Knowledge-Based Systems 81 (2015) 117–130

Contents lists available at ScienceDirect

Knowledge-Based Systems

journal homepage: www.elsevier.com/locate/knosys

Multi-modal fusion of palm-dorsa vein pattern for accurate personal authentication

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ARTICLE INFO

Article history:
Received 6 October 2014
Received in revised form 31 January 2015
Accepted 5 March 2015
Available online 14 March 2015

Keywords:
Biometrics
Vein pattern
Authentication
Verification
Multi-modal fusion

ABSTRACT

This paper proposes an efficient multi-modal authentication system which makes use of palm-dorsa vein pattern. There are four levels of fusion in the system and they are multi-algorithm fusion, data fusion, feature fusion and score fusion. Multi-algorithm fusion is applied to extract genuine vein patterns from a vein image by using various vein extraction algorithms. All false vein patterns are eliminated from the extracted patterns through data fusion. Three types of features are obtained from each extracted vein pattern and they are shape features, minutiae and features obtained from hand boundary shape. Third level of fusion is at feature level to fuse minutiae and shape features. Finally, fused features and hand boundary shape features are matched to obtain matching scores which are fused at score level. The proposed system has been tested on the database acquired from 4120 images of 1030 subjects. It has achieved an accuracy of 100%. Experimental results reveal that it performs better than other existing systems.

1. Introduction

Data protection or security is a major concern in today's digital age because of the availability of large digital data and cheap hardware. Methods based on keys or passwords are not useful because these can be easily spoofed, lost, forgot or stolen. Thus, use of biometrics is proliferated which recognizes an individual based on his/her characteristics [1]. One such biometric trait is a vein pattern which is the formed by the subcutaneous blood vessels. Like any other biometric trait, it has all the properties required in a recognition system, viz., universality, uniqueness [2], permanence [3] and acceptability [4]. In addition, it has the following properties [5] which escalated its utilization in personal authentication: (i) it can be acquired in a contact-less manner; (ii) it assures liveness; (iii) it is hard to forge as it lies inside skin; (iv) it can be easily and instantaneously acquired by using cheap sensors; and (v) it is highly user friendly. Motivated by all these factors, a personal authentication system based on vein pattern is proposed in this paper.

A vein pattern image acquired from X-ray or ultrasonic scanners (in medical imaging) has high quality. But it is highly user inconvenient due to slow acquisition and thus, avoided for biometric purposes. It is observed that areas containing vein pattern have dark intensities as compared to its surrounding tissues when observed under infrared (IR) light because IR light is absorbed by the blood flowing in the veins [6]. Thus, IR imaging is used in the biometrics for contact-less and non-invasive acquisition of vein images. However, genuine veins can be missed or spurious veins can be generated due to the following reasons: (i) skin properties (like the thickness, texture and hairs) [7]; (ii) environmental conditions (like temperature); (iii) non-uniform illumination [8]; (iv) varying width veins; and (v) low local contrast.

This paper proposes an efficient vein pattern based personal authentication system. Its research contributions and underlying motivations are:

1. Vein enhancement is a challenging problem due to variable width veins, low local contrast, non-uniform illumination and skin properties (like hairs). Thus, a hair removal algorithm and multi-scale matched filtering are used for vein enhancement. Also, global thresholding is not useful for vein extraction because it can miss the genuine veins. In contrast, local thresholding can generate spurious veins. Therefore, multi-algorithm fusion of local and global thresholding is proposed in this paper for better vein extraction. In addition, multi-scale matched filtering is used to handle the effects of variable width veins, low local contrast and non-uniform illumination.

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http://dx.doi.org/10.1016/j.knosys.2015.03.007
0950-7051/

2. This paper commences the use of data fusion for removing spurious vein pattern during enrollment. This helps to remove spuriously generated veins and cavities while retaining the true veins.
3. Local features or shape features can be used for vein matching but their performance is restricted. It is because local features like minutiae cannot be accurately extracted and localized in the vein pattern while shape matching fails when spurious veins are generated or genuine veins are missed. Thus, three different types of features, viz., vein shape, minutiae bifurcations and hand boundary are used in this paper to achieve better performance. Some part of palm-dorsa boundary is found to be stable because of the presence of bones. Use of boundary features is also initiated in this paper.
4. A hybrid fusion strategy is proposed in this paper to design an accurate vein pattern based authentication system. Minutiae and shape features are fused to obtain a feature fused image by using feature level fusion. Feature fused image and boundary features are eventually fused by using score level fusion.

The paper is organized as follows. Next section has discussed some of the well known vein pattern based recognition algorithms. An efficient vein pattern based authentication system has been proposed in Section 3. Its performance has been evaluated on IITK database of 4120 images acquired from 1030 subjects. Experimental results have been analyzed in Section 4. Conclusions are given in the last section.

2. Related work

A vein biometric based authentication system mainly consists of vein enhancement, vein extraction, feature extraction and feature matching.

2.1. Vein enhancement and extraction

Palm-dorsa image is enhanced before vein extraction to minimize the effects of low local contrast, non-uniform illumination and noise present in the acquired vein images. Filtering based on Steerable filter [9], Gabor filter [10], Curvelet filter [11] and Retinex [12] can be used for vein enhancement. These are based on the shape of local neighborhoods of vein pattern and hence perform poorly for variable width veins. Vein tracking relies on the principle that by using local minima, vein area can be tracked from a large number of locations as opposed to the background areas [13]. For better performance, maximum curvature information can be used along with vein tracking [14]. Since thin veins can be tracked from fewer locations, these may be missed. Further, spurious veins can be generated due to avoidance of local vein shape during vein tracking. Scattering effect in IR imaging can be reduced by using restoration algorithms [15,16]. Global [17] and local [18] thresholding are applied to the enhanced vein image to extract the vein pattern. Global thresholding perform poorly if significant overlap exists between the intensities of background and foreground pixels. In contrast, local adaptive thresholding performs poorly when local neighborhoods do not have significant variation. Various features are extracted from the vein pattern which are used for vein matching.

2.2. Feature extraction and matching

Local or global features are extracted from the vein pattern and used for matching. Local features refer to the geometrical transformation invariant points [19]. Vein endings and bifurcations are commonly used local features which can be extracted by applying crossing number technique [20] on vein pattern. Extracted minutiae can be represented as features by various ways, such as distances among minutiae pairs [21], minutiae triangulations [22] and orientation [23]. But such representations are error prone because minutiae cannot be accurately localized in vein pattern. Minutiae matching can be carried out by using point-to-point matching algorithms like line segment hausdorff distance (*LHD*) [6] and modified hausdorff distance (*MHD*) [24]. But such matching algorithms are highly sensitive to geometrical transformation. Thus, spectral minutiae representation [25,26] can be used which requires global matching. Usefulness of minutiae features for vein matching is restricted because (1) sometimes few genuine minutiae are available; (2) minutiae location cannot be accurately determined; and (3) sometimes spurious minutiae can be generated due to noise generated by hair and texture. Vein matching can also been done using its shape or global feature. Extracted vein patterns can be matched by using pixel-by-pixel matching [27]. Local binary patterns of extracted vein are matched by using chi-square statistic [28]. Likewise, dilated skeleton can be matched by using correlation [29]. *LHD* is also useful for matching the vein skeletons [30]. Global features in vein pattern can be given by phase information [31] and texture analysis [32]. Global matching can give wrong results due to following reasons: (i) sometime thin vein pattern can be missed out; (ii) some spurious veins can be generated due to hair, noise, texture and non-uniform illumination; (iii) there are errors in localization of extracted vein and skeleton.

3. Proposed system

In this section, a palm-dorsa vein pattern based authentication system is proposed. It consists of six major stages which are (i) vein extraction, (ii) data fusion, (iii) feature extraction, (iv) feature level fusion, (v) feature matching, and (vi) score level fusion. In the first stage, palm-dorsa image is acquired and vein pattern present in it is extracted. In case of enrollment, two palm-dorsa images are acquired and there vein patterns are extracted. These are fused in the data fusion stage to remove the spurious veins. In the next stage, minutiae and boundary features are extracted from the vein pattern. Feature level fusion is done to fuse shape of vein pattern and minutiae features in the subsequent stage. It is followed by the feature matching stage where matching scores for different features are obtained. Score level fusion is done to obtain the matching scores. Its flow-graph is given in Fig. 1.

3.1. Vein extraction

This section consists of three major stages: (i) image acquisition; (ii) region extraction and preprocessing; and (iii) multi-algorithm fusion for vein extraction. Palm-dorsa image is acquired by using the acquisition setup. Its palm-dorsa area referred as region of interest (ROI) is extracted and enhanced. Veins are extracted from the enhanced image by using a multi-algorithm fusion strategy.

3.1.1. Image acquisition

The acquisition setup is enclosed in a box to minimize environmental interference. Palm-dorsa part of the human hand is illuminated by two IR lamp of wavelength 850 nm. An SLR camera is used to acquire vein images which assures high resolution image. The box has

1. a hole on the top where SLR camera is placed,
2. a hole in a side wall from which a hand can slip in,