

A Novel Vein Pattern Recognition System

A Dissertation submitted to the University of Hyderabad in partial fulfillment of the
degree of

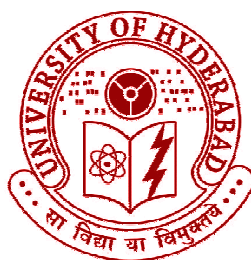
MASTER OF TECHNOLOGY

in

Information Technology

by

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CERTIFICATE

This is to certify that the dissertation entitled “**A Novel Vein Pattern Recognition System**” submitted by **Manchala Siva Krishna** bearing Reg. No **09MCMB22** in partial fulfillment of the requirements for the award of Master of Technology in Information Technology is a bonafide work carried out by him under my supervision and guidance.

The dissertation has not been submitted previously in part or in full to this or any other University or Institution for the award of any degree or diploma.

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DECLARATION

I, **Manchala Siva Krishna** hereby declare that this Dissertation entitled “**A Novel Vein Pattern Recognition System**“, submitted by me under the guidance and supervision of **Dr. M.V.N.K Prasad, Assistant Professor, IDRBT**, is a bonafide work. I also declare that it has not been submitted previously in part or in full to this University or other University or Institution for the award of any degree or diploma.

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ACKNOWLEDGEMENTS

I wish to express my sincere gratitude to Dr. M.V.N.K Prasad, Assistant Professor, IDRBT, Hyderabad, who generously supported and guided me throughout my project, IDRBT for providing me with the infrastructure and technical support that I needed for this project. The project would not have been possible without his assistance.

I also thank Mr. B. Sambamurthy, Director, IDRBT, Prof. Arun Agarwal, Dean MCIS, School of MCIS, Prof. C.R.Rao, Head of the Department (DCIS), University of Hyderabad for extending their cooperation.

The guidance of all the faculty members of IDRBT and the Department of Computer and Information Sciences, University of Hyderabad has been precious and timely. I wish to thank them for being very patient, understanding and helpful.

I would like to thank Dr.Abdul, Naveen, Ilaiah and my classmates for their kind and timely support.

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Abstract

Biometrics plays a vital role in today Networked Security world because of its reliability and uniqueness. Many different recognition methods are proposed to identify an individual based on vein pattern. In this study, the main aim is to develop vein pattern recognition system.

First, we developed a vein pattern recognition system for effective identification of an individual, basically vein pattern has rich set of features like vein bifurcation points, texture, end points etc. We extracted the bifurcation points and ending points using a basic extraction method from the vein pattern images as explained in the following sections and those points are stored as templates. After extracting the bifurcation points and ending points in input image then we match those points with templates. If points are matched then the person is genuine, otherwise he is going to be rejected. We are taken some thresholds like small square areas and if the point is in that small square area then the person is genuine otherwise rejected. After that the Performance of our system calculated by the basic biometric terms FAR and GAR. Performance is improved both in FAR as well as in GAR in the developed system compared to the previous systems.

Further, proposed approaches are 1. Matching with Delaunay triangulation and match with their lengths of the triangles. 2. After Delaunay Triangulation only matching with bifurcation points. These two methods are the possible extensions to our work.

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Chapter 1: Introduction to Biometrics

Biometrics-based authentication is a verification approach using the biological features inherent in each individual. Biometrics overcomes the weaknesses of traditional personal identification schemes including token-based approaches and knowledge-based approaches. In this chapter, a brief introduction to biometrics is presented.

1.1 Introduction

Authentication is a fundamental component of human interaction with computers. Traditional means of authentication, primarily passwords and personal identification numbers (PINs), have been utilized but each has its own disadvantages. However, stronger authentication technologies, capable of providing higher degrees of certainty that a user really is who he or she claims to be, are becoming common. Biometrics is one of such strong authentication technologies [4].

Biometric technologies, as we know them today, have been made possible by explosive advances in computing power and have been made necessary by the near universal interconnection of computers around the world. The increased perception of data and information as near equivalents of money, in conjunction with the opportunities for access provided by the internet, are a paradigm shift with significant repercussions on authentication. If data is money, then server-based or local hard drives are our new vaults, and information-rich companies will be held responsible for their security. Because of this, passwords and PINs are nearing the end of their life cycle for many applications. To overcome the disadvantages with traditional authentication systems (i.e. Knowledge based and Token based) Biometrics came into existence.

Mainly four factors (reduced cost, reduced size, increased accuracy, and increased ease of use) have combined to make biometrics an increasingly feasible solution for securing access to computers, networks and work stations. Problems with traditional authentication systems are overcome with Biometrics so we can say it is simply a replacement of Traditional systems. Below are the some of interesting statics which show the drawbacks (revenue losses) of using Knowledge or Token based approach.

1. According to Nilson report, in 2005, MasterCard, Visa, American Express and Discover incurred US \$ 1.14 billion in fraud losses.
2. Between 20% and 50% of all helpdesk calls for password resets and each password reset costs about US\$70[3].
3. In 2005, 9.3 million US citizens suffered from identity theft. The loss is US\$54.4 billion.

These figures strongly indicate that we need more effective and reliable solution for human identity system. Millions of people around the world use biometric technology in applications as varied as time and attendance voter registration international travel and benefit distribution. Depending on the application, biometrics can be used for security, for convenience, for fraud reduction, even as an empowering technology. According to “The Feature Biometrics” research report Biometrics revenue to reach \$10 billion by 2020.

1.2 Biometric Traits

The selection of biometric traits [4] depends on requirements of applications, and every biometric trait should satisfy minimum constraints (i.e. Universality, Uniqueness, Permanence, Collectability, Performance, Acceptability, and Circumvention) some biometrics traits have high in some requirements some have low, medium. If we say Palmvein in this case Universality is medium, Permanence is High, Collectability is Medium, Performance is High, Acceptability is Medium, and Circumvention is Medium. In this Section, a brief summary of different biometric traits is presented. Every biometric trait has both advantages as well as disadvantages there is no idle biometric trait till now. Fig.1.1 shows different biometric traits [Google images].

1. **Deoxyribonucleic Acid (DNA)**, DNA is comes under Biological Characteristics, and DNA is a nucleic acid containing all genetic instructions for development of organs, is commonly applied to forensic applications such as criminal investigation and corpse identification. Everyone has unique DNA pattern, except identical twins. DNA can be extracted from blood, hair, and skin etc, which can always be collected in crime senses. DNA can be collected unintentionally and it contains all genetic disorder so for this trait User Acceptance is low.

2. **Face**, is a widely acceptable biometric trait, It is one of the Behavioral Biometric trait it can change w.r.t to the mood of the person, which can be captured from distance and even without users' cooperation. Nevertheless, face contains limited information for personal identification. Identical twins have very similar facial features. Another inherent difficulty of using face for personal identification is that face images of a person can change a lot due to facial expression, capture environment and aging. As a result, current face recognition systems cannot support high security applications but it is an important component in surveillance systems. Many researchers used PCA (principle component analysis) for the feature extraction in Face.

3. **Fingerprint**, A fingerprint is made of a number of ridges and valleys on the surface of the finger. Ridges are the upper skin layer segments of the finger and valleys are the lower segments. The ridges form so-called minutia points: ridge endings (where a ridge end) and ridge bifurcations (where a ridge splits in two). Many types of minutiae exist, including dots (very small ridges), islands (ridges slightly longer than dots, occupying a middle space between two temporarily divergent ridges), ponds or lakes (empty spaces between two temporarily divergent ridges), spurs (a notch protruding from a ridge), bridges (small ridges joining two longer adjacent ridges), and crossovers (two ridges which cross each other).the pattern on fingertips, Fingerprints have been used for personal identification for many centuries and current automatic fingerprint systems have achieved high performance. Even identical twins sharing the same DNA also have different fingerprints. The other advantage of fingerprint recognition is that fingerprint scanners are inexpensive and small, which can be embedded in laptops, mobile phones and personal digital assistants. Fingerprints are selected for many large-scale human identity management projects including the US-visit program and the Hong Kong identity card. Although fingerprint recognition has many advantages, it is still not perfect. People with no or few minutia points (surgeons as they often wash their hands with strong detergents, builders, people with special skin conditions) cannot enroll or use the system.

4. **Iris**, This pattern is unique and stable in whole lifetime. Current iris recognition systems can support real-time large-scale identification up to million records and capture iris images up to 3m. Almost all the commercial iris recognition systems are based on Iris Code developed by Daugman. But the major disadvantages with Iris recognition system is Iris capture devices are costly and User Acceptance is less.
5. **Hand geometry**, Authentication of identity using hand geometry (i.e., length and width of the fingers). Hand geometry is a widely acceptable and robust biometric. It is commonly applied to access control. Nevertheless, the geometric features have only limited information so it is suitable only for verification, 1-to-1 comparisons. The size of the capture device is another problem limiting its applications.
6. **Palmprint**, the inner surface of palms, Palmprint technology is a new branch of biometrics used to identify an individual. Palmprint has rich set of features like palm lines, texture, ridges etc. These features can be used for uniquely identifying a person. Currently, there are two types of Palmprint research, high-resolution approach and low-resolution approach. High-resolution approach is suitable for forensic applications while low-resolution approach is suitable for commercial applications. For Higher resolution images minutia points can also be extracted. Chapter 2 gives detailed discussion about Palmprint recognition system.
7. **Signature**, Biometric signature recognition systems will measure and analyze the physical activity of signing, such as the stroke order, the pressure applied and the speed. Some systems may also compare visual images of signatures, but the core of a signature biometric system is behavioral, i.e. how it is signed rather than visual, i.e. the image of the signature. It is widely accepted in governmental, legal and commercial transactions like banking applications. Each person can have several signatures for different applications. Nevertheless, a signature cannot uniquely identify a person. Many factors can influence the consistency of signatures such as emotional and physical conditions. Furthermore, professional forgers are capable of reproducing signatures to fool recognition systems. But well experienced forgers are there to fool the recognition systems by forging the signature of the authenticated user.

8. **Voice** Our voices are unique to each person (including twins), and cannot be exactly replicated. It is regarded as a combination of behavioral and physiological biometrics is based on the size and shape of the appendages that generate sound. Voice recognition is commonly applied to phone-based applications and therefore, no extra input sensor is required. However, voice recognition faces several difficulties. Voice is neither distinctive nor stable. Current voice recognition systems cannot separate identical twins. Voice also changes due to medical condition, emotional state and aging.

9. **Other biometrics** including gaits, lip prints, brain signals, ears, teeth, retinas, odor, keystrokes, heights, weights, Palm vein and genders have been proposed. They have different characteristics and different potential applications.

1.3 Biometric Terms

There are different biometric traits are there, and this biometric refers to broad range of technologies, so it is essential to discuss the terminology, classifications and unique processes that define biometrics. Biometric system is an automated recognition of the person depending on the behavioral or physiological characteristics of the person. An important issue in designing a practical biometric system is to determine how an individual is recognized. Depending on the application context, a biometric system may be called either a verification or identification system.

1. **Genuine user** is a legitimate user of the system (i.e., who registered already in the system).
2. **Imposter user** is a person who is not authorized one but want to access the system.

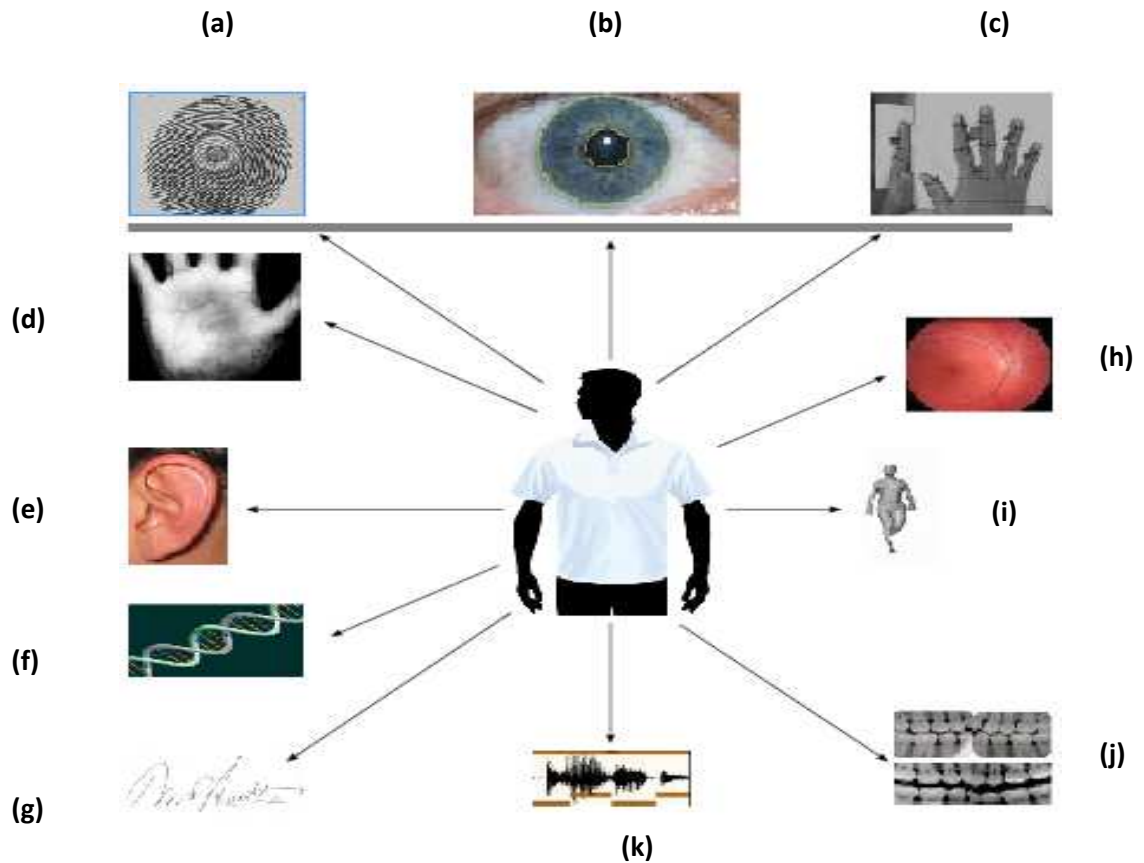


Fig.1.1. Biometric traits (a) Finger print (b) retina (c) hand geometry (d) Palmprint (e) ear (f) DNA (g) Signature (h) iris (i) Gait (j) Dental (k) voice

3. **Template** Data which represents the biometric measurement of an enrollee used by a biometric system for comparison against subsequently submitted biometric samples.
4. **Matching score** is a numerical value that represents similarity or dissimilarity between two biometric signals.
5. **Genuine matching score** is a matching score, by matching two biometric signals from the biometric trait of the same person.
6. **Imposter matching score** is a matching score, which is generated by matching two biometric signals from two different biometric traits (i.e., different users).
7. **Genuine distribution** is a distribution of the genuine matching scores.
8. **Imposter distribution** is a distribution of the imposter matching scores.
9. **Verification system** is a biometric system, simply it is a one-to-one matching first user have to provide user identities like smart cards or other tokens to get the template from the database. Then one-to-one matching is done. By using this matching score generated by comparing an input biometric signal and

retrieved biometric template, depending upon this matching score the recognition system take a decision whether to accept or reject.

10. **Genuine acceptance rate (GAR)** is the probability or the percentage of a verification system correctly verifying a genuine user.
11. **False acceptance rate (FAR)** Measures how frequently unauthorized persons are accepted by the system due to erroneous matching. Potentially serious. The FAR of BioCert devices is currently about .001% is the probability or the percentage of a verification system recognizing an imposter user as a genuine user.
12. **False rejection rate (FRR)**, the probability that the system fails to detect a match between the input pattern and a matching template in the database. It measures the percent of valid inputs which are incorrectly rejected.
13. **Threshold** a numerical value, determines whether to accept two biometric signals from the same trait or not. For dissimilarity measures, if matching score of two biometric signals is greater than a threshold, they are considered to be from two different traits. Otherwise, they are considered to be from the same trait. For similarity measure, if the matching score of two biometric signals is greater than the threshold, they are considered from the same trait. Otherwise, they are considered from different traits.
14. **Receiver operating characteristic (ROC) curve** is a plot of genuine acceptance rate or false rejection rate against false acceptance rate for all possible operating points Fig1.2 shows ROC curve. By seeing this ROC curve we can get the performance of the system.

1.4 Proposed Method

The main aim of our work is extracting the point features and verifying the individual based on the features extracted from the gray scale vein pattern images and designing the vein pattern recognition system. Performance of the unimodal system is evaluated based on the False Acceptance Rate and Genuine Acceptance rates. And results of every method are shown after every step.

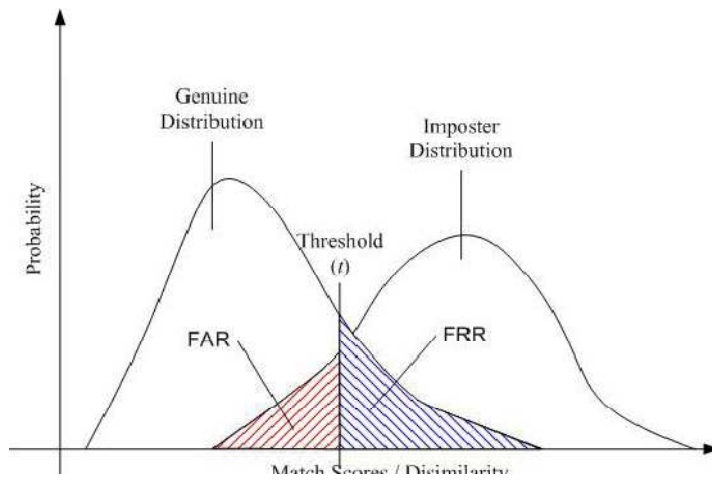


Fig. 1.2 Illustration of common terms used in biometric community

Chapter 2 Outline of Vein Pattern Recognition System

2.1 Introduction of vein pattern

Vein pattern is the new biometric trait in all. Mainly the research is started in Japan and China. Nowadays in Japan over 90% ATM's all are using vein pattern recognition system [1].

2.2 Vein Pattern Recognition System

Vein recognition system consists of following stages [8]. Image Acquisition, Preprocessing, Noise Removing, ROI Extraction, Binarization, Thinning, Feature Extraction, and Matching. Figure 2.1 shows the Vein extraction process flow [21].

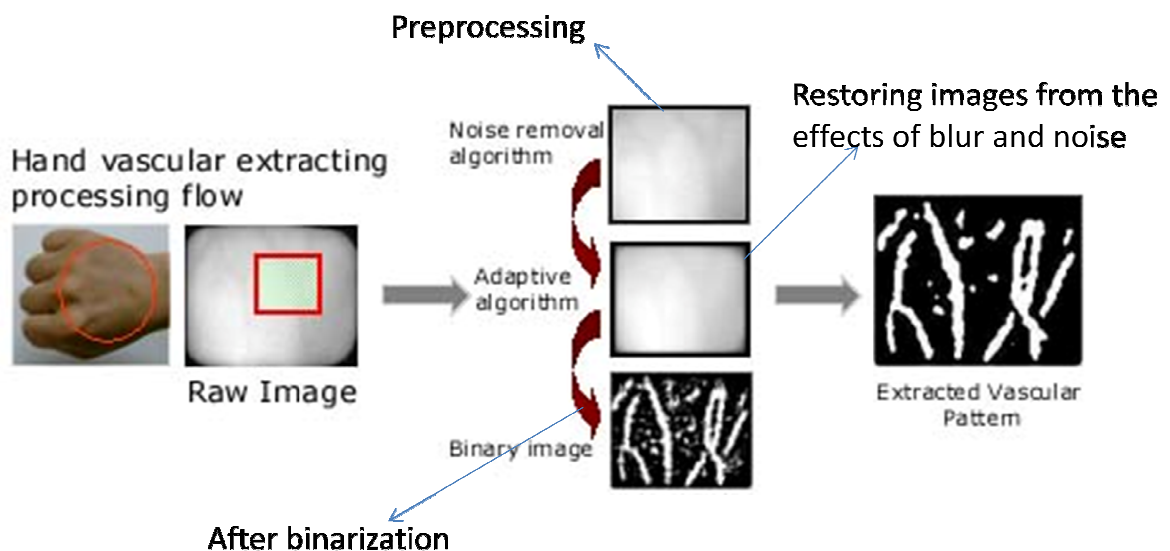


Fig 2.1 Pattern Extraction process view

2.2.1 Image Acquisition

This is the first step in vein pattern recognition system [25]. A technique in which the data from an image are digitized and various mathematical operations are applied to the data, generally with a digital computer, in order to create an enhanced image that is more useful or pleasing to a human observer, or to perform some of the interpretation and recognition tasks usually performed by humans. We are using Near Infrared Cameras to capture the quality image. Sometimes uses CCD (Charge Coupled Device) cameras. Figure 2.2 shows the Vein Pattern Recognition Process [11].

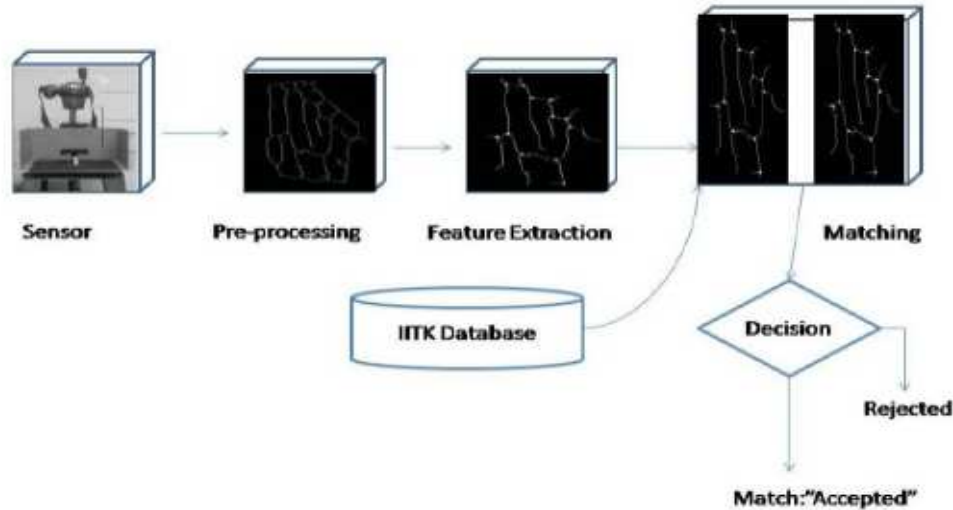


Fig 2.2 Vein Pattern Recognition Process

2.2.2 Preprocessing

Image pre-processing is the name for operations on images at the lowest level of abstraction whose aim is an improvement of the image data that suppress undesired distortions or enhances some image features important for further processing. It does not increase image information content. Its methods use the considerable redundancy in images. Neighboring pixels corresponding to one object in real images have the same or similar brightness value and if a distorted pixel can be picked out from the image, it can be restored as an average value of neighboring pixels. Image pre-processing tool, created in MatLab, realizes many brightness transformations and local pre-processing methods.

Noise Removing

Noise reduction is the process of removing noise from a signal [27] [28]. Noise reduction techniques are conceptually very similar regardless of the signal being processed, however a priori knowledge of the characteristics of an expected signal can mean the implementations of these techniques vary greatly depending on the type of signal.

ROI Extraction

The first step in image pre-processing is image cropping. Some irrelevant parts of the image can be removed and the image region of interest is focused. This tool provides a user with the size information of the cropped image. The output image is of the same class as the input image.

Binarization

A method of binarizing an image by extracting lightness (brightness, density) as a feature amount from the image. When a pixel is selected in an image, sensitivity is added to and/or subtracted from the value concerning the Y value of the selected pixel to set a threshold value range. Next, when another pixel is selected, the sensitivity is added to or subtracted from the value concerning the Y value of the selected pixel and a new threshold value range is set containing the calculation result and the already setup threshold value range. The pixel with the value concerning the Y value of any pixel in the image within the threshold value range is extracted as the same brightness as the selected pixel and the extraction result is displayed.

Thinning

Thinning is a morphological operation that is used to remove selected foreground pixels from binary images, somewhat like erosion or opening. It can be used for several applications, but is particularly useful for skeletonization. In this mode it is commonly used to tidy up the output of edge detectors by reducing all lines to single pixel thickness. Thinning is normally only applied to binary images, and produces another binary image as output.

The thinning operation is related to the hit-and-miss transform [22], and so it is helpful to have an understanding of that operator before reading on.

2.2.3 Feature Extraction

When the input data to an algorithm is too large to be processed and it is suspected to be notoriously redundant (much data, but not much information) then the input data will be transformed into a reduced representation set of features (also named features vector). Transforming the input data into the set of features is called feature extraction [19]. If the features extracted are carefully chosen it is expected that the features set will extract the relevant information from the input data in order to perform the desired task using this reduced representation instead of the full size input.

2.2.4 Matching

Template matching

Template matching [15] is a technique in digital image processing for finding small parts of an image which match a template image. It can be used in manufacturing as a part of quality control, a way to navigate a mobile robot, or as a way to detect edges in images.

Template matching can be subdivided between two approaches: feature-based and template-based matching. The feature-based approach uses the features of the search and template image, such as edges or corners, as the primary match-measuring metrics to find the best matching location of the template in the source image. The template-based, or global, approach, uses the entire template, with generally a sum-comparing metric (using SAD, SSD, cross-correlation, etc.) that determines the best location by testing all or a sample of the viable test locations within the search image that the template image may match up to.

Feature-based approach

If the template image has strong features, a feature-based approach may be considered; the approach may prove further useful if the match in the search image might be transformed in some fashion. Since this approach does not consider the entirety of the template image, it can be more computationally efficient when working with source images of larger resolution, as the alternative approach, template-based, may require searching potentially large amounts of points in order to determine the best matching location.

Template-based approach

For templates without strong features, or for when the bulk of the template image constitutes the matching image, a template-based approach may be effective. As aforementioned, since template-based template matching may potentially require sampling of a large number of points, it is possible to reduce the number of sampling points by reducing the resolution of the search and template images by the same factor and performing the operation on the resultant downsized images (multiresolution, or pyramid, image processing), providing a search window of data points within the search image so that the template does not have to search every viable data point, or a combination of both.

Pattern matching

Pattern matching [16] is a method of identifying features in an image that match a smaller template image (that is, the "pattern" to be matched). The process involves two phases: an off-line learning phase in which the template is processed, and a matching phase that can be executed in real time. This document explains some of the factors involved in pattern matching performance, and strategies that you can use to achieve the best results.

Recognizes the pattern of an image

The target pattern of a reference image is registered and stored in a pattern window. The pattern window then scans the specified search region from the upper left-hand corner to the lower right-hand corner to detect the position that best matches the registered image.

Pattern matching with grayscale processing

Pattern matching uses grayscale image processing, which assigns 256 levels of gray to each pixel and then recognizes the pattern of the target. Binary processing, in contrast, recognizes images only as black and white.

Pattern matching with color extraction

The CV-700/301 Series color vision system recognizes the pattern stored in the pattern window not only through brightness (CV-301), but also through RGB technology which assigns 256 levels of red, green and blue color to each pixel (CV-700). The CV-700/301 Series is ideal for detection of targets with the same shape but different colors.

Histogram matching

Histogram matching is a method in image processing of color adjustment of two images using the image histograms. It is possible to use histogram matching to balance detector responses as a relative detector calibration technique. It can be used to normalize two images, when the images were acquired at the same local illumination (such as shadows) over the same location, but by different sensors, atmospheric conditions or global illumination.

2.3 Advantages

1. Liveness detection is the main advantage.
2. Uniqueness and permanence of the pattern.
3. Contactless detection procedure.
4. Almost impossible to forge or copy.
5. The biometric parameter is hidden from general view.
6. The vein pattern is intricate enough to allow sufficient criteria for positively detecting various subjects even identical twins.

2.4 Disadvantages

1. Injuries or deformations to the hand may cause failure to enroll.
2. Systems which require contact may be considered invasive/unhygienic.
3. Some systems still require PIN or other identification.

2.5 Applications of Vein Pattern Recognition System

1. In ATMs we will use vein pattern biometric for authentication. Over 90% of all ATMs in Japan using vein pattern [26].
2. At Organizations entrances.
3. To secure borders and to authenticate travelers and transportation. For example and US now obtain tamper resistance visas with biometric identifiers.
4. Federal Railroad Administration's (FRA) has developed biometric based Locomotive Security System (LSS) to prevent unauthorized use of locomotives.

Chapter 3 Literature Survey

We started the project with the book titled ‘Vein Pattern recognition’[4], it gives the overview of the vein pattern recognition system and its applications in this world. Vein patterns are of three types those are Palm vein, hand vein and finger vein. Figure 3.1 shows the types of vein patterns

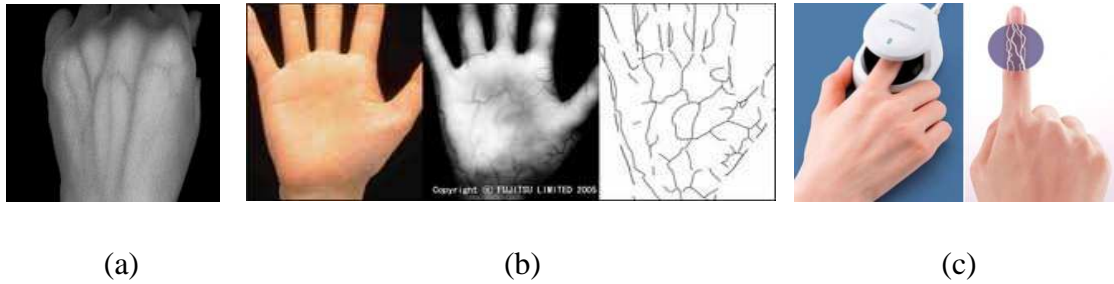


Fig 3.1 Vein Pattern Types (a) Hand Vein (b) Palm Vein (c) Finger Vein (from Google images)

Palm vein as a new and promising biometric feature has drawn lots of research and industry attention. Palm vein owns many outstanding characteristics, such as Liveness detection and verification. However, due to the problem of image rotation, shift and noise, current matching methods are difficult to reach high accuracy. The paper [2] proposed an efficient refinement method for palm vein matching by adopting the iterative closest point (ICP) algorithm, which can accurately align the rotation and shift variations introduced in data acquisition. The experiment results on a large self-collected database show that the proposed method is effective and can greatly improve the accuracy of palm vein verification.

This ICP algorithm overcame the rotation and translation problems. This is the main advantage of this algorithm.

In ‘Palm print verification based on robust line orientation code [6]’, gives a novel robust line orientation code for palm print verification, whose performance is improved by using three strategies. Firstly, a modified finite Radon transform (MFRAT) is proposed, which can extract the orientation feature of palm print more accurately and solve the problem of sub-sampling better. Secondly, we construct an enlarged training set to solve the problem of large rotations caused by imperfect preprocessing. Finally, a matching algorithm based on pixel-to-area comparison has been designed, which has better fault tolerant ability.

The experimental results of verification on Hong Kong Polytechnic University Palm print Database show that the proposed approach has higher recognition rate and faster processing speed.

It works on palm print images, so the line features are extracted from those palm print images for matching. But in veins features are looking like curves. So that it doesn't give good results for vein images.

A New Approach for Vein Pattern-Based Recognition System [8] presents an efficient human recognition system based on vein pattern from the Palma dorsa. A new absorption based technique has been proposed to collect good quality images with the help of a low cost camera and light source. The system automatically detects the region of interest from the image and does the necessary preprocessing to extract features. A Euclidean Distance based matching technique has been used for making the decision. It has been tested on a data set of 1750 image samples collected from 341 individuals. The accuracy of this verification system is found to be 99.26% with false rejection rate (FRR) of 0.03%.

Personal Authentication Using Hand Vein Triangulation and Knuckle Shape [9] paper presents a new approach to authenticate individuals using triangulation of hand vein images and simultaneous extraction of knuckle shape information. The proposed method is fully automated and employs palm dorsal hand vein images acquired from the low-cost, near infrared, contactless imaging. The knuckle tips are used as key points for the image normalization and extraction of region of interest. The matching scores are generated in two parallel stages: (i) hierarchical matching score from the four topologies of triangulation in the Binarized vein structures and (ii) from the geometrical features consisting of knuckle point perimeter distances in the acquired images. The weighted score level combination from these two matching scores are used to authenticate the individuals. The achieved experimental results from the proposed system using contactless palm dorsal-hand vein images are promising (equal error rate of 1.14%) and suggest more user friendly alternative for user identification.

Biometric Authentication by Hand Vein Patterns [10] explains the theoretical foundation and difficulties of hand vein recognition are introduced as first. Then, the threshold segmentation method and thinning method of hand vein image are deeply studied and a new threshold segmentation method and an improved conditional thinning method are proposed. The method of hand vein image feature extraction based

on end points and crossing points is studied initially, and the matching method based on distances is used to match vein images. The matching experiments indicated that this method is efficiently.

And also explains the thinning algorithm, i.e. Conditional thinning algorithm [12]. There are some more literature on thinning is 'Fast Fully Parallel Thinning Algorithms '[13]. This is also a good algorithm for thinning.

Mark the target pixel as 1 and the background 0. The target point in whose 8-neighborhood there is at least one background point is defined as boundary point. The algorithm manipulates the boundary point as follow.

Consider the 8-neighborhood centered by the boundary point. That is to say that the center point is p_1 , its 8-neighbourhood points are signed as p_2, p_3, \dots, p_9 deasil. p_2 is on the top of p_1 is 1 and satisfy the following four conditions at the same time, then delete p_1 .

Conditions are as follows

- 1) $2 \leq N(p_1) \leq 6$; where $N(p_1)$ is no of non-zero boundary points.
- 2) $S(p_1) = 1$; $S(p_1)$ is the changing times of the points value from 0 to 1 in order of p_2, p_3, \dots, p_9 .
- 3) $p_2 * p_4 * p_6 = 0$;
- 4) $p_4 * p_6 * p_8 = 0$;

All points marked are eliminated after all of boundary points have been checked out. repeat it for every point of the image till all of the pixel point can't be deleted.

This algorithm has some drawbacks, so it gives some noise in thinned image. So that pruning concept comes into picture here.

Pruning is the method of removing unwanted edges from the skeleton image. After that we should clean the image. Clean is the method of removing isolated pixels.

By all these literature learned lot about vein pattern recognition system and taken some techniques and implemented in our system. Our vein pattern recognition system detailed explanation in upcoming chapters.

Chapter4. New Approach for Vein Pattern Recognition System

4.1 Binarization

A method of binarizing an image by extracting lightness (brightness, density) as a feature amount from the image. When a pixel is selected in an image, sensitivity is added to and/or subtracted from the value concerning the Y value of the selected pixel to set a threshold value range. Next, when another pixel is selected, the sensitivity is added to or subtracted from the value concerning the Y value of the selected pixel and a new threshold value range is set containing the calculation result and the already setup threshold value range. The pixel with the value concerning the Y value of any pixel in the image within the threshold value range is extracted as the same brightness as the selected pixel and the extraction result is displayed.

We have done binarization using thresholding method. This method is gives good results for me among other all methods. I have taken pixel intensity as the feature to binarize the image. Taken intensity value which is nearer to the vein pattern intensity and set it as threshold. If intensity is more than or equal to the threshold that pixel will be in the resultant image and other are pixels are removed.

We are set some threshold to the image and according to that I can divide image into two values. Here I put 165 as threshold value for the image. The pixel values above the threshold are set to white and other are set to black. Fig 4.1 shows the Vein Pattern ROI images and Fig 4.2 shows the Binarized Images

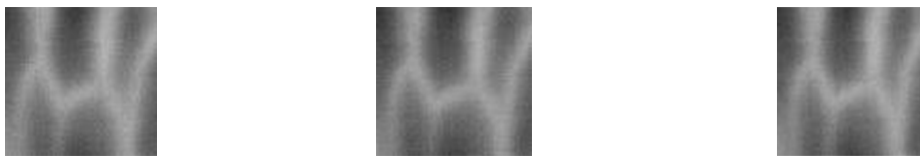


Figure: 4.1 Vein Patten ROI Images



Figure: 4.2 Binarized Images

4.2 Thinning

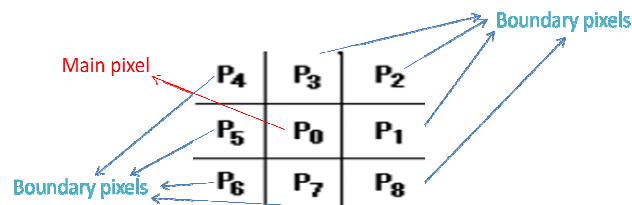
Speedup Method for Real-Time Thinning Algorithm [5] [7]

Hilditch Thinning Algorithm:

This algorithm used to thin the image; it takes 8 points around the pixel to thin the image. In this process it faces some boundary problems.

Boundary problems means according to this algorithm some main or crucial points on the boundary also have possibility to remove.

So this paper overcomes these boundary problems of the Hilditch Algorithm.



Here we take one pixel in the image and take 8 boundary pixels for that image. And then we have to calculate the adjacent pixel for that pixel.

If the pixel value is satisfies the following 5 conditions then this pixel will the target or resulting pixel, otherwise exclude it.

Condition 1

The pixel p_0 is part of a skeleton.

$$\sum_{i \in N_{\text{odd}}} \{1 - |B(p_i)|\} \geq 1$$

Where $B(P_i)$ = Pixel value

P_i here i is from 1 to 8

Condition 2

It will not be deleted when pixel p_0 is boundary of one skeleton.

$$\sum_{i \in N_8} |B(p_i)| \geq 2$$

Condition 3

It will not be deleted when pixel p_0 is isolate pixel.

$$\sum_{i \in N_8} C_i \geq 1$$

Here $C_k = \begin{cases} 1 & \text{for } B(p_i) = 1 \\ 0 & \text{for } B(p_i) \neq 1 \end{cases}$

Condition 4

It will not be deleted when pixel p_0 is a connective pixel.

$$N_c^8(p_0) = 1$$

Here $N_c^8(p_0)$ is

$$\sum_{i \in N_{8w}} \{D(p_i) - D(p_i) \times D(p_{i+1}) \times D(p_{i+2})\}$$

The value of $D(p_i)$ is

$$\begin{cases} 1 & \text{for } |B(p_i)| = 1 \\ 0 & \text{for } |B(p_i)| \neq 1 \end{cases} \quad i \in N_8$$

Condition 5

Only one side will be deleted when the width of skeleton is two pixels. The condition can be represented using two equations.

$$\begin{aligned} B(p_i) &\neq -1 & (i \in N_8) \\ N_c^8(p_0) &= 1 & \text{when } B(p_i) = 0 \end{aligned}$$

Real-Time Thinning Algorithm:

- It is the proposed algorithm in this paper.
- This algorithm overcomes the boundary problems.
- It calculates the values for the adjacent pixels in the image and gives the values 0, 1, -1.
- If the value is -1 pixel will be remove, if it is 1 don't change the pixel and finally it is 0 we will take it as a next pixel. Fig 4.3 shows the Binarized Images and Fig 4.4 shows the Thinned Images.

Results of Thinning



Figure: 4.3 Binarized Images



Figure: 4.4 Thinned Images

4.3 Matching

Matching is the final step in the vein pattern recognition. After matching the finally matching algorithm tells that the user is authenticated or not.

Generally matching is doing in some different types of methods. Those are already explained in the 2nd chapter (2.2.4). Briefly the types are template matching, histogram matching and pattern matching. Apart from that there are two types of matching techniques, one is Feature Based Matching and second is line matching. Vein patterns are lines or curves. [23,24]

In feature based matching, algorithm takes one feature like lines, Knuckle tips and as well as Bifurcation points etc.

In my matching algorithm if bifurcation points and ending point's matches then the two images are matches.

Matching Algorithm consists of two steps.

1. Extraction of Bifurcation and End Points.
2. Matching.

4.3.1 Extraction of Bifurcations Points and Ending Points

The individuality of vein structure is exclusively determined from the relationship among the local vein characteristics. Therefore, the extracted vein pattern is firstly used to locate the key points that are relatively stable, unique and repeatable. The vein

bifurcation and endings points [20] are selected as key points to extract local vein properties [9]. A vein bifurcation is defined as vein point where vein forks or diverges into branch veins, and the vein ending is the point at which vein ends or disappears abruptly. This disappearance could be due to the abrupt ending of blood vessels are their poor visibility from the imaging system. In order to extract the vein endings and bifurcation points we examining the connectivity of every pixel and determine the crossing number $R(m)$ for every pixel m [17]. The crossing number $R(m)$ is the sum of differences between pairs of adjacent pixels in 3×3 window centered at m

$$R(m) = \sum_{z=1}^8 |val(\mathbf{m}_{z \bmod 8}) - val(\mathbf{m}_{z-1})|.$$

The pixel m with $val(m) = 1$, corresponds to vein ending point if $R(m) = 2$, and corresponds to vein bifurcation point if $R(m) \geq 6$.

4.3.2 Matching

Matching the last phase in all vein pattern recognition system .After matching only the user verifies his identity [14].

In our algorithm after extraction of vein bifurcation points and endings, then we have to match two images with their pixel positions of bifurcation points and ending points.

Here find out the positions of Bifurcation Points and Ending Points in template image and match their pixel positions in the input image. One template image compared with the remaining all images in the database. Then we get the matching score of the images with template image.

Matching Score Calculation

Matching score calculated as given below

$$P = z / t * 100$$

Where z is the sum of the no of matching's z_1 , z_2 of the vein bifurcation and ending points respectively. i.e. $z = z_1 + z_2$.

$$\text{Where } t \text{ is the total number of attempts. i.e. } t = S1(2) + S2(2)$$

P is the matching score of the input image with the Template.

Where $S1(2)$ and $S2(2)$ are the number of attempts to match bifurcation and end points respectively.

4.4 Experiment and Results:

I have done the matching for vein pattern authentication with 160 images of 33 users. Got the matching scores one image with all remaining images with different thresholds. Here the threshold means that the small square area around the bifurcation point. Set threshold as a small square area with 4, 6, 8, 10, 12, 14 pixels along x-axis and y-axis. Windows are taken as 4*4, 6*6 ...14*14. Then algorithm checks the bifurcation point in that small square area or not. If it is inside the small square area then the point is matched. Like that all bifurcation and end points compared with one another of the input image, and then we got the final matching scores calculated as given above in section 4.2.

4.4.1 FAR and GAR calculation:

FAR calculation:

FAR is false acceptance rate that means how much percentage of false users accepted by the system? The calculation of FAR is

$$\text{FAR} = \text{No. of False acceptances} / \text{total number of attempts.}$$

GAR calculation:

GAR is genuine acceptance rate that means how much the genuine users are accepted by the system. GAR calculated from FRR i.e. False Rejection Rate.

$$\text{GAR} = 1 - \text{FRR}$$

FRR is false rejection rate the probability that the system fails to detect a match between the input pattern and a matching template in the database. It measures the percent of valid inputs which are incorrectly rejected. Table 4.1 Shows the FAR and GAR results in percentage.

FAR and GAR results:

Threshold (Pixel Range)	FAR (%)	GAR (%)
4	1.2579	98.7421
6	1.8868	98.1132
8	2.5157	97.4843
10	3.7736	96.2264
12	4.4025	95.5975
14	13.2075	86.7925

Table 4.1 Results of FAR and GAR

Chapter 5 Future Work

Vein Pattern is the emerging biometric technique. In our vein pattern recognition system we are using bifurcation points and end points of vein pattern those are called as minutiae points as the features for matching. So that the extension to my work is that by using these minutiae points construct Delaunay triangulation [18] and then match their edges lengths along with points matching.

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