

Alternative Framework for Enhancing Image Quality of the Fingerprint

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Abstract

Fingerprint Identification is one of the most popular biometric methods used to verify and identify a person; formally it is defined as “The pattern of ridges and furrows on an individual finger”. Ridges are the lines in thumb and furrow is shallow trench of skin on an individual’s finger. Furrow is also referred to as valley. The combination of ridges and furrows makes an individual’s fingerprint and it’s called minutiae. A critical step in Fingerprint is to automatically and reliably extract minutiae from input finger print images. However the performance of the Minutiae extraction algorithm and other fingerprint recognition techniques relies heavily on the quality of the input fingerprint image. In order to ensure that the performance of the minutiae extraction algorithm will be robust with respect to the quality of input fingerprint images, an enhancement framework which can improve the clarity of the ridge structures is necessary. In this paper we reviewed, analyzed and evaluated some of the existing frameworks for image enhancement of the fingerprint which used Image or Minutiae Based and anticipated outcome of this effort is alternative hybrid framework of enhancing fingerprint image quality, that is a more proactive and consistent approach of improvement, 100 fingerprint from 4 DBs of FVC2006 was used for experiment and tested in MATLAB & Adobe Photoshop image processing Software’s, result indicates that proposed enhancement framework improved gap knowledge of the analyzed existing frameworks and Fingerprint were enhanced by correcting and removing noise from the input fingerprint.

Keywords: Biometric; Enhancement; Fingerprint; Image Processing; Image Quality; Minutiae.

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1. Introduction

Information Technology and Physical Security convergence is attractive topic in these decades, the primary focus of data protection is often an electronic solution – firewalls, passwords, encryption, etc. – but it's important to overlook the physical protection of data and the equipment on which it is maintained, both from theft and unauthorized access, for that basis [1], Biometrics is defined as an evident physiological or behavioral characteristic that can be used to authenticate or validate an individual's identity [2], Biometric provides automated method to identify a person based on physiological or behavioral characteristics. The unique features measured are face, fingerprints, hand geometry, handwriting, iris, retina, vein, and voice [3].

If look deeply to fingerprint which is the most popular biometric system and the most important approaches for identification in Biometric Security System, Fingerprint Identification is one of the most popular biometric methods used to verify and identify a person; formally it is defined as “The pattern of ridges and furrows on an individual finger”. Ridges are the lines in thumb and furrow is shallow trench of skin on an individual's finger. Furrow is also referred to as valley. The combination of ridges and furrows makes an individual's fingerprint. The combination of ridges and furrows that make the fingerprint of each person unique is called minutiae. The uniqueness of a fingerprint is exclusively determined by the local ridge characteristics and their relationships [4,5]. The fingerprint images are not always provided with good quality due to skin conditions (wet or dry, cuts, and bruises), sensor noise, incorrect finger pressure, and worn-off ridges fingers (elderly people, manual workers), Minutiae points resulted in either ridge ending or ridge bifurcation, the performance of fingerprint recognition system is depends on the quality of fingerprint image, therefore, most of the efforts required for improving the quality of fingerprint image, A critical step in Automatic Fingerprint system is to automatically and reliably extract minutiae from input finger print images. However the performance of the Minutiae extraction framework and other fingerprint recognition techniques relies heavily on the quality of the input fingerprint image. In an ideal fingerprint image, ridges of fingerprint and valleys of fingerprint alternate and flow in a constant direction. However the fingerprint images obtained are usually poor due to elements that corrode the clarity of the ridge elements such as noise. This leads to issues in minutiae extraction [6,7]. Thus, image enhancement techniques will employ to reduce the noise and enhance the definition of ridges against valleys. In order to ensure good performance of the ridge and minutiae extraction algorithms in poor quality fingerprint images of database, an enhancement algorithm is applied to improve the clarity of the ridge structure is necessary. The rest of the paper is organized as follows: Section 2 describes the theoretical background and existing frameworks needed for the understanding of the method. In Section 3 the experimental framework and the enhancement algorithm are explained. The experimental results are presented in Section 4 and the discussion and conclusions in Sections 5 and 6 respectively.

2. Theoretical background

2.1. Biometrics and their Importance

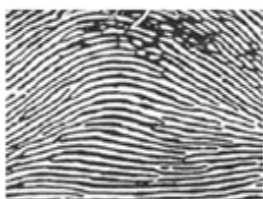
Physical Security for Biometric Systems is desire list for every organization such as Banks, Telecommunications, Schools and even every country, challenges faced by Organizations, including physical security and ICT needs, that it will be interesting to find out at the end of the year the level to which these self-

imposed targets were met, or missed [8]. One of the techniques used in physical security is biometric system and has been broadly classified into two major areas namely behavioral and psychological biometric. Behavioral biometric has certain parameters such as signature, speech and etc. but these parameters change with time and environment and every person can have more than one signature or speech. Whereas the physiological characteristics such as palm print and fingerprint remain unchanged throughout the individual life span and no person can have more than one palm print or fingerprint [9].

2.2. Fingerprint and its Minutiae's

Fingerprints are the patterns formed on the epidermis of the fingertip. Skin on human fingertips contains ridges and valleys which together forms distinctive patterns. A fingerprint is comprised of ridges and valleys, the ridges are shown in the dark area of the fingerprint and the valleys are shown in the white area that exists between the ridges, a ridge is defined as the single curved segment, and valley lies between the two adjacent ridges. These patterns are fully developed under pregnancy and are permanent throughout whole lifetime. Prints of those patterns are called fingerprints. The interleaved pattern of ridges and valleys are the most evident structural characteristic of a fingerprint [7,10]. There are 3 specific classes for all fingerprints which are arches, loops, and whorls:-

- An arch has friction ridges that enter on one side of the finger and cross to the other side while rising upward in the middle. They do not have type lines, deltas, or cores.
- A loop must have one or more ridges entering and exiting from the same side. Loops must have one delta; these patterns are named for their positions related to the radius and ulna bones.
- Whorl is a plain or central pocket whorl has at least one ridge that makes a complete circuit. A double loop is made of two loops. An accidental is a pattern not covered by other categories. Whorls have at least two deltas and a core [11].



5% of the Population (ARCH)



30% of the Population (WHORL)



65% of the Population (LOOP)

Figure 1: Three classes of fingerprint.

In biometrics and forensic science, major features of a fingerprint are minutiae, using which comparisons of matching and recognition of one print with another can be made, Minutiae include: Ridge ending – the abrupt end of a ridge, Ridge bifurcation – a single ridge that divides into two ridges, Short ridge, or independent ridge – a ridge that commences, travels a short distance and then ends, Island – a single small ridge inside a short ridge or ridge ending that is not connected to all other ridges, Ridge enclosure – a single ridge that bifurcates and reunites shortly afterward to continue as a single ridge, Spur – a bifurcation with a short ridge branching off a

longer ridge, Crossover or bridge – a short ridge that runs between two parallel ridges, Delta – a Y-shaped ridge meeting, Core – a U-turn in the ridge pattern[12].

2.3. Existing Framework

With regard to fingerprint framework of recognition, there are exists widely used distinction between identification and verification. Comparing one fingerprint against a reference sample in order to verify an identity claim (i.e., is this person who he claims to be?) is referred to as “verification”. In contrast to this, “identification” refers to the process of potentially recognizing a certain fingerprint within a large database of fingerprints (i.e., within database, who does this fingerprint belong to?) [13].

But when minutiae on prints match, these are called points of similarity or points of identification. At this point there is no international standard for the number of points of identification required for a match between two fingerprints. However, the United Kingdom requires a minimum sixteen points while Australia requires twelve. There are no legal requirements in the United States and other countries on the number of points. Generally, criminal courts will accept 8 to 12 points of similarity; a ridge count is another characteristic that distinguishes one fingerprint from another. The count is made from the center of the core to the edge of the delta [14].

Fingerprint matching is challenging as the matcher has to minimize two competing error rates, which are the False Accept Rate and the False Reject Rate of fingerprint security systems and that why it is important to enhance the fingerprint image quality. Researchers presented a framework which becomes popular to improve the performance of AFVS using ensemble learning approach to fuse related information of fingerprints. They proposed a novel framework of fingerprint verification which is based on the multi template ensemble method; their framework is consisted of three stages. In the first stage, enrollment stage, they adopted an effective template selection method to select those fingerprints which best represent a finger, and then, a polyhedron is created by the matching results of multiple template fingerprints and a virtual centroid of the polyhedron is given. In the second stage, verification stage, they measured the distance between the centroid of the polyhedron and a query image. In the final stage, a fusion rule is used to choose a proper distance from a distance set [15].

Patra and Panda purposed a fingerprint recognition framework based on Minutiae based matching quite frequently used in various fingerprint algorithms and techniques Figure below presents an overview of the project’s design flow. A match score histogram obtains by the minutiae-based fingerprint recognition system under conditions [16].

2.4. Gap of the Study

It is necessary to acquire high quality images of fingerprint, as matching framework should be further improved; Experiments with various versions of matching algorithms from a commercial vendor suggest that there is still some opportunity for improvement. An earlier study had already demonstrated the benefits of such measures, Improvements can be made with respect to adaptations towards fingerprint feature dimensions and image processes enhancement, the qualities of fingerprint images and fingerprint sensor characteristics have a great influence on the performance of a fingerprint matching system, Thus below table is the analysis of existing

framework for fingerprint image, as it contributes the analysis of this table some the existing framework have limitations such as increased the time of performance and high computation, focus of specific part like children, Maritime and wet fingerprint and verification process, evolution and efficient purpose, estimation and definition of rule, only template based, Multi stage image enrollment, less speed and Waves of ridges miss and Storage space is occupied for a more than one encryption method, No data for children above 12 years, No additional metadata such as gender and body height, No high image enhancement, not clear other methods for using it on the framework, It is therefore common to employ fingerprint enhancement to increase the image quality and to improve the matching performance. In this paper, the proposed enhancement method focused the computational speed, improvement of the performance, and making easy the verification and identification processes [17,18].

Table 1: Gap Analysis.

Method	Advantage	Limitations
Fingerprint Recognition using minutiae	enhancement to minutiae extraction of fingerprints	Based only Minutiae, low verification rate
Fingerprint Image Quality Estimation Using a Fuzzy Inference System	Estimates the quality of fingerprints, define rules using experts' knowledge for combining local fingerprint features into a single quality score, improvement in EER	Doesn't shows significant performance or enhancement of fingerprint, only estimation and definition for rule, both FAR & FRR are high possible equal, increased the time of performance
A framework of multi template ensemble for fingerprint verification	With a minutiae-based matching method, the average EER of four databases in FVC2004 drops from 10.85 to 0.88, and with a ridge-based matching method, the average EER of these four databases also decreases from 14.58 to 2.51	Only focused verification, ridge and minutiae based, Multi stage image enrollment, less speed and waves of ridges miss and storage space is occupied for a more than one encryption method
Fingerprint Recognition for Children	Test children fingerprint, quality metrics for under seven year children	Focus children, no data for children above 12 years, no additional metadata such as gender and body height
An Efficient Method for Recognizing the Low Quality Fingerprint Verification by Means of Cross Correlation	Use AFRS method, Edge detected image and Field Oriented Image	Only checks efficient, focus on verification, no high image enhancement, possible high FAR & FRR

3. Materials and Methods

This study takes up experimental research design. The major purpose of utilizing is an attempt to maintain

control over all factors that may affect the result of an experiment, experimental designs produce the strongest, most valid results; it represents the most valid approach to the solution of educational problems, both practical and theoretical, and to the advancement of education as a science. A conceptual framework is an analytical tool with several variations and contexts. It is used to make conceptual distinctions and organize ideas. Strong conceptual frameworks capture something real and do this in a way that is easy to remember and apply. The use of the term conceptual framework crosses both scales (large and small theories), they define a conceptual framework as “the way ideas are organized to achieve a research project’s purpose. FVC 2006 Databases were used for this paper as source of the fingerprints and also Mat-lab 2015 and Adobe Photoshop CS6 were used in the Experiments. This paper depicts the automated process of fingerprint Image quality enhancement in more detail, its main elements are: -

- Acquisition of fingerprint image (by an acquisition device),
- Image processing (to enhance the relevant information),
- Feature extraction (to encode the found information)
- Storing and comparison of the fingerprints.

This is basic method for complete fingerprint system [19] and it is also the based content of our proposed framework.

3.1. Proposed Framework

The fingerprint image has reached many improvements and modifications by various researchers. However, the major concerns with the fingerprint framework are the quality of the image. Fingerprint Image Enhancement is a process for improving the appearance or permanence for particular Fingerprint image. In fingerprint recognition system the enhancement is an essential step for feature extraction and matching. In general performance of the fingerprint system is greatly depends on quality of fingerprint image, thus, good quality input image gives good performance whereas poor quality image gives poor performance. In this paper, a new alternative approach for the fingerprint image enhancement is presented, a fingerprint image enhancement algorithm receives an input fingerprint image in pre-processing and applies a set of intermediate steps on the input image which are image processing and minutiae features extraction, and the post-processing steps, finally outputs the enhanced image. The proposed alternative framework for enhancement of fingerprint image quality is based on hybrid technique, because minutiae-based and image-based techniques have their strengths and weaknesses. The proposed hybrid method is composed of appropriate algorithms from both of the techniques, taking the minutiae based technique as the backbone for this framework. The main aim of the proposed method is to obtain the optimal enhanced fingerprint image to store or to compare the referenced one; Figure below shows the flowchart for the hybrid framework. The framework, as it is with the straight system, consists of the image pre-processing, image processing and minutiae feature extraction, image post processing stage, and finally the fingerprint matching process.

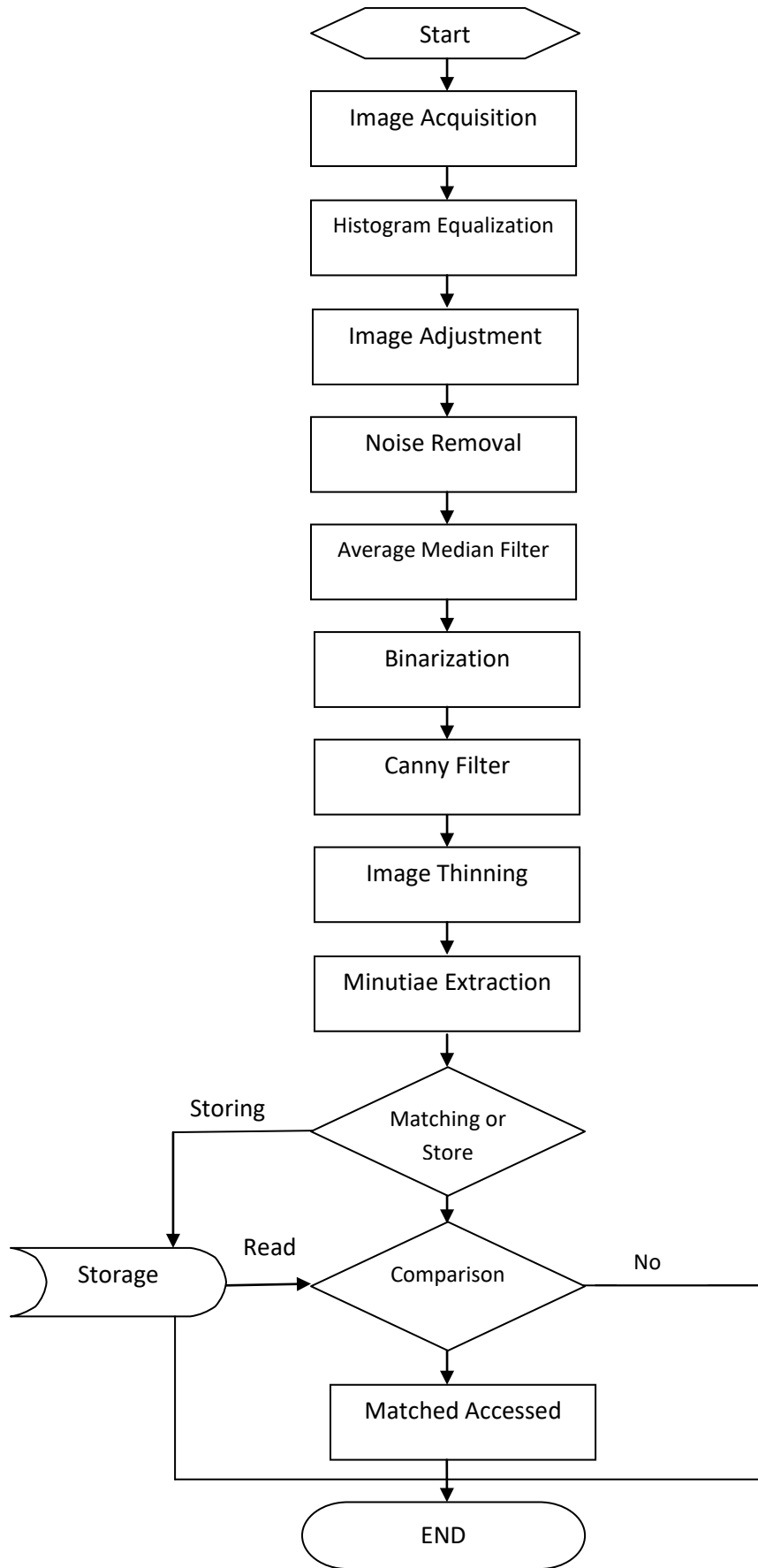


Figure 2: proposed framework for enhancement of the fingerprint image.

In the proposed framework, the first step is to get the input fingerprint image; fingerprint image can be scanned in many different live-scan fingerprint devices and are used as fingerprint acquisition. In generally one of the most important and time-consuming tasks of any biometric system evaluation is the data collection. As mentioned already, this paper uses fingerprint from Fingerprint Verification Competition (FVC 2006), the Fourth International Fingerprint Verification Competition containing four disjoint fingerprint databases, each collected with a different sensor/technology.

Table 2: Fingerprint Verification Competition Databases

Sensor Type	Image Size	Resolution
DB1 Electric Field sensor	96x96 (9 Kpixels)	250 dpi
DB2 Optical Sensor	400x560 (224 Kpixels)	569 dpi
DB3 Thermal sweeping Sensor	400x500 (200 Kpixels)	500 dpi
DB4 SFINGE	288x384 (108 Kpixels)	about 500 dpi

Second Step is Histogram Equalization, which is applied to enhance the ridges of the fingerprint images. Histogram Equalization reassigns a new value of a pixel based on the image histogram. Histogram equalization is a technique of improving the global contrast of an image by adjusting the intensity distribution on a histogram; this allows areas of lower local contrast to gain a higher contrast without affecting the global contrast. Histogram equalization accomplishes this by effectively spreading out the most frequent intensity values. Third step is Image Adjustment, which is to correct the image and enhance it, in this paper fingerprint image is adjusted using Adobe Photoshop, image rotation and cropping adjustment. This process is necessary in order for the images to satisfy the upright requirement for the matching process, which some of the images in available databases may not be in. Histogram image graph is leveling up, and it describes the tonal range of the Fingerprint Image starting with the blacks and continuing white. An ideal Histogram would taper to each end without going off the edge; his process reduces unwanted noise and increases the contrast of the image effectively for fingerprint images with low contrast. Our next adjustment is Curves, In the Curves adjustment; you adjust points throughout an image’s tonal range. Initially, the image’s tonality is represented as a straight diagonal line on a graph, Contrast enhancement remains one of the most important issues in image processing. Among all image processing techniques, it is the one that has the strongest impact on image quality. Many contrast enhancement techniques have been introduced to improve the contrast of an image but there seems to be no universal method for all applications, simply because the kind of correction depends on the scene. The above processes are to detect the core of the fingerprint. These algorithms are part of the image-based matching technique, which is now hybrid with the minutiae-based technique. The core detection algorithm discovers and detects the reference point in a fingerprint image. To determine the region of interest (ROI), a feather image processing and feature extraction is implementing. Basically, a minutia matching is a process is in two steps: Find Total Minutia Points: Find Location of Minutiae Points [20].The fourth Step is Noise removal which is the

process of removing noise from a fingerprint image, Image noise is random variation of brightness or color information in fingerprint images, one goal in image re-establishment is to remove the noise from the image in such a way that the "original" image is visible. The fifth Step is Average and Median Filter, Average (mean) filter smoothes fingerprint image data, thus eliminating noise. This filter performs spatial filtering on each individual pixel in an image using the grey level values in a square or rectangular window surrounding each pixel. Median filter is used to remove salt-and-pepper noises or spot-like noises. If a pixel is accidentally changed to an extreme value caused by various reasons, then the result of filter can achieve excellent result. The advantage of median filter is to keep the edge of the image and to remove salt-and-pepper noises in the images. The sixth step is Fingerprint Image Binarization, to transform the 8-bit Gray fingerprint image to a 1-bit image with 0-value for ridges and 1-value for furrows. After the operation, ridges in the fingerprint are highlighted with black color while furrows are white. A locally adaptive Binarization method is performed to binarized the fingerprint image. Such a named method comes from the mechanism of transforming a pixel value to 1 if the value is larger than the mean intensity value of the current block to which the pixel belongs. Seventh Step and Eighth Step is canny edge detection and image thinning, which starts with linear filtering to compute the gradient of the fingerprint image intensity distribution function and ends with thinning and thresholding to obtain a binary map of edges. Image Thinning eliminates the redundant pixels of ridges till the ridges are just one pixel wide. An iterative, parallel thinning algorithm is using. In each scan of the full fingerprint image, the algorithm marks down redundant pixels in each small fingerprint image window and the pixels to be removed are marked in the first instance and then removed in a second pass over the image. This process is repeated until there are no more redundant pixels left and finally removes all those marked pixels after several scans. The remaining pixels are those belonging to the skeleton of the ridges and no minutiae points have been removed. This is called thinning by successive deletion. After Fingerprint features have been extracted it is to store on storage or to compare the input image to referenced Fingerprint image that has been stored. This stage, if it is enrollment stage to store the fingerprint, it store the enhanced features into the Database or if it verification stage to verify the fingerprint for the purpose of accessing other related system.

4. Experimental Results

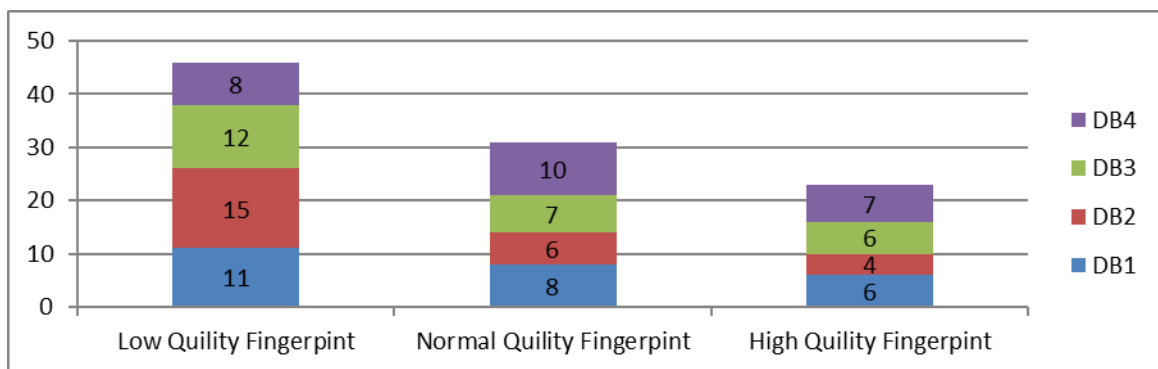


Figure 3: Experiment test for Fingerprint for different qualities from FVC 2006 four DB.

This is done to improve the image quality and to make it clearer for further operations. Often fingerprint images from various sources lack sufficient contrast and clarity. Hence image enhancement is necessary and a major

challenge in all fingerprint techniques to improve the accuracy of matching. It increases the contrast between ridges and furrows and connects the some of the false broken points of ridges and some noise due to insufficient amount of ink or poor quality of sensor input. The proposed fingerprint image enhancement framework is tested on 100 fingerprint images which are selected randomly and without repetition from 4 databases DB-finger of Fingerprint Verification Competition (FVC 2006) to evaluate the efficiency of this framework; FVC contain fingerprint images of various qualities, including normal, high and poor quality. Table 5.1 shows a summary of the database used for this work.

Step 1 image Acquisition to get an input image, the input fingerprint image is enhancing in order to obtain a better fingerprint image quality the acquisition process of this experiment was used as mentioned in Table 4.1 and fingerprint Image was from FVC.

Step 2 after image getting operation, the fingerprint image is to enhance using histogram equalization, which to enhance the ridges of the fingerprint images and reassigns a new value of a pixel based on the image histogram; this process is test using Mat lab and Adobe Photoshop.

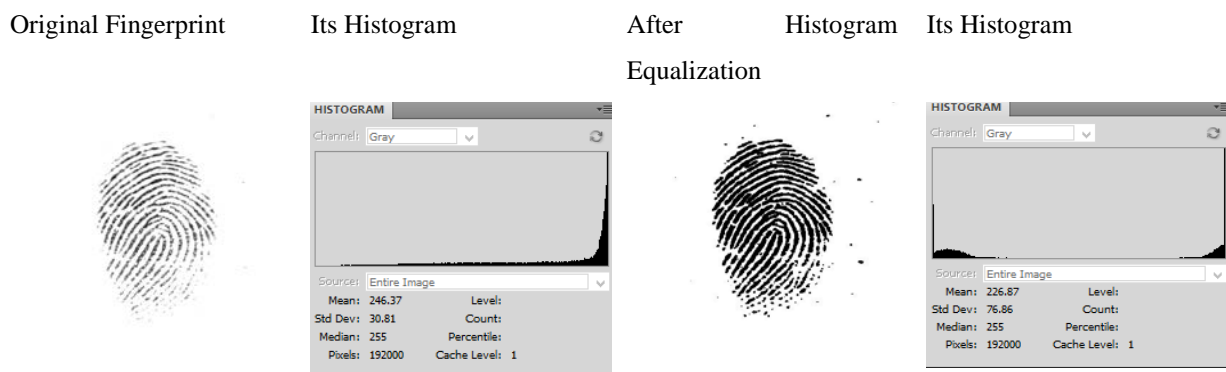


Figure 4: proposed fingerprint enhancement process result view Step 1 & Step 2.

Step 3 the fingerprint image is to correct and adjust using adobe Photoshop, This process is necessary in order for the images to satisfy the upright requirement.

Step 4 and Step 5 the goal in fingerprint image quality improvement is to remove the noise from the image in such a way that the "original" image is able to be seen. The Average and Median Filter, Average (mean) filter smoothes fingerprint image data, thus eliminating noise.

Step 6 after noise is removed from the fingerprint image, it is to binarize, thus ridges in the fingerprint are highlighted with black color while furrows are white.

Step 7 and Step 8 canny edge detection and image thinning, which starts with linear filtering to compute the grade of the fingerprint image strength and ends with thinning the edges of the fingerprint and thresholding to obtain a binary map of edges.

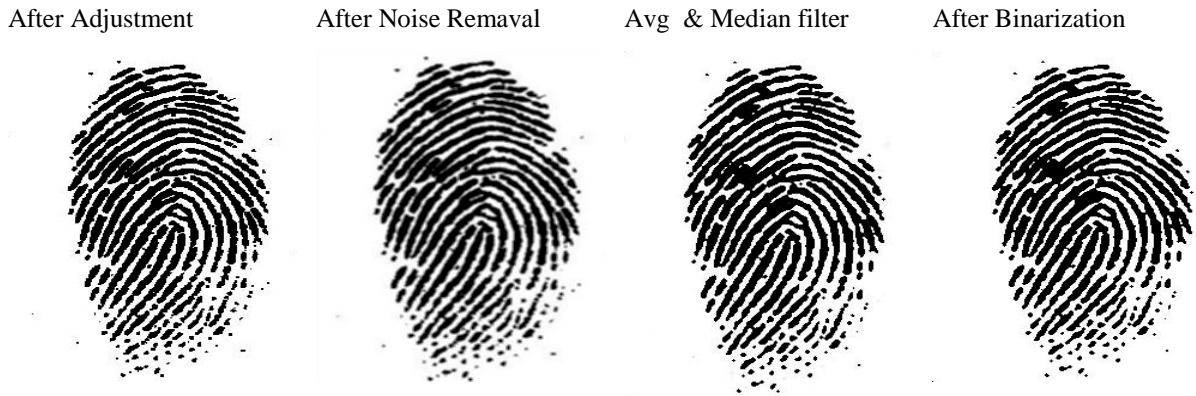


Figure 5: Proposed fingerprint enhancement process result view Step 3 - Step 6

Step 9 up to end after fingerprint image is enhanced feature must extract to enrol or to verify the fingerprint.

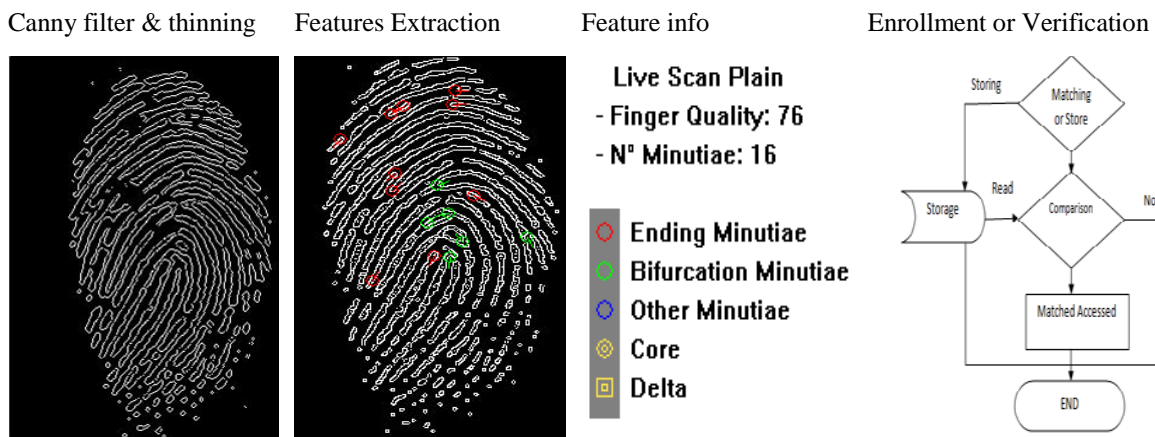


Figure6: proposed fingerprint enhancement process result view Step 7 up to end.

5. Discussions

There have been many framework developed for fingerprint image enhancement. Most frameworks found in the literature are somewhat used Minutiae based only or image based only but in proposed framework, we have used hybrid for both image and Minutiae based. the aims of this hybrid framework is to tackle the issue of fingerprint matching for low quality images and enhance them but it also conduct to the other qualities. The experiment was conducted on 31% normal quality, 23% high quality and 46% low or poor quality images. Each image was treated to the same process as described in proposed framework. Results indicated that the proposed hybrid framework made enhancement and improved the of fingerprint images using hybrid framework as shown above steps about 96% and remain 4% are not enhanced due to the high inked fingerprint which hid 3/4 of the fingerprint image minutiae.

6. Conclusions

In this paper, we have proposed an alternative framework for enhancement of noisy fingerprint images, Which is

hybrid framework to improve on two conventional fingerprint matching techniques, namely the minutiae-based and image-based techniques by taking specific features from the image-based technique, and integrate it into the minutiae-based technique such that the accuracy of fingerprint matching with low quality fingerprint images can be improved. Proposed framework includes all the stages from enhancement to minutiae extraction of fingerprints, which are grouped in three stages, preprocessing stage which is to obtain and enhance the fingerprint and next there are various standard techniques that are used in the intermediate stages of processing such as image processing and feature extraction and end with post-processing stage which is to extract the minutiae and enroll or verify them. We have taken experiments on a 100 fingerprint image from FCV 2006 database. The results show that fingerprint images are enhanced successfully 96%, Remain 4% images were not successfully enhanced due to excessive ink which hides $\frac{3}{4}$ or more of the fingerprint minutiae. This proposed framework shows the good performance for enhancement as correcting and removing noise of the fingerprint. As major challenge in Fingerprint recognition lies in the preprocessing of the bad quality of fingerprint images which also add to the low verification rate thus this framework uses hybrid method to enhance fingerprint image. Results indicate that there are improvements when using the proposed hybrid framework is better than when using Minutiae or Image based only. The improvement is prominent especially when using low, Normal and high quality fingerprint images for fingerprint recognition.

7. Recommendation

There is further improvement in terms of efficiency and accuracy which can be achieved by improving the hardware to capture the image or by improving the image enhancement techniques. So that the input image could be made better this could improve over all security. It is to improve more for excessive ink which ridges and furrows are mostly hiding, and further attributes are also required in order to accomplish the matching of those fingerprint. Also the nearest future is to develop an algorithm for distinguishing diseased fingerprints from the other fingerprints with a low quality.

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