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FINGER-KNUCKLE-PRINT: A BIOMETRIC IDENTIFIER

KELANI NITESH*, NIMODIYA KOMAL AND KELANI NEHA

Department of Computer science and Engineering, JDIET, India.
*Corresponding Author: Email- nitesh.kelani13@gmail.com

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Abstract- Biometric based personal authentication is an effective method for automatically recognizing, with a high confidence, a person's identity. By observing that the texture pattern produced by bending the finger knuckle is highly distinctive, in this seminar we present a new biometric authentication system using finger-knuckle-print (FKP) imaging. First a specific data acquisition device is constructed to capture the FKP images, and then an efficient FKP recognition algorithm is presented to process the acquired data. The local convex direction map of the FKP image is extracted, based on which a coordinate system is defined to align the images and a region of interest (ROI) is cropped for feature extraction. For matching two FKPs, a feature extraction scheme, which combines orientation and magnitude information extracted by Gabor filters is introduced. A competitive coding scheme, which uses 2D Gabor filters to extract the image local orientation information, is introduced which extract and represent the FKP features. When matching, the angular distance is used to measure the similarity between two competitive code maps. Compared with the other existing finger-back surface based biometric systems, the introduced FKP system achieves much higher recognition rate and it works in real time.

Keywords- Biometrics, finger-knuckle-print, personal authentication.

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Introduction

Personal authentication is a common concern to both industries and academic research due to its numerous applications. Biometrics can be used to distinguish between individuals based on their inherent physical and behavioral characteristics and hence can serve as an ideal solution to this problem. In the past three decades, many biometric characteristics have been investigated, including fingerprint, face, iris, retina, palm-print, hand geometry, voice, gait and signature, etc [2]. Recently, it has been noticed that the textures in the outer finger surface has the potential to do personal authentication. Although many biometric techniques are still under the stage of research and development, some biometric systems have been used in a large scale; for example, the Hong Kong government has been using the fingerprint recognition system as the automated passenger clearance system (e-channel) since 2004. Among various kinds of biometric identifiers, hand-based biometrics has been attracting considerable attention over recent years. The popularity of hand-based biometrics should be attributed to its high user acceptance. In fact, the image pattern in the finger knuckle surface is highly unique and thus can serve as a distinctive biometric identifier. In this seminar, a new hand-based biometric technique, namely finger-knuckle-print (FKP), is introduced for personal authentication. FKP refers to the image pattern of the outer surface around the phalangeal joint of one's finger, which is formed by bending slightly the finger knuckle. A specially designed acquisition device is constructed to collect FKP images. Unlike the systems in [3] and [5], which first capture the image of the whole hand and then extract the finger or finger knuckle surface areas, the introduced system captures the image around the finger knuckle area of a finger directly, which largely simplifies the following preprocessing steps. Meanwhile, with such a design the size of the imaging system can be greatly reduced, which improves much its applicability. Since the finger knuckle will be slightly bent when being imaged in the introduced system, the inherent finger-knuckle-print patterns can be clearly captured and hence the unique features of FKP can be better exploited. After an FKP image is captured, a region of interest (ROI) needs to be cropped from the original image for the following feature extraction. An efficient FKP Region of interest (ROI) extraction algorithm is introduced based on the intrinsic characteristics of FKP images. For matching two FKP ROI images, a new feature extraction scheme, which combines orientation and magnitude information extracted by Gabor filters. The rest of this seminar is organized as follows:- chapter 2 introduces FKP system design, chapter 3 introduces ROI extraction, chapter 4 introduces FKP recognition and finally conclusion is presented in chapter 5.

The FKP Recognition System Design

The introduced FKP recognition system is composed of an FKP image acquisition device and a data processing module. The device (referring to Fig. 1) is composed of a finger bracket, a ring LED light source, a lens, a CCD camera and a frame grabber. The captured FKP image is inputted to the data processing module, which comprises three basic steps: ROI (region of interest) extraction, feature extraction and coding, and feature matching. Refer to Fig. 1, a basal block and a triangular block are used to fix the position of the finger joint. Fig. 2-a and 2-d show two sample images acquired by the developed device. A critical issue in data acquisition is to make the data collection environment as stable and consistent as possible so that variations among images collected from the same finger can be reduced to the minimum. In general, a stable image acquisition process can effectively reduce the complexity of the data processing algorithms and improve the image recognition accuracy. Meanwhile, it is required to put as little constraint as possible on the users for high user friendliness of the system. With the above considerations, a semi-closed data collection environment is designed in this system. The LED light source and the CCD camera are enclosed in a box so that the illumination is nearly constant. One difficult problem is how to make the gesture of the finger nearly constant so that the captured FKP images from the same finger are consistent. In this system, the finger bracket is designed for this purpose. Referring Fig. 1, a basal block and a triangular block are used to fix the position of the finger joint.

In data acquisition, the user can easily put his/her finger on the basal block with the middle phalanx and the proximal phalanx touching the two slopes of the triangular block. Such a design aims at reducing the spatial position variations of the finger in different capturing sessions. The triangular block is also used to constrain the angle between the proximal phalanx and the middle phalanx to a certain magnitude so that line features of the finger knuckle surface can be clearly imaged.

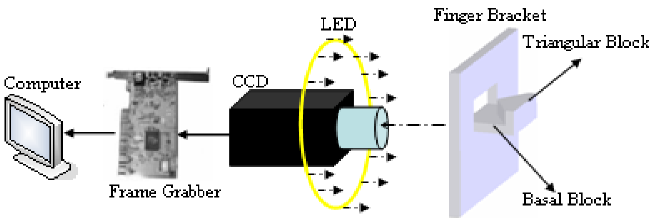

Fig. 1- FKP image acquisition device

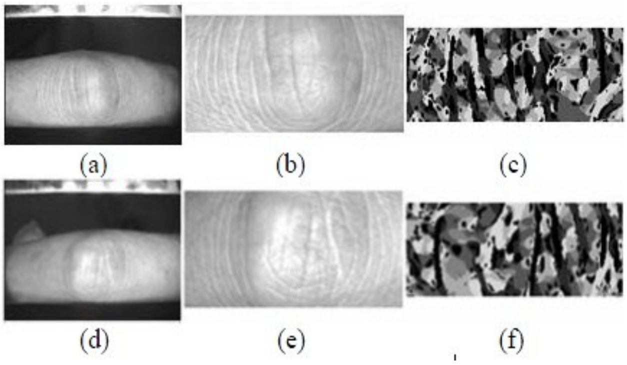

Fig. 2- (a) and (d) are two FKP images; (b) and (e) are the ROI images of (a) and (d); (c) and (f) are the competitive code maps generated from (b) and (e) respectively.

ROI Extraction

It is necessary to construct a local coordinate system for each FKP image. With such a coordinate system, an ROI can be cropped from the original image for reliable feature extraction and matching. The detailed steps for setting up such a coordinate system are as follows.

Step 1: determine the X-axis of the coordinate system. The bottom boundary of the finger can be easily extracted by a Canny edge detector. Actually, this bottom boundary is nearly consistent to all FKP images because all the fingers are put flatly on the basal block in data acquisition. By fitting this boundary as a straight line, the X-axis of the local coordinate system is determined.

Step 2: crop a sub-image IS. The left and right boundaries of IS are two fixed values evaluated empirically. The top and bottom boundaries are estimated according to the boundary of real fingers and they can be obtained by a Canny edge detector.

Step 3: Canny edge detection. Apply a Canny edge detection to IS to obtain the edge map IE.

Step 4: convex direction coding for IE. Here introduced an ideal model for FKP "curves". In this model, an FKP "curve" is either convex leftward or convex rightward. We code the pixels on convex leftward curves as "1", pixels on convex rightward curves as "-1", and the other pixels not on any curves as "0".

Fig. 3 illustrates this convex direction coding scheme and the pseudo codes are presented as follows:

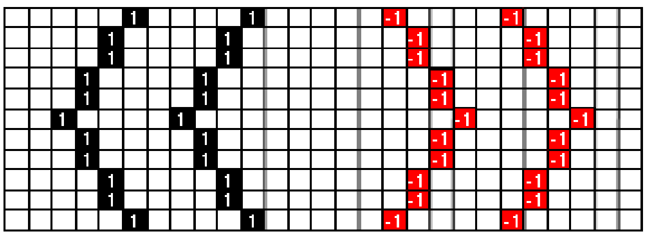

Fig. 3- Illustration for convex direction coding scheme.

Convex_Direction_Coding (I_E)

Input: I_E Output: I_{CD} (convex direction code map)

Step 5: determine the *Y*-axis of the coordinate system. For an FKP image, "curves" on the left part of phalangeal joint are mostly

$y_{mid} = \frac{height\ of\ I_E}{2}$;
for each $I_E(i, j)$:
if $I_E(i, j) = 0$
$I_{CD}(i, j) = 0$;
else if
$I_E(i+1, j-1) = 1$ and $I_E(i+1, j+1) = 1$
$I_{CD}(i, j) = 0$;
else if $(I_E(i+1, j-1) = 1$ and $i \le y_{mid})$ or
$(I_E(i+1, j+1) = 1$ and $i > y_{mid})$
$I_{CD}(i, j) = 1$;
else if $(I_E(i+1, j+1) = 1$ and $i <= y_{mid})$ or
$(I_E(i+1, j-1) = 1$ and $i > y_{mid})$
$I_{CD}(i, j) = -1$;
end if

convex leftward and those on the right part are mostly convex rightward. Meanwhile, "curves" in a small area around the phalangeal joint do not have obvious convex directions. Based on this observation, at a horizontal position *x* (*x* represents the column) of an FKP image, we define the "convexity magnitude" as:

$$conMag(x) = abs\left(\sum_{W} I_{CD}\right)$$

where *W* is a window being symmetrical about the axis *X* = *x*. *W* is of the size *d* × *h*, where *h* is the height of I_S. The characteristic of the FKP image suggests that $conMag(x)$ will reach a minimum around the center of the phalangeal joint and this position can be used to set the *Y*-axis of the coordinate system

Step 6: crop the ROI image. Now that we have fixed the *X*-axis and *Y*-axis, the local co-ordinate system can then be determined and the ROI sub-image I_{ROI} can be extracted with a fixed size. Fig. 2-b and 2-e show two examples of the extracted ROI images.

FKP Recognition

Feature extraction and coding

The Gabor filter can simultaneously capture spatial and frequency uncertainty information [4]. Since 1980s, it has been widely used as a convolution filter to fulfill the feature extraction job. Recently, known the three basic features—magnitude, phase, and orientation— produced by the Gabor filter for face recognition and concludes that the orientation feature is the most robust and distinctive feature. Therefore, in this seminar we introduce the Gabor filter based competitive coding scheme [6] to extract orientation information from FKP images for recognition. The Gabor function is introduced below:

Where $x' = (x - x_0)\cos\theta + (y - y_0)\sin\theta$ and

$$G(x, y, \omega, \theta) = \frac{\omega}{\sqrt{2\pi k}} e^{-\left(\frac{\omega^2}{8k^2}\right)(4x'^2 + y'^2)} \left(e^{i\omega x'} - e^{-(k^2/2)}\right)$$

$y' = -(x - x_0)\sin\theta + (y - y_0)\cos\theta$,(x_0, y_0) is the center of the function, ω is the radial frequency in radians per unit length and θ is the orientation of the Gabor functions in radians. k is defined by $k = \sqrt{2\ln 2}\,(2^\delta + 1/2^\delta - 1)$, where δ is the half-amplitude bandwidth of the frequency response. ω can be determined by $\omega = k/\sigma$,where σ is the standard deviation of the Gaussian envelop.

At each pixel *IROI*(*x*, *y*), we extract the orientation information and represent it as a "competitive code"[6]. With a bank of Gabor filters sharing the same parameters, except the parameter of orientation, the orientation feature can be extracted. only the real part of the Gabor filter is used to perform this job. Mathematically, this competitive coding process can be represented as:

$$compCode(x, y) = argmax\left\{abs\left(I_{ROI}(x, y) * G_R(x, y, \theta_j)\right)\right\}$$

where symbol * represents the convolution operation, G_R represents the real part of the Gabor function *G*, and $\theta_j = \frac{j\pi}{J}, j = \{0, \ldots\ldots, J-1\}$, *J* represents the number of different orientations. In this seminar, we set *J* as 6 and consequently each competitive code is an integer within 0~5. Fig. 2-c and 2-f show two examples for the competitive code maps.

FKP feature matching

Given two competitive code maps of two FKP images, a matching algorithm determines the degree of similarity between them. In this seminar, the angular distance [6] is introduced to fulfill this task. Let *P* and Q be the two feature matrices (competitive codes), and P_M and Q_M be the corresponding masks used for indicating the overlapping areas when one of the features is translated. The angular distance *D*(*P*,Q) is defined by the following equation:

$$D(P, Q) = \frac{\sum_{y=1}^{Rows}\sum_{x=1}^{Cols}\left(P_M(x, y) \cap Q_M(x, y)\right) \times G\left(P(x, y), Q(x, y)\right)}{3\sum_{y=1}^{Rows}\sum_{x=1}^{Cols} P_M(x, y) \cap Q_M(x, y)}$$

where $\cap$ denotes the AND logic operator and

$$G\left(P(x, y), Q(x, y)\right)$$
$$\begin{cases} \min(P(x, y) - Q(x, y), Q(x, y) - P(x, y) + 6), P(x, y) \ge Q(x, y) \\ \min(Q(x, y) - P(x, y), P(x, y) - Q(x, y) + 6), P(x, y) < Q(x, y) \end{cases}$$

Taking into account the possible translations in the extracted subimage, multiple matches are performed by translating one set of features in horizontal and vertical directions. The minimum of the resulting matching distances is considered to be the final distance.

Conclusion

This seminar introduces to use 2D FKP as a new biometric identifier for personal authentication. A cost-effective FKP system, including the image acquisition device and the associated FKP image processing algorithm, is introduced. FKP is very competitive with other hand-based biometric technologies. Meanwhile, the introduced FKP technique has advantages such as user friendliness, no remains, moderate size, cost-effectiveness, etc. It has a great potential to be future improved and employed in real applications. For efficient FKP matching, a feature extraction scheme is introduced to exploit both orientation and magnitude information extracted by Gabor filters. This technique has a great potential to be future improved and employed in real commercial applications.

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