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Review of Touch-Less Fingerprint Recognition Technologies

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Abstract: ***Fingerprint recognition has aided variety of biometric security applications over past few decades. Each person possesses unique fingerprint characteristic in terms of minutia, pore, ridges and patterns. Based on data acquisition methods fingerprint recognition can be touch based or touch less, with later having advantage in terms of better hygiene, safety and stray fingerprints. In Touch-less fingerprint recognition, fingerprints are acquired using a high resolution digital camera or any other optical acquisition system. Such systems find applications in numerous fields such as secure access to laptops, computer systems, cellular phones, banking, ATMs etc. Deceiving the simple appearance various taxing, such as non-uniform light, movement blurriness, defocus and low contrast between ridges and valley etc. To overcome such problems, it is important to focus more on the pre-processing steps. Touch-less fingerprint detection can be classified as two-dimensional and three-dimensional methods depending upon number of cameras used for acquisition of finger-print image. Literature presents different techniques for acquisition and analysis of finger-print images. In this paper, an effort is being made to review some of these techniques and give a brief comparison for the same in terms of accuracy, merits, demerits and their respective solution.***

Keywords: Touch-less fingerprint, Fingerprint features, two-dimensional, three-dimensional**.**

1. Introduction

Biometrics is one of fastest growing area of research which is based on individual identification. It is one of the most significant and difficult task to meet rising demand for strict security. Fingerprint based recognition systems are one of the oldest and most consistent biometric paradigm used for personal detection among all the biometrics recognition systems [1][2][3]. A fingerprint is nothing but the pattern of ridges and valleys on the shell of a fingertip, and the structure of which is determined in the first seven months of fetal growth [4]. The basic fingerprint patterns are the arch, the whorl and the loop [5]. An arch pattern means in which ridge enters one side of the finger and then rises in the middle forming an arch with exits on the other side of finger. The ridges form circularly around central point is whorl pattern. The most regular pattern in fingerprints is loop pattern. In this pattern, Ridges with a loop enter one side of the finger forms a curve and exits on the same side of finger from which it entered. Refer the Fig-1 for the examples of each pattern.

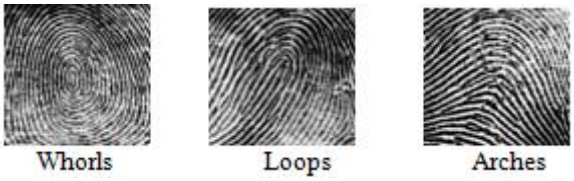

Figure 1: Example of different fingerprint patterns

Current fingerprint recognition system requires that the users touch the device that is sensor for biometric acquisitions. Touch-based systems, though suffers some inherent problems, such as:

- Contamination because of placing fingertip on the same interface which was already used by other person.
- Less durability of the device because of the contact pressure, if the device has been used extensively.
- Different pressure on the fingertips varies the quality of the fingerprint images [3][6][7].

To overcome all these problems, Touch-less fingerprint recognition technology have been recently studied to increase the acceptability, usability, certainty of fingerprint recognition systems [8]. Touch-less recognition system is free from skin distortion, slippage, and fingerprint residue. As compared to touch-based, capture area and tolerance of skin condition, user comfort level is also large in touch-less recognition system.

In touch-less recognition system, acquisition of fingerprint can be based on one or multiple digital cameras, webcams [6][9][10][11]. As compared to touch-based fingerprint system, there are more possibilities of reflections, noise and complex background in touch-less system. To solve all these problems, recent studies have proposed many different software and hardware systems.

1.1 Stages of Touch-Less Fingerprint Recognition

It is found that all the recognition systems in the literature can be classified into following common steps: obtaining a touch equivalent image, acquisition, preprocessing, feature extraction and matching or verification [2][6][7][12].

The general block diagram of such a biometric recognition system is as shown in Fig-2.

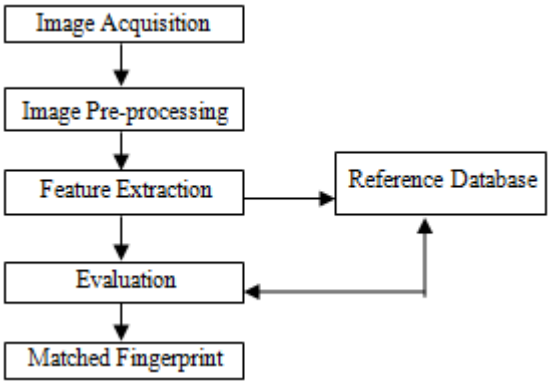

Figure 2: Block diagram of biometric recognition techniques based on touch-less fingerprint.

Acquisition strategy used in recognition system can be divided into different methods depending on two-dimensional and three-dimensional data. Usually two-dimensional acquisition is based on single camera while multiple view setups, variable structured lights can be used in three-dimensional acquisition. After the computation of finger images, enhancement can be done to get ridge pattern. As similar to the algorithms used in touch based technique, feature extraction and matching or verification are usually accomplished.

The various features that can be extracted from fingerprints are as shown in Fig-3[13].These features can be divided into three levels. First level features are the global structure of fingerprint which acts as control points, overall ridge pattern flow. Fingerprint images should be captured at resolution of at least 300 PPI (Pixels Per Inch) to capture the singular points and to find out the ridge pattern type [14]. Second level features which are most frequently used in literature called as minutiae features [1]. To extract these features, fingerprint images must be captured at resolution of at least 500PPI [14]. In third level features, all dimensional attributes of a ridge, like ridge path divergence, width, edge contour, shape, pores, creases, breaks and other stable information. A very high resolution is used, that is more than 1000PPI to capture the fingerprint images for extraction of third level features [14].

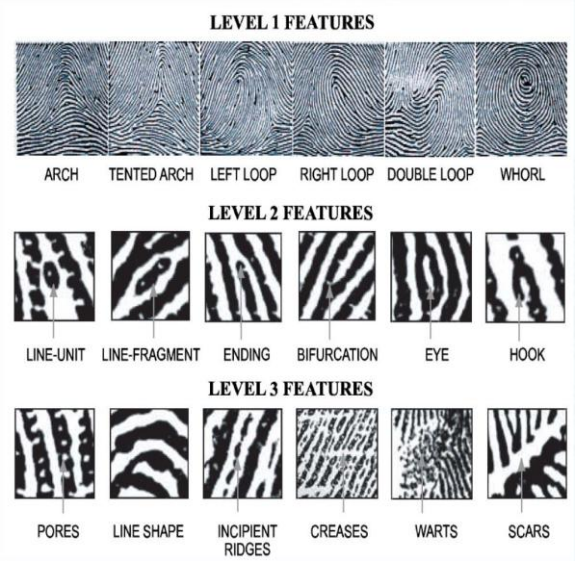

Figure 3: Various features of fingerprints [13].

The paper is prearranged as follows: Section-2 analyzes the literature of acquisition, feature extraction and matching of two-dimensional techniques; Section-3 presents review on Three-dimensional techniques. Lastly, summarization of work is in Section-4.

2. Two-Dimensional Techniques

There are many techniques in the literature based on uninhibited acquisition and inhibited acquisition setups. Uninhibited acquisition setups include mobile devices, laptops etc which requires less accuracy. Inhibited acquisition setups are used in order to get more accuracy e.g. banking services. In both these setups, one or more images are captured by digital camera in touch-less recognition system, and then by using the algorithm used in acquisition setups, touch equivalent fingerprint images can be computed. For other stages like feature extraction and matching, same methods are employed same as in touch-based recognition systems.

The simplest acquisition setup makes the use of single camera in unrestrained light circumstances. A lesson on biometric identification techniques based on images captured using a webcam in natural light environment is performed [9].In this technique the accuracy has been tested by directly comparing the extracted ridges with the ones extracted by using state-of-the-art dedicated sensor on the same persons. In this paper the outcome offered considered a set-up evaluation with a limited number of volunteers. The evaluation is done by using state-of-the art public minutiae extractor [15]. Fig. 4 shows the different fingerprint images captured by touched sensors and digital camera.

Figure 4: Images of fingerprint by (i) capacitive sensor, (ii) optical sensor, (iii) Digital camera

To overcome the problem of low disparity between ridges and valleys, digital camera is used to capture the fingerprint images in RGB system [2][3]. Due to exclusive feature of digital camera like high resolution, auto focusing and zooming, it gives high quality image. B. Y. Hiew et al. presents the touch less fingerprint recognition system based on automatic digital camera. It follows steps: the segmentation of fingerprint, image enhancement and exact core point (point of maximum curvature in the fingerprint image) detection [2][12]. It shows better perfection in the fingerprint segmentation and enhancement. By using this technique, result shows the core point detection accuracy nearly about 95.44% and 4.56% for false core point detection. The results for correct core point detection are not satisfying because of the lighting problem in the images.

Usually there are following types of errors in the matching systems that are false acceptance rate (FAR), ratio of the number of false acceptances and the number of identification attempts and false rejection rate (FRR), the ratio of the number of false rejections and the number of identification attempts [16]. For the purpose of evaluation, false acceptance rate and false rejection rate test are performed [15]. Performance is determined by Equal Error rate(EER) that is false acceptance rate is equal to false rejection rate. Here, by different support vector machine (SVM) classifiers that are Linear SVM, RBF-SVM (Radial Basis Function-SVM), and polynomial SVM accuracy of matching is tested. For the normalized features, matching results of Linear SVM and RBF SVM are well-matched and agreeable as compared to the Polynomial SVM. Even though RBF SVM might perform well here, it is regrettably limited by the working out price and requires the highest time for processing, training and testing.

Images of fingerprint are captured by camera of low resolution and under different lighting conditions were presented by H. Ravi and S. K. Sivanath [6]. In this technique, by using Euclidean distances verification is done. Matching algorithm of fingerprint recognition is based on ridge alignment and accuracy of this technique is almost 93.63%. False acceptance rate is originated to be slightly over simply 0.1%. Error can be reduced by using webcam in surrounding with an appropriate enlightenment.

Usually fingerprints recognition systems based on minutiae do not give the satisfactory results whenever applied to low quality fingerprint images. A new methodology based on correlation coefficient is described to improve the accuracy for consistent fingerprint recognition with special concern in partial fingerprint matching [13]. Here in this system, Equal error rate is found to be 2.02% using region size of 40x40 pixels.

3. Three-Dimensional Techniques

In 3-D technique, finger-print images are captured by using multiple camera set-ups. Literature presents many techniques such as multiple camera set-ups, Surround imager, Mirror reflections and unwrapped techniques etc. 3-D technique has some advantages over 2-D techniques which are shown in Table-1[17].

Table 1: Contact based verses Contactless 2D and 3D fingerprint recognition system

	Contact Based 2D Finger-print	Touch-less 2D Finger-print	Touch-less 3D Finger-print
Recognitin Accuracy	High	High	Very High
Skin Deforma-tion	High	Nil	Nil
Sensor surface smudge	High	Very Low	Very Low
Cost of system	Low	High	Very High
Effective area/Size	Compact	Medium/ Large	Large

Various parts of the same finger may be captured every time. A current three-dimensional fingerprint recognition system uses multiple cameras setting, or various structured lighting, or camera with mirror setups. Brief explanation of the system and related algorithms for three-dimensional techniques and recognition are presented by Feng Liu and R. D. Labati [10][11]. Example of schematic diagram of 3D fingerprint image is as shown in Fig.5 [11].

Figure 5: Example of schematic diagram of 3D fingerprint image [11]

Surround imager (3D multicamera touch-less fingerprint device) as shown in fig.6 gives larger effective area. But this technique is relatively expensive as it uses three cameras. Mirror-reflected imaging device uses only one camera. Side views of the finger reflected by mirrors are captured by the central camera used to form multiviews of fingerprint images. This technique is having low cost. But, there are some weaknesses that are high hardware designing, complication, manually segmentation of region of interest and it gives partial useful area in side view images reflected by mirrors.

The cost of the device is depends upon the number of cameras used in a system. Device will be cheaper if we used less number of cameras. Also too many views of images will increases the complication in algorithms. Whereas by using very few cameras, we might get insufficient view of finger and effect in small overlapping region involving frontal and adjacent images. To eliminate this problem, three cameras used in a system to capture different views of fingerprints [10], one middle camera and two side cameras as shown in Figure. 6. By using mosaicking method [10], fingerprint images with better useful area is obtained and by extracting minutiae, equal error rate is about 9.13%. **B**y adding non-minutiae information like finger crease feature, shape etc. higher accuracy can be achieved.

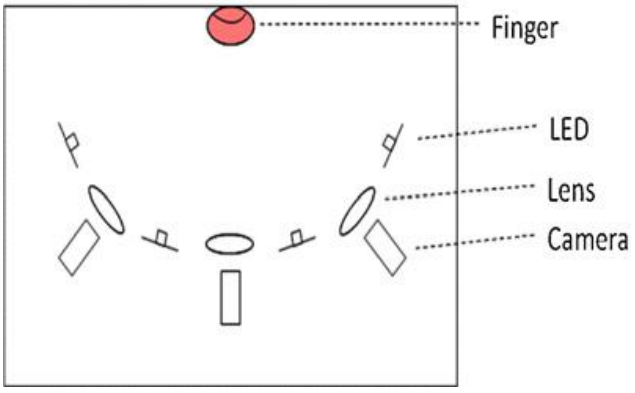

Figure 6: Touch-less multiview fingerprint acquisition device proposed by Feng Liu [10].

The method of quality evaluation of unwrapped image (3D models are converted in bidimensional images) presented by Ruggero Donida Labati et al.[11]. Specific set of features are

proposed for quality evaluation of particular images. Here, in this technique, three dimensional surface estimation and wrapping is done for acquired images. Later than a segmentation of the unwrapped fingerprint image is done, and different sets of features are extracted. These are correlated to the shape of the region of interest (ROI), the number and quality of the minutiae, and the local characteristics of the ridge pattern. The quality estimation is then performed by using neural classifiers. Equal error rate is obtained by this technique is 1.97%

4. Conclusion

Touch-less fingerprint recognition systems gives significant advantages with respect to long-established touch based recognition systems in terms of usability, superiority of acquire images, and healthiness to environmental surroundings. Touch-less recognition systems can be used in highly secure area, to access personal devices like laptops, computers, and mobile phones as well as in banking security safely.

One or multiple cameras are used for the image acquisition. In touch-less, feature extraction and verification is done by using same algorithms which are used in touch based systems. Two dimensional techniques uses single camera while three dimensional techniques uses multiple cameras and different light setups. Normally, as compared to three-dimensional, two-dimensional technique are less expensive, but suffers to insight deformations and non-uniform resolution of the samples.

There are possibilities to improve correctness and effectiveness by improving the biometric which is used for capturing the fingerprint images. Besides this, exactness of matching and execution period can also be improved.

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