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Fusion of Band Limited Phase Only Correlation and Width Centroid Contour Distance for finger based biometrics

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ABSTRACT

In this paper, a new approach of multimodal finger biometrics based on the fusion of finger vein and finger geometry recognition is presented. In the proposed method, Band Limited Phase Only Correlation (BLPOC) is utilized to measure the similarity of finger vein images. Unlike previous methods, BLPOC is resilient to noise, occlusions and rescaling factors; thus can enhance the performance of finger vein recognition. As for finger geometry recognition, a new type of geometrical features called Width-Centroid Contour Distance (WCCD) is proposed. This WCCD combines the finger width with Centroid Contour Distance (CCD). As compared with the single type of feature, the fusion of W and CCD can improve the accuracy of finger geometry recognition. Finally, we integrate the finger vein and finger geometry recognitions by a score-level fusion method based on the weighted SUM rule. Experimental evaluation using our own database which was collected from 123 volunteers resulted in an efficient recognition performance where the equal error rate (EER) was 1.78% with a total processing time of 24.22 ms.

1. Introduction

In information science, the term biometrics refers to technology of an identification system that uses human physical characteristics such as the face, fingerprints, hand geometry or behavioural characteristics like voice and gait. Nowadays, with the increased demand for information security, biometrics is becoming widespread in user authentication for the granting or denial of access control rights to data and system resources. The most familiar biometric applications include door access control, border crossing control, financial security and attendance systems. Over the past three decades, various kinds of biometric modalities have been developed including the face (Luan, Fang, Liu, Yang, & Qian, 2014), iris (Rai & Yadav, 2014), retina (Lajevardi, Arakala, Davis, & Horadam, 2013), fingerprint (Cao, Pang, Liang, & Tian, 2013), palm print (Wang, Liang, & Wang, 2013), hand geometry (Baena, Elizondo, Rubio, Palomo, & Watson, 2013), palm vein (Wu, Lee, Lo, Chang, & Chang, 2013), finger knuckle (Kumar, Hanmandlu, & Gupta, 2013), voice (Adibi, 2014), gait (Choudhury & Tjahjadi, 2013) and signature (Pirlo & Impedovo, 2013).

Among the available biometrics, hand-based systems (fingerprint, palm print, hand geometry, palm vein and finger knuckle) are found to be the most popular due to their high user acceptance (Zhang, Zhang, Zhang, & Zhu, 2010). Fingerprint systems are found to be the most mature biometrics technology. They have been used in many applications for years. Although the use of fingerprints is the most common approach, this method is vulnerable to forgery as the fingerprints are easily exposed to others (Rosdi, Shing, & Suandi, 2011). This can happen when latent information is stolen by an unauthorized person from the fingerprint sensors. Moreover, it also requires physical contact, which is not desirable from a hygienic viewpoint and may cause problems with the device. In addition, the condition of a finger's surface such as sweat and dryness can prevent a clear fingerprint pattern from being obtained. This can degrade the recognition accuracy (Ito, Nakajima, Kobayashi, Aoki, & Higuchi, 2004). As for palm print (Wang & Liang et al., 2013) and finger knuckle print (Kumar et al., 2013) systems, the biometrics traits are easily replicated since the features are extracted from the external human body.

To overcome the limitations of current hand-based biometric systems, a new biometric technology based on human finger vein patterns (Qin et al., 2013; Nguyen et al., 2013; Peng, Li, El Latif, Wang, & Niu, 2013; Xin, Liu, Zhang, & Zhang, 2012) has been developed. Nowadays, it receives a lot of researchers' attention and has become an attractive research direction. As compared to other hand-based biometrics, finger vein systems exhibit some excellent advantages in their application. First, finger veins are difficult to counterfeit. This is attributed to the hidden vein patterns being underneath the skin surface, which makes vein pattern duplication impossible in practice. Secondly, the quality of the captured vein

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pattern is not easily influenced by skin conditions. In addition, as compared with palm vein-based verification systems (Wu et al., 2013), the size of the device can be made much smaller. Moreover, vein patterns are stable and clearly defined, thus allowing a user to use a low-cost and uncomplicated image acquisition device. Lastly, in terms of hygiene, finger vein recognition is non-invasive and utilizes contact-less imaging, which ensures both convenience and cleanliness.

Due to the aforementioned unique properties, the use of vein recognition is becoming a suitable biometrics candidate for personal identification in high-level security systems. Moreover, it can be combined with other biometric modalities such as fingerprints and finger geometry to form multimodal finger-based biometrics. Consequently, this will ensure that security systems are highly robust against forgery. In response to the current needs, this research proposes a new approach to improve the present finger-based biometric techniques. Overall, there are four contributions offered in this paper. First, we propose to utilize the Band Limited Phase Only Correlation (BLPOC) function to measure the similarity of two finger vein images. Unlike previous methods (Rosdi et al., 2011; Xin et al., 2012; Xi, Yang, Yin, & Meng, 2013; Yang, Ma, Li, & Liao, 2013) that work in the spatial domain, the BLPOC is performed in the frequency domain. Hence, our proposed method is fast and robust against finger vein degradation due to brightness variation, translation, rotation and segmentation errors. Secondly, we propose to use a feature extraction technique called Centroid Contour Distance (CCD) (Fotopoulou, Laskaris, Economou, & Fotopoulos, 2013) in finger geometry recognition. To the best of our knowledge, this is the first time the technique is applied in the finger geometry domain. To overcome the limitation of the current methods (Kang & Park, 2009, 2010; Kang, Park, Yoo, & Kim, 2011) that use only the finger width (W) as the geometrical feature, we propose to combine the W with the CCD at the feature level and a new geometrical feature called Width-Centroid Contour Distance (WCCD) is formed. WCCD is not easily affected by finger rotation, translation and segmentation errors. Consequently, the performance of finger geometry recognition can be enhanced. Third, we present multimodal finger-based biometrics by consolidating the finger vein and finger geometry modalities at their score level using weighted SUM rule-based fusion. Our proposed method is shown to be more superior than the current finger-based biometrics (Kang & Park, 2009, 2010; Kang et al., 2011) because our proposed finger vein recognition method is robust against brightness variation while our proposed finger geometry recognition algorithm is not easily affected by the segmentation errors. Fourth, we develop an infrared finger image database to test the proposed algorithms. The database will be released to public as benchmark data and it can be downloaded from our website: http://blog.eng.usm.my/fendi/. The experimental results using this database show that the proposed multimodal approach demonstrates better performance than unimodal biometrics and at the same time, more superior than previous multimodal finger-based biometric methods.

The rest of this paper is organized as follows: Section 2 presents previous methods and highlights some motivations for our study. The detailed approach of our proposed method is described in Section 3. The experimental results are explained in Sections 4 and 5 summarizes our findings.

2. Previous works and motivation

Yu, Qin, Cui, and Hu (2009) extracted finger vein patterns based on the minutiae features including bifurcations and ending points. These feature points are used as a geometric representation of vein patterns' shape. Finally, the modified Hausdorff distance algorithm is employed in their verification process. Song et al. (2011) proposed a new finger-vein verification system using the mean curvature. By treating the intensity surface of an image as a geometric object, their method treats vein patterns as sets of points with negative mean curvature to be determined as a valley-like structure. In the matching stage, they used the Matched Pixel Ratio (MPR) to evaluate their system. In Huang, Dai, Li, Tang, and Li (2010), the finger vein features are extracted using a wide line detector. Based on the proposed line detector, the authors aimed to obtain more precise width of vein information.

Most of the above-mentioned techniques utilize vein features from the segmented blood vessel network. However, segmentation errors may occur during the feature extraction process due to the low quality of finger vein images. Improperly segmented networks may degrade the recognition accuracy significantly. To solve this problem, texture-based methods based on binary patterns have been introduced (Lee, Lee, & Park, 2009, 2010, 2011; Rosdi et al., 2011). Lee et al. (2009) proposed a method of reducing misalignment problems of vein images using vein minutia points such as bifurcations and ending points of the finger vein region. To speed up their computations, they only used a few selected vein regions defined by extracted minutia points. By using the Local Binary Pattern (LBP) technique, they extracted the unique finger vein code from the aligned vein region. Lee, Jung, and Kim (2011) enhanced vein patterns by using a Modified Gaussian high-pass Filter (MGF) through binarization. In their approach, instead of utilizing only vein pattern information, they also exploited the geometrical finger edge information available in the captured finger vein image. For feature extraction, they extracted the finger code (vein and geometry) using LBP and Local Derivative Pattern (LDP) methods. In the recognition procedure, the binary codes are matched using Hamming Distance. Their experimental results show that the LDP method produces better recognition rates than the LBP technique. However, the processing time for LDP is 2.5 times longer than the LBP. Moreover, the memory size to store the binary codes of LDP is four times larger than the LBP. To cope with this limitation, Rosdi et al. (2011) proposed to use a new texture descriptor called Local Line Binary Pattern (LLBP). In their approach, they reduce the feature extraction complexity by examining the neighbourhood pixels in a straight line, unlike in LBP or LDP, which is in a square form. Experimental results tested on 204 fingers showed that the Equal Error Rate (EER) for the LLBP is significantly lower than that of the LBP and LDP approaches. Moreover, they also confirmed that the LLBP computation is faster than the other two methods. As for the LBP and its variants (Yang et al., 2013; Lee et al., 2009, 2011; Rosdi et al., 2011), the vein features are extracted based on the relationship of local neighbourhood pixels folded in a specific sub-region. Therefore, the local binary code is really dependent upon the size of the masking window. This means that with a small window size, low-frequency patterns cannot be detected while with a large window, high-frequency patterns cannot be identified. Since the binary pattern and its variants operate locally, they only cover a small area of neighbourhood on a specific radius. For global feature extraction, they have to slide through the entire region of the image. The local binary codes are then concatenated to form complete texture descriptors. By doing so, the computational time is greater thus slowing down the process. In addition to this, the binary pattern operators usually use zero as the threshold (Kang et al., 2011; Lee et al., 2011). Therefore, any small changes can cause a label result range from one value to another. This makes the description of vein patterns in the sub-region sensitive to noise. To overcome the above-mentioned problems, we introduce a new finger vein recognition algorithm based on the Band Limited Phase Only Correlation (BLPOC) function. BLPOC is a method of image