VEIN PATTERN EXTRACTION USING NEAR INFRARED IMAGING FOR BIOMETRIC PURPOSES

Thesis submitted in partial fulfilment of the requirements for the degree of

Bachelor of Technology

In

Electronics and Instrumentation Engineering

by

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Department of Electronics & Communication Engineering
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Dedicated

to

My teachers,
Family and Friends

Declaration

I hereby declare that this thesis is my own work and effort. Throughout this documentation wherever contributions of others are involved, every attempt is made to acknowledge this clearly with due reference to the literature. This thesis is being submitted for meeting the partial fulfilment for the degree of Bachelor of Technology in Electronics and Instrumentation Engineering, Department of Electronics and Communication Engineering at National Institute of Technology, Rourkela for the academic session 2011 – 2015.

Place: Rourkela **Abhisek Parida (111EI0616)**

Date:

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Certificate of Approval

This is to certify that the thesis entitled "**VEIN PATTERN EXTRACTION USING NEAR INFRARED IMAGING FOR BIOMETRIC PURPOSES**" submitted to the National Institute of Technology, Rourkela by **ABHISEK PARIDA, Roll No.- 111EI0616** for the award of the Degree of Bachelor of Technology in **Electronics and Instrumentation Engineering** is a record of bona fide research work carried out by him under my supervision and guidance. The results presented in this thesis have not been, to the best of my knowledge, submitted to any other University or Institute for the award of any degree or diploma. The thesis, in my opinion, has reached the standards fulfilling the requirement for the award of the degree of Bachelor of technology in accordance with regulations of the Institute.

....

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Associate Professor

Department of Electronics and Communication

National Institute of Technology, Rourkela

Date:

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The true spirit of achieving a goal is through the way of excellence and austere discipline. I would have never succeeded in completing the task without the cooperation, encouragement and help provided to me by various persons.

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I am also very much thankful to all my friends who have helped me to make the hardware connections and fix the errors occurred during writing the code.

At last, I would conclude with my deepest credit to my parents. My full dedication to the work would not have been possible without their blessings and moral support.

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ABSTRACT

Biomedical verification has been broadly examined for many years and pulled in much consideration because of its huge potential security application. Vein is less prone to damage and almost improbable to copy than any other physiological as well as behavioural biometric features such as fingerprint, iris, face and voice recognition. This paper proposes an efficient vein extraction method on low quality vein images taken by a camera absorbing near infrared light (NIR camera). At first, the image is contrast enhanced using contrast limited adaptive histogram equalization (CLAHE); secondly, local threshold method is applied on small blocks of the image followed by several morphological operations such as fill, erosion, dilation, clean and bridge, performed sequentially, for better accuracy. Experimental results obtained for extraction show that the proposed method can reap better results with reduced complexity.

After extraction, matching of the test image with the template images stored in the database are matched using minutiae (point-to-point pattern). An orientation detector which filters out missing or unnecessary or unnatural spurious minutiae pairings while simultaneously using path or ridge orientations to increase performance and similarity score calculation.

Thus the obtained processed images can be used in biometric purposes which in turn enhances the security of the system.

Keywords: Near Infrared (NIR) Imaging, Vein pattern extraction method, CLAHE, morphological operations

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1. INTRODUCTION

- ✓ OVERVIEW
- ✓ MOTIVATION
- ✓ PRINCIPLE
- ✓ OBJECTIVE
- ✓ THESIS ORGANISATION

1.1 OVERVIEW

Security in different fields has been a huge concern lately. Safety plays a major role in every industry such as

- Automobile industry – air bags, central locking system, automatic braking system, etc.
- Medical sector, industries, factories, safety locks and breakage safety in homes and electronic devices, etc.

With the advancement of modern technology and as connectivity and integration continues to spread across the globe, it is pass that old security techniques are essentially not sufficiently solid to secure what's generally imperative. With higher security solutions, biometric authentication techniques have attracted more attention. These techniques focus on how electrical equipment can measure physiological patient data and improve medical care.

There are various biometric identification techniques that utilises human physiological traits such as fingerprints, irises, DNA and face and hand-palm geometries, and behavioural features including typing algorithm, gait and voice characteristics. Owing to certain disadvantages of these techniques, mentioned below, apart from their merits, vein authentication methods have increased and gained popularity lately. Hand vein authentication and recognition technique has become the most favourite and novel biometric method since it requires a low-cost device, and provides stability, and elevated anti-theft.

APPLICATIONS OF BIOMETRICS:

- Locking Door Applications
- Financial Activities
- Immigration Control
- Voting Systems
- Attendance, etc

BIOMETRICS:

Biometrics refers to measurement systems related to human characteristics, behaviours and traits. Biometrics authentication is a type of identification or verification method that utilises physiological and behavioural features of human beings such as fingerprints, faces, irises, gaits and veins.

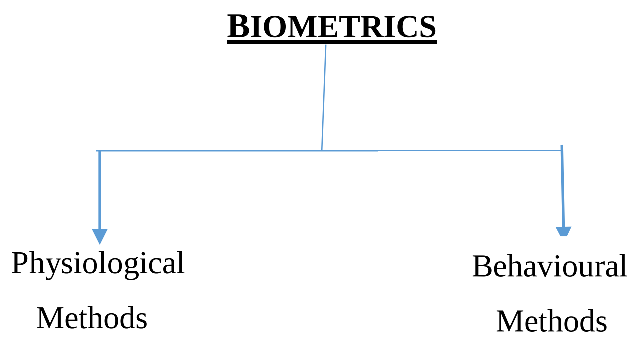


Figure 1: Classification of Biometrics

PHYSIOLOGICAL METHODS:

Related to the shape of the human body. The characteristics focused upon in these methods include

- Fingerprints
- DNA
- Hand-palm and face structures
- Irises

BEHAVIORAL METHODS:

Related to human behavior, including typing style, gait and voice features. Behavioral characteristics are also known as 'behaviometrics'.

1.2 MOTIVATION

DISADVANTAGES OF BIOMETRIC METHODS ELABORATED EARLIER:

- IRIS RECOGNITION
  Holding fake iris in front of the camera, patterned contact lens can cause the iris recognition system to register vague results by declaring unknown as authorised and vice-versa.

- FINGERPRINT RECOGNITION
  Moistures and scars on fingers as well as duplicity of fingerprints also reduces system accuracy.

- FACE RECOGNITION
  Faces are always exposed to external lighting; it is easy to deceive recognition system using mask or photograph. Aging effects, facial expressions also add to further setbacks.

- VOICE, GAIT RECOGNITION
  Added disturbing environment conditions makes the behavioural biometrics infeasible.

To overcome the problems of previous biometric systems, new system using vein pattern from fingers, palms and hands have been instituted lately which have more accuracy and high speed.

VEIN IDENTIFICATION ADVANTAGES:

- Unique Stability
- Anti-counterfeiting or anti-faking
- Low Device Requirement
- Low Cost
- High Accuracy

- High Speed

So because of the disadvantages of above methods and advantages of vein identification systems, a novel vein pattern extraction method using infrared imaging technique is proposed.

VEINS:

In the circulatory system, veins are the branching elastic blood vessels that serve to return deoxygenated blood from the tissues or various regions of the body back to the heart.

ADVANTAGES OF VEIN PATTERN THAN ARTERIES PATTERN EXTRACTION:

Veins are less muscular than arteries and are also present closer to the skin (surface). Thus its pattern can be easily made available and since they are present inside the skin, they are susceptible to less damage and are highly secure and cannot be duplicated unlike other biometric features.

FEATURES OF VEIN PATTERN:

1. Transports deoxygenated blood towards heart for oxygenation.
2. Inherent characteristics and pattern protected by skin.
3. Differs from person-to-person, even in twins.
4. Unique and universal.
5. Less prone to injury.
6. Identical pattern persists throughout lifetime.

INFRARED IMAGING:

- Near infrared imaging
- Far infrared imaging

DISADVANTAGES OF FIR IMAGING:

1. Images acquired have low level of contrast.
2. More sensitive to environment temperature and humidity.

ADVANTAGES OF NIR IMAGING (0.9-1.7 micrometers):-

1. NIR can pierce the biological tissues up to 0.003m of depth. So the vein pattern is obtained easily.
2. IR beam coming out from light source about 850nm avoids undesirable intrusion from the IR radiation (3µm – 14µm) emitted by the human body and the environment.

1.3 PRINCIPLE USED

At the point when a hand is presented to near infrared light (NIR), then the deoxidized haemoglobin present in the vein vessels assimilate light having a wavelength of about 760-1000nm within the near infrared wavelength region. When the image of the hand with infrared ray illumination is captured, only the pattern containing the reduced haemoglobin is visible as series of black lines, which is then contrast enhanced and extracted using various image processing algorithms.

1.4 OBJECTIVE

Our blueprint comprises of the utilisation of background removal to eliminate unnecessary surroundings in the image and then contrast enhancement of the image which increases the brightness of the low quality images and helps in reducing noise, followed by threshold method on small blocks of lesser pixels, formed by division of the enhanced image. Then morphology has been applied on the threshold output image, to get the extracted pattern image. Then the extracted image is converted to binary image (if not in binary image) and then reduced to 1-pixel thickness (morphological operation-skeleton is applied if not applied before during extraction). The image thus obtained is matched with the template images in the database using minutiae based matching, that is, point-pattern matching using an orientation descriptor which filters out unnatural minutiae pairings formed. Similarity scores thus obtained helps in identifying the person if he is authorised or not, which in turn enhances security of the system.

1.5 THESIS ORGANISATION

This thesis is organised as follows: Section 2 consists of the previous related works. A proposed hardware block diagram via which vein acquisition is done is shown in Section 3. Section 4 elaborates the vein pattern extraction scheme both theoretically as well as experimentally. Section 5 illustrates the matching algorithm based on minutiae extraction and an orientation descriptor. To verify the effectiveness of the proposed strategy, the algorithm is applied on several images, and results are displayed in Section 6. Section 7 comprises of conclusions and discussions.

2. LITERATURE REVIEW

- ✓ PREVIOUS RELATED WORK

2.1 PREVIOUS RELATED WORKS

- 2 infrared LED arrays, CCD camera and video card and adoption of phase only correlation and template matching for authentication.
- Introduction of preliminary process to enhance image quality that worsen by light effect and produces noise by the webcam, then segmented the vein pattern by using adaptive threshold method and matched them using improved template matching.

  CONSEQUENCE: Image quality is not good till veins are closer with some appropriate process.
- Identification approach using finger-vein location and Direction Coding (LDC). The brightness difference in the finger vein image is used to extract the vein pattern. Then finger vein LDC creates a structured feature image for each finger vein.
- Algorithm based on adaptive filtering and retinex method for enhancement of hand-vein images. Then gray cosine transform and removal of false hand vein blocks from segmented hand vein images is done.
- **Miura and his co-operators in Hitachi Ltd.** used the finger vein's valley character in pixel gray value and repeated line tracking method to figure out the vein lines. **CONSEQUENCE:** Time Consumption is very large.
- **Yu et al** made progress in modifying the traditional templates into directional templates. Then according to three threshold steps, the final result is given out. **CONSEQUENCE:** Overcomes the time consumption problem but the threshold parameters are set by hand which lacks flexibility due to different light environments.
- Xiang Yu extracted finger veins by applying local threshold method followed by line tracking. Then synthesis of a thorough probability map is done and directional neighborhood analysis is performed. **CONSEQUENCE:** Repeated line tracking can extract vein patterns but for thin vein patterns, the problem is the number that the tracking point moves on those pattern is small. Application of exponential threshold increases the probability of unwanted regions that can be decreased by removing noise using various algorithms, which in turn increases time complexity.
- Fingerprint Matching using A Hybrid shaped detector where it uses minutiae points to match the image and find similarity score.

3. PROPOSED HARDWARE

- ✓ DEVICES USED
- ✓ SOFTWARE USED
- ✓ EXPERIMENTAL SETUP

3.1 DEVICES USED

- Near Infrared LEDs (wavelength about 890nm)
- Modified NIR CCD Camera or NIR Camera – GUPPY F044C NIR IEEE1394 Digital Camera
- Resistors (220ohm , 330ohm)
- IC LM7805
- Adapter
- Laptop

3.2 SOFTWARE USED

- MATLAB
- AVT – stores the captured images taken from the NIR camera

3.3 EXPERIMENTAL SETUP

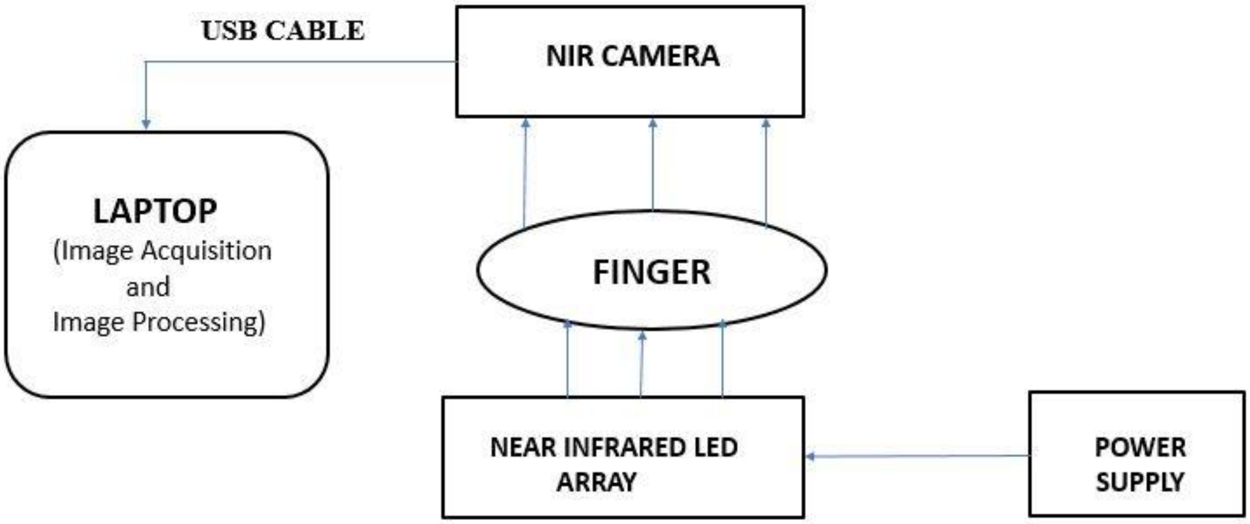


***Figure 2**: Light Transmission Setup*

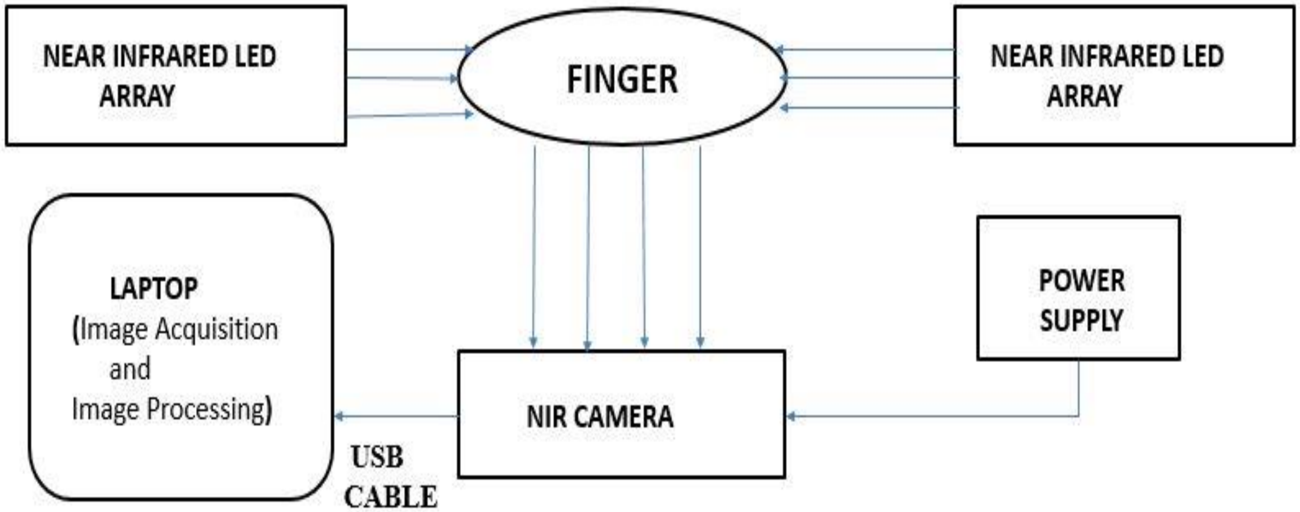


***Figure 3**: Light Reflection Setup*

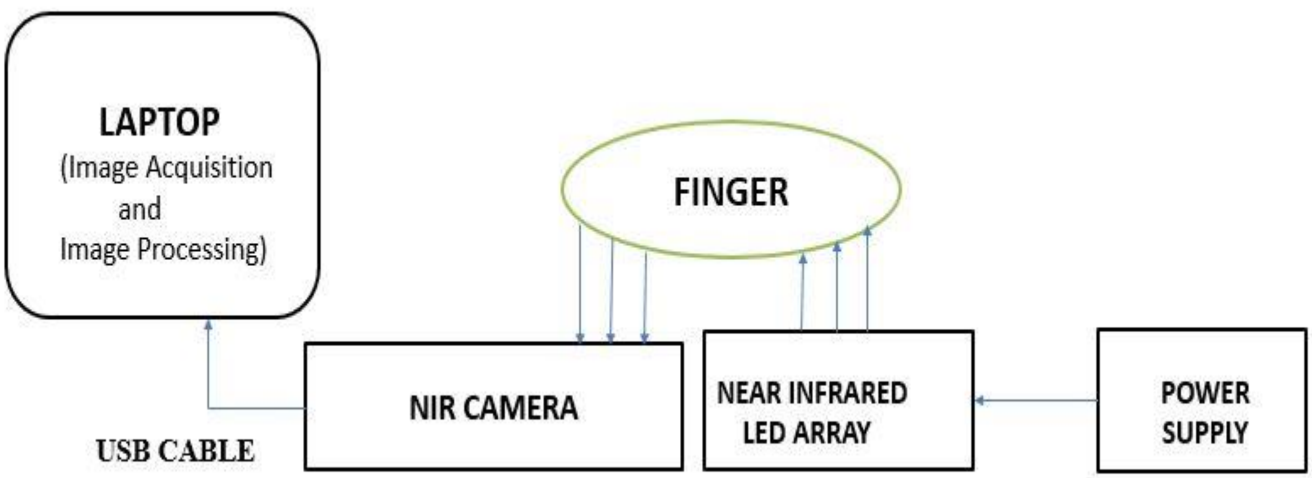


***Figure 4**: Light Scattering Setup*

ADVANTAGES OF SCATTERING LIGHT SETUP / SIDE LIGHTING SETUP:

- Using 2 sets of near infrared led arrays from both sides, either arranged concentric or in a rectangular (or square) position increases more visibility and accuracy. In side lighting, scattering as well as transmission (absorption) and reflection occurs. So this enhances the quality of the infrared image captured.

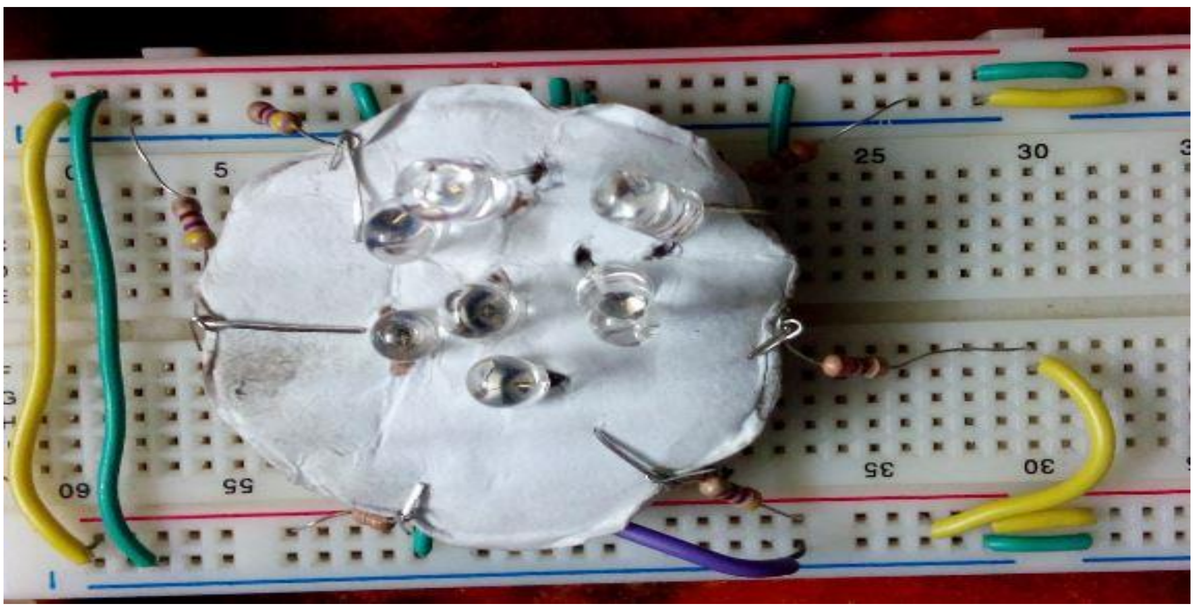


***Figure 5**: Concentric LED Array (IR LEDs)*

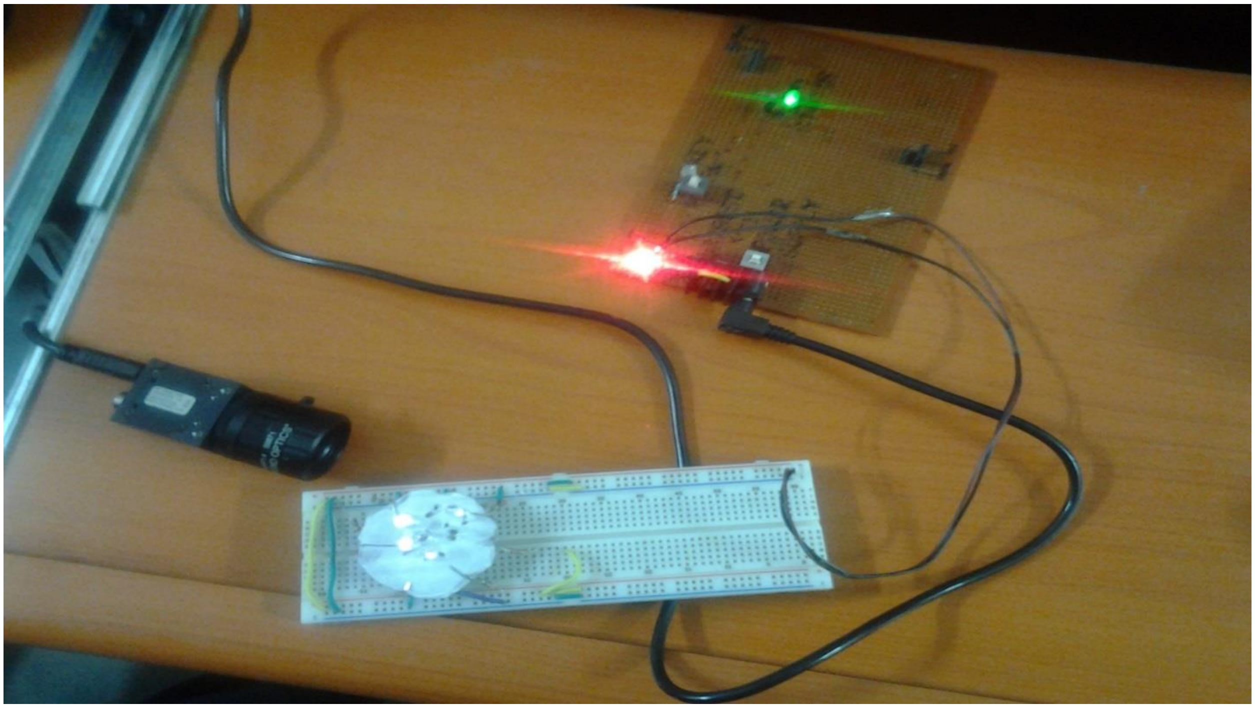
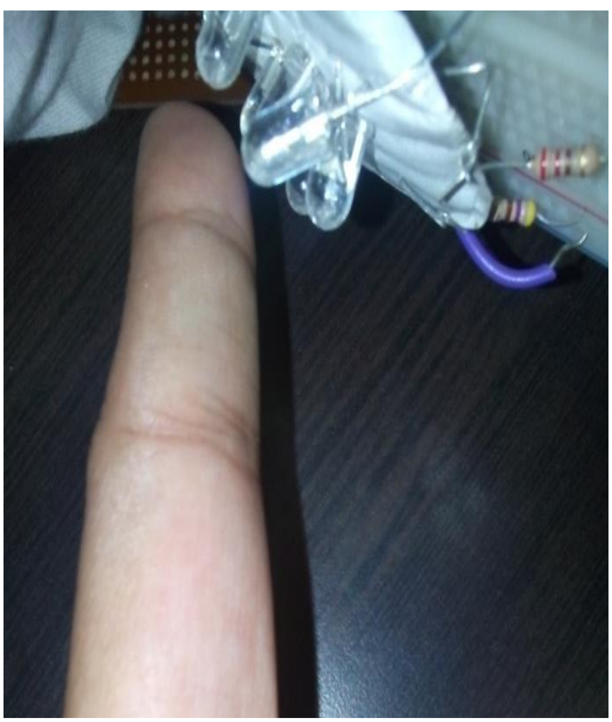


***Figure 6**: Hardware Setup*



(a)

(b)

(c)

***Figure 7(a)**: Positioning of the finger if no device for keeping finger is made*
***(b)**: Cardboard made where the finger is inserted inside the hole seen*
***(c)**: Bottom view of the cardboard with lens attached on which the finger is to be placed*

An array of infrared LED (wavelength 860-1000 nm) is fixed. The finger or palm is placed accordingly with respect to the array, as per the experimental setup (transmission, reflection or scattering setup) or inside the cardboard (biometric device if made). The cardboard consists of a lens fitted inside it on which the finger is placed (for a bigger lens and a bigger hole, a palm can also be placed). Camera and arrays can be fitted as per the type of the experimental setup. Infrared light penetrates the skin and then passes through the infrared high-pass filter of a CCD camera or a NIR camera whose cut-off wavelength is about 860-1000 nm. After NIR camera, the final image is sent to computer i.e. data acquisition is done using AVT software where real-time image is observed. Since reduced haemoglobin (Hb) in blood would assimilate more NIR light than the surrounding environment, vein region in the image appears darker than other parts inside the skin.

4. VEIN PATTERN EXTRACTION ALGORITHMS

- ✓ OVERVIEW
- ✓ PROPOSED FLOW DIAGRAM
- ✓ PROPOSED ALGORITHM
- ✓ BACKGROUND REMOVAL
- ✓ CONTRAST ENHANCEMENT
- ✓ FORMATION OF TEMPLATES
- ✓ MORPHOLOGICAL OPERATIONS
  - ✓ FILL
  - ✓ EROSION
  - ✓ DILATION
  - ✓ CLEAN
  - ✓ BRIDGE
  - ✓ SKELETON
  - ✓ EDGE DETECTION

4.1 OVERVIEW

Our strategy has following steps:

- Background Removal
- Contrast Enhancement
- Formation of templates and summing them
    - Local Normal Threshold
    - Local Exponential Threshold
- Morphological Operations

4.2 PROPOSED FLOW DIAGRAM

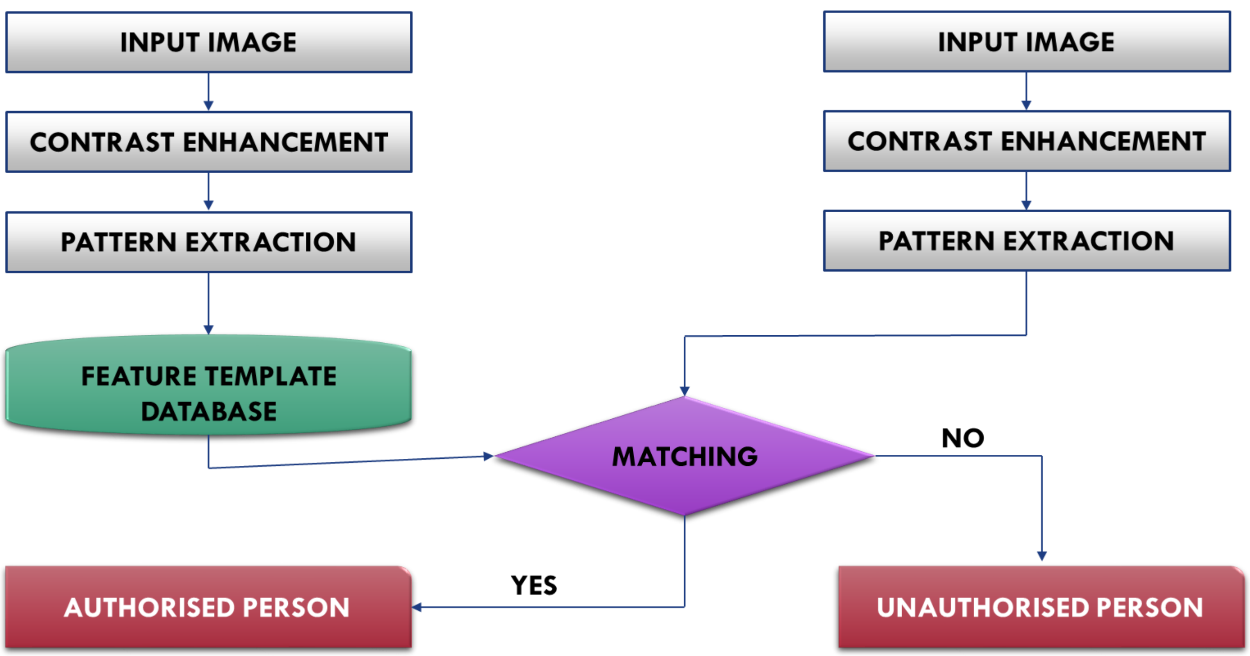


Figure 8: *Proposed Flow Diagram of the Project*

Few images are to be recorded, processed and stored in a database. If the test vein pattern image doesn't match with the one in the database, then the person is declared as **unauthorized** and if it matches then the person is **authorized** to perform the consequent activities.

4.3 PROPOSED ALGORITHM

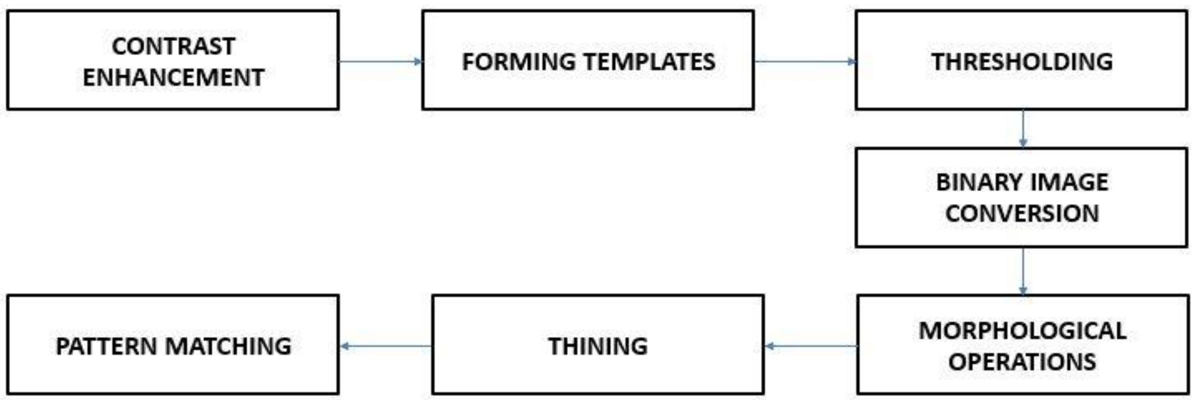


***Figure 9**: Proposed Algorithm*

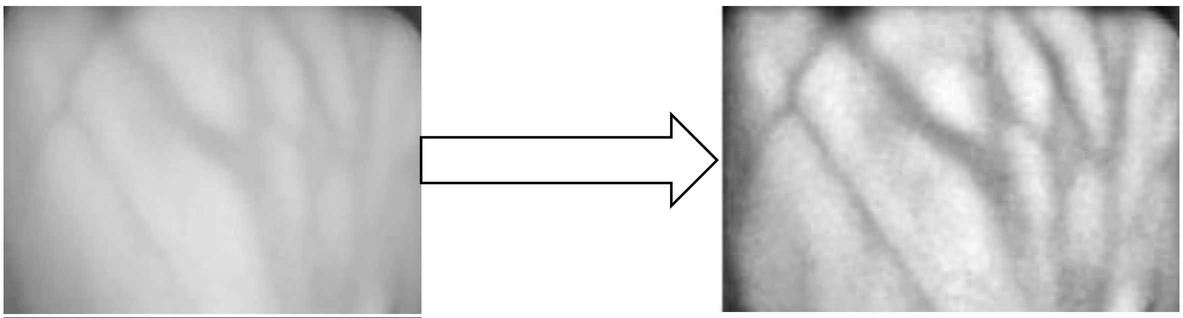
4.4 BACKGROUND REMOVAL

The setup should be constructed such that only the part of the hand (finger or palm) which is exposed to NIR light, is taken up for processing. Presence of background could lead to addition of more noise and local threshold may give erroneous results due to noise present in the background.

4.5 CONTRAST ENHANCEMENT

Contrast Enhancement increases the contrast of the image by mapping the values of the input intensity image to new values, such that data is saturated somewhat in differing values of intensity. It increases the values of the pixels of the image.

Contrast limited adaptive histogram equalisation is used here which registers a few histograms, every relating to a particular segment of the picture, and uses them to redistribute the brightness values of the image. CLAHE is better than normal adaptive histogram equalisation since it doesn't over-amplifies noise. The salt and pepper noise present in the image is removed automatically since the operation is performed in smaller regions i.e. blocks of images.



(a) (b)

Figure 10(a): *Original image of a palm*

10(b): *Contrast enhanced image after performing CLAHE*

4.6 FORMATION OF TEMPLATES

Here in the grayscale contrast enhanced image, the values of the pixels are almost same, that is, the intensity values are almost equal. So thresholding on whole grayscale image is difficult. Since the whole image contains more black regions, the image after thresholding will turn black owing to the value chosen due to auto-threshold or manually chosen threshold value.

Hence dividing the image into smaller blocks or templates would serve as the solution of the above problem. Forming square blocks of different widths (5*5, 10*10, 20*20, etc) and thresholding separately is favourable.

First the image has to be resized to a square image by padding zeros, making number of rows equal to the number of columns or length equal to breadth. Zero padding is preferable than trimming the image to make it a square because by zero padding there would be no data loss and we can retrieve the extracted and original image back without any loss of rows or columns.

Then summing the result images formed after each block formation is added to remove unwanted portions, either due to different intensity values in the original image or due to formation of smaller blocks.

The number of blocks depends on the size of the image. More the size of the image, more is the number of blocks and more is the spacing of the width between the pixels chosen.

LOCAL NORMAL THRESHOLD

It is the simplest form of image segmentation. Here grayscale image is converted to binary image, by designating a label or number (intensity value) to every pixel in the image such that pixels share the same features if they are having the same label.

NIR image of finger vein is always of low quality because of the capturing device which is sensitive to noise. So global threshold can’t be used. Local thresholding is done on the local image characteristics. The lower the gray value of the pixel, the more possibility it is in the vein region.

Let result image be res(x,y)

$$res(x,y) = \begin{cases} a(x,y) & , \ a(x,y)>b \\ 0 & , \text{else} \end{cases}$$

where a(x,y) - intensity at coordinates (x,y) of the padded image of original grayscale image

b – median of a(x,y)

Median of the pixel values of the particular block is better than mean values since it gives more accuracy. The algorithm says that if the pixel value is more than the median value, then the pixel would retain its value, and if the pixel value is less than median of all the pixel values of that block, then set the pixel value as 0, i.e., make it black which is the region of interest (vein).

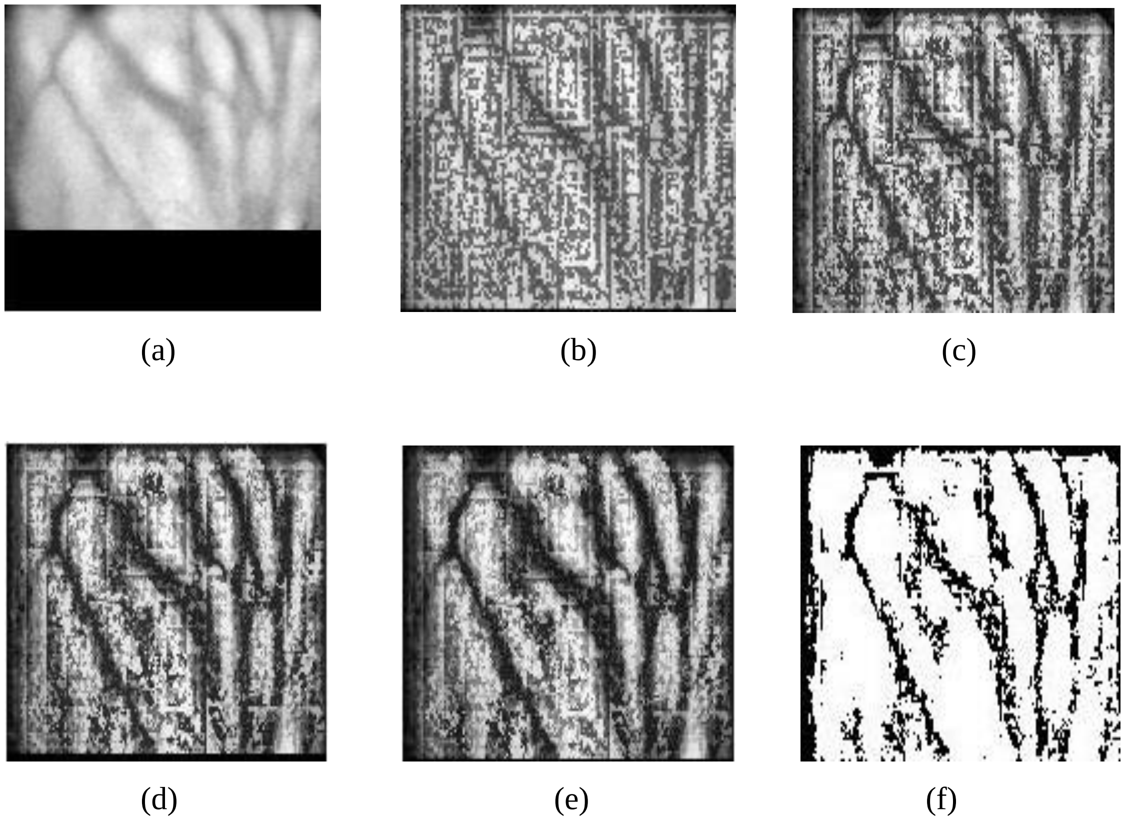


Figure 11(a)*: Padded image (160*160)*
(b)*: Thresholding on 5*5 pixels blocks*
(c)*: Thresholding on 10*10 blocks + previous image*
(d)*: Thresholding on 15*15 blocks + previous image*
(e)*: Thresholding on 20*20 blocks + previous image*
(f)*: Bimary Image of previous image*

In first five images, the black portions represent the darker regions and in the last image, the vein patterns are represented in black.

LOCAL EXPONETIAL THRESHOLD

Let result image be res(x,y)

$$res(x,y) = \begin{cases} a(x,y) - \exp(a(x,y)-b) & , \ a(x,y)>b \\ 0 & , \text{else} \end{cases}$$

where a(x,y) - intensity at coordinates (x,y) of the padded image of original grayscale image
b – median of a(x,y)

The algorithm says that if the pixel value is more than the median value, then the pixel's value would be its grayscale value minus the exponential of difference of pixel value and median, and if the pixel value is less than median of all the pixel values of that block, then set the pixel value as 0, i.e., make it black which is the region of interest (vein). The exponential component is taken for better accuracy.

(a)

(b)

(c)

(d)

Figure 12 (a)*: Exponential Thresholding on 5*5 pixels blocks*
(b)*: Exponential Thresholding on 10*10 blocks + previous image*

*(c): Exponential Thresholding on 15*15 blocks + previous image*
*(d): Exponential Thresholding on 20*20 blocks + previous image*

Considering the final images of normal thresholding (Figure 11(f)) and exponential thresholding (Figure 12(d)), the latter contains unwanted regions which cannot be removed via morphological operations and need more image processing techniques to eliminate them which increases complexity, which is not the case in the former figure. So local normal threshold is used.

4.7 MORPHOLOGICAL OPERATIONS

Morphological operations are carried out on smaller regions, i.e. on small blocks of image to remove unwanted portions and help in restoring the missing portions of the image. The morphological operations used are as follows:

FILL

Fills lone center pixels (individual 0s surrounded by 1s).

1	1	1
1	0	1
1	1	1

Centre pixel will be white now (1). It removes the unwanted black portions those are not veins.

***Figure 13**: Binary image (Figure 11(f)) after filling*

EROSION

Removes pixels on object boundaries, typically white pixels. Value of output pixel is min. value of all the pixels in the input pixel's neighborhood. If mask doesn't match, center pixel is set to 0.

***Figure 14**: Erosion of filled image*

DILATION

Adds pixels on object boundaries typically white pixels. Value of output pixel is maximum value of all the pixels in the input pixel's neighborhood. If center pixel matches i.e. 1, then the whole mask turns 1. It is done for thinning of the image which is required for matching in biometric.

***Figure 15**: Dilated image after erosion*

CLEAN

Removes solitary pixels (individual 1s that are surrounded by 0s). This is a redundant process done to improve accuracy. This operation may not be applied.

0	0	0
0	1	0
0	0	0

It cleans the center pixel, i.e. it sets it as 0 (black).

Figure 16: *Clean image after inversion of dilation image*

BRIDGE

Connects unconnected pixels, that is, sets 0-valued pixels to 1 if they have two nonzero neighbours that are not connected. It helps to connect veins which are not connected, but should be. The veins might have been separated when applying the image processing algorithms.

1	0	0
1	0	1
0	0	1

This matrix is reformed as the matrix given below. The white portions representing the veins are connected.

1	1	0
1	1	1
0	1	1

Figure 17*: Bridge image after cleaning*

SKELETON

Removes pixels on the boundaries of objects but does not allow objects to break apart. The pixels remaining make up the image skeleton. It is further required for matching.

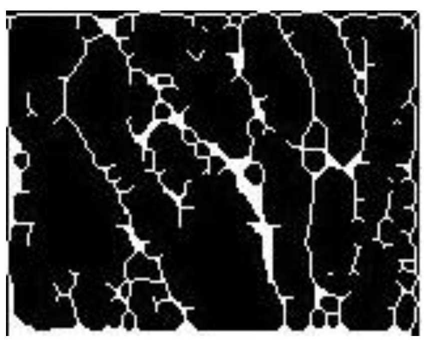


Figure 18*: Skeleton of the bridged image (Final Output)*

EDGE DETECTION

It gives only the boundaries of the pattern and eliminates every other portion. It can also be useful for matching purposes.

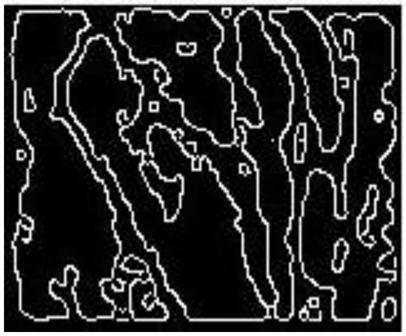


***Figure 19**: Edge Detection of bridged image*

5. MATCHING

- ✓ OVERVIEW
- ✓ PROPOSED MATCHING ALGORITHM
- ✓ MINUTIAE FEATURE MATCHING
- ✓ SIMILARITY SCORE

5.1 OVERVIEW

For matching, three algorithms can be followed. They are as follows:-

- **Correlation-based matching**

  Superimposes both test image and template image in database and checks the correlation between the pixels for distinct translations and rotations.

- **Minutiae feature matching**

  Uses extracted minutiae (points-core + ridge) from both test image and template images by forming alignment between minutiae pairs.

- **Non-Minutiae feature matching**

  Uses non-minutiae features like shape and size of ridges, and orientation to accomplish matching and alignment.

5.2 PROPOSED MATCHING ALGORITHM

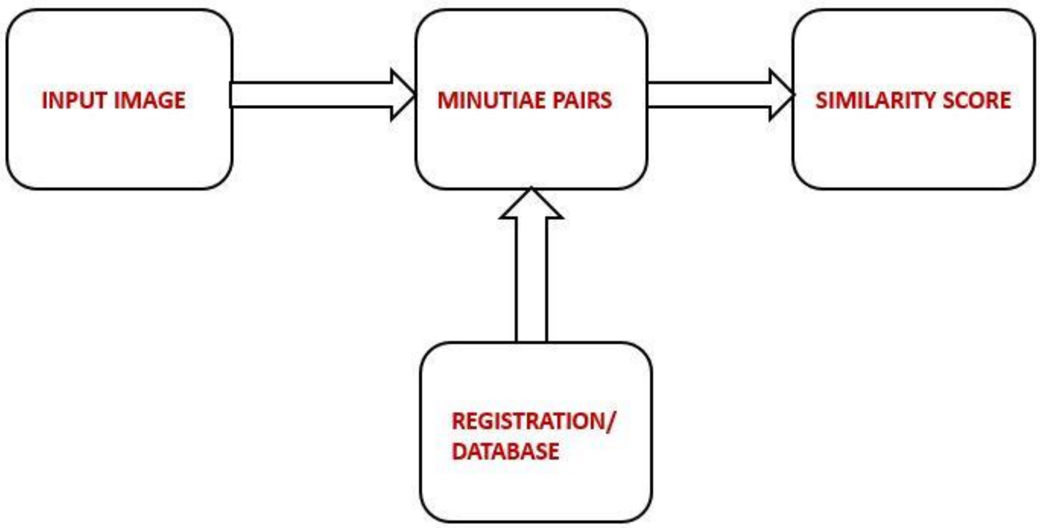


Figure 20: *Matching Algorithm*

The input image is compared with images in the database, and minutiae pairs are formed and their similarity score is calculated on the basis of rotation and translation parameters. On the basis of similarity score, it is known if the person is authorised or unauthorised.

5.3 MINUTIAE FEATURE MATCHING

Minutiae features matching is also known as point-to-point pattern matching. Minutiae extracted are unique. Hence they can be used for matching purposes. Minutiae pixel locations can be identified by the following formula.

cn(p)= 0.5 * $\sum_{i=1}^{8} \left| val(p_{(i-\mathrm{mod}8)}) - (val(p_{i-1})) \right|$

Where val ε {0,1}

cn(p) = 1 for ridge endings

cn(p) = 3 for ridge division

COLOUR CODING FOR MINUTIAE

GREEN - Core point

BLUE - Bifurcations (θ ε [0^o,180^o)) **PURPLE** - (θ ε [180^o,360^o))

ORANGE- ridge endings (θ ε [0^o,180^o)) **RED** - (θ ε [180^o,360^o))

Where θ is measured anti-clockwise

5.4 SIMILARITY SCORE

Similarity score shows the percentage of similarity between two images. For a particular threshold value of the score, the image matches with the templates in the database. The score is calculated by these 4 formulas as predicted by taking into account orientation descriptors, proposed by Tico and Kusomanen (2003). Here the rotation and translation parameters of the minutiae pairings are taken into account by taking a core point initially and drawing concentric circles and calculating the number of minutiaes in it. The matching algorithm terminates if a local maxima is not found that indicates that a ridge bifurcation or a ridge ending has been found.

$$[r,s] = \arg\max_{i,j} P(m_{A_i}, m_{B_j})$$

$$P(m_{A_i}, m_{B_j}) = S(m_{A_i}, m_{B_j})^2 / (\sum_{k=1}^{p} S(m_{A_k}, m_{B_j}) + \sum_{l=1}^{q} S(m_{A_i}, m_{B_l}))$$

$$S(m_{A_i}, m_{B_j}) = (\frac{1}{t}) * \sum_{c}^{L} \sum_{a}^{Kc} \exp(-\frac{2*(\min(|\theta_{c,a}^{A_i} - \theta_{c,a}^{B_j}|), \pi - |\theta_{c,a}^{A_i} - \theta_{c,a}^{B_j}|)}{\pi\mu})$$

Where $S(m_{A_i}, m_{B_j})$ is the similarity function.

[r,s] is the rotation and translation parameters of the minutiae pairings.

$P(m_{Ai}, m_{Bj})$ is the maximum probabilistic value of the minutiae pairs.

t is the total sample points distributed as L concentric circles having K_C points – number of points present in the circle with equidistant angular distribution with step size $2\pi/K_C$

$\theta_{c,a}^{A_i}$ is minimum angle required to rotate the ath sample orientation on cth circle to the orientation of minutia m_{A_i} (likewise for $\theta_{c,a}^{B_j}$), and μ is an empirically chosen parameter.

$$SS(A,B) = \frac{\left(\sum_{(i,j)\in SMP} S(m_{A_i}, m_{B_j})\right)^2}{n_A * n_B}$$

Where SS(A,B) is the similarity score and SMP is the set of minutiae pairs and A_i and B_j are the template/ test minutiae list indexes, respectively.

6. EXPERIMENTAL RESULTS

- ✓ DATABASE
- ✓ SIMILARITY SCORE OF DATABASE IMAGES WITH TEST IMAGE
- ✓ ITERATION

6.1 DATABASE

A database of 3 persons from the internet is taken and the results are found out. First the images are subjected to extraction of images and then minutiae points are found out following the similarity score.

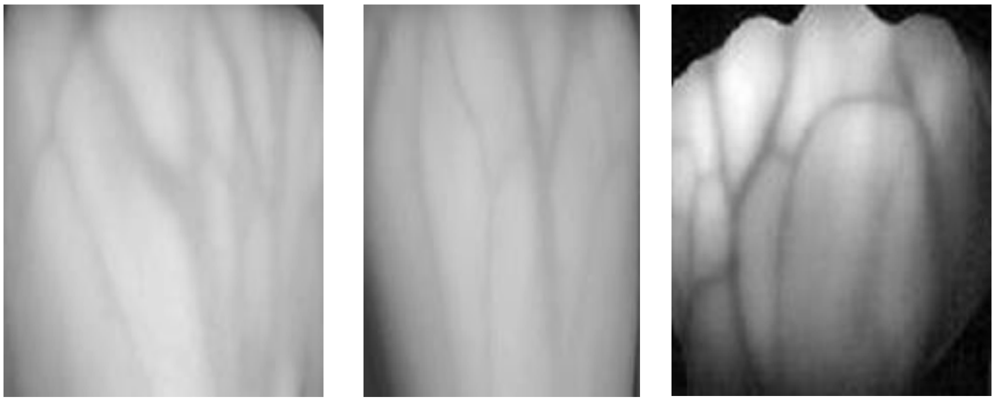


Figure 21(a)*: Palm Vein Pattern of PERSON A*
(b): *Palm Vein Pattern of PERSON B*
(c)*: Palm Vein Pattern of PERSON A*

The images are thinned and made into a skeleton figure.

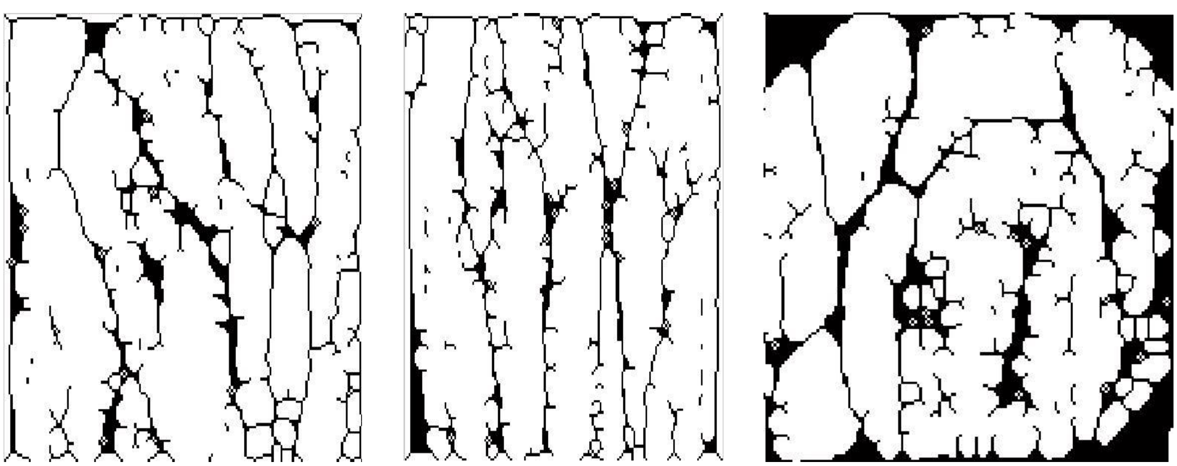
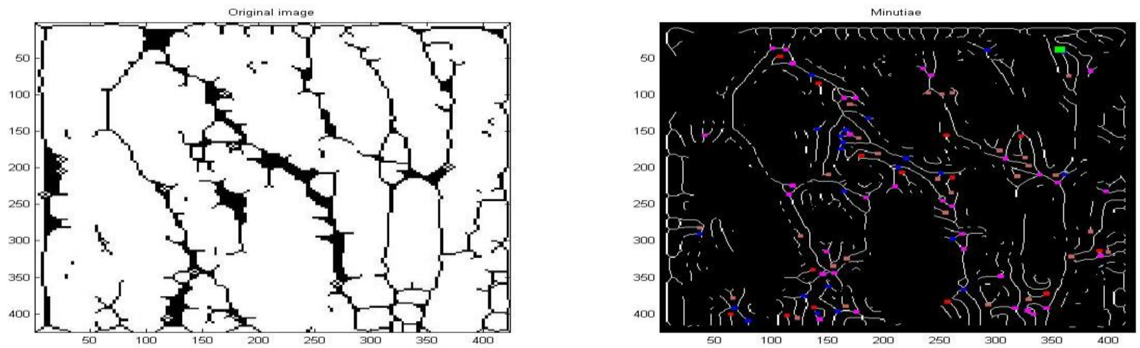
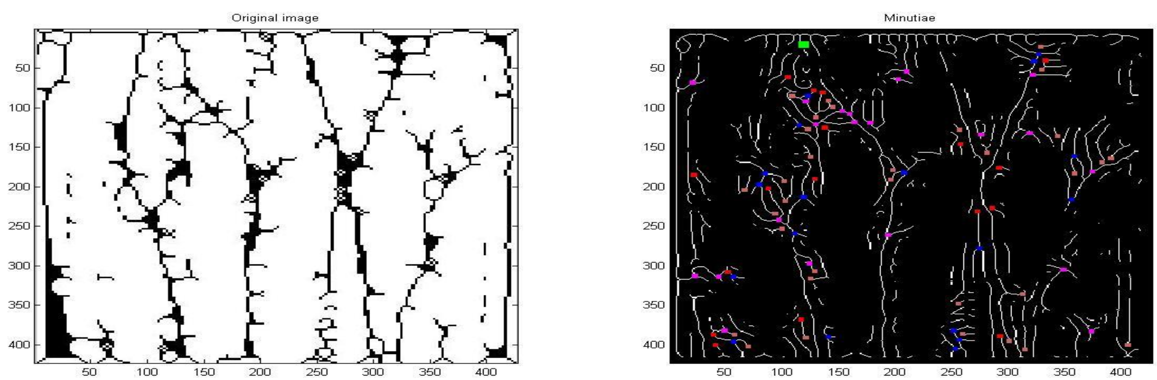


Figure 22(a)*: Extracted skeleton image of PERSON A*
(b): Extracted skeleton image of PERSON B
(c): Extracted skeleton image of PERSON C

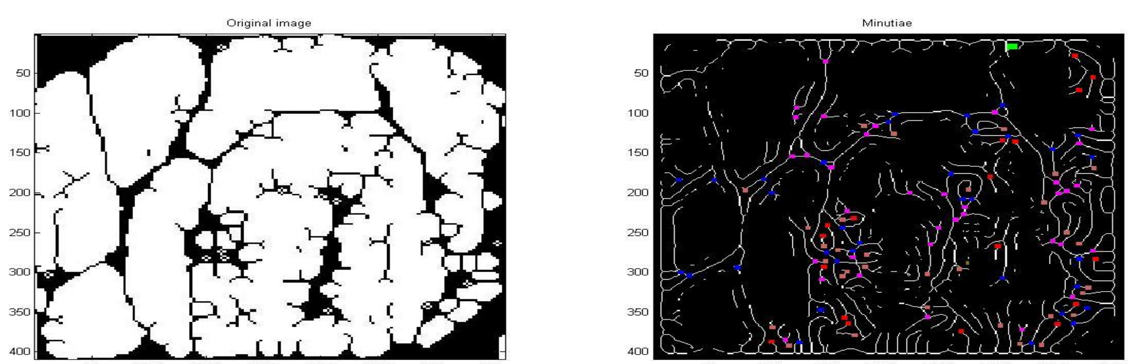
Then the minutiae pairs are extracted from the test image and the images in the database.



(a)



(b)



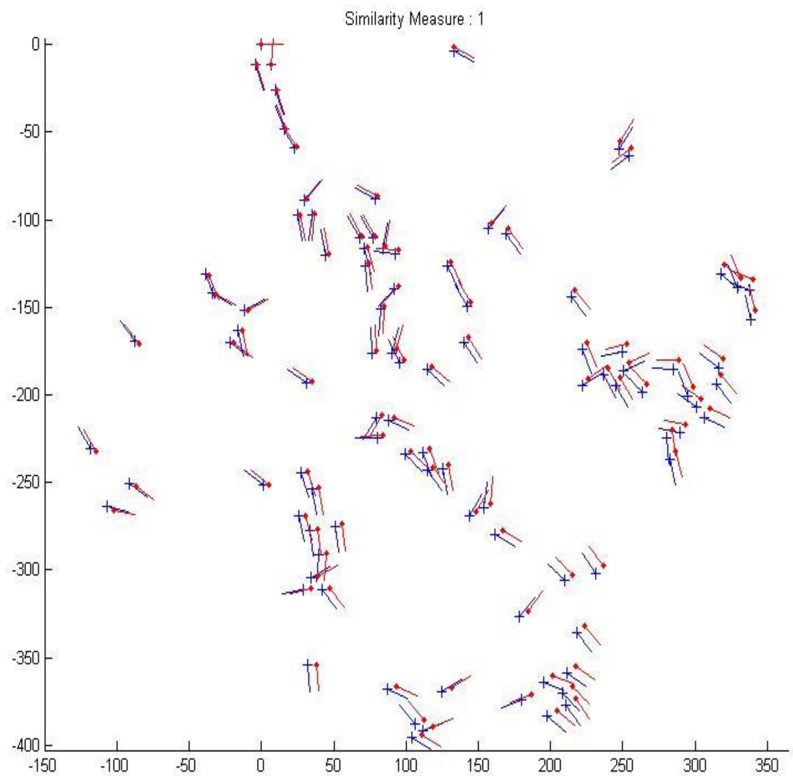
(c)

__Figure 23(a)__: Minutiae Extraction of veins of PERSON A
__(b)__: Minutiae Extraction of veins of PERSON B
__(c):__ Minutiae Extraction of veins of PERSON C

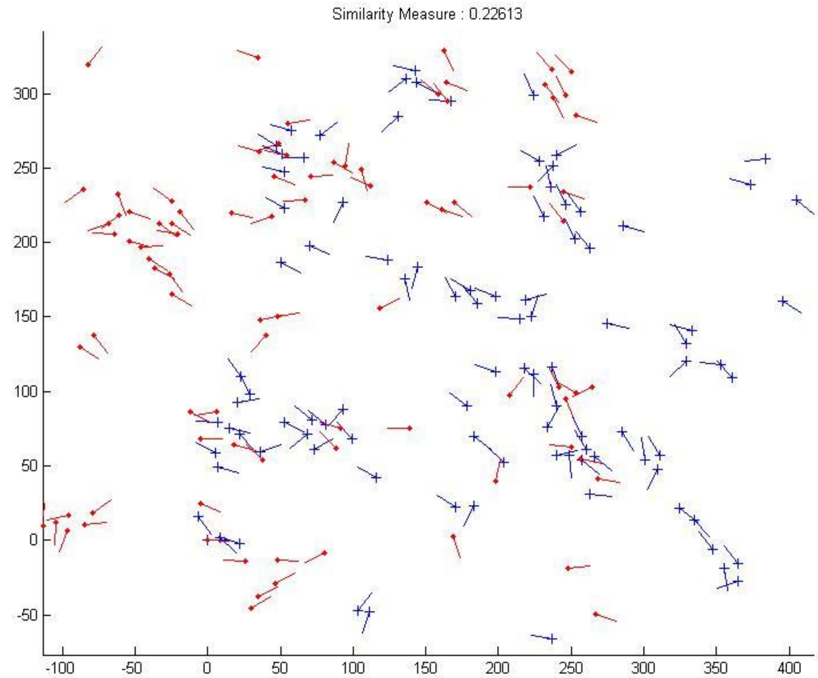
The colour codings of the minutiae are already mentioned above.

6.2 SIMILARITY SCORE OF DATABASE IMAGES WITH TEST IMAGE

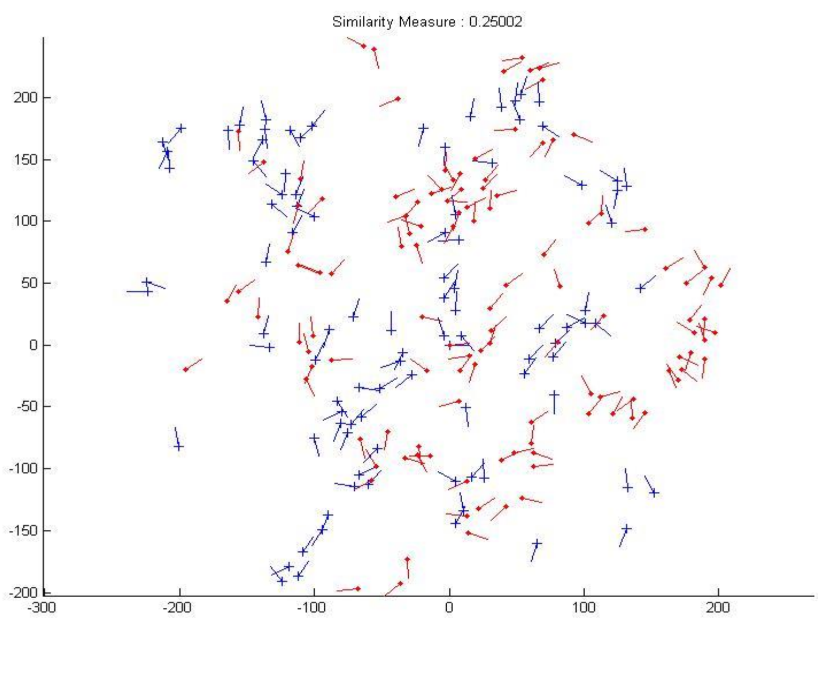
The similarity score of PERSON A is matched with vein images of PERSON B and PERSON C stored in the database.



(a)


Similarity Measure : 0.22613
300
250
200
150
100
50
0
-50
-100
-50
0
50
100
150
200
250
300
350
400

(b)


Similarity Measure : 0.25002
200
150
100
50
0
-50
-100
-150
-200
-300
-200
-100
0
100
200

(c)

Figure 24(a)*: Similarity Score (=1) Matching of PERSON A with PERSON A*
(b)*: Similarity Score (=0.22613) Matching of PERSON A with PERSON B*
(c)*: Similarity Score (=0.25002) Matching of PERSON A with PERSON C*

6.3 ITERATIONS

For the matching of reference image in database and given input for the same image, eliminating 1 row and 1 column with each iteration, similarity score is checked to know the limit of matching. Elimination normally takes place till little more than half of the input image. Here elimination is carried out for 20 loops/iterations.

Sl. No.	ROWS	COLUMNS	SIMILARITY SCORE
1	425	423	1
2	424	422	0.9949
3	423	421	0.9588
4	422	420	0.9279
5	421	419	0.9094
6	420	418	0.8984
7	419	417	0.6319
8	418	416	0.8366
9	417	415	0.8437
10	416	414	0.8673
11	415	413	0.8518
12	414	412	0.8780
13	413	411	0.8847
14	412	410	0.8938
15	411	409	0.8507
16	410	408	0.8437
17	409	407	0.8156
18	408	406	0.7983
19	407	405	0.5689
20	406	404	0.5664

Table 1: *Iteration of Similarity Scores by cropping*

7. CONCLUSIONS AND DISCUSSIONS

- ✓ INFERENCE
- ✓ DISCUSSION / FUTURE SCOPE

7.1 INFERENCE

An input image is matched with its rightful image (in the database) if following both cases are satisfied:-

- similarity score is more than 0.5
- More than two minutiae pairs have similarity score more than 0.5, then the pair of the image having the maximum value is the correct image

Thus image is matched. If the image doesn't satisfy the above conditions, then the input image is not present in the database. Unauthorized person found.

7.2 DISCUSSIONS

In this work, a novel and effective algorithm for extracting vein pattern images from poor NIR images is presented. The algorithm combined normal local threshold method on blocks of the image and morphological operations are carried out. Experimental results revealed that the proposed method could achieve better results by using contrast enhancement using CLAHE and morphological operations with reduced time complexity. This strategy could also be reference for low quality and poor contrast image processing. Due to its advantages, further biometric identification based on vein pattern is expected to achieve good performance than any other features.

The project can be made cost effective by using a modified webcam instead of a NIR camera which is costly. The fact that CCDs are sensitive to infrared+ is a detriment to good photography. To get around this, all CCD cameras have a built in IR filter. The less the cost of camera, the less effective the infrared light beam filter. The infrared blocking filter can be removed to make a good IR camera. Therefore webcam is a good substitute to a costly NIR camera used here.

Edge detection extracted image rather than skeleton can also be used. Edge detection may give out less number of minutiae points than skeleton which may lead to less time complexity but it may hamper accuracy of the authentication.

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