Fast Fingerprint Identification based on the DoG Filter

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Abstract: - Biometric recognition is the study of recognizing individuals through their distinct physiological or behavioral traits, which encompass iris, facial features, fingerprints, retina patterns, vein structures, hand geometry, handwriting, human gait, signatures, keystrokes, and vocal characteristics. Fingerprint images comprise various whorls, arches, loops, ridge ends, and ridge bifurcations on each digit. The extraction of these features with some transformations can uniquely identify an individual. Fingerprints are extensively utilized in numerous biometric identification systems; finger scanning is efficient, user-friendly, and a well-established technique. This study examines the extraction of the fingerprint features and enhances the efficacy of the fingerprint authentication system by implementing a novel extractor for fingerprint features utilizing the DoG(Difference of Gaussian) Filter. The extracted features are encoded and prepared for the matching process to get the system identification and verification results.

Key-Words: - Biometrics, Fingerprint image, Image enhancement, Identification, Feature extraction, Encoding.

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1 Introduction

Biometrics is a technology used to identify and verify individuals based on their distinctive physical or biological attributes. As shown in Figure 1, several biometric characteristics are commonly employed. Physiological-based biometric systems are more reliable than behavior-based systems, [1].

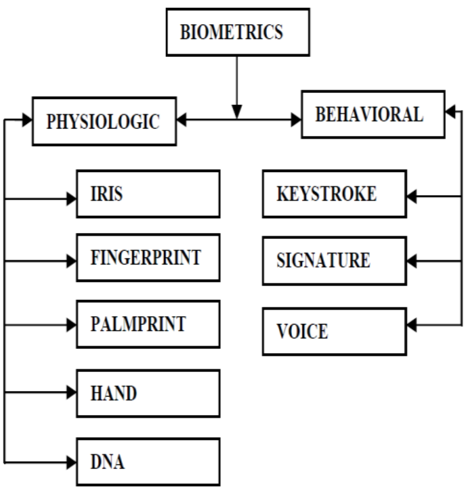


Fig. 1: Types of Biometrics

Depending on the application domain, a biometric system is divided into two procedures (Enrolment and Identification), that are capable of operating in both online and offline modes shown in Figure 2.

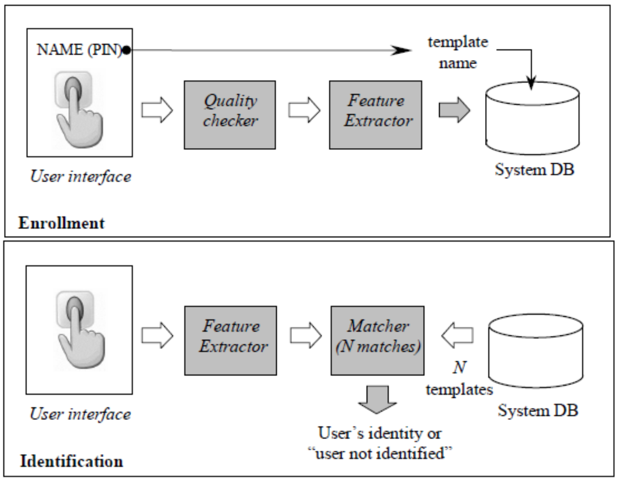


Fig. 2: Biometric System Procedures

Among various biometric technologies, fingerprint recognition stands out as the earliest developed, most extensively applied, and least expensive. This system incorporates a fusion of sensor technology, biotechnology, electronics, digital imaging, and pattern recognition algorithms. Fingerprint images are formed by the impression of ridge patterns on a finger. A ridge is a single curved segment, and a valley is the area between two adjacent ridges. Minutiae, which are local irregularities in the ridge flow pattern, are shown in Figure 3. These characteristics are used for identification, [2].

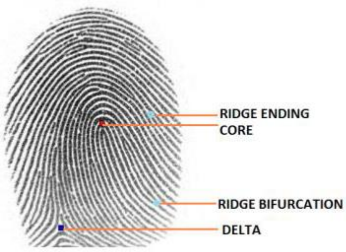


Fig. 3: Fingerprint image

Fingerprint images rarely meet ideal quality standards. They may be compromised and distorted by noise due to several circumstances, including fluctuations in skin and impression conditions. Therefore, it is essential to utilize picture-enhancing techniques before feature extraction to provide a more accurate estimation of feature locations. The fingerprint identification system consists of three stages: the initial stage involves fingerprint image acquisition and enhancement; the second stage encompasses feature extraction and encoding; and the final stage is dedicated to matching and identification, [3].

2 Related Work

In the realm of fingerprint recognition, numerous studies have been undertaken. A notable contribution was developed a method for "Direct gray-scale minutiae observation in fingerprints." Their approach involved binary coding and grayscale conversion to accentuate minutiae patterns, facilitating more accurate fingerprint matching. Additionally, they investigated direct grayscale minutiae matching, yielding superior speed, [4]. A study, "Fingerprint Images Enhancement: Algorithms & Performance Evaluation," proposed algorithms to enhance fingerprint images. The authors evaluated the algorithms' performance using various distribution methods, with the objective of integrating results from diverse environments sharing similar characteristics, [5]. A fingerprint reorganization algorithm improved matching performance for low-quality fingerprint images and those with nonlinear distortions, leading to significant enhancements in recognition accuracy, [6]. To enhance and recreate fingerprint image data, the Fast Fourier Transform and Gabor Filters applied. The extracted minutiae included two key categories: bifurcation points, where fingerprint ridges diverge, and termination points, where ridges conclude, [7], [8].

The extracted features are ultimately used for fingerprint recognition. This research suggested using reinforcement learning for minutiae detection in fingerprint matching. They propose a method where an autonomous agent navigates its environment to optimize minutiae detection. Analyzing fingerprints requires tracing ridges and identifying minutiae. An agent, when provided with a suitable structure and learning environment, can easily identify and learn the key components of its assigned tasks, [9].

A fingerprint verification method utilized Gabor wavelets and co-occurrence matrices to create a distinctive finger code, [10]. Furthermore, introduced an improved fingerprint identification technique, employing four statistical descriptors to characterize a co-occurrence matrix obtained from 129x129 sub-images extracted from the source image, [11].

3 Image Acquisition and Enhancement

The guideline for the sphere of concern indicates that image sensors require digital photographs. The first category comprises physical equipment susceptible to energy discharge from objects. The Digitiser is the second component, responsible for converting the analog outputs from physical sensing instruments into digital data. A specialized hardware image processing system integrates hardware and digitizer components to perform various fundamental operations.

A computer imaging processing system encompasses a spectrum from personal computers to supercomputers. The program is designed for image processing and comprises a specialized computer circuit that executes specific tasks. The capability for mass retention is essential in image processing applications. An image measuring 1024x1024 pixels, with each pixel represented by 8 bits, requires 1 megabyte (MB) of storage space, assuming the image is not compressed. Images demonstrate the utilization of a color television monitor, which is driven by the outputs of image and graphics display cards - essential components of a computer system. The image quality may be compromised by noise that obscures the sharpness of the ridge structure. This corruption may arise from discrepancies in skin and impression circumstances, including scars, dampness, grime, and inconsistent contact with the fingerprint-capturing device. Consequently, image-enhancing techniques are utilized to diminish noise and improve the clarity of ridges relative to valleys. The enhancement module comprises the methods depicted in Figure 4, [12].

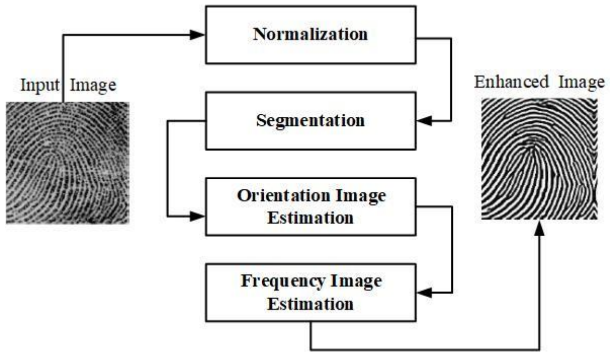


Fig. 4: Image Enhancement Module

3.1 Binarization

The goal of fingerprint image refinement entails converting a grayscale image into a binary image, with 0 representing the ridge sub-graph and 255 representing the background sub-graph.

3.2 Normalization

This method is employed to normalize the intensity values in an image, adjusting the range of gray-level values to fall within a desired range. The normalized fingerprint image still has little contrast and may be unevenly lit. To prevent noise from impacting subsequent feature extraction and recognition, a low-pass Gaussian filter is applied to remove high-frequency noise shown in Figure 5.

A two-dimensional Gaussian filter is described by the following expression**:**

$$f(x,y) = exp\left[\frac{x^2+y^2}{2\sigma^2}\right], \sigma = \text{filter parameter} \quad (1)$$

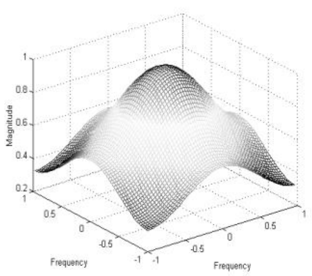


Fig. 5: Two-dimension Gaussian filter

To compensate for the changing in lighting conditions, a brightness and contrast transformation is performed, described by the formula (2).

$$I(x,y)' = \left(\frac{(I(x,y)-\bar{I})}{3\sigma_I} * 128\right) + 128 \quad (2)$$

where

$$\bar{I} = \frac{1}{MN}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1} I(x,y),$$

$I(x,y) = input$ image ; $M, N = image$ dimensions

$$\sigma_I = \sqrt{\frac{1}{MN-1}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}(I(x,y)-\bar{I})^2}$$

3.3 Segmentation

Image segmentation involves distinguishing the foreground areas, comprising the fingerprint region with its characteristic ridges and valleys, from the background areas, which lie beyond the fingerprint boundaries and lack any meaningful fingerprint data.

3.4 Orientation and Frequency Estimation

The orientation estimation stage defines the local orientation of the fingerprint's ridges. This step is essential, as the success of the subsequent Gabor filtering stage relies on precise local orientation information to enhance the fingerprint image effectively. Another important parameter that is used in the construction of the Gabor filter is the local frequency which represents the local frequency of the ridges in a fingerprint, [13].

4 Feature Extraction

The Fingerprint feature extraction is an important part of the identification process. A new algorithm has been proposed in this paper used to extract fingerprint features from enhanced fingerprint images based on using the Difference of Gaussian (DoG) filter. These features extracted using this filter are encoded into *FPCode* pattern, [14].

5 Dog Filter

The DoG filter is an approximation for the LoG filter as it is just the difference between two differently sized Gaussians. It is one of the most computationally effective filters. In comparison with the Gabor filter, DoG can be implemented using an effective recursive algorithm. The 2D-DoG filter is described by the expression (3) and the response in Figure 6.

$$DoG(x,y) = g(x,y,\sigma) - g(x,y,1.6\sigma) \quad (3)$$

where: $g(x,y) = \frac{1}{2\pi\sigma^2}\exp\left(\frac{-(x^2+y^2)}{2\sigma^2}\right)$

And: **σ** is the variance.

To obtain the discrete convolution kernel for DoG, the continuous DoG expression is approximated. It has the advantage of being robust to noise.

To calculate the response of the DoG filter we specify the variance of the filter ($\sigma > 0.5$) on which the filtration is based. And then the filter is ready for the convolution process, which can be implemented using recursive algorithms.

The carried out statistical experiments, allow us to choose the optimum parameters of DoG filters, one of the features of the DoG filter is that the sign of the response changes in the area where there is a difference in brightness in the image. Edge detection is based on this property. The response of the filter equals zeros in homogeneous regions, however such areas are not found in the fingerprint. Hence, the fingerprint structure can be coded by signs of the response of the DoG filter in the Cartesian coordinates.

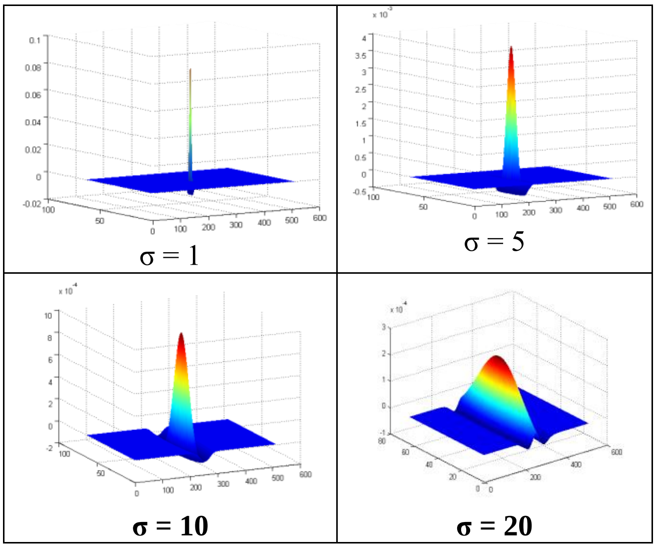


Fig. 6: The response of a Difference of Gaussians (DoG) filter for different values of σ (standard deviation) in a 3D plot: (filter size = 64x512)

6 Features Encoding

Code generation for the DoG filter is much easier, and this returns to the fact that the output of the DoG filter is real only, so the demodulator used is one-dimension only positive or negative, so we are concerned with the sign of the output of DoG filter only, as negative sign takes zero and positive takes one, this means for each block we get an only one-bit code, so we can deduce that DoG is much more efficient code size, [15].

Dividing the filter output into blocks, and then getting the mean for these blocks before coding is used too with this filter, as this saves the space of code storage without affecting the system performance, and the code size is still proportional to the size of the database shown in Figure 7.

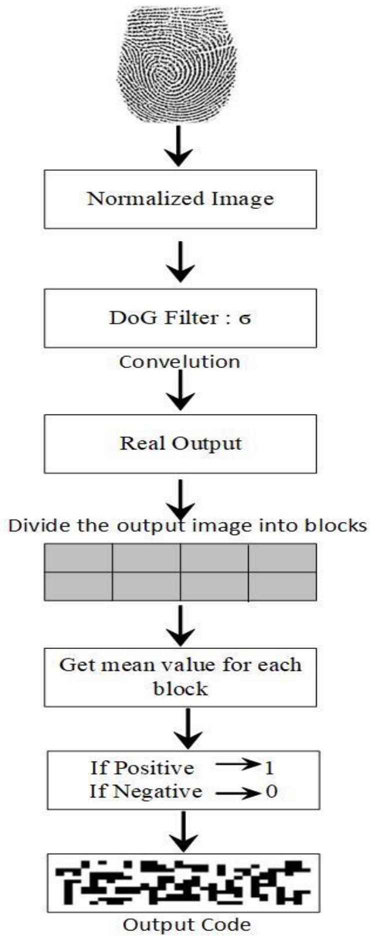


Fig. 7: Image Encoding Flowchart

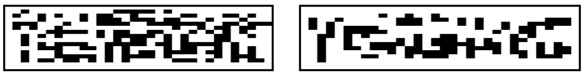
Features of the fingerprint can be encoded by the signs of the response of the DoG filter at each block of the image as in the following expression:

$$D(i,j) = \begin{cases} 1 & if\ D(i,j) \geq 0, \\ 0 & if\ D(i,j) < 0, \end{cases} \quad (4)$$

where: $D(i,j) = I(x,y) * DoG(x,y,\sigma)$

(i , j) The position in which the bit of the Fingerprint sub-image is determined, for the

Fingerprint image will have a 16 x 64 x 1 bits Code as shown in Figure 8.

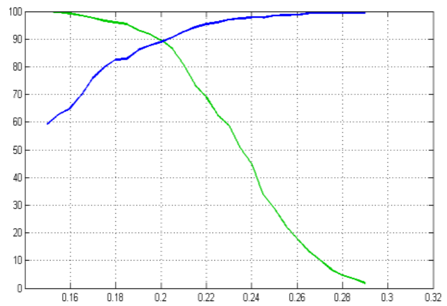


DoG Code (σ = 1) DoG Code (σ = 3)

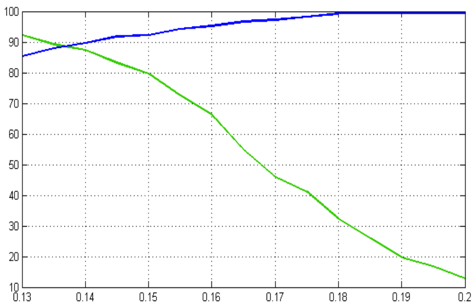
Fig. 8: Fingerprint Samples Codes based on DoG filter

7 Experimental Results

We are going to test our system using a database for 1000 persons x 5 images for each fingerprint = 5000 images, and we will get the optimum filter to be used with its optimum parameters shown in Figure 9.



Dog filter, σ = 3
Identification accuracy = 97.8%
Optimum Threshold = 0.2
Optimum Verification accuracy = 89.2 %



DoG filter, σ = 5
Identification accuracy = 97.6 %
Optimum Threshold = 0.137
Optimum Verification accuracy = 88.6 %

Fig. 9: Experimental results: acceptance and rejection accuracies vs. threshold

8 Conclusion

The effective recursive DoG filter was proposed and investigated to extract fingerprint features, as it is faster and more effective than the Gabor filter. The fingerprint features are encoded by the signs of the DoG filter response at each block of a fingerprint image. The size of the fingerprint code is calculated based on the division of the normalized fingerprint image into blocks, with each block corresponding to a single bit. This yields a code size of 16 x 32 x 1 bits, totaling 512 bits. This compact code size is particularly suited for conventional databases, providing an efficient trade-off between storage space, computational time, and performance. Furthermore, the utilization of a DoG filter successfully minimizes storage requirements without sacrificing system performance.

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Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

- Mohamed A. Hebaisy Contributed to thehas developedment of the methodology, performed statistical analysis, reviewed and edited the manuscript.
- Fathy A. Syam has collected and analysed data, wrote and reviewed the original draft of the manuscript.

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