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AN IMPROVED THINNING ALGORITHM FOR FINGERPRINT RECOGNITION

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Abstract :Thinning is the important steps in pre-processing phase of fingerprint recognition.It explains the visual quality of skeleton with 1-pixel unit width. This paper presents the implementation work of famous thinning algorithms and enhances the Zhang-Suen algorithm in the facet of removal of pixel criteria for preserving the connectivity of pattern, remove noisy points, and for sensitivity of the binary image. The performances of the implemented algorithms are evaluated using Mean Square Error, Peak Signal Noise Ratio, and computational time measurement standard. The implementation is done on fingerprint databases FVC2000 and FingerDos using java platform.

Keywords: Fingerprint image thinning, Hilditch, Zhang-Suen, MSE, PSNR.

1. INTRODUCTION

Thinning process is useful for decreasing an object of theimage for collecting the most useful information which is useful for further analysis and recognitionprocess [1].It is applied on binarized image and produces another binarized image as an output image [2-3] or it is called as skeleton.Thinning process usedin many applications like OCR, document image analysis, fingerprint identification, biometric authenticationusing images of retina,signature authentication and so on [4].

The thinning process gives some benefits like:

- Itdecreases the width size of the ridge pattern up to a single pixel.
- Produces a thin line image of fingerprint image [5].
- Maintain connectivity between the pixels of an object [6].
- The computer can process the data faster and reduce the processing time.
- It reduces the usage of the memory because it generates only essential information and the size of the image becomessmaller [7-8].
- The thinned image can be used for the classification process of fingerprint recognition[9]
- The skeleton image contains information such as end points, bifurcation and connection points.
- It reducesundesirable features and undesirable noise.

Thinning is the main process for fingerprint recognition [10] because post-processing steps like minutiae extraction and core point detection is depended on thinning process. The binarized imagesare not used for extracting the minutiae because the ridges are wide in it. For that make the all ridges of the image thick up to 1 pixel. To find out the global and local features of the fingerprint image which are useful in classification, recognition and in matching [11, 41-43] process is become very easy from thinned image because it does not change the structure of ridge and valley.

2. RELATED WORK

Based on the literature review thinning algorithms either directly wok on grayscale image without binarization[12-16] or maximum algorithms required binary image as an input images[8,17-25]. Three types of algorithm are worked for binary images: 1) sequential algorithms, 2) parallel algorithms, and 3) medial axis transform algorithms [8].
Sequential and parallel algorithms are iterative thinning algorithms while medial axis algorithms are non-iterative thinning algorithms.
The iterative thinning algorithms inspect each single pixel in binary image and remove the boundary pixel of the imageunit pixel-width thinned image remains while in non-iterative thinning algorithm do not examine single pixels one by one, instead of that they produce some centerline of the pattern and then take a decision whether to remove that particular boundary pixel or not [26-27].
The non-iterative algorithms are efficient in computation time but are responsible for creating noisy skeleton while in iterative thinning algorithm the parallel thinning algorithms arefrequently discussed because they are fastand efficient.
The Zhang-Suen et al[28],Guo-Hall et al [29], Abdulla et al[30], R. W. Hall et al[31], etc. are the famous algorithm of thinning. The [32] implemented and compare this all four algorithms and prove that Zhang-suen's algorithm gives the minimum computational time, while Guo- Hall's algorithm constructs the best qualitative skeleton. In that paper proposed effective, faster and better preserves structure outcome on thinning using modified Zhang-Suen's algorithm.

In [33] Guo Z et. al., and Zhang T.Y et. al., are implemented and provethat Zhang-Suenalgorithm give the better result. In [34] proposed Hilditch algorithm to acquire more suitable skeletons obtained and give better results in Chinese characters and numbers as well as [35] and [36] implemented Hilditch algorithm for fingerprint images. The following sections discuss the famous iterative parallel thinning algorithms; Hilditch's algorithm [37], Zhange-Suen's algorithm [28] and proposed enhanced Zhang-Suen's algorithm.

3. IMPLEMENTED WORK

First, implement Hilditch's Algorithm [37]. It follow the below steps.

Hilditch's algorithm 3x3 windows is used. It involves performing various passes on the pattern. On every pass, it check the below four conditions if it satisfied then it change the pixel value from black to white.

- 2 < = N(p1) < = 6
- M(p1)=1
- p2.p4.p8=0 or M(p2)!= 1
- p2.p4.p6=0or M(p4)!=1
  Stop when nothing changes (no more pixels can be removed)
- Here N(p1) = number of non-zero neighbors of p1 and
- M(p1) = number of 0,1 patterns in the sequence p2,p3,p4,p5,p6,p7,p8,p9,p2

Then after implement Zhang-Suen algorithm[28]. This algorithm used 3X3 matrix as mask for binary image move down an entire image and go through the all pixels of the image. The below Fig. 1 show the 3X3 matrix.

P9 (i-1,j-1)	P2 (i-1,j)	P3 (i-1,j+1)
P8 (i,j-1)	P1 (i,j)	P4 (i,j+1)
P7 (i+1,j-1)	P6 (i+1,j)	P5 (i+1,j+1)

[Fig. 1: 3*3 matrix]

This techniqueeliminatesentire contour points of the imageexcluding those which reside to the skeleton [28]. The difficulty in maintaining the image connectivity with 3x3 operator is restricted in fully parallel thinning algorithms [29]. Up to the image is not reach at stable, and for maintaining the image connectivity many parallel algorithms divide the iteration in two sub iteration [28-31].

It follow the below steps.

- Here M(P1) is the number of 0 to 1 transitions from P2 to P9 in a clockwise direction
- N(P1) is the number of non-zero neighbors of P1 that is N(P1) = P2 + P3 + P4 + … + P8 + P9.
- Do until image is in steady state
- In the first sub-iteration, the contour point P1 is deleted from the digital pattern if it satisfies the following conditions:
- 2 <= N(P1)<= 6 or M(P1)= 1or P2*P4*P6 = 0 or P4*P6*P8 = 0
- In the second sub-iteration, the contour point P1 is deleted from the digital pattern if it satisfies the following conditions:
- If 2<= N(P1) <=6 or M(P1) = 1 or P2*P4*P8 = 1 or P2*P6*P8 = 1

See in Appendix-I, that some new noisy points are created after implementing Zhang-Suen's thinning algorithm. To remove this noisy point followed fix ridge algorithm after thinning process. This algorithm checks the each pixel of thinned image using 3X3 matrix like following Fig. 2.

P1	P2	P3
P8	P	P4
P7	P6	P5

[Fig. 2.3*3 matrix implementation of fix ridge algorithm]

See in below e.g. If p is foreground and all its neighbors are background, then remove p. If p is background and check its four neighbors, if there are more than 3 neighbors is foreground and then mark p is foreground.

	1	
1	P	1
	1	

The fix ridge operationapplied two times for deleting the most of noisy point.

4. PERFORMANCE METRICS

There are three measurement standard are used to compare the performance of implemented algorithm.

1) PSNR and MSE value
2) Execution Time
3) Quality of an Image

1) PSNR and MSE value [38]

PSNR:-PSNR is defined as peak signal-to-noise ratio between two images using following equation (6). The quality is measured among original and recreated image using it. The quality of recreated images is given by high PSNR and with low MSE value.

MSE:-MSE is defined as Mean square error whichestimates the alteration among the original image and the thinned image. For example: Suppose two images are undistinguishable in all aspect then MSE among them is measuredas zero. First calculate the MSE value for calculating the PSNR value byusing the below equation (5):

$$MSE(x,y) = \frac{1}{N}\sum_{I=1}^{N}(x_i - y_i)^2$$

Where, N is the total number ofpixels in the input image.

The PSNR is computedusing below equation:

$$PSNR = 10\log_{10}\frac{L^2}{MSE}$$

Where, L is the number of discrete gray level.

2) Execution Time

The execution time is used to count the complete time for the whole process.The calculation is consider as the time between the first line and last line of code.

3) Quality of an image

The standard quality of an image is used to measure the spurious branches, noise, and thickness of an image.

5. EXPERIMENTAL RESULTS AND ANALYSIS

The implementation of thinning algorithms are done using java language and for the experiments the databases FVC 2000 DB1, DB2, DB3, DB4 released on the web [39], and FingerDOS database [40] are used. The details of the databases are given in below Table 1 and Table 2.

[Table 1. FVC2000 Database][39]

FVC2000				
Set B	**Sensor Type**	**Image Size**	**No. of Impression**	**Resolution**
DB1	Low-cost Optical Sensor	300x300	10x8	500 dpi
DB2	Low-cost Capacitive Sensor	256x364	10x8	500 dpi
DB3	Optical Sensor	448x478	10x8	500 dpi
DB4	Synthetic Generator	240x320	10x8	about 500 dpi

[Table 2. FingerDOS Database][40]

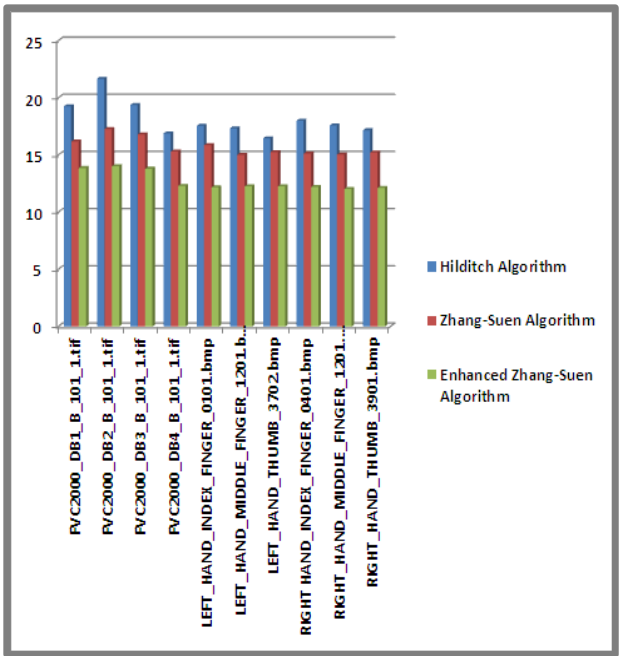
FingerDOS			
Sensor Type	**Image Size**	**No. of Impression**	**Resolution**
optical sensor (SecuGeniD-USB SC)	260 x 300	3600=60x6x10 i.e. No. of subjects=60 No. of fingers=6 (index, middle and thumb of right and left hand) No. of impression=10	500 PPI

The below Table 3 show the comparison of thinning algorithm with the PSNR and MSE value. The following table shows that the performance of the current proposed technique is enhancedthe result which having high PSNR and low MSE value. Thus, interms of PSNR and in MSE value, it prove that the image produced by the proposed thinned algorithm generate the best value compare to other algorithms.

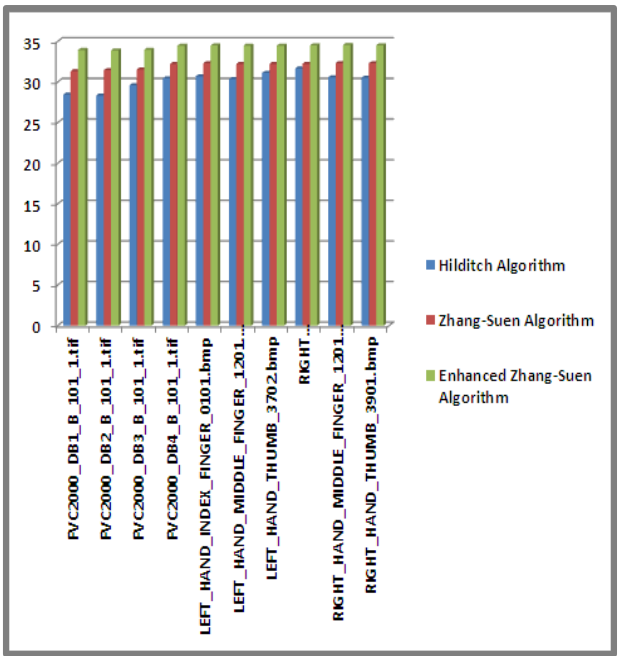
[Table 3. Performance Comparison of Thinning Algorithms using MSE & PSNR value]

Images of FVC2000 and FingerDos Databases	**Hilditch Algorithm**		**Zhang-Suen Algorithm**		**Enhanced Zhang-Suen Algorithm**	
	MSE	**PSNR**	**MSE**	**PSNR**	**MSE**	**PSNR**
FVC2000_DB1_B_101_1.tif	19.254	28.455	16.173	31.322	13.852	33.944
FVC2000_DB2_B_101_1.tif	21.662	28.346	17.249	31.451	14.017	33.893
FVC2000_DB3_B_101_1.tif	19.364	29.584	16.795	31.531	13.795	33.962
FVC2000_DB4_B_101_1.tif	16.875	30.446	15.296	32.231	12.296	34.462
LEFT_HAND_INDEX_FINGER_0101.bmp	17.542	30.704	15.853	32.301	12.173	34.505
LEFT_HAND_MIDDLE_FINGER_1201.bmp	17.323	30.365	15.017	32.232	12.249	34.479
LEFT_HAND_THUMB_3702.bmp	16.454	31.128	15.256	32.243	12.256	34.476
RIGHT HAND_INDEX_FINGER_0401.bmp	17.986	31.694	15.117	32.243	12.201	34.496
RIGHT_HAND_MIDDLE_FINGER_1201.bmp	17.576	30.587	15.029	32.326	12.029	34.557
RIGHT_HAND_THUMB_3901.bmp	17.159	30.529	15.201	32.321	12.117	34.526

The below Figure 4 and Figure 5 give clear idea using graphical representation of MSE and PSNR value comparison for three algorithms



[Fig. 4.Comparison of MSE value]



[Figure 5.Comparison of PSNR value]

The following Table 4 show the comparison of algorithms based on execution time.It is clear that the execution time of Zhang-Suen's compare to Hilditch's algorithm take lower time but the proposed enhanced algorithm take little bit few more milliseconds to compute. But that can be neglect because the quality is important for the next minutiae extraction phase.

[Table 4.Comparisonof Execution Time (in milliseconds) for Thinning Algorithms]

Images of FVC2000 and FingerDos Databases	Execution Time (in milliseconds)		
	Hilditch Algorithm	Zhang-Suen Algorithm	Enhanced Zhang-SuenAlgorithm
FVC2000_DB1_B_101_1.tif	177	150	156
FVC2000_DB2_B_101_1.tif	181	153	158
FVC2000_DB3_B_101_1.tif	174	145	153
FVC2000_DB4_B_101_1.tif	127	106	111
LEFT_HAND_INDEX_FINGER_0101.bmp	134	114	117
LEFT_HAND_MIDDLE_FINGER_1201.bmp	137	114	114
LEFT_HAND_THUMB_3702.bmp	149	127	132
RIGHT HAND_INDEX_FINGER_0401.bmp	143	122	124
RIGHT_HAND_MIDDLE_FINGER_1201.bmp	134	111	119
RIGHT_HAND_THUMB_3901.bmp	143	124	122

The below Table 5 in Appendix-I show that the quality of an images are improved using the proposed enhanced thinning algorithm. The mark on the images show that removal of spurious branches, noise, and thickness of an image.

6. CONCLUSION AND FUTURE WORK

This paper presents the role of thinning in fingerprint recognition. It shows theimplementation of famous algorithm Hilditch and Zhang-Suen's algorithm and also enhances the Zhang-Suen's algorithm. The performance is evaluated on FVC2000 and FingerDOS databases using MSE and PSNR measurement parameter. The experimental result prove that the enhanced Zhang-Suen's algorithm is better than the existing Hilditch and Zhang-Suen's algorithm in above all the mentioned aspect. In future, we try to work on post-processing phase like minutiae extraction, remove false point, core point detection and minutiae matching and try to enhance the accuracy level of fingerprint recognition.

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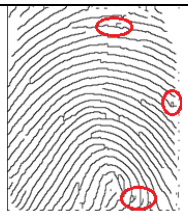
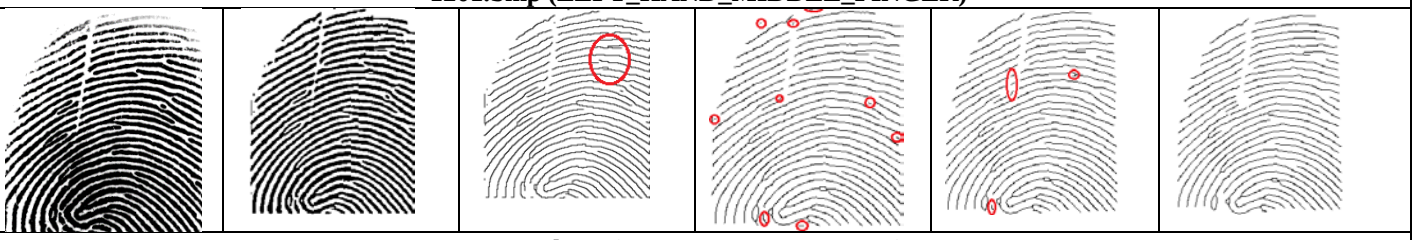
Appendix-I

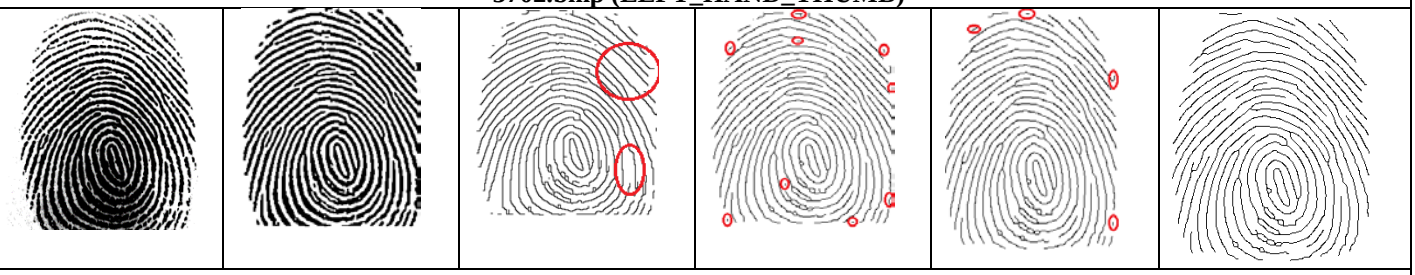
[Table 5. Quality Analysis of an Image]

Original Image	Binarized Image	Hilditch Algorithm	Zhang-Suen Algorithm	Zhang-Suen with Fix Ridge Applied Once	Zhang-Suen with Fix Ridge Applied Twice
FVC2000					
					
DB1 (101_1.tif)					
					
DB2 (101_1.tif)					
					
DB3 (101_1.tif)					
					
DB4 (101_1.tif)					
FingerDOS Database					
					
0101.bmp (LEFT_HAND_INDEX_FINGER)					

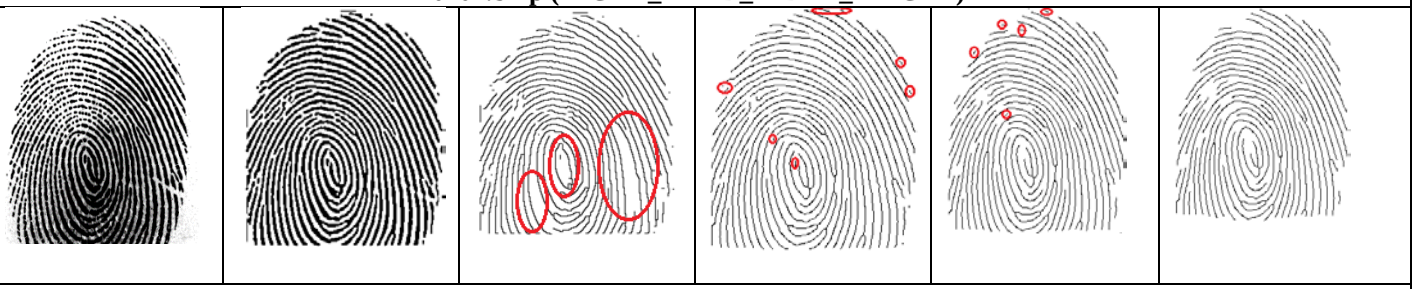
1201.bmp (LEFT_HAND_MIDDLE_FINGER)



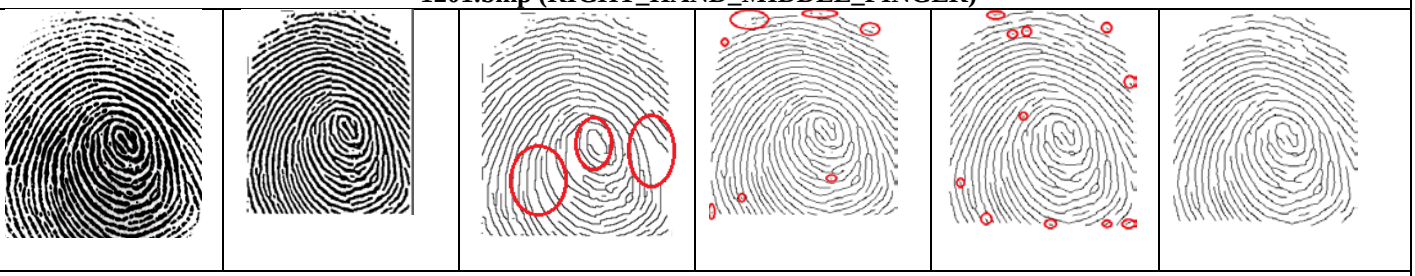
3702.bmp (LEFT_HAND_THUMB)



0401.bmp (RIGHT_HAND_INDEX_FINGER)



1201.bmp (RIGHT_HAND_MIDDLE_FINGER)



3901.bmp (RIGHT_HAND_THUMB)