Image Acquisition & Enhancement of Fingerprint Images

Kalyani Mali #1, Samayita Bhattacharya#2

#1 Department of Computer Science & Engineering, University of Kalyani, Kalyani, India
#2 Department of Computer Science & Engineering, University of Kalyani, Kalyani, India

ABSTRACT

Biometrics is one of the biggest tendencies in human identification. The fingerprint is the most widely used biometric. Fingerprint identification is one of most popular and accurate Biometric technologies. Nowadays, it is used in many real life applications. However, poor quality image of fingerprints in is still a very complex problem, though in recent years, many algorithms and models are given to improve the accuracy of fingerprint system. As the image acquisition is the first phase for a fingerprint system, the accuracy is very much desired in this step. And enhancement of an image helps in better processing of that image.

Key words: Fingerprint, Fingerprint recognition, Image Acquisition, Image Enhancement.

Corresponding Author: Samayita Bhattacharya

INTRODUCTION

Nowadays, fingerprint recognition is one of the most important biometric technologies based on fingerprint distinctiveness, persistence and ease of acquisition. Although there are many real applications using this technology, its problems are still not fully solved, especially in poor quality fingerprint images and when low-cost acquisition devices with a small area are adopted. One of the most popular biometric traits, fingerprints are widely used in personal authentication, particularly with the availability of a variety of fingerprint acquisition devices and the advent of thousands of advanced fingerprint recognition algorithms. Such algorithms make use of distinctive fingerprint features that can usually be classified at three levels of detail [10], as shown in Fig. 5 and referred to as level 1, level 2, and level 3. Level-1 features are the macro details of fingerprints, such as singular points and global ridge patterns, e.g., deltas and cores (indicated by red triangles in Fig. 2). They are not very distinctive and are thus mainly used for fingerprint classification rather than recognition. The level-2 features (red rectangles) primarily refer to the Galton features or minutiae, namely, ridge endings and bifurcations. Level-2 features are the most distinctive and stable features, which are used in almost all automated fingerprint recognition systems (AFRSs) [5], [10], [11] and can reliably be extracted from low-resolution fingerprint images (~500 dpi). A resolution of 500 dpi is also the standard fingerprint resolution of the Federal Bureau of Investigation for AFRSs using minutiae [12]. Level-3 features (red circles) are often defined as the dimensional attributes of the ridges and include sweat pores, ridge contours, and ridge edge features, all of which provide quantitative data supporting more accurate and robust fingerprint recognition. Among these features, pores have most extensively been studied and are considered to be reliably available only at a resolution higher than 500 dpi.

FINGERPRINT

Among all the biometric techniques, fingerprint-based identification is the oldest method which has been successfully used in numerous applications. Everyone is known to have unique, immutable fingerprints. A fingerprint is made of a series of ridges and furrows on the surface of the finger. The uniqueness of a fingerprint can be determined by the pattern of ridges and furrows as well as the minutiae points. Minutiae points are local ridge characteristics that occur at either a ridge bifurcation or a ridge ending.

Fig. 1 shows a sample fingerprint.

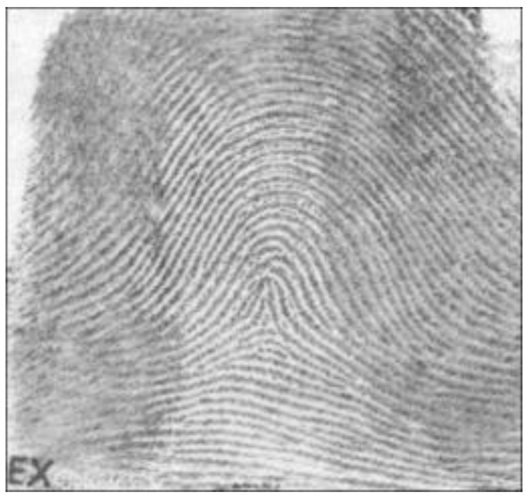

Figure 1: A Sample Fingerprint

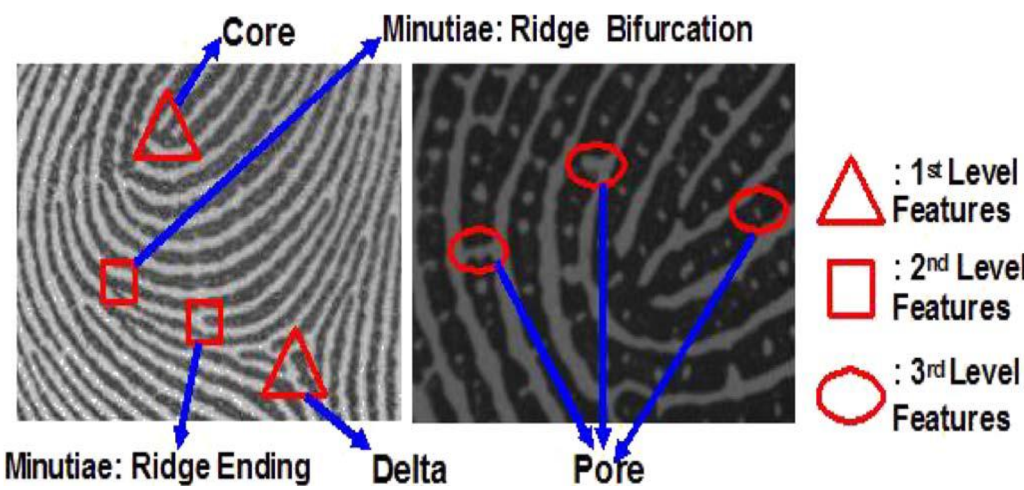

Figure 2: Three levels of fingerprint features

FINGERPRINT RECOGNITION

Large volumes of fingerprints are collected and stored everyday in a wide range of applications including forensics, access control, and driver license registration. An automatic recognition of people based on fingerprints requires that the input fingerprint be matched with a large number of fingerprints in a database (FBI database contains approximately 70 million fingerprints!). To reduce the search time and computational complexity, it is desirable to classify these fingerprints in an accurate and consistent manner so that the input fingerprint is required to be matched only with a subset of the fingerprints in the database.

Fingerprint classification is a technique to assign a fingerprint into one of the several pre-specified types already established in the literature which can provide an indexing mechanism. Fingerprint classification can be viewed as a coarse level matching of the fingerprints. An input fingerprint is first matched at a coarse level to one of the pre-specified types and then, at a finer level, it is compared to the subset of the database containing that type of fingerprints only.

Fingerprints are classified into classes, namely, *whorl, right loop, left loop, arch.*

*F*ig. 3 shows different fingerprint types.

(a) (b) (c) (d)

Fig 2: Fingerprint types: (a) Arch, (b) Left Loop, (c) Right Loop, (d) Whorl

A critical step in automatic fingerprint matching is to automatically and reliably extract minutiae from the input fingerprint images. However, the performance of a minutiae extraction algorithm relies heavily on the quality of the input fingerprint images. In order to ensure that the performance of an automatic fingerprint identification/verification system will be robust with respect to the quality of the fingerprint images, it is essential to incorporate a fingerprint enhancement algorithm in the minutiae extraction module.

Most approaches to recognizing a fingerprint involve five basic stages:

(i) acquisition, where the image is obtained from hardware or a file;

(ii) pre-processing, which may include thinning, noise reduction, image enhancements and error correction;

(iii) structural extraction, where global and local structures may be found;

(iv) post-processing, where the structures are converted into a more useful format;

(v) and then matching, where fingerprints are compared against a database.

These stages are shown in Figure 4 (here the figure depicts a minutia based fingerprint recognition system).

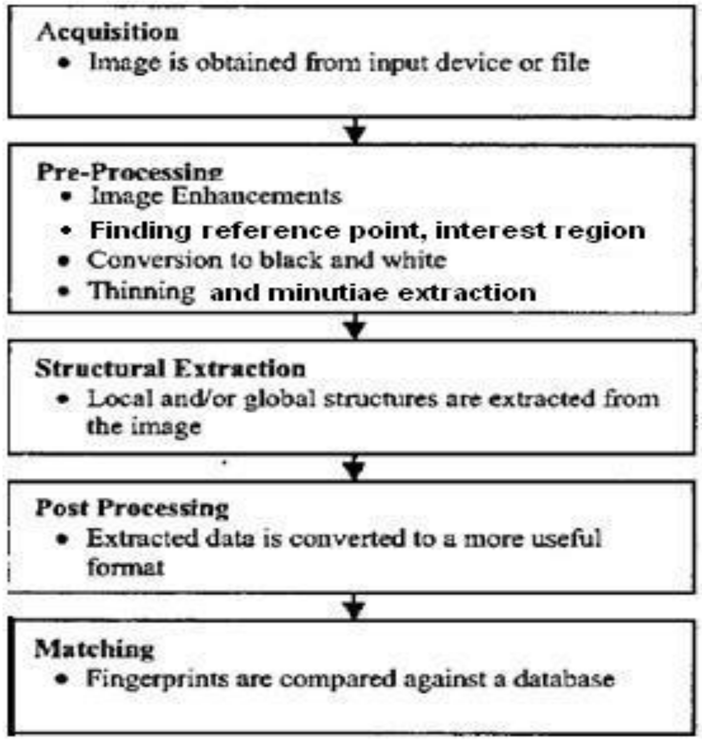

Figure 4: Stages of the fingerprint recognition process

FINGERPRINT ACQUISITION

The first stage of any vision system is the image acquisition stage. *Image acquisition* is hardware dependent. A number of methods are used to acquire fingerprints. Among them, the inked impression method remains the most popular one. Inkless fingerprint scanners are also present eliminating the intermediate digitization process.

The basic two-dimensional image is a monochrome (greyscale) image which has been *digitized*. Describe image as a two-dimensional light intensity function $f(x,y)$ where x and y are spatial coordinates and the value of f at any point (x, y) is proportional to the brightness or grey value of the image at that point.

A digitized image is one where

- spatial and greyscale values have been made discrete
- intensity measured across a regularly spaced grid in x and y directions
- intensities sampled to 8 bits (256 values)

The method chosen for acquisition of a fingerprint image depends on many different factors, including the cost and reliability of an input device.

The performance of a fingerprint recognition system basically depends upon the quality of the input image. Since the images acquired with different kinds of sensors are not of the perfect quality and so they can't be used directly for the matching. Therefore to ensure the accurate working of the system the image is first enhanced.

The first stage of any vision system is the image acquisition stage. Image acquisition is hardware dependent. A number of methods are used to acquire fingerprints. Among them, the inked impression method remains the most popular one. Inkless fingerprint scanners are also present eliminating the intermediate digitization process [3].

A multi-resolution fingerprint acquisition device (or sensor) must be cost-effective but should particularly be able to acquire fingerprint images at multiple resolutions without any negative impact on the quality of the image [5]. There are generally three kinds of fingerprint sensors: solid state, ultrasound, and optical [5], [6]. Solid-state sensors are small and inexpensive but cannot capture high-resolution images [7]. Ultrasound sensors can capture high-resolution images but are usually bulky and expensive [8]. Optical sensors can capture a variety of different image resolutions, varying in a range of sizes and prices. They are easy to implement and have been found to have a high degree of stability and reliability [9]. Most of the systems are thus equipped with an optical fingerprint sensor.
While there are also several different ways to implement optical fingerprint sensors, the oldest and most widely used way [5] to implement the sensor is frustrated total internal reflection (FTIR). As shown in Fig. 5, an FTIR-based fingerprint sensor consists of a light source, a glass prism, a lens, and a charge-coupled device (CCD) or complementary metal–oxide–semiconductor camera. When users put their fingers on the surface of the glass prism, ridges absorb light, and so, they appear dark, whereas valleys and the fine details on ridges reflect light and thus appear bright. Different resolutions can be obtained by simply adjusting the distance between the glass prism and the lens and the distance between the lens and the camera.

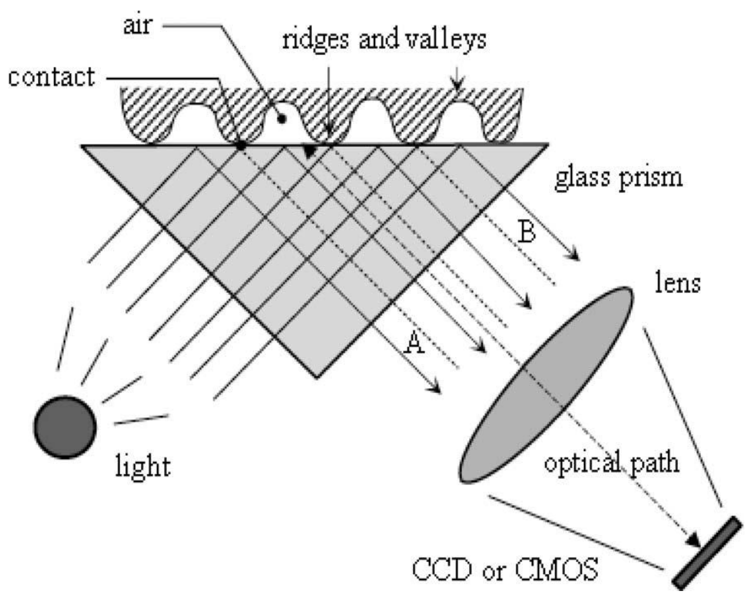

Figure 5: Operation of an FTIR-based fingerprint sensor

FINGERPRINT IMAGE ENHANCEMENT

Three types of degradations affect the quality of the fingerprint image. The ridges get some gaps; parallel ridges connected due to noise and natural effect to the finger like cuts, wrinkles and injuries. The Fingerprint enhancement is anticipated to improve the contrast between ridges and valleys and reduce noises in the fingerprint images.

Noise Reduction

Noise is an unwanted perturbation to a wanted signal. Image noise is generally regarded as an undesirable by-product of image capture. Noise reduction is the process of removing noise from a picture (here it is the fingerprint image).

We have checked and used different types of filtering methods like median filter, global and adaptive thresholding to reduce the noise [2].

Image Normalization

The objective of this stage is to decrease the dynamic range of the gray scale between ridges and valleys of the image in order to facilitate the processing of the following stages.

The processing of fingerprint normalization can reduce the variance in gray-level values along ridges and valleys by means of adjust the gray-level values to the predefined constant mean and variance. And normalization can remove the influences of sensor noise and gray-level deformation.

Let I(i,j) denote the gray-level value of pixel (i,j) in acquired image, the size of fingerprint image is m x n , M and V are the estimated mean and variance of input fingerprint image, respectively, N(i, j) denote the normalized gray-level value at pixel (i, j). The normalized image is defined as follows:

$$N(i,j)=\begin{cases} M_0+\sqrt{\left(\frac{V_0}{V}\right)(I(i,j)-M)(I(i,j)-M)}, & if\ I(i,j)>M \\ M_0-\sqrt{\left(\frac{V_0}{V}\right)(I(i,j)-M)(I(i,j)-M)}, & otherwise \end{cases} \quad (1)$$

where M_0, and V_0 are the expected mean and variance values, respectively. Normalization is a pixel-wise operation and does not change the ridge and valley structures.

CONCLUSION

The reliability of any automatic fingerprint recognition system strongly relies on the precision obtained in the extraction process. Extraction of appropriate features is one of the most important tasks for a recognition system.

Most of the fingerprint recognition systems rely on minutiae matching algorithms. Although minutiae based techniques are widely used because of their temporal performances, they do not perform so well on low quality images and in the case of partial fingerprint they might not be used at all. Therefore, when comparing partial input fingerprints to pre-stored templates, a different approach is needed. Soft computing can help to achieve better result for these types of case.

Different soft computing tools can be applied in different phases of pre-processing.

REFERENCE

[1] H. C. Lee and R. E. Gaensslen, Eds., *Advances in Fingerprint Technology*. New York: Elsevier, 1991.

[2] Rafeal C. Gonzalez, Richard E. Woods, “Digital Image Processing,” Pearson Education Asia, 2002.

[3] Image Digitization Process by Dorothy VanDeCarr.

[4] G.A. Drets and H.G. LiljenstroÈm, ªFingerprint Subclassification: A Neural Network Approach,º Intelligent Biometric Techniques in Fingerprint and Face Recognition, L.C. Jain, U.

Halici, I. Hayashi, S.B. Lee, and S. Tsutsui, eds., pp. 109-134, Boca Raton, Fla.: CRC Press, 1999.

[5] D. Maltoni, D. Maio, A. Jain, and S. Prabhakar, *Handbook of Fingerprint Recognition*. New York: Springer-Verlag, 2009.

[6] A. Ross and A. Jain, “Biometric sensor interoperability: A case study in fingerprints,” in *Proc. Int. ECCV Workshop Biometric Authentication*, vol. 3087, *LNCS*, 2004, pp. 134–145.

[7] J. S. Han, Z. Y. Tan, K. Sato, and M. Shikida, “Thermal characterization of micro heater arrays on a polyimide film substrate for fingerprint sensing applications,” *J. Micromech. Microeng.*, vol. 15, no. 2, pp. 282–289, Feb. 2005.

[8] W. Bicz, D. Banasiak, P. Bruciak, S. Gumienny, Z. Gumulinski,D. Kosz, A. Keysiak, W. Kuczynski, M. Pluta, and G. Rabiej, Fingerprint Structure Imaging Based on an Ultrasound Camera. [Online].
Available: http://www.optel.com.pl/article/english/article.htm

[9] X. Xia and L. O’Gorman, “Innovation in fingerprint capture devices,” *Pattern Recognit.*, vol. 36, no. 2, pp. 361–369, Feb. 2003.

[10] D. R. Ashbaugh, *Quantitative-Qualitative Friction Ridge Analysis: An Introduction to Basic and Advanced Ridgeology*. Boca Raton, FL: CRC Press, 1999.

[11] N. Ratha and R. Bolle, *Automatic Fingerprint Recognition Systems*. New York: Springer-Verlag, 2004.

[12] A. Jain, Y. Chen, and M. Demirkus, “Pores and ridges: High-resolution fingerprint Matching using level-3 features,” *IEEE Trans. Pattern Anal.Mach. Intell.*, vol. 29, no. 1, pp. 15–27, Jan. 2007.