An Interactive Braille-Recognition System for the Visually Impaired Based on a Portable Camera

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ABSTRACT

We develop an interactive Braille-recognition system using a portable camera for visually impaired persons who cannot read Braille. Our system helps them to find and then push a desired button, as is necessary when using an elevator or a ticket vending machine, for example. It is natural to think that the information provided in Braille with specific buttons is sufficient for successful operation in using an elevator or a ticket vending machine. Most visually impaired persons, however, cannot read Braille. To push a desired button, the user needs to hear only the word or letter associated with the specific Braille character so that s/he can correctly relate the buttons to Braille characters. If the user is informed of all the Braille characters in front of her/him, s/he will not be able to relate the buttons to Braille characters. In our system, the user interactively specifies the location of a particular Braille character to be read by using hand gestures. The system recognizes the user's gestures and reads the desired Braille aloud. In our preliminary experiment, six blindfolded subjects were all able to interact with our system, and recognized the meaning of the buttons that s/he identified.

Author Keywords

Braille Recognition, Gesture Recognition, Wearable Computer

ACM Classification Keywords

H.5.2 [**User Interface**]: Interaction styles; I.3.6 [**Methodology and Techniques**]: Interaction techniques; K.4.2 [**Social Issues**]: Assistive Technologies for Persons with Disabilities

INTRODUCTION

Information in Braille for visually impaired people can be found in various places, such as ticket dispensers in train stations, guide plates or elevators (Figure 1). The information provided in Braille may be regarded to be sufficient for every visually impaired person. Most of the visually impaired, however, cannot read Braille. In fact, approximately 90% of them cannot read it in Japan [1]. This is because the number of people with acquired visual impairments increases with age, and it is difficult for the elderly to master reading Braille. In our aging society, the number of visually impaired people who cannot read Braille will increase, as will the number of people with acquired visual impairments. Therefore, systems are required that can recognize Braille characters and read their meanings aloud.

Figure 1. Example of Braille sign (The image on the right is an enlarged image of the region bounded by the rectangle on the left)

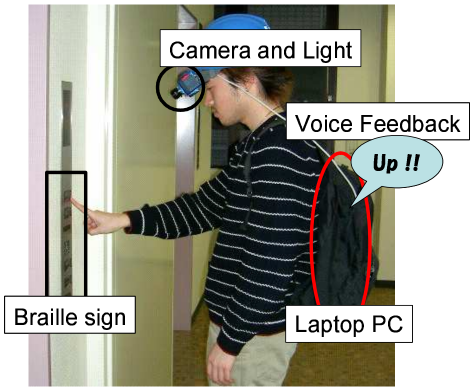

Figure 2. System overview

In this paper, we propose a system that can interactively recognize Braille in outdoor situations (Figure 2) for visually impaired people who cannot read Braille. For example, using our system, they can reach the desired floor on an elevator or buy a train ticket to the correct destination. Moreover, the system assists them in learning Braille.

INTERACTIVE BRAILLE-RECOGNITION SYSTEM

Problems with Existing Braille Recognition Systems

Optical Braille-recognition systems that recognize and digitize characters in Braille using an optical scanner are already in widespread use. However, two main problems exist in the application of these systems to Braille in outdoor situations, such as Braille signs in public places.

1. Existing systems read all the Braille characters in an image captured by the scanner.
2. The existing systems assume that the environment in which the scanner works is static.

The first problem makes a user confused when a system recognizes and reads all the Braille characters inside a given area. This is because the user does not know which Braille characters are being read. For example, on the left of Figure 1, if the system reads all the Braille characters, *e.g.*, one, two, three, etc., the user cannot determine which buttons the user should push. The user, therefore, needs to identify the meaning of a specific button to reach the floor on an elevator or to buy a train ticket using a ticket machine.

With respect to the second problem, on the other hand, existing systems recognize Braille by using the brightness and the shadows generated by illuminating raised dots. They assume that the shadows are always the same. In the outdoor, however, it is difficult to recognize Braille using shadows because of the effect of external light. Braille characters in public areas tend to be small and the color of the dots usually matches with the background. Moreover, whenever someone touches Braille signs, they are contaminated with fingerprints or skin oil.

Design

To solve the two problems above, we set the following functions in designing our system.

1. Read only the Braille characters identified by a user.
2. Robustly detect Braille characters in outdoor situations.

To realize the first function, a user interactively specifies the location of Braille characters with the following hand gestures.

- One or both hands are open (Figure 3), when a user is searching for Braille.
- S/he repeatedly moves a finger from one side to the other side by pointing out the detected characters to be read (Figure 4), when a user specifies Braille characters.

These gestures allow the system to read only the Braille characters identified by the user. These are natural, easy to learn, and less of a burden for the user. Furthermore, to overcome the user's misunderstanding about whether the system correctly identifies whether s/he is searching for Braille, or specifying a desired region, our system uses auditory feedback with rising and falling sounds.

We employ a head-mounted camera in our system so that the system observes user's gestures and Braille (Figure 2). Users can turn the camera toward the desired Braille by turning her/his head toward their fingertips. We first thought whether a finger- or hand-mounted camera can capture Braille better.

Figure 3. Searching for Braille

Figure 4. Finding Braille

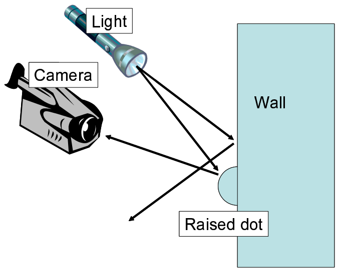

Figure 5. Reflection from Braille

It then turned out that a head-mounted camera interrupts the user in finding the Braille less than a finger-mounted camera.

To realize the second function, i.e., robustly detecting Braille characters that are small and have the same color as the background, we use a high-resolution (1600x1200) optical camera. A light is also mounted with the camera on the user's head. When raised dots are illuminated, some reflected light returns to the camera because the dots are hemispherical, whereas light reflected from the wall does not return to the camera (Figure 5). Consequently, the Braille characters are highlighted (Figure 6). The system thus uses the light reflected only from the Braille for robust detection.

How to Determine Braille Characters

In using the system, a user firstly stands in front of Braille signs and then conducts the following steps.

1. Search for Braille signs.
2. Inform the system that a Braille character has been detected and indicate its location with her/his gesture, when s/he finds it.
3. Obtain auditory feedback about the meaning of the Braille character from the system.

The user repeats these steps to obtain the desired information of the button to push in an elevator, for example.

IMPLEMENTATION

We describe here the implementation of the design of our system. First, the system needs to recognize the user's gestures whether s/he is searching for Braille or pointing out it by analyzing images acquired by the head-mounted camera. After it identifies that the user is pointing out Braille, it

Figure 6. With (left) or without (right) light

tracks her/his finger, then crops the region specified by the user. It then robustly recognizes the Braille characters within the cropped region and reads their meaning aloud.

Gesture Recognition

Our system recognizes gestures depending on the number of detected fingertips. When the system detects a single fingertip in the input image, it understands the gesture as specifying Braille (Figures 4). When it detects more than one fingertip, it understands the gesture as searching for Braille (Figure 3).

We use a color histogram in the *rg*-plane[1] of a fingernail to detect fingertips. A method that uses the *rg*-plane can clearly recognize skin color under changes in light [3]. The system maintains a color histogram of the user's fingertip in advance. The system scans input images and searches for regions that are similar to the color histogram kept in the system.

Cropping Region of Interest

The system crops the region of interest (ROI) by tracking a moving finger for one or two seconds after it determines that the user is pointing out Braille. The width of the cropped ROI is the distance that the user move her/his finger while the system identifies that only one finger exists in the frame. The height of the ROI is assumed to be constant. This is because the distance between the camera and the Braille is almost the same for all users.

Braille Recognition

To extract light reflected from Braille characters, the system extracts an area having great contrast in the cropped ROI. It identifies an edge and then binarizes the image using a threshold (Figure 7). Because all the raised dots within the ROI are expected to reflect similarly, both the size and shape of ROI are similar to those of the binary image. Our system recognizes regions having a circular shape and a certain level of size as raised dots. The system then focuses only on the regions of raised dots.

We use the algorithm proposed by Hermida *et al.* [2] to robustly detect raised dots. To be more concrete, we first detect the skew angle and then detect the horizontal and vertical intervals. Next, we choose a starting point and generates lines with regular intervals from the starting point (Figure 8). The area in the binary image to be recognized as Braille has to

[1] $r = \frac{R}{R+G+B}$, $g = \frac{G}{R+G+B}$

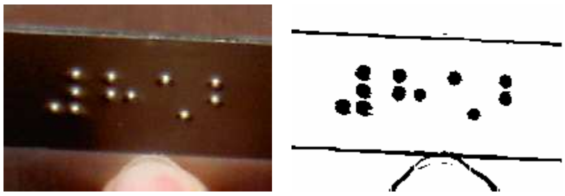

Figure 7. Cropped (left) and Binarized (right) ROI

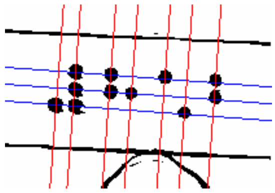

Figure 8. Example of grid determination

be intersections of these lines; raised dots not on such intersections are considered as noise. This is because Braille characters have the property that the horizontal and vertical distances between the raised dots are normalized in each area. Finally, we check each intersection on the grid, and recognize Braille characters by comparing the dictionary stored in the system. The meanings of the recognized Braille characters are then loudly read to the user by the system.

PRELIMINARY EXPERIMENT

We evaluated the proposed system. We tested whether this system recognizes Braille signs robustly and whether blindfolded subjects can interact with the system.

Recognition Rates

We conducted tests in an elevator and on a ticket machine at a train station. In the elevator, we tested whether our system recognizes six different Braille signs. We tested each Braille sign five times. We thus had 30 trials in total. Since the elevator was indoors, external light had no effect. With respect to the ticket machine, we tested whether the system recognizes five different signs. We tested three times for each sign and we had 15 trials in this case. Since the ticket machine was located in outdoors, external light did have effect. The camera that we used was ARTRAY ARTCAM-OV200 with resolution of 1600x1200. Its image pick up device was 1/2-inch CMOS, and its horizontal field of view was 30°.

In this experiment, the first author himself did the testing. He has no physical impairment. The distance between the camera and the Braille characters was approximately 45 cm, and the corresponding photographic field was 240x180 (WxH) mm. At each location, we calibrated a color histogram of his fingertip.

In the elevator, the system correctly recognized all the Braille signs within cropped ROIs. However, in the case of the ticket machine, although external light had little effect on Braille detection by illuminating Braille signs with a light mounted on the head, the system recognized only three of fi-

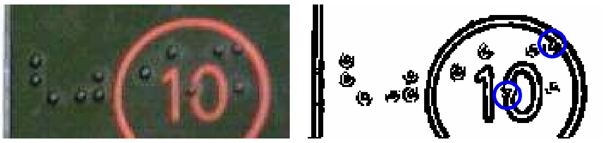

Figure 9. Raised dots overlapped on printed characters

ve Braille signs. This is due to printed characters overlapped on raised Braille dots (see two circles in the right of Figure 9). Our system determines whether a region consists of raised dots or characters by checking only its shape and size. If raised dots are overlapped on printed characters in the same region, the region is not recognized as Braille, and in some cases, some of the raised dots are not detected.

Usability

We tested the usability of our system with six blindfolded subjects in an elevator. None of the subjects had visual disabilities. We calibrated a color histogram of the fingertip of each subject. The distance for all the subjects between the camera and the Braille characters was approximately 45-50 cm. Furthermore, we briefly taught each subject how to specify the Braille characters to be read.

All the subjects could immediately use gestures, and capture desired Braille characters by turning their head toward their fingertip. They could also indicate and determine the desired Braille characters correctly by interacting with our system. Rising and falling tones, which give feedback on the situations that the system recognizes, were preferred by all the subjects.

DISCUSSION AND FUTURE STUDY

In this paper, we proposed an interactive Braille-recognition system that assists visually impaired people who cannot read Braille when going out. Visually impaired people assistances with tags such as RFID have already been proposed. However, it will take a long time for tags to widely become available everywhere, such as Braille. We aim to provide feasible and immediate support with visually impaired people.

We used a head-mounted camera with a lens having a 30° field of view so that visually impaired people can turn the user's head toward her/his fingertips. In our preliminary experiment, all the six blindfolded subjects could make the system capture their gestures that indicate Braille is detected. With this field of view, the system can thus appropriately capture gestures of most people.

The system correctly recognized Braille when no additional characters exist that are printed below the raised dots. However, when the raised dots exist that are overlapped on printed characters, the system could not recognize the Braille. In our experiment, failing in detection of one raised dot results in nonrecognition of all the Braille in the ROI. Therefore, we plan to apply semantic estimation to fill in gaps that are not recognized by using the surrounding dots to be recognized. Furthermore, by improving (1)the image-processing method, (2)the illumination of the Braille, and (3)the camera setup, we detect raised dots that are overlapped on printed characters.

In future studies, we hope to detect printed characters in images acquired by the head-mounted camera. Since printed characters do not provide haptic feedback, even if the system detects and reads the characters, a user will know where they are. Nevertheless, because such characters contain rich information, it may be possible to obtain a number of cues from the characters in the input images. For example, they may show information associated with Braille, and identify a situation or location. If we know where a user is, *e.g.*, in an elevator or at a station, we can reduce the error rate in recognition of our system by searching for appropriate cues that exist in that location.

Finally, we hope to lead users to Braille signs, as proposed in [4, 5]. In most cases, Braille pavement blocks indicate Braille signs. However, it is difficult for people with acquired visual impairment to walk using Braille blocks. We hope to assist them in walking and avoiding obstacles with our system.

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REFERENCES

1. Dept. of Health and Welfare for Persons with Disabilities, Ministry of Health, Labour and Welfare: "Result of A Survey Pertaining to Physically Impaired (surveyed in June 1 2001)" (in Japanese), 2002.

2. X. Fernández Hermida, A. Corbacho Rodríguez and F. Martín Rodríguez: "A Braille O.C.R. for Blind People", *Proc. of ICSPAT*, 1996.

3. J. Terrillon, A. Pilprè, Y. Nishizawa and K. Yamamoto: "Analysis of Human Skin Color Images for a Large Set of Color Spaces and for Different Camera Systems", *Proc. of IAPR Workshop on Machine Vision Application*, pp.20-25, 2002.

4. A. Hub, J. Diepstraten and T. Ertl: "Design and Development of an Indoor Navigation and Object Identification System for the Blind", *Proc. of ACM ASSETS*, pp.147-152, 2004.

5. D. A. Ross and B. B. Blash: "Wearable Interfaces for Orientation and Wayfinding", *Proc. of ACM ASSETS*, pp.193-200, 2000.