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Biometric methods to speed up fingerprint processing using OCT: A survey

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ABSTRACT

Fingerprint recognition is a crucial security technique with a steady growing usage for the identification and verification of people. However, current fingerprint acquisition systems have bound disadvantages that embody the necessities of physical contact with the acquisition device, and also the presence of undesirable artefacts, like scars on the surface of the fingerprint. There are various sectors or domains where Biometric authentication plays a vital role, these areas include Internet of Things (IoT), Smartphones, Healthcare, and many more. This paper evaluates the accuracy of a whole framework for the capturing of uninjured, undistorted fingerprints from underneath the skin's surface using Optical Coherence Tomography (OCT), the extraction and conversion of the submersed knowledge into a usable fingerprint and also the matching of such fingerprints. The main objective of this paper is to provide the study of the biometric algorithms, OCT-based methods and their relative comparisons.

Keywords— *Fingerprint recognition, Internet of Things, Optical Coherence Tomography*

1. INTRODUCTION

Nowadays fingerprint recognition is widely used in Biometric Identification. The fingerprint will always remain unique and permanent throughout human's life. Fingerprint identification is mainly used in forensic science and aids criminal investigations etc. Fingerprint recognition systems are based on the local ridge features known as minutiae. The study related to fingerprinting is known as "Dactyloscopy".

Mostly fingerprint images will undergo degradation and corruption due to factors like skin variations and impression conditions such as scars, dirt, and humidity. This paper elaborates how OCT (Optical Coherence Tomography) is used for Image Acquisition and further Image Enhancement and Matching is done. OCT gathers 3D data and also image sweat pores, which provide an additional means for identification. Finally, Fingerprint Identification is done by matching the captured fingerprint with stored fingerprint templates of every user in the database.

2. DISCUSSION

2.1 Fingerprint on the Internet of Things (IoT)

A fingerprint is consists of a distinct pattern of ridges and valleys on a finger surface of each an individual. A ridge is defined as a single curved segment whereas a valley is an area between two adjacent ridges. Dark areas are said to be ridges and white areas which exists between them is called as valleys. Identical twins can share the same DNA but they can't have the same fingerprints. Fingerprints will be made of an arrangement of ridges, called friction ridges. Each ridge contains pores, which are joined to sweat glands under the skin. Humans leave fingerprints on glasses, tables or anything else because of this sweat. The IoT (Internet of Things) refers to a network of physical objects that are associated with an IP address for the Internet or Intranet connectivity and the communication that occurs between these objects and other IP-enabled devices and systems. The existing IoT devices have too much variation in protocols or functionality and it is difficult to come out with one general approach for fingerprint processing.

2.2 Normal Image Acquisition

An optical scanner works by directing a bright light over an individual's fingerprint. The scanner uses a light-sensitive microchip which might be either a CCD (Charge-Coupled Device) or a CMOS (Complementary Metal-Oxide Semiconductor) image sensor to produce a digital image. Finally, the computer analyzes the image automatically by selecting just a fingerprint and then uses sophisticated pattern-matching tool to turn it into a code.

There is another type of scanner known as a Capacitive scanner which measures a finger electrically. When a finger rests on a subsurface, the ridges in a fingerprint touches the surface while the valleys between the ridges stand slightly clear of it. Capacitive scanner builds up a picture of a fingerprint by measuring these distances between ridges and valleys. These

scanners are mostly used in iPhones, iPads and many more devices.

2.3 Acquisition Process using OCT

Generally, it is problematic to obtain high-quality fingerprint images in the cases of dry, wet, or scarred fingers, or when dust is present on the sensor. Image of user's fingerprint is captured by the fingerprint scanner. This captured image is also called a live scan. This live scan is processed digitally to create a biometric template which is a collection of certain extracted features that is stored and used for matching. OCT machine produces 3D volume data per fingerprint which is used to produce corresponding 2D images.

The 3-D lifted scan is processed on basis of cross-sectional image. Firstly the cross-sectional image is filtered to reduce the effects of speckle noise, then one dimensional Sobel edge detection is applied horizontally. The 3D to 2D conversion produces two 2D images one is original 2D image and other is its complement.

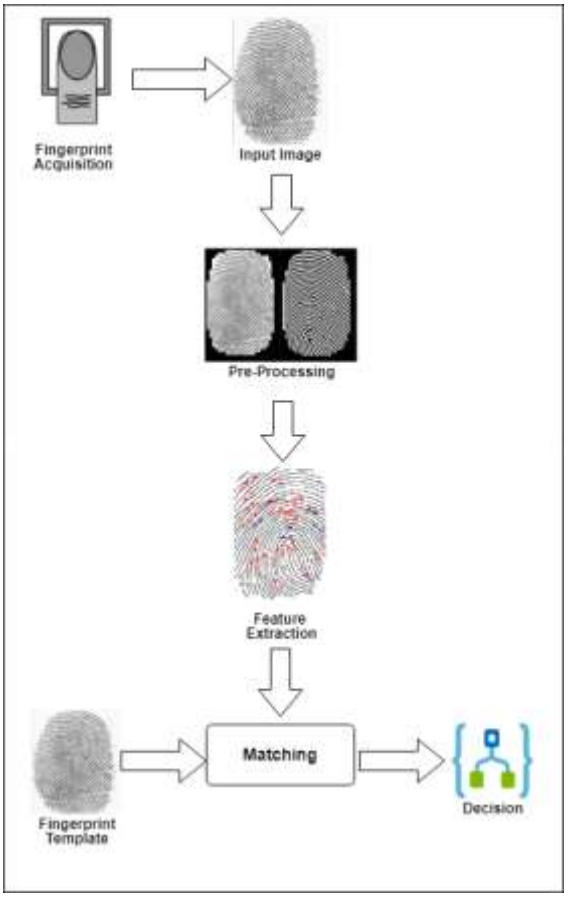

Fig. 1: Fingerprint Image Processing Workflow

2.4 Feature extraction methods

In feature extraction methods we consider a registration step to provide translation in variance. As per studies, the following are feature extraction methods:

(a) Correlation-based Technique: The correlation-based technique is totally about fingerprint verification system which first selects desired styles within the first fingerprint and then makes use of sample matching within the secondary fingerprint, and compares the sample positions of each fingerprint.

(b) Ridge-based Technique: The ridge significance is measured by the function of the length, the contrast and the lifetime of ridge via scales.

(c) Minutiae-based Technique: The main purpose of minutiae extraction is to identify the representative features called minutiae and to extract them from the input fingerprint images.

Table 1: Comparison among various fingerprint extraction techniques

S. No.	Feature extraction techniques	Advantages	Disadvantages
1.	Minutiae-based	1. Target fingerprint and other fingerprints are stored in the database. 2. Sustained for further study of the statistical analysis of fingerprints.	1. The local Ridge structure cannot be completed. 2. User acceptance rate is low. It is time-consuming.
2.	Correlation-based	1. No minutiae can be extracted reliably. 2. Missed or False minutiae does not affect/ decrease the matching performance	1. It requires the precise location of the registration point. 2. It gets affected by image translation and/ or rotation. 3. It is not capable of dealing with more than about to degree rotations.
3.	Ridge-based	Provides outcome with better clarity of the ridge structures while reducing noise.	Provide a natural representation of fingerprint imperfections such as noise and corrupted elements.

2.5 Fingerprint Enhancement

The fingerprint enhancement algorithms considered in this paper are introduced in this section and are as follows:

(a) Gabor Filter: It is a linear filter which is mainly used for edge detection. It might be the most popular fingerprint image enhancement algorithm due to its capability of extracting two important fingerprint features: Orientation Field and Ridge Frequency.

(b) Laplacian Filter: t is a linear high-pass filter used to enhance images' edges. It does the work of Edge Detection to compute the second derivatives of a particular image also measures the rate at which previous derivative changes.

(c) Velterra Filter: It is a nonlinear filter whose input-output relation is a Volterra series and it represents the most natural extension of linear filters.

(d) Wiener Filter: It is an important image processing technique to compensate the Image Distortion in the presence of noise. To apply a Wiener filter to enhance a fingerprint image, the fingerprint image is initially processed/ converted into a grey-scale image.

2.6 Fingerprint Matching

A fingerprint matching is done with the help of match score between two fingerprints, which should be high for fingerprints from the same finger and low for those from different fingers i.e. templates of fingerprint images.

(a) K-Nearest Neighbor (K-NN)Minutiae Clustering: Mainly two considerations lies in this algorithm which

is as follows :

- It uses the graph as a fingerprint data structure.
- Fingerprint search is done by clustering fingerprint graph feature.

(b) Minutiae-based Algorithm: The basic method of minutiae extraction includes Pre-processing, Minutiae Extraction, Post processing.

(c) Threshold Cryptography Technique: In Threshold cryptographic technique, the fingerprint image is divided into two or more shares/ parts using a visual cryptographic technique which is followed by compression. In this one share/ part of the fingerprint is stored in server & remaining shares/ parts are provided to the user.

(d) Fingerprint Matching using Gabor Filter: Gabor filters will optimally capture both frequency information and local orientation from a fingerprint image.

Table 2: Comparison of various fingerprint pattern matching techniques

S. No.	Pattern Matching Techniques	Objective	Limitations
1.	Threshold Cryptography Technique	To develop a technique by partitioning it into small parts.	It requires compression for the reorganization of a fingerprint image.
2.	Minutiae-based Algorithm	To design an algorithm with the purpose of privacy and security.	It is not suitable for low-quality templates.
3.	K-NN Minutiae Clustering	To recognize the fingerprint it reads. Each fingerprint is clustered in graph templates from a database.	It increases overall processing time.
4.	Gabor Filter for Fingerprint Matching	To increase the acceptance rate.	It needs a number of Gabor Filters.

2.7 Comparative Analysis of the Fingerprint Processing Algorithms

As per our survey, we have compared some of the efficient Fingerprint processing algorithms for their EER (Equal Error Rate) percentage. The dataset used here is from FVC2000 database, FVC2000 is a collection of fingerprint databases made available in Fingerprint Verification Competition. It consists of four databases DB1, DB2, DB3, and DB4 which are collected using different sensors/ technologies namely Low-cost Optical Sensor "Secure Desktop Scanner" by KeyTronic, Low-cost Capacitive Sensor "TouchChip" by ST Microelectronics, Optical Sensor "DF-90" by Identicator Technology and Synthetic Fingerprint Generation. Following is the comparative analysis of some algorithms:

Table 3: Comparative Analysis among fingerprint processing algorithms (Computation Time in Seconds)

Database	Bozorth	Jiang	Deng	MCC
FVC2000 (DB 1)	7.481	12.945	7.633	8.207
FVC2000 (DB 2)	8.751	16.451	9.308	8.578
FVC2000 (DB 3)	18.750	24.954	14.814	20.216
FVC2000 (DB 4)	5.817	8.166	17.006	6.026

3. RELATED WORK

There are various researches which have been studied and implemented over Fingerprint Processing for Biometric Level Security, especially in the Internet of Things (IoT) and Data Science domain. Some of the studies and implementations are described further in this section.

Shuang Sun[1] and Zhenhua Guo[1] has implemented a sweat gland extraction method which detects each gland's position using Frangi's filter and segments them by thresholding method. Authors also show that by combining sweat glands information with fingerprint valleys and ridges can improve the performance of fingerprint identification.

Jaehong Aum[2] and other authors[2] has introduced a novel spectral-domain OCT-based 3-D fingerprint scanner that is capable of obtaining an internal fingerprint image within 2 seconds. In this paper, the robustness of the OCT fingerprint scanner was established by comparing fingerprint images of wet, stained, and damaged fingertips that were obtained by the OCT system with those from a commercially available optical fingerprint scanner. Authors have used graphics processing unit for massively parallel computation, along with an automated method for extracting the internal fingerprint from a 3-D scan of a fingertip.

Sisanda Makinana[3], Portia N. Khanyile[3] and Rethabile Khutlang[3] have proposed an algorithm that enhances the OCT latent fingerprint image to ensure reliable extraction of features. Authors tests their proposed algorithm latent prints were collected and stored as a database. Two statistical and biometric system measurement namely False Match Rate and Equal Error Rate were used. The results of these two measures give the FMR of 3% and ERR of 1.9% for denoised images which are better than non-denoised images were 8.7%.

Sun Bei[4] and other authors[4] has proposed a model which is based on the relative location of minutiae and core point, in which a core point of the fingerprint is firstly confirmed, and then minutiae around the core point are extracted by an improved FVS algorithm. The topological relationship is built on the extracted minutiae and the core point. Finally, they have adopted Neural Network to verify the proposed feature model which is based on FVC2000, where the comparison results to several similar excellent algorithms show that the proposed model has high computational efficiency and a significant improvement on robustness.

Angelo Genovese[5] and other authors[5] has implemented the first innovative method in the literature which is able to extract Level 3 features, in particular, sweat pores, from fingerprint images captured with a touch-less acquisition using a commercial off the-shelf camera. The authors have used the method of image processing algorithms to extract a set of candidate sweat pores. Then, computational intelligence techniques based on neural networks are used to learn the local features of the real pores and selects only the actual sweat pores from the set of candidate points. The results show the validity of the proposed methodology, with the majority of the pores correctly extracted, indicating that a touch-less fingerprint recognition using Level 3 features is feasible.

4. CONCLUSION

In the era of IoT and Data Science today, there is a growing need of privacy and security in all aspects of every sector or domain, and Biometric security is one of the most popular and effective media to provide privacy and security. There are various

methods and algorithms available today for Biometric Fingerprint Processing, amongst which some of those have been explained in this paper. OCT, on the other hand, is a medium that is capable of capturing 3D images of a finger which can help in further more analysis of fingerprints. In this paper, Fingerprint processing is elaborated with the methods and the algorithms and their comparative analysis. This study can help other researchers and developers to understand and choose the methods for their works.

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