Hybrid Fuzzy Logic and Neural Network Model for Fingerprint Minutiae Extraction

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Abstract

This paper presents research into the use of fuzzy-neuro technology in automated fingerprint recognition for the extraction of fingerprint features, known as minutiae. The work presented here is an addendum to work carried out earlier[1].

1. Introduction

Among the different types of biometrics, fingerprints can be considered to be one of the most widely used. While two faces can be alike, for example twins, no two fingerprints are identical. In addition, most people generally have no fear about putting their fingers on a scanner for identification; unlike retina scans in which eyes are scanned. Fingerprint recognition is therefore proven, safe, easy and convenient to use.

Automated fingerprint recognition or identification consists of the basic process of extracting important fingerprint features, or minutiae, which uniquely identify a person. A fingerprint consists of two basic types of minutiae, ridge-endings and bi-furcations. Figure 1 shows a portion of a 256-grayscale scanned fingerprint and some of its minutiae.

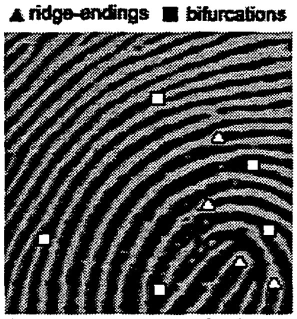

Figure 1: Examples of Minutiae

The minutiae and their relative positions to each other are then used for comparisons. It is therefore evident that the more accurate the process of extraction of minutiae, the more accurate and reliable the entire automated fingerprint recognition system becomes. There are numerous ways to extract minutiae from a fingerprint image. Minutiae extraction techniques are classified into three approaches in this paper, they are: classical approach, fuzzy approach and fuzzy neural approach

The classical approach using heuristics, extracts minutiae through several image processing steps to finally arrive at a line-thinned structure of the original fingerprint image. Minutiae are identified in the line-thinned structure by matching the line-thinned structure with templates using 3×3-pixel windows.

An alternative approach [1] (fuzzy approach) is minutiae extraction using fuzzy logic[2]. This approach strives to detect minutiae using the grayscales on the original fingerprint image. Although the results of the fuzzy approach are promising, the fuzzy rules are not sufficiently defined to cover certain situations. This results in false detection of minutiae (i.e. detecting a minutia when it is not).

As a result, neural networks were investigated and proposed in this paper, as an addition to the fuzzy logic system described above, to model the fuzzy rules (fuzzy neural approach).

2. The Classical Approach

In the effort to reduce the "irrelevant" information until a line-thinned structure is obtained in the classical approach, valuable information is lost. This results in the need for computationally expensive algorithms to enhance the image for filtering and binarization [3], or equally computationally expensive line-restructuring algorithms [4] to correct line-thin structures before minutiae extraction in order to reduce false detection of minutiae.

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Figure 2 shows the typical classical approach with minimal image processing steps for extracting minutiae.

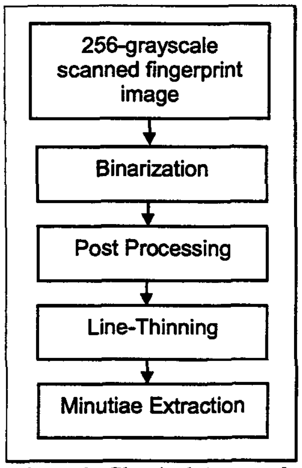

Figure 2: Classical Approach

3. The Fuzzy Approach

In contrast to the classical approach, the fuzzy approach makes use of the grayscale information for the extraction of minutiae. A grayscale fingerprint image consists of two distinct levels of gray pixels. The darker pixels, constituting the ridges, form one such level. The lighter pixels, constituting the valleys or furrows, form one other such level. Using human linguistics, these two levels of gray can be described as DARK and BRIGHT levels correspondingly. By using fuzzy logic, these levels can be modeled and used along with the appropriate fuzzy rules to extract minutiae accurately. Figure 3 shows the fuzzy approach for extracting minutiae.

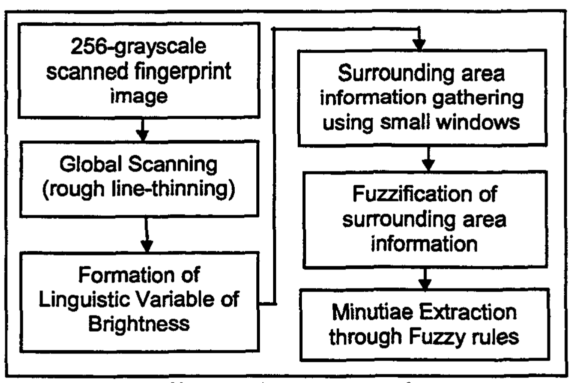

Figure 3: Fuzzy Approach

As the fuzzy approach forms the basis of the fuzzy neural approach, this paper will discuss the fuzzy approach up till the "fuzzification of surrounding area information" stage.

Global scanning is similar to line-thinning except that only rough line-thinned structures of the ridges and valleys are needed. The purpose of obtaining line-thinned structures for both the ridges and valleys is to restrict placement of test windows to these centers later in the algorithm. Since bifurcations can be seen as valley endings, the same algorithm for determining ridge-endings could be applied to determine these valley endings. Thus the need for obtaining line-thinned structure of the valleys. As the line-thinned structures act only as a guide, rough and fast line-thinning algorithms can be used.

Once the line-thinned structures are obtained, a 5×5-pixel test window is placed every point of the line-thinned structure. Figure 4 shows the placement of the test window. The average value (middle average) of the 25 pixels is then obtained. In addition, the average value (border average) of pixels within a 2-pixel border surrounding the test window is also obtained.

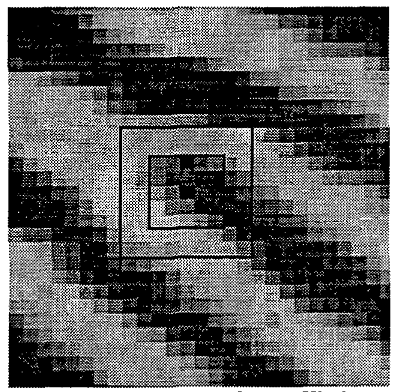

Figure 4: Placement of Test Window (fingerprint image enlarged 500%)

These two averages form the linguistics variable of brightness as shown in Figure 5. For ridge-endings detection, the first average determines the DARK full membership and the second average determines the BRIGHT full membership. This is reversed for bifurcation detection.

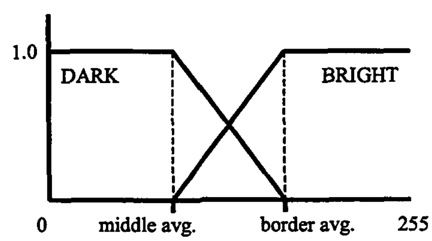

Figure 5: Linguistics Variable of Brightness (for ridge-ending detection)

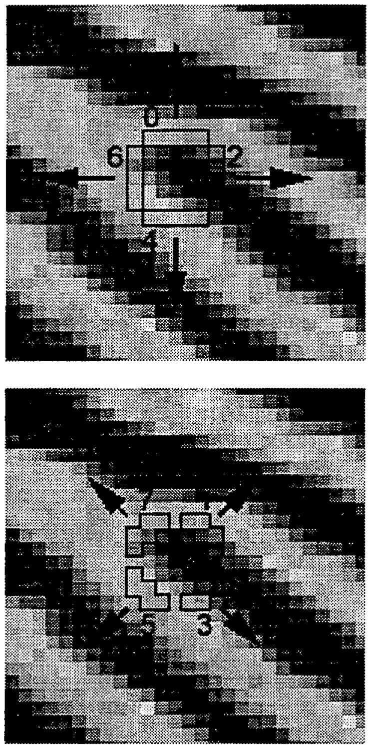

Figure 6: Initial Positions of Sub-windows
(fingerprint images enlarged 500%)

A set of 8 sub-windows are used to gather the surrounding area information. These windows are of size 1×5 pixels as shown in Figure 6. To cater for uneven widths of ridges and valleys, these 8 windows are shifted outwards pixel by pixel (scanning) until a range of 4 pixels as indicated in Figure 6. The average of each window is taken and fuzzified using the linguistic variable of brightness. Therefore, a total of 32 values are taken (8 windows × 4). Using these fuzzy values of BRIGHT and DARK, fuzzy rules are modeled to determine if a minutia is detected. However, these fuzzy rules are very difficult to formulate by hand to cover all possibilities of a true minutia.

4. Fuzzy Rules Modeling

The fuzzy neural approach is essentially an extension of the fuzzy approach. The surrounding areas of a potential minutia can be considered as a pattern of DARK and BRIGHT windows. Neural networks can then be used to recognize these patterns, and therefore, model the fuzzy rules of the system.

These surrounding areas are captured using the 1×5-pixel sub-windows, spanning a distance of 4 pixels. Together with 8 directions (North, Northeast, East, Southeast, South, Southwest, West and Northwest), the total number of 1×5-pixel windows is 32. The averages of these windows are then fed to a fuzzification engine. The fuzzification engine, using the linguistic variable of brightness, converts the average of each window into two fuzzy values: BRIGHT and DARK.

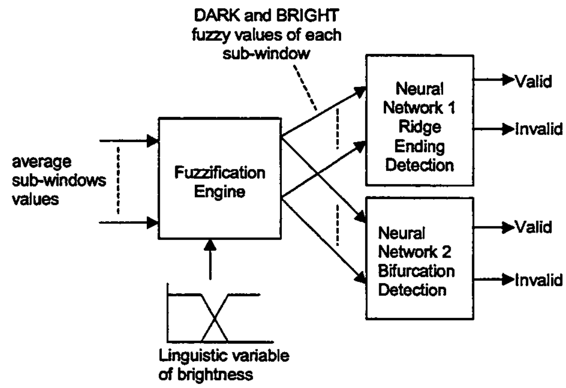

Figure 7: Fuzzy Neural Model

The neural networks as shown in Figure 7 are 64×32×32×2 back-propagation neural networks. The fuzzy values of BRIGHT and DARK as obtained earlier are then fed into either one of these networks, depending on ridge ending or bifurcation detection. Each network has a "winner-take-all" output layer of 2 neurons to determine if the fuzzy patterns constitute a valid or invalid minutia.

5. Results

The assessment of the techniques is based on the percentage of true minutiae that are extracted and the percentage of false minutiae extracted. Figures 8a-8d show the result of minutiae extraction using each of the three approaches.

Figure 8a: Original Image before Extraction

Figure 8b: Minutiae Extraction using (minimal) Classical Approach

Figure 8c: Minutiae Extraction using Fuzzy Approach at acceptance threshold of 0.75 [1]

As the fingerprint is scarred, any minutia extracted due to the scars will be counted as a false detection. This results in a low percentage of correct minutiae detection for the purpose of discussion. As summarized in Table1, the neural fuzzy approach produced the best extraction.

Figure 8d: Minutiae Extraction using Fuzzy Neural Approach

Total number of true minutiae (as pick up visually): 19

	Total Minutiae Extracted	Correct		Processing Time
Classical	107	5	5 %	0.900s
Fuzzy	47	6	13 %	1.659s
Neural Fuzzy	41	8	20 %	6.234s

	True Minutiae Missed	
Classical	14	74 %
Fuzzy	13	68 %
Neural Fuzzy	11	58 %

Table 1

On average, the percentage of true minutiae extracted using the fuzzy neural approach is more than that of the fuzzy approach, marking an improvement. This also implies fewer true minutiae are missed. With proper and sufficient training of the neural networks, the fuzzy neural approach proves to be a better approach. Future work are under way to improve on the performance of the fuzzy neural approach.

6. Conclusions

The results showed that on average, the fuzzy neural approach is a better alternative. The hybrid fuzzy and neural network model performs the minutiae extraction in two stages, a fuzzy front-end and a neural back-end. By such a separation, designing and training of the neural networks can be done in isolation. In addition, other neural networks can be investigated and used instead of the back-propagation networks.

To conclude, using the fuzzy neural hybrid model, fingerprint minutiae extraction is more accurate since fewer false minutiae are identified and more true minutiae identified.

7. References

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