# Hand Region Extraction and Gesture Recognition using entropy analysis

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**Summary**
In this paper, we propose the gesture recognition system using motion information from extracted hand region in complex background image. First, we measure entropy for the difference image between continuous frames.
Using color information that is similar to a skin color in candidate region which has high value, we extract hand region only from background image. Chain code has been applied to acquire outline detection from the extracted hand region and hand gestures recognition is carried out by improved centroidal profile. In the experiment results for 6 kinds of hand gesture, unlike existing methods, we can stably recognize hand gesture in complex background and illumination changes without marker. Also, it shows the recognition rate with more than 95% for person and 90～100% for each gesture at 15 fps.

***Key words:***
*Redundancy, hand gesture, entropy, recognition*

## Introduction

Individual communications are often carried out by means of vocal sounds, gestures, and facial expressions. And body languages also take substantial roles. In many cases, most of information is well included in such actions. Therefore it has been widely studied to extract information from such actions[1-3].
Gestures are used as a secondary means to assist voice communication, or as an independent means in sign language and hand signaling. It is also the most perspective means of communication for manipulating objects. Gestures have been widely proven as a suitable means in such applications as 2D/3D mouse, TV control, Windows management for Computer-Human interaction in real world, and even as a means of virtual manipulation and communication in fast-growing virtual world applications[4-7].
Hand gestures can be divided into two categories. Static gestures utilize only spatial information and dynamic gestures utilize both spatial and timed information. With static gestures, as number of predefined gestures is increased, the differences between gestures become harder to distinguish. In the case of dynamic gestures, they are easier and more comfortable to express and larger number of gestures can be predefined, but there are some difficulties with extracting proper data from load of meaningless information.
Glove based techniques and computer vision techniques are the two well-known means of recognizing hand gestures. The first utilizes sensor-detached mechanical glove devices that directly measure hand and/or arm joint angles and spatial position. But glove-based gestural interfaces require users to wear cumbersome patch of devices. The latter approach suggests using a set of video cameras and computer vision techniques to interpret gestures providing more natural way of interactions. However, since it is troublesome to analyze hand movements and recognize postures from complex images, methods such as putting certain colored marker on hands or wearing special types of gloves in restricted set of backgrounds are widely acknowledged limitations.
In this paper, we propose a method of hand gestures recognition based on computer vision techniques but, without restricting backgrounds or using any markers. The proposed method separates hand-motion region from complex background images by measuring entropy from difference images from adjacent frames and recognize hand gestures by improved centroidal profile.
This paper consists of 5 sections. The section 2 describes the hand region extracting method from a sequential color images with entropy analysis. The section 3 stresses on gesture recognition techniques from the extracted hand region images. The section 4 shows the experiment results by proposed method. The section 5 concludes this proposal.

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## 2. Motion detection and hand region extraction

The block diagram for the proposed method is in Fig. 1. The first step to recognize hand gestures is the extracting hand region from background and tracing the motion.

There are 4 well known methods for detecting hand regions. The first one utilizes color images, extracting hand region by extracting near-skin color object from source images using HIS, YIQ, or normalized RGB color model. However, this method requires to process up to 3 times more data than gray image, which significantly burdens the process.

The second method utilizes the difference between frames, such as optical flow and difference image method. Data processing is significantly reduced since this method uses gray images, but the detection is not properly carried out if there is no motion in the image. The third method uses modeling[8]. Gray images are sufficient and hand region motions are not required for the extraction, but a great number of models are necessary for each hand shapes and requires very long processing time. The last method is combination of three methods mentioned, utilizing both color information and motion images[9].

In this paper, the proposed method extracts motion region from complex background by entropy analysis, and then utilizing color information based on color model, extracts skin-colored hand region.

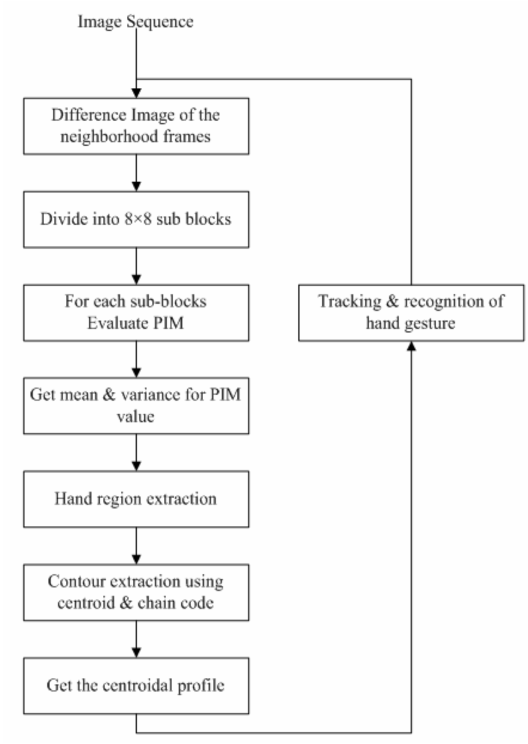



Fig. 1 Block diagram for proposed hand gesture recognition method

Acquiring difference images from sequential images fed in real-time, we divide images into 8×8 blocks, then analyze entropy for each block to find the blocks with large entropy difference and from those blocks, extract hand region from background by acquiring blocks with near-skin color distribution. This method can extract hand region adaptively from background regardless of lightings and individual differences, since entropy provides not only motion information, but also color information on large entropy region. Chain code has been applied to acquire outline detection from the extracted hand region and hand gestures recognition is carried out by improved centroidal profile.

### 2.1 Motion detection based on PIM

In this paper, entropy between pixels are used to obtain the characteristic of image data, and utilizes PIM(Picture Information Measure)[10] which was suggested by Chang to quantify the entropy obtained. The following is the equation for PIM method.

$$PIM = \sum_{i=0}^{L-1} h(i) - Max_j h(i) \tag{1}$$

In equation, $h(i)$ means i-th histogram value of each image or block. L is number of gray color level used and were 256 for this paper. $Max_j h(i)$ is maximum value of histogram and j is representing the value. PIM value is evaluated by the difference between the total number of pixels in each block and the histogram value with maximum frequency. When all pixel values within the block is identical, that is to say the block's entropy is '0', Eq. 1 can be rewritten as eq. 2, and thus yielding the minimum, PIM = 0.

$$\sum_{i=0}^{L-1} h(i) = Max_j h(i) \tag{2}$$

When each level value of pixels is uniformly distributed within the block, that is to say in the case of high entropy, the value of $Max_j h(i)$ is small and yields a high PIM value. PIM yields higher value when the block has large quantities of information and yields low value when the block has small quantities of information. Normalized PIM is defined as eq. (3), and $PIM_k$, $NPIM_k$ are given as eq. (4), (5).

$$NPIM = 1 - Max_j P[h(i)] \tag{3}$$

$$PIM_k = \sum_{i=0}^{L-1} h(i) - \sum_{i=0}^{k} h(i) \quad (4)$$

$$NPIM_k = 1 - \sum_{i=0}^{L-1} P(i) \quad (5)$$

Fig. 2 shows the result of hand region segmentation produced by PIM applied to a difference image of hand region with a complex background.

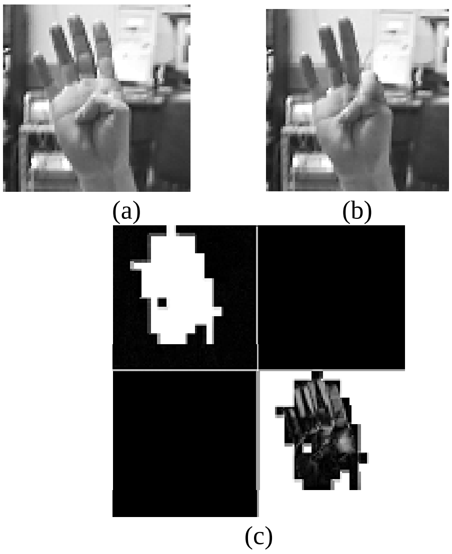



Fig. 2. Extraction of Hand Region using PIM.

Fig. 3 shows continuous sequential input images(left) and results of hand region tracing by entropy analysis from the input images(right).

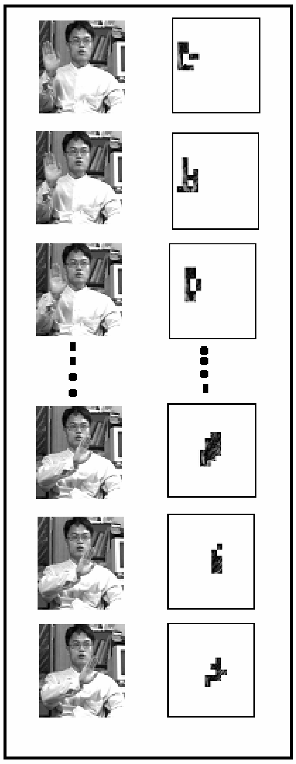


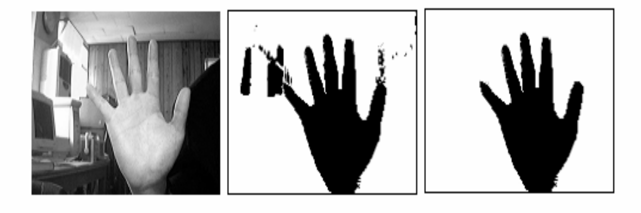
Fig. 3. Tracking of hand region using the proposed method.

## 2.2 Hand region extraction

Entropy provides not only motion information, but also color information on large entropy region. Thus hand region can be extracted by selecting high entropy regions with near-skin color distribution. Since entropy can provide color information of hand region adaptively based on background images, it can be used as a stable means of hand region extraction, regardless of lightings and individual differences.

To obtain skin color data, color models such as YIQ, normalized RGB, and HSI are used. In this paper, HSI color model was used for its versatility in image processing algorithm development. Utilizing hue adaptively on large PIM value region can improve details on hand region for the extraction.

Fig. 4 shows hand region extraction by PIM and entropy analysis with adaptive hue modification.



(a) (b) (c)

Fig. 4. Hand Extraction through entropy analysis. (a) Given hand gesture, (b) Using fixed color distribution, (c) Using adaptive color distribution through entropy analysis.

## 3. Hang Gesture Recognition

Chain code has been applied to acquire contour from the extracted hand region and hand gestures recognition is carried out by improved centroidal profile. Gesture recognition experiments were performed with six different hand postures which are shown in Fig. 5.

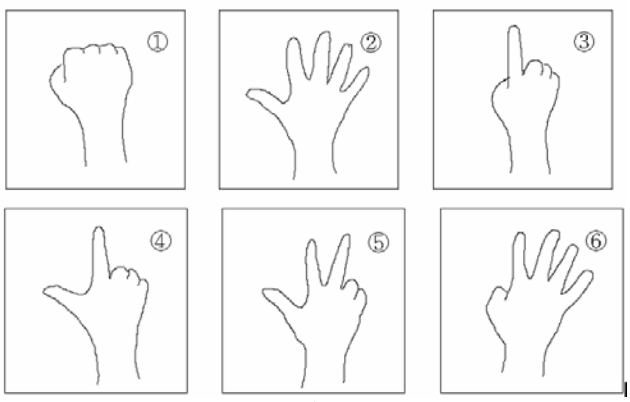
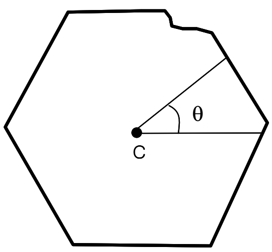


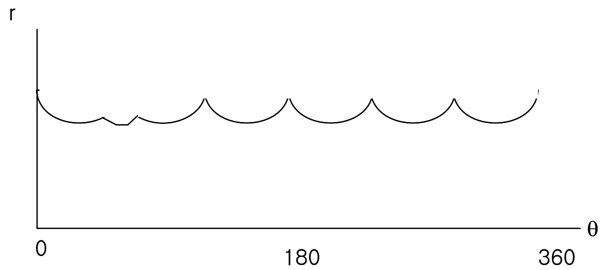

Fig. 5. 6 kinds of hand posture

### 3.1 Centroidal Porfile

Centroidal profile[13] expresses detected object with set of vectors of its contour. Usually this type of algorithm computes the centroid and expresses the shape with normalized distance from the centroid. Fig. 6 shows the centroidal profile for object recognition. This algorithm computes centroidal profile and compares it with profile of ideal object to recognize the shape of the object.




(a)




(b)

Fig. 6. Centroidal profile for object recognition.

When the contour of an object has more than one point for any angle, you usually take the one closest to the center. However in the case of hand shape, it is not possible, thus every pixel point on the contour is used to compute normalized distances. Chain code expresses contour of an object with predefined set of vectors, moving along the edge of the object and evaluates the boundary. In this study, 8 directional chain code is used.

Compute the distance($r$) of $(\bar{x}, \bar{y})$ each point on the contour from the centroid. The distance can be computed with eq. 6. The centroid can be computed with each pixel's intensity as its weight. The centroid is computed with eq. 7. $I(i, j)$ is the intensity of the pixel and $A$ is total number of pixels in the image and can be expressed as eq. 8.

$$r = \sqrt{(x_i - \bar{x})^2 + (y_i - \bar{y})^2} \quad (6)$$

$$\bar{x} = \frac{\sum_{i=1}^{N}\sum_{j=1}^{M} jI(i, j)}{A}, \bar{y} = \frac{\sum_{i=1}^{N}\sum_{j=1}^{M} iI(i, j)}{A} \quad (7)$$

$$A = \sum_{i=1}^{N}\sum_{j=1}^{M} I(i, j) \quad (8)$$

## 4. Experimental Results

The experiments were carried out on a PC with C/C++ program language. Low-priced USB color camera was used as image input device, and resolution size of images was 320×240.

Fig. 7 is the screens from gesture recognition system on PC. It shows that each step of hand region extraction by entropy analysis, detecting contour from the extracted region with chain code, applying and centroidal profile to detected contour to recognize hand gestures.

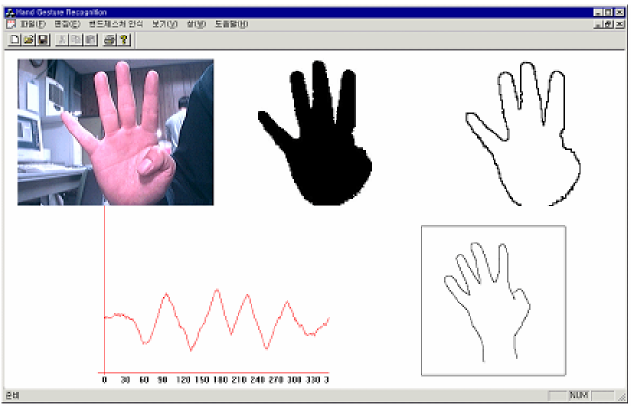


Fig. 7. Hand gesture recognition system.

The hand region extraction and centroidal profile results by the propose method is shown in fig. 8. From fig. 8, it is suggested that the hand gestures can easily be recognized with maximum distribution values of centroidal profile.

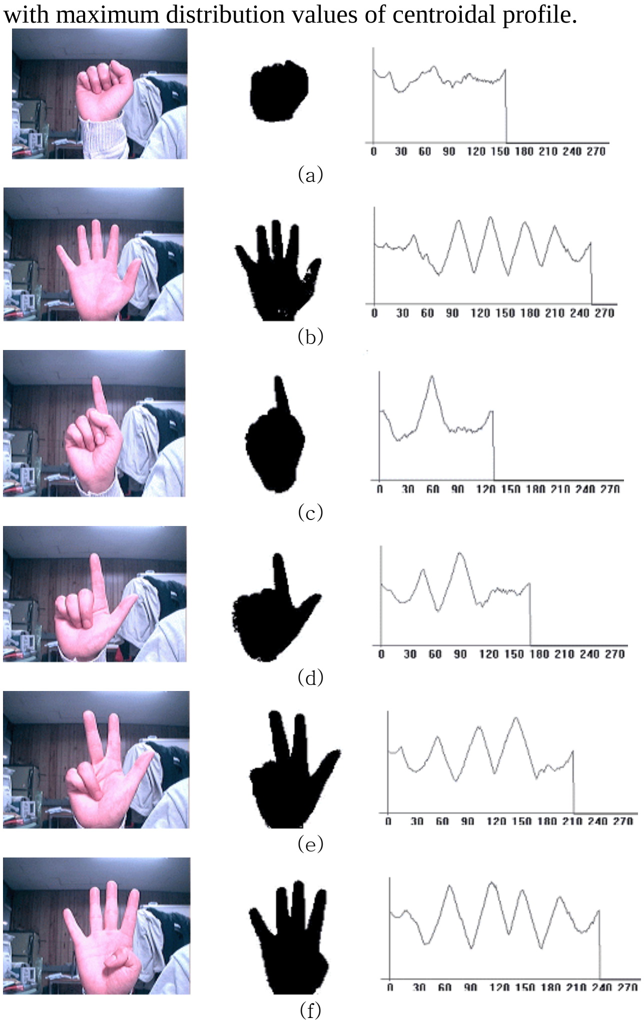



Fig. 8. Hand region extraction and centroidal profile results on six hand postures.

Since each individual has different way of performing same hand gestures and there are also variations in skin color, the experiment was carried out with six different individuals to test proposed adaptive PIM algorithm. Table 1 shows the recognition results from 20 input images of six different hand gestures. The numbers in the table represent each hand gesture number in fig. 5.

Table 1: Recognition rate of hand posture using the proposed algorithm

| Posture / person | 1 | 2 | 3 | 4 | 5 | 6 | Total |
|---|---|---|---|---|---|---|---|
| #1 | 20/20 (100%) | 19/20 (95%) | 20/20 (100%) | 18/20 (90%) | 19/20 (95%) | 20/20 (100%) | 116/120 (97%) |
| #2 | 20/20 (100%) | 20/20 (100%) | 20/20 (100%) | 19/20 (95%) | 20/20 (100%) | 19/20 (95%) | 118/120 (98%) |
| #3 | 20/20 (100%) | 18/20 (90%) | 20/20 (100%) | 19/20 (95%) | 19/20 (95%) | 18/20 (90%) | 114/120 (95%) |
| #4 | 20/20 (100%) | 20/20 (100%) | 20/20 (100%) | 18/20 (90%) | 19/20 (95%) | 19/20 (95%) | 116/120 (97%) |
| #5 | 20/20 (100%) | 18/20 (90%) | 20/20 (100%) | 19/20 (95%) | 20/20 (100%) | 19/20 (95%) | 116/120 (97%) |
| #6 | 20/20 (100%) | 19/20 (95%) | 20/20 (100%) | 20/20 (100%) | 20/20 (100%) | 20/20 (100%) | 119/120 (99%) |

The proposed method can recognize hand gestures without much restriction on backgrounds and regardless of directions of the gestures. Misrecognitions are mostly caused by similar hand gestures. Images of adjacent fingers produce noise and disrupt accurate hand region detection. Proposed hand gestures recognition method can process the recognitions at the rate of 15 frames/sec on a Pentium PC.

## 5. Conclusion

In this paper, a new method has been proposed to extract hand regions from complex images and recognize hand gestures. Recognition process is performed comfortably with entropy analysis on input images from camera. Unlike other methods, gesture recognition is performed with hand regions which are extracted from complex background without any restricted backgrounds or any markers.
Experiments were carried out with chain code and improved centroidal profile on six different hand gestures. The resulted recognition rate was 15 frames/sec and over 95% accuracy per test subjects and 90~100% recognition rate per gestures. The proposed method is not limited to six basic gestures, and can be expanded to accommodate more gestures for sign language or virtual reality environment recognition.

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