A Comprehensive Review On Fingerprint Identification System

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ABSTRACT

Fingerprint authentication stands out as the most sophisticated among biometric techniques, having undergone extensive validation across diverse applications. Unlike features like a person's face or signature, which can change over time and may be subject to fabrication or imitation, a fingerprint uniquely belongs to an individual and remains constant throughout a lifetime. This paper delineates the diverse aspects and methods essential for the implementation of a fingerprint-based identification system.

Keywords — Biometric, Minutiae, Fingerprint, Identification System.

1. INTRODUCTION

Fingerprints, being one of the oldest and readily accessible biometric traits, provide an infallible means of personal identification. The accuracy achieved through fingerprint techniques surpasses that of other existing biometric traits [2]. Unlike facial and vocal patterns, fingerprints exhibit persistence with age and resist easy alteration. This makes fingerprinting one of the most researched and matured fields in biometric authentication. The origins of biometrics trace back to China, where fingerprinting was first employed [3].

Fingerprints stand out as an unparalleled and unchanging form of signature compared to other methods [4]. Defined by a set of ridge lines running parallel, intersecting, and occasionally terminating, fingerprints are characterized by points known as Minutiae, where ridge lines end [5]. According to Galton, ridges possess numerous minute peculiarities known as Minutiae, including divisions, immediate reunions, small circular or elliptical spaces, or independent beginnings or endings [5].

In a fingerprint image, ridges appear dark, while valleys are bright. They often run in parallel, bifurcate, or terminate. Minutiae-based fingerprint identification systems focus on accurately extracting ridge patterns. A high-quality fingerprint typically contains 25-80 minutiae points, depending on sensor resolution and finger placement [6]. However, fingerprints captured through suboptimal scanners may exhibit fewer minutiae points. To ensure the efficacy of minutiae extraction procedures, enhancing fingerprint images becomes crucial, especially when dealing with input from poor-quality scanners.

2. REVIEW OF RESEARCH WORK

In the realm of fingerprint identification, diverse research endeavours have explored various methodologies, each contributing to the advancements in the field. A comprehensive overview of the research landscape, including methodologies and techniques employed, is presented in this section:

I. Fast Fourier Transform and Gabor Filters

A study on fingerprint recognition leverages the power of Fast Fourier Transform and Gabor Filters [7]. These techniques are employed to enhance and reconstruct fingerprint image information, facilitating the extraction of crucial minutiae types such as ending points and bifurcations. The extracted features are subsequently utilized for effective fingerprint recognition.

II. Fusion and Context Switching Frameworks

The Fusion and Context Switching framework is implemented in forensic science applications, specifically for matching latent fingerprints. Unlike traditional approaches of matching latent prints with inked or live fingerprints, this concept prioritizes a meticulous analysis and attention to detail.

III. Segmentation Algorithm

Segmentation stands as a pivotal pre-processing step in fingerprint verification, significantly influencing the outcome of fingerprint analysis and recognition. Various segmentation algorithms have been explored, including the following:

Gauss Filtering: The process of collecting fingerprints often introduces noise into the fingerprint image due to factors such as dust inhalation and spots on the sensor surface [8]. To mitigate this effect and enhance image quality, the Gaussian filter is employed.

Histogram Processing: Histogram manipulation emerges as an effective technique for fingerprint image enhancement. Its simplicity in software calculation and suitability for economical hardware implementations make histograms a popular tool for real-time image processing.

Histogram Equalization: In the context of image enhancement, we delve into the concept of histogram equalization, where we consider a continuous function denoted by the variable r, representing the gray levels of the image under consideration. It is assumed that r has been normalized to the interval [0, 1], with $r=0$ representing black and $r=1$ representing white. The transformation function, denoted as $s = T(r)$, is applied within the range of $0 < r < 1$.

The transformation function T(r) adheres to the following conditions:

1. T(r) is a single-valued and monotonically increasing function in the interval $0 < r < 1$.
2. $0 < T(r) < 1$ for $0 < r < 1$.

This transformation yields a corresponding level, s, for every pixel value r in the original image, ensuring that the enhancement process is governed by defined and essential conditions.

3. PATTERN RECOGNITION AND FEATURE EXTRACTION

A pattern is essentially an arrangement of descriptors, distinguished by the order of its constituent elements rather than the inherent nature of those elements. Pattern recognition encompasses two fundamental areas: Decision theoretic and Structural. Decision theoretic involves patterns described using quantitative descriptors, such as length, area, and texture. On the other hand, the Structural category deals with patterns best characterized by qualitative descriptors, specifically relational descriptors. A pattern class constitutes a group of patterns sharing common properties, denoted as w1, w2, …, ww, where W signifies the number of classes. Machine-based pattern recognition involves automatic assignment of patterns to their respective classes, minimizing human intervention. Three prevalent pattern arrangements are vectors, strings, and trees.

Pattern vectors, represented as x = [x1, x2, …, xn], encapsulate each component (xi) denoting the ith descriptor, and n represents the total number of descriptors associated with the pattern. The nature of these components in a pattern vector depends on the chosen approach to describe the physical entity itself. In the realm of fingerprint recognition, the interrelationships of print features, known as minutiae, form the basis for this arrangement, as illustrated in Figure 1 below.

Figure.1: Fingerprint Images

The critical consideration is that the selection of descriptors profoundly influences the performance of object recognition based on the pattern vector approach.

4. METHODOLOGY

The Biometric Identification System (BIS) block diagram is visually represented in Figure 2 below. It comprises three integral components, elucidated through a process to recognize fingerprint image. Each component in the flowchart is expounded upon as follows:

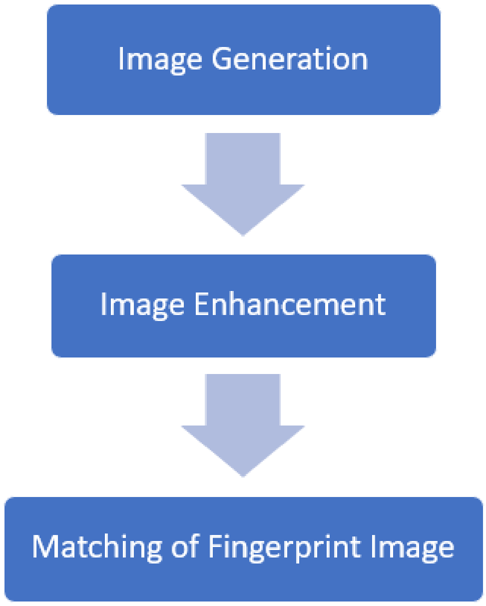

Figure. 2: Process to recognize fingerprint image

Image Generation

In the problem domain, the image sensor captures digital images. The first component is a physical device sensitive to the energy emitted by the object. The second, known as a Digitizer, converts the output of the physical sensing device into digital form. The computer serves as the image processing system, ranging from PCs to supercomputers. Software for image processing comprises specialized modules for distinct tasks. Mass storage capability is imperative in image processing applications. An image of size 1024x1024 pixels, with each pixel's intensity as an 8-bit quantity, necessitates one megabyte (MB) of storage space if uncompressed.

Image Enhancement

Image enhancement stands as a pivotal phase within the realm of digital image processing, aiming to augment the visual quality and interpretability of images. The primary objective is to accentuate pertinent information, diminish noise, and refine the overall perceptual quality of the image. Diverse techniques are deployed to achieve these objectives, broadly classified into spatial domain methods and frequency domain methods.

Spatial Domain Methods:

Spatial domain methods operate directly on the pixel values of the image, involving the manipulation of intensity values for individual pixels or groups of pixels. Key spatial domain techniques encompass:

Histogram Equalization: This method enhances image contrast by redistributing intensity values across the entire range.

Filtering Operations: Techniques like convolution with specific filters, such as Gaussian or median filters, selectively reduce noise or blur an image.

Point Processing: Involves modifying individual pixel values using mathematical operations, like contrast stretching or intensity scaling.

Frequency Domain Methods:

Frequency domain methods entail transforming the image into its frequency components. This transformation facilitates the manipulation of image characteristics in the frequency domain before reconversion to the spatial domain. Common frequency domain techniques include:

Fast Fourier Transform (FFT): Employed to analyze the frequency content of an image. Filtering operations can be applied in the frequency domain to selectively enhance or suppress specific frequencies.

Bandpass Filtering: A technique isolating a specific range of frequencies, beneficial for emphasizing image details at different scales.

Wavelet Transform: Enables multi-resolution analysis, permitting localized enhancement or suppression of image features.

The selection of an enhancement method hinges on the distinct characteristics of the image and the desired improvements sought. Image enhancement finds widespread application across various domains, such as medical imaging, satellite image processing, and computer vision, ensuring superior interpretability and analysis of visual data.

Matching of fingerprint image

Recognition techniques based on matching involve representing each class with a prototype pattern vector. In this approach, an unknown pattern is assigned to the class whose prototype it is closest to, using a predefined metric. One of the basic methods employed in this paradigm is the minimum-distance classifier.

Minimum Distance Classifier:

The idea behind this classifier is to calculate the distance between the unknown pattern and each prototype vector. Suppose we define the prototype of each pattern class as the mean vector of the patterns in that class. This mean vector represents the central tendency of the patterns in a particular class. This proximity is measured using the Euclidean distance, which involves calculating the distance between the unknown pattern and the mean vector of each class. The class with the minimum distance becomes the assigned class for the unknown pattern. In essence, the minimum-distance classifier is a straightforward method that relies on the notion of closeness to make classification decisions. While it serves as a fundamental approach, more advanced recognition techniques build upon this concept to achieve higher accuracy and robustness in pattern recognition tasks.

5. CONCLUSION

This paper explores diverse methods and techniques for person identification based on fingerprints. The findings highlight the efficiency and accuracy of fingerprint-based systems, emphasizing their reliability and security. Notably, the Gabor filter method emerges as a valuable approach for feature extraction in this context. The methodology of the biometric identification system is elucidated through diagrams and flow charts, offering insights into image quality enhancement and identity verification processes. For future research, there is potential to enhance image quality further by refining image enhancement techniques and advancing matching methodologies. This ongoing exploration could contribute to the continuous improvement of fingerprint-based identification systems, addressing challenges and optimizing performance for heightened security and reliability.

6. REFERENCES

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