Minutiae Matching Algorithm using Artificial Neural Network for Fingerprint Recognition

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***Abstract*— This article present a minutiae matching algorithm using hardware based artificial neural network intended to be implemented in embedded system environment. Hardware based artificial neural network CM1K consist of 1024 neuron in Cognistix device is used in this research. Fingerprint template as a vectors of minutiae points is used as an input to artificial neural network device. Matching process is based on the calculation of the distance from two vectors from two set of minutiae points comming from two fingerprints. Using hardware based of artificial neural network provide faster processing in matching process and the used of Cognistix making faster and easy in development of prototype.**

Keywords-component; minutiae, fingerprint, recognition, neural network

I. INTRODUCTION

In fingerprint recognition, minutiae template matching is an important process as well as the extraction process to get minutiae points it self. Many algorithm had been proposed, some of them using an artificial neural network as part of process in software environment.

Learning Vector Quantization (LVQ) neural network (NN) is applied to Automatic Fingerprint Verification (AFV). This approach is based on both local (minutiae) and global image features (shape signatures). The matched minutiae are used as reference axis for generating shape signatures which are then digitized to form a feature vector describing the fingerprint. A LVQ NN is trained to match the fingerprints using the difference set of a pair of feature vectors.[1]

An appliction of neural network is presented in [2] to clasify fingerprint image in to six classes like arch, tented arch, right loop, left loop, whorl and twin loop. The classification result given by the system with minimum of rejection ratio is very accurate, about 80.2 % in average of accuracy. It is obvious that presented method has greatly improved fingerprint image classification accuracy. From the simulation results verified that the proposed algorithm is accurate and effective.

The used of Backpropagation training network method in ANN to recognize the exact thumb impressions from the match with the images that has already stored is presented in [3]. The input is an image, the thumb impression, of a person is got from the device (fingerprint sensor). The first step in he matching process is clasifying the fingerpirnt image using neural program. Actually this classification process is conducted, in order to reduce the search time between numerous number of images.[3]

Another method in ANN is Levenberg-Marquardt back propagation (LMBP) algorithm. It was used for training purpose because LMBP is fastest technique for complex data sets and gives better performance. The Input image is trained by trainlm function, this funtion produce different result sets like performance plot, regression values, simulation network of input image, histogram graph etc. Ther are so many advantages using neural networks over other methods like adaptive learning, self organization, realtime operation, fault tolerance. Neural network has many applications such as hand writing and type writing recognition, fraud detection, criminal sentencing, optimization, pattern recognition etc. The application of trainlm function for training network is for producing different result sets [4]

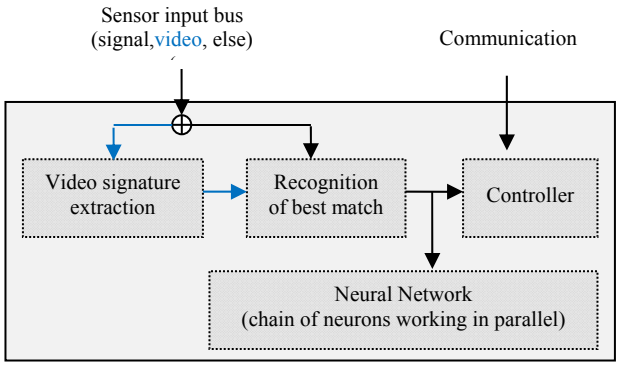

Figure 1. Common approach in using hardware neural network for patter recognition.[5]

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In hardware environment there is a device of neural network processing device known as CM1k Cognimem consist of 1024 neuron.[5]. Fig.1 present the use of this device for pattern recognition, input bus is used for sending the pattern signature to be processed in neural network as chain of neuron working paralalel.

II. MINUTIAE POINTS AS FINGERPRINT TEMPLATE

Simple fingerprint template is a colection of minutiae points composed as a vectors formated as : x,y,angle, minutiae point type (1 for EP and 3 for BP). For example, minutiae point on location 70 ,41 with 135 degree and an bifurcation minutiae points will have vector : 70,41, 135,3. An example of 23 end point minutiae and 14 bifurcation point see Fig.2, the vector template are :

70	41	135	3
163	41	-15	3
167	66	315	1
145	67	315	1
179	67	315	3
142	71	285	1
137	72	270	1
199	74	345	1
160	78	300	3
142	82	255	1
186	87	300	1
200	87	300	1
159	96	285	1
149	101	270	1
175	105	285	3
197	110	105	3
85	121	90	1
155	129	270	1
85	136	240	1
200	147	315	3
148	152	255	1
115	171	240	1
186	171	285	1
149	176	225	3
170	177	255	1
186	190	285	1
60	202	45	3
196	214	285	1
194	225	120	1
189	226	285	1
190	230	150	3
178	233	90	3
131	238	45	3
173	251	30	1
114	255	60	3
92	271	75	3
74	290	45	1

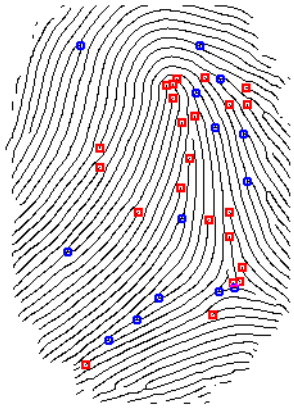

Figure 2. Fingerprint image with minutiae pooints extacted and their vector template, red points for end point (EP) and blue points for bifurcation point (BP).

An example of artificial neural network used as minutiae points extraction process is presented in [6], a neural network with two hidden layers 25 neurons in each. Output layer consists of 3 neurons, each representing one class of the patterns. Fig.3 is the example of trainning data used in learning process for network layer to clasify the windowed fingerprint image when extracting the minutiae points.[6]

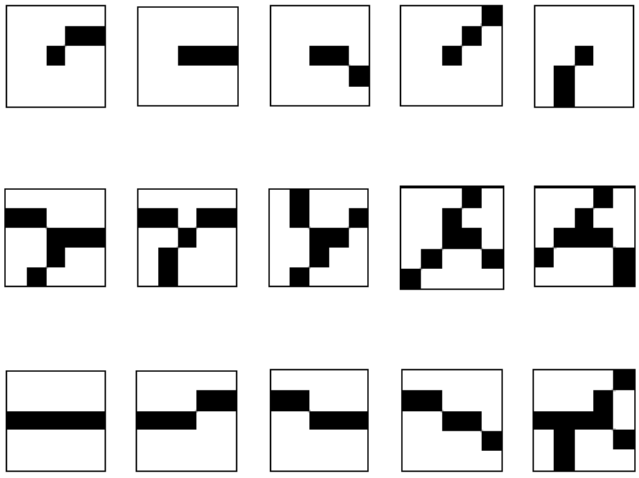

Figure 3. . Examples of the training data. Upper row: termination pattern s, midd le row: bifurcation patterns and lower row: no minutiae patterns. [6]

III. HARDWARE NEURAL NETWORK

Hardware based neural network used in this research is CogniMem CM1K. This device is a fully parallel silicon neural network: consist of a chain of 1,024 identical elements (called “neurons”) which can store and process information simultaneously. This parallel architecture enables the following key strengths of the CM1K:. [7

- **Constant recognition time.** This device can recognize an input data point in 10us, *independent of the number of connected neurons*.
- **Constant learning time.** The time needed by CM1K for learning a new training example is about 10us, again independent of the size of the network.
- **Scalable network size.** This neural network can be expanded by cascading additional chips, up to 1,024 chips in parallel for a total of 1 million neurons in the current generation.

Two powerful non-linear classifiers are implemented in CM1K, which are Radial Basis Function Network (RBF) and K-Nearest Neighbor (KNN). The learning and recognition operations are implemented in dedicated hardware; there are no software instructions running on the CM1K. There is a top-level controller managing the neurons, but each neuron operates independently on its own data. There are so many feature in CM1K including a Save and Restore mode. The knowledge built by the CM1K can be read off the device in order to be replicated to other devices, or to be restored at different time.

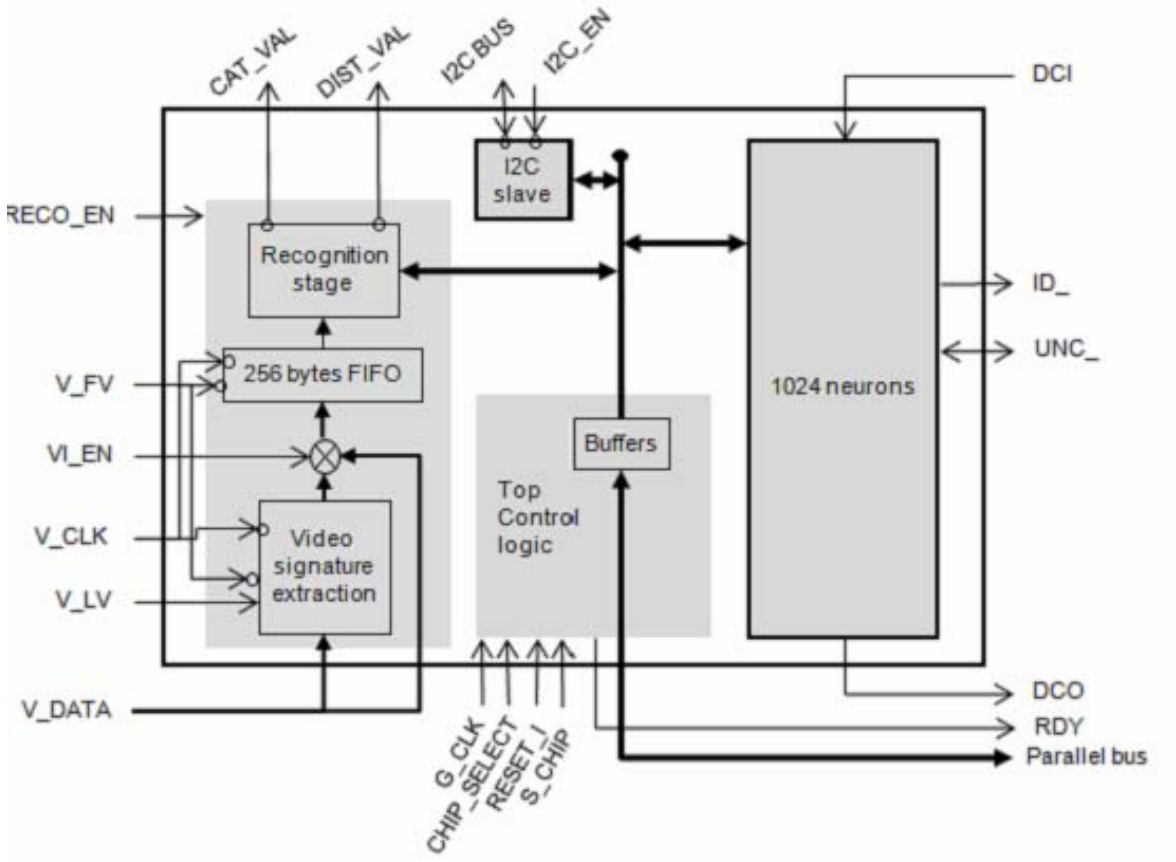

Figure 4. Block diagram of CM1K neural network device.[7]

Fig.4 is diagram blok of CM1K, which is a high-performance pattern recognition chip featuring a network of 1024 neurons operating in parallel. Embedded in the chip is a recognition engine ready to classify a digital signal received directly from a sensor. The CM1K is composed of the following modules :[7]

- Top control logic (NSR and RSR registers, Ready and Busy control signals)
- Clusters of 16 neurons
- Recognition stage (optional usage)
- I2C slave (optional usage)

Classifying a new data point or an input, the input is broadcast to all of the neurons on the parallel bus. Each neuron on the parallel bus receives the input at the same time, see Fig.5. Each neuron computes the distance between the input and the data point in its buffer (called distance calculation based on L1 distance, see eq.1.), and stores the result in the neuron's distance register. This distance calculation is performed *simultaneously* across all neurons.

The L_1 distance between two n-dimensional vectors a and b is computed as the sum of the absolute differences between each component of the two vectors, see eq.1.[7]

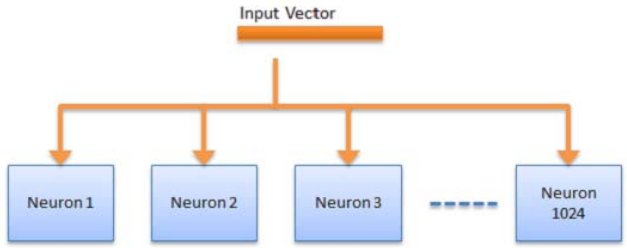

Figure 5. A new input vector, simultaneously broadcast to all neurons on the parallel bus.[7]

$$dist_{L1}(a,b) = \sum_{i=0}^{n} | a_i - b_i | \qquad (1)$$

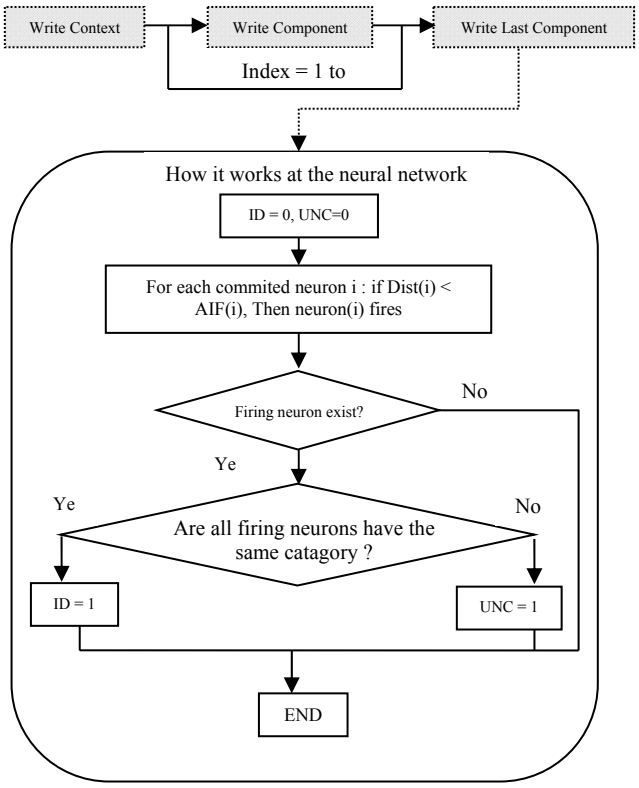

Figure 6. Flowchart of minutiae matching alogorithm.[7]

IV. MINUTIAE MATCHING ALGORITHM

Basically the algorithm is simple, the two vectors of minutiae points (as an input) are sent to CM1K device in CogniStix device and than wait the calculaion result whether this two vector s is match or not based on the distance value of the two vectors. ID=1 mean that the vector is identified, and UNC=1 mean uncertainty result. Fig.6. present the flowchart of the algorithm, specially in calculating the distance. The more complex problem in this application is interfacing and sending data to the device.

Fig7. present the GUI fingerprint application using hardaware based neural network for minutiae matching process. The fingerprint image can be from file or fingerprint sensor.

Figure 7. GUI fingerprint recognition application using hardware based nerual network.

V. CONCLUSION

The minutiae matching algorithm for fingerprint recognition using hardware neural network has been presented with recognition time it self about 10us without interfacing time which is slower.

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