Minutiae Fusion Based Framework for Thumbprint Identification of Identical Twins

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Abstract− Identical twins identification is a challenging task because they share the same DNA sequence. This research paper presents minutiae coordinates and orientation angles fusion based technique for thumbprint identification of identical twins. Six different thumbprint images of identical twins were taken at a fixed time interval using H3 T&A terminal. The minutiae coordinates and orientation angles of these thumbprints were fused to form a union set. The union set values were stored in the smartcard memory for further identification.

The minutiae coordinates and orientation angles of a thumbprint of the person to be identified are computed and fused together for online identification. The fused minutiae are compared with the minutiae union set values stored in the smartcard memory for identity verification. The proposed method was tested on a self generated identical twin dataset and 50 identical twins of standard FVC04 and FVC06 datasets. We observed in experiments that the proposed method is accurately differentiating the identical twins of self generated and FVC datasets.

Index Terms − Minutiae Coordinates, Orientation Angles, Minutiae Union Set, Identical Twins, and Thumbprint Patterns

I. Introduction

Soft Computing is a tool which deals effectively with uncertainty, vagueness, and imprecation and it provides a low cost solution. It plays an indispensable role in computational engineering. Soft computing provides us an option for finding optimal solutions which are unpredictable, uncertain, and partially true. Many soft computing techniques (Artificial Neural Networks, Genetic Algorithms, Fuzzy Logic Models, and Particle Swarm Techniques etc.) are used in Biometric systems. We can determine the partial true value of binary set depending upon completeness or incompleteness of results by using fuzzy logic model whereas artificial neural networks are designed for pattern reorganization and data classification. Fuzzy set can be used for storing the minutiae coordinates and orientation angles in the form of rough set or trained set which will be useful for identifying identical twins. Chen has used fuzzy set for storing the local triangle features of a thumbprint [4, 32].

Neurons are the biological elements which are used for information processing in the brain. Neural network approach was first introduced by Leung in 1990 [20]. A neural network consists of a number of heads or tails where heads are the nodes and tails are the links. The neural network provides interconnection between nodes [21]. Biometric system is a method used for identifying a person on the basis of physical and behavioral characteristics. Physiological features based biometrics include iris image, finger prints, thumb print, palm print, face, finger veins, hand geometry, DNA sequence, and palates. Behavioral features based biometrics includes gaits (style of walking and style of talking), signature, body language, hand writing, and voice [31].

Twins are classified in two categories: fraternal twins and identical twins. We can easily identifying the

fraternal twin because they differ in face structure, DNA sequence, and genetic compositions. Identical twins are produced from the same egg. Therefore, they share same DNA sequence and face structure [28, 29]. Identical twins can be identified on the basis of their thumbprints. A thumbprint image includes bifurcation points, ridges, left loop, right loop, arc and end points. These features of thumbprints play very important role in identical twins identification [11].

This paper classifies identical twins identification in two phases:

Phase 1: Train the thumbprint data sets using soft computing techniques.

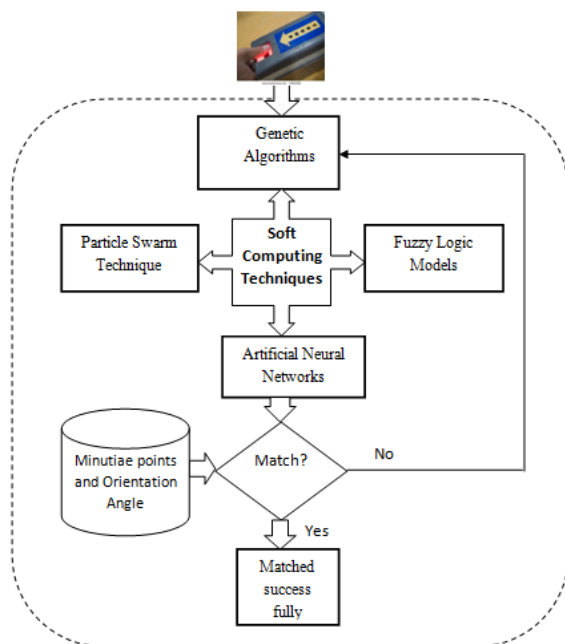*Phase 2:* Authenticate the person using a predefined process.

Fig. 1: Represents the soft computing techniques used by researchers for identifying an identical twin

The breakage points and bifurcation points of a thumbprint are called as minutiae points. The orientation angle of a minutia point is called as minutia orientation angle. This research paper uses minutiae coordinates and orientation angles fusion based fuzzy set technique for identification of identical twins. In the next section (section II) we have discussed the literature review related to identical twins identification. The section III describes a mathematical model of minutiae fuzzy set based thumbprint identification method. In section IV of this paper we have proposed a novel minutiae fusion based union set technique for classifying identical twins. The section V discusses the experimental analysis of proposed method on self generated and standard datasets. The section VI describes conclusions and future research work.

II. Literature Review

Jung proposed a robust fingerprint identification method based on hybrid pattern recognition system for identifying identical twins. The structural characteristics of a thumbprint are fetched and then fuzzy set is applied to the extracted features for identification. Finally, the result is determined on the basis weighted matching scores of quantitative extracted features [16]. Chen proposed an algorithm for distorted fingerprint matching on the basis of local triangle feature set. He represented a fingerprint by fuzzy feature set and local triangle feature set. The similarities of fingerprints were measured on the basis of fuzzy features and local triangle features [4, 5]. Mudholkar developed an effective authentication technique for fingerprint recognition using intrusion detection system. Mudholkar proposed a new algorithm which includes two basic steps (enrollment and authentication processes) for identifying identical twins [25].

Indi proposed a new technique for identifying a person using Personal Unique Identification System (PUIS). The PUIS includes pre-processing, binarization, thinning, minutiae detection, minutiae extraction, and minutiae feature matching steps [11]. Sun proposed a multi-biometric system for identifying identical twins and he proved in his research that a multi-biometric model is better in terms of robustness and accuracy in comparison to a single feature based biometric system [28].

Anil K. Jain compared the performance of single biometric and multi-biometric systems and concluded that a multi-biometric system can overcome the bottlenecks of a single biometric system [12]. He proposed a ridge and minutiae patterns based technique for thumbprint verification of identical twins [13, 14]. Kulkarni proposed a minutiae orientation fields based fingerprint verification system. Kulkarni used two databases; University of Bologna and Biometric Laboratory databases for testing the proposed algorithm. The proposed method showed better GAR (Genuine Acceptance Rate), low FAR (False Acceptance Rate), and low computational complexity [19].

Chen T. P. proposed that magnetic strip cards are no more required for authentication purpose because we have venerable microprocessor technology (smart card) which can be used for developing fingerprint based authentication system [3].

Krishneswari K. calculated the performance of multimodal biometrics using Discrete Cosine Transform (DCT) and information gain [17]. Tao X. proposed P071 and SDK verifinger algorithms for identical twins identification. Tao used 83 twin pairs for evaluating the performance and he observed that his algorithms are clearly distinguishing identical twins on the basis of their fingerprints [30]. Chen proposed a normalized fuzzy similarity measurement algorithm for distorted fingerprints recognition. The algorithm

includes two steps namely fingerprint alignment based topological score computations, and similarity matching between the templates and input fingerprints [4, 5].

Velamuri recognized the fingerprints using a fuzzy inference technique. The method uses template creation and fingerprint matching steps [32]. Iancu introduced a fuzzy logic based technique for fingerprint identification. In this technique Iancu compared two matching sets and selected the optimal from these using a fuzzy reasoning system [10]. Bennet proposed a fuzzy set measurement method for fingerprint recognition. The proposed method is based on discrete wavelet transform (DWT) and singular value decomposition (SVD) approaches [2]. Homem proposed a new methodology for mobile phone user identification using fuzzy fingerprints. He used filtered space saving (FSS) algorithm which uses bitmap counter. The bitmap counter values are determined by hash function [7].

Kondekar proposed a new method for fingerprint recognition system which is based on Extended Fuzzy Hyper Line Segment Neural Network (FHLSNN). Kondekar used finger code feature extraction technique for extracting the fingerprint features [18]. Bazan proposed a roughest based behavioral pattern identification system. He used a method called online elimination of non relevant parts for online reduction of irrelevant objects to identify a behavioral pattern [1]. Meva proposed a neural network based new approach for fingerprint recognition technique [21].

Josphineleela proposed an efficient fingerprint based attendance system. In this research paper Josphineleela presented a method for overcoming with buddy-punching a well known loophole of traditional attendance system. He used novel fingerprint reconstruction algorithm to reconstruct the image from minutiae and then change it to a gray scale image. Evaluation of the proposed algorithm is based on success rates of type –I "matching sample with original" and type –II "matches reconstructed image with different impression of original finger print images" attacks [15].

Patil D. S. proposed an input image and a query image based minutiae matching technique for fingerprint recognition. The method was tested for FAR and FRR to evaluate the performance of a fingerprint recognition system[26].

III. Mathematical Background of Minutiae Fusion Based Universe Of Discourse

Let Z be a fixed nonempty set to be called as the universal set. We can define it as:

$f : Z \rightarrow \{0,1\}$

Here, f is a characteristic function.

Let's take n samples of thumbprints for each person of identical twin pairs. These samples can be mathematically represented as:

$Person\_1\_Twin1 = \{ f_{a1}(x), f_{a2}(x), \dots \dots f_{an}(x) \}$

Here, $f_{a1}(x)$ represents first sample, $f_{a2}(x)$ represents second sample, and $f_{an}(x)$ represents n^{th} sample of first person of first identical twin pair.

A minutia point consists of three values: X coordinate, Y coordinate, and orientation angle (θ). The directions of a minutia orientation angle can be categorized into eight parts namely north (N), north-east (NE), east (E), south-east (SE), south (S), south-west (SW), west (W) and north-west (NW). If each direction of a minutia point is represented by a number then a minutia point and its orientation angle can be represented by following mathematical equations:

$Minutia\ Point = (X, Y, \theta);$

Where, θ is the angle of orientation of a minutia point.

$$\theta = \{N, NE, E, SE, S, SW, W, NW\};$$
$$\Rightarrow \theta = \{1, 2, 3, 4, 5, 6, 7, 8\}; \qquad (1)$$

The identical twins can be identified on the basis of fusion of minutiae coordinates and orientation angles using following three steps:

Step 1: *Create a set F_U (where F_U is the union of the thumbprints).*

In this step, we have taken the union of minutiae coordinates with orientation angles of first n thumbprints of a person of the identical twin pair. This union can be represented by following equation:

$$F_U = A_1 \bigcup A_2 \bigcup \dots \bigcup A_m \qquad (2)$$

In abbreviated form equation (2) can be written as:

$$\bigcup_{i=1}^{i \rightarrow n} f_{ai} = f_{a1} \bigcup f_{a2} \bigcup \dots \bigcup f_{an} \qquad (3)$$

Therefore, we can now say that $F_U(x)$ is a union set which contains the union of minutiae coordinates and orientation angles of n thumbprints of a person of the identical twin pair. Here, value of 'n' may vary from two to six.

Step 2: *Take the input thumbprint image for identity verification of identical twin.*

In this step, we will scan at least two thumbprints for the first person and two thumbprints for second person

of the identical twin. It can be mathematically written as:

$$F_A = \{TA_1, TA_2\}$$
$$and \; F_B = \{TB_1, TB_2\} \tag{4}$$

Here, TA_1, TA_2 are the newly scanned thumbprints of first person and TB_1, TB_2 are the newly scanned thumbprints of second person of the identical twin pair.

Step 3: *Thumbprints Verification.*

We know that U is a union set which contains all the minutiae coordinates and orientation angles of first n thumbprints of a person where $2 \leq n \leq 6$. Therefore,

$$\bigcup_{i=1}^{i \rightarrow n} f_{ai} \geq f_{ai} \tag{5}$$

The relationship between a union thumbprint set and a newly scanned thumbprint can be represented by figure 2.
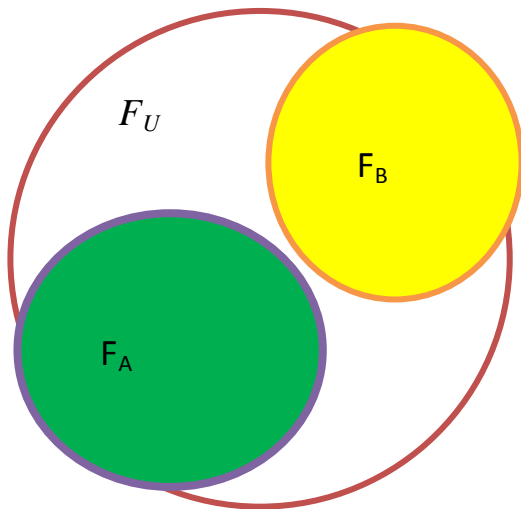
Fig. 2: Union set representation of minutiae coordinates and orientation angles of thumbprints

IV. Proposed Methodology

Identical twins can be identified accurately with the help of their thumbprint patterns but the verification will be more authentic if we compare a single thumbprint sample with the union of thumbprints. The thumbprints for identical twin pair of figure 3 were taken using a scanning device (H3 T & A terminal) from Sachcha Adhyatma Sanskrit Mahavidyalay, Sachcha Baba Ashram, Arail, Allahabad, Uttar Pradesh, INDIA, Phone No.: 0091-9452367236.

Fig. 3: Facial images of identical twin pair Servesh and Dhermesh

The proposed methodology uses three phases *(A to C)* for verifying the identity of identical twins.

4.1 Preprocessing Phase

A scanned thumbprint image is given as input to the preprocessing phase. An input image (raw image) is converted to a thinned binary image in preprocessing and it also includes following steps for converting thinned input:

Step 1: *Image Smoothing* [Join the broken ridges of inner parts of a thumbprint image.]

Step 2: *Ridge Thinning* [Decrease the thickness of ridges to a single pixel value using bwmorph( ) function of MATLAB 7.0.]

Step 3: *Black and White Binary Image Conversion* [Convert the thinned image to a binary image using im2bw ( ) function of MATLAB 7.0]
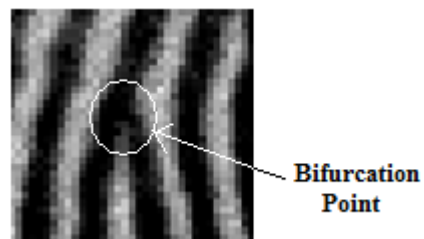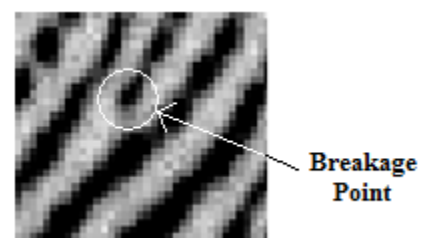

Fig. 4(a)

Fig. 4(b)

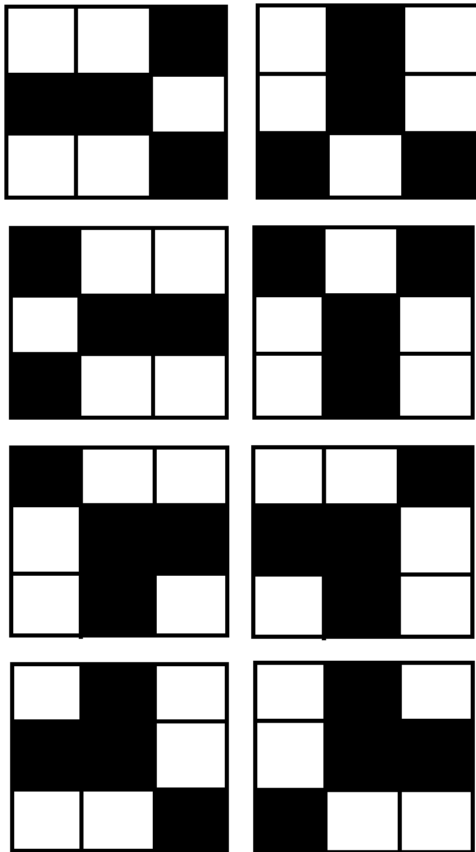Fig. 4: The ridges of a thumbprint image [22]

Fig. 5: The ridge bifurcation points represented in the form of pixels [22]

found out that we can represent the ridge bifurcations in 24 different forms of matrices (m1 to m24), which are given figure 6. Similarly, we are able to represent the ridge breakages in 8 different forms of matrix patterns (m25 to m32) as represented in figure 7 [22]:
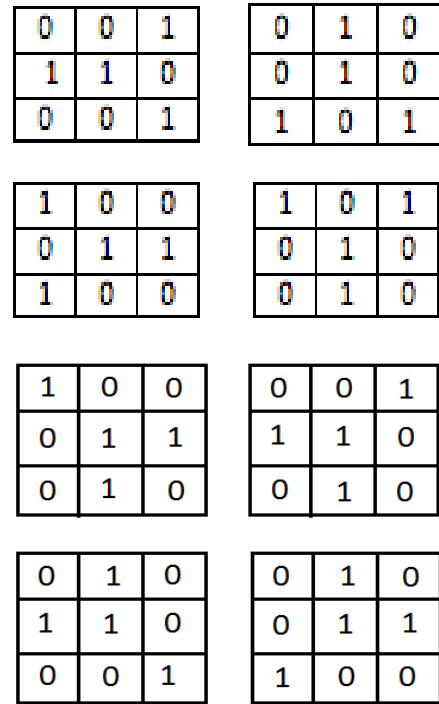

Fig. 6: Ridge bifurcations in integer format [22]

4.2 Find the Minutiae Coordinates and Orientation Angles of a Thumbprint

After converting the thinned (obtained by using inbuilt MATLAB function 'bwMorph()') image into black and white binary image it becomes ideal for the purpose of minutiae points extraction. The minutiae points are those points in the thumbprint from where the ridges bifurcate or converge. In order to find such minutiae points in the image we have written our own algorithm [22]. This algorithm uses a pattern searching technique in the binary image. The pattern to be searched is a two dimension binary pattern that forms a specific shape when viewed as a matrix. The pattern is a representation of a minutiae point which is present in the thumbprint in the form of a two dimensional matrix. The minutiae points are the bifurcation and the abrupt breakages of the ridges. The sample minutiae points that are present in an image will look like figure 4. The ridge bifurcation patterns of figure 4 can be represented figure 5. The patterns of figure 5 can be represented in the form of matrix of 3x3 dimensions by figure 6.

As the image must be rotated in any direction, thus the pattern may also be present in many orientation and directions. Hence, to capture maximum possible patterns, we have to modify our matrices so as to include all kind of bifurcations and ridge breakages. After having many tests and observations we have

$m1 = [0,0,1;1,1,0;0,0,1];$ $m2 = [0,1,0;0,1,0;1,0,1];$

$m3 = [1,0,0;0,1,1;1,0,0];$ $m4 = [1,0,1;0,1,0;0,1,0];$

$m5 = [1,0,0;0,1,1;0,1,0];$ $m6 = [0,0,1;1,1,0;0,1,0];$

$m7 = [0,1,0;1,1,0;0,0,1];$ $m8 = [0,1,0;0,1,1;1,0,0];$

$m9 = [0,0,0;1,1,1;0,1,0];$ $m10 = [0,1,0;1,1,0;0,1,0];$

$m11 = [0,1,0;1,1,1;0,0,0];$ $m12 = [0,1,0;0,1,1;0,1,0]$

$m13 = [1,0,1;0,1,0;1,0,0];$ $m14 = [1,0,1;0,1,0;0,0,1];$

$m15 = [0,0,1;0,1,0;1,0,1];$ $m16 = [1,0,0;0,1,0;1,0,1];$

$m17 = [0,1,0;1,1,1;1,0,0];$ $m18 = [0,1,0;1,1,1;0,0,1];$

$m19 = [1,0,0;1,1,1;0,1,0];$ $m20 = [0,0,1;1,1,1;0,1,0];$

$m21 = [0,1,0;0,1,1;1,1,0];$ $m22 = [1,1,0;0,1,1;0,1,0];$

$m23 = [0,1,1;1,1,0;0,1,0];$ $m24 = [0,1,0;1,1,0;0,1,1];$

$m25 = [1,0,0;0,1,0;0,0,0];$ $m26 = [0,1,0;0,1,0;0,0,0]$

$m27 = [0,0,1;0,1,0;0,0,0];$ $m28 = [0,0,0;0,1,1;0,0,0]$

$m29 = [0,0,0;0,1,0;0,0,1];$ $m30 = [0,0,0;0,1,0;0,1,0]$

$m31 = [0,0,0;0,1,0;1,0,0];$ $m32 = [0,0,0;1,1,0;0,0,0]$

Fig. 7: Representation of ridge bifurcation and ridge breakage in matrix format [22]

To detect these patterns in the thumb print image, we perform some pre-processing steps after which we get the thinned ridge image. We have to search these 3x3 dimensional images in the thinned ridge image using simple pattern searching.

Each minutia point will have X coordinate, Y coordinate, and orientation angle θ. The steps for finding minutiae coordinates and orientation angles of a thumbprint image are presented figure 8.

4.3 Matching Results

Find the union of minutiae coordinates and orientation angles of first n thumbprints for a person using Eq. (5) and store these values in the memory for further identification. Here, values of n may vary from two to six. The stored minutiae values will be compared with minutiae coordinates and orientation angles of an online scanned thumbprint. If online calculated minutiae values have 80% and above matching score then it means that the stored and online calculated minutiae values are belonging to the same person.

Step 1: Read the thumbprint image of identical twin using MATLAB 7.0 predefined function.
      i =imread("imagename");

Step 2: Convert the image into binary image using predefined function.
      j=im2bw(i);

Step 3: Convert the gray scale image into binary image using predefined function.
      ibw = im2bw(j);

Step 4: Thinning the ridges of thumbprint using predefined function.
thin_image = bwmorph('ibw', 'thin', 'inf');

Step 5: Use our own function getminutiaes( ) for finding the minutiae points.
list_of_minutiae_points = getminutiae(thinned_image);

Step 6: Find the orientation angles using our own function showdirection( ).
orientation_angles = showdirection(thinned_image);

Fig. 8: The steps of an algorithm for finding minutiae coordinates and orientation angles of a thumbprint [22, 23, 24]

V. Experimental Analysis and Results

5.1 Analysis of Results for Actual Dataset

The proposed method is tested on self generated identical twin dataset using H3 T & A terminal and FVC datasets. For each person of the identical twin pair nine thumbprint images were scanned. The actual size thumbprints of identical twin pair (Servesh and Dhermesh) are varying from S1 to S9 and D1 to D9 in figure 9.
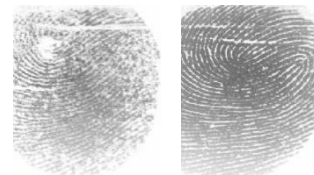

9(a) S1   9(b) D1

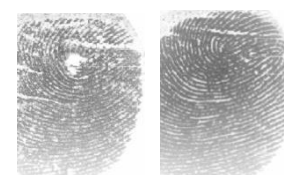9(c) S2   9(d) D2

9(e) S3   9(f) D3

9(g) S4   9(h) D4

9(i) S5   9(j) D5

9(k) S6   9(l) D6

9(m) S7   9(n) D7

9(o) S8   9(p) D8

9(q) S9   9(r) D9

Fig. 9: Thumbprint images of Servesh(S) and Dhermesh(D)

The thinned images of figure 10 are obtained after implementing steps 1 to 6 of section IV. The thinned images for thumbprints of figure 9 in actual format are represented by figure 10.
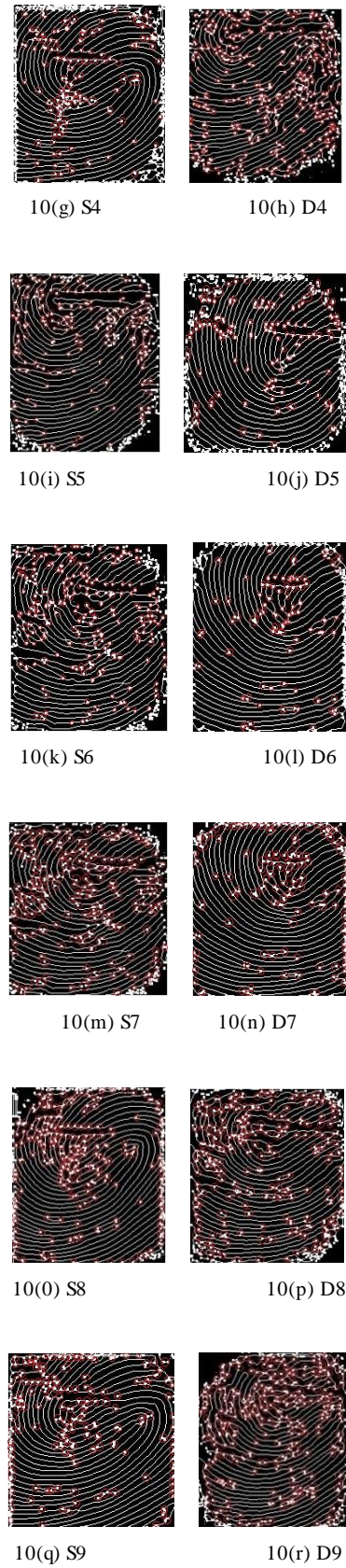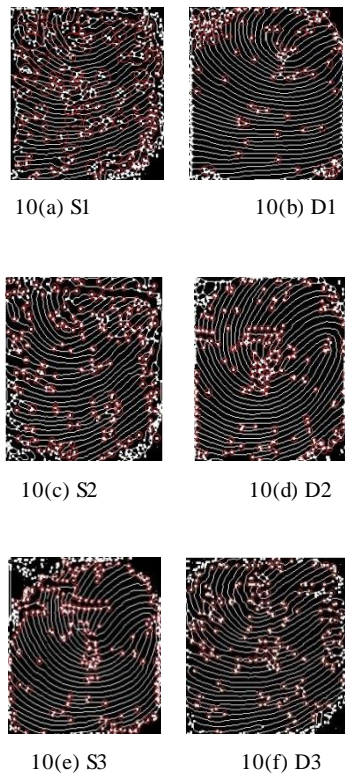
10(a) S1   10(b) D1

10(c) S2   10(d) D2

10(e) S3   10(f) D3

10(g) S4   10(h) D4

10(i) S5   10(j) D5

10(k) S6   10(l) D6

10(m) S7   10(n) D7

10(0) S8   10(p) D8

10(q) S9   10(r) D9

Fig. 10: Nine pairs of thinned thumbprint images of   Servesh(S) and Dhermesh(D) [23, 24]

11(a) S1

11(b) D1

11(c) S2

11(d) D2

11(e) S3

11(f) D3

11(g) S4

11(h) D4

11(i) S5

11(j) D5

11(k) S6

11(l) D6

11(m) S7

11(n) D7

11(o) S8
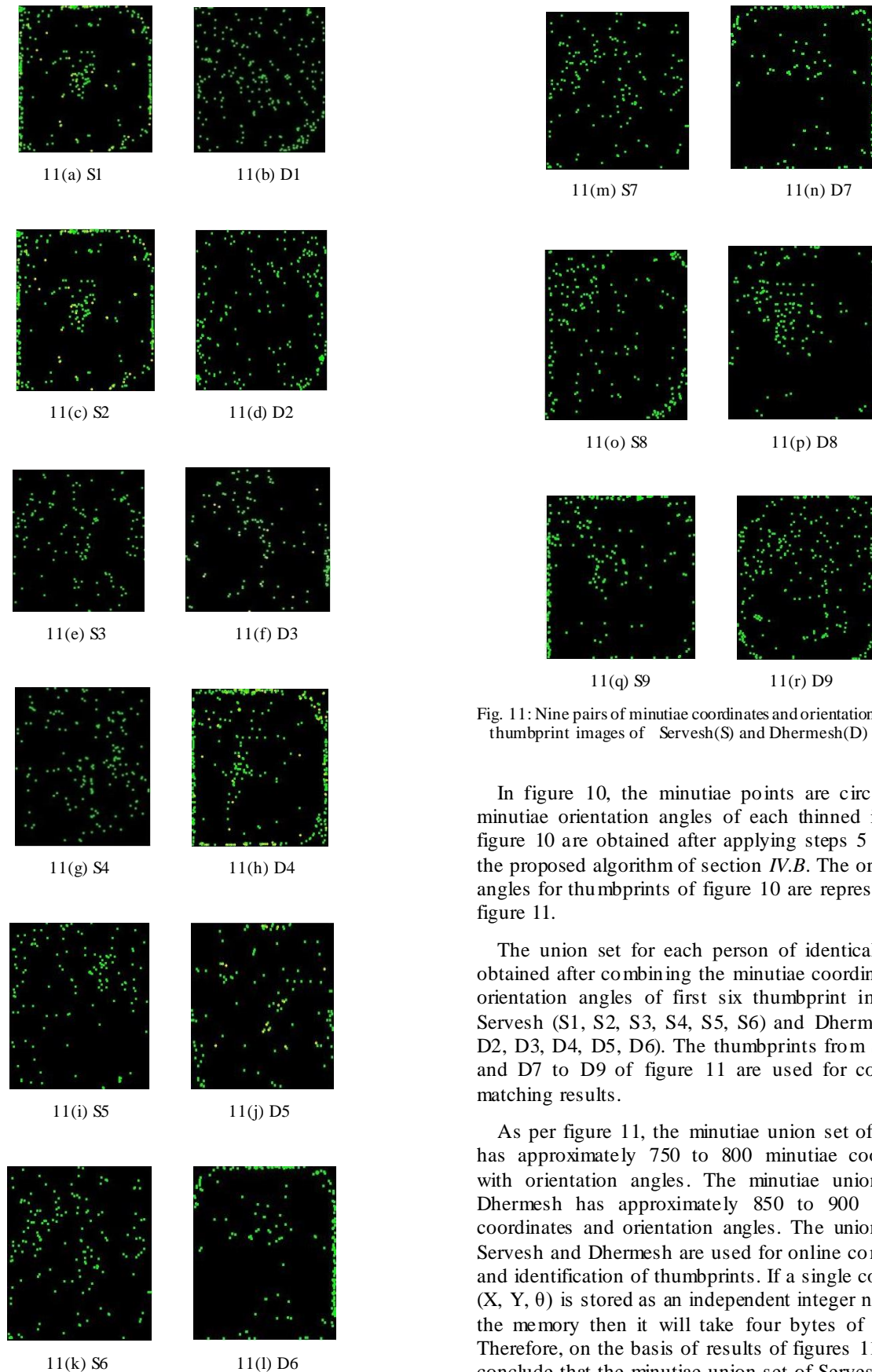

11(p) D8

11(q) S9

11(r) D9

Fig. 11: Nine pairs of minutiae coordinates and orientation angles for thumbprint images of Servesh(S) and Dhermesh(D) [23, 24]

In figure 10, the minutiae points are circled. The minutiae orientation angles of each thinned image of figure 10 are obtained after applying steps 5 and 6 of the proposed algorithm of section *IV.B*. The orientation angles for thumbprints of figure 10 are represented by figure 11.

The union set for each person of identical twin is obtained after combining the minutiae coordinates and orientation angles of first six thumbprint images of Servesh (S1, S2, S3, S4, S5, S6) and Dhermesh (D1, D2, D3, D4, D5, D6). The thumbprints from S7 to S9 and D7 to D9 of figure 11 are used for comparing matching results.

As per figure 11, the minutiae union set of Servesh has approximately 750 to 800 minutiae coordinates with orientation angles. The minutiae union set of Dhermesh has approximately 850 to 900 minutiae coordinates and orientation angles. The union sets of Servesh and Dhermesh are used for online comparison and identification of thumbprints. If a single coordinate (X, Y, θ) is stored as an independent integer number in the memory then it will take four bytes of memory. Therefore, on the basis of results of figures 11 we can conclude that the minutiae union set of Servesh can be stored in 2.5KB to 3KB memory and the same of Dhermesh will require 3KB to 3.5KB memory

On the basis of 7th, 8th, and 9th thumbprints of figure 11, we can conclude that approximately 150 to 170 minutiae points are there in a thumbprint of Dhermesh. If we store a thumbprint of Servesh or Dhermesh in the form of minutiae coordinates then we need approximately 600bytes to 800bytes of memory. The result comparisons of Servesh and Dhermesh thumbprints with their union minutiae sets are presented in tables 1, 2, and 3.

Table 1: Comparing results of Servesh thumbprints union set with 7th, 8th, and 9th thumbprints of Servesh

		Servesh			
		Thumbprint Union set	7th image	8th image	9th image
Servesh	Thumbprint Union set	100%	86%	70%	81%
	7th image	86%	100%	65%	69%
	8th image	70%	65%	100%	62%
	9th image	81%	69%	62%	100%

Table 2: Comparing results of Dhermesh thumbprints union set with 7th, 8th, and 9th thumbprints of Dhermesh

		Dhermesh			
		Thumbprint Union set	7th image	8th image	9th image
Dhermesh	Thumbprint Union set	100%	100%	89%	83%
	7th image	100%	100%	80%	70%
	8th image	89%	80%	100%	76%
	9th image	83%	70%	76%	100%

Table 3: Comparing the results of thumbprints of Servesh and Dhermesh

		Dhermesh			
		Thumbprint Union set	7th image	8th image	9th image
Servesh	Thumbprint Union set		25.2%	26%	60%
	7th image	32.3%	15%	14%	23%
	8th image	33%	22%	25%	27%
	9th image	30%	12%	20%	39%

The results of table 1 show that a new thumbprint of Servesh is very close to the union set of Servesh and the results of table 2 show that a new thumbprint of Dhermesh is very similar to that of Dhermesh minutiae union set.

The comparisons of new thumbprints of Servesh and Dhermesh with each other are presented in table 3. The results of table 3 show that minutiae coordinates with orientation angles of Servesh and Dhermesh thumbprints are totally different. Therefore, Dhermesh and Servesh can be differentiated and identified on the basis of their thumbprints minutiae union sets.

5.2 Analysis of Results for FVC Datasets

The proposed minutiae fusion based method presented in section 4 was tested for FVC2004 and FVC2006 standard datasets. The FVC datasets have more than 100 identical twins thumbprints.
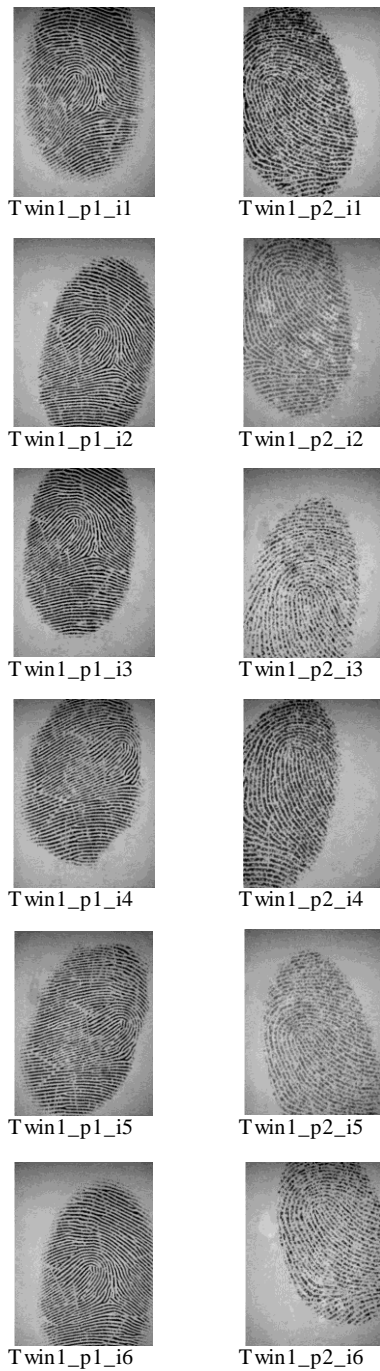
Fig. 12: First twin pair thumbprint images for FVC datasets [8, 9]

Fig. 13: Second twin pairs thumbprint images for FVC datasets [8, 9]

For each person eight thumbprints are provided by FVC dataset but only six thumbprints are of good quality. Therefore, we have considered these six thumbprints of each person for analyzing the performance of our proposed algorithm. The thumbprints of two different pairs of identical twins for FVC datasets are presented in figures 12 and 13 respectively.
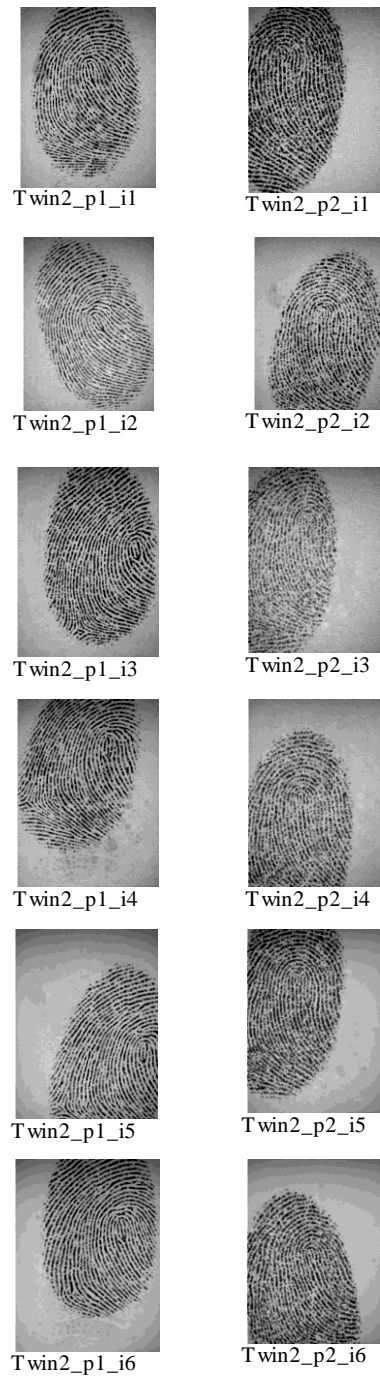
We implemented the steps of section IV on first four thumbprints for a person of identical twin pairs specified in figures 12, and 13. The union of minutiae coordinates and orientation angles of first four thumbprints of a person for FVC dataset were considered as minutiae union set. The fifth and sixth images of figures 12 and 13 were compared with minutiae fuzzy sets for identity verification.

For comparing a thumbprint image with minutiae union sets we deviated the minutiae coordinates from -10 to 10 and the best comparison results were taken

into considerations. The result comparisons of 5th and 6th thumbprints of identical twins with minutiae union sets for FVC2004 and FVC2006 datasets are presented in table 4.

Table 4: Comparing the results of FVC04 and FVC06 dataset thumbprints

	FVC4 and FVC6 data set			
	Twin1_P1 Thumb Print Fusion	Twin1_P2 Thumb Print Fusion	Twin2_P1 Thumb Print Fusion	Twin2_P2 Thumb Print Fusion
Twin1_p1_5th	78%	22%	10%	16%
Twin1_p1_6th	82%	20%	21%	19%
Twin1_p2_5th	14%	80%	10%	13%
Twin1_p2_6th	18%	79%	11%	12%
Twin2_p1_5th	10%	18%	81%	9%
Twin2_p1_6th	11%	13%	82%	16%
Twin2_p2_5th	13%	16%	14%	77%
Twin2_p2_6th	8%	9%	18%	81%

Table 5: Memory requirements for actual size thumbprints, minutiae fuzzy sets, and an independent minutiae thumb

	Person	Actual size of thumbprint (in KB)	Minutiae thumb Union set memory size (in KB)	An independent minutiae thumb size (in KB)
1.	Servesh	55 KB to 60 KB	2.5 KB to 3 KB	0.7 KB to 0.8 KB
2.	Dhermesh	55 KB to 60 KB	3.0 KB to 3.5 KB	0.8 KB to 0.9KB
3.	FVC_twin1_p1	105KB to 110KB	3.0 KB to 4.0 KB	0.8 KB to 1.0 KB
4.	FVC_twin1_p2	105KB to 110KB	3.0 KB to 4.0 KB	0.8 KB to 1.0 KB
5.	FVC_twin2_p1	105KB to 110KB	3.0 KB to 4.0 KB	0.8 KB to 1.0 KB
6.	FVC_twin2_p2	105KB to 110KB	3.0 KB to 4.0 KB	0.8 KB to 1.0 KB

The results of table 4 show that the 5th and 6th thumbprints are very close to their corresponding minutiae union sets. After comparing twin1_p1_5th and twin1_p1_6th images with twin1_p2_thumbprint, twin2_p1_thumbprint and twin2_p2_thumbprint union sets, we observed that identical twins thumbprints are totally different in terms of minutiae coordinates and orientation angles values.

Similar analysis was conducted for fifty identical twins of FVC thumbprint datasets and we observed that the identical twins of FVC thumbprint datasets are dissimilar with each other.

The memory requirements for minutiae union sets of standard and self generated data sets are given in table 5. The actual size of Servesh and Dhermesh thumbprints are in the range of 55KB to 60KB. The actual memory requirements for FVC thumbprint datasets are varying from 105KB to 110KB. The minutiae thumb union sets for Servesh and Dhermesh require approximately 3.0KB memory. If we store an independent thumbprint image in the integer form of

minutiae coordinates and orientation angles then we need approximately 0.7KB to 1.0KB memory for self generated and standard datasets.

5.3 Result Analysis for Fusion of Two and More Thumbprints of Identical Twins

We took the union sets of minutiae coordinates and orientation angles for two to six thumbprints of identical twins and compared with randomly selected thumbprints. These results are presented in figure 14.

The results of figure 14, show that if we compare the fusion of two thumbprints of Servesh with a randomly selected thumbprint of Servesh then the match percentage is approximately 80% whereas if we compare the fusion of two thumbprints of Servesh with randomly selected thumbprint of Dhermesh then the match percentage is bellow 20%. The thumbprint matching percentage for the same person increases if we increase the number of thumbprints of union set.
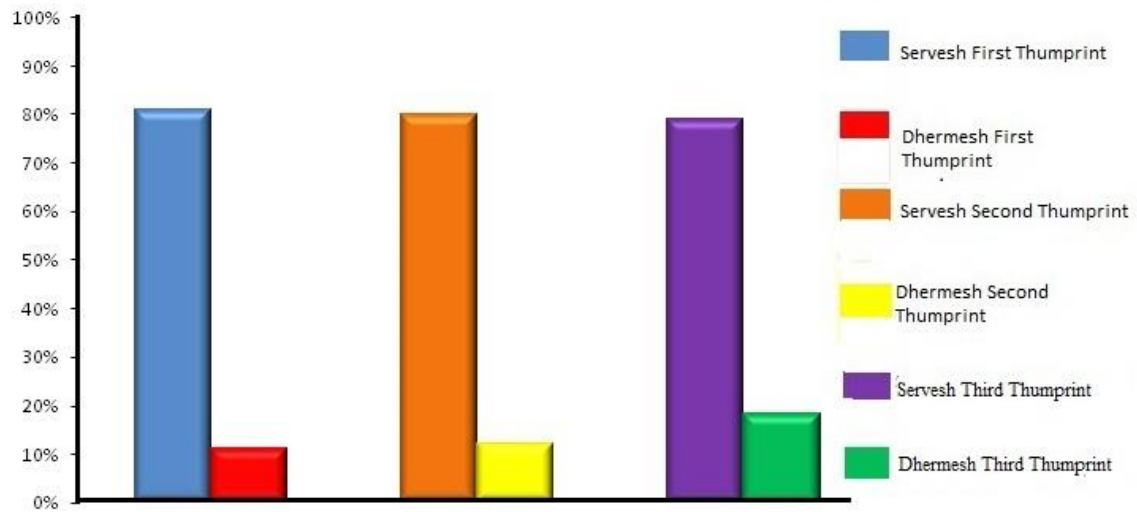
Fig. 14(a): Comparing the fusion of two thumbprints of Servesh with randomly selected thumbprints of Servesh & Dhermesh
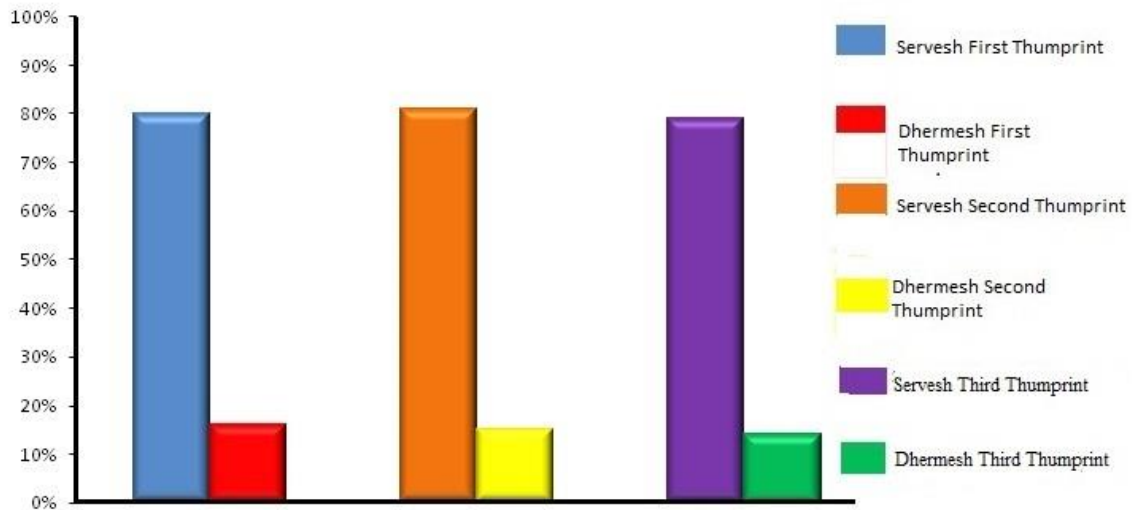

Fig. 14(b): Comparing the fusion of three thumbprints of Servesh with randomly selected thumbprints of Servesh & Dhermesh
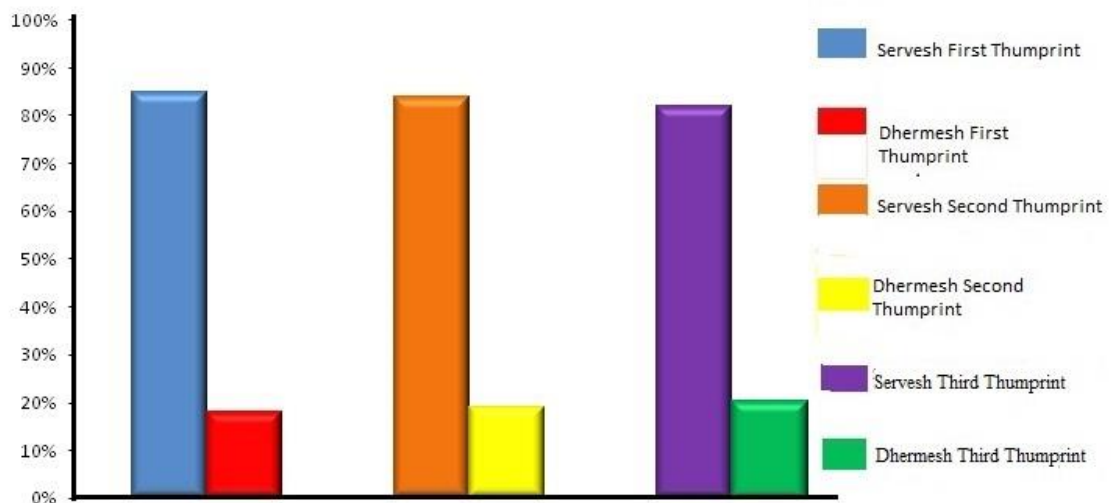

Fig. 14(c) Comparing the fusion of four thumbprints of Servesh with randomly selected thumbprints of Servesh & Dhermesh.
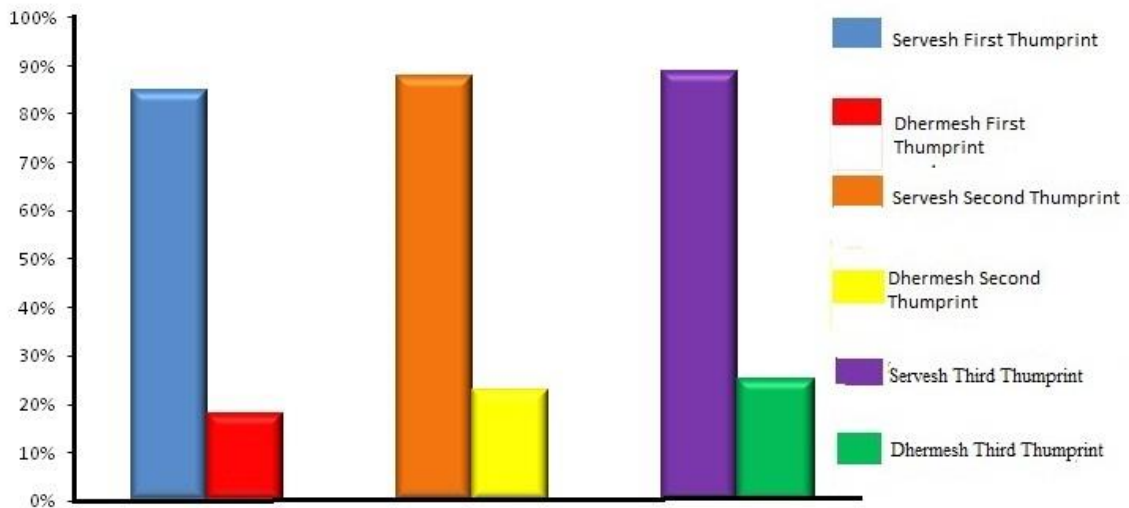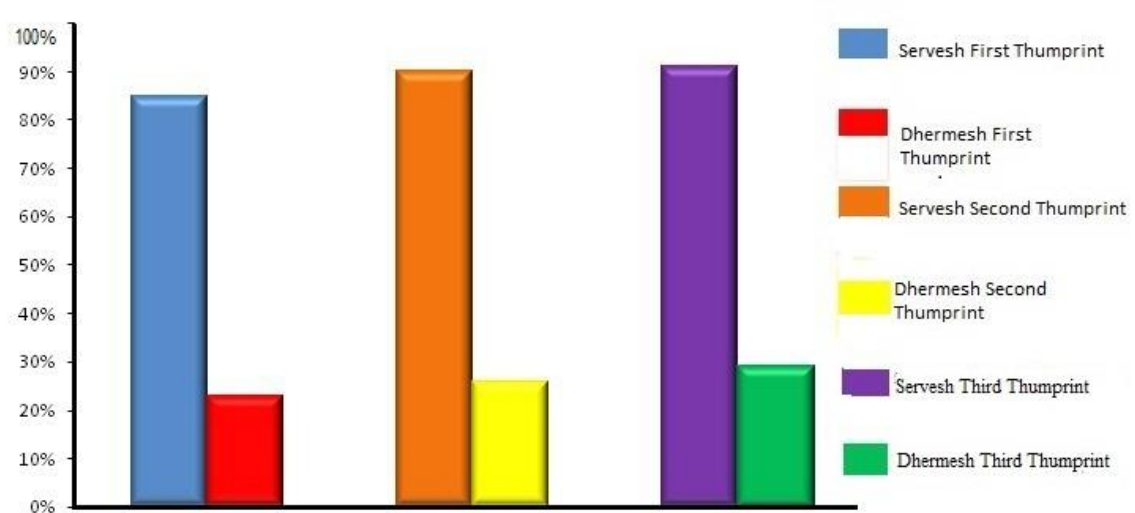
Fig. 14(d): Comparing the fusion of five thumbprints of Servesh with randomly selected thumbprints of Servesh & Dhermesh

Fig. 14(e): Comparing the fusion of six thumbprints of Servesh with randomly selected thumbprints of Servesh & Dhermesh.
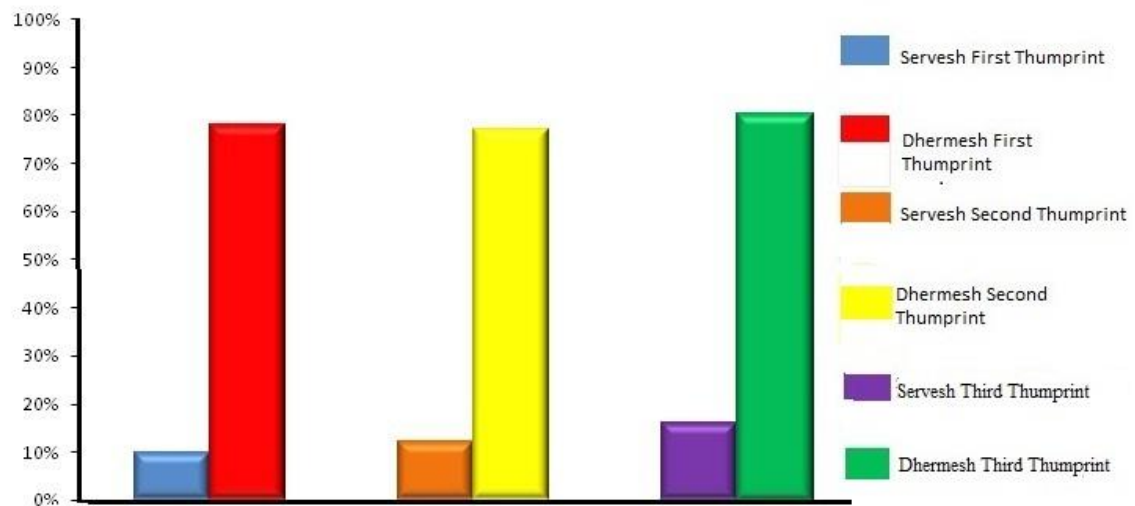

Fig. 14(f): Comparing the fusion of two thumbprints of Dhermesh with randomly selected thumbprints of Dhermesh & Servesh
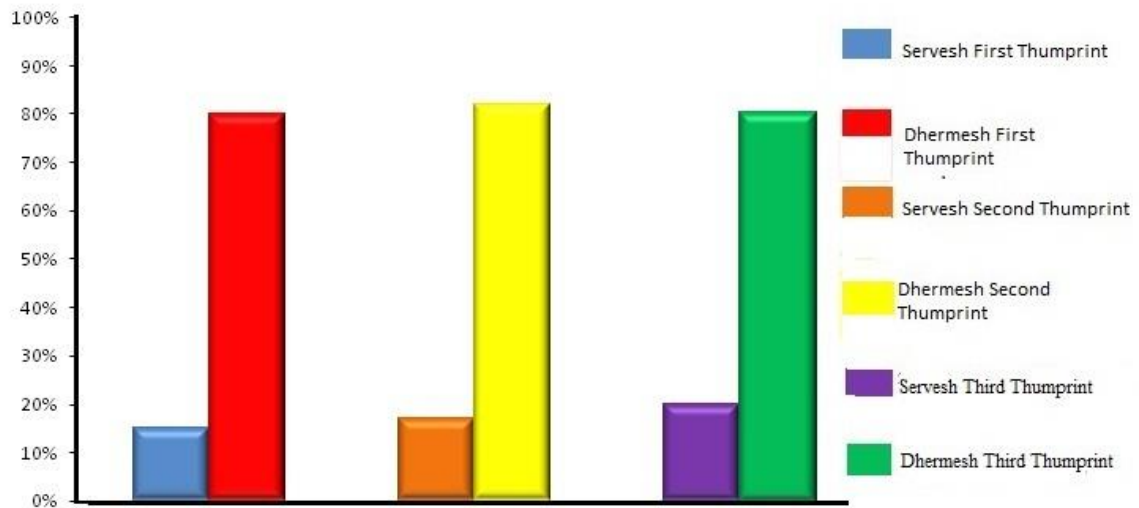
Fig. 14(g): Comparing the fusion of three thumbprints of Dhermesh with randomly selected thumbprints of Dhermesh & Servesh.
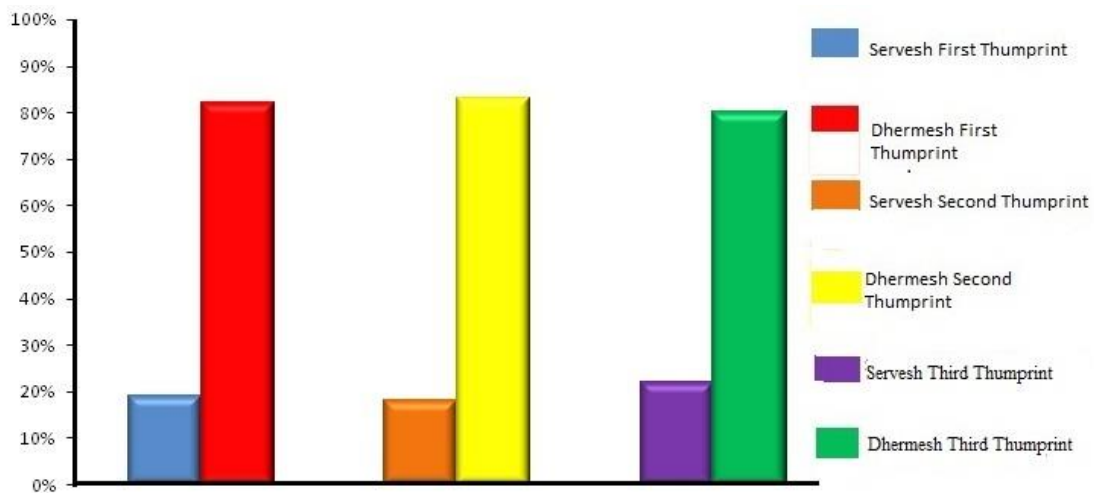

Fig. 14(h): Comparing the fusion of four thumbprints of Dhermesh with randomly selected thumbprints of Dhermesh & Servesh.
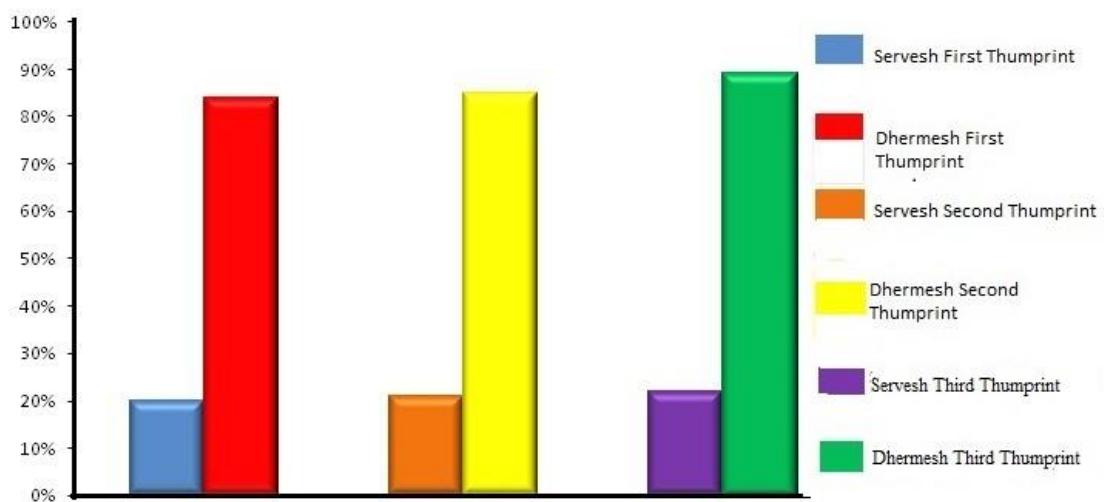

Fig. 14(i): Comparing the fusion of five thumbprints of Dhermesh with randomly selected thumbprints of Dhermesh & Servesh.
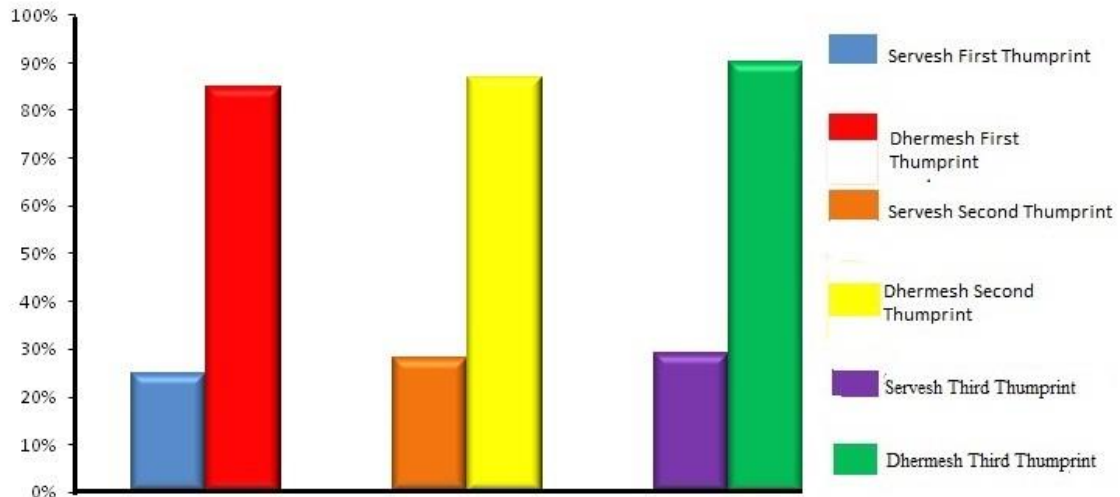
Fig. 14(j): Comparing the fusion of two thumbprints of Dhermesh with randomly selected thumbprints of Servesh and Dhermesh

Fig. 14: Comparing the fusion of two to six thumbprints of identical twins with randomly selected thumbprints

Table 6: Comparing the results of proposed method with other methods.

	Algorithm	Matcher Name	Matching Results (Identical Twins)
1.	Jain [13]	Minutiae	FAR: 2 - 6% higher
2.	Han [6]	Minutiae	EER: 1 – 2% higher
3.	Srihari [27]	NFIS	EER: 6.17%
4.	Sun [28]	VeriFinger	EER: 6.79%
5.	Tao [30]	VeriFinger	EER: 5.83%
6.	Mishra [23]	ITIS	EER: 5%
7.	Proposed		EER: 2% approx.

If we compare the union of minutiae coordinates and orientation angles of five thumbprints of Servesh with a randomly selected thumbprint of Servesh then the match percentage increases to 90% whereas after comparing the union of five thumbprints of Servesh with a new thumbprint of Dhermesh, we observed that the match percentage is in the range of 20% to 25%. Similar results are obtained after comparing the union of thumbprints of Dhermesh with randomly selected thumbprints of Servesh and Dhermesh.

Finally, we found that either we take the union of six or seven or eight thumbprints of a person the matching percentage for a new thumbprint of the same person is approximately 90% or for a different person it is approximately 25%. Thus, we are convinced at this point that the union of six thumbprints for a person of an identical twin pair can give the best matching result.

5.4 Comparing the Result of Proposed Technique with Standard Methods

We compared 50 identical twins of FVC datasets and we found that the proposed minutiae fusion based method is able to identify all the twins excluding one pair for which we did not get appropriate matching percentage. The proposed method is compared with existing identical twins thumbprint verification methods and the outcome is presented in table 6.

VI. Conclusions

In this research paper we have introduced a novel minutiae coordinates and orientation angles fusion based union set technique for thumbprint identification of identical twins. The proposed method is successfully identifying identical twins for self generated dataset and FVC datasets. The proposed method has proved that the dissimilarities between thumbprints images of identical twins are above 80% for self generated and standard (FVC2004, FVC2006) datasets.

The proposed method uses approximately 0.7KB to 1.0KB memory to store a thumbprint image of 55KB to 60KB. The minutiae union set of a person requires 2.5KB to 3.5KB memory for storing minutiae features of six different samples which were scanned at a fixed time interval.

The researchers can use left and right thumbprints fusion based soft computing technique for identifying identical twins. The socio behavioral features of identical twins can be combined with minutiae fusion based techniques for improving the matching results of identical twins identification methods.

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