# Removal of False Minutiae with Modified Fuzzy Rules



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# Removal of False Minutiae with Modified Fuzzy Rules

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**ABSTRACT**

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 further processing 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 effective in identifying and removing the spurious minutiae. Some critical cases are considered to extend existing proposed rules. There is a significant difference in performance of a verification system if the false minutiae are not removed. Experimental results show the impact of removing false minutiae.

## 1. INTRODUCTION

False minutiae are the ones that appear to be minutiae points, but not legitimate minutiae. Hence they are called false minutiae. There are many factors that cause the presence of the false minutiae in the extracted minutiae of a fingerprint image. Some of the factors are mentioned below

- False minutiae may be introduced into the fingerprint image due to the presence of noise in the fingerprint image
- Most of the minutiae detection algorithms use greedy detection scheme that minimizes the chance of missing true minutiae; however, many false minutiae are included in the candidate list. Because of this, much effort should be spent on removing the false minutiae.
- Due to different properties of fingerprint sensors and different conditions under which a fingerprint is scanned, the quality of a fingerprint image can vary greatly. For a fingerprint image of low quality, a large number of false minutiae may be extracted.
- Latent fingerprints or the fingerprints at the crime location are gathered in the most un-controlled environment. So it is quite obvious of acquiring spurious minutiae along with true minutiae when minutiae points are detected from such fingerprints (even after enhancement).
- The use of different preprocessing stages, occasionally introduce some artifacts which later lead to spurious minutia.
- False ridge breaks appear due to insufficient amount of ink and ridge cross-connections appear due to over inking, in the case of acquiring fingerprint image through traditional ink impression approach.

Due to all the factors that are described above, the extraction algorithm produces a large number of spurious minutiae such as break, spur, bridge, merge, triangle, ladder, lake, island, and wrinkle, as shown in Figure 1.

## 2. EXISTING TECHNIQUES & MOTIVATION

False minutiae decrease the performance of the fingerprint identification system by increasing both False Rejection Rate and False Acceptance Rate. The more spurious minutiae are eliminated, the better the matching performance will be. In addition, matching time will be significantly reduced because of the reduced minutiae number. Hence, after the minutiae are extracted, it is necessary to employ a post processing stage in order to validate the minutiae.
The problem of fingerprint image post processing for false minutiae elimination have been addressed before by different authors. Most of current post processing algorithms (Moayer B, Fu KS. , 1986), (L. O'Gorman

and J. L. Nickerson , 1989) eliminate the false minutiae by evaluating the statistical characteristics within an M × M matrix moving along the image pixel by pixel. (Xiao and Raafat , 1991) developed a new post processing algorithm using both the statistical and structural information to eliminate the false minutiae. However, the method relies heavily on pixel connectivity computation, which is very time-consuming. by (Maio and Maltoni, 1998) introduced a neural network-based minutiae filtering technique, which operates directly on the gray scale images. But this method relies greatly on the type and quality of training data.

(Farina et al., 1999) proposed a method to remove 'bridge' based on ridge positions instead of directional maps that is used by conventional methods. They argued that evaluation of the directional maps is very time-consuming. In (Hung, 1993) presents a structural approach to connect the ridge breaks using both ridge and valley spaces. Xiao and (Raafat , 1991) remove bridge, triangle, and ladder by calculating the number of "connected" minutiae and their structural relations. (Stosz and Alyea, 1994) propose to eliminate wrinkle by analyzing the spatial relationship of the consecutive minutiae on the wrinkle. (Feng Zhao, Xiaoou Tang, 2007) defined an *H*-point structure to remove several types of spurious minutiae including bridge, triangle, ladder, and wrinkle all together.

It can be observed from the literature that most of the methods focus on removing false minutiae are effective and compete with one another by identifying some limitations in other techniques. Many of these methodologies that are described in the literature are more complex with lot of statistical data and many calculations.

In the present work, it is proposed to develop a simple method that makes use of fuzzy type of rules to remove several types of spurious minutiae. The proposed method does not explore all the components of fuzzy system for removing false minutiae; rather it is built on the simple fuzzy rules to serve the purpose. The rules that are used to remove false minutiae take the form fuzzy if-then rules, thus the proposed method is called fuzzy rule based approach.

The proposed algorithm tests the validity of each minutiae point in thinned image and examines the local neighborhood around the point. The first step in this algorithm is finding the distance between each extracted minutiae of a fingerprint image. Euclidian distance is used to find distance (M. James Stephen, P.V.G.D Prasad Reddy, 2012). After finding distance, some fuzzy rules are used to remove these false minutia points. A threshold 'D' is used in the algorithm. The proposed fuzzy rules take the format of 'If A THEN B'

The proposed method is very simple and easy to implement but proved very effective in terms of removing false minutiae from the extracted minutiae.

## 3. PROPOSED METHODOLOGY

A new methodology based on fuzzy based system for removing the false minutiae from the extracted minutiae is proposed. In fact as mentioned earlier, all the components in the fuzzy system are not used but the Fuzzy if-then rules are used. Fuzzy rules and fuzzy reasoning are the backbone of fuzzy inference systems, which are the most important modeling tool based on fuzzy set theory.

The false minutiae removal algorithm should remove the false minutiae at the same time at most care should be taken that during the process the legitimate minutiae should not be disturbed. Therefore reliably differentiating spurious minutiae from genuine minutiae while the false minutiae are removed in the post processing stage 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.

### 3.1. Procedures to remove false minutia

To remove false minutiae from the extracted minutiae of a fingerprint image the fuzzy rules are used, which are of the form 'IF A THEN B'. First the minutiae points which are close to the border (within 10 pixels) are ignored to avoid extracting false minutiae that are obtained from the cutting edge of the thinned fingerprint image. Based on the empirical results on large fingerprint image database, a simpler and compact set of fuzzy rules are proposed for removing false minutiae as described below. (M.J.Stephen,et al., 2012)

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

$$D = \frac{\text{sum all the pixels in the row whose value is one}}{\text{row length}} \quad (1)$$

The average inter-ridge width refers to the average distance between two neighboring ridges. The way to approximate the D value is simple. Scan a row of the thinned ridge image and sum up all pixels in the row whose value is one. Then divide the row length 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, finally all the inter-ridge widths are averaged to get the D.

Enormous experiments were conducted on large set of fingerprints to calculate inter pixel ridge distance to directly 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 (Feng Zhao, Xiaoou Tang, 2007). 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'.

### 3.2. 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 1, 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

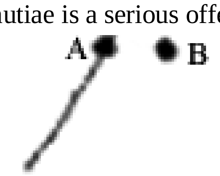


**Figure 1: True Ridge Ending (A) and False Minutia (B)**

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 still there is a problem with the above rule. Consider a ridge break case as shown in the Figure 2.

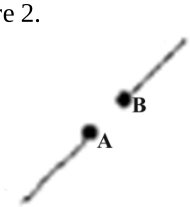


Figure 2: False minutiae (Ridge Break)

In Figure 2, though it appears as two ridges, it is a single ridge, which is broken. So according to the newly introduced rule both these false minutiae (though in the distance less than D) are not removed because even though it is a single broken ridge, it is considered as two ridges. Hence both A and B (both are false minutiae) are not removed as there are not on the single ridge. So a new fuzzy rule is introduced

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

With the proposed modification 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 and their directions are synchronized with a minimal angle variation and no other termination is located between the two terminations. **THEN** the two terminations are removed

### 3.3. 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 (1)

Step 5: Remove false minutiae from the extracted minutiae using modified fuzzy rules

Step 6: Find the location of true minutiae points.

Step 7: Export true minutiae into a text file

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)

Once the false minutiae are removed, the true minutiae points are exported to a text file in the workspace. The number of terminations and bifurcations could be compared in the cases of removing the false minutiae and with the prior fingerprints of non-removed ones so as to check the accuracy of the system in removing the false minutiae.

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.

## 4. EXPERIMENTAL RESULTS

### 4.1. Accuracy Rate

To evaluate the performance of the proposed methodology, a series of experiments were conducted on huge fingerprint dataset CASIA Version5. So some portions of the research in this paper use the CASIA-FingerprintV5 collected by the Chinese Academy of Sciences' Institute of Automation (CASIA)". The accuracy rates of applying the minutiae extraction algorithm on ridge skeleton before and after preprocessing are reported in Tables 1. In the tables, 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:

$$Total\ rate = \frac{E_t + B_t}{E_e + B_e} \quad (2)$$

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. The average results of about 50 fingerprint images are presented in table 1

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, it can be seen that after post processing with the proposed methodology the accuracy rate of bifurcation and ridge endings are improved significantly, especially for the ridge bifurcation. It demonstrates that the proposed post processing algorithm does eliminate a large number of spurious false ridge endings and bifurcations.

### 4.2. Number of Minutiae

The NIST user manual (Watson, G. I., Garris, M. D., et al., 2004), described that typically there are on the order of 100 minutiae on a tenprint (fingerprint acquired from a digital scanner) (Hong.et.al, 1998) mentioned that a good quality fingerprint typically contains about 40 to 100 minutiae. 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 8.2 shows that the retained minutiae number is close to the order of 100.

Many experiments were conducted on large data set to verify the number of minutiae before and after the post processing. The Table 2 shows some sample comparative results on number of ridge endings and ridge bifurcations before post processing and after post processing.. These experiments were carried out on fingerprint images of DB1_A of FVC 2002 database. (*J. Fierrez-Aguilar* , et al., 2005). Table 2 shows the results of 10 randomly selected images.

Table 2: No. of terminations and bifurcations - before and after post processing

| 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 |

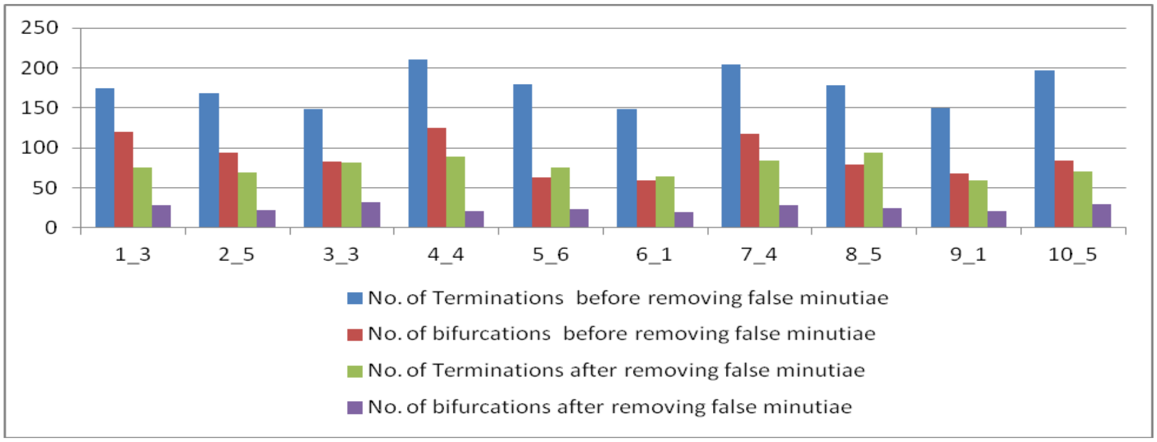


Figure3: number of minutiae – before and after removal of false minutiae

It can be observed from the table 2 and figure 3 that the average number of minutiae has come down to about 50% less after the post processing of removing false minutiae from the fingerprint image.

### 4.3. Robustness Index

The presence of true minutiae in the fingerprint image after post processing cannot be just judged only based on the number of minutiae. So to prove the validity of the genuine minutiae the Robustness Index is used. So the efficiency of the proposed post processing method is also validated using Robustness Index (R.I). Two tests are carried out on ATVS-FFp DB fake and real database (J. Galbally, J. Fierrez, 2011) in calculating R.I. In first test the R.I is calculated between poor quality fingerprint and corresponding real (original) fingerprint image before applying the proposed post processing. In second test, the Robustness Index (R.I) is calculated between fake fingerprint image and corresponding real fingerprint image after applying proposed post processing. In these test fake fingerprints are the enhanced ones through an enhancement technique (M. J. Stephen, et.al, 2013)

The formula that is used to calculate Robustness Index (*RI*) of a Fingerprint image is

$$RI = p / u + v - p \quad (3)$$

within a tolerance bound of 18 pixels and 30 degrees, respectively. Where '*p*' is the number of paired minutiae and ($u + v - p$) represents the total union count of minutiae detected in both the images. The tolerance bound is taken higher than the normal case because the R.I calculation is done between poor quality fake fingerprints and corresponding real fingerprints. So it may be a reasonable consideration.

A low *RI* value indicates large variance in the number of minutiae detected in two images and hence reflects poor image quality. The results that are presented in the graph show the significant improvement in R.I after performing post processing.

It can be observed from the graph in figure 4 that the robustness index values that are computed without removing the false minutiae has drastically fell down.

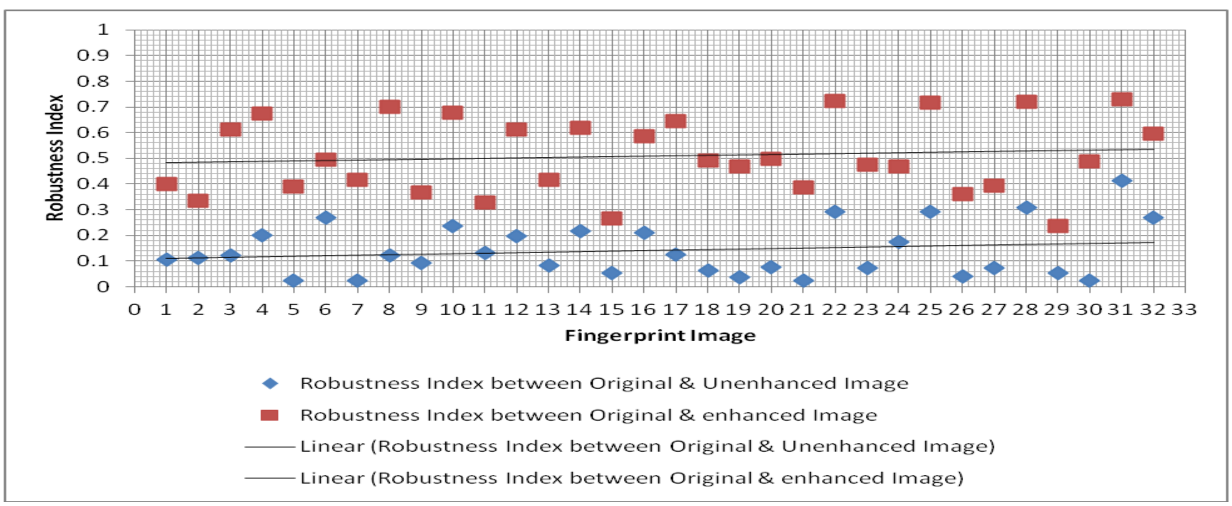


Figure 4: Robustness Index – before and after the removal of false minutiae

## 5. CONCLUSIONS AND FUTURE SCOPE

A fuzzy rules based system for removing false and spurious minutiae is described in this paper. Once after the minutiae are extracted from the enhanced fingerprint image then the process of removing false minutiae begins. That's why it is called post processing activity. The proposed methodology is simple and proved effective in removing false minutiae from the extracted minutiae of a fingerprint image. The proposed method was also proved to be effective with respect to easy implementation and less computational effort.

There is lot of scope for further improving this methodology. This simple methodology can be integrated with any other method like the one which is mentioned in NIST user's manual to build more robust system.

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