A fully CNN based fingerprint recognition system.

Reza Abrishambaf[1]
Hasan Demirel[1]
Izzet Kale[2]

[1] Department of Electrical and Electronic Engineering, Eastern Mediterranean University
[2] School of Electronics and Computer Science, University of Westminster

Copyright © [2008] IEEE. Reprinted from the IEEE 11th Cellular Neural Networks and Their Applications (CNNA 2008). IEEE, pp. 146-149. ISBN 9781424420896.

11th International Workshop on Cellular Neural Networks and their Applications
Santiago de Compostela, Spain, 14-16 July 2008

A Fully CNN Based Fingerprint Recognition System

Reza ABRISHAMBAF, Hasan DEMIREL
Department of Electrical and Electronic Engineering
Eastern Mediterranean University
Famagusta, TRNC, Via Mersin10, Turkey
{reza.abrishambaf, hasan.demirel}@emu.edu.tr

Izzet KALE
Applied DSP and VLSI Research Group
Department of Electronic Systems
University of Westminster, London, UK
kalei@westminster.ac.uk

Abstract— **In this paper, a fully Cellular Neural Networks (CNN) based fingerprint recognition system is introduced. The system includes a preprocessing phase where the input fingerprint image is enhanced and a recognition phase where the enhanced fingerprint image is matched with the fingerprints in the database. Both preprocessing and recognition phases are realized by means of CNN approaches. A novel application of skeletonization method is used to perform ridgeline thinning which improves the quality of the extracted lines for further processing, and hence increases the overall system performance.**

I. INTRODUCTION

Nowadays fingerprint verification systems are widely used in personal identification and verification systems. In the early twentieth century, fingerprint recognition has been accepted officially for personal identification. The fingerprints left on suitable surfaces has been used by the security departments to identify the criminals and also special fingerprint reader systems are used to verify the identity of the persons at security checks such as in airports and critical building access points.

There are many methods proposed for fingerprint recognition in the literatures. After the introduction of the first paradigm of the Cellular Neural Networks (CNN) by Chua and Yang [1], many papers have been published about the CNN and its application in image processing [2] [3] [4] [5]. The parallel and simple structure of CNN makes it very suitable for image processing. The CNN architecture contains many processing cells which operate in parallel in a 2D grid where each cell is connected to the cells in its local neighborhood only. The CNN cells are very simple circuit nodes and hence many of them can easily be integrated into a single chip. Consider an image of 64x64 pixels to be processed, then a 64x64 CNN cells can be used to process the image by using a series of CNN algorithms, in other words each pixel corresponds to each cell in the CNN [1]. The built in parallelism provides faster processing. The structure of the CNN is very simple and suitable for VLSI implementation. By changing the template coefficients of the CNN, different image processing tasks, such as edge detection, noise removal, contrast stretching, dilation and erosion can be performed.

This work is supported by the Ministry of National Education and Culture of Turkish Republic of Northern Cyprus with the Project Number MEKB-07-02.

In this paper, a CNN based fingerprint recognition system is proposed. The system includes two phases, one of which is the preprocessing and the other is the recognition phases. The preprocessing phase includes: contrast stretching, Gabor-type filters, lowpass filters and thresholding. The matching phase includes: ridgeline thinning and feature point extraction. The proposed skeletonization procedure improves the quality of the extracted lines for further processing, and hence increases the overall system performance when compared with a similar system introduced by Gao in [8]. The extracted 2D feature vector is used in the fingerprint matching process. The False Acceptance Rate (FAR) and False Rejection Rates (FRR) are also generated for changing threshold values to reflect the full system performance for a possible application.

II. FINGERPRINT IMAGE PREPROCESSING USING CNN

The fingerprint image preprocessing is the first step in the proposed recognition system. In order to have a reliable recognition, the preprocessing is required. In reality, the fingerprint images have poor quality which is primarily due to the acquisition process. The fingerprint image preprocessing steps include contrast stretching, gabor-type, low pass filtering and grayscale to binary conversion [3] [6]. This section briefly describes these preprocessing steps one by one.

A. Contrast Stretching

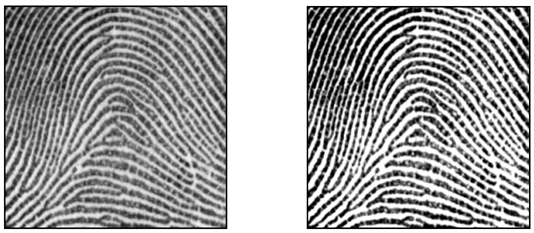
Contrast stretching is the first step in the fingerprint image enhancement. When the fingerprint is obtained by the acquisition device, it is mapped to the grayscale level, in which the values of the pixels are in the range of [0,255]. By rescaling the pixel values between [-1,1] and using the respective CNN templates for contrast stretching, the image is enhanced [6]. Fig. 1(b) shows the enhancement obtained by using contrast stretching over the initial image in Fig. 1(a).

B. Gabor-Type Filtering

The Gabor-Type filters are very suitable for fingerprint images. There are ridgelines with different directions in the fingerprint images, and by tuning the gabor-type filters to these ridgelines, there will be no noise between the ridgelines and the output image will be clearer than the original one. What is removed by these filter, is the noise between these

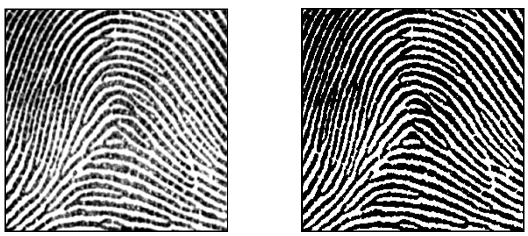
978-1-4244-2090-2/08/$25.00 ©2008 IEEE

lines. The Gabor-Type filtering is implemented on CNN by [6]. Using the CNN templates for Gabor-type and low pass filtering, a clearer fingerprint image can be obtained as shown in fig. 2.



(a) (b)

Figure1. The original fingerprint image (a), contrast stretched image using CNN (b).



(a) (b)

Figure 2. The input image (a), The result of Gabor-Type and lowpass filtering (b).

C. Gray-Scale to Binary Thresholding

In this section the result of the Gabor-Type filtering is applied to the gray-scale to binary thresholding procedure. This step is required, because there are still some gray values in the output of the Gabor-Type filtered image. Conversion to binary image helps the feature point extraction process before the fingerprint recognition. We use the CNN templates given in [6] and the Fig. 3(b) shows the result of thresholding on Fig. 3(a).

(a) (b)

Figure 3. The Gabor-Type filtering result (a), The binary image (b).

The gray-scale to binary conversion is the final step in the fingerprint image preprocessing. The importance of the fingerprint image preprocessing can be realized by comparing the binary fingerprint image with the original one. The result of this step can now be used for the extraction of the feature points which is part of the fingerprint matching procedure described in the next section.

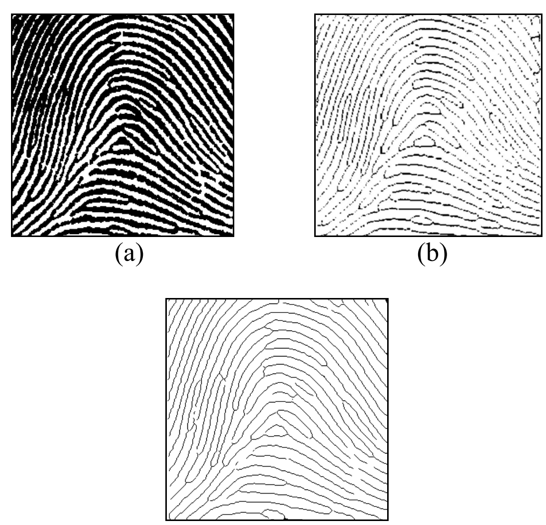
III. Fingerprint Recognition

This section describes the fingerprint recognition procedure, which is based on the matching of the extracted features with the features of the fingerprints in the database. The recognition procedure includes ridgeline thinning, extraction of the feature points and the fingerprint matching.

A. Ridgeline Thinning

Bifurcations and ridgeline endings are the main features of the fingerprint images. In order to extract these features, each ridgeline should be thinned. There are many methods for thinning. In this paper, a novel application of skeletonization method is used in order to perform thinning operation. The eight different CNN templates [7] are used in order to thin the ridgelines. The result of the proposed skeletonization method is compared with the result of Gao's method [8]. Fig. 4(c) shows that there is no discontinuity in the ridgelines. However, Fig. 4(b), which uses the Gao's thinning procedure, contains some discontinuities in the ridgelines. Discontinuities in the ridgelines affect the bifurcations and ridgeline endings which decrease the effectiveness of the feature extraction process and hence may cause unreliable recognition.

There are eight CNN templates used for thinning of the ridgelines, which introduces thinning from eight directions (North, Northeast, East, Southeast, South, Southwest, West and Northwest). The thinned ridgelines can now be effectively used to extract the feature points before starting the feature matching process.



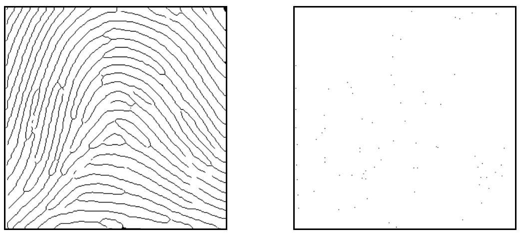
(a) (b)

(c)

Figure 4. The enhanced image (a), Gao's method for thinning (b), and the result of the proposed skeletonization method (c).

B. Feature Extraction

As it's mentioned before, the individuality of the fingerprint images is due to the arrangement of the bifurcations and ridgelines. Once the ridgelines are thinned, these features can be extracted. By using the method proposed in [9] these features have been extracted. Fig. 5(a) shows the resulting image after ridgeline thinning and the Fig. 5(b) gives the extracted feature points to be used in the feature matching process.



(a) (b)

Figure 5. The ridgeline thinned image (a), extracted feature points (b).

C. *Feature Matching*

The feature matching step is the most critical step in a fingerprint recognition system. In this step the similarity between two images is measured, and by calculating the correlation between these images, the decision is given.

In [10], Gao proposed a method for measuring the similarity between two fingerprint images. One of the images is considered to be the input image that should be verified and another image is the one which is stored in the system database. By using this method the difference between two mentioned images can be measured. The smaller the difference between the two images indicates more similarity [10].

IV. System Performance

In image processing applications such as fingerprint, iris and face recognition, there are two important factors for measuring the system performance. The probabilities that a righteous person is rejected and a malicious person is accepted, are called False Reject Rate (FRR) and False Accept Rate (FAR), respectively. In a biometric systems there is a trade-off between FAR and FRR. It is desirable that both FAR and FRR be the smallest possible values. But in reality they are not independent.

In order to measure the system performance, 4 different fingerprint images of 15 persons have been used. By choosing the threshold as low as 0.02, the FRR graph in Fig.6 has been generated. In order to analyze the overall system performance, both FAR and FRR versus threshold is shown in Fig. 7. As Fig. 7 implies, the FAR and FRR graphs have an common intersection point, which is called Equal Error Rate (ERR). Typically the threshold of the system will be chosen at this point, but, for instance, in some applications that high security system is required, the threshold can be chosen to be less than the ERR point, because choosing the value less than the ERR point, implies more rejections which is not desired and less false acceptances which is desired. Therefore, different trade-off can be considered for different applications.

V. Conclusion

In this paper, a fully CNN based fingerprint recognition system has been introduced. First the fingerprint image preprocessing has been described, which is used to enhance the quality of the fingerprint image that is typically degraded due to the acquisition process. Then in order to extract the fingerprint image features, the ridgelines are thinned, where a novel application of skeletonization method has been used to perform ridgeline thinning. The proposed method shows improved thinning performance. Furthermore, the system performance is analyzed by the help of two biometric factors FAR and FRR for possible trade-off analysis in real life applications.

Acknowledgment

We would like to thank Dr. Ertugrul Saatci for providing us a copy of his PhD thesis and Prof. Dr. Vedat Tavsanoglu for sharing his ideas with us.

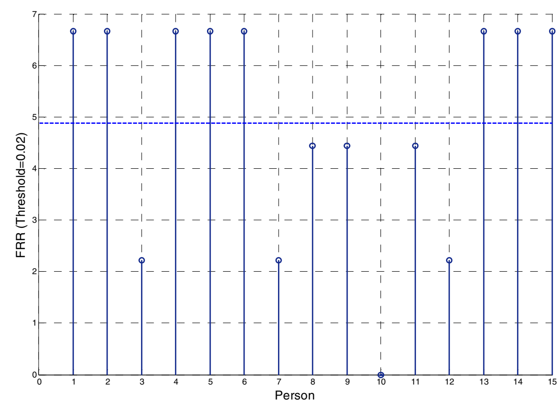


Figure 6. The system FRR for 0.02 as threshold

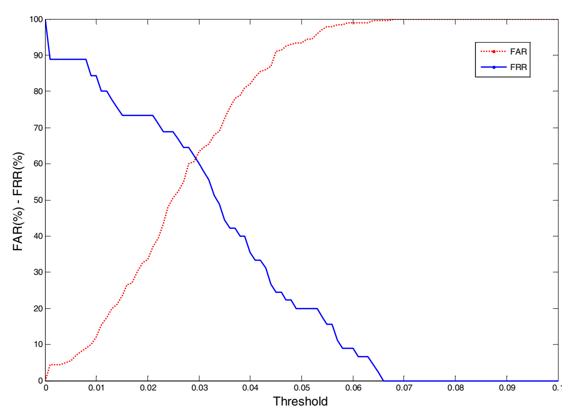


Figure 7. FAR and FRR versus threshold

References

[1] L. O. Chua and L. Yang. “Cellular neural networks: Theory”, *IEEE Transaction on Circuits and Systems,* vol. 35, pp. 1257-1272, Oct. 1988.

[2] M. D. Doan, M. Glenser, R.Chakrabaty, M. Heidenreich, S.Cheung, "Realization of a Digital Cellular Neural Network for Image Processing", *IEEE International Workshop on Cellular Neural Networks and Their Applications*, 1994.
[3] E. Saatci, "Image Processing Using Cellular Neural Networks", PhD Thesis, London South Bank University, September 2003.
[4] L. O. Chua, LIN YANG, "Cellular Neural Networks: Applications ", *IEEE Transaction on Circuits and Systems*, vol.35, pp.1273-1290, Oct. 1988.
[5] Kenneth R. Crounce, L. O. Chua, "Methods for Image Processing and Pattern Formation in Cellular Neural Networks: A Tutorial", *IEEE Transaction on Circuits and Systems, Fundamental Theory and Application,* vol. 42, No. 10, Oct. 1995.
[6] E. Saatci, and V. Tavsanoglu, "Fingerprint Image Enhancement using CNN Gabor-Type Filters", *Proceeding of Seventh IEEE International Workshop on Cellular Neural Networks and their Applications*, pp.22-24, July 2002.
[7] CANDY CNN Simulator. "http://lab.analogic.sztaki.hu/Candy/candy.html"
[8] Qun Gao, Philipp Forster, Karl R. Mobus and George S. Moschytz, "Fingerprint Recognition Using CNNs: Fingerprint Preprocessing", *Proceeding of the IEEE International Symposium on Circuist and Systems,* ISCAS*,* vol. 3. pp. 433-436, May 2001.
[9] Te-Jen Su, Yan-Yi Du, Ying-Jen Cheng, Yi-Hui Su, "A Fingerprint Recognition System Using Cellular Neural Networks", *Proceeding of 9th IEEE International Workshop on Cellular Neural Networks and their Applications.* P. 170-173, 2005.
[10] Qun Gao, George S. Moschuytz, "Fingerprint Feature Matching Using CNN", *Proceeding of the IEEE International Symposium on Circuits and Systems,* ISCAS*,* vol. 3, p. 73-76, 2004.