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An Efficient Approach for Fingerprint Identification through Finger Images

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Abstract: *Vein pattern is the network of blood vessels beneath a person's skin. This vein pattern can be used to authenticate the identity of an individual. In the ubiquitous network society, where individuals can easily access their information anytime and anywhere, people are also faced with the risk that others can easily access the same information anytime and anywhere. Because of this risk, personal identification technology, which can distinguish between registered legitimate users and imposters, is now generating interest. Currently, passwords, Personal Identification cards are used for personal identification. However, cards can be stolen, and passwords and numbers can be guessed or forgotten. To solve these problems, biometric authentication technology, which identifies people by their unique biological information, is attracting attention. Finger vein recognition is that it is not affected by dryness or roughness of skin or by physical injury on surface of the hand but sometimes the temperature and humidity can affect the quality of the captured image. We will be using MATLAB software for our proposed work.*

Keywords: *Feature Extraction, Finger Vein Recognition System, Median Filter*

1. INTRODUCTION

Biometrics is the unique features of a person. Biometric recognition refers to an automatic recognition of individual based on feature vectors derived from their physiological and/or behavioral characteristic. Biometric systems for human identification at a distance have ever been an increasing demand in various significant applications. Smart recognition of human identity for security and control is a global issue of concern in our world today. Financial losses due to identity theft can be severe, and the integrity of security systems compromised. Hence, automatic authentication systems for control have found application in criminal identification, autonomous vending and automated banking among others. Among the many authentication systems that have been proposed and implemented, finger vein biometrics is emerging as the foolproof method of automated personal identification. Finger vein is a unique physiological biometric for identifying individuals based on the physical characteristics and attributes of the vein patterns in the human finger. It is a fairly recent technological advance in the field of biometrics that is being applied to different fields such as medical, financial, law enforcement facilities and other applications where high levels of security or privacy is very important. This technology is impressive because it requires only small, relatively cheap single-chip design, and has a very fast identification process that is contact-less and of higher accuracy when compared with other identification biometrics like fingerprint, iris, facial and others. This higher accuracy rate of finger vein is not unconnected with the fact that finger vein patterns are virtually impossible to forge thus it has become one of the fastest growing new biometric technology that is quickly finding its way from research labs to commercial development.

Biometric techniques can generally be classified into two main categories: Physiologica1 and Behavioral. Physiological techniques include fingerprint recognition, retinal and iris scanning, facial recognition, hand and finger geometry and DNA analysis. Behavioral techniques include handwriting recognition, voice authentication, gait, and keystroke dynamics just to name a few [3]. There are mainly far infrared scanning technology and near infrared scanning technology and there are thermal hand vein pattern verification systems for security evaluation of biometric systems. Today, this technology plays a major role in providing authentication. Main advantage of Finger vein recognition is that it is not affected by dryness or roughness of skin or by physical injury on surface of the hand but sometimes the temperature and humidity can affect the quality of the captured image. Even though is little bit expensive it is highly adaptable as it is highly secure because blood vessels are hidden within the body. And also in this there is no physical contact between the user and system but it causes apprehension. Finger vein pattern recognition is a convenient and easy to use biometric technology with high security and accuracy level. There are mainly far infrared scanning technology and near infrared scanning technology and there are thermal hand vein pattern verification systems for security evaluation of biometric systems. Today, this technology plays a major role in providing authentication. Finger vein biometric system can verify a person's identity by recognizing the pattern of blood veins in the Finger. Finger vein authentication [4] uses the vascular patterns of an individual's Finger as personal identification data. Like fingerprints, the pattern of blood veins in the Finger is unique to every individual, even twins have different patterns and apart from size, this pattern will not vary over the course of a person's lifetime

2. METHODOLOGY

In this project, the finger images obtained from the database are separated into finger vein and finger texture images. These two images are processed separately as per the concept represented in paper. The process involved is image preprocessing, image enhancement, feature extraction and matching. For feature extraction we have use Gabor filter and for matching we implement score level combination as holistic and nonlinear fusion. This system has taken more advantage than the existing system in term of security purpose because since the vein pattern is not visible to human vision without any special device and it will not produce any trace in any object.

2.1 Fingerprint Enhancement Techniques

2.1.1 BINARIZATION

Binarization is a method of transforming grayscale image pixels into either black or white pixels by selecting a threshold. The process can be fulfilled using a multitude of techniques. Binarization is relatively easy to achieve compared with other image processing techniques. A binary image is a digital image that has only two possible values for each pixel. Typically the two colors used for a binary image are black and white though any two colors can be used. The color used for the object(s) in the image is the foreground color while the rest of the image is the background color. In the document scanning industry this is often referred to as bi-tonal. Binary images are also called bi-level or two-level. This means that each pixel is stored as a single bit (0 or 1). The names black-and-white, B&W, monochrome or monochromatic are often used for this concept, but may also designate any images that have only one sample per pixel, such as grayscale images. In Photoshop parlance, a binary image is the same as an image in "Bitmap" mode. Binary images often arise in digital image processing as masks or as the result of certain operations such as segmentation, Thresholding, and dithering. Some input/output devices, such as laser printers, fax machines, and bi-level computer displays, can only handle bi-level images.

A binary image can be stored in memory as a bitmap, a packed array of bits. A 640×480 image requires 37.5 KB of storage. Because of the small size of the image files, fax machine and document management solutions usually use this format. Most binary images also compress well with simple run-length compression schemes. Binary images can be interpreted as subsets of the two-dimensional integer lattice. Binary images are produced from color images by segmentation. Segmentation is the process of assigning each pixel in the source image to two or more classes. If there are more than two classes then the usual result is several binary images. The simplest form of segmentation is probably Otsu Thresholding which assigns pixels to foreground or background based on grayscale intensity. Another method is the watershed algorithm. Edge detection also often creates binary image with some pixels assigned to edge pixels, and is also a first step in further segmentation.

Otsu's Thresholding method involves iterating through all the possible threshold values and calculating a measure of spread for the pixel levels each side of the threshold, i.e. the pixels that either falls in foreground or background. The aim is to find the threshold value where the sum of foreground and background spreads is at its minimum.

Otsu's Method:

a. separate the pixels into two clusters according to the threshold
b. find the mean of each cluster
c. square the difference between the means

d. multiply by the number of pixels in one cluster times the number in the other
e. compute histogram and probabilities of each intensity level
f. set up initial $q_i(0)$ and $\mu_i(0)$
g. step through all possible threshold maximum intensity
h. update q_i and μ_i
i. compute $\sigma_b^2(t)$
j. desired threshold corresponds to the maximum

2.1.2 GLOBAL THRESHOLD

The first technique considered focused on finding the global threshold. The main black and white pixel values of each image are determined. The pixel range in between these pixel values is used to separate the black and white colors. Global binarization involves the formulation of a histogram consisting of the number of pixels versus the pixel value.

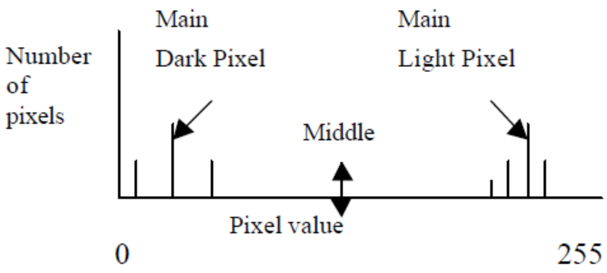


Fig 1. *Histogram for the Calculation of Most Numerous Light and Dark Pixel Values*

The two major peaks will be found, assumed to be the most commonly used dark pixel and the most common light pixel. The middle rage pixel will then be used to discriminate between black and white pixels for binarization. Complications may arise if there is more than one main pixel value or the contrast of the image is poor.

Normalization is used to standardize the intensity values in an image by adjusting the range of grey-level values so that it lies within a desired range of values.

The mean and variance of a gray level fingerprint image I are:

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

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

Let *N*(*i*; *j*) represent the normalized grey-level value at pixel (*i*, *j*). The normalized image is defined as

$$N(i,j) = \begin{cases} M_0 + \sqrt{\frac{VAR_0(I(i,j)-M(I))^2}{VAR}} & if\ I(i,j)>\text{M} \\ M_0 - \sqrt{\frac{VAR_0(I(i,j)-M(I))^2}{VAR}} & \text{otherwise} \end{cases}$$

where M_0 and VAR_0 are the desired mean and variance respectively. Normalization is pixel-wise operation. It does not change the clarity of the ridge and furrow structures.

The main purpose of normalization is

1) To have images with similar characteristics
2) To remove the effect of the sensor noise.

3) To reduce the variation in gray level values along ridges and valleys.

2.1.3 ADAPTIVE THRESHOLD BINARIZATION

Another method that will be experimented with is called contrast enhancement binarization. The method involves passing a low pass filter over the image and using the resulting grayscale pixel number to discriminate between a black or white pixel. The low pass filter does not process edges, one pixel wide in the image.

Low-pass filtering involves a spatial convolution process within a window. These windows can be quite large. The window size that will be used will be 3 pixels by 3 pixels wide.

-1 -1 -1
-1 8 -1
-1 -1 -1

The convolution matrix used for low-pass filtering

The matrix will be moved along the image, producing a new image. For instance, the first pixel to be processed will be at coordinate [2,2]. Each pixel will be multiplied with the corresponding mask. So coordinate [2,2] will be multiplied by 8. The surrounding coordinates will be multiplied by –1. The process is repeated on the entire image, row by row until a new, binarized image is formed.

Adaptive Thresholding typically takes a grayscale or color image as input and, in the simplest implementation, outputs a binary image representing the segmentation. For each pixel in the image, a threshold has to be calculated. If the pixel value is below the threshold it is set to the background value, otherwise it assumes the foreground value.

There are two main approaches to finding the threshold: (i) the *Chow and Kaneko* approach and (ii) *local* Thresholding. The assumption behind both methods is that smaller image regions are more likely to have approximately uniform illumination, thus being more suitable for Thresholding. Chow and Kaneko divide an image into an array of overlapping sub images and then find the optimum threshold for each sub image by investigating its histogram. The threshold for each single pixel is found by interpolating the results of the sub images. The drawback of this method is that it is computational expensive and, therefore, is not appropriate for real-time applications.

An alternative approach to finding the local threshold is to statistically examine the intensity values of the local neighborhood of each pixel. The statistic which is most appropriate depends largely on the input image. Simple and fast functions include the *mean* of the *local* intensity distribution,

$$T = mean$$

the *median* value,

$$T = median$$

or the mean of the minimum and maximum values,

$$T = \frac{max + min}{2}$$

The size of the neighborhood has to be large enough to cover sufficient foreground and background pixels, otherwise a poor threshold is chosen. On the other hand, choosing regions which are too large can violate the assumption of approximately uniform illumination. This method is less computationally intensive than the Chow and Kaneko approach and produces good results for some applications.

2.1.3 MEDIAN FILTERING

Median filters calculate the average of pixel values in a pre-specified window size. The central pixel is then assigned that value.

For a window size of 3x3, the central pixel would have the value

$$\sum_{i=1}^{9}(pi)/9$$

Median filters result in areas of small features (usually smudges) being removed whilst areas of larger shapes will remain untouched by the filtering action. Several repetitions of a median filter over an image will remove all small, isolated noise spikes.

The Median Filter is performed by taking the magnitude of all of the vectors within a mask and sorted according to the magnitudes. The pixel with the median magnitude is then used to replace the pixel studied.

The Simple Median Filter has an advantage over the Mean filter since median of the data is taken instead of the mean of an image. The pixel with the median magnitude is then used to replace the pixel studied. The median of a set is more robust with respect to the presence of noise. The median filter is given by

Median filter(x1…xN)=Median(||x1||2……||xN||2)

Median Filters can be very useful for removing noise from images. A median filter is like an averaging filter in some ways. The averaging filter examines the pixel in question and its neighbor's pixel values and returns the mean of these pixel values. The median filter looks at this same neighborhood of pixels, but returns the median value. In this way noise can be removed, but edges are not blurred as much, since the median filter is better at ignoring large discrepancies in pixel values.

The algorithm for the median filter is as follows:

Step 1: Select a two dimensional window W of size 3×3.Assume that the pixel being processed is Cx,y**.**

Step 2: Compute **-** Wmed the median of the pixel values in the window W.

Step 3: Replace Cx,y by Wmed.

Step 4: Repeat Steps 1 to 3 until all the pixels in the entire image are processed.

Advantage:

1. Easy to implement.

2. Good in denoising different types of noises.

2.1.4 THINNING

The aim of thinning is to reduce the fingerprint to lines one pixel wide. Thinning is a morphological operation performed on binary images. This is achieved by successive deletions of pixels from different sides of each image. Each of the four sides are eroded away according to some set template. Eventually, the image being thinned will no longer possess any points which match the deletion templates. This remaining image will be the thinned representation of the original image.

If the image template matches, the middle pixel is removed. Once all eight matrices have been sampled on the entire image, the process is repeated on the newly formed Image. Processing only stops when no more points can be deleted.

Four point thinning algorithms are also available, these algorithms have only one template for each position. The resulting thinned image isn't as refined as the eight matrices algorithms because it places fewer criterions on the image. The result usually possesses more spur points. For this reason, four matrices processing will not be implemented.

3. MODULES

Module 1. Finger Vein Identification

Image preprocessing:

Finger images are noisy with rotational and translational variations. To remove these variations, it is subjected to preprocessing steps.

1. Image normalization
2. ROI extractor
3. Image enhancement

Image normalization:

Normalization is a process that changes the range of pixel intensity values. In this, the image is subjected to binarization with threshold value of 230. Sobel edge detector is applied to the image to the remove background portions connected to it. Eliminating the number of connected white pixels being less than a threshold, to obtain the binary mask. Binarization is a method of transforming grayscale image pixels into either black or white pixels by selecting a threshold. The process can be fulfilled using a multitude of techniques. Binarization is relatively easy to achieve compared with other image processing techniques. Fingerprint Image Binarization is to transform the 8-bit Gray fingerprint image to a 1- bit image with 0-value for ridges and 1-value for furrows. After the operation, ridges in the fingerprint are highlighted with black color while furrows are white. A locally adaptive binarization method is performed to binarize the fingerprint image.

ROI extractor:

In the finger images, there are many unwanted regions (that cannot be taken for analysis) has been removed by choosing the interested area in that image. The useful area is said to be "Region of Interest".

The obtained binary mask is used to segment the ROI (Region of Interest) from the original finger-vein image. The orientation of the image is determined to remove the low quality images that present in finger vein image. This orientation is used for the rotational alignment of the ROI in vein image.

Fingerprint Image Segmentation:

In general, only a Region of Interest (ROI) is useful to be recognized for each fingerprint image. The image area without effective ridges and furrows is first discarded since it only holds background information. Then the bound of the remaining effective area is sketched out since the minutia in the bound region is confusing with that spurious minutia that is generated when the ridges are out of the sensor. To extract the ROI, a two-step method is used. The first step is block direction estimation and direction variety check, while the second is intrigued from some Morphological methods.

- **Block direction estimation**

The direction for each block of the fingerprint image with W x W in size(W is 16 pixels by default)is estimated. The algorithm is:

I. The gradient values along x-direction (gx) and y-direction (gy) for each pixel of the block is calculated. Two Sobel filters are used to fulfill the task.

II. For each block, following formula is used to get the Least Square approximation of the block direction.

$$tg2\beta = 2 \sum\sum (g_x * g_y) / \sum\sum (g_x^2 - g_y^2)$$

for all the pixels in each block.

The formula is easy to understand by regarding gradient values along x-direction and y-direction as cosine value and sine value. So the tangent value of the block direction is estimated nearly the same as the way illustrated by the following formula.

$$tg2\theta = 2\sin\theta \cos\theta / (\cos^2\theta - \sin^2\theta)$$

After the estimation of each block direction, those blocks without significant information on ridges and furrows are discarded based on the following formulas:

$$E = \{2 \sum\sum (g_x * g_y) + \sum\sum (g_x^2 - g_y^2)\} / W*W*\sum\sum (g_x^2 + g_y^2)$$

For each block, if its certainty level E is below a threshold, then the block is regarded as a background block.

- **ROI extraction by Morphological operations**

Two Morphological operations called 'OPEN' and 'CLOSE' are adopted. The 'OPEN' operation can expand images and remove peaks introduced by background noise. The 'CLOSE' operation can shrink images and eliminate small cavities. The bound is the subtraction of the closed area from the opened area. Then the algorithm throws away those leftmost, rightmost, uppermost and bottommost blocks out of the bound so as to get the tightly bounded region just containing the bound and inner area.

Image enhancement:

The acquired image is thin and it is not clear. So the image is enhanced by using bicubic interpolation for better visualization.

Fingerprint Image enhancement is to make the image clearer for easy further operations. Since the fingerprint images acquired from sensors or other Medias are not assured with perfect quality, those enhancement methods, for increasing the contrast between ridges and furrows and for connecting the false broken points of ridges due to insufficient amount of ink, are very useful for keep a higher accuracy to fingerprint recognition. The Method adopted in fingerprint recognition system is Histogram Equalization

Histogram equalization is to expand the pixel value distribution of an image so as to increase the perceptional information. The original histogram of a fingerprint image has the bimodal type. The histogram after the histogram equalization occupies all the range from 0 to 255 and the visualization effect is enhanced.

Module 2. Finger Texture Image Preprocessing

- Localization and Normalization
- Image Enhancement

Localization and Normalization:

In texture preprocessing, Sobel edge detector is used to obtain the edge map and localize the finger boundaries. This edge map is isolated with noise and it can be removed from the area threshold. Such noise is eliminated from the area Thresholding, i.e., if the number of consecutive connected pixels is less than the threshold. The slope of the resulting upper finger boundary is then estimated.

This slope is used to automatically localize a fixed rectangular area, which begins at a distance of 20 pixels from the upper finger boundary and is aligned along its estimated slope. We extract a fixed 400 160 pixel area, at a distance of 85 and 50 pixels, respectively, from the lower and right boundaries, from this rectangular region. This 400 160 pixel image is then used as the finger texture image for the identification.

Image Enhancement:

In image enhancement, finger texture image is subjected to median filtering to eliminate the impulsive noise. The resulting images have low contrast and uneven illumination. Therefore obtain the background illumination image from the average of pixels in 10×10 pixel image subblocks and bicubic interpolation. The resulting image is subtracted from the median-filtered finger texture image and then subjected to histogram equalization.

Finger Vein and Texture Image Feature Extraction

Gabor filter is used for finger vein and texture image feature extraction. Gabor filters optimally capture both local orientation and frequency information from a fingerprint image. By tuning a Gabor filter to specific frequency and direction, the local frequency and orientation information can be obtained.

We have creating the Gabor with specified orientations and these Gabor filter is convolved with the enhanced image to remove the unwanted regions other than the vein and texture regions.

In vein images, the extracted vein images are further processed into morphological top-hat operation for obtaining the clear vein patterns.

Module3. Finger Vein and Texture Matching

The general block diagram for matching is given below

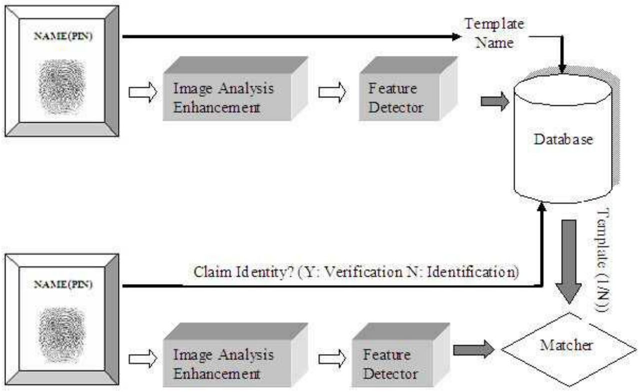


Fig 2. *Block Diagram for Matching*

In that, the matcher block predicts that the vein and texture image is matched with the database. The database contains the features of all vein and texture images.

For matching, two steps has been done

i. Extract features
ii. Match features

These two steps are done by using matlab in built commands.

Vein regions extracted from the image are stored in database.

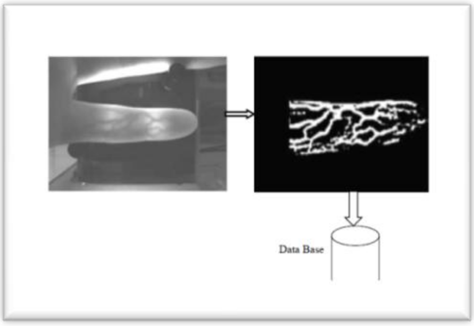


Fig 3. *Database*

Vein matching:

The features extracted from finger vein images are already stored in a database. The features of the input image are matched with all the extracted veins in the database to check whether the input image is matched with any one of the extracted veins.

I. If the input image is matched with any one of the extracted veins, the message box will be opened and display “vein matched”.
II. If the input image is not matched with any one of the extracted veins, the message box will be opened and display “vein not matched”.

Texture matching:

The features extracted from finger texture images are stored in the same database. The features of the input image are matched with all the extracted texture in the database to check whether the input image is matched with any one of the extracted textures.

III. If the input image is matched with any one of the extracted textures, the message box will be opened and display “texture matched”.

IV. If the input image is not matched with any one of the extracted textures, the message box will be opened and display “texture not matched”.

Module 4. Score Combination

In score level combination, two techniques are used.

a. Holistic fusion
b. Nonlinear fusion

These two techniques are used to combine the resultant finger vein and texture images. The result of this fusion is used to check whether the fingerprint is genuine or not.

Holistic Fusion:

This approach is developed and investigated to utilize the prior knowledge in the dynamic combination of matching scores. Let s_v , s_t and $\hat{s}$ represent the matching score from finger vein, finger texture, and combined score, respectively, and this holistic rule of score combination is given below:

$$\hat{s} = \{(s_v * \square) + (s_t * (1 - \square))\} + \frac{\{(s_v * \square) + (s_t * (1 - \square))\}}{(2 - s_v)}$$

The above equation can also be written as,

$$\hat{s} = \{(s_v * \square) + ((s_t * (1 - \square))\} * (1 + \frac{1}{2 - s_v}) .$$

By using this equation, the final combined scores have a similar trend as the score from vein matching, i.e., when the score from finger-vein matching is high, the fused score will also become high and vice versa. Factor □ is selected to reflect the reliability of each modality or matching score. We choose the matching score from finger vein as the controlling factor since the performance of finger-vein matching is more stable, as compared with that of the texture.

Nonlinear Fusion

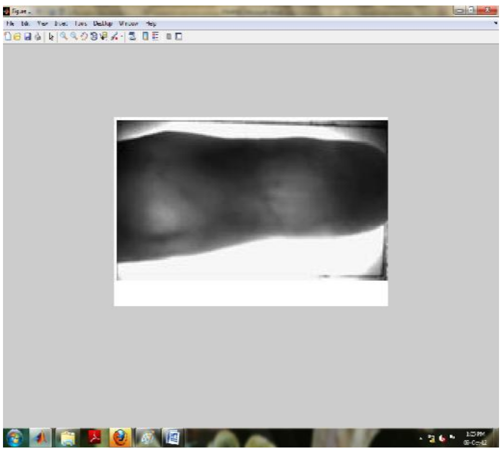
This nonlinear score combination attempts to dynamically adjust the combined score according to the degrees of consistency between the two matching scores and is illustrated as below:

$$\hat{s} = \left(\frac{c + s_t}{c + s_v}\right)^{\gamma} * (c + s_v)^2$$

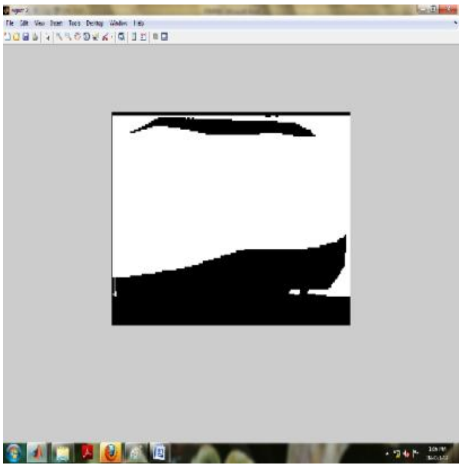
Where γ is a positive constant and is fixed to 1 in our experiments and is selected in the range of [1, 2]

4. Simulation Results

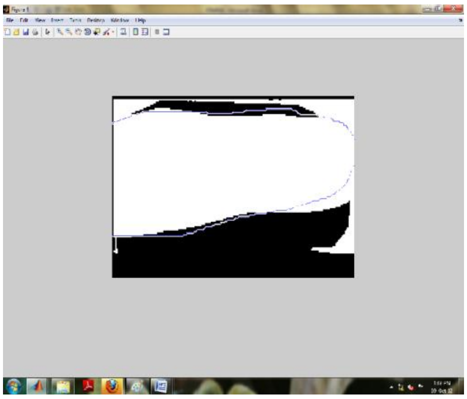
1. Input Image or Original Image



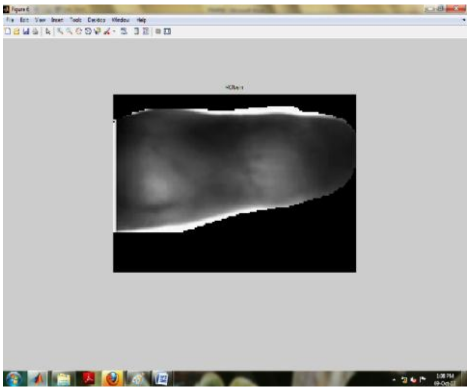
2. Binarised Image



3. Freehand Selection for Roi Extraction

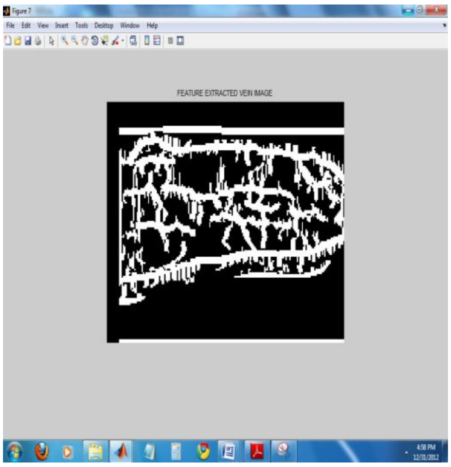


4. ROI

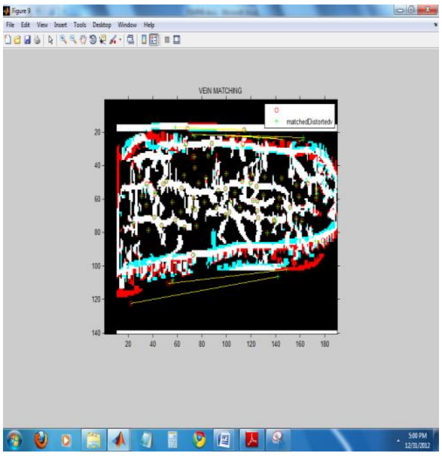


5. Enhanced Image

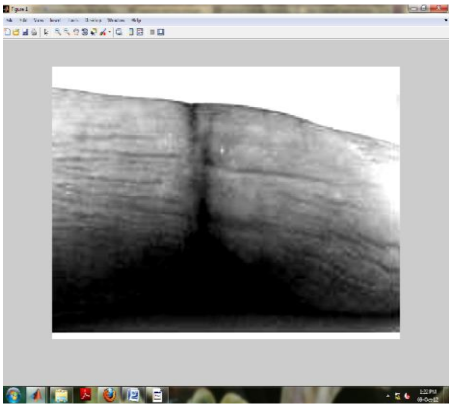
6. Feature Extracted Vein



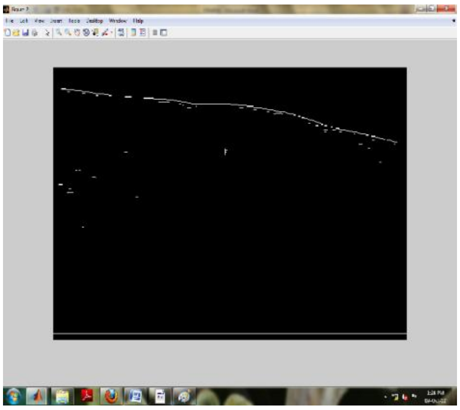
7. Vein Match



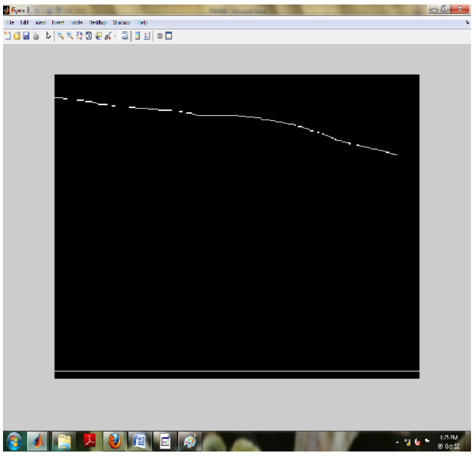
8. Texture Input Image



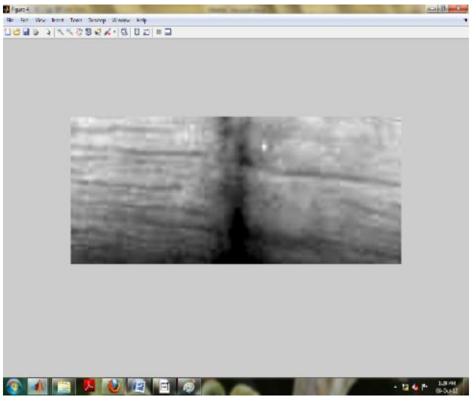
9. Edge Detection Using Sobel



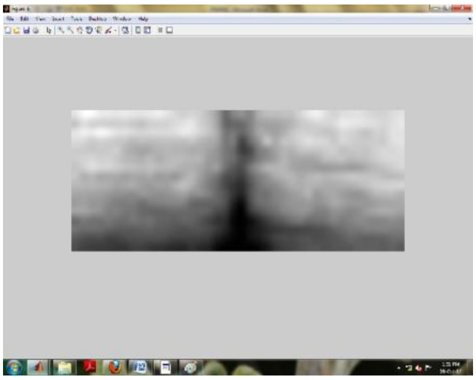
10. Image After Area Thresholding



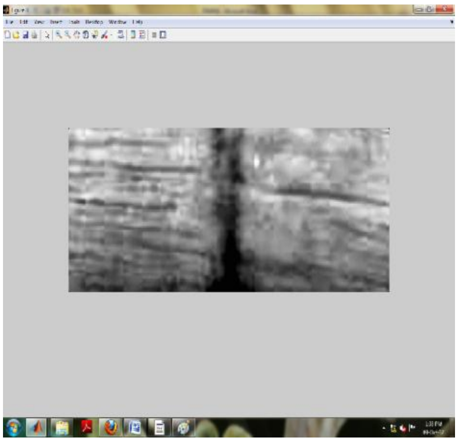
11. Segmented Texture Image



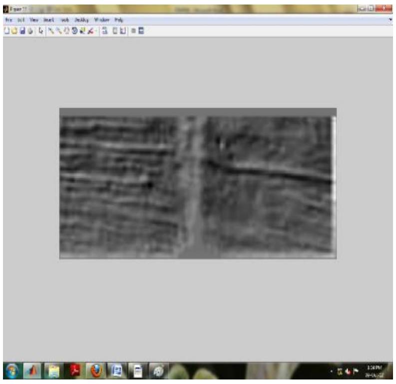
12. Median Filtered Image



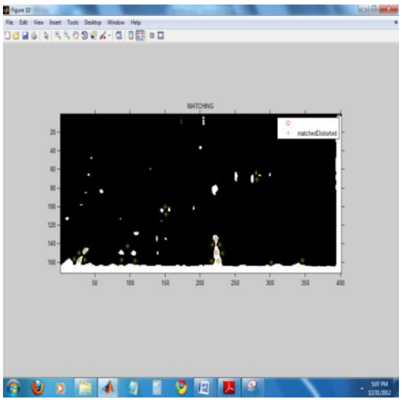
13. Enhanced Texture Image



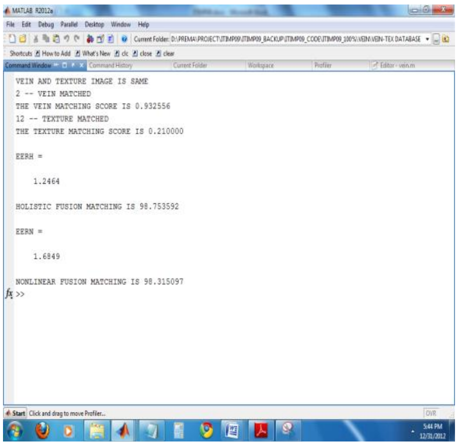
14. Feature Extracted Image



15. Texture Match



16. Matching Scores



5. Conclusion

We have presented a complete and fully automated finger image matching framework by simultaneously utilizing the finger surface and finger subsurface features. We presented a new algorithm for the finger-vein identification, which can more reliably extract the finger vein shape features and achieve much higher accuracy than previously proposed finger-vein identification approaches. Our finger-vein matching scheme works more effectively in more realistic scenarios and leads to a more accurate performance, as demonstrated from the experimental results.

In proposed and investigated two new score-level combination approaches, i.e., nonlinear and holistic, for effectively combining simultaneously generated finger-vein and finger texture matching scores. The nonlinear approach consistently performed better than other promising approaches, average, product, weighted sum, Dempster–Shafer, and likelihood-ratio approaches.We examined a complete and fully automated approach for the identification of low resolution finger surface texture images for the performance improvement. This investigation and they obtained results are significant as they point toward the utility of touch less images acquired from the webcam for personal identification and its extension for other utilities such as mobile phones, surveillance cameras, and laptops. Finally, the availability of the acquired database from this paper for the benchmarking/comparison will help further the research efforts in this area. Currently, there is no publicly available database for the performance comparison and research efforts on finger-vein identification.

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