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Removal of False Minutiae Using Fuzzy Rules

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ABSTRACT :*A fuzzy rules based system for removing false and spurious minutiae is experimented in this paper. Removal of false minutiae begins only after their extraction is complete from the enhanced fingerprint image. Hence this process is named as post processing activity in the enhancement process. The proposed methodology is simple and proved effective in removing false minutiae from the extracted minutiae of a fingerprint image. It also proved to be effective with respect to its implementation as it needs less computational effort.*

I. INTRODUCTION

Removing false minutiae is a post processing technique in fingerprint image enhancement. On successful completion of preprocessing techniques for fingerprint image enhancement, fingerprint minutiae are extracted. Before going to the process of fingerprint matching, an important post processing step of removing false minutiae should be performed. In this paper, a fuzzy rule based system is proposed for removing false minutiae from the extracted minutiae of a fingerprint image. The proposed method looks very simple but works very effectively in identifying and removing the spurious minutiae. Different authors addressed the problem of false minutiae elimination. Some of the post processing algorithms [1], [2] eliminate the false minutiae by estimating the statistical characteristics within an M × M matrix moving along the image pixel to pixel. Later Xiao and Raafat [3] developed a new post processing algorithm using both the statistical and structural information to eliminate the false minutiae. This method relies heavily on pixel connectivity computation, so it may consume more time. Maio and Maltoni [4] introduced a Neural Network-based minutiae filtering technique, which operates directly on the gray scale images. In this method, the type and quality of training data set is crucial. Farina et al. [5] proposed a method to remove 'bridge' based on ridge positions instead of directional maps that are used by conventional methods. Hung presents a structural approach to connect the ridge breaks using both ridge and valley spaces [6]. Xiao and Raafat [7] proposed a new approach to remove bridge, triangle, and ladder by calculating the number of "connected" minutiae and their structural relations. Stosz and Alyea [8] described a new method to eliminate wrinkles by analyzing the spatial relationship of the consecutive minutiae on the wrinkle.

II. PROPOSED METHODOLOGY

The components in the fuzzy system are not used in the proposed system but the Fuzzy if-then rules are used. Fuzzy rules and fuzzy reasoning are the backbone of fuzzy inference systems, and are considered as the most important modeling tools based on fuzzy set theory.

The false minutiae removal algorithm should remove the false minutiae but at the same time utmost care should be taken so as not to disturb the legitimate minutiae during the process. Therefore reliably differentiating spurious minutiae from genuine minutiae while the false minutiae are removed is very crucial.

To implement the proposed algorithm for removing false minutiae, a distance threshold 'D' should be set. D is the averages inter ridge width representing the average distance between two parallel neighboring ridges.

2.1 Procedures to remove false minutiae

As mentioned earlier, first the minutiae points which are close to the border (within 10 pixels) are ignored to avoid extracting false minutiae. Initially some simpler and compact set of fuzzy rules are proposed for removing false minutiae as described below:

Rule1: **IF** the distance between termination and bifurcation is less than D,
THEN remove both the minutiae.
Rule 2: **IF** the distance between two bifurcations is less than D,
THEN remove both the minutiae.
Rule 3: **IF** the distance between two terminations is less than D,
THEN remove both the minutia.

The average inter ridge distance (D) between two neighboring ridges which is computed by the formula

$$D = \frac{\text{sum all the pixels in the row whose value is one}}{\text{row length}}$$

The average inter-ridge width refers to the average distance between two neighboring ridges. The way to approximate the D value is very simple. A row of the thinned ridge image is scanned and all pixels in the row whose value is one are summed up. Then the row length is divided with the above summation to get an inter-ridge width. For more accuracy, such kind of row scan is performed upon several other rows and column scans are also conducted, and finally all the inter-ridge widths are averaged to get the value of 'D'.
Many experiments were conducted on large set of fingerprints to calculate inter pixel ridge distance to fix up the value of 'D'. Analyzing various results, it is observed that the value of 'D' is never less than 6. This is quite obvious because the average ridge width of a fingerprint images is typically six pixels [11]. So after thinning the fingerprint image, it is impossible to get a minutiae point which is closer than pixel width of '6' to another minutiae point.

To make the process simpler and computationally easy, the value of 'D' is empirically set to '6' and the system to remove the false minutiae is implemented. The experimental results proved that it works quickly in removing the false minutiae but not very efficient because many important parameters are not considered while forming the fuzzy rules.

2.3 Modified Fuzzy rules
The major drawback with the above methodology is, though it looks very simple there is a danger of removing legitimate minutiae along with the false minutiae.
For example consider the Figure 3, where it can be observed that there are two ridge endings A and B, where A is the true ridge termination and B is false and the distance between them is less than 'D'. The proposed rules (rule no. 3) eliminate both A and B. Removing a legitimate minutiae along with false minutiae is a serious offence.

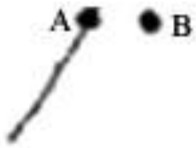


Figure 3: True ridge ending (A) and false minutia (B)

So the rule should be modified as follows:
IF the distance between two ridge terminations / bifurcations is less than D and they are on the same ridge **THEN** remove the both the terminations / bifurcations

Now the problem of removing true minutiae along with spurious minutiae is solved but there is still a problem even after the above modification. Consider a ridge break case as shown in the figure 4

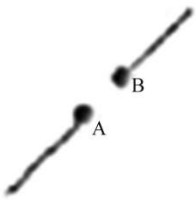


Figure 4: False minutiae (ridge break)

Though it appears as two ridges in Figure 4, it is a single ridge, which is broken. So according to the newly introduced rule both these false minutiae (though with the distance less than D) are not removed because, even though it is a single broken ridge because as it appears, it is considered as two ridges. Hence both A and B (both are false minutiae) are not removed as they are not on the single ridge.
So to address this problem one more fuzzy rule is introduced.

IF two terminations are within the threshold distance 'D' and their directions are synchronized with a small angle variation. And no other termination is located between those two terminations. **THEN** the two terminations are regarded as false minutia derived from a broken ridge and are removed.

With the proposed modifications to the existing rules, the modified fuzzy rules are as follows:

Rule1: **IF** the distance between termination and bifurcation is less than D and both are on the same ridge

THEN remove both the minutiae.

Rule 2: **IF** the distance between two bifurcations is less than D

and both are on the same ridge

THEN remove both the minutiae.

Rule 3: **IF** the distance between two terminations is less than D

and both are on the same ridge

THEN remove both the minutiae.

Rule 4: **IF**two terminations are within a distance D but on different ridges and their directions are synchronized with a minimal angle variation and no other termination is located between those two terminations.
THEN remove both the terminations.

2.3 Algorithm for removing false minutiae

Step 1: Get the enhanced fingerprint image after preprocessing

Step 2: Extract minutiae from the fingerprint image using Crossing Number (CN) technique

Step 3: Ignore / cancel minutiae points which are close to the border (within 10 pixels)

Step 4: Calculate distance threshold 'D' using equation (8.1)

Step 5: Calculate the orientation angle 'θ' between two serial ridges endings

if their distance is less than 'D'

Step 6: Remove false minutiae from the extracted minutiae using modified fuzzy rules

Step 7: Find the location of true minutiae points

Step 8: Export true minutiae into a text file

This algorithm removes the false minutiae from the extracted minutiae of a fingerprint image and exports the genuine minutiae into a text file for further processing and analysis. While the minutiae points' location is found, the following three points are obtained.

- X and Y coordinate
- Orientation angle between these coordinates
- Type of minutiae (ridge ending or bifurcation)

The number of terminations and bifurcations of a fingerprint image after removing the false minutiae can be compared with the number of minutiae points before removing the false minutiae, so as to check the accuracy of the proposed system.

The advantage with the proposed system with modified fuzzy rules is that it effectively eradicates the false minutiae without affecting the true minutiae. This system operates with very less computational effort.

2.4 EXPERIMENTS AND RESULTS

Different experiments were conducted to test the efficacy of the proposed methodology. Varying types of databases were used in these experiments and different approaches were used to evaluate the performance of the proposed algorithm.

2.1 Accuracy Rate

A series of experiments were conducted on a portion of CASIA V5 fingerprint dataset (file: 004 – 014) [154]. The accuracy rates, before and after applying the false minutiae removal algorithm on fingerprint ridge skeleton are reported in

Tables 1. The accuracy rates of ridge ending and bifurcation are computed by E_t/E_e and B_t/B_e respectively. The total rate is calculated using the following formula:

$$Total\ rate = \frac{E_t+B_t}{E_e+B_e}$$

where E_t and B_t are the number of true endings and true bifurcations in the extracted endings (E_e) and bifurcations (B_e), respectively.

Table 1: Accuracy rate

	Before Post processing	**After post processing**
Ridge Ending	**10.2%**	**22.1%**
Bifurcation	**24.6%**	**38.7%**
Total rate	**15.3%**	**29.6%**

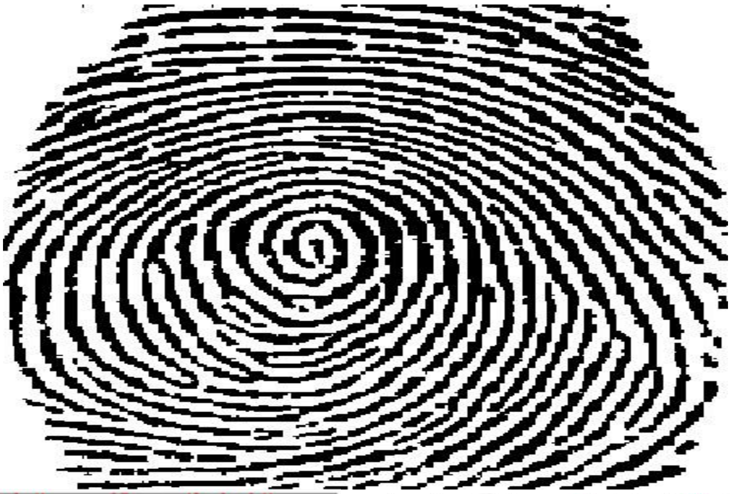
From the results in table 1, it can be seen that after post processing with the proposed methodology the accuracy rates of bifurcation and ridge endings are improved. It demonstrates that the proposed post processing algorithm does eliminate a large number of spurious false ridge endings and bifurcations.

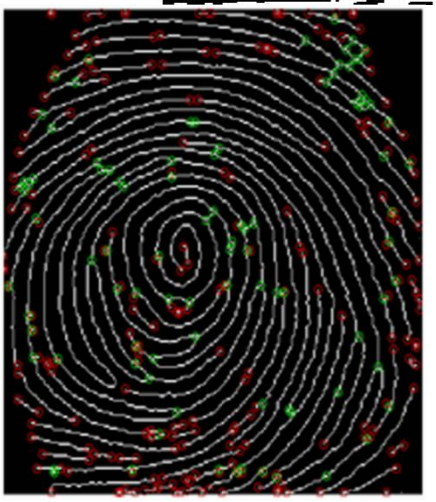
2.2 Number of Minutiae

Typically there are on the order of 100 minutiae on a ten print (fingerprint acquired from a digital scanner) [136]. Hong.et.al mentioned in [23] that a good quality fingerprint typically contains about 40 to 100 minutiae. But during the experiments on detection and extraction of minutiae from fingerprint image, in most of the occasions, it is observed that more minutiae were extracted from fingerprint images than these numbers. This indicates the presence of false minutiae. The false minutiae removal algorithm has been successfully implemented to eliminate the spurious false minutiae. The process of minutiae extraction and removal of false minutiae is depicted in Figures 5.

(a) Input Noisy Fingerprint

(b) Enhanced Fingerprint





(e) Minutiae extraction from thinned fingerprint
Terminations (red):168, Bifurcations (green):83

(f) After removing false minutiae
(Terminations: 63, Bifurcations: 21)

Figure 5: The process of minutiae extraction and removal of false minutiae

The table 2 shows the number of minutiae in a fingerprint image before post processing and after post processing. Some sample results of FVC 2002 DB [61] out of many are presented in the table 2 in terms of number of ridge endings and ridge bifurcations[11].

Table.2: Number of minutiae: – before and after removal of false minutiae

Image	Before post processing		After post processing		Total before	Total after
	No. of Terminations	No. of bifurcations	No. of Terminations	No. of bifurcations		
1_3	175	120	75	28	295	103
2_5	168	94	69	22	262	91
3_3	148	83	81	32	231	113
4_4	210	125	89	21	335	110
5_6	179	63	75	23	242	98
6_1	149	59	64	19	208	83
7_4	204	118	84	28	322	112
8_5	178	79	94	24	257	118
9_1	150	68	59	21	218	80
10_5	197	84	71	30	281	101

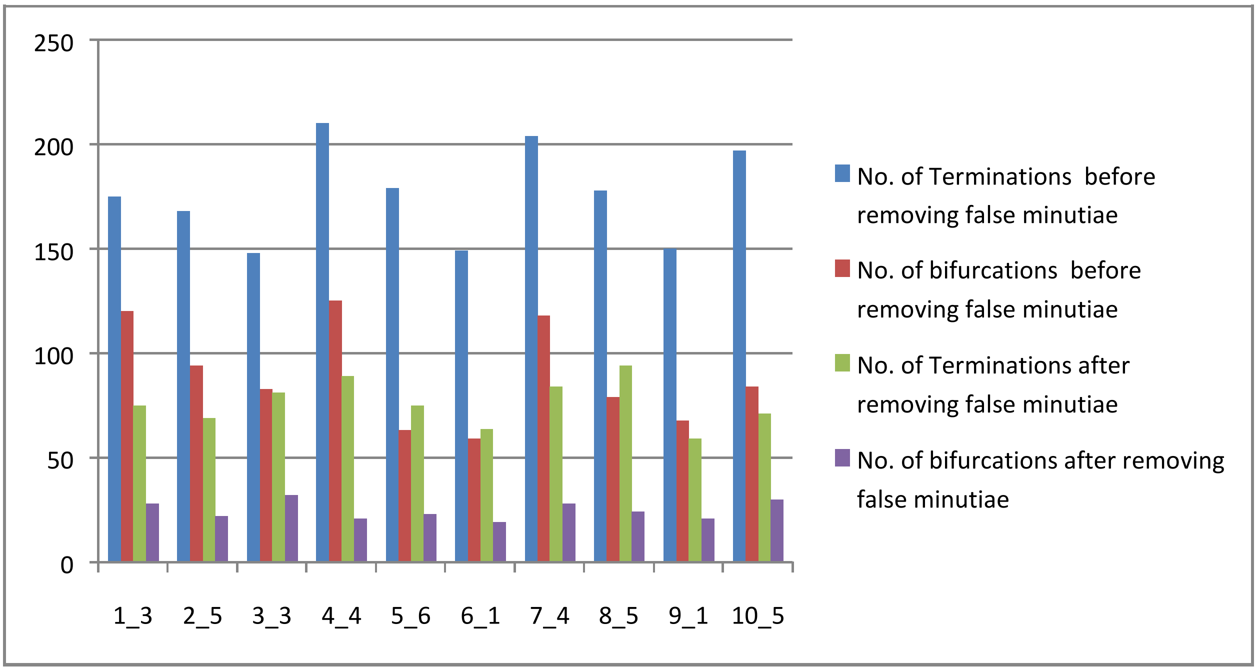


Figure 6: Number of minutiae: – before and after removal of false minutiae

It can be observed from table 2 and Figure 8.6 that the average number of minutiae has come down to about 50% less after applying the post processing of removing false minutiae from the fingerprint image. So after applying the proposed method of removal of false minutiae the false minutiae are removed and the true minutiae points are retained. The table 2 shows that the retained minutiae number is close to the order of 100. But the presence of true minutiae in the fingerprint image after post processing cannot be judged only on the basis of number of minutiae. So to prove the validity of the proposed algorithm, the Robustness Index is also used.

2.3 Robustness Index

The effective removal of false minutiae shows a considerable impact on the Robustness Index (RI). The Robustness Index has been used as an evaluation criterion of the enhancement process.The formula that is used to calculate Robustness Index (*RI*) of a Fingerprint image is

$$RI = p / u + v - p$$

within a tolerance bound of 18 pixels and 30 degrees, respectively.

Where '*p'* is the number of paired minutiae and $u + v$ represents the total number of minutiae detected in both the images. It is quite obvious to note that, if the values of '*u*' and '*v*' are more in number then there is more possibility of getting less robustness index value. So it is very important to remove false minutiae before calculating robustness index [12]. If the 'RI' value is more then there is a greater possibility of good matching. The graph in figure 7 shows the robustness index values of fingerprint images taken from (ATVS-FFP DB) fingerprint database. The same 32 sample fingerprints are used for effective comparative analysis. Two tests are carried out. In the first test, the 'RI' is calculated between enhanced fake fingerprint image and corresponding real fingerprint image without removing the false minutiae and in the second test, the 'RI' is calculated between enhanced fake fingerprint image and the corresponding real fingerprint image after removing the It can be observed from the graph in figure .7 that the robustness index values that are computed without removing the false minutiae has drastically fallen down. Every time the robustness index is computed, the false minutiae had been first removed. false minutiae. The results are presented in graph in figure 7

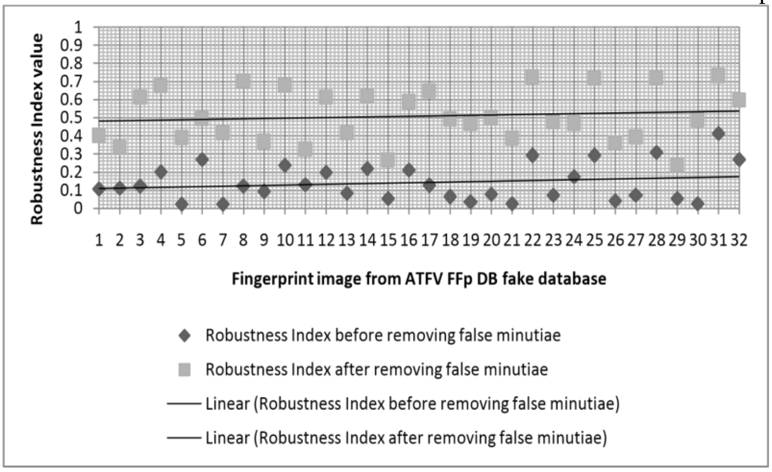


Figure 7: Robustness Index: – before and after the removal of false minutiae

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