Feature-level Fusion of Palm Print and Palm Vein for Person Authentication Based on Entropy Technique

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Abstract
This paper presents a new approach to authenticate individuals using multiple biometric modalities. It deploys palm print and palm vein images for greater accuracy and flexibility. The contactless system uses a multispectral camera to capture the visible and Near Infrared Images (NIR) simultaneously. Subjects are allowed to place their hands freely below the camera. The Region of Interest (ROI) extraction method used is rotation and translational invariant. Different pre-processing techniques are used for noise reduction. We introduce a simple entropy based technique to extract the palm print and palm vein features. The feature level fusion adopted in this system uses least features (only 16). For 100 subject’s, distance based matching yields promising recognition rate (GAR) of 99%

Keywords
Feature Level Fusion, Palm Print, Palm Vein, Entropy

I. Introduction
In this age of internet technology, e-commerce, net banking and fast transactions, security is of foremost importance. Initially passwords and tokens were used for security but they were faced with problems like ease of forgery as they could be guessed, stolen or forced out of people. Humans use face or voice for recognizing each other. This ability of humans is further exploited to develop a security system based on biometric features of the humans like our palm prints, face, iris, gait, voice etc. Nowadays, personal identification system based on biometric feature is being increasingly used in applications such as public security, access control, banks and so on. The single modality based systems undergo shortcomings such as people having damaged modality and lower accuracy. To overcome these shortcomings, a multimodal system fusing more than one modality can be used which facilitates higher accuracy. Palm prints are being used for recognition in a number of applications. Using palm vein fused with palm print helps in increasing the robustness of the system. Biometric recognition systems based on palm vein patterns are becoming popular as they possess properties like universality, uniqueness, stability, permanence and strong immunity to the forgery. Since the veins lie underneath the skin and are, in most cases, not visible to the naked eye, they provide a strong resistance against forgery. The complex vascular pattern present inside the hand allows the computation of a good set of features that can be used for personal identification. Infrared sensors can be used to capture the pattern of the subject’s veins when illuminated by a source of infrared radiation. The veins can be imaged since the deoxidized hemoglobin in veins absorbs light at a wavelength of about 760 nm, which is in the range of NIR band. Therefore, when the palm is illuminated by infrared light, unlike the image seen by the human eye, the deoxidized hemoglobin in the palm vein appears as a dark pattern [1]. The next section presents the brief review of the prior work.

A. Prior Work
There have been many challenges while designing the palm print and palm vein authentication system like the issue of hygiene in a contact based system, the complexity involved in handling the large feature vectors etc. Lin and Wan [2] proposed the thermal imaging of palm dorsal surfaces, which typically captures the thermal pattern generated from the flow of (hot) blood in cephalic and basilic veins. Goh Kah Ong Michael, Tee Connie Andrew [3] introduces an innovative contactless palm print and palm vein recognition system. They designed a hand vein sensor that could capture the palm print and palm vein image using low resolution web camera. The images captured exhibit considerable noise. Huan Zhang proposed a Local Contrast Enhancement technique for the Ridge Enhancement [4]. Principle Component Analysis (PCA) aims at finding a subspace whose basis vectors correspond to the maximum variance directions in the original space. The features extracted by PCA are best description of the data, but not the best discriminant features. Fisher Linear Discriminant (FLD) finds the set of most discriminant projection vectors that can map high dimensional samples onto a low dimensional space. The major drawback of applying FLD is that it may encounter the small- sample-size problem. Jing Liu and Yue Zhang introduce 2DFLD that computes the covariance’s matrices in a subspace of input space and achieved optimal discriminate vectors. This method gives greater recognition accuracy with reduced computational complexity but is difficult to implement on hardware [5]. David Zhang extracted texture features from low resolution palm print images, based on 2D Gabor phase coding scheme. [6]. Ajay Kumar used minutiae based technique for hand vein recognition. The structural similarity of hand vein triangulation and knuckle shape features are combined for discriminating the samples. Vein edge points can be detected by locating the zero crossings of second order derivative preferred ‘Laplacian of Gaussian’. Adaptive histogram equalization is used. This methodology gives rotation and translational invariant representation of the local information but is computationally complex. Matching scores are assigned according to the distance triangle matching and knuckle shape perimeters [7]. S.F.Bahgat analyses four different statistical approaches for person recognition using palm vein and face images and concludes that Moment Invariant (MI) feature vector facilitates better recognition rate. MI vector is invariant under rotation, translation and scale. [11] Zhifang Wang reduces feature vector using PCA and calculates the Canonical Correlation Analysis (CCA) to provide improved recognition rate. It faces problems of reduced accuracy [12]. Using minutiae extraction for fingerprint image, local binary pattern for extracting features of palm print and combining using wavelet based fusion technique outperforms individual modalities being used for recognition. This is sensitive to varying rotation and translation. [13]

ISSN: 2230-7109 (Online) | ISSN: 2230-9543 (Print)

IJECT VOL. 5, ISSUE SPL-1, JAN - MARCH 2014

www.iject.org

INTERNATIONAL JOURNAL OF ELECTRONICS & COMMUNICATION TECHNOLOGY 53
1. The system requires being contactless, background and illumination independent and registration free authentication system, utilizing the data captured simultaneously through a single sensor for both modalities.
2. Most of the researchers have used pixel level fusion or score level fusion. One of the major issues in pixel level imaging fusion is image alignment or registration, which refers to pixel-by-pixel alignment of the images. Score level fusion undergoes normalization problems and important discriminatory information is lost. Feature level fusion reduces the complexity of alignment and overcomes normalization issues.
3. Researchers have used some complex methods or algorithms like Kernel Principle Component Analysis (KPCA), Principle component analysis (PCA), Direct Linear Discriminant Analysis (DLDA), Fisher Linear Discriminant (FLD) and Laplacianpalm. These algorithms are very hard to implement on hardware. So a simple algorithm needs to be developed.
4. Generally the minutiae based approach gives the matching with high feature vector values. They are mostly dependent on the position of the minutiae points. The systems are rotationally and translationally sensitive.
5. The number of features and False Acceptance Rate (FAR) and False Rejection Rate (FRR) do not share a linear relation and hence it is necessary to optimize the number of features and select the appropriate ones. Developing a computationally less complex system with low FAR and FRR is an important requirement.

Thus, in this work, an attempt is made to find out possibilities of using multiple biometric modalities to overcome above mentioned problems and satisfy the mentioned requirements. Developing a computationally less complex system which is translational and rotational invariant, less complex, with minimum features and higher accuracy.

B. Proposed System

In this paper, we have proposed a very simple entropy based method for the recognition based on palm print and palm vein. The block diagram of the system is as shown in fig. 1. We developed a system for capturing the palm print and palm vein simultaneously by using a multispectral camera.

The image contours extracted from the acquired images are used for locating region of interest (ROI) which is detailed in Sections II-III. The extraction of features is elaborated in section IV. The experiments and results from this work are presented in Section V.

II. Image Acquisition

In this research, a JAI AD-080-GE camera is used to capture NIR hand vein images. The camera contains two 1/3" progressive scan CCD with 1024x768 active pixels, one of the two CCD's is used to capture visible light images (400 to 700 nm), while the other captures light in the NIR band of the spectrum (700 to 1000nm).

Since most light source don’t radiate with sufficient intensity in the NIR part of the spectrum, a dedicated NIR lightning system was built using infrared Light Emitting Diodes (LED’s ) which a have a peak wavelength at 830nm.

The fig. 2 below shows the acquisition device used in this paper.

III. Pre-Processing & ROI Extraction

Captured image is converted to gray scale. Image is filtered using Gaussian filter in order to remove any noise which may cause problems while thresholding the image. The proposed method uses Gaussian filter G(x, y) on the original image, I(x, y) to obtain a blur version of the image M(x, y).

\[ M(x,y) = G(x,y) \ast I(x,y) \]  

This filtered image is converted to binary image using a global threshold T. For determining the threshold the Isodata thresholding method proposed by El-Zaart [8] is used. Since the binarized result might generate some notch edges on the contour of the palm, the “erosion” and “dilation” operations of morphology is used to reduce this effect. Suzuki [9] developed a contour extraction algorithm using border following. The same method is used here to extract the hand contour from binarized image.

The fig. 3 below shows the different pre-processing stage
The hand contour plays a very important role in extracting the tip and valley points of the palm. To locate the peak and valley points on the hand boundary, the basic steps are as follows.

Algorithm for ROI extraction
1. Find the lower left most point of the palm in the binarized image.
2. Find the lower right most point of the palm in the binarized image.
3. Find the midpoint of the above two points this mid point is used as reference point for tip and valley point detection.
4. Find the Euclidean distance of all contour pixels with respect to the reference point and plot all these distance’s with respect to the index of all points.
5. The maxima in the plot represent the tip points and the minima represent the valley points of the palm [10].
6. Now to extract the main ROI, the valley points between index and middle finger and little and ring finger are joined. The midpoint of this line is found.
7. A perpendicular bisector is drawn on the line joining the two valley points. Now the bottom most point on the hand which satisfies the equation of this bisector is detected.
8. Then mid-point of the line joining these two points is found out. This point is taken as reference to locate the ROI (Region of Interest) of size 128*128.

For the noise reduction of ROI, different pre-processing techniques are applied. Median filter is employed for speckle noise removal. Then to suppress the effect of high frequency noise, a 2D wiener filter is applied. To enhance vein visibility, contrast limited adaptive histogram equalization is applied, improving the resulting image contrast. The tip and valley point detection used ensures the rotation and translation invariance.

The extracted ROI for palm print and palm vein along with their enhanced images are shown below in fig. 4.

**Fig. 3(c): Eroded (d). Edges**

**Fig. 4(a): ROI for Palm (b). Enhanced ROI**

**Fig. 4(c): ROI Palm Vein (d). Enhanced ROI**

### IV. Feature Extraction

Entropy is the measure of the average uncertainty. It is used in the problem of assigning measure to the occurrence or non-occurrence of single events. Image entropy is a quantity which is used to describe the ‘business’ of an image, i.e. the amount of information which must be coded for by a compression algorithm. Low entropy images have very little contrast and large runs of pixels with the same or similar values. An image that is perfectly flat will have entropy of zero. On the other hand, high entropy images have a great deal of contrast from one pixel to the next.

Image entropy as used in my paper is calculated with the same formula use by the Galileo Imaging Team.

\[
Entropy = -\sum_i p_i \log (p_i) / \log 2 \tag{2}
\]

In the above expression, \( p_i \) is the probability that the difference between 2 adjacent pixels is equal to \( i \). For an enhanced ROI of size 128*128 the block wise entropy is obtained. For a block size of 32x32, total 16 features each are calculated. The Features of the palm print and palm vein are concatenated while fusing. Different types of distances are used for matching like Canberra, Lorentzian, Euclidean, city block etc.

#### A. Canberra Distance

The Canberra metric is similar to the Manhattan distance. The distinction is that the absolute difference between the variables of the two objects is divided by the sum of the absolute variable values prior to summing.

\[
d(x, y) = \sum_{j=1}^{N} \frac{|x_j - y_j|}{|x_j| + |y_j|} \tag{3}
\]

where, \( x_i \) = Testing feature vector  
\( y_i \) = Trained feature vector

\( N \) = Total number of features
V. Experiments and Results

Binarizing the image helps in making the system background and illumination independent. The Table 1 below shows the performance of the system by using single modality i.e. palm print alone.

Table 1: FAR and FRR for Palm Print Alone

<table>
<thead>
<tr>
<th>Distance</th>
<th>FAR(%)</th>
<th>FRR(%)</th>
<th>GAR(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canberra</td>
<td>15.17</td>
<td>35.00</td>
<td>65.00</td>
</tr>
<tr>
<td>City block</td>
<td>14.01</td>
<td>36.00</td>
<td>64.00</td>
</tr>
<tr>
<td>Lorentzian</td>
<td>15.12</td>
<td>35.50</td>
<td>64.50</td>
</tr>
<tr>
<td>Euclidean</td>
<td>17.41</td>
<td>36.50</td>
<td>63.50</td>
</tr>
</tbody>
</table>

Table 2 below shows the performance of the system by using single modality i.e. palm vein alone.

Table 2: FAR and FRR for palm vein alone

<table>
<thead>
<tr>
<th>Distance</th>
<th>FAR(%)</th>
<th>FRR(%)</th>
<th>GAR(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canberra</td>
<td>16.22</td>
<td>23.00</td>
<td>77.00</td>
</tr>
<tr>
<td>City block</td>
<td>20.71</td>
<td>20.00</td>
<td>80.00</td>
</tr>
<tr>
<td>Lorentzian</td>
<td>21.47</td>
<td>20.50</td>
<td>79.50</td>
</tr>
<tr>
<td>Euclidean</td>
<td>18.70</td>
<td>23.50</td>
<td>76.50</td>
</tr>
</tbody>
</table>

The Table 3 below shows the performance of the system by fusing the features of palm print and palm vein together. From the Table 3 it can be concluded that the Canberra distance achieves highest recognition rate with minimum FAR.

Table 3: FAR and FRR for Fusion of Palm Print and Palm Vein

<table>
<thead>
<tr>
<th>Distance</th>
<th>FAR(%)</th>
<th>FRR(%)</th>
<th>GAR(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canberra</td>
<td>0.2929</td>
<td>1.00</td>
<td>99.00</td>
</tr>
<tr>
<td>City block</td>
<td>0.7222</td>
<td>1.00</td>
<td>99.00</td>
</tr>
<tr>
<td>Lorentzian</td>
<td>0.4494</td>
<td>1.00</td>
<td>99.00</td>
</tr>
<tr>
<td>Euclidean</td>
<td>3.89</td>
<td>3.00</td>
<td>97.00</td>
</tr>
</tbody>
</table>

Comparing all three tables it is clear that that the performance of a multimodal system is better than using any single modality. Feature level fusion of palm print and palm vein using different distances gives very low FAR and FRR with recognition rate nearly 99%.

VI. Conclusion

The feature level fusion framework proposed facilitates good recognition accuracy up to 99%. Reduction in the feature space dimensions leads to less complex system in terms of number of computations required for matching. The system proposes user friendly environment with increased security. Experimental results clearly show that the proposed multimodal system provides very good results when compared to the corresponding unimodal systems.

We have developed a contactless, registration free person authentication which uses average uncertainty for feature extraction and feature level fusion of palm print and palm vein. It is also background and illumination independent. The proposed method utilizes only 16, entropy based features for palm print and palm vein modalities facilitating a lesser complex integration scenario. We achieve low computational complexity and high accuracy with large reduction in features.

VII. Acknowledgement

We are thankful to Board of Research in Nuclear Sciences, Dept of Atomic Energy, Govt of India for their constant support and encouragement.

References

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