Image Altered Finger Identification and Matching Using Fingerprint Matching

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Abstract: - Existing security measures rely on knowledge-based approaches like passwords or token based approaches such as swipe cards and passports to control access to physical and virtual spaces. Though ubiquitous, such methods are not very secure. Tokens such as badges and access cards may be shared or stolen. Furthermore, they cannot differentiate between authorized user and a person having access to the tokens or passwords. Biometrics such as fingerprint, face and voice print offers means of reliable personal authentication that can address these problems and is gaining citizen and government acceptance. Fingerprints were one of the first forms of biometric authentication to be used for law enforcement and civilian applications. Contrary to popular belief and despite decades of research in fingerprints, reliable fingerprint recognition is still an open problem. In this thesis, we present three specific contributions to advance the state of the art in this field. Reliable extraction of features from poor quality prints is the most challenging problem faced in the area of fingerprint recognition. FP is one of the most successful and matured biometric trait for the personal identification all over the world. Due to this, threats to AFIS are also increasing. FP alteration is one among them especially in border control security systems [12], [13]. The increased use of AFIS in immigration control and forensic application motivated the illegal immigrants and criminals to alter the FP for masking their identity. A number of websites are available in the internet that discusses the different ways of alteration of the FP. Cases related to altered FP is also reported all over the world. The above facts motivated to find a solution to defeat this problem. The development of the methods or algorithms for alteration detection, classification and matching is also motivated by different reason.

Key Words: — ***Biometrics, Fingerprint, Fingerprint matching, Bit strength, Image processing, Matlab, GUI.***

I. INTRODUCTION

In an increasingly digital world, reliable personal authentication has become an important human computer interface activity. National security, ecommerce, and access to computer network are some example where establishing a person's identity is vital. Existing security measures rely on knowledge-based approach like password or token-based approaches such as swipe card and passport to control access to physical and virtual space. Though ubiquitous, such methods are not very secure. Tokens such as badges and access card may be shared or stolen. Password and PIN number may be stolen electronically. Furthermore, they cannot differentiate between authorized user and a person having access to the tokens or knowledge.

Biometrics such as fingerprint face and voice print offer mean of reliable personal authentic-cation that can address these problem and is gaining citizen and government acceptance.

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1.1 General Biometric Recognition System

A biometric system is essentially a pattern recognition system that operates by acquiring biometric data from an individual, extracting a feature set from the acquired data, and comparing this feature set against the template set in the database

A generic biometric system basically consists of four modules. They are

- Scanner module: I acquires biometric data of an individual.
- Feature extraction module: Process the acquired data to extract a feature set to represent biometric trait.
- Matching module: The extracted feature set is compared against the templates residing in the database through the generation of matching scores.
- Decision making module Matching scores are used to either validate the user's claimed identity or determine his/her identity.

Depending on the application context, a biometric system may operate either in verification mode or identification mode. Enrollment is a process of making a database of template and is common to both verification and identification system. An enrollment system consists of scanner to capture the FP image, a quality checker and a feature extractor. This process is usually carried under the supervision of a trained person with an aim to maintain the quality of the FP image used for making the template.

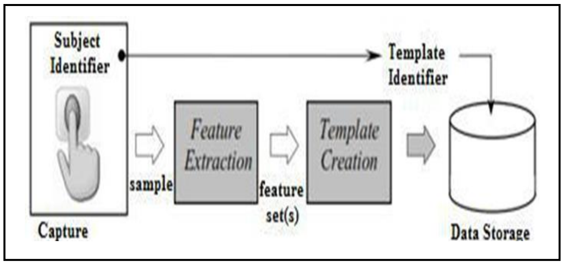

Fig.1.Verification System

1.2 FP Based Biometric Systems

A comparison of widely used biometric identifiers is given in Table. Entries in the table as given in second edition of Hand book of FP recognition. The letters H, M and L denotes High, Medium and Low respectively. Table shows that FPs have very good balance between properties as compared to other biometrics.

Table.1. Comparison of general biometric traits

Biometric identifier	Universality	Distinctiveness	Permanence	Collectability	Performance	Acceptability	Circumvention
Face	H	L	M	H	L	H	H
FP	M	H	H	M	H	M	M
Hand Geometry	M	M	M	H	M	M	M
Hand/Finger vein	M	M	M	M	M	M	L
Iris	H	H	H	M	H	L	L
Signature	L	L	L	H	L	H	H
Voice	M	L	L	M	L	H	H

All humans have FP that are distinctive from others. Their details are permanent, even if they temporarily change slightly due to cuts and bruises on the skin. FP recognition has become one of the most matured biometric as far as technologies are concerned. It has wide use in forensic sciences to identify the criminals. Forensic experts use the latent FP obtained from the crime scenes and makes the match with a watch list of FP. FP scanners are small in size and can get with affordable prices. These reasons make FP one of the most widely used biometric traits in the world.

1.3 Features of FP

The overall area of FP image captured by scanner contains foreground and background region. Foreground region is a pattern of ridges and furrows or valleys and possess the important features needed for matching. The background area has to be segmented off from the image and does not contain any information. The features possessed by FP image are categorize into three levels; level 1, level 2 and level 3 features.

Level 1 Features also known as global ridge pattern shows macro details of ridge flow. These features are a pattern of alternating convex skin called ridges and concave skin called valleys with spiral curve like line shape. There are two types of ridge flows: the pseudo-parallel ridge flows and high-curvature ridge flows located around the singular point. This representation relies on the ridge structure, global landmarks and ridge pattern characteristics. The commonly used global or level 1 FP features are:

Singular points: There are two types of singular points known as core and delta. A core is the uppermost point of the innermost curving ridge. Delta is the junction point where three ridge flows meet. Both core and delta. They are usually used for FP registration and FP classification. According to the ridge flow around singular points and number of singular points, FP is classified into 6classes. They are Right loop(R), Left loop (L), Whorl (W), Arch (A) and Tented Arch(T).

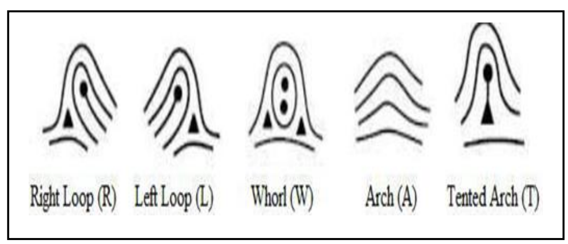

Fig.2. Different classes of FP with core and delta marked.

- Ridge orientation Field: It gives the local direction of ridge-valley flow. It is widely used for classification, image enhancement, matching, minutiae feature verification and filtering.
- Ridge Frequency: The local ridge frequency (or density) *fxy* at point [x, y] is the number of ridges per unit length along a hypothetical segment centere t[x, y] and orthogonal to the local ridge orientation. A frequency image F can be defined if the frequency is estimated at discrete positions and arranged into a matrix.

II. Objectives of Research

The countermeasures to defeat altered FP threats are detection, classification and matching. Detection is first step needed against the altered FP threats. Once the altered FP is detected, it has to be matched with unaltered mates available in the database to find criminals who have altered the FP. In order to match the altered FP successfully, classification of altered FP has to be performed. This is due to the fact that altered FP consists of transplanted region and this increase the rate of false matching.

III. Finger Print Detection

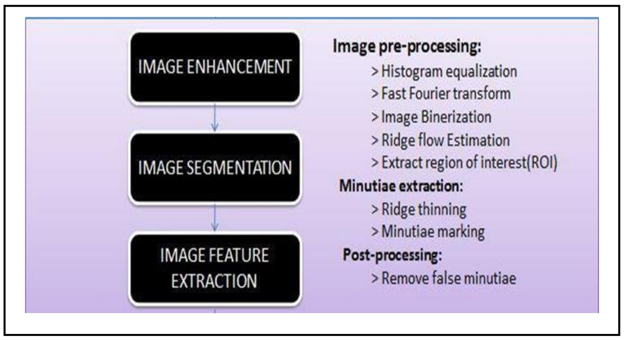

Fig.2. Block diagram of feature extraction

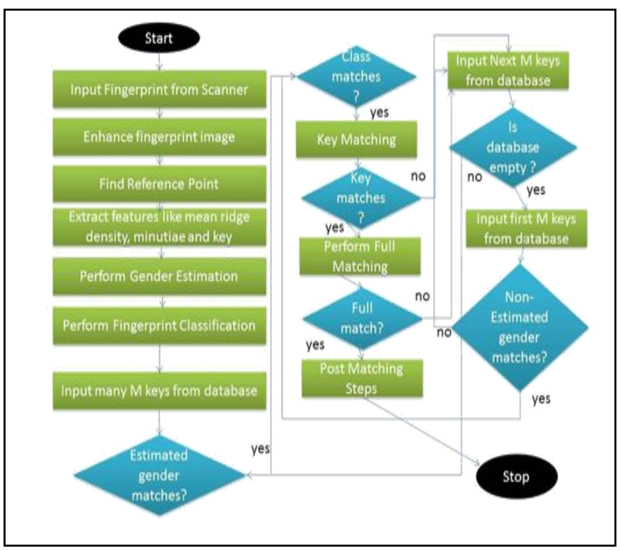

Fig.3.Flow chart of proposed method

3.1 IFP Enhancement

The performance of the minutiae extraction algorithm relies heavily on quality of the FP image. Noise and dryness on the unaltered FP image cases broken ridges which in turn may increase minutiae density and be wronglydetected as altered FP image. The purpose of enhancement is to aid the extraction of the ridge ending producrd by alteration and remove spurious ridge ending produced by dryness and noise in the image. Enhancing the FP by Fourier Transform Techniques gives directional smoothing to the ridges and fills the broken ridges produced by dryness in the FP while retains ridge ending produced by alteration process.

FP image is initially divided into 32X32 processing block. Then fast Fourier transform is performed on each block so that each block is converted into frequency domain. Fast Fourier transform (FFT) is performed.

3.2 Minutiae Density Extraction

The first step in minutiae density feature extraction is the detection of minutiae points known as ridge ending and bifurcation. There are two methods used for finding the ridge ending and bifurcation from the FP image. One is based on gray scale image and other is based on binaries image. The second method is used in this work. The different steps applied for finding minutiae points are explained below.

3.3 Thinning

Thinning is done to make the ridges one pixel wide so that the ridge ending are easily found by scanning with a 3X3 window. It is a morphological operation that successively erodes away. The foreground pixel until they are one pixel wide. The application of a thinning algorithm to a fingerprint image preserve the connectivity of the ridge structure while forming a skeletonized version of the binary image which is then used in the subsequent extraction of ridge ending.

Minutiae consist of two features, namely ridge endings and bifurcations as shown in Fig (a) and (b) respectively. Fig (a)and(b) shows 3X3 window for scanning the thinned image to find ridge ending and bifurcation respectively .In this method, if the central pixel is zero and has exactly 3 zero-valued neighbors then the central pixel is considered as a ridge branch or bifurcation. If it has only one zero-valued neighbor, then the central pixel is a ridge branch or bifurcation.

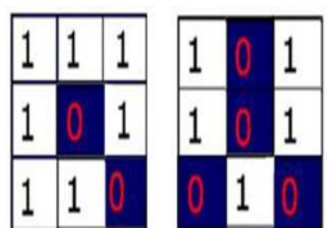

Fig.4. 3X3 window for (a) Ridge ending, (b) Bifurcation

3.4 Ridge Discontinuity Analysis

Ridge Orientation of altered FP is determined using gradient based method described as follows. Denote the gradient of an image at a point (x, y) as $[G_x(x,y), G_y(x,y)]$, then G_x and G_y gives the variation of intensity in x and y directions respectively. The principal axis of variation of gradients in x direction, diagonal directions and y direction is obtained as

$G_{xx} = G_x * G_x$

$G_{xy} = G_x * G_y$

$G_{yy} = G_y * G_y$

Then $\sin 2\theta = G_{xy} / \sqrt{[(G_{xy})^2 + (G_{xx} - G_{yy})^2]}$ And

$\cos 2\theta = (G_{xy} - G_{yy}) / \sqrt{[(G_{xy})^2 + (G_{xx} - G_{yy})^2]}$

Where θ(x, y) is the orientation field at point (x,y).

Where θ_{org} (x, y) denotes the orientation of altered FP before enhancement. After finding the orientation θ_{org}, the altered FP is enhanced by FFT as explained in section.

The orientation field of enhanced FP is again found by gradient based method and is denoted as θ_{en}. Enhancement gives more smoothing to the altered region while normal region is smoothed by lesser amounts. Thus, the ridge discontinuity map is obtained by comparing the ridge orientation field before and after the FFT enhancement as given in equation below.

$RD = \min (|\theta_{org} (i, j) - \theta_{en} (i, j)|), \pi - (|\theta_{org} (i, j) - i\theta_{en} (i, j)|) / (\pi/2)$

Fig.5. RD map of (a) Obliteration, (b) Distortion (c) Imitation and (d) normal FP

3.5 Analysis of SCAR

Pontus Hymer developed two methods for the detection of scar present in the normal FP. First method is based on average filtering and thresholding. The average filter is used to remove the high frequency components from the FP. Once these are removed, thresholding is applied to detect the scar. Second method is based on Gabor filtering. David Vernon used Hough transform for the detection of scar. He considered the co-linearity of ridge endings present at the boundary of the scar for the detection. In the proposed work, average filtering is made adaptive by changing the windows size of the filter with respect to dryness present in the image.

3.6 Adaptive Average Filtering

The quality of FP changes with the dryness of the fingers being scanned. Dry, wet and normal (good quality) FP .The lack of moisture in the finger is the cause of dry FP. This leads to broken ridges and valleys in the fingerprint image. Excess of moisture in the fingertip causes the wet images. The ridges and valleys in the wet images are not well separated. The averaging filter preserves the sharp edges in the image. The image is convolved with average filter in the spatial domain to accentuate the present scars. The dryness on the fingerprint affects the preservation of scars in the fingerprint. This difficulty is solved by changing the window size by setting a threshold for mean of pixel intensity of the image. The mean varies for dry, wet and good quality images. Pixel intensity mean for dry FP varies between 190 to 250, while for wet images, it lies in between 30 and for good quality normal fingerprint images, the pixel intensity lies between and 190. Thus the filter is adapted to the dryness of the fingerprint. The mean and standard deviation varies for wet, dry and normal fingerprint images. Window size is selected as 3×3, 5×5 and 7×7 for wet, normal and dry FP respectively.

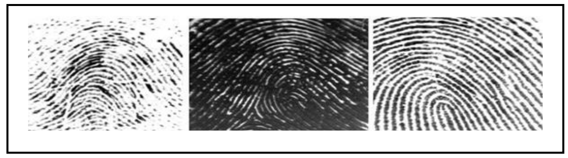

Fig.6. (a) Dry FP (b) Wet FP (c) Normal FP

3.7 Thresholding

Thresholding is used for segmenting the scars from the filtered FP image. Shows the segmented scars from the obliteration type altered fingerprint images.

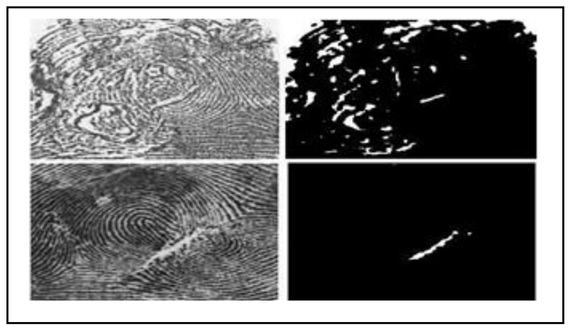

Fig.7. Scar detected from obliteration type of altered FP

IV. Experimental Result

Performance Evaluation Index: Two indexes are well accepted for determining the performance of a fingerprint recognition system:

False Rejection Rate (FRR): For an image database, each minutia sample is matched against the remaining samples of a particular finger to compute the FRR.

False Acceptance Rate (FAR): Also in a database the first sample of each finger is matched with the first sample of the remaining fingers in order to compute the FAR. A system's FAR is calculated by the formula.

4.1 Results

In our experiments distribution curve is obtained which gives an average correct match score of around 33 and average incorrect match score of around 25 on the database chosen. Histogram is a process that attempts to spread out the gray levels in an image so that they are evenly distributed across their range. It basically reassigns the brightness value of each pixel based on the image histogram. Histogram is a technique to produce more visually pleasing result across a wider range of images to produce as flat as possible histogram of the image.

(HISTOGRAM: The histogram of an image is a graphical plot of the number of occurrences of gray levels in the image against the gray level value.)

Procedure to perform histogram equalization:

- Find the running sum of histogram values.
- Normalize the value from step (1) by dividing by the total number of pixels.
- Multiply the values from step (2) by the maximum gray-level value andiround.
- Map the gray level values to the results from step (3) using a one-to-one correspondence.

In MATLAB histogram equalization is done using an ingenious MATLAB function "histeq (image)‟. Below the figure shown for the original image histogram and corresponding image histogram after histogram equalization .The illustrates FP enhancement processed image.

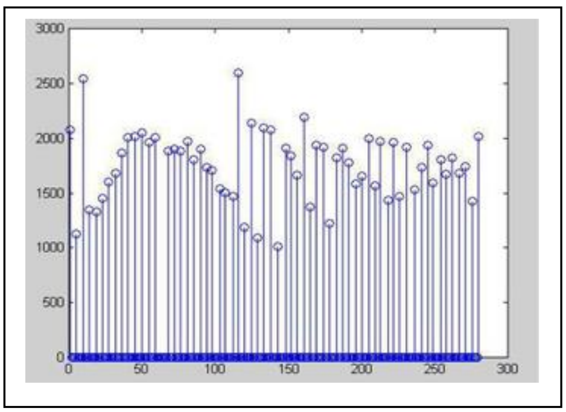

Fig.8. Original histogram

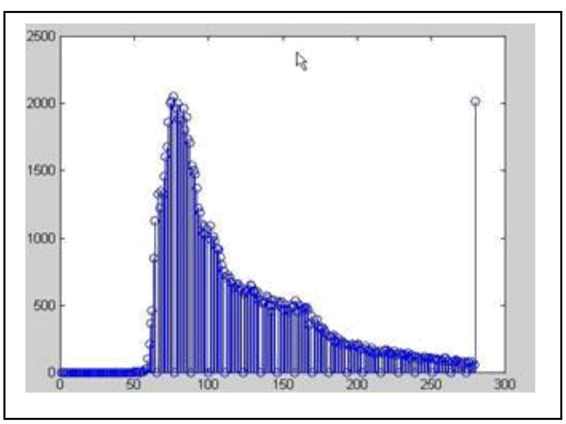

Fig.9. Histogram after histogram

4.1.1 Equalization

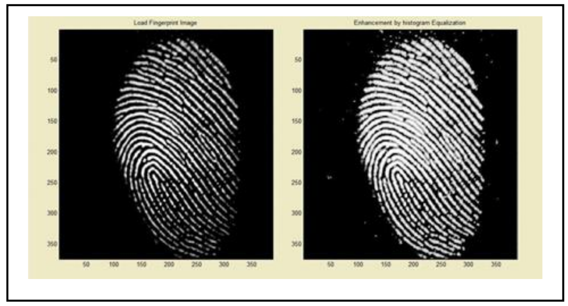

Fig.10. Histogram Enhancement (left: original image, right: enhanced image)

4.1.2 Enhancement

In this enhancement, the image is divided into small processing blocks of 32 by 32 pixel termination minutiae might become bifurcation minutiae. Represents the image after FFT enhancement and the image after histogram equalization.

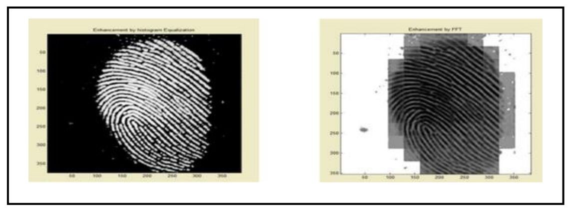

Fig.11. Histogram equalized imagee

4.1.3 Fingerprint Binarization

Fingerprint image binarizationis done to transform an 8-bit gray image to a 1-bit binarized image where 0-value holds for ridges and 1 value for furrows. And after the binarization operation ridhes are highlighted with black color and furrows are highlighted with white color.

A locally adaptive binarization method called as "adaptive thresholding" to binarize the fingeprint image is used. In this method we transform the gray level to 0 if it is below threshold value and to1 it is above threshold value. The threshold value is the mean taken from the gray level of the current block (16*16) to which the pixel belong.

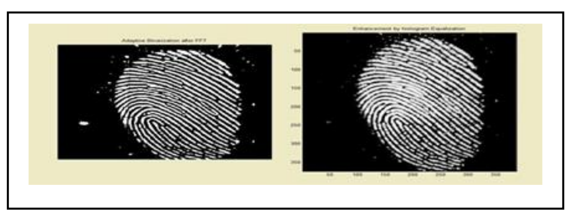

Fig.12. Binarisedi image

The tables shown below elaborates the classification of altered and normal finger print image. The table shows the classification of FP listing number of imags as altered, distorted, imitated and normal. The Table shows the calculation of true positive rate and false positive rate.

Table.2. Classification results on altered and normal FP using H_{th1}

FP images	No. of FP	Normal FP	No. of FP classified as Imitation	Distortion	Obliteration
Normal	60	49	7	4	0
Imitation	60	3	39	12	6
Distortion	60	0	30	25	5

Table.3. Classification results using H_{th1} in terms TPR and FPR

Fingerprints	*TPR in %*	*FPR in %*
Normal FP(60 images)	81.667	1.667
$H_{th1} \leq 6$		
Imitation(60 images)	65	23.33
$6 < H_{th1} \leq 10$		
Distortion(60 images)	41.667	26.667
$10 < H_{th1} \leq 13$		
Obliteration(60 images)	38.33	6.11
$H_{th1} > 13$		

V. CONCLUSION

This paper presents a solution to prevent altered FP threats against AFIS by detection, classification and matching using ridge and minutiae features. First step to defeat the altered FP threat is the detection. A method for altered FP detection based on Minutiae Density (MD), Ridge Discontinuity (RD) and Scar(S). Scar is an important feature present in altered FP since all process of alteration creates the absences of ridges and valleys. Scar detection is performed by average filtering and thresholding. Extraction of scar from low quality FP images is difficult. This difficulty is overcome by changing the window size with respect to dryness of the FP. Thus the average filtering process becomes adaptive. It is concluded that addition of scar increases the TPR and decreases FPR as compared to the methods proposed in literature.

Once the detection of altered FP is performed, it needs to be automatically classified into different types to take appropriate countermeasures and also to help the matching stage. A Hough transform based method that utilizes the variation in ridge ending density for the classification of altered. This method classifies the altered FP in to imitation, distortion or obliteration. If FP is classified as distortion or imitation, the reconstruction of transplanted region have to be performed or can go for the identification of doctor who had done the surgery.

If the altered FP is classified as obliteration, it goes to the matching stage. Minutiae based matching is not possible to perform for obliterated FP since the alteration process causes the large amount of spurious minutiae. Thus the matching is performed using the reconstructed ridge orientation and ridge texture features in the unaltered region. A method based on orthogonal wavelet is proposed to reconstruct the ridge orientation of altered FP. This reconstructed orientation is used to confirm the alteration detection and also used as a feature in matching stage. Matching is performed in two stages. First stage utilizes the reconstructed ridge orientation and second stage uses the ridge texture and frequency in the unaltered region.

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