Braille Block Recognition for an Autonomous Wheelchair

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Abstract

By using a Braille block on a sidewalk, a senior citizen and a handicapped person may run safely getting on an autonomous wheelchair. A Braille block is a sign to guide a visually handicapped person and its standard color is yellow, but the colors other than a standard color are often used. In addition, misrecognition of Braille block by a color is often happen under various light conditions. Therefore, we examine the recognition method of Braille blocks using two dimension discrete cosine transform (DCT). We find that the average recognition rates of guide blocks and of warning blocks are 77% and 68%, respectively.

Keywords: Braille Block Recognition, DCT, Autonomous Wheelchair

1 Introduction

According to a report on disability children and persons [1], there are about 300,000 visually handicapped persons in Japan. Visually handicapped persons of the first class, who cannot walk using their sight, are about 100,000. 80 percent or more of them lose their sight midway through their life. About 30,000 persons can walk alone with a white cane and the other persons cannot walk without a help or doesn't walk at all.

Aging society is proceeding and persons who lose their sight increase, so walking support systems are more important in the future. One of walking support systems is an autonomous mobile robot [2,3]. It must have a function that it can run in various environments. Therefore, there are various researches of an autonomous mobile robot, which runs out of doors recognizing typical objects in a complex environmental condition.

In this research, we propose a recognition method of a Braille block set up on a sidewalk for a visually handicapped person by discrete cosine transform.

2 Braille Block

A Braille block is a sign to guide visually handicapped persons and set up on a sidewalk. A Braille block in our work is shown in Fig. 1, 2. There are two kinds of Braille blocks. One is a warning block where small round convex parts line up like the lattice and another is a guide block where rectangular convex parts line up in parallel. A standard color of a Braille block is yellow so that a weak-sighted person can recognize it easily by the contrast with surroundings. However, blocks of another color are often used in consideration of the correspondence with a surrounding spectacle. A Braille block is used in the world and its size and shape are various types. So in this research we consider a Braille block designed in Japan.

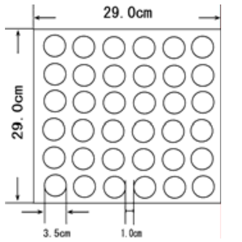


Fig.1 A warning block

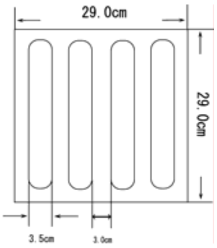


Fig.2 A guide block

3 Detection and Recognition of a Braille Block

Since a warning block consists of small round convex parts lining up like the lattice and a guide block consists of rectangular convex parts lining up in parallel, we consider a Braille block a constant periodic pattern. Therefore, we propose a method of using two dimensional discrete cosine transform that resolves light and shade information in the image to the frequency element to detect and recognize a Braille block.

3.1 Two Dimensional Discrete Cosine Transformation

Discrete cosine transform (DCT) is orthogonal transformation that uses the cosine function for the transformation base, and the image data is transformed into the frequency element. Two dimensional DCT and inverse DCT of an $M \times N$ pixels image $f(x,y)$ are given by

DCT :

$$F(u,v) = \alpha(u)\alpha(v)\sum_{x=0}^{M-1}\sum_{y=0}^{N-1} f(x,y)\cos\left(\frac{(2x+1)u\pi}{2M}\right)\cos\left(\frac{(2y+1)v\pi}{2N}\right)$$

IDCT :

$$f(x,y) = \sum_{u=0}^{M-1}\sum_{v=0}^{N-1} \alpha(u)\alpha(v)F(u,v)\cos\left(\frac{(2x+1)u\pi}{2M}\right)\cos\left(\frac{(2y+1)v\pi}{2N}\right)$$

where

$$\alpha(u) = \begin{cases} \sqrt{\frac{1}{M}} & u = 0 \\ \sqrt{\frac{2}{M}} & u = 1,2,\dots,M-1 \end{cases}, \quad \alpha(v) = \begin{cases} \sqrt{\frac{1}{N}} & v = 0 \\ \sqrt{\frac{2}{N}} & v = 1,2,\dots,N-1 \end{cases}$$

and $f(x,y)$ is an image and $F(u,v)$ is a frequency element (DCT coefficient).

In this research 640×480 pixels image is divided into the block of 12 pieces, called the unit block, that consists of 160×160 pixels. We perform two dimensional DCT to each unit block and obtain a frequency element that indicates the feature of a Braille block.

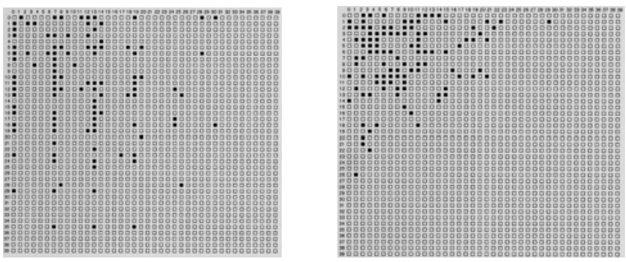
3.2 Feature Mask

As a preprocessing of Braille block recognition, a feature mask of the warning block and the guide block is constructed by DCT coefficient. First we prepare three images of warning blocks and guide blocks, respectively, as training images and perform DCT to them to determine the frequency elements that show the feature of a Brail block. In each image there are 12 unit blocks, so that we have 36 unit blocks for the warning block and the guide block, respectively.

Next we select DCT coefficients, which are high rank 10% of absolute values of DCT coefficients except for the direct current element included in all the unit blocks. Then we calculate the average and the standard deviation of their DCT coefficients and determine *average - standard deviation* as a threshold, which judges whether a unit block is a Braille block.

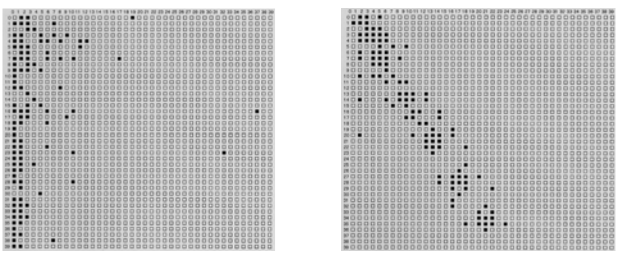
In addition, there is a characteristic distribution of large absolute value of DCT coefficients of the warning block and the guide block respectively. Figure 3 and 4 are the distributions of large absolute value of DCT coefficients of the high rank 3% for a Braille block. Therefore, the remarkable frequency domains are 40×40 except the low frequency area of 10×10, which show the periodicity of the light and shade image of the warning block and the guide block.

Moreover the distribution of DCT coefficients of the high rank 10% is also different depending on the inclination angle of a Braille block. For instance, distributions for various inclination angle are shown in Fig. 5 in the guide block. The feature mask of the warning block and the guide block is constructed according to the inclination angle of each block. The feature mask used in our experiment is shown in Table 1 and 2.



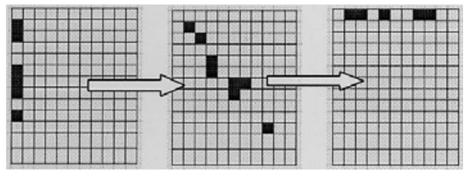
(a) angle=0 ° (b) angle=30 °

Fig.3 Distributions of DCT coefficients for warning blocks

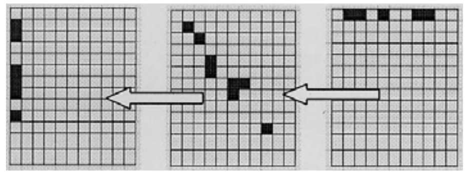


(a) angle=0 ° (b) angle=30 °

Fig.4 Distributions of DCT coefficients for guide blocks



(a)angle = 0 ° ～ 90 °



(b)angle = 90 ° ～ 180 °

Fig.5 Changes of distributions of DCT coefficients for angles of guide blocks

3.3 Perspective Transformation

The video camera that takes a picture of Braille blocks is set up in the electric wheelchair at constant height and the angle. Therefore, we convert images of Braille blocks into images taken at a vertical angle using perspective transformation shown in Fig. 6. When the height of the video camera from the ground is represented by H, and the angle with a horizontal plane is represented by θ, the perspective transformation equations are given by

$$\begin{cases} x' = \dfrac{Hx\cos^2\theta}{H - y\sin\theta\cos\theta} \\ y' = \dfrac{Hy\cos^3\theta}{H - y\sin\theta\cos\theta} \end{cases}$$

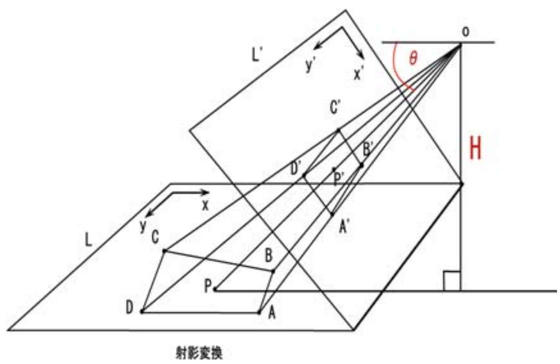


Fig.6 Perspective transformation

4 Detection of a Braille Block

4.1 Detection of a Braille Block in Each Unit Block

The image taken with the video camera is transformed by perspective transformation, DCT coefficients corresponding to the feature mask are taken out at each unit block, and they are compared with the threshold. If the ratio of absolute value of DCT coefficients larger than the threshold is 50% or more, we classify the unit block as a Braille block, and if the ratio is less than 50%, we classify the unit block as another image. In Fig. 7, we shows a Braille block classification chart, in which the unit block classified as a Braille block is described by [O] and the unit block is described by [X] if it is not a Braille block.

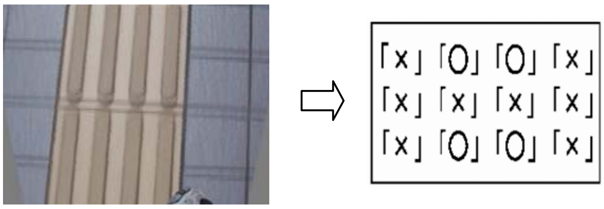


Fig.7 Perspective transformation image and Braille block classification chart

4.2 Braille Block Area

Next we determine a Braille block area in the classification chart. If there are unit block classified as a Braille block ([O]) in surroundings of a unit block classified as other ([X]), the unit block is classified as a Braille block ([X] --> [O]) as shown in Fig. 8.

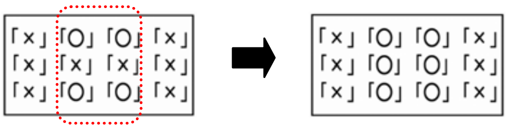


Fig.8 Extraction of Braille block area

5 Recognition of a Braille Block

If the unit block is denoted by [X] both in the warning block classification chart and in the guide block classification chart, its unit block is recognized as a part which is not a Braille block. If the unit block is denoted by [O] only in the guide block classification chart, its unit block is recognized as a guide block. If the unit block is denoted by [O] both in the warning block classification chart and in the guide block classification chart, its unit block is recognized as a warning or guide block according to classification of neighborhood unit blocks.

6 Experiment and Results

6.1 Experimental Conditions

Experimental conditions are as follows.

Video camera : SONY DCR-TRV20
Height of camera : 58cm
Downward angle of camera : 40°
Electric wheelchair : SUZUKI MC2000 (Fig. 9)
Velocity of electric wheelchair : 1.0km/h
Experimental location: Kyoto Prefectural University


Fig.9 Electric wheelchair

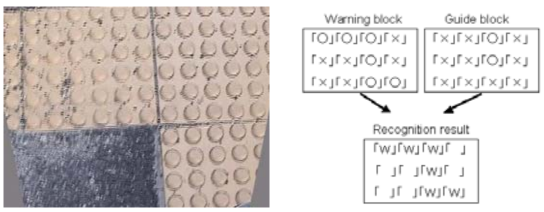
6.2 Experiment

We run the electric wheelchair along Braille blocks in Kyoto Prefectural University. Images taken with the video camera are converted into vertical angle images using perspective transformation. Then we examine the recognition rate of Braille blocks.

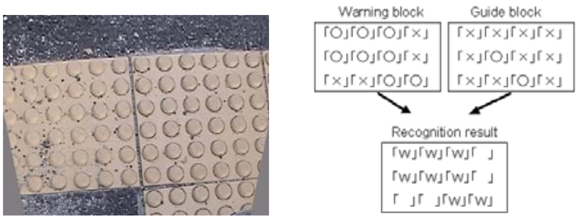
6.3 Results

We investigate recognition of 10 warning block images and 20 guide block images captured with the video camera. For 10 warning block images, the experiment results are shown in Fig. 10, where [W], [G] and [ ] denote a warning block, a guide block and other, respectively. For 20 guide block images, the experiment results are shown in Fig. 11.

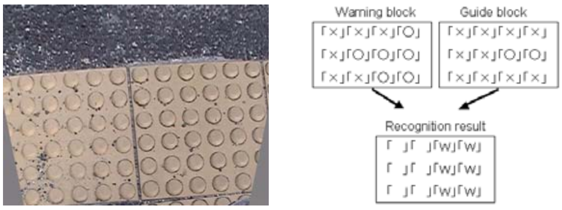
The recognition rates of 10 warning block images and 20 guide block images shown in Table 1 and 2, respectively. We find that the average recognition rate of the warning block and the guide block are 68% and 77%, respectively, and the average recognition rate in the part that was not the Braille block is 64%.



(a) First image

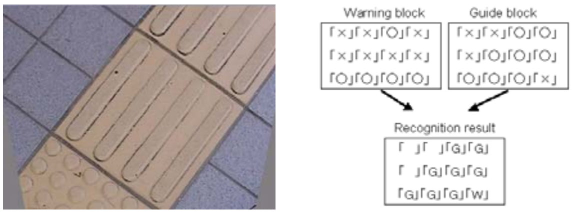


(b) 5th image

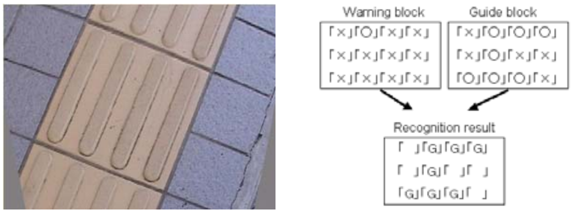


(c)10th image

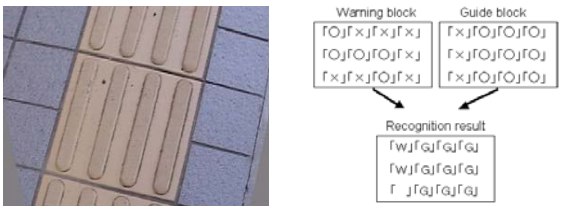
Fig.10 Recognition of warning blocks



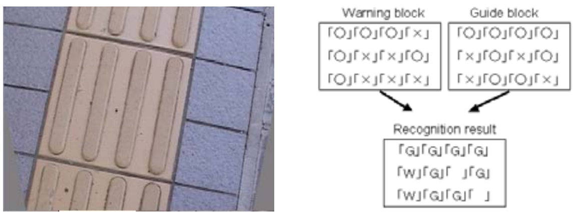
(a)First image



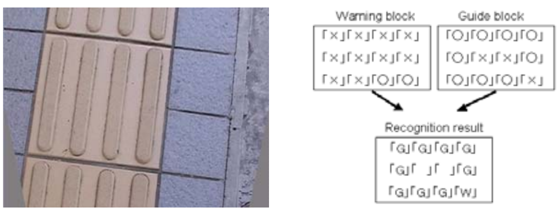
(b)5th image



(c)10th image



(d)15th image



(e)20th image

Fig.11 Recognition of guide blocks

7 Conclusion

In this paper, we propose a recognition method of a Braille block using specific frequency elements of the warning block and the guide block obtained by discrete cosine transform. In the experimental results recognition rate of the warning block and the guide block were 68% and 77% on the average, respectively. These results are not sufficient because we use only one condition that judge whether each unit block is a Braille block.

In the future, we consider a method of recognizing a Braille block by processing time series images to raise the recognition rate. Moreover, we consider a method that can distinguish a Braille block from other objects, which have a similar periodic pattern.

Table 1 Recognition rates of warning blocks

image	# of unit blocks in a warning block	#of unit block recognized a warning block	recognition rate	# of unit blocks in other	# of unit block recognized other	recognition rate
1	10	6	0.60	2	2	1.00
2	12	9	0.75	0	0	—
3	12	5	0.42	0	0	—
4	12	11	0.92	0	0	—
5	12	8	0.67	0	0	—
6	12	8	0.67	0	0	—
7	11	5	0.45	1	0	0.00
8	10	9	0.90	2	1	0.50
9	10	6	0.60	2	2	1.00
10	10	8	0.80	2	2	1.00
ave			0.68			0.78

Table 2 Recognition rates of warning blocks

image	# of unit blocks in a guide block	# of unit block recognized a guide block	recognition rate	# of unit blocks in other	# of unit blocks recognized other	recognition rate
1	10	8	0.80	2	1	0.50
2	10	6	0.60	2	0	0.00
3	10	6	0.60	2	2	1.00
4	11	9	0.82	1	1	1.00
5	10	7	0.70	2	2	1.00
6	9	7	0.78	3	3	1.00
7	10	8	0.80	2	2	1.00
8	10	10	1.00	2	2	1.00
9	10	10	1.00	2	2	1.00
10	9	7	0.78	3	0	0.00
11	10	8	0.80	2	2	1.00
12	10	7	0.70	2	0	0.00
13	9	6	0.67	3	3	1.00
14	9	4	0.44	3	2	0.67
15	9	6	0.67	3	1	0.33
16	9	6	0.67	3	1	0.33
17	10	8	0.80	2	1	0.50
18	10	9	0.90	2	1	0.50
19	9	9	1.00	3	3	1.00
20	9	7	0.78	3	0	0.00
ave			0.77			0.62

References

[1] “Report on disability children and persons”, The Ministry of Health, Labour and Welfare statistics database system, 2001.

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