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Morphological and Canny Filter Based Algorithm for Fingerprints Recognition

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Abstract: One of the most reliable personal identification methods is fingerprint verification and it plays an important role in commercial and forensic applications. Designing a recognition system that will increase the accuracy is required. Yet the accuracy of fingerprint recognition systems remains a challenge This article proposes a fingerprint recognition system using canny filter and morphological operator through path analysis test case. The steps involved in the proposed recognition system include; image acquisition, pre-processing, features extraction and matching. Fast fourier transform is used to enhance the quality of the images and the features extracted efficiently to determine the minutia points in fingerprints with morphological operation, and the distribution of grey level co-occurrence matrix (GLCM) with canny filter. The proposed morphological operation can determine the bifurcation, termination of the ridges and valleys, and their corresponding angles, and Euclidean distance is recommended to be used for matching. On the other hand, features such as energy, homogeneity, entropy and correlation are extracted after canny filter is applied and Euclidean distance is again used for matching. The accuracy results from this proposed methods through path analysis cases after comparing for their success rate, false accepted rate and false rejected rate should be about 99% which is higher than any previous techniques.

Keywords: Fingerprint recognition, canny filter, morphological operator, algorithm

I. Introduction

Fingerprint recognition is a metric for authenticating an individual through fingerprints identifiers or traits [1]. . Fingerprints are one of many forms of biometrics used to identify an individual and verify their identity. Due to their uniqueness and consistency over time, fingerprints have been used for over a century. In recent times it has become more recently automated (biometrics) due to the advancement in computing capabilities. According to Ito et al. [2] fingerprints recognition remains the most popular and widely used biometric techniques. It is commonly used in forensic and commercial applications and it had been used for security related purposes for a very long time. Yet the accuracy of fingerprint recognition systems remains a challenge. Previous techniques use minutiae points for fingerprint representation and matching. However, these techniques are not rotation invariant and fail when enrolled image of a person is matched with a rotated test image. Moreover, such techniques fail when partial fingerprint images are matched. This paper proposes a fingerprint recognition technique which uses local robust features for fingerprint representation and matching. The technique performs well in presence of rotation and able to carry out recognition in presence of partial fingerprints. This technique mainly use canny filter and morphological algorithm for fingerprint recognition system to enhance accuracy.

II. Previous Work Related to Fingerprint Recognition

Tico et al.[3]proposed wavelet domain features for fingerprint recognition, the image based automatic fingerprint matching approach is proposed. The fingerprint images are matched based on the features extracted in the wavelet domain. The feature vector represents an approximation of the image energy distribution over different scales and orientation. Using this method, about a 95.2% recognition rate is achieved.

Wan *et al*.[4]proposed fingerprint recognition in wavelet domain, the slopes of these lines are then stored as numerical values in a matrix form, which are then used as the template values for the fingerprint image. Fingerprint recognition is performed by comparing the slope values of the input image with the stored template values. This method yields about a 95% recognition rate.

Kadhem *et al*. (2010)[5] proposed Fingerprint Recognition based on coding algorithm. The modified chain coding algorithm converts the two dimensions of matrix which represents the two dimensions of input image to one dimension vector (v) where this vector consists of important features on the information of an input finger print image that is used for testing. Furthermore, the fingerprint image is translated into its edges features and the processing of edge extraction depending on 8-neighbourhood window. In the proposed algorithm, the coordinate (x,y) of any edge is not recorded, but the edge direction is recorded only which refers to the next edge point in the chain.

Bana and Kaur [6] proposed a study on the implementation of a fingerprint recognition system based on Minutia. The approach mainly involved extraction of minutia points from the sample fingerprint images and then performing fingerprint matching based on the number of minutia pairings among two fingerprints in question. The implementation mainly incorporates image enhancement, segmentation, feature (minutia) extraction and minutia matching process. It finally generates a percent score which tells if the two fingerprints matched. Under image enhancement, Histogram Equalization and Fast Fourier Transform are used to increase the quality of the input image and Binarization is used to convert the grey scale image into binary image to reduce the data. Then, image segmentation is performed which extracts a region of interest using ridge flow estimation and morphological functions given. Subsequently, the minutia points are extracted in the final extraction step via ridge thinning, Minutia Marking and Removal of False Minutia processes. By using the above Minutia Extraction process, the Minutia sets are obtained for the two fingerprints to be matched. The minutia matching process iteratively chooses any two minutia as a reference minutia pair and then matches their associated ridges. If the ridges match well, two fingerprint images are aligned and matching is done

Meenakshi *et al*. [7] proposed Minutiae based Fingerprint Verification and Recognition Algorithm for Offline Systems, pre-processing stage includes Image Enhancement, Binarization, Segmentation, ROI extraction and thinning. Quality of poor and distorted images is improved by image enhancement. Improved images are binarized and segmented to extract region of interest (ROI). This image is thinned to extract minutiae. Feature extraction stage includes the extraction of minutiae, ridge terminations and ridge bifurcations. Post processing stage includes removal of false minutiae and then saving of templates. In matching stage, template generated by test image was matched with the saved one. This algorithm has been tested with FVC-2004 database, 90 % accuracy with 5% FAR and 2% FRR

Suvarna and Abhay [8] proposed fingerprint verification based on correlation filters because of their properties like shift invariance capability to accommodate in class image variability and closed form terms. A specific type of correlation filter is called the minimum average correlation energy (MACE) filter has been evaluated using a FVC database given online. The MACE filter consists of sharp peak for genuine test images. It assumes that there are N training images and each image is of size d x d. The steps to perform MACE are:

a) Computation of 2D -FT in training image.
b) The resultant image matrix conversion in single column vector space.
c) The frequency domain representation of test image by performing 2D-FT of the test image.
d) Finally, the representation of the 2D filters with column vector.

Josphineleela and Ramakrishnan [9] proposed a novel fingerprint reconstruction algorithm to reconstruct the phase image that is converted into grey-scale image format. The proposed algorithm reconstructs the phase image from minutia based approach. The proposed reconstruction algorithm is used to automate the whole process of taking attendance manually is a laborious, troublesome work and a waste of time. The proposed reconstruction algorithm has been evaluated with respect to the success rates of type-I attack (match the reconstructed fingerprint against the original fingerprint) and type-II attack (match the reconstructed fingerprint against different impressions of the original fingerprint) using a commercial fingerprint recognition system. When a reconstructed image from the proposed algorithm is tested, it shows that both types of attacks can be effectively launched against a fingerprint recognition system.

Madhuri & Mishra [10] proposed fingerprint recognition based on robust local features. There exist many human recognition techniques which are based on fingerprints. Most of these techniques use minutiae points for fingerprint representation and matching. However, these techniques are not rotation invariant and fail when enrolled image of a person is matched with a rotated test image. Moreover, such techniques fail when partial fingerprint images are matched. This paper proposes a fingerprint recognition technique which uses local robust features for fingerprint representation and matching. The technique performs well in presence of rotation and able to carry out recognition in presence of partial fingerprints. Experiments are performed using a database of 200 images collected from 100 subjects, two images per subject. The technique has produced a recognition accuracy of 99.46% with an equal error rate of 0.54%.

The results of previous work related to fingerprint recognition as shown in Table 1 below:

Table 1. Results Previous Work Related to Fingerprint Recognition

Author / Year	Methods	Accuracy (%)
Tico*et al.* [3]	Wavelet Domain Features for Fingerprint Recognition	95.2
Wan *et al.* [4]	Proposed Fingerprint Recognition in Wavelet Domain	90

Kadhem *et al.*[5]	Chain Coding Algorithm	80-90
Bana & Kaur[6]	Minutiae Based Technique	65-70
Suvarna & Abhay[8]	Correlation	98
Meenakshi *et al.* [7]	Fingerprint Verification and Recognition Algorithm	90
Madhuri & Mishra [10]	Fingerprint recognition based on robust local features	99.46

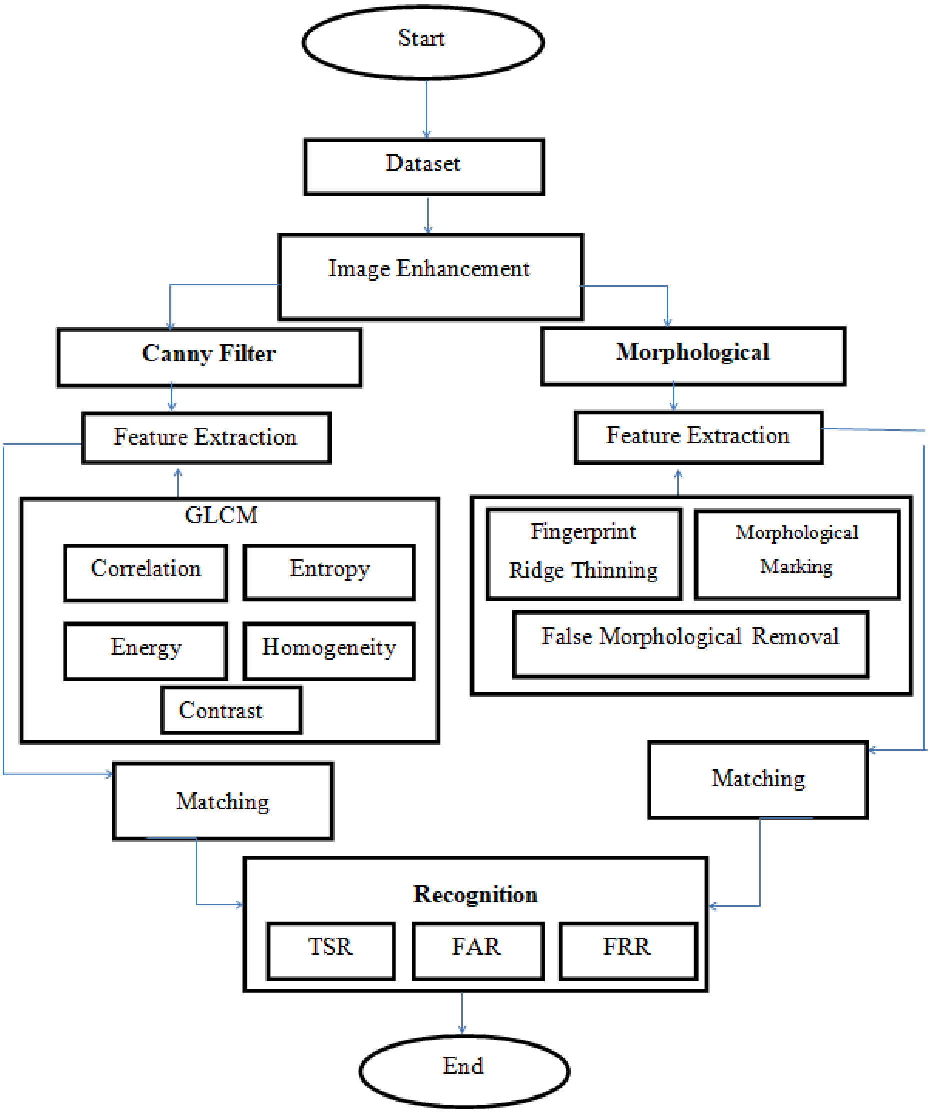
III. The Advantages of Using Canny Filter and Morphological Operation in Designing Fingerprint Recognition

There are several reasons that exist behind the proposed two methods for obtaining an accurate fingerprint recognition system. Among these reasons are:

a) Morphological operation has the advantages of identifying the ridges and valleys from the fingerprint image by assigning background and foreground of the image template.
b) Morphological operation represents the information of the fingerprint image as connected lines and this helps in identifying the minutia of the fingerprint.
c) Canny filter enhances the appearance of the ridges in the fingerprint images.
d) Canny filter represents the fingerprint image in four different orientations which would help in identifying people based on their fingerprints easily.

IV. Proposed Fingerprint Recognition Solution

The flow chart in Fig 1 below illustrates the methods used in this study.



The Fig. 1 above illustrates the summary of the proposed Solution. As could be seen from Figure 1, the dataset is based on Fingerprint Verification Competition (FVC) 2004 using 672 images to 84 different users. The image enhancement of the fingerprint recognition system is one of the most important stages in obtaining very accurate result. Fast Fourier Transform (FFT) is considered as one of the filters for enhancing the ridges and valleys of fingerprint images. The enhanced image goes for feature extraction which will depend on the variation of grey scale colouring of the image data, after that apply feature extraction by two algorithm canny filter and morphological. In morphological the feature extraction based on fingerprint ridge thinning, morphological marking and false morphological removal.

In canny filter algorithm, the energy is the sum of squared elements in the Grey Level Co-occurrence Matrix (GLCM). The range is between zero and one. This feature will return a value of the distribution of grey colour in the fingerprint image. Entropy is a statistical measure of randomness that can be used to characterize the texture of the input image. This feature also deals with the distribution of grey colour in the image and it results in a value that is bounded and normalized between zero and one. Obtaining more information about the finger template will result in more features that will result in obtaining more details. The feature correlation measures how correlated a pixel is to its neighbour over the whole image. This feature will return the percentage of differences between two objects or the similarities between them. The feature homogeneity measures the closeness of the distribution of elements in the GLCM to the diagonal of the image. The value return by this measure is normalized between zero and one. The value one means more data and the value zero means less data founded that is similar to the other diagonal. The contrast will measure how similar is the light or brightness of the image at each segment of the image. Change in brightness will result in loss of information in the image. When the brightness of the image does not change, it shows the efficiency of the algorithm in detecting the change of the colour after applying some image enhancement technique.

The features extracted above go for matching stage which is based on the nearest neighbouring. The score of the similarity will be measured and returned in percentage as the recognition rate, the recognition based on TSR, FRR and FAR.

A. Dataset

The experiment was performed on Database 3 (DB3-A), Fingerprint Verification Competition (FVC2004), (http://extras.springer.com/2009/978-1-84882-253-5/FVC 2000/Dbs). The fingerprint database of FVC2004 DB3-A had 800 fingerprints of 100 different fingers (8 images per finger). The fingerprint images were numbered from 1 to 100, followed by another number (the first to 8th impression of certain finger), and 672 fingers which represent 84 different people were used [11].

B. Image Enhancement

Fingerprint Image enhancement is the process that makes the image clearer for easy diagnosis or investigations. Since the fingerprint images were acquired from sensors or other media, they were not assured with perfect quality. Thus, enhancement methods were used to increase the contrast between the ridges and furrows and for connecting the false broken points of ridges due to insufficient amount of ink. Histogram equalization and Fast Fourier Transform were the two processes used to enhance the fingerprint images.

A. Histogram Equalization

Fig2 was the result after applying histogram equalization locally using local windows of NxN pixels, defined in Equation 2.1 [6]. This resulted in expanding the contrast locally and changing the intensity of each pixel according to its local neighbourhood. Histogram equalization was used to expand the pixel value distribution of an image so as to increase the perception information. Histogram equalization defines a mapping of grey levels p into grey levels q such that the distribution of grey level q is uniformly distributed. This mapping stretched contrast for the grey levels near the histogram maxima such as expanding the range of grey levels near the histogram maxima. In the meantime, contrast was expanded for most of the image pixels; the transform improved the detectability of many image features.

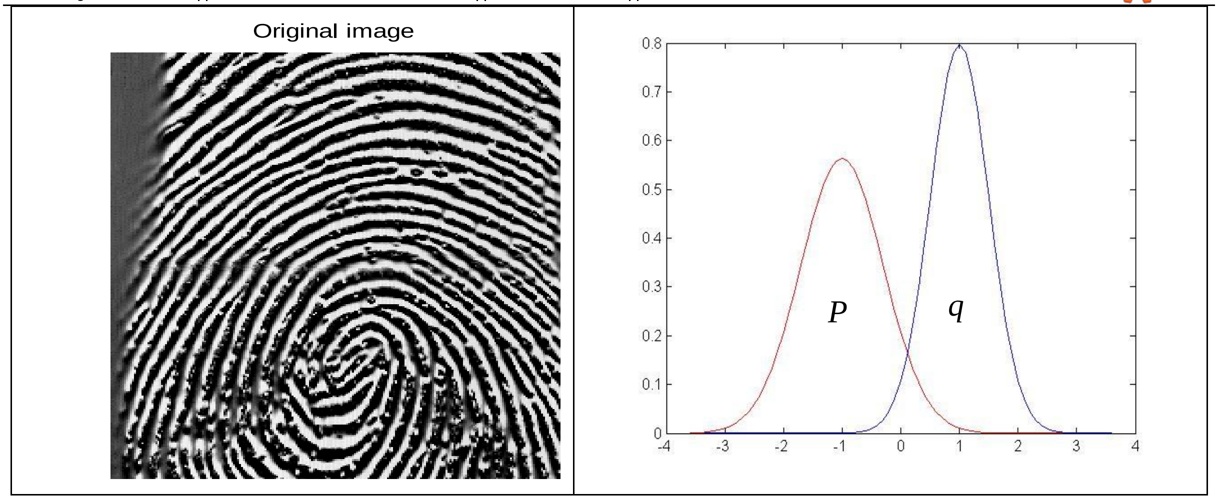


Figure 2: Histogram Image [6]

B. Fast Fourier Transform (FFT)

The propose method used the FFT to fingerprint recognition as defined in Equation 2.3. The first step in this approach involves the normalization of the fingerprint image so that it has a pre-specified mean and variance. Orientation of the image is then calculated, which is a matrix of direction vectors representing the ridge orientation at each location in the image. Ridge frequency image defines the local frequency of the ridges contained in the fingerprint. Filtering increases the contrast between the foreground ridges and the background whilst effectively reducing noise [12]. Performing segmentation, which is the process of separating the foreground regions in the image from the background regions, the foreground regions correspond to the clear fingerprint area containing the ridges and valleys, which is the area of interest. The background corresponds to the regions outside the borders of the fingerprint area, which do not contain any valid fingerprint information. The Fast Fourier Transform is a computationally accelerated technique for determining the frequency spectrum of a signal.

Fig. 3.the image after apply the Fast Fourier Transform. The basic steps in filtering an image using the FFT techniques are summarized below:

a) Convert the image to suitable dimensions (the number of pixels in the x and y axis must be a factor of 2).
b) Perform FFT on the image to transform it to frequency space.
c) Create a filter mask.
d) Multiply the image by the filter mast.
e) Transform the result back to the spatial domain

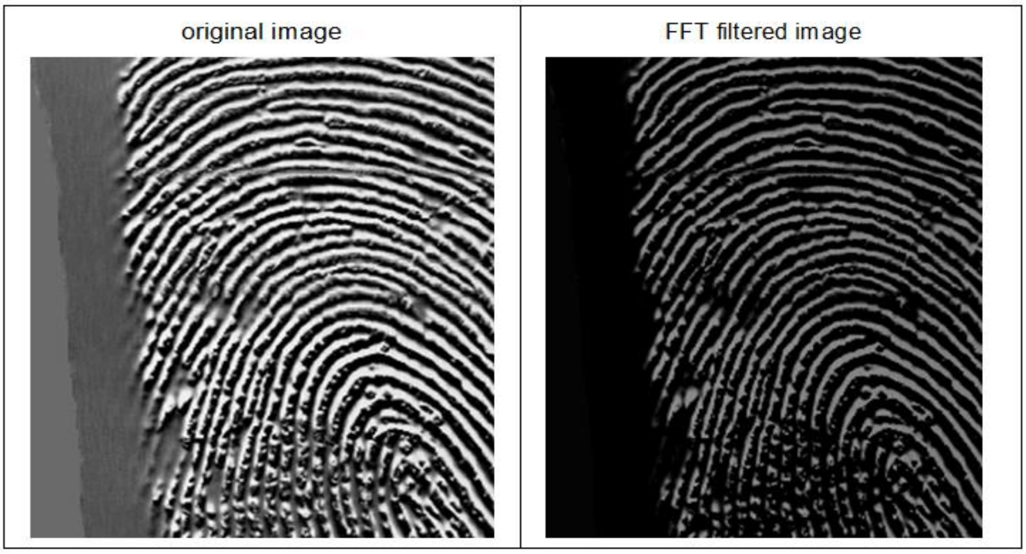


Figure 3: Fast Fourier Transform [6]

C. Region of Interest extraction by Morphological operation

After enhanced the image and segmented the required area, the job of minutiae extraction closes down to operations, ridge thinning, minutiae marking, false minutiae removal and minutiae representation, it uses the code as defined by Latha and Rajaram, [13], Deshpande., et al [14] and Valdes-Ramirez [15].

a) Fingerprint ridge thinning.
b) Morphological marking.
c) False morphological removal.

Fig4.to Figure 6 shows ridge thinning, morphological marking and false morphological removal.

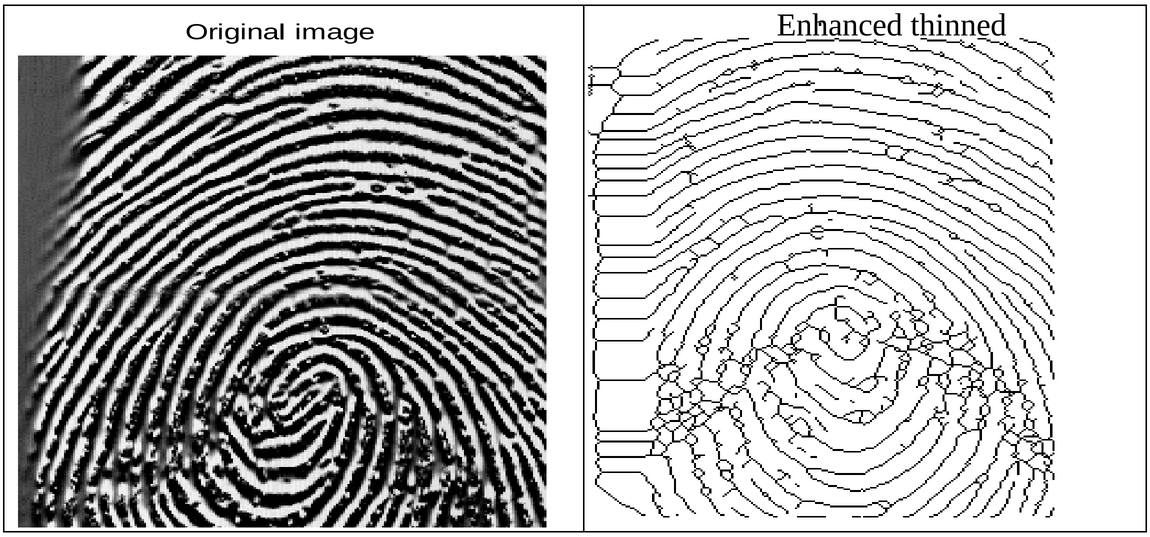


Figure 4: Ridge Thinning [6]

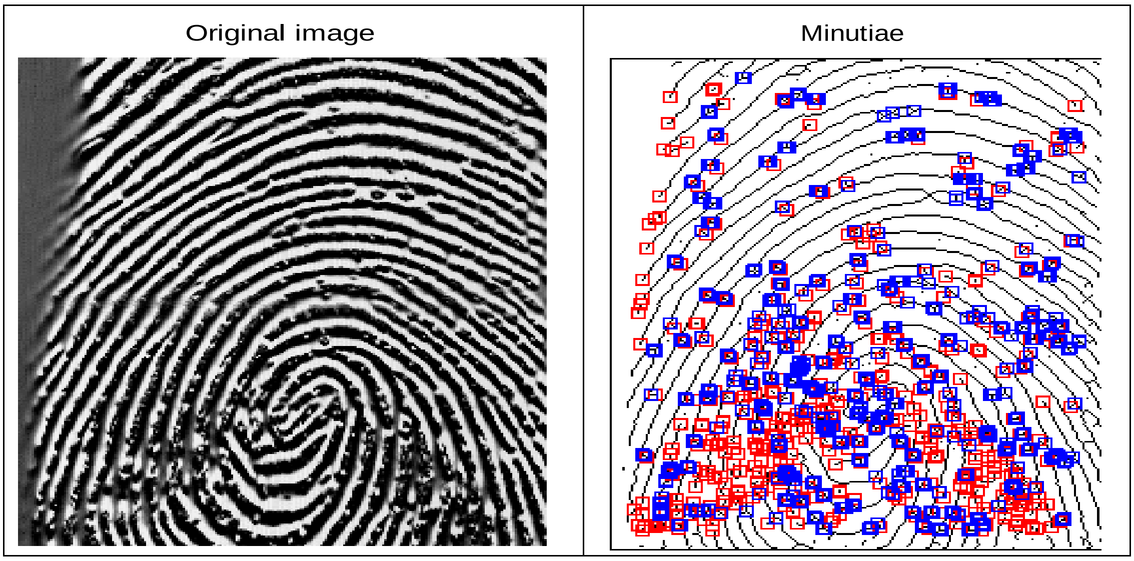


Figure 5: Morphological Marking [6]

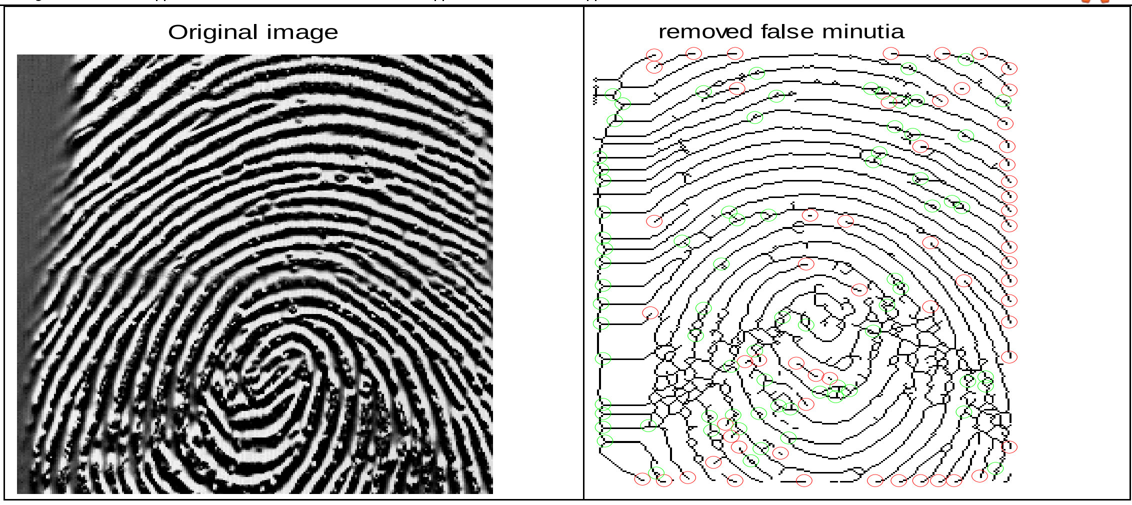


Figure 6: False Morphological Removal [6]

D. The Procedure of the Proposed Technique (Canny Filter and Morphological Operation)

The following are the steps used in this study:

a) Image enhancement is performed.
b) The image is cropped to predetermined size.
c) Thinning is performed.
d) Minutia and core point are obtained.
e) False minutia are removed.
f) Alignment stage**.**
g) Matching stage.
h) The test images are classified using Euclidian distance.

1) Features Extraction under Canny filter

Several features were extracted from the trained and tested images. The most commonly used features were (energy, homogeneity, correlation, contrast and entropy) of the images. The GLCM was used to extract the features from the whole data and they were stored and used for comparison at the matching step/process and as defined in Equation 2.6 to Equation 2.10.

2) Matching stage

Several features were extracted from the trained and tested images and concatenated as single feature vector. The used features were; energy, homogeneity, correlation, contrast and entropy of the images. The GLCM was used to extract the features from the whole data and they were stored and used for comparison at the matching step/process.

3) Classification

In the proposed method, *K*-nearest neighbour classifier was used to classify the fingerprint test samples. The features were extracted from the test image *X* using the proposed feature extraction algorithm and then, compared with corresponding feature values stored in the feature library using the Euclidean distance formula given in the Equation below:

$$D(M) = \sqrt{\sum_{i=1}^{N}[f_j(x) - f_j(M)]^2} \qquad (3.1)$$

Where

Nis the number of features in the feature vector *f*, $f_j(x)$ represents the j^{th} feature of the test sample *X* and $f_j(M)$ represents the j^{th} feature of M^{th} class in the feature library.

Then, the test sample *X* was classified using the *k*-nearest neighbour (*K*- NN) classifier.

In the *K*-NN classifier, a test sample was classified by a majority vote of its *k* neighbours where *k* is a positive integer typically small. If *K* equal 1, then the sample was just assigned to the class of its nearest neighbour. However, it is better to choose *K* to be an odd number to avoid tied votes. Therefore, in this method, the *K*- nearest neighbours were determined and the test image was classified as the language type of the majority of these *K*-nearest neighbours.

The final feature vector of test fingerprint was determined and compared with the feature vector sets of fingerprint database. The Euclidean distance was computed between fingerprint data base and test fingerprint. The matching and non-matching are based on the prefixed Euclidean distance which constituted threshold value, if the Euclidean distance was less than the threshold value, then it is matched.

4) Evaluation of Fingerprint Recognition with Morphological and Canny Filter

After performed the features extraction for both of algorithms, evaluation is performed using TSR, FRR and FAR, depend on Equation 2.12 to Equation 2.14.

V. Conclusion

Automated or semi-automated recognition of a person is one of the critical issues. Fingerprint recognition is among the commonly used methods of biometrics. Fingerprint recognition is cheap and relatively robust biometric method and it has been extensively studied and applied for many popular applications. This article presents a proposal to recognise fingerprints using canny filter and morphological operator. FFTis to be used for image enhancement and edge structure preservation. GLCM features allows extraction from the gradient and coherence images and used later for classification of the fingerprint to obtain the final match values; Total Success Rate (TSR), False Accepted Rate (FAR) and False Rejected Rate (FRR). It is expected that this algorithm could provide upto 99% accuracy. This rate is more than any other available method.

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