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Faster and Better: A Deep Learning Approach to Finger Vein Authentication

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Abstract

In the present era of electronic development in the world it is sensibly challenging to secure the personal information. Considering the constraint of the uni-modal biometrics authentication the appropriate selection of modality plays vital role for authentication. This paper discusses about a topical authentication system using finger vein. The performance of identification process may degrade due to these factors and implies the need of defining Region of Interest (ROI). In this paper, the extraction of features of finger vein based on deep learning technique is proposed, RROI localization which proves to be much effective and forcefulness. Two types of errors false acceptance rate (FAR) and false rejection rate(FRR) is discussed in this paper.

Keywords: *Deep Learning, Robust Region of Interest (RROI), Features from Accelerated Segment Test (FAST).*

1. INTRODUCTION

With the advancement and growth of modern society, recognizing identity of humans and protecting their information security is a social key problem, which needs to be addressed in the current era of information technology. Traditionally there are two methods of identifying humans - based on known contents (passwords, secrets codes, etc.) and processing (certificates, credentials, smart cards, keys, etc.). Many abusing methods were practiced in the recent past due to the development of infrastructural equipment, fraud, misuse, cracks and hackings. Individual's passwords are often cracked, misused by others and forgotten which adds further to the complication of traditional methods. Thus, there is an emerging need for better recognition system which is fool proof, secure and easy to operation and this urge instigated development of modern technology for personal recognition[1-5].

The presence of oxygenated and deoxygenated haemoglobin enables the visibility of finger veins and its subcutaneous structures that develops inside a finger randomly. The visibility is enabled due to reflection of light and its absorption of near infrared lights and helps as strong force to avoid theft and forgery. Finger Vein Recognition System (FVRS) ideally suffers from various factors which are external in nature – the models used for imaging and uneven illumination[16,18].

2. LITERATURE SURVEY

David Mulyono et. al suggests an philosophy for finger vein image off-line and online acquisition. Online images are those images which are captured during the course of real time. Offline images are considered form the database, historical information etc. Online images can be captured by using Web Camera or any device which is designed using the technology called as light transmission[6][7].

In finger vein based biometric frameworks, different pre-handling task are to be performed – recovering data with respect to edges, upgrade of difference and brightness, noise removal and so on so as to improve the nature of picture caught. These pre-processes assists with improving picture quality, which can be utilized as a contribution during later phase of procedure for getting progressively important data and authentication tool[8-11].

Fernando C. Monteiro [12,13] proposed a novel method for segmenting finger vein image based on edge information which can be obtained by watershed of morphological algorithm and spectral method. By implementing pre-processing step of initially reducing the noise by using bilateral filter and subsequently preliminary segmentation is performed for region merging as well region similarity. R. V. Patil [14] prerogative that better result can be provided by K-means image segmentation, if the estimation of cluster numbers are measure accurately.

N. Miura, A. Nagasaka, and T. Miyatake proposed a new method for future extraction based on repeated line tracking technique. This method adopts the pattern of extraction by applying the concept of number of times the tracking lines pass through the points[15]. This method helps to identify local dark lines, which starts at various positions for line tracking and the same is executed by moving along with the lines by pixel by pixel.

Finger vein identification plays very important role in the process of classification and matching. Database stores the data of historical images which can be matched with real time input finger vein images and the comparison can be performed in this process. Once the finger vein features are mined[17-19] this process has to performed instantly. The next stage is minute matching performed just after the completion of this process which involves following stages .

(a) Minutiae Pairing (b) False Removing (c) Score Calculating and template matching

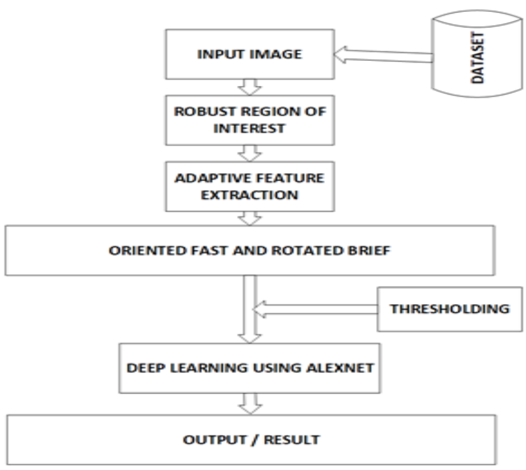
3. PROPOSED METHODOLOGY

3.1 Introduction

The limitations which are experienced in traditional biometric systems, to overcome this another method is studied with basic concept for finger vein recognition as the finger vein has distinct patterns. This unique feature can be used as an effective tool for personal verification. A new methodology is required for finger vein detection based on machine learning authentication, which can process the images of finger vein, in much lesser processing time of 5%. This can be achieved by simplifying the detector and repeatability optimization without compromising on its efficiency. By applying RROIs localisation stages accurately – segmentation, orientation, RROI detection and correction, will support to achieve higher accuracy towards ROIs localization. The robustness of the proposed method is testified by extensive analysis based on FV-USM database of finger vein images. Inferring to the tabulated results, we could establish that the processing time of less than 22ms can achieved by proposed method and proves to provide better accuracy over segmentation.

3.2 Architecture

The architecture of the proposed methods for finger vein based identification system based on ROI extraction and matching process is as given below:



3.3 Algorithm

Based on the artchitecture given above, an algorithm with can suit to the given architecture is as given below :

Step 1: Normalization of Input Image

Step 2: Extraction of Finger Vein shape feature based on Robust Region of Interest methodology.

Step 3: With the application of following method, Compute Orientation Estimation in order to preserve orientation feature of finger vein image by the subsequent encoding method:

Step 3.1: Determination of Orientation

Step 3.2: Computation of Difference Curvature

Step 3.3: Encoding the Orientation of Vein

Step 4: Computation of Adaptive Oriented Features of finger vein image from Accelerated Segment Test (FAST) and Rotated BRIEF

Step 5: Feature Point Matching using Deep/Machine learning Technique

3.4 Normalization

In the process of finger vein image a pixel wise operation is performed which is known as Normalization process. The main determination of this process is to obtain the desirable variance and mean value for an output image. This helps for the subsequent process of matching and identification of the image with the stored information. For the normalization of uniformed lightened image is obtained by using the below formula:

$$M = \frac{1}{M \times N} \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} I(i,j) \qquad \ldots\ldots(1)$$

$$VAR = \frac{1}{M \times N} \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} (I(i,j) - M(I))^2 \qquad \ldots\ldots(2)$$

$$G(i,j) = \begin{cases} M_0 + \sqrt{\frac{VAR_0}{VAR} \times (I(i,j) - M)^2}, I(i,j) \geq M \\ M_0 - \sqrt{\frac{VAR_0}{VAR} \times (I(i,j) - M)^2}, I(i,j) < M \end{cases} \qquad \ldots\ldots(3)$$

Where, the estimated mean and variance of the input image are denoted as M and VAR respectively. The desired mean and variance value for the given input image is defined as M_0=150, VAR_0=255.

3.5 Robust Region of Interest Extraction of Finger-Vein Shape Feature

The meaningful and important region of an image which needs to be identified for further processing of the same is called Regions of interest (ROI). The identification of ROI will help to avoid wastage of time by processing irrelevant information and point in an image, which can help to speed up the processing time. In the image processing activity, the feature of extracting the optimum ROI from a given image in more important and unresolved topic. Consider Finger Vein Image as F, and the grey scale value of pixel $F(x, y)$ is el (x, y), then point(x,y) is the cross sectional profile which is denoted by *P(z)* and curvature is given below:

$$K(z) = \frac{|P''(z)|}{\{1+P'(z)^2\}^{3/2}} \qquad \ldots\ldots(4)$$

where $P''(z)=d^2P/dz^2$ and $P'(z)=dP/dz$.

With reference to above formula, maximum difference curvature can be calculated from the given formula :

$$D_{max} = \max_{0\leq\theta\leq\pi} \Delta K_\theta \qquad ......(5)$$

where $\Delta K_\theta = \begin{cases} K_\theta(z) - K_{\theta+\pi/2}(z) & if \;\; \theta \leq \pi/2 \\ K_\theta(z) - K_{\theta-\pi/2}(z) & if \;\; \theta > \pi/2 \end{cases} \quad (0 < \theta \leq \pi)$, and $K_\theta(z)$ and $K_{\theta+\pi/2}(z)$

Computationally, the curvature in the direction and its perpendicular value is represented as Θ. Once the computation of maximum curvature difference value of all the pixels we can obtain the enhanced vein image. Subsequently by use of threshold value, we can binarized the vein pattern for matching and identification. The important factors to be considered for the given method are :

(a) The value of D_{max} will be more for the vein region due to large curvature value in the ridge direction of finger image and small in the perpendicular direction.

(b) The value of D_{max} will be less due to the curvatures in all directions are small

(c) The value of D_{max} will be still less, due to high isolated noise and irregular shading, the curvature in all directions is large.

3.6 Orientation Estimation For Preserving Orientation Features By Encoding Method

For biometric based personal identification system, where the individuals are identified based on image and computer algorithm and not the person themselves. The image encoding and decoding algorithm should effectively control the process in such a way that the important and most relevant features of the images are preserved after pre and post processing[20]. In this thesis work, a new method is proposed for the processing of finger vein image having following process executed systematically.

Determination of Orientation

As the vein spreads along the finger, it has clear orientation field value. The ridge position of a pixel (x,y) is divided into eight directions, to estimate the orientation of the image as shown in Figure 1. The recognized eight directions of the image which are divided into four groups. In each group two directions which are perpendicular to each other and denoted as $G_j = \{j, j+4\}$ be jth group.

3	4	5	6	7
2				8
1		(x,y)		1
8				2
7	6	5	4	3

Fig.1. Eight directions of a pixel.

Computation of Difference Curvature

Curvatures in two directions G_j is calculated on the difference value of curvatures in each group based on the given formula :

$$\Delta K_j = \begin{cases} K_j[z] - K_{j+4}[z] & if\ j \leq 4 \\ K_j[z] - K_{j-4}[z] & if\ j > 4 \end{cases} \quad (j = 1, 2, \ldots, 8)$$
......(6)

Encoding Orientation of Vein

We can determine the ridge orientation of pixel (*x*, *y*) as given below:

$$j_{\max} = \arg\{\max_{j \in \{1,2,\ldots,8\}} (\Delta K_j)\}$$
.......(7)

In this proposed method, based on largest rotational changes, $\pi/8$ is the orientation encoding scheme it can address, as the directions of all pixels are quantized to only eight orientations. The proposed orientation scheme will be robust with reference to rotation variations, if the number of quantized orientations is too small and are not distinguishable. [21-24].

3.7 Rotated BRIEF and Adaptive Oriented Features Obtained From Accelerated Segment Test (FAST)

For identification of process to extract adaptive oriented features from accelerated segment test is employed based on :

(a) Level Adjuster (b) Constant Fraction Discriminator (c) Double Differentiator

Based on the above algorithm the resulting matching of BRIEF pairs is (ideally) rotation-invariant. For avoiding the multiplication of matrix for every test, pre-computation of rotated BIEF masks for 0°, 12°, 24°, …, 348° can be calculated and picked the nearest and closed one for the desired orientation.

3.8 Feature Point Matching using Deep / Machine learning Technique

The deep learning technique is basically built up on relative distance and angle of the pixels presents in vein image. This method fully taken into consideration of following ideologies:

(a) Uniqueness of topology,

(b) Varied distances between the intersection points of two different vein images, and

(c) Differences in angles produced by these intersection points connections,

For a better vein image identification process all the above ideologies are to be fully considered. Hence this new approach can help to overcome the impact of image translation and rotation with the underlying concept that the relative distance and angle of pixels in an image will not change. Considering its uniqueness of characteristics and compactness, this methods of greatly in use in the field of biometric based personal identification technology [25-27].

The process involved in this methodology is to extract and connect all the intersecting points of finger vein image which is thinned and repaired. We can compute the relative distance feature M based on its relative distances and angles. Two images can be matched based on the pixels relative distance and angles that correlate and fusing these two features using "Logical And". The matching of vein image will be succeeded only when these both features relatively same else the matching will be failed one. Once the finger-vein skeleton is extracted, it will processed further as thinned and repaired and subsequently a fully meshed topology is formed. From the thinned finger vein image the intersecting points can be selected and connecting these points with each other and separating these points into several regions will help to enhance the performance of matching process [28 29].

3.9 Matching finger-vein images using relative distance and angles

The following are the various steps involved in the process of equivalent finger vein images by using relative distance and angels.

(a) We need to calculate the angles and relative distances of the pixels of finger vein image. Considering, the intersection points of an image as 'd' and the relative distance is considered as $d(d-1)/2$. The produced number of angels by point connection is denoted as $d(d-1)(d-2)/2$.

(b) $R=(l_m,\theta_u)$ is the set of finger vein image features. The distance of any two intersecting points denoted by l and the angle produced by them is denoted by θ, m and u are the number index respectively. Suppose, $R_1= (l_m,\theta_u)$, and $R_1= (l_n,\theta_v)$, are two sets of finger-vein image features.

(c) The relative distance denoted as 'm' is compared with the R1 with 'n' relative distance from R2, based on the calculation of alike relative distance number approximately. If the threshold number is less than the pre-defined one, then go to subsequent step else it is supposed that the matching is failed.

(d) We need to take care of the position error of these points by defining, $\| lm-ln\|<e$ to show the extent of similarity between any two Eigen values (e is the allowable error range). From experimental analysis, $e=0.0005$ is very appropriate.

(e) The approximately relative equivalent distance is 'q' Eigen values then, connect 'q' character points in the two sets respectively, with each other which produces the 'z' angles. These are denoted as θ_{z1} and θ_{z2} in R_1 and R_2 respectively.

(f) Based on above assumption, we need to calculate the approximately equivalent angles number and if the same is greater than pre-defined threshold value, then the matching is considered as successful else it is failed. Similarly, $\| \theta_m-\theta_n\|< e'$ is used to show the relationship of two approximately equivalent. From experimental analysis, $e'=0.006°$ is very appropriate.

4. EXPERIMENT RESULTS & ANALYSIS

The prime objective of this thesis work is to develop an integrated finger vein based authentication system which is should be robust and state of art technology in the field of biometric based personal identification system. The proposed methods should be in line with objective of this thesis work to overcome the following criteria:

(a) Time complexity

(b) Minimize the occurrence of spurious minutiae

(c) Reduce the ratio of missing minutiae.

This chapter is developed based on the experimental analysis with reference to process and algorithm mentioned in earlier Chapters to analyse the performance of the proposed methods and its improvements as compared to earlier methods and technique based on simulation process using test databases and modern computer systems.

The proposed algorithms are coded using the software MATLAB for implementation using the latest version of present generation computer having Intel processor with 4 GB of RAM. The input images and reference database are stored in the local hard disk of the computer for effective processing and quicker response. The detailed description of the data base used for experimentation analysis is briefly explained in subsequent paragraphs. In this thesis work, experiments were conducted for the proposed method and results derived are suitably tabulated plotted for easy understanding. In this thesis work three experiments are designed to evaluate the proposed methods:

(a) Performance Comparison for computation time

(b) Performance comparison on Image quality assessment and

(c) Experimental EER of Each Hierarchical Verifications in Public Datasets

4.1 The Experimental Database

The finger vein based recognition system has achieved remarkable achievements in the last decade due to its own advantages and merits.

Deep Learning process data in two main phases are training and inferring. Training phase as a process of labelling large amounts of data, which determining their matching characteristics like intersecting vein crossing points, inner characteristics points and inner structure. Training process includes extracting numerical values of sub image and classifying data according to the similarity for labelling it. During the inferring phase, the deep learning makes conclusion and new labelling the unexposed data using their previous knowledge. While matching input image with database image the similarity measure (SSIM, M-SSIM, PSNR, H-PSNR) was analysed. For positive input pattern of RROI-Deep learning has achieved 0.903 maximum similarity while comparing with adaptive fast for MMCBNU_6000 database. For negative input pattern of RROI-Deep learning has achieved 0.165 minimum similarity while comparing with adaptive fast and same kind of outcome achieved for FV-USM database.

The Error Equal Rate (ERR) is evaluated based on the performance index of the images considered for experimental analysis. ERR is determined with reference to the values of False Acceptance Rate (FAR) which should be equal to False Rejection Rate (FRR). FAR is defined as the error rate obtained while testing of the samples and matching to the other classes. FRR is defined as the error rate obtained while testing of the samples and mismatching to the other corresponding class. Based on the registered finger vein pattern and different finger vein patterns, the FAR and FRR are measured respectively. The EER value obtained based on the image quality assessment configuration are tabulated in the below table based on the experiments carried out using FV-USM database for the values of SSIM, PSNR and HPSNR.

Methods	**SSIM**	**MS-SIM**	**MS-SSIM**	**PSNR**	**H-PSNR**	**Avg. Time (ms)**
Adaptive Fast **(FV-USM Database)**	0.157%	0.245%	0.135%	0.143%	0.130%	36
RROI-Deep Learning **(FV-USM & MMUBNU Database)**	0.128%	0.124%	0.160%	0.260%	0.122%	22

Table 1: Experimental EER of each Hierarchical verification FV-USM and MMUBNU database

Based on above result, it shows that for single database (FV-USM) to execute adaptive fast method taking 36 ms to matching input with finger vein image with database. In RROI-deep learning performs matching process within 22ms for combined database images. The large data volumes are the more efficient this process is called deep process, because with the time passing, it covers a growing number of levels. The deeper this process penetrates, the higher its productivity is. Deep learning proved to determine the most important features allows deep learning to efficiently provide deep analysis of data with concise and reliable analysis results.

5. CONCLUSION

In the recent era person identification which is based on finger vein details is evolving biometric technology. This system is significantly focused in the field of biometric based recognition systems. ROI based finger vein authentication system as proposed in this work will have high robustness as compared to old traditional methods. With the consideration of experimental results, it can be proved that ROI based authentication method will be one among the best in terms of recognition accuracy. However, in terms considering the processing time, we can conclude that the application of binarization scheme will be the better choice. For the future research work we propose to consider, an alignment method based on a guided software program, which can help to use the binary patterns in the identification process.

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