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An Algorithm for Fingerprint Minutiae Extraction

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Abstract—Human fingerprints are reliable characteristics for personnel identification as it is unique and persistence. Fingerprint biometric authentication is one of the challenging pattern Recognition problems. A Fingerprint pattern contains ridges, valleys and minutiae. Minutiae extraction is an important post-processing step of biometric fingerprint recognition system. The minutiae are key points and the main features of a fingerprint, with which you can compare one print with another. Generally minutiae extraction is carried out after different preprocessing stage like image enhancement and image thinning so image also contains large number of false minutia which can decrease the performance of the fingerprint recognition system. A novel algorithm of fingerprint minutia extraction is proposed in this paper: The algorithm work on the thinned binary image of the fingerprint, in order to eliminate the false minutiae.The implementation of research work is done in .Net platform using custom fingerprint database of 100 images of 25 users.

Keywords— Biometric, Fingerprint Recognition, Minutiae Extraction, Fingerprint Thinning, Fingerprint Enhancement

I. INTRODUCTION

The term Biometrics relates to the measurement (metric) of Characteristics of a living (Bio) thing in order to identify a person. Biometric recognition is used as an automatic recognition of individuals based on the physiological or behavioral characteristics [1]. A physiological characteristic such as Fingerprint, Face, Iris, Hand geometry and Retina remains same throughout the lifetime of a person. Behavioral characteristics such as signature, gait, voice and keystroke changes with age and mentality of a person.

Human fingerprints are reliable characteristics for personnel identification as it is unique and persistence [1]. There are various types of applications for fingerprint recognition which is used for different purposes .fingerprint is one of the challenging pattern Recognition problem. The Fingerprint Recognition system divided into four stages [2, 3]. First is Acquisition stage to capture the fingerprint image, the second is Pre-processing stage to enhancement, binarization, thinning fingerprint image. The Third stage is Feature Extraction Stage to extract the feature from the thinning image by use minutiae extractor methods to extract ridge ending and ridge bifurcation from thinning. The fourth stage is matching(Identification, Verification) to match two minutiae points by using minutiae matcher method in which similarity and distance measure are used.

(i) Fingerprint image acquisition
(ii) Pre-processing Stage.
- (a)Image Enhancement
- (b)Binarization
- (c)Thinning

(iii)Minutiae extraction
(iv)Matching and recognition

Those approaches up to minutiae extraction called pre-processing of fingerprint recognition.

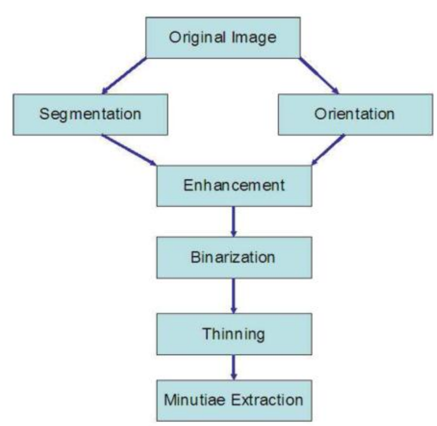


Figure 1 Preprocessing of fingerprint recognition

Although automatic fingerprint recognition systems have been around for several decades, the problem is still not entirely solved. This is the result of a number of difficulties, both in the problem itself, namely the high intra-class variability (the same fingerprints can look very different between impressions) and high interclass similarity (two different fingerprints can yield similar features), as well as practical issues including uncooperative data subjects, elastic distortion during scanning, inconsistent moisture conditions, and damaged fingerprints[4].

In general, the analysis of fingerprints for matching purposes requires the comparison of several features of the print pattern. These include patterns, which are aggregate characteristics of ridges, and minutia points, which are unique features found within the patterns.There are three different basic patterns of fingerprint: Loop, Arch and Whorl.

(Loop) **(Arch)** **(Whorl)**

Figure 2 Three different basic patterns

The major minutia features of fingerprint ridges are: ridge ending, bifurcation, and short ridge (or dot).

A new algorithm of fingerprint minutia extraction is proposed in this paper: The algorithm work on the thinned binary image of the fingerprint, in order to eliminate the false minutiae. The implementation of research work is done in .Net platform using custom fingerprint database of 100 images of 25 users. Various results are also discussed in this paper.

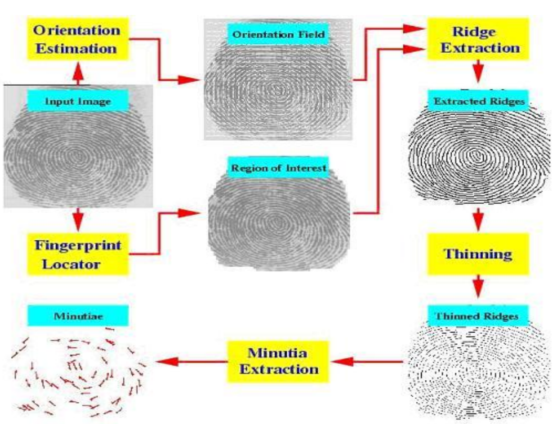


Figure 1 Flowchart of the minutia extraction algorithm [3]

II. LITERATURE REVIEW

(Danny Thakkar, 2017) reveals that, to extract minutiae in thinned binarized image two ways are used: morphology operators and crossing number. The method based on morphology operator is used when the image is pre-processes using orphology operator for reducing the effort during post-processing. The morphology operators are used to eliminate false minutiae like bridge, spur and so on at the time of pre-processing. Then after minutiae extraction are done with hit or miss transform. The second method based on crossing number is used in thinned binarized image. It is the most widely-employed technique. It is adapted more compare to others because of intrinsic simplicity and computational efficiency [6].

(Gowthami A T., et. al., 2015) presented an algorithm for fingerprint verification based on linear binary pattern. In this algorithm, an image is divided into equal size 9 zones. The linear binary pattern is identifying in each zone for recognition. Euclidean distance similarity and neural network are used as measurement standard. Total 8 databases contain 3500 images are used for testing purpose. The accuracy 94.28% recognize for neural network and 91.15% for nearest neighbor classifier method [7].

(F. A. Afsar et al., 2004) also carried out minutiae extraction work using approach of Crossing Number. In Crossing Number, Cn (P) at a point P is defined as half of cumulative successive differences between pairs of adjacent pixels belonging to the 8-neighborhoods of P. An author considers ridge ending and bifurcation for minutiae extraction. An approach worked on the condition that, if the value of Cn (P) = = 1 then considered as ridge ending and if value of Cn (P) = = 3 then considered as ridge bifurcation [8].

(L. Coetzee et al., 1993) introduced binarization method which used Marr-Hildrith operator for extracting edges. To obtain the binarized image, combine the original gray-scale image with resultant edge image. It's a recursive technique for line thinning and line following. The steps of recursive method used gray scale window and edge window. First, identify the pixel which contains lower grayscale value then placed window on that value. To decide next position of window detected boundary of window. This process was done recursively for outlining ridge boundary and completed when up to monitored all pixels of ridge [9].

(Ratha et al., 1996) proposed segmentation techniques based on adaptive flow orientation. The ridge direction of each point in an image is getting by calculating orientation field. To perform segmentation of ridges, 16x16 block is used to find out ridge direction. Then calculate projection sum besides ridge direction. The peak point is considered as centres of ridges from projection. The skeleton of ridge is done by morphological operator. Then extraction of ridge bifurcation and end point are done from thinned image [10].

(P. Peer et al., 2010), introduced minutiae based fingerprint verification method. In proposed work, enhancement of an image is carried out by Gabor filter then extract from binary image is done using crossing number method. After getting minutiae points matched, it using thresholding technique. However, the author did not consider the texture features of finger image in his framework. That is the drawback of this framework because same finger can be consider as different finger if scaling variance is bigger. Like same way rotation and translation also make the difference in same finger. The solution of these problems makes increase in accuracy of verification [11].

(Farina et.al., 1999) proposed an algorithm which used curves for minutiae extraction. This approach is used for cleaning bridges and finalized minutia for thinned image [12].

(Hoi Le et al.,2009) states that its challenging task to develop accurate and fast biometric recognition system. During fingerprint identification, one issue is encountered that is fast fingerprint indexing. The researcher contributes his work and introduces new reliable indexing technique for accurate and fast identification process [13].

(Manvjeet Kaur et al.,2008) introduced an algorithm which extracts minutiae based on minutiae matching technique. Although, this technique is not working well when poor quality images are there. As well as shown distortion is creating main trouble during matching of fingers. The alignment of fingerprint is changed due to distortion and that will fail the matching of same finger images. This paper also reveals that find out correct minutia and false minutia rejection are still under research. This work follows many phases like split image using morphology operator, thinning of an image, remove false minutiae, extract minutiae as features, three termination of branch done by minutiae unification and used x-y coordinate technique for matching [14].

(Shunshan li et al.,2005) proposed improved redefine Gabor filter which enhance quality of an image for fingerprint matching. Refined Gabor filter fills the blanks and connect broken ridges as well as reduce the deformation. It also includes orientation of ridge in algorithm. The Gabor filter decreases the noise as well as make proper distance within two ridges and create a rough orientation map of ridges. These same processes are done by refined Gabor filter and also able to reimburse for nonlinear distortions. This method does not work properly while ridge structure is spurious [15].

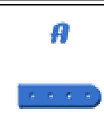
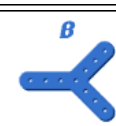
(Anil Jain et al., 2006) proposed matching of fingerprint using Level 3 features like pores and ridges. Three Levels are defined: ridge patterns, minutia, ridge shape and pores for extract details of ridge. Various fingerprint verification system work on Level 1 and Level 2. It is possible to extract Level 3 feature form higher resolution about ~1000dpi. The researcher introduces matcher algorithm for Level 3 features in higher resolution. The features are extracting using different methods like Gabor filter and Wavelet transform then matched it using ICP technique. The performance is checked and remains significant in medium size database and EER value is decreased when combined all level features [16].

(Mayank Vatsa et al., 2009) designed algorithm to increase fingerprint verification using minutiae with pores and features of ridges. The author presents an efficient algorithm using level 2 features like minutiae and level 3 features like pores features of ridges. To enroll finger image used two stage process: In first phase for rough enroll, image transformation based on Taylor series is used and in second phase for fine enroll image transformation is used based on thin plate spline. They also proposed an efficient algorithm for segmenting and extracting level 3 complex ridge features and pore based on Mumford shah function. To provide consistency in structure and reliability in minor variation affected by noise or distortion during acquisition of an image proposed fusion algorithm based on Delaunay triangulation for combining level 2 and level 3 features. To generate a feature super vector, they used level 2 and level 3 topological characteristics to describe eight quantifiable measurements. Using feature super vector differentiate imposter and genuine cases implements 2n-SVM. The experimental study and result shows that compare to existing fusion and identification algorithms proposed algorithm prove that feature super vector generate high accuracy and discriminatory information [17].

III. PROPOSED WORK

The minutiae are core points and major features of a fingerprint, using which comparisons of one print with another can be made.

The categories of minutiae showed as below:

	Ridge ending – the abrupt end of a ridge
	***Ridge bifurcation*** – a single ridge that divides into two ridges

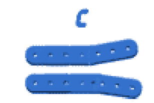
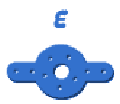
	**Ridge Divergence** - two parallel ridges divergent from this point
	***Island*** – a single small ridge inside a short ridge or ridge ending that is not connected to all other ridges
	***Ridge enclosure*** – a single ridge that bifurcates and reunites shortly afterward to continue as a single ridge
	***Short ridge*, or *independent ridge*** – a ridge that commences, travels a short distance and then ends

Figure 4 The categories of minutiae

In this process, minutiae will be detected and extracted.

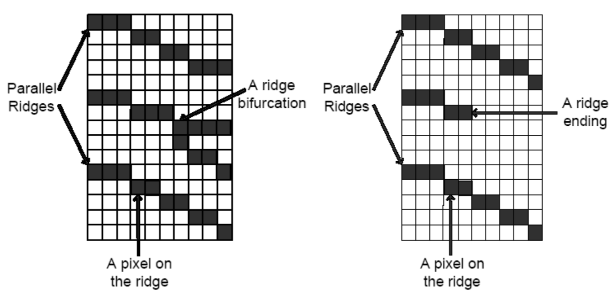


Figure 5. Minutiae in thinned fingerprint images[18]

After minutiae collection, those minutiae which not necessary for the matching process, will be removed using minutiae validation technique.

Minutiae Extraction and Validation

Fingerprints are one of the biometrics which plays an important role in identifying a person based on some minutiae features [25]. Most fingerprint recognition techniques, including the techniques I would like to use in my paper are based on minutiae matching. The minutiae of a fingerprint, as I mentioned before are core points and major features of a fingerprint. There are six different types of minutia: ridge ending, ridge bifurcation, ridge divergence, island, ridge enclosure and short ridge.

The most fingerprint recognition techniques only focus on the first two types of minutiae – ridge ending and bifurcation.

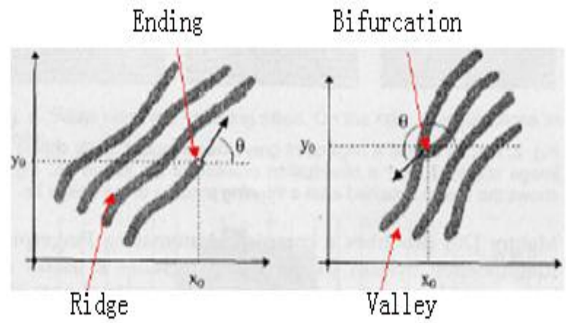


Figure 6 Ridge ending and bifurcation of a fingerprint [19]

Minutiae extraction works after image thinning process. As the number of minutiae detected is more the probability of accurate result increases. The concept of Crossing Number (C_n) is widely used for extracting the minutiae. Rutovitz's definition of crossing number for a pixel P is given below [19].

$$C_n(P) = \left(\frac{1}{2}\right)\sum_{i=1}^{8} |P_i - P_{i+1}|$$

Where Pi is the binary pixel value in the neighbourhood of P with Pi = (0 or 1) and P1 = P9. The crossing number C_n (P) at a point P is defined as half of cumulative successive differences between pairs of adjacent pixels belonging to the 8- neighbourhoods of P. If $C_n(P) == 1$ it's a ridge ending and if $C_n(P) == 3$ it's a ridge bifurcation point.

In other words, similar with Zhang-Suen thinning technique, we use a 3X3 matrix slide over the thinned fingerprint image to detect candidate minutiae. For example, if the matrix matches the pattern shown in figure 24, we say the pixel P is a ridge ending or bifurcation.

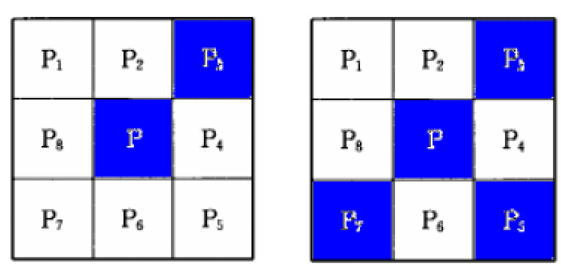


Figure 7 Two sample 3X3 matrix pattern of ridge ending and bifurcation [20]

The 3X3 matrix slides over the thinned fingerprint image in sequence to collect all candidate minutiae.

Figure 8 An original thinned fingerprint (left) and a copy of the image with all candidate minutiae represented on it (right). Squares represent ridge endings and circles represent bifurcations [21]

The false minutiae may be identified in the thinned binary image either as part of false minutia structures (e.g. spikes, bridges, holes, breaks, spurs, ladder structures) or at the boundary of the image region where the fingerprint pattern is located (boundary effect).

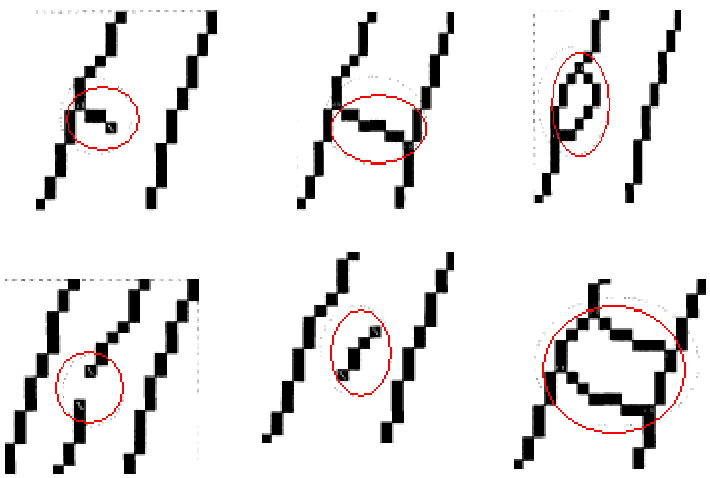


Figure 9 Some samples of false minutiae, from left to right are: spike, bridge, hole, break, spur, ladder structures [22]

The boundary effect is treated by cancelling all minutiae which are below a certain distance to the boundary of the fingerprint pattern. The other false minutiae can be eliminated by the following algorithm:

For each candidate minutia (ridge ending or ridge bifurcation)[23].

1. Create an image L of size W x W and initialize it with 0. Each pixel of L corresponds to a pixel of the thinned image which is located in a W × W neighborhood centered in the candidate minutia.
2. Label with -1 the central pixel of L (Figure.10 a, Figure.11 a). This is the pixel corresponding to the candidate minutia point in the thinned ridge map image.

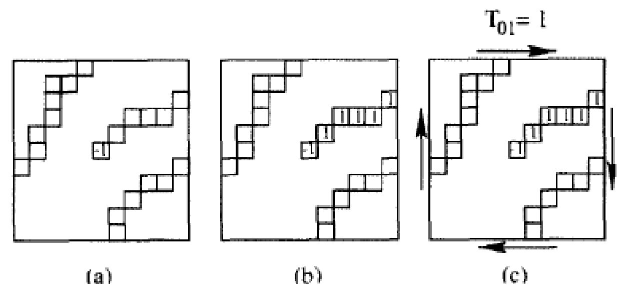


Figure 10 Minutiae validation for a ridge ending [23]

3. If the candidate minutia is a ridge ending then:

   (a) Label with 1 all the pixels in L which correspond to pixels connected with the candidate ridge ending in the thinned ridge map image (Figure.10 c).
   (b) Count the number of 0 to 1 transitions (T_{01}) met when making a full clockwise trip along the border of the L image (Figure.10 f).
   (c) If T_{01} = 1, then validate the candidate minutia as a true ridge ending.

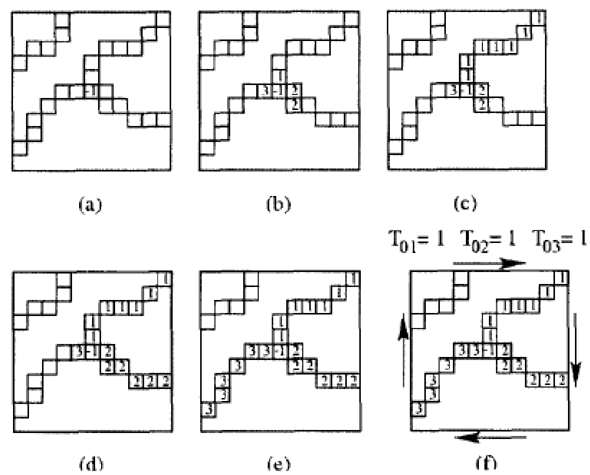


Figure 11 Minutiae validation for a ridge bifurcation [23]

4. If the candidate minutia is a ridge bifurcation then:
   (a) Make a full clockwise trip along the 8 neighborhood pixels of the candidate ridge bifurcation, and label in L with 1, 2 and 3 respectively the three connected components met during this trip (Figure. 11b).
   (b) For each *l* = 1, 2, 3 (Figure.11 c,d,e), label with *l* all pixels in L which:
      i. have the label 0;
      ii. are connected with an *l* labeled pixel;
      iii. correspond to 1 valued pixels in the thinned ridge map;

(c) Count the number of 0 to 1, 0 to 2 and 0 to 3 transitions met when making a full clockwise trip along the border of the L image. The above three numbers are denoted by T_{01}, T_{02} and T_{03} respectively as shown in Figure.11 f.

(d) If $T_{01} = 1 \wedge T_{02} = 1 \wedge T_{03} = 1$, then validate the candidate minutia as a true ridge bifurcation.

The dimension W of the neighborhood analyzed around each candidate minutia is chosen larger than two times the average distance between two neighborhood ridges. In this way the algorithm succeeds to cancel close minutiae belonging to the same ridge.

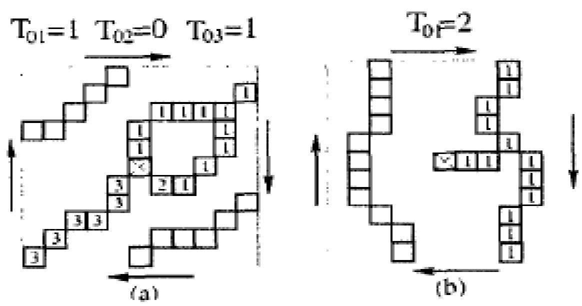


Figure 12 An example of false minutiae detection for a hole configuration (a) and spike configuration (b)[23]

After this algorithm, all false minutiae will be eliminated from thinned image and the image can be used in next stage of fingerprint recognition – minutiae matching.

IV. IMPLEMANTATION

The implementation of research work is done in .Net platform using custom fingerprint database of 100 images of 25 users.

The following result is obtain by applying Gaussian Mask for making smooth image and then use two 3*3 Sobel convolution mask[24].

Table 1. Image quality of proposed enhanced algorithm Using Gaussian Mask and Sobel Convolution[24]

Original Image	Enhanced Image
	
101_01_Original	101_01_Enhanced Image
	
102_01_Original	102_01_Enhanced Image
	
103_01_Original	103_01_Enhanced Image
	
104_01_Original	104_01_Enhanced Image
	
105_01_Original	105_01_Enhanced Image

	
106_01_Original	106_01_Enhanced Image

The following result is obtain by applying Zhang-Suen thinning algorithm on enhanced image which is get by Gaussian Mask and two 3*3 Sobel convolution masks [24].

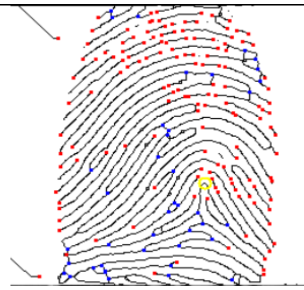
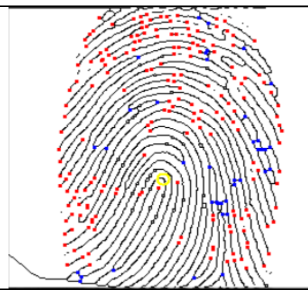
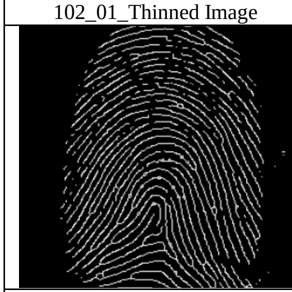
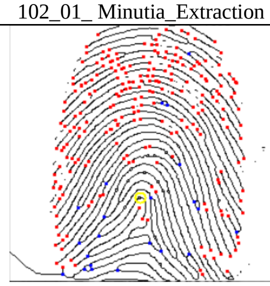
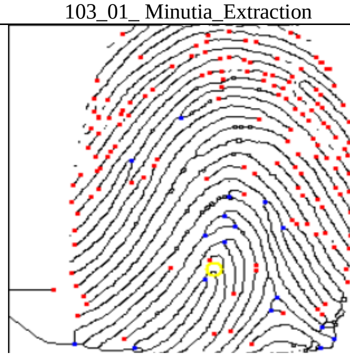
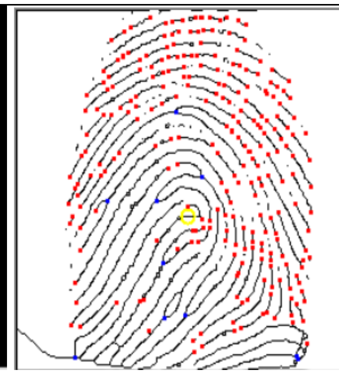
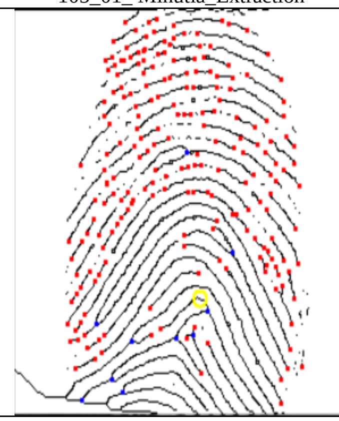
Table 2. Thinning Image Using Zhang-Suen thinning algorithm

Enhanced Image	Thinned Image
	
101_01_Enhanced Image	101_01_Thinned Image
	
102_01_Enhanced Image	102_01_Thinned Image
	
103_01_Enhanced Image	103_01_Thinned Image
	
104_01_Enhanced Image	104_01_Thinned Image
	
105_01_Enhanced Image	105_01_Thinned Image
	
106_01_Enhanced Image	106_01_Thinned Image

The following result is obtain by applying our Minutia extraction algorithm on thinned image which is get Using Zhang-Suen thinning algorithm

.

Table 3. Minutia extraction algorithm on thinning image

Thinned Image	Minutia Extraction
	
101_01_Thinned Image	101_01_Minutia_Extraction
	
102_01_Thinned Image	102_01_ Minutia_Extraction
	
103_01_Thinned Image	103_01_ Minutia_Extraction
	
104_01_Thinned Image	104_01_ Minutia_Extraction
	
105_01_Thinned Image	105_01_ Minutia_Extraction
	
106_01_Thinned Image	106_01_ Minutia_Extraction

V. Conclusion and Future Scope

The research paper shows the implementation of algorithm of fingerprint minutia extraction. The concept of Crossing Number (C_n) is used for extracting the minutiae in our paper. The algorithm is capable enough for extracting minutia from fingerprint image. Minutia extraction is carried out on thinned binary image of fingerprint. The implementation of research work is done in .Net platform using custom fingerprint database of 100 images of 25 users. In Future minutia matching can be carried out and fingerprint recognition can be performed.

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