Fingerprint Identification System Using Half Smoothing Filters

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Abstract

Fingerprints have been significantly utilized for enormous security systems for their high-level accuracy. They even have been used effectively in smartphone devices for payment in addition to the security purpose. In this paper we propose a new finger print recognition method based on ridge and valley features in finger print images. These features extracted by rotating Gaussian semi _filters. The novelty of this finger print approach based on the mixing of directional filters and differences of Gaussian filter ideas. We obtain a new ridge/valley detector enabling very precise detection of ridge/valley points. This method conducted on different fingerprints database images, the proposed method achieves recognition accuracy rate of more than 99% for three fingerprint image datasets ATVS, LivDet2009, and LivDet2011

Keywords

Fingerprints, Features Extraction, Ridge And Valley Detection, Gaussian Semi _Filters.

Introduction

Acquisition of fingerprint images has two types which are the offline acquisition and online acquisition. The first one is done by maculation the fingers into ink and pressing them on the paper, after that the fingerprint is scanned as softcopy. The latter is acquire the image from fingerprint sensor directly.

There are different fingerprint sensing technologies available: (Jain, Ross, & Nandakumar, 2011).

Solid-state or silicon sensors: as shown in the fig. 1, it consists of array of pixels, each one of them regards as a standalone sensor. The formed ridge/valley after the user touch the silicon surface by his finger can be converted into electrical signals: capacitive, thermal,

electric field and piezoelectric. It is smaller than optical sensor therefore it is easier to be deployed. However, it is not cost effective.

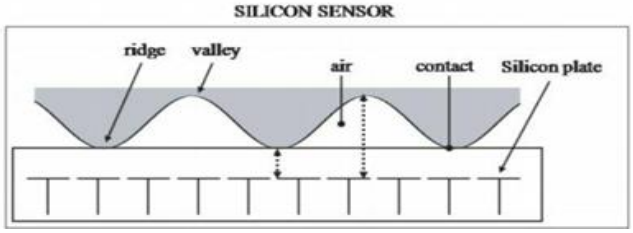


Figure 1 Acquisition principles for the (silicon sensor)

Optical sensor: The finger presses a glass prism then the glass prism is lighted with diffused light. Valleys and absorbed at the ridges make the light reflection. The reflected light is focused onto a CCD or CMOS sensor, as shown below in Fig. 2. It provides decent image quality and large sensing area while facing optical distortion with small sensing areas. The distortion happens because the reduction of the distance between prism and the image sensor.

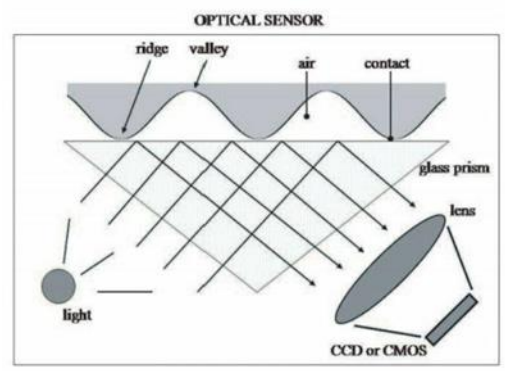


Figure 2 Acquisition principles for the (optical sensor)

- Ultrasound sensor: The fingerprint surface image are captured as echo reflection for the sent Acoustic signal. It provides a good quality images since the acoustic signal can cross stained fingerprint with oil and dirt. However, ultrasound sensors are large in size and time consuming to acquire image. A new type of touchless scan devices that generate 3D representation of fingerprints is now appearing in the market. In this type of fingerprint scanners the finger print recorded from different view using multi cameras to construct the 3D shape for the fingerprint.

Touchless sensing technology provides a solution for the contact base technology (oil and dirt) and supply high-quality image acquisition. This technology overcome some of the pros of the previous technologies.

Fingerprint regards as one of the widely used biometric technologies. Below are the strengthens of fingerprint recognition:

- Cost effective and portability make it deployable in e-commerce, physical authentication, etc.
- Recognition wise, it provides high level of accuracy.
- User friendly
- However, there are certain cases can influence the efficiency of using fingerprint recognition which regards as weaknesses:
- It regards as one of the forensic and criminal applications.
- It can be affected by injuries or diseased.
- Overlapping of different user fingerprint during acquisition due to small size of sensor area in portable devices.

Fingerprints applications:

a. For security (for example, to control the access to certain areas or systems)
b. Person identification such identify the victims of the disasters and amnesia victims
c. Background checks such as government employment and security clearance.

The contribution of this paper build simple active and fast system to finger print recognition, which can be used effectively for establishing security system. The access or the authorisation for using the network can be simply done using this robust finger print identification system (Maltoni, Maio, Jain, & Prabhakar, 2009) (Jain & Kumar, 2010) (Fierrez, Ortega-Garcia, Toledano, & Gonzalez-Rodriguez, 2007).

Related Work

For thousands of years, humans use the voice the face and fingerprint to identify each other. Fingerprint matching for security has been shown very high accuracy. The fingerprint surface is a structure from valleys and ridges which are formatted during the fatal development. The fingerprint are different even in identical twin and for the same person. Today, the cost for recording fingerprint images are reduced dramatically, many smart devices such as computer laptops provide finger print acquisition system with high recoding resolution and quality (Prabhakar, Pankanti, & Jain, 2003).

The accuracy of the current fingerprint identification systems able to recognise a few hundred users. For large scale identification system which involves millions of person,

multiple fingerprint image for the same person provide more information for accurate recognition.

The problem in the current fingerprint high accuracy identification systems, they required large computational operations.

In spite of using the fingerprint effectively in person identification systems, it can be inappropriate for accurate automatic recognition systems because of environmental, ageing or gens factors. For example, many manual workers have a large number of cuts on their fingerprint which caused unclear fingerprint image (Maltoni, Maio, Jain, & Prabhakar, 2003).

The past people discerning about the fingerprint in person recognition, for example in china the specified the fingerprint ridges as human character. The first recognition system manifested in the sixteenth century. In 1684, Nehemiah Grew, published the first scientific study about te fingerprint ridges and valleys structure. He open the door for many research about fingerprints and their practical applications (Jain, Bolle, & Pankanti, 2006).

Meyer in 1788 described the fingerprint anatomical structure and indemnified in details a lot of the fingerprint ridges characteristics. In 1809 Bewick recorded his fingerprint, and did the first fingerprint classification, he classified the fingerprint to nine categories according to the fingerprint surface structure. In the 19th century, Galton introduced the minutiae features for the fingerprint images. All these finding help in producing the modern fingerprint identification system. In the 20th century, Edward summarized the individual differences in human fingerprint characteristics, this help in a more clear understanding of fingerprint biological principles. He specified that the human fingerprint ridges and minute details are permanent and unchangeable through human life and the fingerprint characteristics are different from one person to another (Vij & Namboodiri, 2014).

The first principle underpins fingerprint recognition, whereas the second and third concepts underpin fingerprint classification. Simultaneously, fingerprint recognition was formally recognized as a method of personal identity. Numerous recognition techniques have been developed, including the capture of latent fingerprints, fingerprint classification, and fingerprint matching. Numerous fingerprint identification organizations and criminal fingerprint databases have been formed worldwide. In 1924, the FBI developed a fingerprint division with a database of over 810,000 fingerprint cards in the

United States of America. This database has grown to over 200 million fingerprint cards and is continually expanding. Increasing the amount of fingerprints in databases makes manual analysis in a short period of time unfeasible. Thus, in the 1960s, the FBI's headquarters in the United Kingdom and the Paris Police Department developed an automatic fingerprint recognition system (AFIS). Their invention was motivated by observations of how human fingerprint experts recognize fingerprints. Three critical stages in the development of a fingerprint identification system were discovered and described: digital fingerprint representation, extraction of local ridge features, and pattern matching. Automatic fingerprint recognition systems have become so prevalent that they have become synonymous with biometric technologies (Jia et al., 2013) (Tran & Nguyen, 2012).

Proposed Algorithm

In this subsection, we describe the approach we use for person identification using the fingerprint image. An automated approach has the benefit of bringing technology to a wider general use and opening up a potential for developing efficient security software. Figs 3 display block diagrams of the proposed approach, which are explained below.

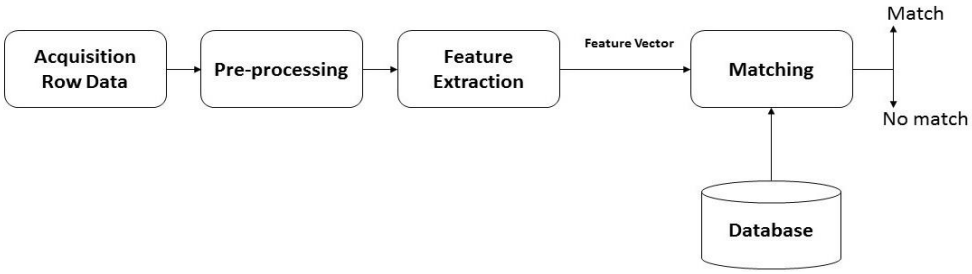


Figure 3 The block diagrams of the proposed approach

Acquisition Row Data:

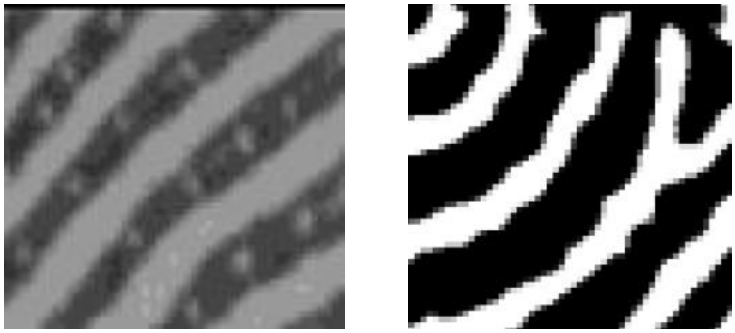
There are two methods for recording the fingerprint images, the online method which used the optical fingerprint scanner and the offline method which records the fingerprint image by putting some ink on the finger and then stamp it on white paper after that the image scanned to get digital image. The quality of scanned image depend on two factors:

- Sensors factors which deals with the quality of the recorded images, these factors are for example the resolution, the noise and the dirtiness.
- Fingerprints factors these factors depend on the human skins, these factors for example skin transformation, dirtiness and dryness.

Pre-processing: This stage is very important because image enhancement is depend on the steps which is performed in this stage. The pre-processing is vital to increase the visibility of fingerprint ridge structure

In this paper the following pre-processing steps are implemented:

- Remove noise and reflection: the Median filter is used for that purpose.
- Image segmentation: In this step, the fingerprint is isolated from the background using the region of interest (ROI) image masking technique.
- Binarization: In this step the image changes to binary image as shown in fig4.



a-gray image b- binary image

Figure 4 The binarization process

- Filling the holes: In this step the holes in the ridges are filled. In case we do not fill the holes, the minutiae features calculation for the fingerprint will be incorrect because these holes will looked like two bifurcations near to each other.
- Dilation: In this pre-processing step the width of the ridges is increased, in this case the gap between the two ridge pixels can be joined.

The above point represent the pre-processing steps we used in implementing the proposed Fingerprint Identification System in this paper. The table 1 summaries the most popular fingerprint pre-processing techniques which used in the state of art fingerprint recognition researches.

Table 1 Fingerprint pre-processing steps summary

Reference	Dataset	Pre-processing
(Zhou & Gu, 2004)	THU	ridge enhancement, orientation filed, and region segmentation
(Yang, Shin, Min, Park, & Park, 2006)	FVC2002	Discrete wavelet Transformation (DWT)
(Yuan, Lixiu, & Fuqiang, 2007)	FVC2002	Binarization, Thinning, mask estimation and Gabor filter
(Abrishambaf, Demirel, & Kale, 2008)	FVC2004	FFT, Gobar filter, normalization, region segmentation
(Zahedi & Ghadi, 2015)	FVC2002	Normalization, Ridge orintation and Ridge segmention

Feature Extraction

The feature extraction operation of fingerprint image is performed on the output of pre-processing stage. There are many algorithms to extract the features from the fingerprint images. In this work the features extracted depending on the location and the encoding of ridge bifurcations and ending. Fig 5 shows the ridges and valleys of the fingerprint image.

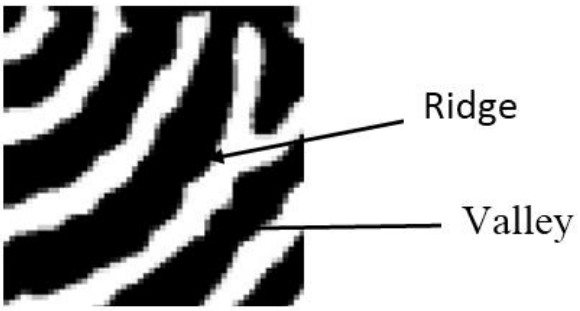


Figure 5 The ridge and valley of fingerprint image

In this work, the finger print identification and recognition features is called the minutiae features which are represented the ridge endings and the ridge bifurcation, see as fig 6. Thus detection the ridges and valleys in the fingerprint image is essential step to calculate the minutiae feature vector. In this research, mixing of directional filters and differences of Gaussian filter ideas is used to highlight effectively the fingerprint image ridges and valleys (Maltoni et al., 2003).

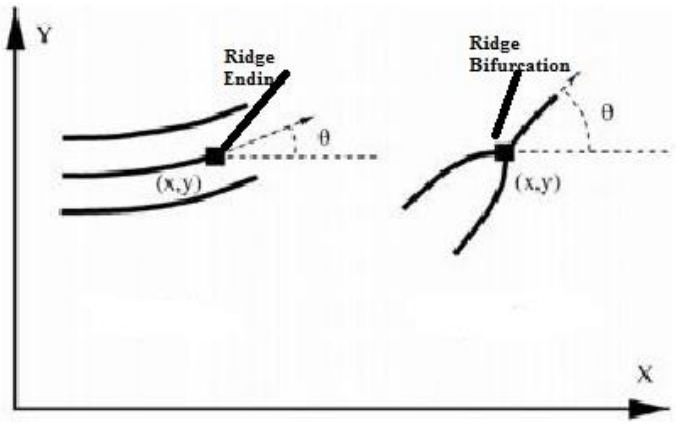


Figure 6 Ridge ending and Bifurcation

A. Ridges and Valleys Detection

In this paper, we utilize a rotating filter to detect the ridge and valleys in the fingerprint images.

Two half smoothing filters are used for the valley and ridges detection. The fingerprints images operators (valleys and ridges) are computed by finding the difference between these two smooth rotating filters. The ridge operator is represented the maximum local directional orientation line while the valley is represented the minimum local directional orientation line.

This method of detecting the fingerprint ridges and valleys proved its robustness in detection the bended lines and line junctions. Finally using the two rotating half smooth filters produce valleys and ridges detection method not sensitive to noise image(Magnier, Montesinos, & Diep, 2011a) (Magnier, Montesinos, & Diep, 2011b).

B. Minutiae Points Extraction

The minutiae points in the fingerprint image are ridge ending and bifurcation. Ridge ending is the location where a ridge arrives to an end while bifurcation is the location where a ridge is divided into two sub ridges.

To calculate the minutiae a 3*3 mask moved across the image, the (m) point properties is calculating according to the number of blacks points from (m1) to (m8), This number is called it (N). According to this number value the (m) properties is specified:

- N=0, Isolated Point
- N=1, End Point
- N=2, Connective Point
- N=3, Bifurcation

m1	m2	m3
m8	m	m4
m7	m6	m5

In this stage the extracted features compared with stored templates in the database, that mean the matching is the process of calculating the degree of matching or the similarity between the extracted features from the acquired fingerprint image and the stored template for the person we want to identify him. The matching process can be done in three approaches:

- Hierarchical approach: multiple features are extracted and different matching criteria are adopted at different levels to achieve high accuracy by using coarse-to-fine guided investigation.

- Classification method: There are many classification algorithms such as SVM (support vector machine and KNN (k-nearest neighbors algorithm).
- Coding approaches: In this approach one matching method used for the whole database, such as using the Euclidean distance between the input image and the template image.

In this work, the input and the template fingerprint features are transforms to same rotation, translation and scale. The first step of matching is comparing the input image with the sub templates classification value, then the minutiae of the input fingerprint image is compared with minutiae of the template fingerprint (Maltoni et al., 2009) (Tran & Nguyen, 2012).

Experimental Results

In this paper the proposed fingerprint identification system is conducted on three datasets ATVS (Galbally, Fierrez, Alonso-Fernandez, & Martinez-Diaz, 2011), LivDet2009 (Marcialis et al., 2009), and LivDet2011 (Yambay et al., 2012).

ATVS dataset: This dataset is contain of 3,168 fingerprint images captured from total 17 subjects using the flat and thermal sweeping sensors.

LivDet2009 dataset: This data set set is widly used as benchmark for fingerprint recognition systems, this data set contain 17,993 image collected using mostly Cross Match Verifier 300CL and Identix DFR2100 sensors.

LivDet2011 dataset It is an extended version of LivDet2009, this data contain 16000 fingerprint image recoded using Biometrika, Italdata, Digital Persona sensors. Fig 7 illustrates the three fingerprint datasets images example used in this work.

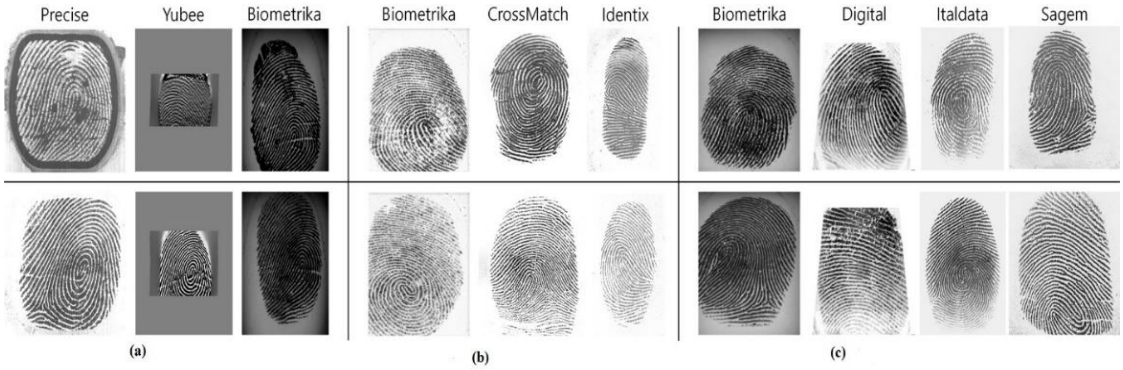


Figure 7 The fingerprint datasets (a) the ATVS, (b) LivDet2009, and (c) LivDet2011

Performance evaluation is an important step to evaluate the proposed system performance. In this paper four evolution metrics are used FAR, FRR, EER and accuracy.

- False Acceptance Ratio (FAR): is the ratio of false acceptance identified sample, it can calculate by the ratio between the false sample to the total number of samples in the dataset.
- False Rejection Ratio (FRR): it is the rejected samples from the system that should not rejected. The ratio of false rejected samples to the total number of samples in the dataset is used to calculate this performance metric.
- Equal Error Ratio (EER) : it is the average score of FAR and FRR values
- Accuracy (ACC): it is the corrected recognized fingerprint samples.

Table 2 the performance evaluation for the proposed system using the ATVS (Maltoni et al., 2003), LivDet2009 (Jain et al., 2006), and LivDet2011 (Vij & Namboodiri, 2014) datasets.

Table 2 The performance evaluation

Dataset	FAR	FRR	EER	ACC
ATVS	0.02	0.02	0.02	99.50
LivDet2009	0.07	0.05	0.06	99.00
LivDet2011	0.07	0.07	0.07	99.20

Discussion

The suggested system's identification method has been updated to address several issues discovered in fingerprint images. Using two smoothing filters Gaussian semi _filters are provided clear structure for the ridge and valleys in the fingerprint images and this increase the performance of extracting the minutiae features. Consequently, the identification accuracy is increased dramatically compared to many state of art papers conducted their proposed systems on ATVS LivDet2009, and LivDet2011.

Table 3 and 4 compares the performance accuracy for the proposed system with state of art systems. This table recorded the minutiae features are the better features to represent the fingerprint image comparing to the local features such as SIFT (Lowe, 2004), BRISK (Bay, Ess, Tuytelaars, & Van Gool, 2008) and SURF or global features which focused on the surface structure patterns (Leutenegger, Chli, & Siegwart, 2011).

Table 3 The performance compression based on the LivDet2009 dataset various studies in this area of iris recognition systems based on NIR iris images have been carried out.

The reference	The method	ACC
(Abhyankar & Schuckers, 2006)	LPQ	78.87
(Määttä, Hadid, & Pietikäinen, 2011)	LTP	89.29
(Ghiani, Marcialis, & Roli, 2012)	LSP	89.22
	The proposed method	99.00

Table. 4 The performance compression based on the LivDet2011 dataset

The reference	The method	ACC
(Ghiani et al., 2012)	LBP	80.99%
(Kim, Suh, & Han, 2015)	LSP	77.46%
	The proposed method	99.20

Recently, Wani M.A. (Wani, Bhat, Afzal, & Khan, 2020) the deep learning (especially convolutional neural network (CNN)) is used to extract featurees and classified the images of NIST DB4 consists of 4000 images, the recognition accuracy reached to 95%. Therefore, the proposed method in this paper acquired better results. In addition, the proposed fingerprint system is easy to implement and the time consuming for recognition is less than the CNN system.

Conclusion

Identification task in biometric systems is a very vital operation because of the problems in the biometric samples. The fingerprint still an effective method for person identification all over the world. With wide and virtual development in the information technology it became critical to develop effective and easy to implement authentication system. Therefore, in this paper a new person identification is adopted. This system is based on two half smoothing filters are used for the valley and ridges detection in fingerprint image, this produce more accurate minutiae features. The proposed performance evaluated by using on ATVS LivDet2009, and LivDet2011 datasets, to measure the performance the FAR,FRR,EER and ACC are used.

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