**Appendix B**

**Fingerprint Recognition Algorithms for Partial and Full Fingerprints (Published in Proc. of IEEE HST 2008)**

S. Mil’shtein, A. Pillai, A. Shendye, C. Liessner and M. Baier

Advanced Electronic Technology Center

ECE Dept., UMass Lowell, MA 01854,

[sam\_milshtein@uml.edu](mailto:sam_milshtein@uml.edu), (978)934-3310

**Abstract—**An urgent need for accurate biometric recognition systems exists amongst law enforcement and other governmental agencies at the local, state, and federal levels, as well as within the private sector. Minutiae based algorithms are widely used today for fingerprint authentication. The uniqueness of a fingerprint can be determined by the pattern of the ridges and the valleys a fingerprint is comprised of. However, minutiae algorithm has some serious drawbacks. If the core is missing from the fingerprint, then the comparison cannot be done. Also multiple impressions of the same fingerprint could have only a small region of overlap. In this study we propose two new algorithms. The first algorithm, called the Spaced Frequency Transformation, is based on taking the Fast Fourier Transform of the images. The second algorithm called Line Scan algorithm is an algorithm that we developed to reduce the time taken for comparison in case of the Spaced Frequency Transformation algorithm. Combining the line scan technique with the line scan algorithm, we have a very efficient scanning as well as matching technique*.*

**Introduction**

Fingerprints offer a unique method for personal identification. Fingerprints afford an infallible means of personal identification, because the ridge arrangement on every finger of every human being is unique and does not alter with growth or age. Fingerprint authentication is the most preferred method because of their distinctiveness and persistence over time [1]. The individuality of fingerprints has been discussed in detail in [2]. It has served almost all the governments worldwide over many years to provide accurate identification of criminals. No two fingerprints have been found to be the same in the billions of comparisons that have been done to date unless they belong to the same person. It outperforms DNA and other human identification systems to identify more number of criminals. The minutiae algorithm is widely used for fingerprint authentication. Minutiae points are local ridge characteristics that appear as either a ridge ending or a ridge bifurcation .

A complete fingerprint consists of about 100 minutiae points in average. The measured fingerprint-area consists in average of about 30-60 minutiae points depending on the finger and on the sensor area. These minutiae points are represented by a cloud of dots in a coordinate system. They are stored together with the angle of the tangent of a local minutiae point in a fingerprint-code or directly in a reference template. A template can consist of more than one fingerprint-code to expand the amount of information and to expand the enrolled fingerprint area. In general this leads to a higher template quality and therefore to a higher similarity value of the template and the sample. To overcome the drawbacks of minutiae, hybrid methods have been proposed [3]. In this paper, we report about the development of two new fingerprint recognition algorithms a) Spaced Frequency Transformation algorithm and b) Line Scan algorithm. Both these algorithms have been tested on fingerprints obtained from [4].

**Fingerprint Classification**

It was English scientist Sir Francis Galton, who suggested the first elementary system for classifying fingerprints based on grouping the patterns into arches, loops, and whorls. Fingerprints are classified in a three-way process: by the shapes and contours of individual patterns, by noting the finger positions of the pattern types, and by relative size, determined by counting the ridges in loops and by tracing the ridges in whorls. The information obtained in this way is incorporated in a concise formula, which is known as the individual's fingerprint classification.

There are several variants of the Henry system, but that used by the Federal Bureau of Investigation (FBI) in the United States recognizes eight different types of patterns: radial loop, ulnar loop, double loop, central pocket loop, plain arch, tented arch, plain whorl, and accidental. Whorls are usually circular or spiral in shape. Arches have a moundlike contour, while tented arches have a spikelike or steeplelike appearance in the center. Loops have concentric hairpin or staple-shaped ridges and are described as "radial" or "ulnar" to denote their slopes; ulnar loops slope toward the little finger side of the hand, radial loops toward the thumb. Loops constitute about 65 percent of the total fingerprint patterns; whorls make up about 30 percent, and arches and tented arches together account for the other 5 percent. The most common pattern is the ulnar loop. We use the system of classification mentioned in [5] before proceeding to use our algorithms for fingerprints comparison.

**Spaced Frequency Transformation algorithm—**

The Spaced Frequency Transformation algorithm uses the 2D Fast Fourier Transform (FFT) to compare fingerprints. The Fourier Transform is an important image processing tool which is used to decompose an image into its sine and cosine components. The output of the transformation represents the image in the Fourier or frequency domain, while the input image is the spatial domain equivalent. In the Fourier domain image, each point represents a particular frequency contained in the spatial domain image.

**Figure – 1** Fourier Transforms of two different fingerprints

The motivation for this algorithm has come from the fact that the patterns of the ridges for two different fingers are different. As a result, the FFT for these two fingers should also be different. This point is very well proved in Figure 1. This algorithm was tested on a database of 750 fingerprints. It has accuracy rate of about 99% for full fingerprints. In the comparison of small fingerprint portions taken from the flat part of the finger with full fingerprints, the rate of success was 85%. Such partial-print to partial-print comparisons had a success rate of 77%.

**Line Scan algorithm—**

The line scan algorithm is an algorithm that we developed to reduce the time taken for comparison in case of the Spaced Frequency Transformation algorithm. The algorithm is divided into the following modules:-

1) In the first module, the images are read into a subroutine that crops out the unwanted information present in the image. The unwanted information consists of a black portion on both the sides of the actual fingerprint image.



**Figure – 2** The black portion to the right side of the image is unwanted portion



**Figure – 3** Cropped image containing only the region of interest

2) The second module calculates the boundaries of the image and resizes the images such that they all become of equal dimensions.

3) The third one draws the average intensity curves corresponding to the rows for all the images. These curves are very similar for same fingerprints and are much different for dissimilar fingerprints. The curves are smoothened. The similarity between the curves is estimated in the frequency domain by taking a Fourier transform and then compared using a certain threshold value to see if the prints are similar or not. These steps have been summarized in the flowchart in Figure 5:



**Figure – 4** Flowchart for the Line Scan Algorithm

The motivation for this algorithm has come from [6]. The advantages of this algorithm is that it is much more faster than the Fourier transform algorithm, even if you have cluster of lines from a fingerprint you can match it to your database and come to a decision. When we tested this algorithm on a database of about 150 partial fingerprints we had an accuracy rate of 95% and in case of full fingerprints we had an accuracy rate of close to 99%.

We continue to test this algorithm for a wider database containing close to 1000 fingerprints. Combining the line scan technique with the line scan algorithm, we have a very efficient scanning as well as matching technique. The test statistics mentioned in both of the above algorithms are independent of the testing procedures mentioned in [7]. Further we do not need to introduce any distortion into the fingerprint database before matching as mentioned in [8].

**Conclusions**

The two algorithms reported in this paper are very powerful algorithms that can be used for both the full fingerprints as well as partial fingerprints. The most notable advantages of these algorithms in specific the Line Scan algorithm is the high accuracy in case of partial fingerprints. Current research is focused on testing these algorithms on a much wider database as well as developing a new way for classification of fingerprints which will be much more easier and efficient to use along with these algorithms.

**References**

[1] Maltoni, D., Maio D., Jain A.K., Prabhakar S., *Handbook of Fingerprint Recognition* Springer-Verlag, New York, 2003

[2] S. Pankanti, S. Prabhakar, A.K. Jain, “On the individuality of fingerprints” *Proceedings of the 2001 IEEE Computer Society Conference on Computer Vision and Pattern Recognition. CVPR 2001 Volume 1, 2001 pp I-805-I-812* ***vol.1****.*

[3] Anil Jain, Arun Ross, Salil Prabhakar, *Fingerprint Matching using Minutiae and Texture Features*.

[4] Palma J, Liessner C, Mil’shtein S, “Contactless Optical Scanning of Fingerprints with 180° View” *Scanning, 28,* ***6****, pp 301-304, 2006*

[5] Anil Jain, Sharath Pankati, *Fingerprint Classification and Matching*

[6] Mil’shtein et al, “Method of correlation of images in biometric applications”,

*US 6,961,449 B2*

[7] Raffaele Cappelli, Dario Maio, Davide Maltoni, James L. Wayman, Anil K. Jain, “Performance Evaluation of Fingerprint Verification Systems”, *IEEE Transactions on Pattern Analysis and Machine Intelligence, 28,* ***1****, pp 3-18, 2006*

[8] Arun Ross, Sarat C. Dass, Anil K. Jain, “Fingerprint Warping Using Ridge Curve Correspondences”, *IEEE Transactions on Pattern Analysis and Machine Intelligence, 28,* ***1,*** *pp 19-30 , 2006*