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Clustering In Fingerprint Recognition System

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Abstract

Clustering of fingerprints can help to reduce the complexity of the search process in a database. This can be done by grouping fingerprints with the same characteristic in the same group. The matching algorithm can compare stored fingerprint codes with only one cluster instead of the entire database. In this research, we classify fingerprints into five categories which are arch, left loop, right loop, whorl, and others. The last category is use to categorize fingerprint pattern other then the four categories. Finally, experiments were carried out to show that clustering can reduce the recognition time. Experiments were carried out using neural network classifier, fuzzy logic and neuro-fuzzy. Results showed that neural network classifier is the best among the three.

Keywords: Fuzzy Logic, Neural Networks, Fingerprint, Clustering

1. Introduction

There are many different ways of acquiring fingerprints, such as frustrated total internal reflection(FTIR) and optical methods [1], CMOS capacitance [1],[2], thermal method [1],[2], ultrasound [1] and re-imaging [2]. Once fingerprints images were captured there are a number of different methods that can be used to extract important information. There are two possible details that can be identified in a fingerprint. The first one is the directional field [3]. This method describes the coarse structure or the basic shape of a fingerprint and defines as the local orientation of the ridge-valley structures at each position in the fingerprint. The directional field is normally used for fingerprints classification. The second is the minutiae [3]. This method provides details of the ridge-valley structures such as ridge-endings and bifurcations. The minutiae will be used for one-to-one comparison of two fingerprints. In this research the minutiae extraction were used for the recognition purpose

The second stage is the recognition process, which. is the main focus of the paper. The recognition time was extremely reduced with the used of clustering technique. There are a number of methods available for the recognition stage such as Neural-Network [4], a Correlation-Based Fingerprint Verification System [5], fingerprint matching using feature space correlation [4], combination of flat and structural approaches [6], fuzzy logic, neuro fuzzy and computational intelligence in fingerprints identification [7].

A simple matching algorithm can recognize a fingerprint image easily. However, with a huge database, the system will be very slow. There are a few different clustering algorithms such as hierarchical methods, partitioning methods, density-based algorithms, grid-based methods, clustering algorithms used in machine learning such as neural networks, fuzzy logic and fuzzy neural [8]. In our research, neural network, fuzzy logic and neuro fuzzy clustering system was developed and tested against a simple matching algorithm. Results were compared between all these techniques.

2. Motivation

In our previous work [9], we had developed a fingerprint recognition system which is minutiae based and uses Euclidean distance for the fingerprint matching. The system is able to perform verification and recognition. The system will extract features from the provided fingerprint image and then the extracted feature will be use to create a finger code. This is based on the arrangement of the fingerprint's minutiae and it is different for every fingerprint. The finger code is then stored in the database to perform recognition and verification. A fingerprint recognition system has to tolerate three problems such as, transition, rotation and scale. In our matching algorithm we had applied finger code to solve the transition and rotation problem. Figure 1 shows our earlier work.

In the earlier work, the recognition time was very long. In order to overcome the problem, clustering method can be applied. This was inspired by fact that

fingerprints can be grouped together with the same characteristics [8].

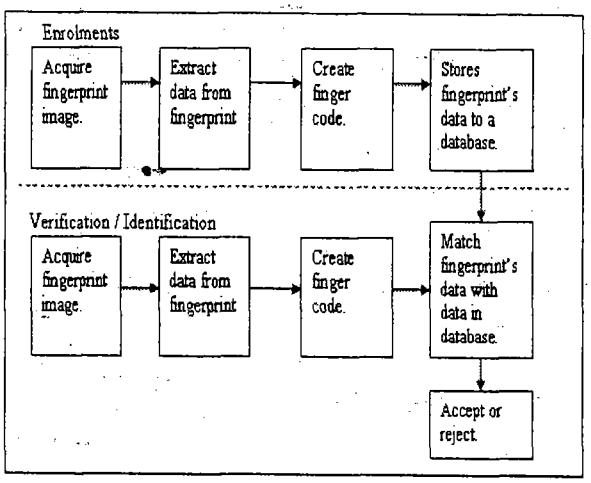

Figure 1. Fingerprint recognition system

Classification can be done with many different methods. The most common are neural networks, fuzzy logic, simulated annealing, graph matching and neuro fuzzy or fuzzy neuro [10]. Combination of neural network and fuzzy logic can be done in many different ways. Neural network models are able to provide algorithms for numeric classification, optimization, and associative storage and recall while fuzzy logic able to work at the semantic level and provide a solution to process inexact or approximate data. Fuzzy neural is the combination of neural network with fuzzy logic, this combination will provide us even greater representation power, higher processing speed, and are more robust than conventional neural network. There are many other researches proposed and claim that fuzzy neural is good.

In our research we proposed and developed fuzzy neural classifier for our fingerprint classification system. Besides testing the accuracy and efficiency of fuzzy neural classifier, we also implemented neural network assifier and fuzzy logic classifier to make a comparison ith fuzzy neural classifier. The comparison will cover areas such as the accuracy and efficiency.

3. Methodology

A module that is responsible to convert the fingerprint pattern from a 256 x 256 pixels grayscale image into a 256 columns array was build. The grayscale image will first be divided into 256 blocks. Each of this block's direction will be read and store into the 256 columns array. These directions are obtained by reading the fingerprint pattern according to the ridges and valleys of the fingerprint. These directions are divided into six categories (90°-270°, 0°-180°, 30°-210°, 60°-240°, 120°-300° and 150°-330°) and every direction will be represented with the numbers from 1 to 6. As the end result the 256 columns array will be the input for the three clustering methods.

Our study showed that fingerprint can be classified into approximately seven different types such as arch, tent arch, loop, double loop, pocked loop, whorl, and mixed figure [11]. We proposed five categories that are whorl, right loop, left loop, arch and others. The main four categories are the most common type of fingerprints. The fifth category that is the 'others' can cater for all other types which are not too common.

Figure 2 shows that the newly developed system. A direction reader and a clustering module are added to the system. The function of direction reader is to convert the fingerprint pattern from a 256 x 256 pixels grayscale image into a 256 columns array. The 256 array is fed to the clustering module to perform classification on the fingerprint image. This will decide on which class the fingerprint image belongs to. The classification result is then store into database with the finger code

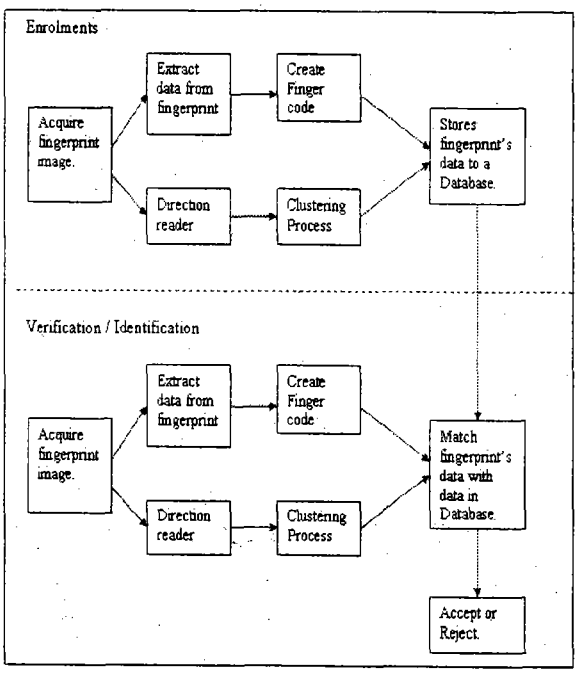

Figure 2. Fingerprint recognition system with the clustering approach

Figure 3 shows the clustering framework. After the direction reading, there are going to be three different classifier methods to classify the fingerprint image and after classifying the system will categorize the image

into five classes such as whorl, right loop, left loop, arch and others.

3.1. Neural network

In our neural network mode we have used 256 input nodes, 10 hidden nodes and 5 output nodes and all nodes are fully connected. Therefore, there are 2610 (256 x 10 + 10 x 5) weights to compute for every clustering process. The directions generated from the direction reader model will be the input for this neural network. Then after setting up the structure of neural network, 120 different fingerprint images were used to train this neural network. These 120 fingerprint images have the mixture of whorl type, arch type, left loop and right loop.

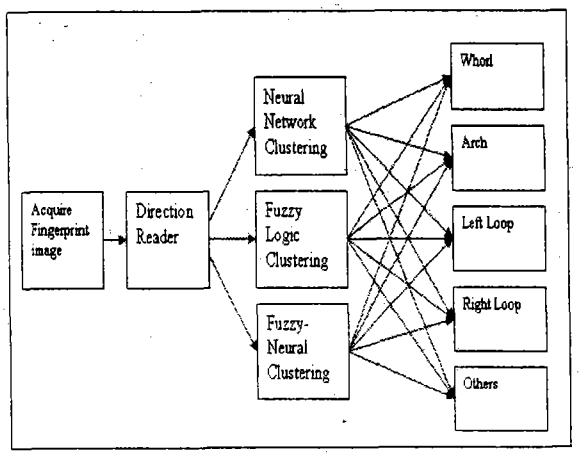

Figure 3. Clustering framework for fingerprint recognition system

The fingerprint will first be segmented into 8 x 8 segments. Then each of these segments will consist of 16 x 16 pixels and will be read by the direction reader. There are total of six directions that this direction reader can differentiate and these directions are (90°-270°, 0°-180°, 30°-210°, 60°-240°, 120°-300° and 150°-330°) and every direction will be represented with the numbers from 1 to 6. A series of direction will be generated by the direction reader and will be the input to the neural network.

This neural network structure was inspired by the neural network using a quick propagation training algorithm build by Prabhakar [12] and neural network by Wilson [6] which uses edge detection to create eigenvector from a given fingerprint image, then Kohonen Loeve transform (KLT) are then being applied to reduce the dimension of the input from the eigenvector, before feeding it to a multi layer perceptron.

The similarity of our neural network compare to the neural network of Prabhakar [12] and Wilson [6] is that all are Multi Layer Perceptron (MLP) with 3 layer network and fully connected. The different between our neural network classifier with Prabhakar [12] is mainly the structure of the neural network and the training algorithm. The structure of the Prabhakar's [12] has one layer of hidden nodes with 20 units, 192 input nodes and has 5 output nodes and the algorithm that they use to train is quick propagation training algorithm. Our neural network uses one layer of hidden nodes with 10 units, 256 input nodes correspond to the 256 features provided form the direction reader and 5 output nodes and the algorithm that we apply to train is backpropagation training algorithm.

Another difference is that the number of weights that neural network of Prabhakar's [12] have to compute is 3940 (192 x 20 + 20 x 5) weights while our neural network only have to compute 2610 (256 x 10 + 10 x 5) weights. The difference between Wilson's [6] and our work are our neural network takes input from direction reader instead of eigenvector and never go through and transformation to reduce the dimension of input.

3.2. Fuzzy logic

From our study on fuzzy logic and according to [10] fuzzy logic is a technique to mimic human mind to have to ability of reasoning approximately instead of exact. This means that it tries to compute a reason or a decision with the ability to tolerate of imprecision. For examples understand sloppy handwriting, recognize and classify images. In fuzzy logic there is a fuzzy inference system which able to solve a nonlinear mapping of the input data vector into a scalar output by using fuzzy rules. Therefore, to build the rules for fuzzy logic we performed a study on a number of fingerprints images and then generated a graph shown in figure 4, to show the frequency of direction distribution through different type of fingerprint images.

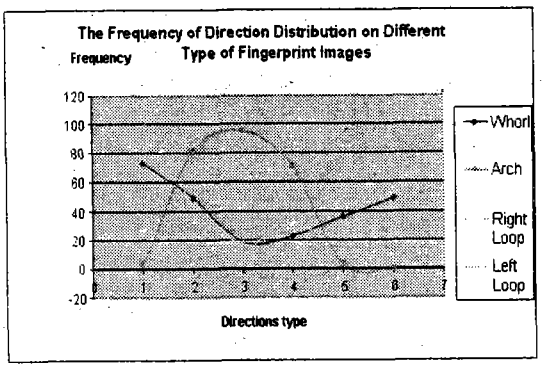

Figure 4. Frequency of Directions Distribution on Different Type of Fingerprint Images

Fuzzy logic's production rules and fuzzy input sets values can be set from the frequency from Figure 4. For examples, we can set the production rule for the Arch type as "if directions type 1 is low and directions type 2 is high and directions type 3 is high and directions type 4 is high and directions type 5 is low and directions type 6 is low then it is a Arch type fingerprint image." The value of the input fuzzy set can also be determine from these graph, for instance we have set that value below frequency 30 is very few, value above 25 is few, value above 45 is considered as average and lower then 55 is few, value above 65 is considered much and value below 75 is average, and if value above 80 is considered very much and below 90 is much.

These rules enables the fuzzy system to maps an input vector to an output vector. The function of fuzzifier is to maps input number into corresponding fuzzy membership in order to activate rules that are in the form of linguistic variables. It takes the input value and determines the degree of belonging to the fuzzy sets along membership functions. Then the inference engine which responsible to map the fuzzy input to fuzzy output by determining the degree to which the antecedent is satisfied for each rules and if then the rules have more then one clause, the fuzzy operators will be applied to obtain one number that represents the result of the antecedent for that rules. There are also possibilities that more then one rules are being fired at the same time. Therefore the outputs for all these rules are then aggregated by combining the fuzzy sets that represent the output into a single fuzzy set. Lastly the defuzzier maps the output fuzzy sets in to a crisp number. There are several methods of defuzzification such as centroid, maximum, mean of maxima, height, and modified height defuzzifier [10].

3.3. Neuro fuzzy

Figure 5, shows our neuro fuzzy system. The input of this system will be from the direction reader a 256 array. Then the input wills firstly processed by the fuzzy inference system and it will make decision on which neural network classifier will be used. There will be one out of the six multilayer neural network models to perform classification and each of this neural network models will responsible on differentiating only two types of fingerprints and one unidentified fingerprint type which will be cluster to the 'others' class.

We need to have six multilayer neural networks because our system has five classes of fingerprint needed to be classified. The six neural network classifier are the classifier that only classify between Whorl and Right Loop (WR), Right and Arch (RA), Left Loop and Right Loop (LR), Left Loop and Arch (LA), Whorl and Left Loop (WL), and Whorl and Arch (WA). If the chosen

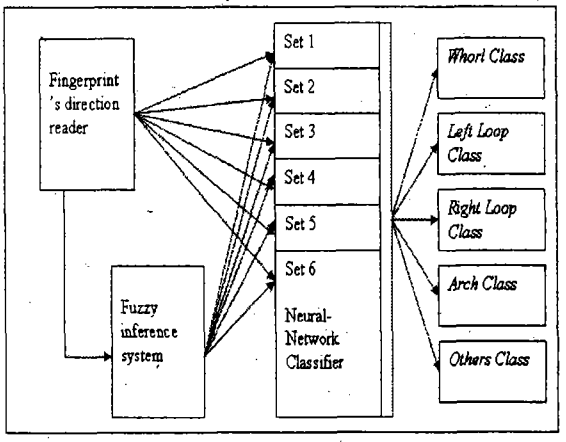

Figure 5. Neuro Fuzzy System

neural network failed to classify the fingerprint image then it will classify that image to the *Others* class. Currently, we have successfully implemented this model; therefore we are able to give all the exact details on this model. Implementation and experiments on this model was written at the coming sections.

The structure of neural network and fuzzy logic in this fuzzy neural classifier is slightly different from the neural network classifier and the fuzzy logic classifier that we built to compare with this fuzzy neural classifier. The structure for the six neural networks are the same, instead of using the same structure like the neural network classifier which uses 256 input nodes correspond to the 256 features provided form the direction reader, one hidden layer with 10 nodes and 5 output nodes, this fuzzy neural uses 256 input nodes, one hidden layer with 5 nodes and 2 output nodes and backpropagation training algorithm was applied.

The differences between fuzzy logic classifier that we built and this fuzzy neural is that the number of membership functions in the fuzzy input sets and fuzzy output sets, instead of using 5 membership functions in the fuzzy input sets it uses only 2 membership functions in the fuzzy neural input sets and instead of using 6 membership functions in the fuzzy output sets it uses 7 membership functions in the fuzzy neural output sets.

The differences between our fuzzy-neural classifier with Prabhakar's [12] classifier is that our fuzzy-neural uses 256 features as input while his classifier uses 192 features as input. The inputs to these two systems are also different, we uses fingerprint's ridge and valley orientation while Prabhakar's [12] classifier uses feature that generated by Gabor filter. Instead of using 10 sets of neural network classifiers, our fuzzy-neural classifier uses only 6 sets because every classifier responsible to classify two type of fingerprints and for all unidentified type of fingerprints to a specific class.

4. Experimental results

There are three different clustering approaches that were taken in our work. Same set of trained data were used. The trained data consists of 120 images with +10 and -10 degree of rotations. There are total of 5 comparisons being made, such as Accuracy of Classification for Trained Fingerprint Images, Accuracy of Classification for Untrained Fingerprint Images, Efficiency of Neural Network, Fuzzy Logic and Fuzzy Neural. The 120 images consist of 4 types of fingerprint where each type has 30 images (30 whorls, 30 arches, 30 left loops, and 30 right loops). After the process of training, image of the same sets of the training images is again feed into these classifiers to perform validation. If the submitted fingerprint is classified correctly then we will consider it as TRUE while if the classifier classified it wrongly then we will consider it as FALSE.

Figure 6 and 7 shows the accuracy results. Neural networks accuracy rate is the best. It is able to achieve 100% accuracy, while fuzzy neural have the worst performance which manage to score 94.17% accuracy. The error of fuzzy neural are concentrated on the classifying Arch type fingerprints, while fuzzy logic have errors classifying whorl type and right loop cluster but not as serious as error in fuzzy neural, therefore fuzzy logic achieved 95.83% accuracy.

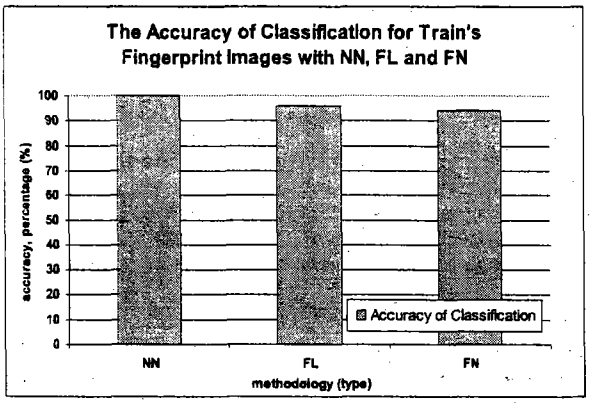

Figure 6. The accuracy of classification for trained fingerprint images

The accuracy test for untrained fingerprint images uses a set of 260 images with +10 and -10 degree of rotations, these 260 images never been exposed to the three classifiers. These untrained images also like the 120 images set, it consist of 4 types of fingerprint where each type has 65 images. Then all these fingerprints will be submitted and classified by each classifier, if the classifier correctly then we will consider it as TRUE while if the classifier classified it wrongly then we will consider it as FALSE.

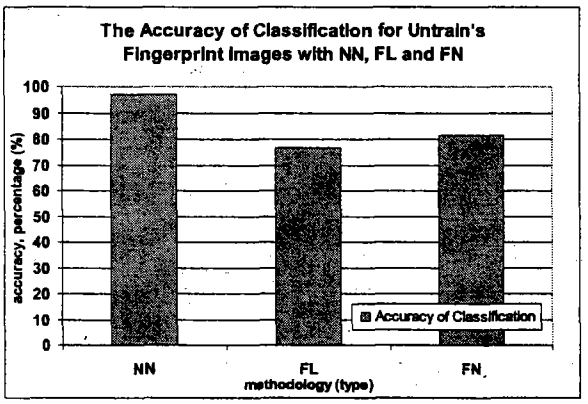

Figure 7. The accuracy of classification for untrained fingerprint images

The test of efficiency is being performed after we embedded the classifier into the fingerprint recognition system. This test uses 150 fingerprint images; these images are being registered into the system by 10 by 10 basics and for every 10 images being register, the matching process will be performed to get the matching time (duration of identifying a fingerprint images with different amount of fingerprints data in the database). This is also the same test that we had performed on the previous fingerprint recognition system without classification.

The results of this experiment on the three classifiers are almost the same, the identification and reject imposter time for fingerprint recognition are successfully reduce more then 5 times, the old fingerprint recognition system from 80 seconds to approximately 12 seconds and from 140 seconds to approximately 25 seconds to identified a fingerprint that does not exist in the database which registered with 150 fingerprint images.

5. Conclusion and future work

Although neural network classifier perform better then fuzzy neural and fuzzy logic, but we cannot conclude that neural network classifier is the best. Other aspects that need to be considered are such as the suitability of the methodology in a given problem domain, the choice of feature representation and the degree of the feature representation discrimination.

Experiments showed that neural network classifier is the best classifier followed by fuzzy logic and fuzzy neural. Neural network classifier have good training algorithm. The limitation of direction reader deteriorates fuzzy logic and fuzzy neural performance but not in neural network. Fuzzy logic performance also deteriorates because of incompleteness and inaccurate

representative of productions rule. Fingerprint image enhancement is also very crucial to produce better results

Problems with neural network classifier are that it performs classifying task in a black box manner, it is difficult to predict its behavior and to be enhanced later. In fuzzy logic input and output values are difficult to be defined. The performance of neuro fuzzy classifier is very dependent on the structure of the model. Different combination can produce different sets of results. Therefore, different model of neuro fuzzy classifier can be developed to see which can produce better results.

After several investigations, we believe a better neuro fuzzy classifier can be developed by rearranging the structure of fuzzy neural and enhance the direction reader to have the ability to distinguish more directions

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