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Prototype of a Method to Support the Walking of Visually Impaired by Detecting the Walkable Area Using Pedestrians

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***Abstract*—The goal of this study is to support the walking of visually impaired people using AI and a small camera. It is difficult for the visually impaired to walk straight toward the target due to the characteristics of the disability. Even if they think they are walking straight, they will move off to the left and right. For this reason, they may have an accident such as falling from the platform of the train. In this report, in order to enable visually impaired people to walk safely toward the target, a small camera attached to the body captures the direction of travel, detects the area where the pedestrian can walk safely from the recorded pedestrian, and guide users there. We consider that the place where there are pedestrians is an area where we can walk safely. Pedestrians are detected from camera images using AI. Use sound to inform the user of the direction of travel. We prototyped these methods.**

***Index Terms*—Visually impaired, veering tendency, deep learning, wearable device**

I. INTRODUCTION

This study aims to support visually impaired people's walking using AI and a small camera [1, 2]. One of the walking problems of the visually impaired is that it is difficult for them to walk straight toward the target, and even if the person intends to walk straight, they move off to the left or right. For this reason, accidents such as falling from the platform of a train are endless. This paper describes a prototype system that guides visually impaired people to walk safely. The prototype system captures the direction of travel with a tiny camera attached to the body and detects areas where people can walk safely. For the area where the user can walk safely, AI is used to detect a pedestrian in front of the camera, and where the detected pedestrian has passed is set as the pedestrian area. Use sound to guide you to walk straight toward the selected walkable area. The system is operated by a finger sign that recognizes the shape of the user's finger taken by the camera using AI and assigns a command to that shape.

II. RESEARCH BACKGROUND

There is a behavior recognition/support method for understanding human motion using a wearable camera. This method aims to analyze the meaning of the action from the viewpoint of the attached camera and to provide support to the action. However, if the user is a visually impaired person, it isn't easy to learn and estimate by analyzing the action's meaning from the camera's viewpoint video. The reason is that, due to visual impairment, the camera's viewpoint image is not always an image that leads to action recognition. This is because the user's operation includes a redundant part, which makes machine learning difficult.

Many studies have been conducted to support cognitive maps for visually impaired people to keep walking outdoors [3–7]. The primary approach of the studies was to analyze walking environment images and identify characters such as signboards to identify the position of movement and pedestrian crossings and signals. In these studies, it was challenging to avoid danger when sufficient information could not be obtained during walking.

III. RELATED WORK

Many image recognition services for the visually impaired have appeared, such as OrCam, which uses a dedicated wearable device, and Microsoft Seeing AI, a smartphone app. In addition, "EyeRing," which attaches a camera to the fingertip, was developed by Nanayakkara *et al.* [8]. The camera used in EyeRing was initially designed and included a control device that fits the user's fingertip. This system recognizes an object by pointing the camera attached to the finger to the thing. Pointing at the target is a natural motion and can be done by the user without difficulty.

These services recognize images captured by a smartphone camera or a dedicated device, readout characters, identify currency and show surroundings to the visually impaired. In particular, Seeing AI uses Microsoft's Azure Cognitive Services and can develop applications, so we are considering using it in this research.

Other than wearable devices, recent studies on walking support for the visually impaired have used new technologies such as haptics and drones [9–13]. This study does not conflict with these studies or the white cane and guide dogs currently in use. We believe that by combining these and the results of this research, we can support the visually impaired to walk even more safely. For example, to output by haptics to a white cane that the walkable area detected by our research, etc.

IV. STUDY ON WAKING SUPPORT FOR THE VISUALLY IMPAIRED

Most of the conventional studies that support visually impaired people to walk outdoors have analyzed the image of the walking environment, identified the characters on the signboard, the moving position, and determined pedestrian crossings and signals. In these studies, it was challenging to

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avoid danger when sufficient information could not be obtained while walking. One of the reasons why it is challenging to prevent risk is the veering tendency when walking, that is, the characteristic of deviating from the trajectory.

Sekita *et al.* are conducting the following experiment regarding veering tendency [14, 15]. This experiment showed the walking factors when they did not obtain visual information by wearing an eye mask on five visually impaired persons, one blind person, and four with amblyopia. Figs. 1 and 2 show the results. Fig. 1 shows the subject facing the target at the starting point and walking straight for 11m. As a result of walking each issue three times for a total of 15 cases, there were 11 cases veering to the right and four to the left. The probability of leaving 5m or more from the center line when walking 20m was 30.8%.

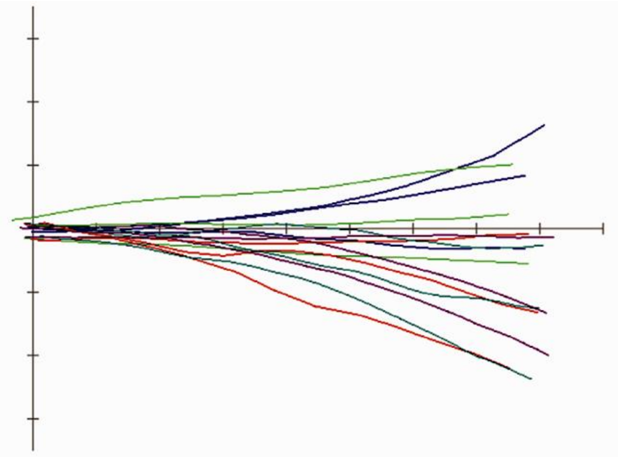

Fig. 1. Magnetization as a function of applied field.

Fig. 2 shows the result of turning around the rectangle line counterclockwise. It can be seen that the deviation veering increases with each turn. The veering tendency of visually impaired people to turn around is also a cause of station-platform accidents.

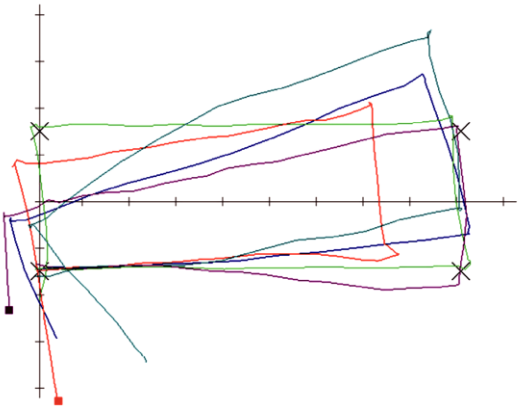

Fig. 2. Veering tendency in orbit.

The system to be developed in this study is to understand the surroundings of the visually impaired by using the user's pointing motion, the wearable camera, and its image recognition. At the same time, the system presents to the user, by its voice, the object pointed by the finger out of the surrounding conditions understood by the image recognition. The user selects the target thing required for the following action from the presented objects. The target chosen by the user is detected from the latest image of the wearable camera, and the difference from the previous position is calculated. The obtained difference means the veering tendency. The purpose of this study is to correct the motion of the visually impaired based on the detected veering tendency.

V. SYSTEM OVERVIEW

The walking support system under development captures the direction of travel with a camera worn by the user on the body or held in hand and uses AI to detect pedestrians in the direction of travel from the captured images. It is considered that the place where the detected pedestrian walks can walk safely. This is the "Walkable area." The walkable area is displayed on the display of the smartphone or tablet. The user traces the display with their finger and notifies the user by voice when the finger enters the walkable area. After that, the direction of travel is determined by turning the camera and user body so that the walkable area on display is in the center of the display.

At that time, the distance between the walkable area and the center of the display is indicated by the pitch of the sound.

This system uses a trained neural network to detect pedestrians. The neural network is executed using an OAK consisting of a camera and an AI processor developed by Luxonis. The software is created based on DepthAI, the API for OAK development, and the pedestrian detection sample program and the trained neural network are used.

1) Pedestrian detection person-detection-retail-0013_openvino_2020.1_4shave.blob
2) Identification of pedestrians person-reidentification-retail-0031_openvino_2020.1_4shave.blob

A. OAK

OAK [16] in Fig. 3 has a built-in camera and AI processor in the housing, and it is possible to execute a trained neural network with OAK alone. Changing the neural network allows various processes such as object recognition, people counting, face recognition, and vehicle recognition to easy performed. It is relatively cheap and can buy $199. There is an API called DepthAI, and you can develop applications in Python or C ++. Since OAK performs the processing by AI, it is possible to create a system using a weak device such as Raspberry Pi.

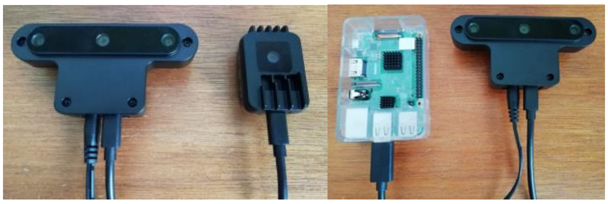

Fig. 3. OAK-D and OAK-1, Raspberry Pi and OAK-D.

B. MediaPipe

In this system, commands are input by finger sign. It is difficult for a visually impaired person to operate the screen of a terminal when giving instructions to the system. Therefore, in this system, a sign using a finger is photographed with a camera, and a command is an input. For that purpose, it is necessary to acquire the coordinates of the fingertips and joints to recognize the finger and the shape of the finger. In this report, we use MediPipe [17], an open source and platform-independent machine learning library provided by Google that supports live cameras and streaming. MediaPipe can perform more than ten processes such as body pose detection, face detection, and hand tracking from the video taken by the camera.

MediaPipe is easy to use by simply installing the library. In this report, hand tracking of MediaPipe is used to identify finger signs. MediaPipe can set 21 landmarks on each finger's palm and acquire their 3D coordinates. Fig. 4 is an example of modifying a part of the hand tracking sample program to display the circle at the position of the index finger from the coordinates of the acquired landmark. There are two methods for recognizing finger signs: detecting the shape of a finger from the distance and angle of a landmark and a form of machine learning. In this report, the former method is used to recognize simple signs. In the future, we will do machine learning and increase the number of signs.

Fig. 4. Execution of commands by finger sign.

VI. WALKABLE AREA DETECTION

Some areas are closed to traffic due to temporary obstacles and construction work in the actual walking environment. However, it is difficult for AI to learn all those obstacles. Therefore, in this report, instead of detecting obstacles and non-walking areas, it is considered that there are no obstacles or non-walking areas in places where pedestrians other than yourself are walking. The place where other pedestrians walk is the walkable area. In addition, some studies using AI have been conducted to detect pedestrians, and the accuracy is high.

Fig. 5 shows the walkable area detected by the prototype system. The green square in (A) is the walkable area, and the color difference is the direction of travel of the pedestrian. The green area is a pedestrian moving in the same direction as the user and can walk, and the blue area (B) is a pedestrian moving toward the user and cannot walk. This image is displayed on the user's smartphone or tablet.

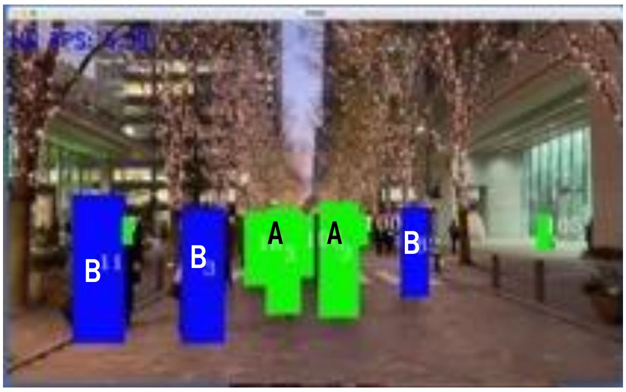

Fig. 5. Detected walkable area.

The user traces the displayed image with their finger, and when the finger enters the walkable area or the non-walkable area, the user notifies the fact by voice. In Fig. 5, there is a walkable area in the center. In addition, the left and right indicate that pedestrians are coming toward us, which are non-walkable areas.

VII. DETECTION OF PEDESTRIAN MOVEMENT DIRECTION

For the user, a pedestrian traveling in the same direction indicates a walkable area, but there is a risk of collision when coming toward the user. Therefore, it is essential to determine the traveling direction of the pedestrian. In this report, the direction of travel of a pedestrian was detected by the following procedure.

The AI used for pedestrian detection returns the coordinates of the vertices of the rectangle containing the pedestrians in the image.

This report compares the length of this rectangle's upper side with a few frames before and the latest frame. If the side of the newest frame is long, the image of the pedestrian is getting bigger, so we judge that the pedestrian is coming toward this side. If it is short or the same, it is believed that they are heading in the same direction. In Fig. 6, the left is a few frames before, the right is the latest frame, and the arrow shows the length of the upper side. The arrow on the right is longer than the one on the left, so you can see that you are approaching here.

The direction of travel can be roughly detected by this method. However, the size returned by AI is not strictly proportional to the distance and may not be detected correctly, so improvements are needed in the future. The OAK used is equipped with a stereo camera and has a function to see the distance, and its use is under consideration.

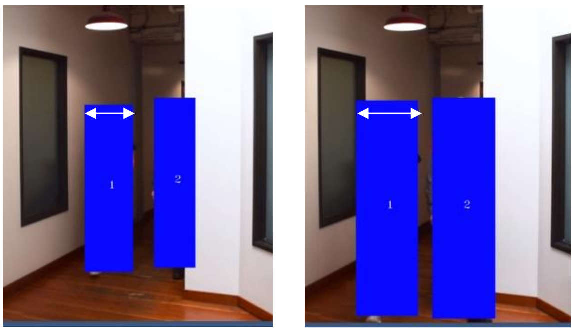

Fig. 6. Movement direction detection.

VIII. DIRECTING THE DIRECTION OF TRAVEL BY SOUND

This system uses sound to give instructions and changes the pedestrian's travel direction to the detected walkable area. The direction of travel is adjusted by moving the camera to move the displayed walkable area to the center of the display. However, visually impaired people cannot operate by looking at the display. Therefore, the distance between the walkable area and the center of the display, Fig. 7, is shown by the pitch of the sound. When the distance is long, the sound is low, and as it gets closer, the sound is raised, and the camera's position is adjusted by listening to the change in the sound. Through this operation, there is a walkable area in the direction the camera faces, and it is possible to walk safely.

This method is used in shooting competitions for the visually impaired, such as the Paralympics. In competitions, visually impaired people use a dedicated beam rifle. The beam rifle indicates the error between the target and the aim by the pitch of the sound, and the athlete relies on the sound to aim the gun at the target. Using this method, even visually impaired people can align the walkable area with the center of the display.

When I conducted a blindfold experiment with the prototype program, I could point the camera accurately with some practice. This method does not require any special equipment and is easy to realize.

It is necessary to use earphones for actual use, but it is essential to consider that wearing earphones makes it challenging to hear surrounding sounds.

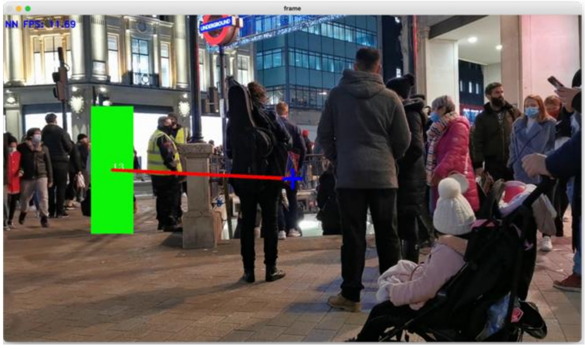

Fig. 7. Distance between the walkable area and the center of the display.

IX. CONCLUSION

It is difficult for visually impaired people to walk around the city safely. Due to the nature of the disability, it is not possible to walk straight toward the target. Therefore, they may have an accident.

In this study, we are developing a system that enables visually impaired people to walk safely toward their goals. In this report, we proposed and prototyped a method for finding areas where visually impaired people can walk safely. Detect pedestrians using trained AI and OAK to determine walkable areas. The walkable area is obtained from the detected pedestrian, and the camera is moved toward the walkable area to determine the moving direction. By using sound to point the camera in the direction of travel toward the walkable area, it is possible for visually impaired people to operate it. System commands can also be used by the visually impaired by using finger signs.

We believe that the system we are developing is useful for walking support for the visually impaired.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Yasuyuki Murai conducted a literature survey, programming, and tests and evaluated the test results. Yumiko Ota supported with tests. Hisayuki Tatsumi and Masahiro Miyakawa provided technical guidance. Yasuyuki Murai wrote the paper. All authors had approved the final version.

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