfinding apps,” International Journal of Information Management, vol. 37, no. 6, pp. 505-519, Dec. 2017.

[21] S. Spagnol, R. Hoffmann, M. H. Martínez, R. Unnthorsson, “Blind wayfinding with physically-based liquid sounds,” International Journal of Human-Computer Studies, vol. 115, pp. 9-19, Jul. 2018.

[22] M. Murata, D. Ahmetovic, D. Sato, H. Takagi, K. M. Kitani, C. Asakawa, “Smartphone-based localization for blind navigation in building-scale indoor environments,” *Pervasive and Mobile Computing*, vol. 57, pp. 14-32, Jul. 2019.

[23] A. Abdurrasyid, I. Indrianto, R. Arianto, “Detection of immovable objects on visually impaired people walking aids”, TELKOMNIKA, Vol.17, no. 2, pp. 580-585, 2019, DOI: /10.12928/telkomnika.v17i2.9933, [Online].

[24] I. Ouali, M. S. Sassi, M. B. Hallima, A. Wali, “A New Architecture based AR for Detection and Recognition of Objects and Text to Enhance Navigation of Visually Impaired People,” *Procedia Computer Science*, vol. 176, pp. 602-611, Oct. 2020, DOI: 10.1016/j.procs.2020.08.062, [Online].

[25] C. Tsirmpas, A. Rompas, O. Fokou, D. Koutsouris, “An indoor Navigation system for visually impaired and elderly people based on Radio Frequency Identification (RFID),” *Information Sciences*, vol. 30, pp. 288-305, Nov. 2015.

[26] G. L. Gragnani, S. Bergamaschi, C. Montecucco, "Algorithm for an indoor automatic vehicular system based on active RFIDs," *ICT Express*, vol. 3, no. 4, pp. 188-192, Dec. 2017, DOI: 10.1016/j.icte.2017.11.012, [Online].

[27] J. Cho, J. Song, J. Kwok, M. Kang, "Braille Block Detection System using Back-projection in Image Processing", in *Proc. KIIT*, Gwangju, Korea, 2018, pp. 299-301.

[28] T. Yoshida, A. Ohya, S. Yuta, "Braille Block Detection for Autonomous Mobile Robot Navigation," in *Proc. IEEE/RSJ ICIRS,* Las Vegas, USA, 2000, pp. 633-638.

[29] R. Joshi, S. Yadav, M. Dutta, C. Travieso-Gonzalez, "Efficient Multi-Object Detection and Smart Navigation Using Artificial Intelligence for Visually Impaired People," *Entropy*, vol. 22, no. 9, 941, Aug. 2020, DOI: 10.3390/e22090941, [Online].

[30] A. Khalifa, E. Badr, H. Elmahdy "A survey on human detection surveillance systems for Raspberry Pi," *Image and Vision Computing*, vol. 85, pp. 1-13, May. 2019.

[31] N. Gupa, A. Agarwal, "Object Identification using Super Sonic Sensor: Arduino Object Radar," in *Proc. SMART,* Moradabad, India, 2018, pp. 92-95.

[32] Z. Zhu, Y. Cheng, "Application of attitude tracking algorithm for face recognition based on OpenCV in the intelligent door lock," *Computer Communications*, vol. 154, pp. 390-397, Mar. 2020.

[33] K. Jaskolka, J. Seiler, F. Beyer, A. Kaup, "A Python-based laboratory course for image and video signal processing on embedded systems," *Heliyon*, vol. 5, e02560, Oct. 2019, DOI: 10.1016/j.heliyon.2019.e02560, [Online].

[34] S. Laaroussi, A. Baataoui, A. Halli, S. Khalid, "A dynamic mosaicking method for finding an optimal seamline with Canny edge detector," *Procedia Computer Science*, vol. 148, pp. 618-626, Feb. 2019, DOI: 10.1016/j.procs.2019.01.050, [Online].

[35] Y. Meng, Z. Zhang, H. Yin, T. Ma, "Automatic detection of particle size distribution by image analysis based on local adaptive canny edge detection and modified circular Hough transform," *Micron*, vol. 106, pp. 34-41, Mar. 2018.

[36] I. S. Masad, A. Al-Fahoum, I. Abu-Qasmieh, "Automated measurements of lumbar lordosis in T2-MR images using decision tree classifier and morphological image processing," *Engineering Science and Technology, an International Journal*, vol. 22, pp. 1207-1034, Aug. 2019, DOI: DOI: 10.1016/j.jestch.2019.03.002, [Online].

[37] Microsoft Speech SDK5.1 Documentation, Microsoft.