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Discriminative common vector based finger knuckle recognition

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ABSTRACT

The main issue in personal authentication systems for military, security, industrial and social applications is accuracy. This paper presents a finger knuckle print (FKP) recognition approach to identity authentication. It applies a discriminative common vectors (DCV) based method to obtain the unique feature vectors, called discriminative common vectors, and the Euclidean distance as matching strategy to achieve the identification and verification tasks. The recognition process can be divided into the following phases: capturing the image; pre-processing; extracting the discriminative common vectors; matching and, finally, making a decision. In order to test and evaluate the proposed approach both the most representative FKP public databases and an established non-uniform FKP database were used. Experiments with these databases confirm that the DCV-based FKP recognition method achieves the authentication tasks effectively. The results showed the performance of the system in terms of the recognition rate had 100% accuracy for both training data and unseen test data.

1. Introduction

Biometric technologies cover a wide range of techniques that can be used to identify people, and automate the authentication of identity by using the distinct physical or behavioral characteristics of the individuals concerned. In the past few decades the use of a number of biometric characteristics including the fingerprint, face, iris, palm print, hand geometry, voice and ear have been exhaustively investigated with the rapid development of computing techniques [1,2]. Hand-based biometrics including identifiers such as the fingerprint, hand geometry, hand vein, inner-knuckle-print, palm print and finger knuckle print (FKP) have attracted considerable attention from researchers in recent years. As they are reliable, low-cost and user-friendly viable solutions to personal authentication, most of these approaches have been well investigated in the literature [1–3]. Hand-based biometric systems also have several advantages over other techniques. These systems include simple and economical data acquisition capabilities, suitability for both indoor and outdoor usage, including use and availability in extreme weather and varying lighting conditions, and the stability of the hand features over time; these features make them the most user-friendly techniques in the biometrics field [2,3]. Although hand-based systems have all these advantages for large scale personal authentication, their usage requires further research to explore additional features that can be simultaneously extracted from hand images [4]. Some hand-based biometric approaches which achieve results by constraining the position and posture of the hands present physical inconvenience and difficulties for some user groups, especially children and the elderly [4].

While the palm side hand surface regions are highly popular for personal identification and are employed to acquire fingerprint, palm print and hand shape features, the back surface of the hands is plainer as it has no specialized functions [5]. The most frequently used hand-based biometric modality, namely palm print recognition, uses the principal lines and wrinkles for identification. However, FKPs which refer to the inherent skin pattern of the outer surface around the phalangel joint of the finger have even more obvious line features than the palm surface [4]. In addition, the FKPs, compared with the fingerprint which is the most commonly used biometric identifier, cannot be easily abraded and have a higher user acceptance [1,6].

In FKP-based studies, the biometric system verifies a person's identity by measuring and analyzing the knuckle lines and the texture pattern produced by finger knuckle bending. These features are unique and make the surface a distinctive biometric identifier [4,7]. The main task in FKP-based biometric recognition systems is analyzing and processing the FKP patterns to extract the discriminative feature sets of the FKPs [8].

This paper proposes a new FKP recognition approach using a discriminative common vector based method that was introduced and successfully applied for face recognition [9]. The experimental

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results demonstrate that the DCV-based FKP authentication system can verify personal identity with a 100% recognition rate for both training data and unseen test data.

The remainder of this paper is organized as follows:

Section 2 summarizes the earlier studies related to FKP recognition. The scheme of the proposed FKP-based biometric authentication system is introduced in Section 3. The experiments with both commonly used databases and an established non-uniform database are described in Section 4. In addition, the results obtained are evaluated and commented upon in Section 4. In the last section, we conclude the paper by stating the conclusions and future work.

2. Related works

Biometric systems which use FKP-based recognition methods are reliable authentication technologies. They have recently received considerable attention. According to the "method and system for identifying a person using their finger joint print" patent [7] and FKP-based biometric recognition studies [1–6,8,10–16], the unidirectional bending of the fingers generates unique pattern formations on the finger surface joining the proximal phalanx and middle phalanx bones and these patterns contain useful information that is capable of uniquely identifying the identity of an individual [4,5]. The existing FKP-based biometric recognition studies are summarized in Table 1. The five main features of related works, such as authors, publication year, purpose of the study, basic features of the system and the working principles of the presented method, database size and the best performance achieved in the study are given in Table 1.

When FKP based identity authentication studies in Table 1 are investigated, it can be obtained that FKP-based studies aim to identity authentication process. FKP detection, feature extraction, matching and making decision processes are the critically important stages of those systems. In general, FKP based biometric systems have required a device or environment specially designed for acquiring the FKP images. FKP images that were obtained from 2D or 3D finger surface could be used in FKP based uni-modal or multi-modal biometric systems. FKP recognition techniques in the literature can be summarized as follows.

In the literature, Phase-Correlation Function (PCF) based matching methods [3] or local and global features of FKP based methods were used in personal verification [1]. Some methods using geometrical features of the finger and FKP patterns for personal authentication [4] have been preferred by scientist in biometrics. Gabor filter was applied to enhance the FKP information [10] or to extract the orientation and magnitude information [2,14]. Methods using 2D Gabor Filter [13] or scale invariant feature transform (SIFT) to extract the features [10] were also from attractive alternatives methods for FKP based personal authentication. Similarly, there were Band-Limited Phase-Only Correlation (BLPOC) based methods [8] and methods aimed to identity authentication using the orientation features from the random knuckle lines using finite Radon transform [6] in the literature. Personal identification via KnuckleCodes using localized Radon transform was also achieved [5] and Texture-based knuckle features [12] was applied in FKP-based biometric systems. In some studies, more than one technique like Principal Component Analysis (PCA), Linear Discriminant Analysis (LDA) and Independent Component Analysis (ICA) were applied [15]. The curvature based shape index to represent the fingers' surface method was also used [16]. When the FKP based studies were investigated from aspect of the performance, it is obtained that: because of their high accuracy FKP based biometric systems were appropriate for use in high security applications.

We are able to draw some conclusions from Table 1.

1. FKP-based studies have received considerable attention since 2009.
2. FKP-based biometric recognition systems are reliable systems and exhibit exceptional performances.
3. Multi-modal biometric systems including FKPs have been applied and deployed recently.
4. Various techniques have been developed and applied for FKP recognition.
5. Generally the FKP of four fingers (middle and index fingers of both right and left hands) are used for FKP recognition.
6. Generally EER, GAR, FAR and RR are used for evaluation of the system performance (EER: Equal Error Rate, GAR: Genuine Acceptance Rate, FAR: False Acceptance Rate, RR: Recognition Rate).

3. Design of the FKP recognition system

In the proposed study, a FKP-based biometric recognition system is designed. Fig. 1 shows the overview of the system architecture. The FKP-based biometric recognition scheme combines three basic modules: the image enrollment module; the image processing module, which achieves the pre-processing duties and the feature extraction tasks; the matching, decision-making and the test & evaluation module.

3.1. FKP image enrollment module

In the literature, FKP recognition systems achieved their objectives using FKP images obtained from a peg-free imaging system that uses a digital camera focused against a white background under uniform illumination [4], or from a specialized image acquisition device consisting of a finger bracket, a ring LED light source, a lens, a CCD camera and a frame grabber [8,13]. On the contrary, in our approach we have not use such a special designed acquisition device like the previous studies have preferred. In the image acquisition phase, we wanted to establish a non-uniform FKP database. For acquiring images, a digital single-lens reflex camera with 10.2 megapixel DX format CCD was used. Our database is established from images taken by the camera with a variety of environmental conditions such as lighting, distance, angular position of the camera and position of the hands. Images are taken in daily time and in door laboratory in natural light without extra light. While taking the images, we did not set any stable condition for the camera and we took the photos of the hands manually. The sizes of the hand images and FKP images were 4608×2592 and 90×90, sequentially. Since we created the FKP database over three stages and at varying times, there is no uniform lighting in our database. Even these pictures were taken in different day light. The distance of the camera was randomly changed (between 15 and 25 cm) from the imaging surface. In this experiment we do not use any special area or tool to take images. The purpose of this is to make experiment independent from effects of environment like the taken place, light, angle, and distance. In spite of the changing environmental conditions and all corruptive effects like non-uniform illumination, shadows and reflections at the hand boundaries, our system achieved perfect accuracy (100% accuracy with both training data and unseen test data). As is reported in [4], these factors significantly reduce the performance of the FKP-based biometric system. Avoiding these corruptive effects on their systems, the authors preferred a uniformly illuminated image acquisition device [4]. There is no need to use such a specialized data acquisition system in our work; a normal quality FKP image obtained from an ordinary digital camera is enough for the identification and verification processes.