Advances In Multidisciplinary & Scientific Research
AIMS Research Journal
A Multidisciplinary & Interdisciplinary Journal
Vol. 6 No. 1, March, 2020

An Adoption of Minutiae-Based Feature Extraction Technique for a Finger Vein Recognition System.

[1]Oloyede, A.O., [2]Akinola, W.A., [3]Nwaocha Vivian .O, [4]Longe, O. & [5]Ugwoke F.N.,
[1]Department of Computer Science Caleb, University, Imota Lagos, Nigeria.
[2]Department of Data Science, iubh University of Applied Sciences, Germany
[3]Department of Computer Science, National Open University of Nigeria, (NOUN) Abuja, Nigeria.
[4]School of IT & Computing, American University of Nigeria, Yola, Nigeria
[5]Department of Computer Sciences, Michael Okpara University of Agriculture,
Umudike Abia State, Nigeria.
Corresponding Author Email: ayglo55@yahoo.com
Phone: +2348033937115

ABSTRACT

Finger vein recognition system is a biometric recognition system that uses the features of the vein to identify or verify a user. The Vein is a subcutaneous element of the skin with its distinct feature reliable enough to identify a user. A standard finger vein reignition system requires a reliable device to take the image of the vein, pre-process the image for feature extraction with the capability to use the extracted feature for identification or verification. Apart from having a good quality of the vein, effective feature extraction is key to the efficiency of the finger vein recognition system.

Keywords: Finger vein recognition system. Vein feature extraction, False Rejection Rate, Security Image Enhancement.

Aims Research Journal Reference Format:
Oloyede, A. O., Akinola, W.A., Nwaocha Vivian. O , Longe, O. &Ugwoke F.N., (2020): An Adoption of Minutiae-Based Feature Extraction Technique for a Finger Vein Recognition System.. Advances in Multidisciplinary Research Journal. Vol. 6. No. 1, Pp 47–58. Article DOI: dx.doi.org/10.22624/AIMS/V6N1P4

1. INTRODUCTION

Finger vein recognition system (FRS) uses feature of the vein to identify or verify a user. The feature of the vein is unique to specific user, located beneath the skin surface. It is difficult to forge, not affected by race, age and dermal related issues [6]. The vein image is captured when a near infrared rays of between 700nm to 1000nm passes through the skin tissues. It can only be used on a life body [3]. The Deoxygenated blood in the vein absorbs the ray of light making the vein to appear darker than other parts of the skin. (FRS) has a false acceptance rate (FAR) of as low as 0.0001 % and false reject rate (FRR) of 0.1% [9]. Generally, finger vein recognition system comprises of 3 stages: Vein image capturing. Pre-processing of the vein image, feature extraction and matching for decision making. However, improvement in combination use of various image processing algorithms could alter the sequence of the stages [3][4]. For example, Xie et al. was able to extract the vein pattern directly from the vein image for recognition without going through the segmentation stage [6]. Segmentation and enhancement are principal functions in pre-processing stage [3].

Also, 2D Gabor filter was also used directly on vein image to extract directional texture and phase feature use in recognition from finger vein image. [5] Feature extraction is a very important stage whose outcome largely defines the effectiveness and efficiency of an FRS [3]. There are various ways vain feature can be extracted for individual identification [3], these various methods can be grouped into 4 different techniques [3]:

i. Vein-based: Vein-based feature extraction techniques basically, look out for the specific vein pattern for extraction. The vein vessel has an oriented pattern [3], local orientation and frequency of the vein are some of the distinguished features of the vein [7].
ii. Local Binary-based Method. It is implemented by comparing the grey value of a central pixel with its neighbouring pixels to produce ordered set of binary values which can be represented in decimal form [3].
iii. Dimensionality Reduction-Based Method: It is a machine learning based approach, vein image. In dimensionality reduction-based method, finger vein image is changed to low dimensional space through dimension reduction transformed into a low dimensional space by dimension reduction, in which the required information is kept and spurious data are discarded. [8]
iv. Minutiae Point-Based Method. Minutiae points refer to points where the vein pattern ends and bifurcates. Mantrao et al. [9] and Prabhakar et al. [10] based their vein feature extractions on where blood vessel ends and bifurcate, improved FRS performance and precision were recorded.

The following section describes the design algorithm. Section 2 describes pre-processing stages, Section 3 gives details on feature extraction based on minutiae feature of the vein image while the section gives the conclusive view of the work.

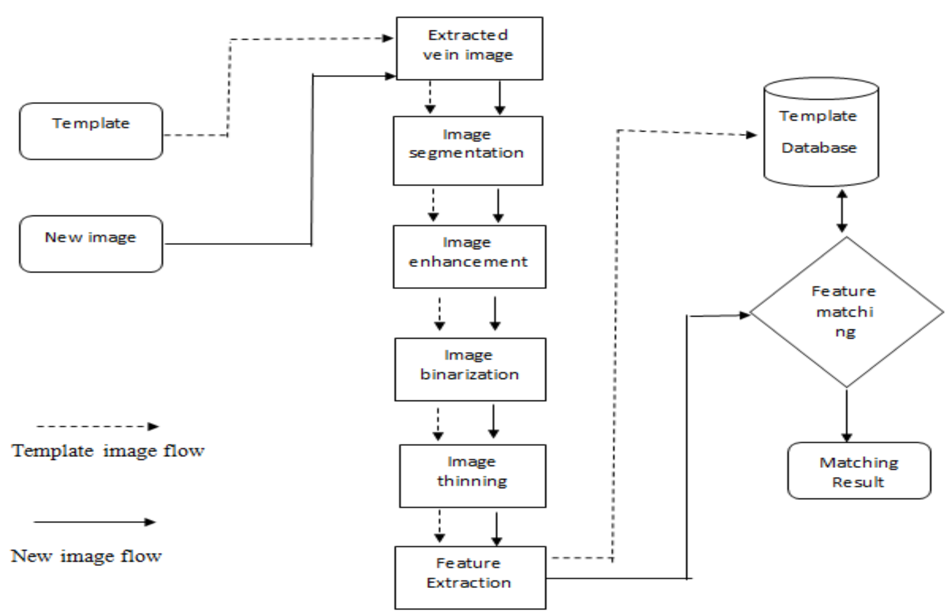

Figure 1: Design algorithm flow

1.1 Image Acquisition

The acquisition of the finger vein image is a critical step in biometric identification system because the system's quality, depend largely on the quality of the image to be processed. The finger vein image is acquired through a method that uses near infrared light to reflect the image of the vein beneath the epidermis [3]. The Deoxygenated blood in the vein absorbs the ray of light making the vein to appear darker than other parts of the skin [12]. There are three methods of image acquisition used in FRS: The light transmission, light reflection and two-way radiating methods. Among the three, the light transmission produced the high contrast image and most widely implemented [11]. A good image-acquiring device is very important; the product of the image acquisition process has direct impact on the quality of the features to be extracted during image processing [2]. An Image of Finger Vein Scanner is shown below.

Figure 2: Image of finger vein scanner

2. IMAGE PRE-PROCESSING

Basically, this stage comprises of 2 processes: Segmentation and enhancement. there are 2 types of image processing: Image filtering and image warping [13]. Filtering requires that the values of pixels are change while their positions remain unchanged, whereas, warping an image changes the position of the image while the colour of the pixel remain unchanged. (image). The primary goals of filters are to modify or enhance properties of an image and to extract needed information from the image such as edges blobs and corners [13]. Moving average filters and image segmentation filters are commonly used. Basically, the moving average filter works by replacing each pixel with the average pixel value of it and a neighbourhood window of adjacent pixels. Often use in smoothing image. Image segmentation filters on the other hand are used to divide image into regions based on the attributes of the pixel, making the image simpler in identifying objects and boundaries. One of the popular methods of implementing segmentation is thresholding. There are global and local thresholding. Global threshold uses single threshold across the image, while local threshold uses different threshold in different areas of the image having different illumination. Image segmentation is essentially used to extract region of interest (ROI) in finger vein image processing [3]. It is a common

2.1. Finger Vein Image segmentation

The next stage after the finger vein image has been acquired and fit is to extract region of interest (ROI) from the image in order to focus on only important part of the image. The work uses adaptive thresholding for segmenting the vein region from the background noise. Generally, adaptive or dynamic thresholding takes a grayscale (or colour) as input and converts it to a binary image which represents the segmented image [14]. Unlike global thresholding, for each pixel in the image, a threshold has to be calculated thereby making it suitable for image with uneven illumination across the image area. If the pixel value is below the threshold it is set to the background value, else it is set to foreground value [15].

$$T(x,y) = \frac{\sum_{i=0}^{N-1}\sum_{j=0}^{N-1} g(x+i, y+j)}{N^2}$$

T(x, y) is the threshold value of the threshold image in the position (x, y) related to the original image f(x, y), N is the window size, g is the gray value of the original image, using a 15 X 15 window size. Each pixel f(x,y) of the image is compared with the calculated threshold value T(x,y) where if , f(x,y) less than or equal to T(x,y) (set as background pixel) ,then f(x,y) = 0, else, f(x,y) = 255 (set as foreground pixel). 0 is black while 255 is white. Hence, the background and the foreground image is separated [1] .

2.2. Finger Vein image enhancement

The primary purposes of image enhancement are to provide clarity for structure of the finger vein image for better human understanding of the required data and to provide a quality image for the binarization stage [3]. The segmented image is not very clear or sufficient data for feature matching. At this stage there are lots of noises across the image. Median filtering is efficient in denoising and smoothing of edges and Connected Component Labelling (CCL) giving the image clarity along vein's original local connection of the vein structure. This will aid to provide clearer understanding of the vein's image for extraction as spurious vein image outside the connection path are removed [1,3]. Median filter works by considering each pixel in the image in turn and looks at its nearby neighbours to determine whether or not it is representative of its surroundings if not, it replaces the non-representative pixel value with the *median* of the neighbourhood values. For example:

Table of 3X3 neighbourhood

114	117	156	123	142
118	123	112	121	127
134	130	267	152	132
122	136	131	144	155
114	126	114	101	128

Neighbourhood values: 112, 121, 123, 130, 131, 136, 144, 152, 267
Median Value: 131.

Advances In Multidisciplinary & Scientific Research
AIMS Research Journal
A Multidisciplinary & Interdisciplinary Journal
Vol. 6 No. 1, March, 2020

After de-noising with median filtering, the next is to ensure that the remnant artefacts along the vein pattern are removed after the median filtering. CCL will be applied on the enhanced image. CCL works by scanning all pixels one after the other (top to bottom and left to right) identifying each pixel based on intensity of adjacent pixels. Basically, it scans image by grouping its pixels into component based on pixel connectivity. CCL can work on Binary image or grey-level image with different numbers of connectivity possible. In this case, regions of adjacent pixels which share the same set of intensity values *V*. (For a binary image *V={1}*; however, in a grey-level image *V* will take a range of values, say: *V={51, 52, 53, ..., 77, 78, 79, 80}*.)

The connected components labelling operator scans the image by moving along a row until it comes to a point *p* (where *p* denotes the pixel to be labelled at any point in the scanning process) for which *V={1}*. When this is true, it inspects the four neighbours of *p* which have already been scanned (*i.e.* the neighbours (i) to the left of *p*, (ii) above it, and (iii and iv) the two upper diagonal terms).

Based on this information, the labelling of *p* goes as follows:

i. If all four neighbours are 0, assign a new label to *p*, else
ii. if only one neighbour has *V={1}*, assign its label to *p*, else
iii. if more than one of the neighbours have *V={1}*, assign one of the labels to *p* and make a note of the equivalences.

When scan is completed, the equivalent label pairs are arranged into equivalence classes and a unique label is assigned to every class. Finally, a second scan is made through the image, during which each label is substituted by the label assigned to its equivalence classes.

2.3. Finger Vein image Binarization

Basically, the binarization converts the grey scale image to 0 or 1, black and white. The simple reason for this conversion is because, a simple black and white image is clearer and contains less noise compared to grey level image [16]. Otsu is better for grey scale image binarization than other algorithms for binarization [16]. The steps for Otsu binarization are as follow:

1. Separate the pixels into two clusters according to the threshold.

$$q1(t) = \sum_{i=1}^{t} p(i) \quad and \quad q2(t) = \sum_{i=t+1}^{I} p(i)$$

2. Find the mean of each cluster

$$1(t) = \sum_{j=1}^{t} \frac{ip(i)}{q1(t)} \; and$$

$$2(t) = \sum_{j=t+1}^{I} \frac{ip(i)}{q2(t)}$$

.

Advances In Multidisciplinary & Scientific Research
AIMS Research Journal
A Multidisciplinary & Interdisciplinary Journal
Vol. 6 No. 1, March, 2020

3. Calculate the individual class variance.

$$\sigma_1^2(t) = \sum_{i=1}^{t}[i - \quad 1(t)]^2 \frac{p(i)}{q1(t)}$$

and

$$\sigma_2^2(t) = \sum_{i=t+1}^{I}[i - \quad 2(t)]^2 \frac{p(i)}{q2(t)}$$

4. Square the difference between the means.

$$\sigma_b^2(t) = \sigma^2 - \sigma_w^2(t)$$

$$= q1(t)[1 - q1(t)] [\quad 1(t) - \quad 2(t)]^2$$

5. Finally, this expression can safely be maximized, and the solution is **t** that is Maximizing.
$\sigma_b^2(t)$ [16]

2.4. Finger vein image thinning (Skeletonization)

The next stage is to turn the image to 1 pixel-width based image. This is a process where the vein pattern is 1-pixel width size. Thinning is normally only applied to binary images and produces another binary image as output [17]. Like any other morphological operators, the behaviour of the thinning operation is determined by a structuring element. The thinning of an image *I* by a structuring element *J* is:

$$\text{thin}(I, J) = I - \text{hit-and-miss}(I, J)$$

where the subtraction is a *logical subtraction* defined by:

$$X - Y = X \cap \text{NOT}\, Y$$. [17]

The thinning operation is calculated by converting the origin of the structuring element to each possible position of the pixel in the image, and at each such position, comparing it with the pixels of the image underlying it. If the foreground and background pixels in the structuring element *exactly match* background and foreground pixels in the image, then the image pixel under the origin of the constructing element is set to background 0. Else it is left untouched. And the element must have a blank or 1 at the origin Note that the constructing element must always have a 1 or a blank at its origin for it to have any effect. [17]

Advances In Multidisciplinary & Scientific Research
AIMS Research Journal
A Multidisciplinary & Interdisciplinary Journal
Vol. 6 No. 1, March, 2020

3. FINGER VEIN FEATURE EXTRACTION

Thinning the binarized image would produce a simpler binary output image that can easily be processed to extract feature. The pixel-wise image can easily be scanned to determine vein ending and bifurcation points, pixel wise. Once pixels that fall on ending and branching points are identified, their x and y coordinates, orientation value and vein property (ending or bifurcation) are identified [18]. Once all the pixels of interest have been identified along with the associated parameters (distance and direction) then a crossing number approach would be used to extract the feature as explained below: 3*3 window to scan the local neighbourhoods of each ridge pixel '*p*' in the image. The crossing number of '*p*' is defined as half the sum of the differences between pairs of adjacent pixels defining the 8-neighborhood of '*p*'.[18] Mathematically:

$$CN = 0.5 \sum_{i=1}^{8} |P_i - P_{i+1}|,$$

where Pi is the pixel value (zero or one) in a 3 x 3 neighbourhood of P

3*3 Mask

N	Characteristcs
0	Isolated Point
1	End Point
2	Continuing Point
3	Branch Point
4	Crossing Point

Characteristics of crossing number

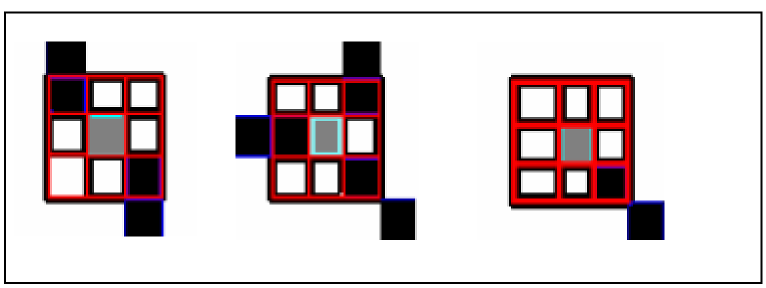

Figure 3 [Source: 18]

cn (p)=2,cn (p)=3 and cn (p)=1 representing a non-minutiae region, a bifurcation and a vein ending.

4 FINGER VEIN IMAGE MATCHING AND DECISION MAKING

The extracted and stored feature is matched with a stored template for identification.Minutiae based matching will be used. Minutiae based matching consists of finding the similarity between the stored template and the new input minutiae group that results in the maximum number of minutiae pairing. [19]

The algorithm compares two minutiae sets: template T = {m1, m2……….mj} from reference fingerprint and input I={m1, m2……….mi} from the query and returns similarity score S (T, I). The minutiae pair mi and mj are said to be matched only if difference in their position and directions are below tolerance distances:

$$sd\left(m_i, m_j\right) = 1 \Leftrightarrow \sqrt{\left(x_i - x_j\right)^2 + \left(y_i - y_j\right)^2} \le r_0$$

$$dd\left(m_i, m_j\right) = 1 \Leftrightarrow \min\left(\left|\theta_i - \theta_j\right|, 360 - \left|\theta_i - \theta_j\right|\right) < \theta_0$$

[19]

5 PERFORMANCE METRICS

Metrics for computing accuracy (acc) is giving below:

$$\textbf{Acc} = \left(100 - \frac{\left(FAR(\%) + FRR(\%)\right)}{2}\right)$$

Where $FAR = \dfrac{\sum_{i=1} W_{ai}}{\mathbf{t}} X100\%$

$$FRR = \frac{\sum_{i=1} W_{ri}}{\mathbf{t}} X100\%$$

W_a is the wrongly accepted individual

W_r is the wrongly rejected individual

$\mathbf{t}$ is total no. of users experimented with

[20]

6 RESULT

Finger vein templates of 40 volunteered members of staff of Evans therapeutics Ltd. With age range of 21 - 62 years having 10 females and 30 males. The vein image taken has an image size of 256 X 360 pixels. The finger vein image templates of the 20 users were stored in a database. New finger vein image of all the 20 users were taken to be matched against the templates for verification purpose. The remaining 20 users had no template stored in the database but were equally subjected to verification as given below:

User	Template	False rejection (FR)	False Acceptance (FA)	Accuracy
User1	1	-		
User2	1	-		
User3	1	-		
User4	1	-		
User5	1	-		
User6	1	-		
User7	1	-		
User8	1	-		
User9	1	-		
User10	1	-		
User11	1	-		
User12	1	1		
User13	1	-		
User14	1	-		
User15	1	-1		
User16	1	-		
User17	1	-		
User18	1	-		
User19	1	-		
User20	1	-		
User21	0		-	
User22	0		-	
User24	0		-	
User25	0		-	
User26	0		-	
User27	0		-	
User28	0		-	
User29	0		-	
User30	0		-	
User31	0		-	
User32	0		-	
User33	0		-	
User34	0		-	
User35	0		-	
User36	0		-	
User37	0		-	
User38	0		-	
User39	0		-	
User40	0		-	
		FRR = 2	FAR=0	99.75

7. EXPLANATION OF RESULT

User 1 to 20 had their templates stored in the database base for matching; user 21 to 40 had no templates in the database. Users 1 to 20 were subjected to verification by taking new finger vein image of the same finger taken during template registration. 2 out of the users were falsely rejected at single attempt. User 21 to 40 that had no previous template in the database was subjected to verification to test false acceptance capability of the device. None of the 20 users whose template was not in the database was successfully verified, hence false acceptance rate is nil. The system has an accuracy of 99.75 %. However, a large database may increase the likelihood of having false acceptance and a higher false rejection which may change the value of performance accuracy

8. CONCLUSION

The process to produce a high-performance finger vein recognition system starts from vein image acquisition stage. The pre-processing stage is equally important to any of the four techniques of feature extraction mentioned in this paper. However, image enhancement is sacrosanct to minutiae-based feature extraction before binarization and thinning of the image are done, this is because, image enhancement actually makes the image interpretable and gives decisive details about the vein properties such as ending and bifurcation points among others (a helpful function in dealing with oriented image pattern) as regard to vein properties, unlike in Vein-based feature extraction method where a high-quality image that gives enough pattern of the vein may only be required for feature matching, despite not going through the image segmentation.

REFERENCES

[1] Mulyono, David & Horng, Shi-Jinn. (2008). A study of finger vein biometric for personal identification. 1 - 8. 10.1109/ISBAST.2008.4547655. Retrieved From: https://www.researchgate.net/publication/4343630_A_study_of_finger_vein_biometric_for_personal_identification

[2] Kejun Wang, Hui Ma, Oluwatoyin P. Popoola and Jingyu Liu (2011). Finger vein recognition, Biometrics, Dr. Jucheng Yang (Ed.), ISBN: 978-953-307-618-8, InTech, Available from: http://www.intechopen.com/books/biometrics/finger-vein-recognition

[3] Kashif Shaheed. 2018. A systematic Review of Finger Vein Recognition Techniques. Retrieved from https://www.mdpi.com/2078-2489/9/9/213/pdf

[4] Sapkale, M.; Rajbhoj, S.M. A biometric authentication system based on finger vein recognition. In Proceedings of the 2016 International Conference on Inventive Computation Technologies (ICICT), Coimbatore, India, 26–27 August 2016; Volume 3, pp. 1–4.

[5] Wang, K.; Liu, J.; Oluwatoyin, P.P.; Feng, W. Finger vein identification based on 2-D gabor filter. In Proceedings of the 2010 2nd International Conference on Industrial Mechatronics and Automation (ICIMA), Wuhan, China, 30–31 May 2010; Volume 2, pp. 10–13.

[6] Xie, S.J.; Yang, J.C.; Yoon, S.; Yu, L.; Park, D.S. Guided Gabor filter for finger vein pattern extraction. In Proceedings of the 2012 Eighth International Conference on Signal Image Technology and Internet Based Systems (SITIS), Naples, Italy, 25–29 November 2012; pp. 118–123.

[7] Khellat-kihel, S.; Abrishambaf, R.; Cardoso, N.; Monteiro, J.; Benyettou, M. Finger vein recognition using Gabor filter and Support Vector Machine. In Proceedings of the Image Processing, Applications and Systems Conference (IPAS), Sfax, Tunisia, 5–7 November 2014; pp. 1–6.

[8] Liu, Z.; Yin, Y.;Wang, H.; Song, S.; Li, Q. Finger vein recognition with manifold learning. J. Netw. Comput. Appl. **2010**, 33, 275–282 https://www.sciencedirect.com/science/article/pii/S1084804509001428?via%3Dihub

[9] Mantrao, N.; Sukhpreet, K. An Efficient Minutiae Matching Method for Finger Vein Recognition. Int. J. Adv. Res. Comput. Sci. Softw. Eng. **2015**, 5, 657–660.

[10] Prabhakar, P.; Thomas, T. Finger vein identification based on minutiae feature extraction with spurious minutiae removal. In Proceedings of the 2013 Third International Conference on Advances in Computing and Communications (ICACC), Kerala, India, 29–31 August 2013; pp. 196–199.

[11] Yang, L.; Yang, G.; Yin, Y.; Zhou, L. A survey of finger vein recognition. In Proceedings of the Chinese Conference on Biometric Recognition, Shenzhen, China, 28–29 October 2014; Springer: Cham, Switzerland, 2014; pp. 234–243.

[12] The journal.ie. 2014. Here is why your veins look blue. https://www.thejournal.ie/why-are-veins-blue-1353954-Mar2014/

[13] Standford.edu. 2015. Introduction to computer Vision. Retrieved from: http://ai.stanford.edu/~syyeung/cvweb/tutorial1.html

[14] J. Bernsen, "Dynamic thresholding of gray level images," Proc. Intl. Conf. on Pattern Recognition,pp. 1251–1255, 1986.

[15] Fisher R., Perkins S., Walker A. Wolfart E. 2003. Adaptive Thresholding. https://homepages.inf.ed.ac.uk/rbf/HIPR2/adpthrsh.htm

[16] Puneet et al. 2013. Binarization Techniques used for Grey Scale Images. Retrieved from:https://www.researchgate.net/publication/271070053_Binarization_Techniques_used for_Grey_Scale_Images
[17] Fisher et all, 2003. Thinning. Available at: https://homepages.inf.ed.ac.uk/rbf/HIPR2/thin.htm
[18] Lukasz Wieclaw. 2014. A minutiae-based matching algorithms in fingerprint recognition systems.https://www.researchgate.net/publication/228644313_A_minutiae-based_matching_algorithms_in_fingerprint_recognition_systems