Basic Investigation into Hand Shape Recognition Using Colored Gloves Taking Account of the Peripheral Environment

Takahiro Sugaya, Takayuki Suzuki, Hiromitsu Nishimura, and Hiroshi Tanaka

Kanagawa Institute of Technology,
1030 Shimo-ogino, Atsugi-shi, Kanagawa, Japan
s0921071@cce.kanagawa-it.ac.jp,
{suzuki,nisimura,h_tanaka}@ic.kanagawa-it.ac.jp

Abstract. Although infrared cameras are sometimes used for posture and hand shape recognition, they are not used widely. In contrast, visible light cameras are widely used as web cameras and are implemented in mobile and smart phones. We have used color gloves in order to allow hand shapes to be recognized by visible light cameras, which expands both the type of background that can be used and the application areas. It is considered that the hand shape recognition using color gloves can be used to express many patterns and can be used for many applications such as communication and input interfaces, etc. The recognition performance depends on the color information of the color gloves, which is affected by the environment, especially the illumination conditions, that is bright or dim lighting. Hue values are used to detect color in this investigation. The relative finger positions and finger length are used to confirm the validity of color detection. We propose a method of rejecting image frames that includes a color detection error, which will, in turn, give rise to a hand shape recognition error. Experiments were carried out under three different illumination conditions. The effectiveness of the proposed method has been verified by comparing the recognition success ratio of the conventional method and with the results using the proposed methods.

Keywords: Colored Gloves, Visible Light Camera, Color Detection, Hue Value, Peripheral Environment.

1 Introduction

Communication is one of their largest barriers to independent living for hearing impaired or speech-impaired persons. Although most of people who are born with a disability have opportunities to study sign language or Braille, those who become handicapped later and non-handicapped people rarely learned such communication methods. Gesture recognition systems etc. have been developed in order to solve these problems [1]. A comparison between an inertia sensor based gesture recognition method and a vision based method has been reported [2]. In addition, a finger Braille recognition method using a special-purpose sensor has been reported [3].

S. Yamamoto (Ed.): HIMI/HCII 2013, Part I, LNCS 8016, pp. 133–142, 2013.

Gesture recognition using a 3D sensor has also been reported [4]. However, some problems remain with these methods. The methods with a special sensor or devices [2-4] involve a high cost of introduction and this makes it difficult to expand the area of usage. Locations where these systems can be used will also be restricted in the case of special purpose sensors. Therefore, it is difficult to use these systems to achieve easy communication for handicapped people.

If we assume that a handicapped person can carry a computer system, we can achieve gesture recognition realize by using a camera and a laptop PC. We have selected a vision-based recognition method, because it does not require sensor to be attached to the human body. Although its range for satisfactory viewing is limited, this is not a problem because the distance between two persons when communicating is not great. There are two kinds of approach as methods for vision-based gesture recognition. One is a method using a color marker, such as a color glove, and the other is a method which does not use a color marker [5]. Of course, the recognition method that does not use a color marker is more user-friendly. However, it is quite difficult to realize a highly reliable recognition system in an environment with a complex background color and under both, bright and dark light conditions without using a color marker. We have given priority to use in a variety of environments. Therefore, in this research we decided to use a color glove in which a different color was assigned to each finger.

In general, the use of color detection techniques alone cannot maintain high performance in an environment of varying light conditions, and as a result it is difficult to realize high recognition accuracy. We propose a technique for recognizing hand shape with high accuracy under varying illumination conditions by taking additional features of fingers into account.

2 Proposed Color Gloves and Hand Shape

Color gloves have an advantage in facilitating the recognition of hand shapes in comparison with recognition by contour abstraction of hand shapes, especially when considering the background environment. We have used colored gloves on each hand, with the fingers being identified with different colors. Six colors were selected by considering the appropriate hue values, and the positions of the colored areas are the tip of each finger and the wrist as shown in Fig.1. The viewing region of a single camera is divided into two separate regions and the crossing of hands during use is not allowed. This makes it possible to distinguish between the two hands as right hand and left hand.

We propose a new set of finger patterns which is easy to memorize. Some examples of these finger patterns are shown in Fig.2. Each finger represents a binary number, where 1 means visible from the camera, and 0 means an invisible finger, that is a finger which is folded back and not extended. The order of digits in a number follows the order of fingers, that is, the right hand digit is represented by the thumb, and the left hand digit by the little finger. Since each finger pattern in each hand can represent different information, $2^5 \times 2^5$ different signals could theoretically be created.

In practice, $2^4 \times 2^4$ finger shape patterns are used, as some finger patterns are difficult to form.

Since the proposed finger patterns can be formed easily and quickly, the number of possible signal patterns is quite large, and this method seems to have many possible applications. In addition, a high hand shape recognition performance can be expected, because each finger can be identified correctly by the color of the finger.

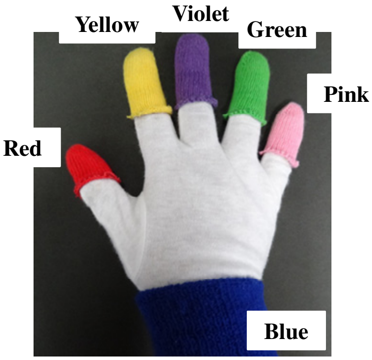

Fig. 1. Color glove

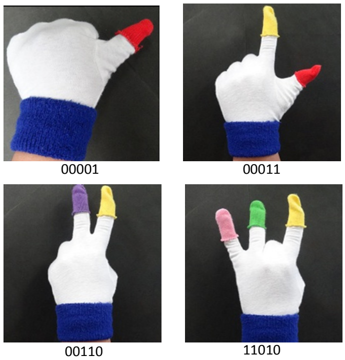

Fig. 2. Some examples of finger patterns

3 Recognition Methods

3.1 Hue Value Threshold Patterns for Color Detection

The hue value is used for color detection in this investigation, as this value corresponds to the color that we see. Two hue value thresholds patterns are considered: one is the nominal threshold pattern which uses narrow regions to avoid color detection errors, as shown in Fig.3 (a), while the other uses broader regions as shown in Fig.3 (b). This broader pattern is expected to provide high sensitivity for color detection in a variety of environments, especially under bright conditions. However, this thresholds pattern might be more likely to cause color detection errors that result in finger pattern recognition errors as a side effect.

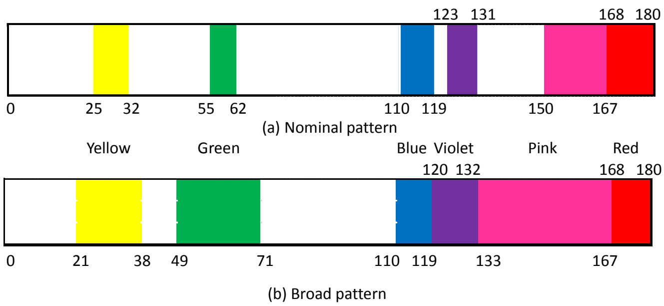

Fig. 3. Hue value threshold patterns for color detection

3.2 Recognition Model and Introduction of Features of Hand Shape

We used a nearest neighbor method for hand shape recognition. First, the distance between the center of the wrist and the tip of each finger is calculated by finding the center of gravity of each colored region. The feature vector **f** of a hand shape is defined as follows.

$$\mathbf{f} = \{d_1, d_2, d_3, d_4, d_5\} \quad (1)$$

where,

d_i : distance between the center of the wrist and center of the colored area at the tip of each finger as shown in Fig.4.

$$d_i = \frac{\sqrt{(fx_i - w_x)^2 + (fy_i - w_y)^2}}{\sqrt{S}} \quad (2)$$

where,

(fx_i, fy_i) : center of gravity of the tip of each finger $(i = 1, 2, 3, 4, 5)$

(w_x, w_y) : center of gravity of wrist

S : Area of wrist

S is used to normalize the distance so that the recognition is not influenced by the distance between the finger and the camera. The five elements of distance form a feature vector that represents a hand shape, where the element value of a colored region which is invisible due to a finger being bent is set to 0. The shape recognition result is obtained by selecting the hand shape which has the minimum distance between template feature vectors prepared in advance and the target feature vector which is to be recognized.

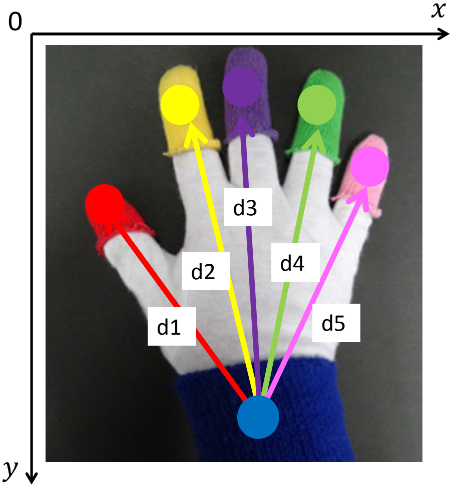

Fig. 4. Feature vector elements of hand shape

There exists a problem that the peripheral illumination affects the hue values that are used to distinguish each finger tips. This change of values gives rise to a color detection error, which degrades the performance of the shape recognition. We have therefore introduced a new operation of validation before the recognition process, which involves calculating the vector distance between a template feature vector and targeted feature vector to be recognized. The relationships of the position of each finger, and the length of the fingers are taken into account when checking the validity of the color detection. Figure 5 shows examples of color detection error. Color detection errors may be of two kinds, an example of one being shown in Fig. 5(a). In this case, the color pink is detected in a different position to that it should be, on the little finger. The other type of error, called, "over detection", as shown in Fig.5 (b). The color yellow is found, but this color should not have appeared because the forefinger is bent. We consider the relationships between each finger in order to guarantee the correct color detection. Table 1 shows the judgment criteria for color detection error, taking the relative finger positions into account. The intersection of the position of the column headings at the top and the row headings on the left indicates the position of the relationship between two fingers. If the finger position relationship satisfies this Table 1, the frames are removed from recognition process as a frame including color detection error. But this criteria cannot remove errors such as that in Fig.5 (b), which results from over detection.

However, the length of each finger also can be used to detect color detection errors. To detect color detection errors, the following conditions are applied, on the assumption that the finger length, d_i, is between 1.5 to 3.5 for correct color detection. The color detection error as shown in Fig.6 in which the distance between the wrist and the tip of ring finger is abnormal can be detected by considering length of finger, with the following conditions assumed to indicate an error.

$$d_i < 1 \text{ or } d_i > 4 \tag{3}$$

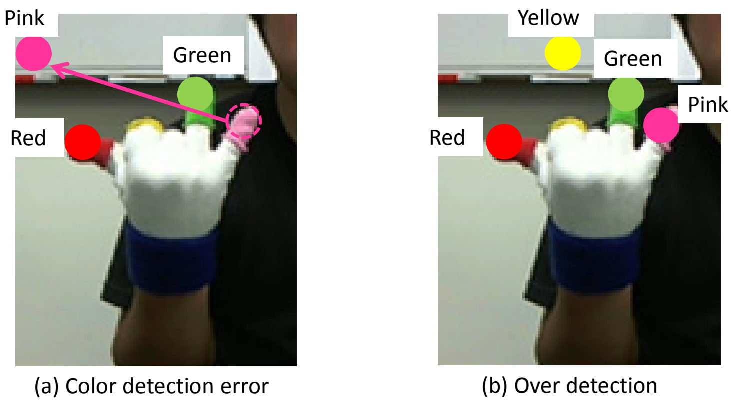

Fig. 5. Examples of color detection errors

Table 1. Jugment criteria of color detection error

	Red (Thumb)	Yellow (Forefinger)	Violet (Middle finger)	Green (Ring finger)	Pink (Little finger)
Red (Thumb)	–	left	left	left	left
Yellow (Forefinger)	right	–	left	left	left
Violet (Middle finger)	right	right	–	left	left
Green (Ring finger)	right	right	right	–	left
Pink (Little finger)	right	right	right	right	–
Blue (Wrist)	Right or below	below	below	below	Left or below

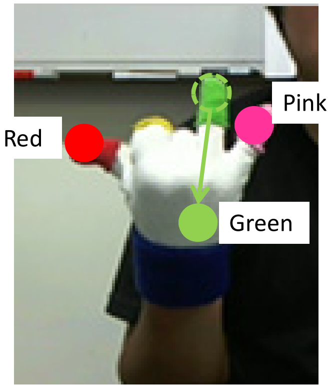

Fig. 6. Example of abnormal finger length

3.3 Hand Shape Recognition Sequence

The flow chart of the finger shape recognition sequence is shown in Fig.7. Template feature vector files for each finger shape are prepared in advance. The first step of the proposed sequence is to capture a camera image and to proceed to color detection to find the position of the fingers and wrist. The key feature of the proposed sequence is the detection of color detection errors as described in section 3.2. That means that any frame containing a feature vector that includes erroneous vector elements is rejected before the recognition process.

The Web camera captures hand shapes at about 30 frames per second, so, it is not a problem to remove any frames that include a color detection error. The distance between the template vectors and the detected feature vector is calculated, and the hand shape with the minimum distance between the template and the detected vector is selected as the recognition result. This sequence can enhance the recognition performance because frames that include a color detection error can be removed from the recognition process.

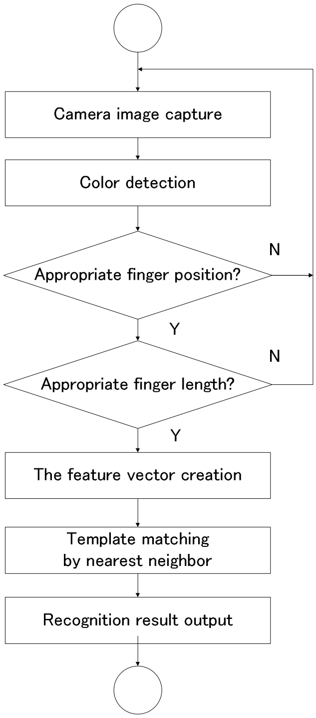

Fig. 7. Hand shape recognition sequence

4 Experiment and Evaluation

4.1 Experimental Environment and Conditions

The purpose of the proposed recognition methods is to maintain high recognition performance independent of the peripheral environment. Therefore three different locations were selected for the experimental evaluation of the proposed method. The experimental locations were, a place far from a window, a place at mid-distance from the window and a place near to the window, as shown in Fig.8. The illumination conditions due to the room light and sun light from the window, which will affect recognition performance, are summarized in Table 2. A Web camera (Logicool HD Pro Webcam C910, 5 million pixels, 30 frames/s) was used in this experiment. The camera was mounted on the notebook PC as shown in Fig.8 and the distance between hand and camera was set to about 50 cm.

The recognition performance was evaluated using two methods, that is, with frame rejection based on considering the validity of color detection and without frame rejection, in order to clarify the effectiveness of the proposed method. The following three experiment conditions, summarized in Table 3 were used to evaluate the proposed method. Case1 is the base case, which used the conventional method. Case2 used the expanded color detection threshold pattern to confirm the effectiveness of enhancing the color detection sensitivity to avoid situations where detection was impossible. Case3 was for full evaluation of the proposed sequence, that is, using the expanded color threshold pattern for color detection and the rejection of frames which indicated a color detection error.

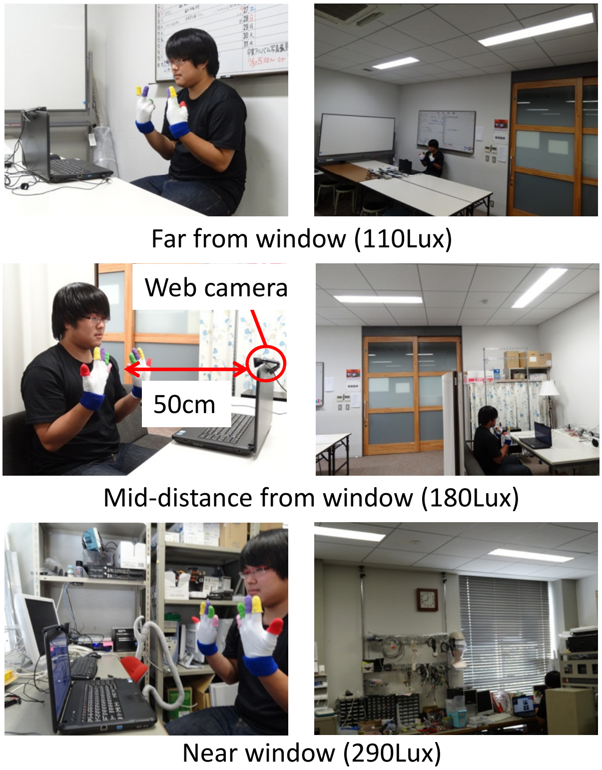

Fig. 8. Experimental environment

Table 2. Illumination conditions of experimental environment

Illumination	Position of room light	Influence of sunlight
110Lux	Above, Left slanting	Small
180Lux	Above, Back	Medium
290Lux	Above, Left slanting	Large

Table 3. Experiment conditions

	Threshold pattern	Frame rejection	Experiment purpose
Case1	Nominal	None	Base case
Case2	Broad	None	Enhancement of color detection sensitivity
Case3	Broad	Enabled	Evaluation of proposed sequence

4.2 Results and Evaluation

Experiments were carried out in each environment for each of the three cases. 6 typical hand shapes, as shown in Table 4 were used in each experiment. The number of frames evaluated for each experiment that is for each light condition and each of the 3 Cases described above was 1800, that is, 100 frames, 3 times (each test was repeated three times), and 6 different hand shapes. Table 5 shows the experimental results. For each set of tests, the total of 1800 frames were classified into three types, frames rejected by color detection error (Case3 only), error frames and success frames (correctly recognized frames). An evaluation factor was also calculated as the summation of the number of rejected frames (R) and 4×number of error frames (E). The recognition success ratio was defined as follows.

Recognition success ratio = success frames / (total frames − rejected frames) (4)

The following conclusions may be drawn from these results. The effect of hue values expansions that is extending the hue threshold region is confirmed by the experiments carried out in a bright environment (290Lux), as shown in Case2 and Case3. The recognition success ratio was increased to 79.3% in a dark environment (110 Lux) by introducing both hue value expansion and frame rejection based on hand shape characteristics. The average success ratio for the three cases, that is, Case1 (base case), Case2 (hue value expansion) and Case3 (hue value expansion and frame rejection) was 63.6%, 87.2% and 93.0%, respectively. These results demonstrate the effectiveness of the proposed method.

Table 4. Hand shapes used in experiment

Finger pattern	00001	00010	00100	01000	10000	11111
Fingers extended	Thumb	Fore-finger	Middle finger	Ring finger	Little finger	All fingers

Table 5. Experimental results

Case	Illumination	Total frames	Rejected frames (R)	Error frames	Success frames (E)	R+4E	Recognition success ratio
Case1	110Lux	1800	N/A	619	1181	2476	65.6%
	180Lux	1800	N/A	18	1782	72	99.0%
	290Lux	1800	N/A	1327	473	5308	26.3%
Case2	110Lux	1800	N/A	663	1137	2652	63.2%
	180Lux	1800	N/A	27	1773	108	98.5%
	290Lux	1800	N/A	1	1799	4	99.9%
Case3	110Lux	1800	590	250	960	1590	79.3%
	180Lux	1800	11	0	1789	11	100.0%
	290Lux	1800	21	7	1772	49	99.6%

5 Conclusion

This paper presents a hand shape recognition method using colored gloves which takes into account the surrounding environment. Two methods are proposed to maintain a high recognition performance under different illumination conditions. The hue value threshold region is enlarged to enhance the sensitivity for color detection. In addition, image frame rejection is introduced to maintain recognition accuracy by considering hand shape features and finger length. A success ratio of 99.6% was obtained under bright illumination conditions, and 79.3% is under dark conditions. This verifies that the proposed method is effective in enhancing the recognition performance. To raise success ratio of 79.3% under dark conditions remains as one of further studies.

References

1. Khan, Z.R., Ibraheem, A.N.: Comparative Study of Hand Gesture Recognition System. In: Proc. of International Conference of Advanced Computer Science & Information Technology in Computer Science & Information Technology (CS & IT), vol. 2(3), pp. 203–213 (2012)
2. Baatar, B., Tanaka, J.: Comparing Sensor Based Techniques for Dynamic Gesture Recognition. In: The 10th Asia Pacific Conference on Computer Human Interaction, APCHI 2012, Poster 2P-21 (2012)
3. Matsuda, Y., Sakuma, I., Jimbo, Y., Kobayashi, E., Arafune, T., Isomura, T.: Development of Finger Braille Recognition System. Journal of Biometrical Science and Engineering 5(1), 54–65 (2010)
4. Jing, L., Zhou, Y., Cheng, Z., Wang, J.: A Recognition Method for One-stroke Finger Gestures Using a MEMS 3D Accelerometer. IEICE Transactions on Information and Systems E94-D(5), 1062–1072 (2011)
5. Yoruk, E., Konukoglu, E., Sankur, B., Darbon, J.: Shape - Based Hand Recognition. IEEE Transactions on Image Processing 15(7), 1803–1815 (2006)