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A New Location Method of Touchless Knuckleprint based on Computer Vision

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Abstract. The knuckleprint positioning is the key basis for the biometric recognition. This paper introduces a new location method of touchless knuckleprint based on computer vision. Firstly, in order to reduce the light impact, the RGB image is converted into YCbCr color space. We use a hybrid algorithm of elliptical model and circular gradient to segment gesture area in YCbCr color space. Subsequently, an efficient algorithm for the extraction of fingertips and finger valleys is proposed based on the distance curve, which usually takes 1 to 3 filtering operations. After obtaining the fingertips and finger valleys, the region of interest (ROI) could be located with the quadrangular window shape. Finally, because the gradient value at the knuckleprint firstly decreases to a local minimum and then increases to a local maximum, the knuckleprint could be found from the gradient curve. The method was tested on a data set of 20 people (400 hand images), and the correct rate could reach 97 percent. Experiments show that the location method of touchless knuckleprint has good effects in terms of the time complexity, space complexity and accuracy.

Keywords: feature extraction; ROI segmentation; knuckleprint location.

1. Introduction

Biometric-based identity authentication technology is favored for its stability, convenience, and difficulty in forgery. At present, the main researches of biometrics include fingerprints, facial features, iris pattern, auricle, palmprint, handwriting, etc [1]. In 2005, Ribaric proposed a novel hand feature named knuckleprint [2], which is transverse line formed on the surface of hands due to long-term flexion and extension of fingers. The direction of the line is relatively uniform and stable. More and more biometrics technologies use knuckleprint as an important mean of identity authentication.

Initially, Masahiro used a touch-type optical sensor to capture finger images [3]. This touch-type acquisition method has many problems such as knuckleprint deformation, knuckleprint residue, sensitivity to skin conditions, the spread of germs at the time of collection and so on [4]. In touchless knuckleprint image acquisition, the surface of the hand does not contact with camera or sensor directly, which can not only reduce these disadvantages, but also has high recognition performance and anti-counterfeiting performance. Therefore, touchless knuckleprint recognition technology has become a promising research direction in the field of identity recognition.

In recent years, a large number of studies have been put forward on the location and recognition of knuckleprint. Kunlun Li studied the preprocessing algorithm of the touchless knuckleprint [5]. However, factors such as complex background, different illumination and change of finger attitude will affect the effect of image processing. At present, it is still difficult to apply touchless knuckleprint recognition technology to identity authentication. The knuckleprint positioning is the key basis for the biometric recognition. Therefore, in this paper, a new method of knuckleprint location based on computer vision is proposed for the whole hand images collected without contact.

2. Hand Gesture Segmentation

Hand gesture segmentation divides the hand from the image, and only retains the hand gesture in the foreground. The segmentation effect will affect the accuracy of feature extraction directly. Skin color is one of the most commonly used visual features of gesture segmentation. In this paper, the elliptical model is used to detect the skin color in the YCbCr color space, and then the circular gradient is used to detect the boundary of the gesture, thereby filling the holes and edge defects to obtain a more detailed gesture segmentation effect. This algorithm can fill the hole and edge defects, so as to obtain a more accurate gesture segmentation effect.

The flow of hand gesture segmentation algorithm: (1) Image preprocessing, through Gaussian filtering to suppress noise. (2) Convert RGB color space to YCbCr color space, skin color detection through elliptical model. (3) Using circular gradient operator to detect skin color boundary.

In RGB color space, R, G and B represents red, green and blue color component respectively. These three-color components have strong correlation. The change of brightness has a great influence on the skin color detection, and is not suitable for skin color model. Therefore, it is necessary to transform RGB color space to other color space. In YCbCr color space, Y represents brightness component, Cb represents blue color component, and Cr represents red color component, which separates brightness information from other information, and meanwhile skin color has a good clustering property in this color space. Formula (1) realizes the conversion of RGB color space to YCbCr color space [6].

$$\begin{bmatrix} Y \\ Cb \\ Cr \end{bmatrix} = \begin{bmatrix} 65.481 & 128.553 & 24.996 \\ -37.797 & -74.203 & 112 \\ 112 & -93.786 & -12.214 \end{bmatrix} \cdot \begin{bmatrix} R \\ G \\ B \end{bmatrix} + \begin{bmatrix} 16 \\ 128 \\ 128 \end{bmatrix} \tag{1}$$

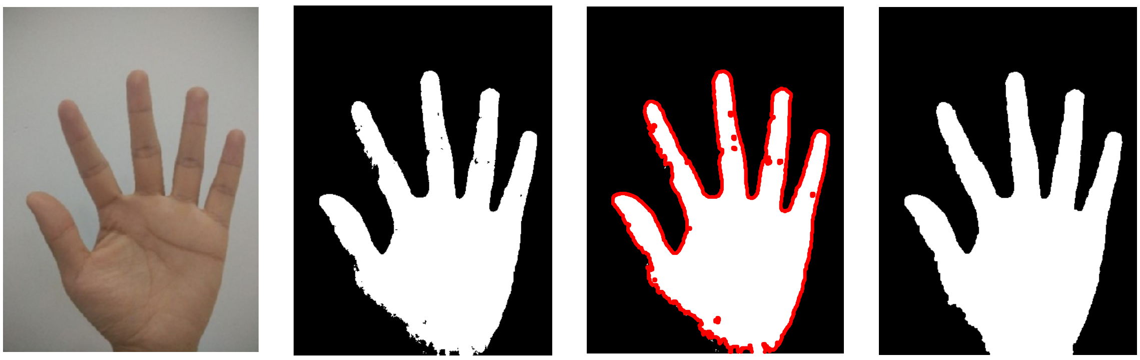
Statistic shows that the skin color exhibits an elliptical distribution on the Cb-Cr plane, so skin color detection can be achieved by an elliptical model [6]. The formula of elliptical model is as follows.

$$\frac{(x-ecx)^2}{a^2} + \frac{(y-ecy)^2}{b^2} = 1 \tag{2}$$

$$\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} cos\theta & sin\theta \\ -sin\theta & cos\theta \end{bmatrix} \cdot \begin{bmatrix} Cb - cb_0 \\ Cr - cr_0 \end{bmatrix} \tag{3}$$

Where ecx= 1.60, ecy= 2.41, a= 25.39, b= 14.03, cb_0= 109.38, cr_0= 152.02. When the point (Cb, Cr) is inside the ellipse (including the boundary), it is determined as the skin color point, otherwise it will not be determined as the skin color point. The result of the skin color segmentation based on the elliptical model is shown in Figure 1(b).

In the YCbCr color space, the elliptical model can detect most of the skin color areas. Due to the influence of light or shadow, the skin color segmentation results still have internal holes and edge defects. In order to obtain a more accurate gesture segmentation effect, the circular gradient algorithm is used to detect the edge of the skin color region [7]. Firstly, the skin color boundary is selected as the seed points, as shown in Figure 1(c). Then the gradient is calculated centered on the seed point, and the edge is detected around it. Finally, the missing skin color areas is filled, the end result of hand gesture segmentation are shown in Figure 1 (d).



(a) (b) (c) (d)

Fig. 1 (a) Original image (b) Hand gesture segmentation based on elliptical model (c) Seed points (d) The result of improved gesture segmentation.

The experimental results show that the elliptical model is used for rough extraction. The circular gradient algorithm can fill the edges and holes of gesture to obtain more accurate gesture segmentation results, which provides a good basis for subsequent feature extraction.

3. Feature Extraction

The features that need to be extracted in this paper are fingertips and finger valleys, which are the prerequisites for extracting the ROI (region of interest). The steps of our method are constructed as below: (1) Extracting the contour of hand gesture from the binary image. (2) The number of erosions is adaptively determined by the maximum inscribed circle of the gesture, and the erosion operation of the corresponding number of times is performed to obtain the center of gravity of the hand. (3) In this paper, an algorithm for fingertips and finger valleys detection is proposed to locate all these points by the distribution curve of distance.

3.1 Contour Extraction

If a pixel in the binary image satisfies the following two conditions, it is considered as the hand edge pixel: one is that the value of the pixel is equal to 1, and the other is that the neighborhood of the pixel has one or more pixels whose value is equal to 0. The result of contour extraction is shown in Figure 4(a).

3.2 Obtain the Center of Gravity

The general approach of extracting the center of gravity of the hand is to calculate the center of gravity of the entire hand. This is only applicable if the finger is not extended. If a finger is extended, the position of the center of gravity obtained will be offset to the position of the finger. In order to obtain the accurate position of the center of gravity, it is necessary to eliminate the influence of fingers. In this paper, an algorithm for extracting the center of gravity of palm accurately is proposed, which can eliminate the influence of fingers through a certain number of erosions.

Since the width of the finger is smaller than the palm of the hand, it is possible to eliminate the influence of the finger by a certain number of erosions. In this paper, the number of times of erosion is adaptively calculated by the radius of the maximum inscribed circle of the gesture contour.

The binary image of the gesture is a single connected region. From the shape of the hand palm, the maximum inscribed circle must be in the palm of the hand. The center coordinate and radius of the maximum inscribed circle can be determined by the gesture contour, as shown in Figure 4(b). The structure element is a is a 3 x 3 matrix shown in Figure 2, with the anchor point at its center.

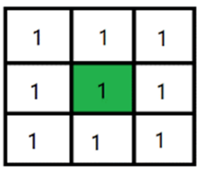


Fig. 2 Structure element

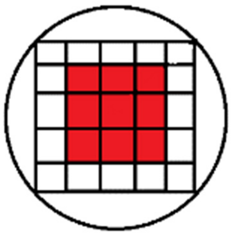
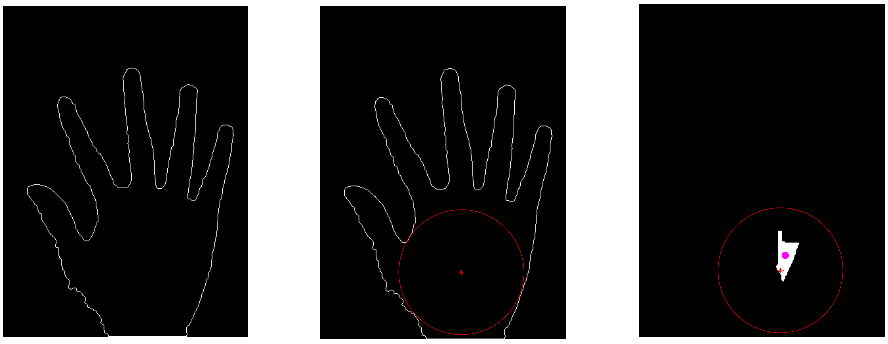


Fig. 3 The effect of one-time erosion on the circle

Each time the maximum inscribed circle is eroded, the edge length of the inner square decreases by one pixel, and the radius of the circle decreases by $\sqrt{2}$ pixels. When the number of corrosion times is $(R/\sqrt{2}-1)$ the maximum inner circle can be eroded to a minimum. Therefore, we erode the binary image of the gesture $(R/\sqrt{2}-1)$ times, which can not only avoid over-eroding of the palm, but also completely eliminate the influence of finger and edge pixels. The center of gravity of the erosion image is the position of the center of gravity of the hand palm, as shown in Figure 4(c).



(a) (b) (c)

Fig. 4 (a) Contour extraction (b) The maximum inscribed circle of contour (c)The center of gravity

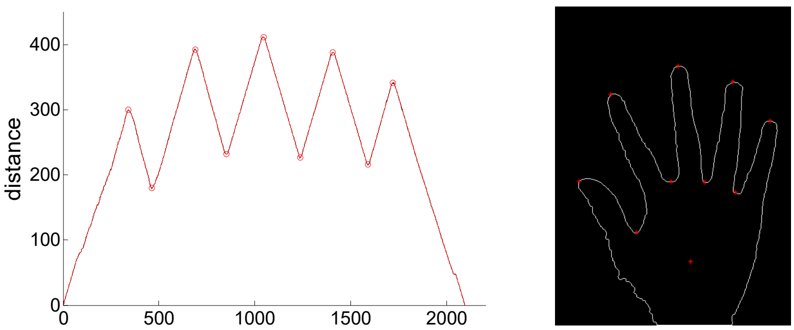
3.3 Fingertips and Finger Valleys Detection

This paper calculates the distance from the contour to the center of gravity, where the point with the largest distance is the tip of the middle finger. The intersection of the line connecting the fingertip and the center of gravity with the contour is used as the wrist point. And the curve of the distance from the contour to the wrist point determines all fingertips and the finger valleys.

A common method of fingertip detection is the K-cosine algorithm. This algorithm requires multiple K-cosine calculations for all contour points, which consumes a lot of time.

This paper proposes an algorithm for fingertips and finger valleys detection. Due to the contour has good stability for image rotating and scaling, fingertips can be extracted by the distance distribution curve. Specific method is as follows: the distance from the contour to the wrist point is calculated clockwise from the wrist point. The contour has a slightly serrated border, so we filter the curve several times until there are only five peaks in the distance curve. These five local maximums correspond to the five fingertips. The proposed method has good effects in terms of running time, running space and detection rates.

After each filtering operation, the number of local maximums is calculated. When the number is more than 5, the filtering operation is continued until only 5 peaks are left, and the positioning of the fingertips is completed. Experiments show that it usually takes 1 to 3 filtering operations to detect the fingertips and finger valleys. The test result is shown in Figure 5(b).



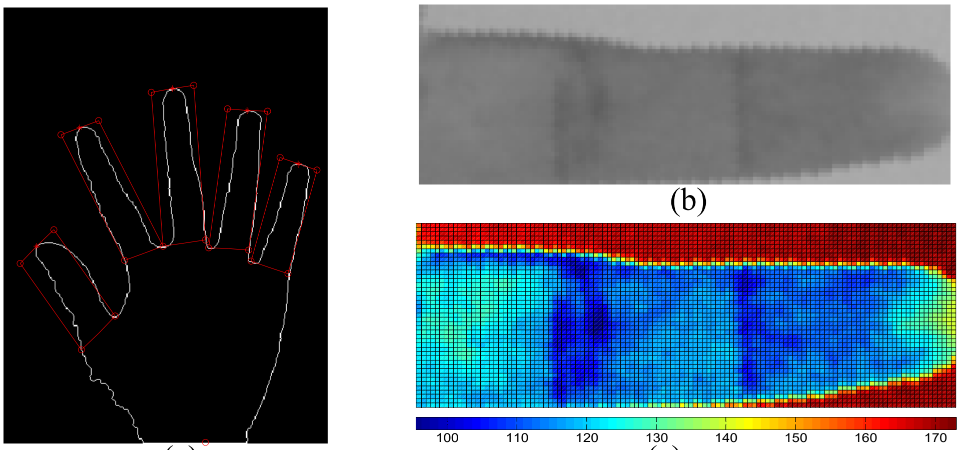
(a) (b)

Fig. 5 (a) Distance curve (b) Fingertips and finger valleys detection

4. ROI Segmentation and Knuckleprint Location

The knuckleprint is thick and distinct horizontal line at the joint of the phalangeal joints, which is divided into three parts including the first, the second, and the third knuckleprint. The first knuckleprint nears the fingertip. The third knuckleprint nears the finger valleys, which can be obtained directly from the position of the finger valleys. This paper mainly studies the location method of the first and the second knuckleprint.

After obtaining the fingertips and finger valleys, the ROI can be located with the quadrangular window shape [5], as shown in Figure 6(a). This paper takes the pinkie as an example, the segmentation of ROI is shown in Figure 6(b) and its gray values can be visualized in the Figure 6(c). The left side corresponds to the finger valley and the fingertip is on the right side.



(a) (b) (c)

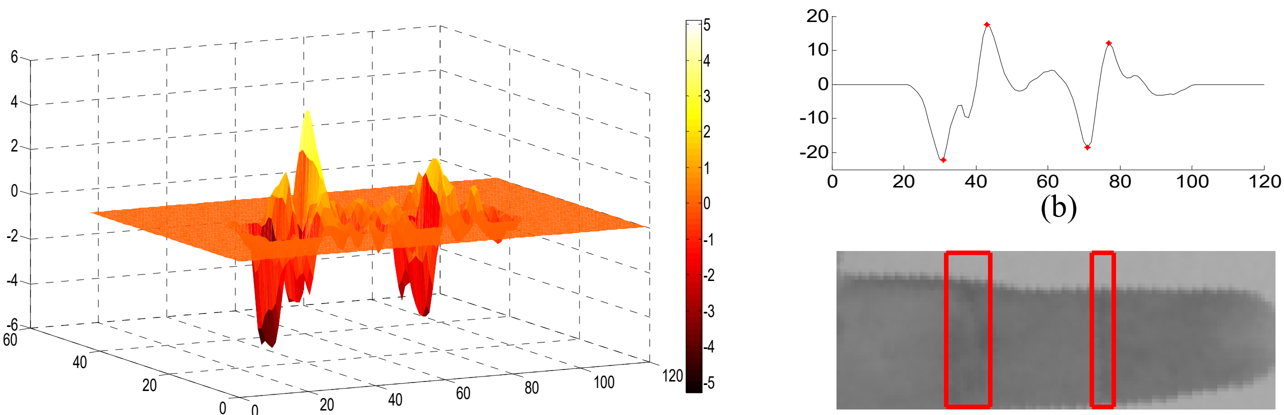
Fig. 6 (a) ROI locating schematic diagram (b) ROI segmentation (c) Gray values of the ROI

The gray value of the knuckleprint is smaller than that of the other regions, so there will be a large gradient value at the knuckleprint. Therefore, the knuckleprint can be located by the gradient along the direction of finger. The gradient formula is as follows [9].

$$dx(i,j) = I(i+1) - I(i,j) \tag{4}$$

To eliminate the interference of finger boundary, the ROI needs to be further narrowed down. In this paper, taking *1/2* of the middle of the finger in the X direction and *3/5* of the middle of the finger in the Y direction as the more precise ROI. The three dimensional image of gradient within this range is shown in Figure 7(a).

Since the gradation value of the knuckle is smaller than its neighborhood, the gradient value at the knuckle firstly decreases to a local minimum and then increases to a local maximum. Gradient values are accumulated in Y direction and median filtered [9]. Figure 7(b) shows the gradient curve. Therefore, the knuckleprints can be located by the local minimums and the local maximums. The recognition result of knuckleprints is shown in Figure 7(c).



(a) (b) (c)

Fig. 7 (a) Three dimensional image of gradient (b) Gradient curve
(c) Recognition result of knuckleprints

5. Experimental Results and Analysis

We use digital camera to build a data set which consists of 400 hand images collected from 20 individuals in the natural light. Each sample in the database needs to locate 9 knuckleprints (thumb needs to locate 1 knuckleprint, and the other four fingers need to locate 8 knuckleprints). Therefore, a total of 3600 knuckleprints need to be located in the dataset. The experiment result shows that the correct rate could reach 97 percent. By analyzing the wrong segmentation, we find that some images fail to detect ROI because of the interference of flesh-colored background or the shallow color of the knuckleprints.

6. Summary

In this paper, a new method of knuckleprint location based on computer vision is proposed for the hand images collected without contact. The elliptical model is used to detect the skin color in the YCbCr color space, and then the circular gradient is used to fill the holes and edge defects. This hybrid algorithm is helpful to obtain the accurate result of gesture segmentation, which provides a good basis for feature extraction. In this paper, an algorithm for fingertips and finger valleys detection is proposed to locate all these points by the distance curve. We filter the distance curve several times until there are only five peaks. It usually takes 1 to 3 filtering operations. Experiments show that this adaptive algorithm has good effects in terms of running time and running space. After obtaining the fingertips and finger valleys, the ROI can be located with the quadrangular window shape. Because the gradient value at the knuckleprint firstly decreases to a local minimum and then increases to a local maximum, the knuckleprints could be found from the gradient curve. The correct rate could reach 97 percent. The following work will focus on the interference of background, which will be helpful to expand the range of application.

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