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# An accurate infrared hand geometry and vein pattern based authentication system

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ABSTRACT

In this paper, hand dorsal images acquired under infrared light are used to design an accurate personal authentication system. Each of the image is segmented into palm dorsal and fingers which are subsequently used to extract palm dorsal veins and infrared hand geometry features respectively. A new quality estimation algorithm is proposed to estimate the quality of palm dorsal which assigns low values to the pixels containing hair or skin texture. Palm dorsal is enhanced using filtering. For vein extraction, information provided by the enhanced image and the vein quality is consolidated using a variational approach. The proposed vein extraction can handle the issues of hair, skin texture and variable width veins so as to extract the genuine veins accurately. Several post processing techniques are introduced in this paper for accurate feature extraction of infrared hand geometry features. Matching scores are obtained by matching palm dorsal veins and infrared hand geometry features. These are eventually fused for authentication. For performance evaluation, a database of 1500 hand images acquired from 300 different hands is created. Experimental results demonstrate the superiority of the proposed system over existing systems.



## 1. Introduction

In today's digital age, technologies are rapidly evolving both in terms of hardware and software due to which information security is a major concern. Traditional authentication systems based on possession (like keys) or knowledge (like password) are not much advantageous to provide the security because these systems can be easily transferred, forged, lost or forgot. However, biometric based authentication systems are proliferating, which handle these issues using behavioral and physiological characteristics of the user [11]. In this paper, infrared (IR) hand dorsal images are used for authentication, which consists of two biometric traits, viz., palm dorsal veins and IR hand geometry. Hand dorsal refers to the back side of hand and palm dorsal vein refers the pattern formed by the subcutaneous blood vessels present in the palm dorsal, i.e., the area behind the palm. The following factors provide the motivation for the fusion of palm-dorsal vein and IR hand geometry:

1. Palm dorsal vein pattern possesses all the necessary characteristics required in an authentication system, like, universality, permanence, acceptability and distinctiveness [7]. Moreover, its applicability in authentication is further enhanced due to the following factors: (i) it assures liveness [44]; (ii) it is difficult to spoof because it lies inside skin; and (iii) it can be easily and instantaneously acquired by low cost sensors in a user friendly manner. Due to these factors, palm dorsal veins are used in this paper.
2. Hand images can be easily acquired using a low cost camera and hand features can be easily and accurately extracted from the images. Moreover, it is easily accepted and possessed by most of the users [49]. Also, hand shape is shown to be distinctive in nature even though to a smaller extend than palm dorsal veins [48]. In addition, hand shape does not change much with the time [40]. However, detecting accurate hand boundary is a challenging task, but it can be easily handled by acquiring the images in IR light [28]. Thus, IR hand geometry is used in this paper.
3. Applicability of a multi-modal system depends upon performance improvement, acquisition cost (in terms of sensor cost and time) and user friendliness. Palm dorsal vein and IR hand geometry can be acquired using a low cost sensor, which makes the proposed system highly user-friendly and time inexpensive [2].

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An accurate IR hand dorsal based authentication system is presented in this paper. It uses a low cost acquisition setup for acquiring IR hand dorsal images in an unconstrained and contact-less manner. Each acquired image is segmented into palm dorsal and fingers, which are used to extract palm dorsal vein and IR hand geometry features respectively. Matching scores obtained by matching the palm dorsal vein and the IR hand geometry features, are eventually consolidated for authentication. The main research contributions of the paper are:

1. Existing quality approaches assign a global quality score to the vein image. These aim to reject the poor quality images during matching for enhancing the performance. These can assign high values to the pixels containing hair. In this paper, a new quality approach is proposed for palm dorsal veins which assigns the quality at each pixel and use it for vein extraction. It is formed by consolidating an anisotropic measure local range and the existing quality measure gradient [47]. It assigns high values to vein pixels and low values to the remaining pixels, especially to the pixels containing hair.
2. Spurious veins can be generated or genuine veins can be missed in the existing systems due to non-uniform illumination, hair, skin texture and variable width veins. The major contribution of this paper is that of accurate vein extraction. Initially, multi-scale matched filtering is used to enhance variable width veins. Veins are extracted from the enhanced image using a variational approach and the vein quality.
3. Texture present at the interphalangeal joints of hand dorsal is not acquired in IR hand images. Several existing IR hand geometry features like finger profile [29] and triangles [25], require this texture information for accurate feature extraction. In the paper, stable features like finger length and finger width are used. Often these cannot be accurately determined, thus some post processing techniques are applied. Moreover, various well known IR hand geometry features are rigorously analyzed and the factors which limit their efficacy are discussed.

This paper is organized as follows. Some well-known palm dorsal vein and IR hand geometry systems have been described in the next section. Section 3 discusses some well-known algorithms that are used to design the proposed vein quality. The proposed system has been described in Section 4. Its efficacy has been analyzed in the next section. Conclusions are presented in the last section.

## 2. Related work

In this section, palm dorsal vein and IR hand geometry based systems are described.

### 2.1. Palm dorsal veins

Usually, a palm dorsal vein based authentication system consists of quality estimation, vein extraction and vein matching.

#### 2.1.1. Quality estimation

Quality plays a crucial role in a biometric based authentication. It is experimentally shown in [33] that the performance decreases as the quality of vein images are degraded. Some of the useful measures for vein recognition are: (1) gradient which measures the clarity in the orientation of the vein pattern structure [47]; (2) contrast which measures the brightness variation [19]; and (3) entropy which measures the dispersion in the image intensities [31]. These quality measures assign high values to good quality palm dorsal vein images however, it can also assign high values to the pixels containing hair or skin texture. These assign a global quality score to a vein image which is used to classify the image as good or poor quality images. The performance of a system is increased by rejecting the poor quality images during matching.

#### 2.1.2. Vein extraction

Palm dorsal image may contain low local contrast, non-uniform illumination and noise due to hair and skin texture. These problems should be minimized prior to vein extraction otherwise spurious veins can be generated or genuine veins can be missed. Line tracking algorithm [26] can be used for vein enhancement. It is based on the principle that vein pixels contain a local minima, as opposed to the background and thus, a vein pixel can be tracked from several other nearby vein pixels. Since thin veins can be tracked from a relatively fewer number of locations, it is possible that they are ignored. Moreover, several pixels containing noise due to hair and skin texture also contain local minima and thus, sometimes these are spuriously marked as vein pixels. Various filtering algorithms can also be used vein enhancement like Gabor filter [6], Steerable filter [46] and Matched filter [25]. For effective enhancement, the filter must correspond to the shape of vein in a local neighborhood. Unfortunately, palm dorsal images contain variable width veins and thus, a single filter cannot be accurately designed for enhancement. Motivated by this, a multi-scale matched filtering algorithm is proposed in [13] where several filters are designed corresponding to different shapes of vein pattern and the filter responses for these filters are consolidated to enhance variable width veins. Eventually, veins are extracted from the enhanced image using threshold based algorithm [16]. It is possible that pixels containing noise due to hair and skin texture can be spuriously marked as vein pixels in the filtering based algorithm.

#### 2.1.3. Vein matching

Veins can be matched by local feature matching. Local features are the points which are invariant to geometrical transformations like vein bifurcations and endings [22]. Vein minutiae can be matched by line segment hausdorff distance (*LHD*) [41] and the modified hausdorff distance (*MHD*) [42] but these are extremely sensitive to geometrical transformations. Moreover, the usage of minutiae features for vein matching is limited, due to (1) lack of availability of genuine minutiae sometimes; (2) problems in determining the location of minutiae accurately; and (3) the hair and texture in the image inducing spurious minutiae points in some cases. Another approach to vein matching is based on global feature matching. One way to do so is to perform a pixel-to-pixel matching [12]. Another way for global matching involves matching of local binary patterns using chi-square statistic [43]. Phase information can also be used as global features [16]. The global matching can give erroneous results when (1) thin vein patterns are missed; (2) spurious veins are generated due to hair, non-uniform illumination and skin texture; and (3) localization of extracted vein is erroneous.

### 2.2. IR hand geometry

A hand shape based authentication system uses the information derived from a hand silhouette [49]. It requires hand silhouette based matching where two silhouettes are aligned prior to matching. Accurate hand silhouette alignment is not possible when fingers are opened or closed in different ways which is usually the case when images are acquired under unconstrained environment [1]. Hence, geometric features of hand silhouette are usually preferred for the matching. Some well-known geometric features are finger lengths, finger widths, finger profile and area of hand [49]. Systems relying on matching such features are referred as hand geometry based system. One of the main problems with any hand based system is that of segmenting the accurate hand silhouette when images are acquired in visible light and varying backgrounds. This problem is solved in [28] by acquiring hand image