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Minutiae Fingerprint Recognition Using Mahalanobis Distance

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Abstract— Fingerprints are the most popular and studied biometrics features. Their stability and uniqueness make the fingerprint identification system extremely reliable and useful for security applications. A minutiae matching is widely used for fingerprint recognition and can be classified as ridge ending and ridge bifurcation. In this paper we have modified the existing technique for finger print recognition by incorporating Phong (2D) Reflection Model to make the illumination even which leads to effective extraction of minutiae features, Mahalanobis distance which is an improvement over the present Hausdorff distance in pattern recognition and Fast Fourier transformation which further bridges the falsely broken points on the ridges. A performance evaluation has been after integrating the features and the results show that it can significantly improve the performance which in turn can help in further improving the performance of fingerprint recognition system.

Index Terms— Biometrics, Fingerprint Recognition, Minutiae technique, Ridge ending and ridge bifurcation, Mahalanobis Distance, Phong Reflection Model, Fast Fourier Transform.

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1 Introduction

Biometric authentication has been receiving extensive attention over the past decade with increasing demands in automated personal identification. Biometrics is to identify individuals using physiological or behavioural characteristics, such as fingerprint, face, iris, retina, palm-print, etc. Among all the biometric techniques, fingerprint recognition is the most popular method and is successfully used in many applications.[22] Major approaches for fingerprint recognition today can be broadly classified into feature-based approach and correlation-based approach. Typical fingerprint recognition methods employ feature-based matching, where minutia (i.e., ridge ending and ridge bifurcation) are extracted from the registered fingerprint image and the input fingerprint image, and the number of corresponding minutiae pairs between the two images is used to recognize a valid fingerprint image. [22] Feature based matching is highly robust against nonlinear fingerprint distortion, but shows only limited capability for recognizing poor-quality fingerprint images with low S/N ratio due to unexpected fingertip conditions (e.g., dry fingertips, rough fingertips, allergic-skin fingertips) as well as weak impression of fingerprints. However, the performance of the phase-based fingerprint matching is degraded by nonlinear distortions in fingerprint images. [22]

In this paper we are using the minutia exaction based approach using Mahalanobis distance. Mahalanobis distance is used to find outliers in a set of data. It provides a way to measure how similar some set of conditions is to a known set of conditions. It accounts the covariance among variables.

Another technique used in this paper is illumination of fingerprint image using Phong reflection model and to remove the varius discrepancies from the image, we have used Fast Fourier Transform (FFT).

This paper is structured as follows: Section 2 explains about what fingerprint recognition is. Section 3 gives the details of various fingerprint matching techniques. Section 4 throws the light on the details of various fingerprint recognition techniques proposed in earlier papers. Section 5 provides an insight to the details of the fingerprint recognition technique proposed in this paper using Phong Reflection Model, Mahalanobis distance and Fast Fourier Transform. Section 6 describes the details of how new features are integrated and executed in our paper. Section 7 ends the paper with a conclusion.

2 FINGER PRINT RECOGNITION

2.1 WHAT IS A FINGERPRINT

A fingerprint is the feature pattern of one finger (Figure 1). It is an impression of the friction ridges and furrows on all parts of a finger. [22] These ridges and furrows present good similarities in each small local window, like parallelism and average width.

Figure 1: Fingerprint image from a sensor [22]

However, shown by intensive research on fingerprint recognition, fingerprints are not distinguished by their ridges and furrows, but by features called Minutia, which are some abnormal points on the ridges (Figure 2). Among the variety of minutia types reported in literatures, two are mostly signifi-

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cant and in heavy usage:

- Ridge ending - the abrupt end of a ridge
- Ridge bifurcation - a single ridge that divides into two

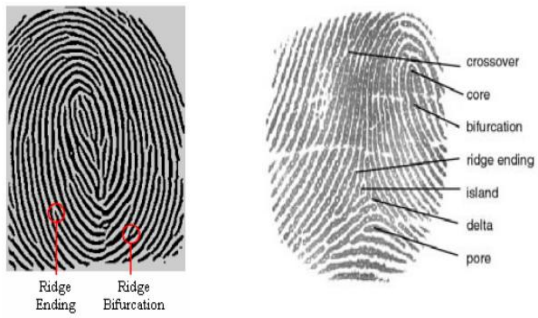

Figure 2: (a) two important minutiae features (b) other minutiae features [22]

2.2 WHAT IS FINGERPRINT RECOGNITION

Fingerprint recognition (sometimes referred to as dactyloscopy) is the process of comparing questioned and known fingerprint against another fingerprint to determine if the impressions are from the same finger or palm. It includes two subdomains: one is fingerprint verification and the other is fingerprint identification. [22]

In addition, different from the manual approach for fingerprint recognition by experts, the fingerprint recognition is referred as Automatic Fingerprint Recognition System, which is program-based. [22] However, in all fingerprint recognition problems, either verification(one to one matching) or identification(one to many matching), the underlining principles of well-defined representation of a fingerprint and matching remains the same.

3 FINGER PRINT MATCHING TECHNIQUES

The large number of approaches to fingerprint matching can be coarsely classified into three families:

3.1 CORRELATION-BASED MATCHING:

Two fingerprint images are superimposed and the correlation between corresponding pixels is computed for different alignments (e.g. various displacements and rotations).

3.2 MINUTIAE BASED MATCHING:

This is the most popular and widely used technique, being the basis of the fingerprint comparison made by fingerprint examiners. Minutiae are extracted from the two fingerprints and stored as sets of points in the two- dimensional plane. Minutiae-based matching essentially consists of finding the alignment between the template and the input minutiae sets those results in the maximum number of minutiae pairings.

3.3 PATTERN BASED (Image Based) MATCHING:

Pattern based algorithms compare the basic fingerprint patterns (arch, whorl, and loop) between a previously stored template and a candidate fingerprint. This requires that the images be aligned in the same orientation. To do this, the algorithm finds a central point in the fingerprint image and centers on that. In a pattern-based algorithm, the template contains the type, size, and orientation of patterns within the aligned fingerprint image. The candidate fingerprint image is graphically compared with the template to determine the degree to which they match.[22]

In this paper we have implemented a minutiae based matching technique. This approach has been intensively studied, also is the backbone of the current available fingerprint recognition products.

4 LITERATURE SURVEY

G. Sambasiva Rao et al., [1] proposed fingerprint identification technique using a gray level watershed method to find out the ridges present on a fingerprint image by directly scanned fingerprints or inked impression.

Robert Hastings [2] developed a method for enhancing the ridge pattern by using a process of oriented diffusion by adaptation of anisotropic diffusion to smooth the image in the direction parallel to the ridge flow. The image intensity varies smoothly as one traverse along the ridges or valleys by removing most of the small irregularities and breaks but with the identity of the individual ridges and valleys preserved.

Jinwei Gu, et al., [3] proposed a method for fingerprint verification which includes both minutiae and model based orientation field is used. It gives robust discriminatory information other than minutiae points. Fingerprint matching is done by combining the decisions of the matchers based on the orientation field and minutiae.

V. Vijaya Kumari and N. Suriyanarayanan [4] proposed a method for performance measure of local operators in fingerprint by detecting the edges of fingerprint images using five local operators namely Sobel, Roberts, Prewitt, Canny and LoG. The edge detected image is further segmented to extract individual segments from the image.

Raju Sonavane, and B.S. Sawant [5] presented a method by introducing a special domain fingerprint enhancement method which decomposes the fingerprint image into a set of filtered images then orientation field is estimated. A quality mask distinguishes the recoverable and unrecoverable corrupted regions in the input image are generated. Using the estimated orientation field, the input fingerprint image is adaptively enhanced in the recoverable regions.

Eric P. Kukula, et al., [6] purposed a method to investigate the effect of five different force levels on fingerprint matching performance, image quality scores, and minutiae count between optical and capacitance fingerprint sensors. Three images were collected from the right index fingers of 75 participants for each sensing technology. Descriptive statistics, analysis of variance, and Kruskal-Wallis nonparametric tests were conducted to assess significant differences in minutiae counts and image quality scores based on the force level. The results reveal a significant difference in image quality score based on the force level and each sensor technology, yet there is no significant difference in minutiae count based on the force levels of the capacitance sensor. The image quality score, shown to be effected by force and sensor type, is one of many factors that influence the system matching performance, yet the re-

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moval of low quality images does not improve the system performance at each force level.

M. R. Girgisa et al., [7] proposed a method to describe a fingerprint matching based on lines extraction and graph matching principles by adopting a hybrid scheme which consists of a genetic algorithm phase and a local search phase. Experimental results demonstrate the robustness of algorithm.

Luping Ji, and Zhang Yi [8] proposed a method for estimating four direction orientation field by considering four steps, i) preprocessing fingerprint image, ii) determining the primary ridge of fingerprint block using neuron pulse coupled neural network, iii) estimating block direction by projective distance variance of a ridge, instead of a full block, iv) correcting the estimated orientation field.

Duoqian Maio et al., [9] used principal graph algorithm by kegl to obtain principal curves for auto fingerprint identification system. From principal curves, minutiae extraction algorithm is used to extract the minutiae of the fingerprint. The experimental results shows curves obtained from graph algorithm are smoother than the thinning algorithm.

Alessandra Lumini, and Loris Nanni [10] developed a method for minutiae based fingerprint and its approach to the problem as two - class pattern recognition. The obtained feature vector by minutiae matching is classified into genuine or imposter by Support Vector Machine resulting remarkable performance improvement.

Xifeng Tong et al., [11] proposed a method to overcome non linear distortion using Local Relative Error Descriptor (LRLED). The algorithm consists of three steps i) a pair wise alignment method to achieve fingerprint alignment ii) a matched minutiae pair set is obtained with a threshold to reduce non-matches finally iii) the LRLED – based similarity measure. LRLED is good at distinguishing between corresponding and non corresponding minutiae-pairs and works well for fingerprint minutiae matching.

L. Lam et al., [12] presented a method, thinning is the process of reducing thickness of each line of patterns to just a single pixel width. The requirements of a good algorithm with respect to a fingerprint are i) the thinned fingerprint image obtained should be of single pixel width with no discontinuities ii) Each ridge should be thinned to its central pixel iii) Noise and singular pixels should be eliminated iv) no further removal of pixels should be possible after completion of thinning process.

Mohamed et al., [13] presented fingerprint classification system using Fuzzy Neural Network. The fingerprint features such as singular points, positions and direction of core and delta obtained from a binarised fingerprint image. The method is producing good classification results.

Ching-Tang Hsieh and Chia-Shing – Hu [14] has developed a new method for Fingerprint recognition. Ridge bifurcations are used as minutiae and ridge bifurcation algorithm with excluding the noise–like points are proposed. Experimental results show the humanoid fingerprint recognition is robust, reliable and rapid.

Lie Wei [15] proposed a method for rapid singularities searching algorithm which uses delta field Poincare index and a rapid classification algorithm to classify the fingerprint in to 5 classes. The detection algorithm searches the direction field which has the larger direction changes to get the singularities. Singularities detection is used to increase the accuracy.

Hartwig Fronthaler, et al., [16] Proposed fingerprint enhancement to improve the matching performance and computational efficiency by using an image scale pyramid and directional filtering in the spatial domain.

Mana Tarjoman and Shaghayegh Zarei [17] introduced structural approach to fingerprint classifications by using the directional image of fingerprint instead of singularities. Directional image includes dominant direction of ridge lines.

Bhupesh Gour et al., [18] have developed a method for extraction of minutiae from fingerprint images using midpoint ridge contour representation. The first step is segmentation to separate foreground from background of fingerprint image. A 64 x 64 region is extracted from fingerprint image. The grayscale intensities in 64 x 64 regions are normalized to a constant mean and variance to remove the effects of sensor noise and grayscale variations due to finger pressure differences. After the normalization the contrast of the ridges are enhanced by filtering 64 x 64 normalized windows by appropriately tuned Gabor filter. Processed fingerprint image is then scanned from top to bottom and left to right and transitions from white (background) to black (foreground) are detected. The length vector is calculated in all the eight directions of contour. Each contour element represents a pixel on the contour, contains fields for the x, y coordinates of the pixel. The proposed method takes less and do not detect any false minutiae. [19]

5 PROPOSED FRAMEWORK

In our paper, we have taken different measures to improve upon the existing techniques of fingerprint recognition. We have introduced a new way of illuminating the fingerprints and provided a means of determining the resemblance of one point set to another which was never used before in fingerprint recognition. We have modified the exisiting technique by using better methods and techniques as follows. Figure 4 shows the modified framework as compared to exisiting framework in figure 3.

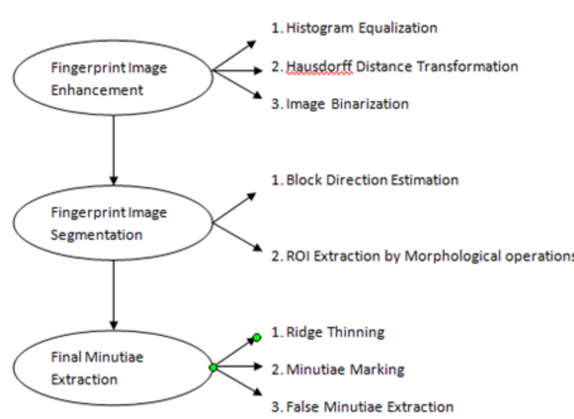

Figure 3: Existing Framework of Fingerprint Recognition

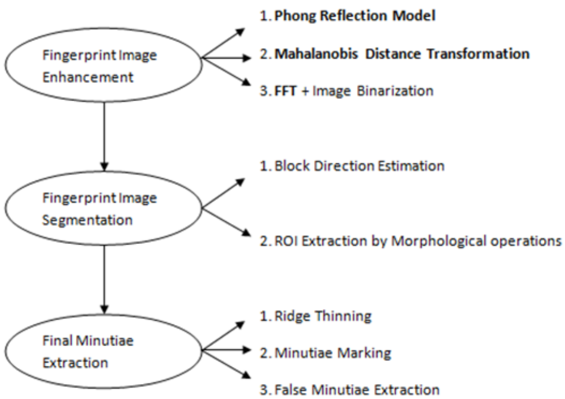

Figure 4: Proposed framework for Fingeprint recognition

5.1 Phong reflection for illumination

We have used the technique of Phong Reflection as a way of illuminating the fingerprints. In this model, we think of the interaction between light and a surface as having three distinct components:

The *ambient* component is usually given a dim constant value, such as 0.2. It approximates light coming from a surface due to all the non-directional ambient light that is in the environment. In general, you'll want this to be some tinted color, rather than just gray. $[r_a,g_a,b_a]$. For example, a slightly greenish object might have an ambient color of [0.1,0.3,0.1]. [20]

The *diffuse* component is that dot product n•L that we discussed in class. It approximates light, originally from light source L, reflecting from a surface which is diffuse, or non-glossy. One example of a non-glossy surface is paper. In general, you'll also want this to have a non-gray color value, so this term would in general be a color defined as: $[r_d,g_d,b_d](n\bullet L)$. [20]

Finally, the Phong model has a provision for a highlight, or *specular* component, which reflects light in a shiny way. This is defined by $[r_s,g_s,b_s](R\bullet L)^p$, where R is the mirror reflection direction vector we discussed in class (and also used for ray tracing), and where *p* is a specular power. The higher the value of *p*, the shinier the surface. [20]

The complete Phong shading model for a single light source is:
$[r_a,g_a,b_a] + [r_d,g_d,b_d]\max_0(n\bullet L) + [r_s,g_s,b_s]\max_0(R\bullet L)^p$

If you have multiple light sources, the effect of each light source L_i will geometrically depend on the normal, and therefore on the diffuse and specular components, but not on the ambient component. Also, each light might have its own [r,g,b] color. So the complete Phong model for multiple light sources is:

$[r_a,g_a,b_a]+ \Sigma_i([L_r,L_g,L_b]([r_d,g_d,b_d]\max_0(n\bullet L_i) +[r_s,g_s,b_s]\max_0(R\bullet L_i)^p))$

This technique has an edge over the other fingerprint illumination techniques as it describes the way a surface reflects light as a combination of the diffuse reflection of rough surfaces with the specular reflection of shiny surfaces. The reflection model also includes an *ambient* term to account for the small amount of light that is scattered about the entire scene. [20]

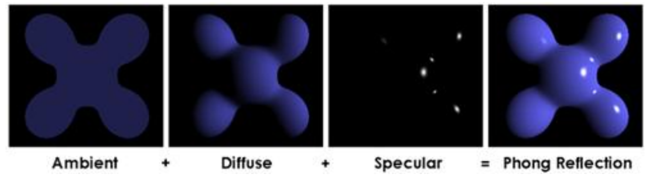

Figure 5: Working of Phong Reflection Model [20]

5.2 Mahalanobis distance

The Mahalanobis distance is a descriptive statistic that provides a relative measure of a data point's distance (residual) from a common point. [21] The Mahalanobis distance is used to identify and gauge *similarity* of an unknown sample set to a known one. We have used it in our project as a fingerprint enhancement technique. **The Mahalanobis Distance is a better distance measure when it comes to pattern recognition problems. [21] It takes into account** the covariance between the variables and hence removes the problems related to scale and correlation that are inherent with the Euclidean Distance. It is given as:

$$d(x, y) = \sqrt{(x-y)^T C^{-1}(x-y)}$$

Where C is the covariance between the variables involved. [21]

5.3 Fast Fourier Transform (FFT)

In this paper, a feature extraction method based on the fast Fourier transform (FFT) is proposed for the use of fingerprint matching. In this method we divide the image into small processing blocks (32 x 32 pixels) and perform the Fourier transform according to equation:

$$F(u,v) = \sum_{x=0}^{M-1}\sum_{y=0}^{N-1} f(x,y) \times \exp\left\{-j2\pi \times \left(\frac{ux}{M}+\frac{vy}{N}\right)\right\} \quad (1)$$

for u = 0, 1, 2, ..., 31 and v = 0, 1, 2, ..., 31.

In order to enhance a specific block by its dominant frequencies, we multiply the FFT of the block by its magnitude a set of times. Where the magnitude of the original FFT = abs (F (u, v)) = |F (u, v)|.

So we get the enhanced block according to the equation:

$$g(x,y) = F^{-1}\{F(u,v) \times |F(u,v)|^k\} \quad (2)$$

where F^{-1}(F (u, v)) is given by:

$$f(x,y) = \frac{1}{MN}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1} F(u,v) \times \exp\left\{j2\pi \times \left(\frac{ux}{M}+\frac{vy}{N}\right)\right\} \quad (3)$$

For x = 0, 1, 2 …31 and y = 0, 1, 2 ...31.

The k in formula (2) is an experimentally determined constant, which we choose k=0.45 to calculate. A high value of k improves the appearance of the ridges by filling up small holes in ridges, but too high value of k can result in false joining of ridges which might lead to a termination become a bifurcation.

The advantage of this approach is the enhanced image after FFT has improvements as some falsely broken points on ridges get connected and some spurious connections between ridges get removed. Another advantage is that it does not require the computation of intrinsic images for its operation. This has the effect of increasing the dominant spectral components while attenuating the weak components. However, in order to preserve the phase, the enhancement also retains the original spectrum F(u,v). [23]

6 EXPERIMENTAL RESULTS

Performance evaluation is the key aspect of undertaking any research work. So we have evaluated our work and finally concluded by elaborating the efficiency of our work. In the following section we show the results obtained on integrating our proposed work with the exisiting work and extending its capabilities to produce better results.

Our proposed framework shows considerable improvements in result as compared to the exisiting framework proposed by Sachin Hame [22]. By extending the framework and using better surface illumination algorithms the efficiency in finger print recognition went up.

6.1 Phong reflection for illumination

The **Phong reflection model** (also called **Phong illumination** or **Phong lighting**) is an empirical model of the local illumination of points on a surface. The following parameters are defined:

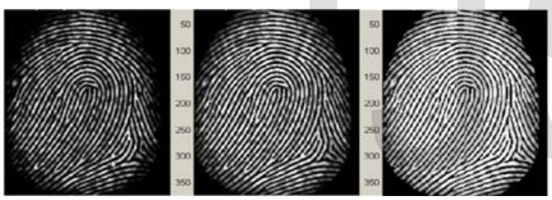

Figure 6: (a) original fingerprint (b) other illumination techniques (c) phong reflection technique

The above figure shows that how the fingerprint image is illuminated using Phong illumination technique.We also, have plotted a histogram which shows the changes occurred using this illumination method. The surface became brighter as compared to other techniques.

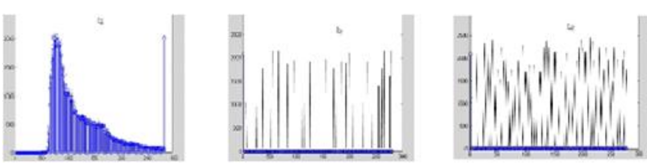

Figure 7: (a) Histogram of the original fingerprint (b) Histogram obtained after using other illumination techniques. (c) Histogram obtained using Phong illumination method.

6.2 Mahalanobis distance

The Mahalanobis distance has the following advantages over other techniques, like Hausdorff Distance:

- It accounts for the fact that the variances in each direction are different.
- It accounts for the covariance between variables.
- It reduces to the familiar Euclidean distance for uncorrelated variables with unit variance.

The Mahalanobis distance accounts for the variance of each variable and the covariance between variables. Geometrically, it does this by transforming the data into standardized uncorrelated data and computing the ordinary Euclidean distance for the transformed data. In this way, the Mahalanobis distance is like a univariate z-score: it provides a way to measure distances that takes into account the scale of the data.

6.3 Fast Fourier Transform (FFT)

After applying Fast Fourier Transform, the obtained image is as the following:

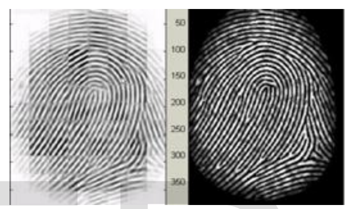

Figure 8: (a) Image before FFT, (b) Enhanced Image after FFT

6.4 Comparison of efficiency

The following table shows us the comparison in efficiency of different fingerprint recognition technique. It helps us to conclude that Mahalanobis distance when applied with Phong reflection model and Fast Fourier transform produce better results as compared to other techniques, evidently. Shown below is the table comparing efficiency of different fingerprint recognition techniques, proving Mahalanobis method is better and efficient than other techniques:

METHOD	EFFICIENCY
Mahalanobis Distance	99.65
Hausdorff Distance	97.45
Garbor Filters	99.24
Occlusion	99.02

Figure 9: Efficiency comparison of various techniques

CONCLUSION

In this paper, we have extended the exisiting fingerprint recognition technique by integrating new features, Phong reflction model, Mahalanobis Distance and Fast Fourier transform. New methods have improved the fingerprint illumination, filled the broken ridges and improved the efficiency in fingerprint comparison considerably at latr stages. Experimental results have shown improve in efficiency when new methods are integrated in the existing system. With the proposed work, the effectiveness of fingerprint comparison has been studied carefully. Further investigation to the topic reveals that fingerprint recognition using Mahalanobis distance can yield good results. The concept has been worked out and can be used in future.

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