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Design & Implementation of Features based Fingerprint Image Matching System

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Abstract

Fingerprints are a great basis for identification of persons. Fingerprint recognition is one of oldest procedures of biometric identification. However outcome a good fingerprint image is not always easy. So a fingerprint image must be pre-processed before matching. The objective of this paper is to present animproved and enhanced fingerprint image. We have considered the factors relating to obtaining high performance feature points detection algorithm, such as image quality, separation, image improvement and feature detection. Commonly used features for increasing fingerprint image quality are Fourier spectrum energy and local orientation. Accurate separation of fingerprint ridges from noisy background is necessary. For operative enhancement and feature extraction algorithms, the segmented features must be void of noise. A pre-processing method containing of field orientation, frequency estimation, filtering, segmentation and enhancement is performed. The resulting image is applied to a thinning algorithm and subsequent minutiae extraction. The methodology of image pre-processing and minutiae extraction is discussed. The simulations are done in MATLAB environment tool to evaluate performance of the implemented algorithms. Results and observations of fingerprint images are presented at the end.

Keywords: *Fingerprinting, Image Matching, feature extraction, minutia details, analysis of fingerprints.*

1. Introduction

In computer science and electronic engineering image processing, image processing is any form of processing of signals for which the input is an image, such as pictures or frames of video the output of image processing can be either an image or a set of characteristics or parameters related to the image [1]. Image processing techniques have been developed tremendously during past five decades. Sometimes a distinction is made by defining image processing as a discipline in which both input and output of a process are image.

Biometrics, which refers to identifying an individual based on his or her physiological or behavioral characteristics, has the capability to reliably distinguish between an authorized person and an imposter. Since biometric characteristics are distinctive, cannot be forgotten or lost, and the person to be authenticated needs to be physically present at the point of identification, biometrics is inherently more reliable and more capable than traditional knowledge-based and token-based techniques. Biometrics also has a number of disadvantages. For example, if a password or an ID card is compromised, it can be easily replaced. However, once a biometrics is compromised, it is not possible to replace it. Similarly, users can have a different password for each account, thus if the password for one account is compromised, the other accounts are still safe. [2].

Skin on human fingertips contains ridges and valleys which together forms distinctive patterns. These patterns are fully established under pregnancy and are permanent throughout entire lifetime. Prints of those patterns are called fingerprints. Injuries like cuts, burns and contusions can provisionally damage worth of fingerprints but when fully healed, patterns will be restored. Automatic fingerprint recognition has become a widely used technology in both forensic and biometrics applications. Despite a part of a thousand years during which finger prints have been used as individual's proof of identity and decades of research on automated systems, reliable fully automatic fingerprint recognition is still an unsolved stimulating research problem. Moreover, most of research thus far, assumes that two finger print templates being matched are approximately of the same size and cover large areas of fingertip. However, this assumption is no longer valid. The miniaturization of finger print sensors has led to small sensing areas and can only capture partial fingerprints. Incomplete fingerprints are also common in forensic applications [3].

Fingerprints are patterns designed on skin of fingertip. The fingerprints are of three types: arch, loop and whorl. The bounded pattern of ridges and valleys are the most obvious structural characteristic of a fingerprint. The fingerprint of each individual is considered to be unique. No two persons have same set of fingerprints. Also, Finger ridge schemes do not change throughout the life of an individual. This property makes fingerprints an excellent biometric identifier. So it is one of popular and active means for identification of an individual and used as forensic evidence [4].

Fingerprints are very popular as biometrics measurements. Unfortunately fingerprint matching is a composite recognition problem. Physical fingerprint matching is not only time consuming but education and training of experts takes a long time. Therefore since 1970s there have been done a lot of effort on progress of automatic fingerprint recognition systems. Automatization of fingerprint recognition process turned out to be success in forensic applications. Achievements made in scientific area expanded usage of the automatic fingerprint recognition into civilian applications [5].

The paper is organized as follows. In section II, we discuss related work with recognition of fingerprint images. In Section III, It describes steps of fingerprinting system. In Section IV, it describes the design and implementation algorithms used in fingerprinting image processing technique. The results are given in Section V. Finally, conclusion is explained in Section VI.

2. Related Work

In literature, authors presentseveral improvements to an adaptive fingerprint enhancement technique that is based on con-textual filtering. The term adaptive implies that parameters of the method are automatically adjusted based on the input fingerprint image. Five processing blocks include adaptive fingerprint enhancement method, where four of these blocks are efficient in our proposed system. Hence, proposed global system is innovative. The four modernized processing blocks are: 1) pre-processing; 2) global analysis; 3) local analysis; and 4) matched filtering. In pre-processing and local analysis blocks, a nonlinear active range adjustment technique is used. In global analysis and matched filtering blocks, different methods of order statistical filters are applied. These processing blocks produce an improved and new adaptive fingerprint image processing method [6].

Author proposed that there occur many human recognition procedures which are based on fingerprints. Most of these methods use minutiae points for fingerprint demonstration and matching. However, these methods are not rotation invariant and fail when enrolled image of a person is coordinated with a rotated test image. Moreover, such methods fail when partial fingerprint images are coordinated. This paper suggests a fingerprint recognition technique which uses local robust features for fingerprint representation and matching. The technique achieves well in presence of rotation and able to carry out recognition in presence of partial fingerprints. Experiments are done using a database of 200 images collected from 100 subjects, 2 images per subject. [7].

Some proposed that automatic recognition of a person is one of most critical issues in modern society. Common biometric systems rely on surface topography of an object and, thus, are potentially susceptible for spoofing. Optical coherence tomo-graphy is a technology that has capability to probe the internal structure of multilayered tissues. The paper defines an algorithm for automation fingerprint recognition that algorithm is applied on OCT fingerprint images. This algorithm is based on scanning of enhanced and segmented OCT images [9].

Authors proposed that heart of social equality is voting. The heart of voting is trust that each vote is verified and matched with accuracy and impartiality. The accuracy and neutrality are matched in high rate with biometric scheme. Among these signs, fingerprint has been investigated the longest period of time, and shows most promising future in real-world applications. Because of their exclusivity and reliability over time, fingerprints have been used for identification over time. However, because of complex alterations among the different impression of the same finger in real life, fingerprint matching is still a stimulating problem. Hence in this study, authors are interested in designing and analysing Electronic Voting System based on fingerprint minutiae which is core in current modern approach for fingerprint analysis [8].

3. Fingerprint Image Processing

A fingerprint recognition system constitutes of fingerprint device, Features extractor and Features matching. For fingerprint acquisition, optical or semi-conduct sensors are extensively used. They have large efficiency and acceptable accuracy except for some cases that user's finger is too dirty or dry.

A. Fingerprint Features

There are mainly three key fingerprint features
a) Global Ridge Pattern
b) Local Ridge Detail
c) Intra Ridge Detail

- **Global Ridge Detail**

There are two types of ridge flows: the pseudo-parallel ridge flows and high-curvature ridge flows which are located around the core point and/or delta point(s). This representation relies on ridge structure, global landmarks and ridge design characteristics [13].
The commonly used features are:

1. Singular Points – They are discontinuities in orientation field. There are two kinds of singular points- core and delta. A core is uppermost of a curving ridge, and a delta point is point where three ridge movements meet. They are used for fingerprint registration and classification.
2. Ridge Orientation Map – They are local direction of the ridge-valley structure. It is helpful in organization,

image enhancement, and features verification and filtering.

3. Ridge Frequency Map – They are the reciprocal of the ridge distance in the direction perpendicular to local ridge orientation. It is used for purifying of pattern images.

- **Local Ridge Detail**

This is most widely used and studied fingerprint representation. Local ridge details are discontinuities of local ridge structure referred to as minutiae. They are used by forensic specialists to match two patterns. There are about 150 dissimilar types of features. Among these features types, ridge ending and ridge bifurcation are the most commonly used as all the other types of minutiae are combinations of ridge endings and ridge bifurcations [11].

- **Intra Ridge Detail**

On every ridge of finger epidermis, there are many small sweat pores and other permanent details. Pores are distinctive in relations of their number, position, and shape. However, removing pores is feasible only in high-resolution fingerprint images and with very high image quality. Thus cost is very high. Therefore, this way of representation is not adopted by current automatic fingerprint identification systems (AFIS).

B. Functional Block Diagram of Proposed System

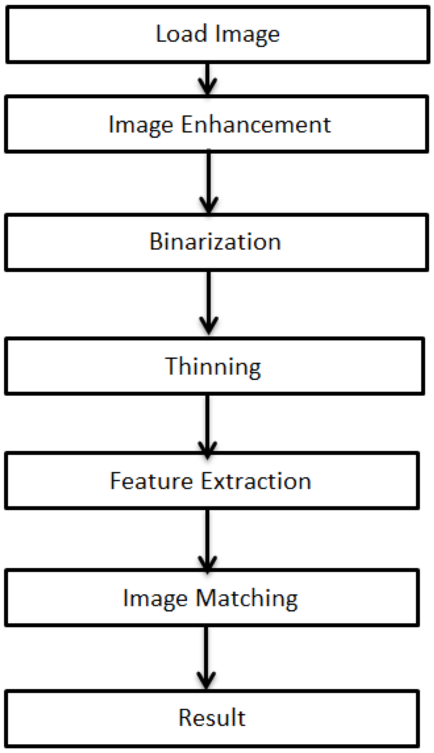

Figure 1: Functional Block Diagram of Proposed Approach

Fingerprint technique is one of the most popular applications in identification & verification as it develops a low-cost fast computing system. Applications include accessing buildings or facilities withdrawing money or using a credit card, gaining contact to electronic info on a local computer or over the internet. There are various approaches for fingerprint recognition among which Pixel based is mostly preferred nowadays due to its pixel based localization [10].

C. Image Acquisition

Image acquisition is first step in the approach. It is very important as quality of fingerprint image must be good and free from any noise. A good fingerprint image is desirable for better performance of fingerprint algorithms. Based on the mode of acquisition, a fingerprint image may be divided into off-line or live-scan. An off-line image is obtained by smearing ink on fingertip and creating an inked impression of fingertip on paper. A live-scan image, on other hand, is acquired by sensing tip of finger directly, using a sensor that is accomplished of digitizing the fingerprint on contact. Live-scan is done using sensors. There are three types of sensors used. They are optical sensors, ultrasonic sensors and capacitance sensors [15].

Optical sensors capture a digital image of fingerprint. The light reflected from finger passes through a phosphor layer to an array of pixels which captures a visual image of the fingerprint. Ultrasonic sensors use very high frequency sound waves to penetrate the epidermal coating of skin. The sound waves are generated using piezoelectric transducers. The reflected wave measurements can be used to form an image of the fingerprint. Electrical charges are created between surface of finger and each of the silicon plates when a finger is placed on chip. The magnitude of these electrical charges depends on distance between fingerprint surface and capacitance plates. Thus fingerprint ridges and valleys result in different capacitance patterns across the plates [2].

D. Fingerprint Image Enhancement

Fingerprint image quality is an important factor in performance of minutiae extraction and matching algorithms. A good quality fingerprint image has high contrast between ridges and valleys. A poor quality fingerprint image is low in divergence, noisy, exhausted, or smudgy, causing spurious and missing minutiae. Poor quality can be due to cuts, crinkles, or bruises on surface of fingertip, excessively wet or dry skin condition, uncooperative attitude of subjects, broken and impure scanner devices, little quality fingers (elderly people, manual worker), and other factors [11].

Fingerprint Image enhancement is to make image clearer for easy further operations. Since fingerprint images acquired from sensors or other Medias are not assured with perfect excellence, those enhancement methods, for increasing contrast between ridges and furrows and for connecting the false broken points of ridges due to insufficient amount of ink, are very valuable for keep a higher accuracy to fingerprint recognition.Two Methods are adopted for image enhancement stage: the first one is Histogram Equalization; the next one is Fourier Transform [14].

Histogram equalization is to expand pixel value distribution of an image so as to increase perception information. The original histogram of a fingerprint image has bimodal type, histogram after the histogram equalization occupies all range from 0 to 255 and the visualization effect is improved. Image enhancement techniques are employed to decrease noise and enhance the definition of ridges against valleys. In order to ensure good performance of ridge and minutiae extraction algorithms in poor quality fingerprint images, an enhancement algorithm to improve clarity of ridge structure is necessary. A print image contains regions of different excellence. They are:

1) Well-defined region
2) Recoverable region
3) Unrecoverable region.

Well-defined regions, recoverable regions and unrecoverable regions may be identified according to image contrast, alignment consistency, ridge frequency, and other local features. The goal of an enhancement algorithm is to improve the clarity of the ridge structures in recoverable regions and mark the unrecoverable regions as too noisy for further processing. The contribution of enhancement algorithm is a gray-scale image. The output may either be a grey-scale or a binary image [10].

E. Fingerprint Image Binarization

Fingerprint Image Binarization is to alter 8-bit Gray fingerprint image to a 1-bit image with 0-value for ridges and 1-value for furrows. After operation, ridges in fingerprint are highlighted with black color while furrows are white. A nearby binarization method is performed to binarize fingerprint image. Such a named method comes from mechanism of converting a pixel value to 1 if value is larger than mean intensity value of current block (16x16) to which pixel belongs [12].

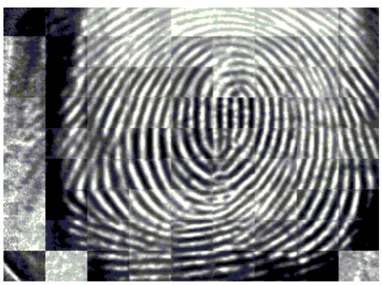

Figure 2: Enhanced Image

Figure 3: Image after Binarization

F. Fingerprint Image Segmentation

In general, only a Region of Interest is useful to be recognized for each fingerprint image. The image area without operative ridges and furrows is first discarded since it only holds background information. Then bound of remaining effective area is sketched out since the minutia in bound region are confusing with those spurious minutia that are generated when the ridges are out of the sensor [9].

Local segmentation can be seen to belong to a continuum of approaches to image understanding. At a higher level is global segmentation which attempts to group together related pixels from throughout image. The highest level is object recognition, whereby global segments are combined into logical units representing real world objects of interest. The fundamental component of local segmentation approach is segmentation algorithm itself. Most segmentation algorithms are designed to operate upon a whole image, or a large portion thereof. Local segmentation can only utilise a small number of pixels belonging to fragments of larger segments. Thus a local segmentation algorithm differs in that it has less data and fewer contexts to work with. Those image processing tasks suited to local segmentation are often first to encounter raw image data. This data is usually contaminated with one or more forms of noise. The fundamental attribute of a local segmentation based algorithm should be to preserve as much image structure (useful information) as possible, and to suppress or remove as much noise as possible. These goals are complementary and inseparable ability to identify structure implies ability to identify noise, and vice versa [14].

G. Minutiae Extraction

After enhancement of fingerprint image, image is ready for minutiae extraction. For proper extraction, however, a thinning algorithm is applied to enhanced image. It produces a skeletonised representation of image.

- **Thinning of Image**

Thinning is a morphological operation that is used to remove selected foreground pixels from binary images. It is used to eliminate redundant pixels of ridges till ridges are just one pixel wide. Thinning is normally only applied to binary images, and creates another binary image as output. It is final step prior to minutiae extraction. It uses an iterative, parallel thinning algorithm. All pixels on boundaries of foreground regions that have at least one background neighbour are taken. Any point that has more than one foreground neighbour is deleted as long as doing so does not locally disconnect the region containing that pixel [15].

- **Features Extraction**

After enhancement of fingerprint image next step is features extraction. The method extracts features from the enhanced image. This method extracts ridge endings and bifurcations from skeleton image by examining the local neighbourhood of each ridge pixel using a 3×3 window. The method used for features extraction is crossing number (CN) method. This method involves the use of skeleton image where ridge flow pattern is eight-connected. The minutiae are pulling out by scanning local neighbourhood of each ridge pixel in image using a 3×3 window. CN is defined as half the sum of differences between the pairs of adjacent pixel. Thus features points can be extracted [19].

- **False Features Removal**

The pre-processing stage does not totally heal fingerprint image. For instance, false ridge breaks due to insufficient amount of ink and ridge cross-connections due to over inking are not totally eliminated. Actually all earlier stages themselves occasionally introduce some artefacts which later lead to spurious minutia. This false minutia will expressively affect accuracy of matching if they are simply regarded as genuine minutia. So some mechanisms of eliminating false minutia are essential to keep the fingerprint verification system effective [16].

- **Fingerprint Matching**

Given two set of features of two fingerprint images, minutia match algorithm determines whether two minutia sets are from same finger or not. An alignment-based match procedure is used. It includes two consecutive stages: one is alignment stage and second is match stage [16].
1. Alignment stage. Given two fingerprint images to be matched, any one feature from each image is chosen, and similarity of feature points is calculated. If similarity is larger than a threshold, each set of features is changed to a new coordination system whose origin is at referenced point and whose x-axis is coincident with direction of referenced point.
2. Match stage: After obtaining two set of transformed minutia points, elastic match algorithm is used to count matched minutia pairs by assuming two minutia having nearly same position and direction are identical.

4. Design and Implementation

In recent years, there have been significant advancements in algorithms and architectures for the processing of image. These advancements have proceeded along several directions.

A. Proposed Algorithm of Fingerprinting Matching

1. Read two input images manually.
2. Find the enhancement of images by mean adjustment technique.
3. Separate R, G and B by image segmentation process.
4. Apply thresholding process to remove noise.
5. Find the thinning of images by morphological operations.
6. Find features of extracted images.
7. Find the differences of two images.
8. If differences are detected, then images are not same, else they are same.

B. Proposed Parameter: Signal Quality

This term is often used to characterise the signal at the output of decoder. There is no universally accepted measure for signal quality.One measure that is often cited is the signal to noise ratio SNR, which can be expressed as eq. (1):

$$SNR = 10log10\frac{Input\ signal\ energy}{noise\ error} \quad (1)$$

The noise signal energy is defined as energy measured for a hypothetical signal that is difference between the encoder input signal and the decoder output signal. Note that, SNR, defined here is given in decibels (dB). In the case of images, $PSNR$ (peak signal-to-noise ratio) is used instead of SNR

5. Results

Figure 4: Original Input First Fingerprint Image

The fingerprint image must be pre-processed before matching. For fingerprint matching, it requires two input images. One is of victim and one for comparison. The figure 4 and 5 show the original 1st and 2nd image respectively and figure 6 shows the enhancement of image by contrast adjust technique. Enhancement of images is done by pixel approach. Using pixels, it can affect the intensity of images. Enhancement is calculated with help of mean square error and PSNR parameter.

Original fingerprint of 2nd image

Figure 5: Original Input Second Fingerprint Image

enhanced fingerprint of 1st image

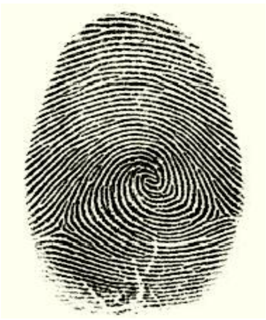

Figure 6: Enhanced Image of 1st Fingerprint Image

segmented fingerprint of 1st image

Figure 7: Segmentation of 1st Fingerprint Image

thinning image of 1st image

Figure 8: Thinning of 1st Fingerprint Image

minituae extraction of 1st image

Figure 9: Features Extraction of 1st Fingerprint Image

enhanced fingerprint of 2nd image

Figure 10: Enhanced Image of 2ndFingerprint Image

segmented fingerprint of 2nd image

Figure 11: Segmentation of 2ndFingerprint Image

thinning image of 2nd image

Figure 12: Thinning of 2ndFingerprint Image

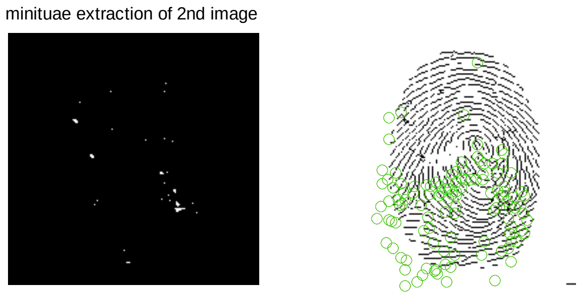

Figure 13: Features Extraction of 2[nd]Fingerprint Image

Figure 6 and 10 shows the enhancement of image by mean adjust technique. Enhancement of images is done by pixel approach. Using pixels, it can affect the intensity of images. Segmentation involves partitioning an image into groups of pixels which are homogeneous with respect to some criterion. Different groups must not intersect each other and adjacent groups must be heterogeneous. Segmentation is basically the separation of R, G and B colour from the images. It can be done using segmented process. Results are shown in fig 7 & 11.

Thinning process removes the boundary of image as shown in figure 4.7 and 4.8. Thinning was done using morphological algorithms, A Fast Parallel Algorithm for Thinning Digital Patterns. A 3x3 window is move down throughout the image and calculations are carried out on each pixel to decide whether it needs to stay in the image or not. The results are shown in fig 8 & 12. After thinning process, features of image are required to be extracted. So region props are used for feature extraction process and results are shown in figure 9 and 13.

After the four steps of pre-processing are completed the image can be used for the matching process. However, first we had to show that the region data was a good indication of matching minutiae. That is we need to show that the amount of regions between two minutiae is consistent across many different scans of the same fingerprint.

Figure 14:1[st] Extracted Image

Most modern fingerprint matching technologies use minutiae matching. The idea being if you can find enough minutiae in one image that have corresponding minutiae in another image then the images are most likely from the same fingerprint. Minutiae are usually matched together by their distance relative to other minutiae around it. If multiple points in one image have similar distances between them then multiple points in another image then the points are said to match up.

Figure 15: 2[nd] Extracted Image

After this, both images are applied to fingerprinting matching system which matches images pixel by pixel as shown in fig 14 and 15. For this, it calculates the difference of the images. If both are matched, then difference image shows no error. But if both are different, then it shows error image as shown in fig 16.

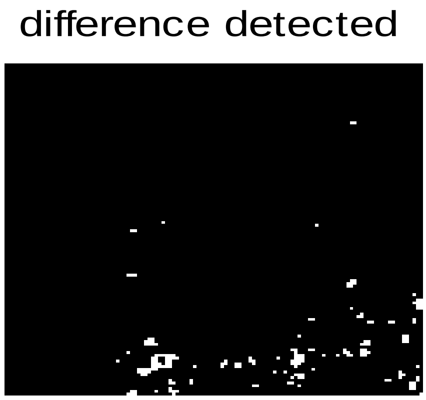

Figure 16: Fingerprint Matching Output

Proposed Parameters

MSE (mean square error) measures the average squared difference between the estimator image (img1) and the original (img), a somewhat reasonable measure of performance for an estimator. In general, any increasing function of the absolute distance (img-img1) would serve to measure the goodness of an estimator. PSNR is also calculated with the help of MSE. Higher the value of PSNR better is its enhancement. Here, Table 4.1 shows the value of MSE and PSNR of both input images. Difference in these values shows that both fingerprints are not same.

Table 4.1: Proposed Parameters Comparison

Parameters	Image1	Image2
MSE	252.26	189.19
PSNR	24.14	25.39

Table 4.2: Comparison between Proposed with Histogram Technique

Mean Square Error (MSE) Comparison			
Images	MSE (Proposed)		MSE (Hist)
Image 1	252.26		4907.78
Image 2	189.19		7821.15
Peak Signal to Noise Ratio (PSNR) Comparison			
Images	PSNR (Proposed)		PSNR (Hist)
Image 1	24.14		11.25
Image 2	25.39		9.23
Computation Time Comparison of Pixel Based & Block Based			
Computation Time	Proposed (Pixel based)	Full Search (16)	Full Search (32)
	16.9 sec	1089 sec	4225 sec

Conclusions

The goal of this thesis is to design a system of image matching. It is used in the application of fingerprint matching system. It is used to study the security impact of partial fingerprints on automatic fingerprint recognition systems and to develop an automatic system that can overcome the challenges presented by partial fingerprint matching.The proposed algorithm is implemented in MATLAB. The reliability of any automatic fingerprint system strongly relies on the precision obtained in the minutia extraction process. A number of factors are detrimental to the correct location of minutia. Among them, poor image quality is the most serious one. In this work, we have combined many methods to build a minutia extractor and a minutia matcher. The following concepts have been used- segmentation using Morphological operations. This proposed enhanced algorithm is able to overcome the drawbacks of spatial domain methods like thresholding, histogram equalization and frequency domain methods. The number of processes is used to match these images. This algorithm is able to get good contrasted image which increases the brightness of the low contrasted images. This algorithm is tested on different type of images.

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