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Hand Gesture Recognition Based on Convex Defect Detection

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Abstract

Human centered human-computer interaction technology tends to replace the traditional computer centered technology with its growing applicability to a wide variety of applications. Acting as a way of most natural communication between human and machine, vision based hand gesture recognition is becoming the pursuit of human-computer interaction. General vision based hand gesture recognition generally consists of sample capturing, image reprocessing, feature extraction and classification. Among these procedures feature extraction aims to detect and extract features that can be used to determine the meaning of a given hand gesture. The extracted features should be able to describe gesture uniquely and be robust to the shift and rotation of hand gesture in order to achieve a reliable recognition. In this paper, we propose a method to extract a series of features based on convex defect detection, taking advantage of the close relationship of convex defect and fingertips. This method is simple, efficient and free from gesture direction and position.

Keywords: feature extraction, hand gesture recognition, convex defect, human-computer interaction

INTRODUCTION

Hand gesture recognition aims to identify the meaning that signer want to express based on the gestures made. With human hand as the input device of computer, the communication between human and machine will no longer need special medium, but users can simply define a series of appropriate gestures to control surrounding machines. Compared with other input forms of human-computer interaction, hand gesture has better characteristics of natural, simple but with rich expression and direct [1].

Depending on the different ways of gesture image acquisition, hand gesture recognition can be divided into sensor includes acceleration hardware based and computer vision based ones. Due to the limitation of complex data gloves and position tracker needed, the hand gesture recognition system based on sensors in expensive and difficult to be popularized, while vision based hand gesture recognition is simple and easy to operate without relying on complex devices or interfaces [2], it has been becoming a challenging interdisciplinary research and hot topic in the field of human-computer interaction.

Generally, the process of vision based hand gesture can be divided into four stages [3]: sample images capturing, image preprocessing, feature analysis and identification parameters extraction, classification and recognition. Wherein, feature extraction aims to find out a feature or a set of features which can describe the specified hand gesture uniquely and suit for classification easily. The most commonly used features of static hand gesture include: gradient histogram, image subspace projection, shape features, etc. [4]. The traditional gradient histogram is easy to calculate and implement, it has the invariance of translation but not rotation [5]. Image subspace projection is able to removing the correlation of higher-order statistics and making relatively comprehensive representation of the local features of training sample images, but it very rely on the position scale and rotation [6]. Shape based features such as contour, silhouette, fingertips are free of translation, size and rotation of hand gesture, feature extraction algorithm based on shape is most commonly used currently [7]. This paper introduced a series of fingertip related features based on convex defect detection, which will be described in next chapters.

CONVEX DETECT BASED FINGERTIP DETECTION

In issues involving human hands such as sign language recognition and gesture recognition, fingertip is one of the most popular characteristics because the number of fingertips can be considered to be the number of fingers and the direction of fingertips can effectively express the stretch information of fingers. Contour analysis is a commonly used method for fingertip detection, which achieves the location of fingertip based on geometric features of contour, such as the edge curvature method used in literature [8] for contour detection, and the least square ellipse fitting method used in [9] for fingertip detection, this kind of algorithms require high accuracy of contour and a large amount of computation, and are very dependent on the quality of gesture segmentation. In this paper, a method of fingertip detection based on convex defect is adopted. For the first, we would explain some concepts of convex defect [10].

1) Contour

The contour of hand is a series of points which are the boundary pixels of the hand area. After obtaining the contour, the gesture and its shape then can be detected and recognized by using contours analysis. Contour is constituted by the connection of edges, common edge recognition algorithms contain Sobel, Canny, Prewitt, Roberts, and Fuzzy logic methods [11]. Here we use Canny edge detection method to extract the contour of hand gesture, the red curve in Figure 1 is the contour of hand gesture contained.

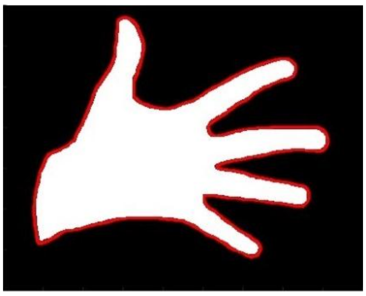
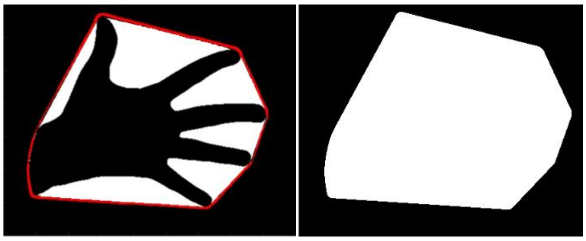


Figure 1: Detected contour of hand gesture

2) Convex hull

The convex hull of hand gesture contour is the convex polygon surrounded by all the convex vertices in gesture contour, as shown in figure 2 (a), the polygon composed by red curve is the convex hull of hand gesture in the figure, and (b) is the separated convex hull extracted from (a).



(a) (b)

Figure 2: Convex hull of hand gesture

3) Convex defect

The convex defect is defined as the difference between gesture convex hull and contour, they are contained in the convex hull but not hand area. As shown in figure 3, the white areas ①-⑥ are all the convex defects. The data structure of each of the convex defects contains three components: start contour point, end contour point and concave contour point. For example, for convex defect ②, P1 is its start contour point which is the starting point of the defect, P2 is its end contour point which is the termination point of the defect, and P3 is the concave point which is the furthest point away from the convex hull, and the furthest distance is the depth of convex defect.

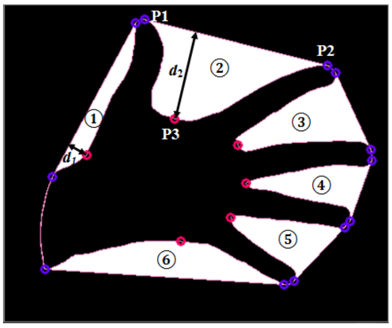


Figure 3: Convex defects of hand gesture

We can get from figure 3 that the fingertip is closely related to the convex defect, which is close to the start and end contour points of convex defect.

Therefore, it is possible to detect the fingertips by using hand gesture contour and convex defects. The count and position of fingertips can be determined as following:

1) Conduct noise elimination on the obtained convex defects. The normalized depth of convex defect cannot be too small or too large, figure 3 shows that the depth of convex defects between fingers is more obvious than other convex defects, so the depth of convex defect can be used to distinguish whether a convex defect is a convex defect between fingers or not. Based on the physiological structure of human hand and large numbers of experiments, it is appropriate to define the depth minimum and maximum threshold as big as the 1/5 and 1/2 of the height of hand gesture contour respectively, and the height of hand gesture contour is defined as the length of the quadrilateral formed by points composed of the minimum *x*-coordinate value, maximum *x*-coordinate value, minimum *y*-coordinate value and maximum *y*-coordinate value, namely, points of (x_{min}, y_{min}), (x_{min}, y_{max}), (x_{max}, y_{min}), (x_{max}, y_{max}) as shown in figure 4. Thus, for the convex depth in figure 3, d_2 is the depth meeting the condition of gesture convex defects while d_1 is not.

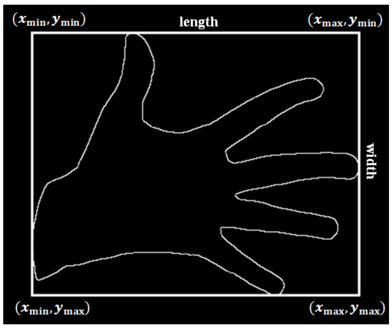


Figure 4: Definition of length and width of hand gesture contour

2) Scan filtered convex defects clockwise, take the start contour point of the first convex defect and the end contour point of the last convex defect as the first and last fingertip respectively.

3) Take use of the average position of the end contour point of current convex defect and the start contour point of next convex defect as the position of current fingertip.

FEATURES EXTRACTION

For the binary image with convex defects, we can extract the convexity of gesture and relative position of fingertips as features used for hand gesture recognition.

Through the observation and analysis of gesture contour and convex hull, we can get that with different gesture the tightness to its convex hull is also different, as shown in figure 5, the convex hull of the fist gesture in (a) almost contains the whole gesture contour, but the gesture contour in (b) has big difference with its convex hull, with several depression existing between.

The tightness of hand gesture contour to its convex hull is defined as the gesture convexity, which is denoted by δ, its value is the area ratio of gesture contour and convex hull.

$$\delta = \frac{contourArea}{hullArea}$$

Where, hullArea is the area of convex hull, contourArea is the area of gesture contour, we can get according to the image that hullArea > contourArea, so $\delta \in (0,1)$, and the bigger the value, the tighter the gesture contour to convex hull.

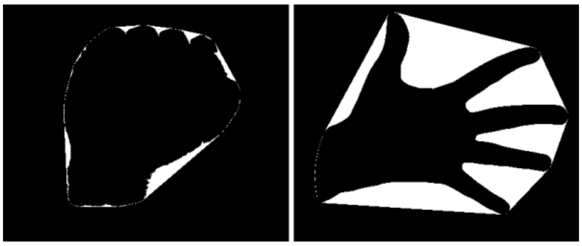


Figure 5: Tightness of different gestures to convex hulls

In addition, different gestures can be distinguished by the relative position of fingertips, which is composed of two values of α and β, α is the summation of angles with centroid as vertex, lines from centroid to the first fingertip and other fingertips as edges, and β is the value of the angle with centroid as vertex, lines from centroid to the first fingertip and last fingertip as edges, that is, $\alpha = \theta_1 + \theta_2 + \cdots + \theta_{N-1}$, $\beta = \theta_{N-1}$, where N is the number of fingertips and θ is the angle between the first fingertip and the other fingertip to the gesture centroid been considered as vertex, as shown in figure 6, it has $N = 3, \alpha = \theta_1 + \theta_2, \beta = \theta_2$. Figure 7 shows that different gestures have significantly different relative position of fingertips, so α, β can be used to the further recognition of different hand gestures.

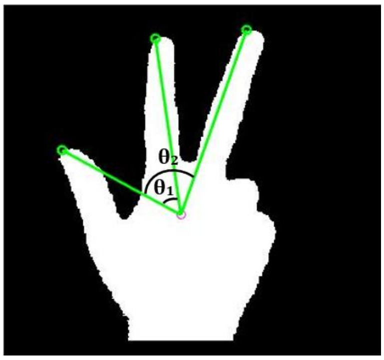


Figure 6: Definition of relative position of fingertips

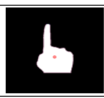
Figure 7: Different fingertip relative position of different hand gestures

RESULTS AND CONCLUSION

This paper focuses on the study of feature extraction based on convex defect for the recognition of static hand gesture. The proposed features include the tightness of gesture contour to its convex hull, namely, convexity, and the relative position of fingertips.

We used the 5 commonly used number gestures to verify the applicability of those features based on convex defect, Euclidean distance metric was adopted for the similarity measurement [12] [13]. Table 1 lists features adopted of some standard number gestures, it can be seen that these features have a certain ability to distinguish the number gesture templates.

Table 1: Features proposed in this paper

Hand Gesture					
δ	0.7707	0.7048	0.6968	0.6915	0.6776
α(°)	0	31	131	159	351
β(°)	0	31	79	84	128

The experiment results are shown in figure 8, it tells that the features are more ideal for gestures like number 5, 2 and 3, but not 1 and 4. By analyzing the experiment data we found that only the use of depth to determine the convex defect may cause the missed or mistaken detection of convex defect, as shown in figure 9 (a), in theory, the count of number gesture 1 should be 0, however, there was an effective convex A detected in the experiment. The limitation to not applicable to gestures whose plane are not parallel to the screen or not completely open, which means it is not robust to the vertical rotation of the hand gesture, and claims for the poor accuracy rate of number gesture 4 used in this paper, because the series number 4 gestures we used is almost not completely open as shown in figure 9 (b), so most of them are mistakenly recognized as number 3.

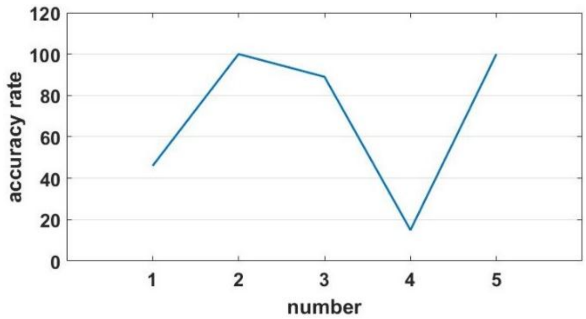
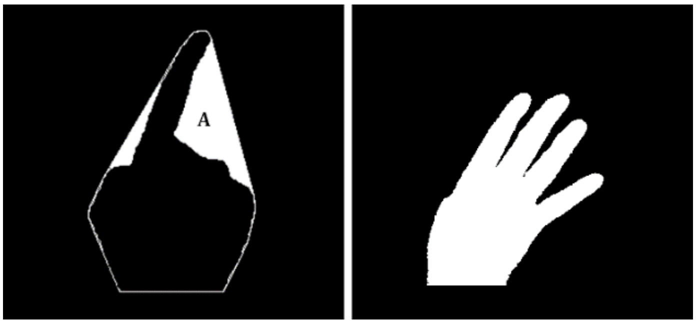


Figure 8: Experiment result of 5 simple number gesture



(a) (b)

Figure 9: Instance of erroneous recognition results

Even having the listed shortcomings above, the hand gesture recognition method based on the convex defect can greatly reduce the count of contour scanning and the amount of computation. Since the features used for hand gesture recognition cannot be one or two but many, and features based on convex defect is proposed as one of the features that can describe the overall characteristic of the hand gesture due to its simple and fast, for more effectively describe the hand gesture in detail we would need the assistance of other features, which we will include in our future work.

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