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DESIGN AND DEVELOPMENT OF A FAST FOURIER TRANSFORM-BASED FINGERPRINT MATCHING SYSTEM

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Abstract

A significant challenge in fingerprint verification systems is their vulnerability to degraded image quality, which can lead to inaccurate and incomplete feature extraction, ultimately compromising system performance. The importance of assessing the quality and validity of captured fingerprint images cannot be overstated, as poor-quality images can have far-reaching consequences. In particular, false non-matches can have severe implications in negative recognition applications, such as watch list and duplication detection, where malicious individuals may intentionally tamper with their fingerprints to avoid identification. To address this issue, we propose a novel fingerprint identification and comparison approach based on the Hough transform. In high-stakes applications, individuals with malicious intent may deliberately alter their fingerprints to evade identification. Current methods rely on matching datasets by identifying the Rigid Core Delta point to facilitate fingerprint recognition. This paper introduces a novel approach to detect and correct skin distortion in individual fingerprint images. Our method employs a patch-based strategy, where rectangular regions are defined to identify areas of distortion within the fingerprint. By varying the patch size, distortion detection is improved, and a Support Vector Machine (SVM) classifier is trained to perform classification tasks. Furthermore, we treat distortion rectification as a regression problem, where the input is a distorted fingerprint image, and the output is a distortion-free field, enabling accurate fingerprint recognition.

Keywords: FFT, SVM, classification,

2. Introduction

Human fingerprints are composed of intricate ridge and valley patterns that form a distinctive structure, which is fully developed during fetal development and remains unchanged throughout an individual's lifetime. The uniqueness of these patterns ensures that each person's fingerprint is distinct from others, making it an ideal biometric identifier. Fingerprint recognition, a widely adopted biometric technology, extracts unique features from the impressions left by the ridges of an individual's fingertips, enabling accurate identification and verification. Fingerprints can be categorized into two primary types: flat and angled. The flat type involves the impression of the central area between the fingertip and the first knuckle, whereas the angled type, also known as a rolled print, features ridges on either side of the finger. The ease of acquisition and the availability of extensive databases have contributed to the widespread adoption of fingerprint technology, particularly among immigration and law enforcement agencies. The concept of using fingerprints for individual identification dates back to the 19th century, when Sir Francis Galton's pioneering work highlighted the unique characteristics of fingerprints, paving the way for their use in identifying individuals. The distinctive features known as Galton Points or minutiae points have served as the foundation for fingerprint identification, with significant advancements and updates over the past century. Specifically, ridge endings and bifurcations are classified as minutiae points, which play a crucial role in fingerprint identification and verification methodologies. The automation of fingerprint technology began to take shape in the 1960s, driven by the rapid development of computing technologies. Today, specialized software programs can accurately compute minutiae points or Galton points using computer systems, thereby facilitating the automation of fingerprint identification processes.

A. Fingerprint Image Pattern: The fingerprint image is distinguished by a unique graphical pattern of ridges and valleys on the outer surface of the fingertips. The ridges appear as dark lines, while the valleys or furrows are the areas between the ridges in the image. The ridge lines exhibit varying shapes and are categorized into regions of high curvature or multiple ridge endings, which are considered distinctive features. Fingerprint patterns are diverse and can be broadly classified into three primary types: arches, whorls, and loops.

B. Arches: Characterized by a continuous ridge pattern that originates from one end and terminates at the other, arches are incomplete patterns that do not form a complete circle. They can be further subdivided into four categories: plain, ulnar, radial, and tented arches.
B. Whorls: Whorls are circular patterns formed by ridges that revolve around a central point. Based on the number of whorls and delta patterns, they can be classified into four types: plain, central pocket loop, accidental, and double pocket loop whorls.

C. Loops: Loops are ridge patterns that enter from one side, recurve, and terminate on the same side, forming a continuous loop. They can be categorized into four subtypes: plain, lateral pocket, twinned, and central packet loops.

The human fingertip skin is composed of intricate ridges and valleys that combine to form unique patterns. These patterns, known as fingerprints, are fully developed during fetal development and remain unchanged throughout an individual's lifetime. Research has consistently shown that no two individuals possess identical fingerprints, making them a distinctive biometric identifier. The uniqueness of fingerprints has led to their widespread adoption in biometric applications. However, fingerprint matching is a complex pattern recognition problem that requires significant expertise and training. Manual fingerprint matching is not only time-consuming but also demands extensive education and training for experts to accurately identify and verify fingerprints.

Fingerprints possess a remarkable degree of permanence and uniqueness, remaining consistent over time. Our observations suggest that fingerprints offer a more secure and reliable means of personal identification compared to traditional methods such as passwords, ID cards, or keys. In fact, modern devices, including computers and mobile phones, are increasingly being equipped with fingerprint sensing technology to provide fingerprint-based password protection, which is being adopted as a more secure alternative to conventional password protection methods.

Biometric identifiers are defined as unique anatomical, physiological, or behavioral characteristics that can be used to verify or identify an individual. These identifiers, which include fingerprint, iris, face, and voice patterns, as well as DNA and gait, are widely employed by law enforcement agencies, intelligence departments, and the Federal Bureau of Investigation (FBI) for identification and authentication purposes. Among these biometric modalities, fingerprint recognition stands out as a particularly popular and enduring method, having been used for personal identification for over a century. The enduring popularity of fingerprint recognition can be attributed to its unique properties: fingerprints remain unchanged throughout an individual's lifetime, and no two individuals, including identical twins, possess identical fingerprints.

The unique properties of fingerprints have driven the development of automated systems for Automatic Fingerprint Identification and Authentication (AFIA), with interest in this field steadily increasing over the years. Researchers, academics, and industry professionals have been exploring the complexities of fingerprints to design a robust and accurate AFIA system. By integrating image processing algorithms with fingerprint impressions, AFIA systems can map a fingerprint to an individual from a vast fingerprint database. Despite the abundance of published research and the maturity of the field, fingerprint research remains a vibrant and active area of investigation. The Automatic Fingerprint Identification and Authentication (AFIA) system involves a series of crucial steps, including fingerprint acquisition, segmentation, image enhancement, feature extraction, minutiae matching, and classification. Researchers have been focusing on different aspects of the AFIA system, with particular attention being paid to the classification step in recent years. This step plays a vital role in improving the overall accuracy of AFIA systems and is used for indexing in fingerprint databases, thereby significantly enhancing the performance of Automated Fingerprint Identification Systems (AFIS). Fingerprint classification involves categorizing a given fingerprint into specific classes, such as left loop, right loop, whorl, arch, tented arch, double loop, and others, which is a critical process in the AFIA system.

3. Literature Survey

Biometric systems can be broadly defined as technological solutions that leverage unique biological traits of individuals to achieve a specific objective. The primary goal of these systems is to verify or establish an individual's identity based on their distinct physiological or behavioral characteristics. These characteristics, which can be either physiological or behavioral in nature, serve as the foundation for biometric-based identification and authentication processes. A wide range of potential physiological and behavioral characteristics have been explored in the literature as viable options for biometric systems, each offering unique advantages and challenges.

Chu-Chiao Liao and Ching-Te Chiu [1] A range of approaches have been proposed to enhance the accuracy of fingerprint recognition. One approach involves leveraging minutiae information and ridge features to improve matching performance. This method extracts various ridge features, including the number of ridges, their length, direction of curvature, and frequency, and groups them for each minutiae. The similarity between minutiae pairs and the set of ridge features exceeding predefined thresholds is then calculated.
Adhiyaman M and Ezhilmaran D [2] another approach prioritizes minutiae points as key features, considering them more crucial than singular points, frequency maps, and orientation maps of ridges. This method involves comparing each minutiae point of the query image with the corresponding minutiae points stored in the database.

Sangram Bana and Dr. Davinder Kaur [3] other researchers have developed fingerprint recognition systems that employ minutiae matching techniques. These approaches extract minutiae features and then match them with minutiae combinations within two fingerprints.

Iwasokun Gabriel Babatunde [4] some algorithms have been designed to address matching problems related to differences in image ridge size and orientation. These algorithms focus on fixed Euclidean and spatial associations between minutiae and singular points, regardless of orientation flow at an even image size.

Apurva N. Ganar et al., [5] other techniques involve using local structure for fingerprint matching. The input image is pre-processed through gridding, binarization, thinning of ridges, and noise removal. The Minutia Score Matching method is used for minutiae matching, which aids in fingerprint recognition.

Shashi Kumar D. R et al., [6] Fingerprint verification techniques have also been developed based on the fusion of ridges and minutiae using Strength Factors (FVMRSF). The preprocessing stage involves binarization and thinning. The block filter is applied to estimate the minutiae matching score, and the score corresponding to the match of ridges is valued using the Hough Transform.

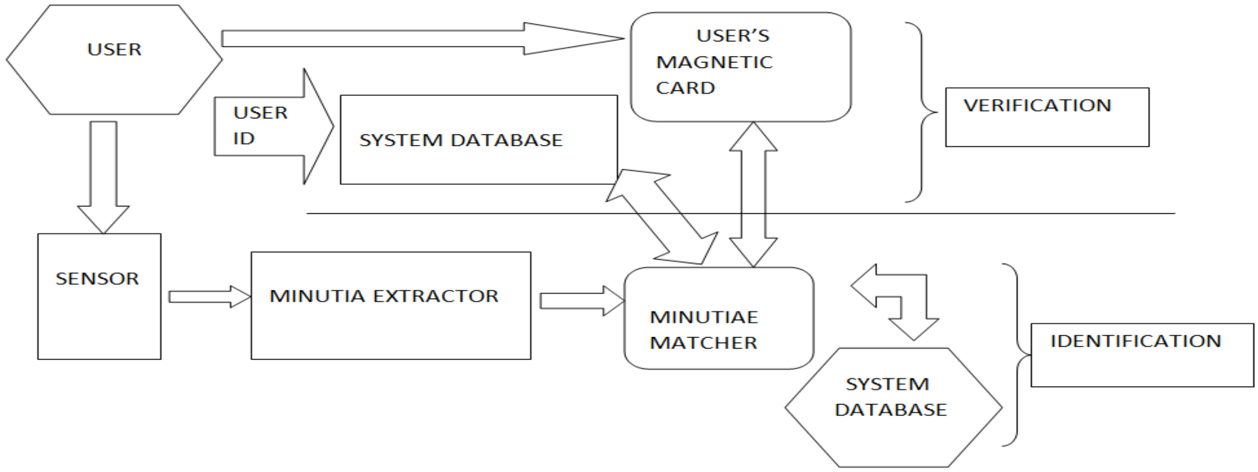
P. I. Mistry and C. N. Paunwala [7] Delaunay triangle-based structures have been used to extract local ridge texture information of the matched candidate triangle. The full weightage is given to triangle matching score, and specified weightage is given to minutiae matching score as per the requirement.

S. Bana and D. Kaur [8] Minutiae extraction from sample images has also been proposed, followed by matching based on the count of minutiae pairings between two fingerprints. The paper mainly involves enhancement, segmentation, feature extraction, and finally minutiae matching. A score is generated, and based on the score, the matching/non-matching can be concluded.

Aliaa et al., [9] Feature extraction algorithms have been presented involving four vital steps. The first step determines the center point of the image, followed by forming small squares or blocks around the center point. The third step uses Gabor filtering to find the region of interest, and the final step computes the average absolute deviation from the mean

3. Methodology of the work

The fingerprint recognition problem can be grouped into two sub-domains such as:- i) fingerprint



verification ii) fingerprint identification (Figure 1).

Figure 1: Block diagram

Fingerprint verification involves comparing a claimed fingerprint with a stored fingerprint, with the goal of confirming the authenticity of an individual. This process is primarily used to verify a person's identity, and it requires the individual to submit their fingerprint to the verification system. The fingerprint representation is then saved in a compressed format, along with the person's identity and name. When the individual's fingerprint is applied to the verification

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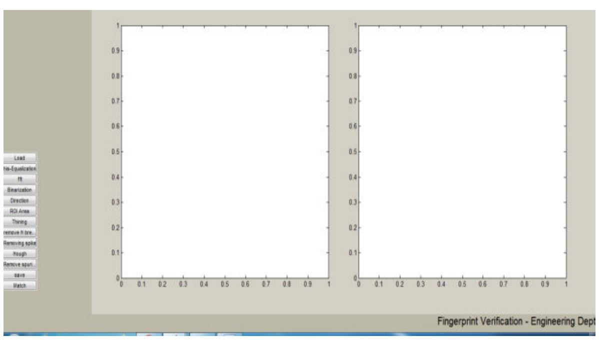
system, their identity can be easily confirmed. This process is also referred to as one-to-one matching.

On the other hand, fingerprint identification is used to determine an individual's identity based on their fingerprint. This process is commonly used in criminal investigations, where the system matches an unknown fingerprint against a database of fingerprints to associate a crime with an identity. This process is also known as one-to-many matching. Fingerprint identification has traditionally been used to solve crimes and apprehend criminals.

4. Results and Discussions

Two distinct datasets, each comprising eight fingerprint images, are employed to assess the accuracy of fingerprint recognition. The performance of the fingerprint recognition system is evaluated by calculating the False Matching Ratio (FMR), False Non-Matching Ratio (FNMR), and threshold. The FMR refers to the instances where a fingerprint matches with multiple fingerprints, whereas the FNMR represents the cases where a fingerprint fails to match with a different individual's fingerprint. The threshold value serves as a criterion to determine whether a match is true or false. If the matching value exceeds or equals the threshold, it is considered a valid match; otherwise, it is rejected. The results obtained for FMR and FNMR for the two datasets are presented.

The Matlab procedure as follows:



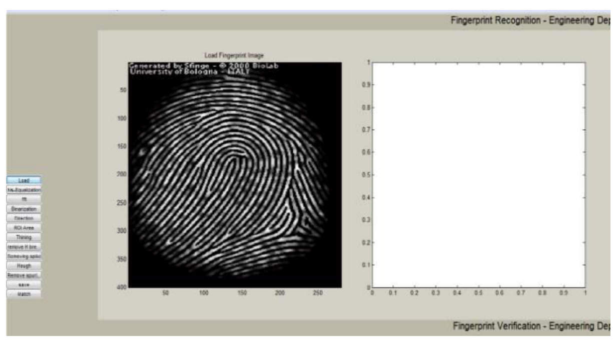


Figure 2: Main window of the GUI tool **Figure 3: Load the finger print image**

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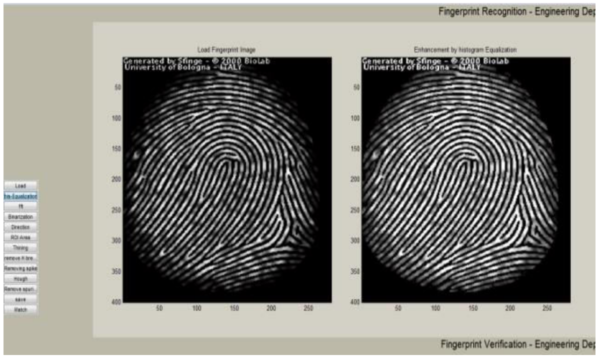


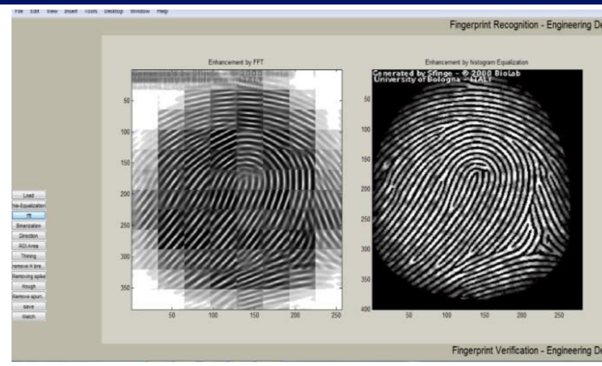
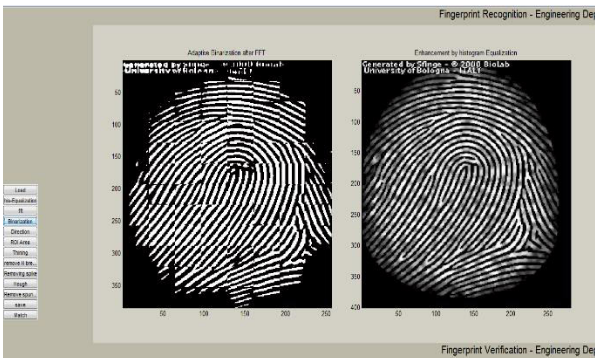


Figure 4: Histogram equalization **Figure 5: FFT**



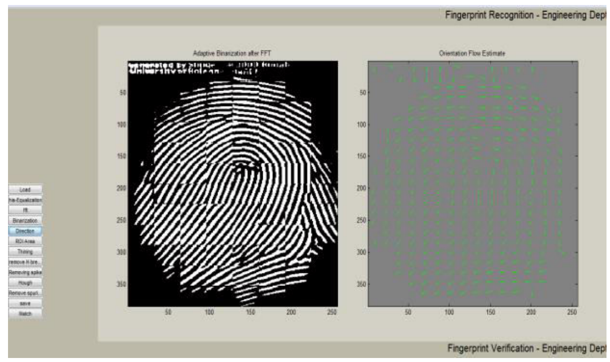
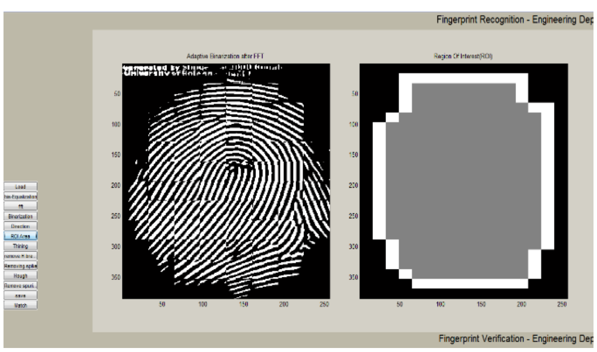


Figure 6: Direction **Figure 7:**
Binarization



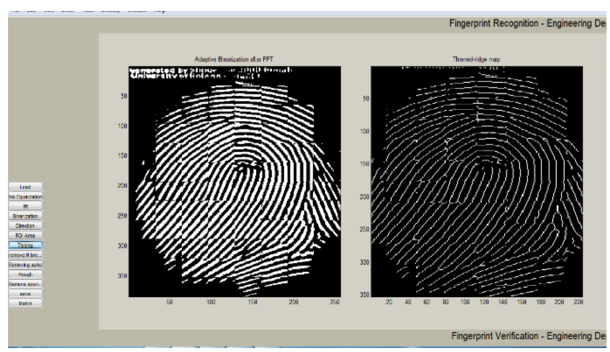


Figure 8: Region of Interest **Figure 9: Thinning**

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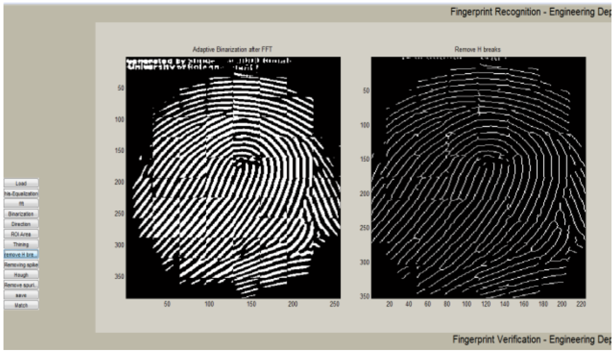


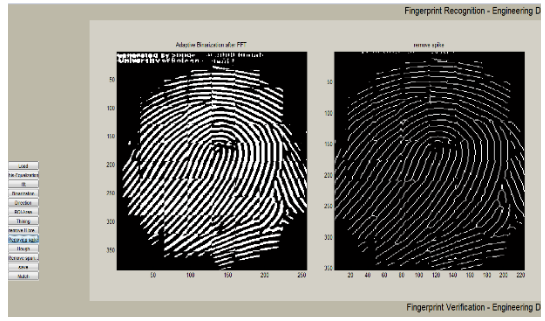
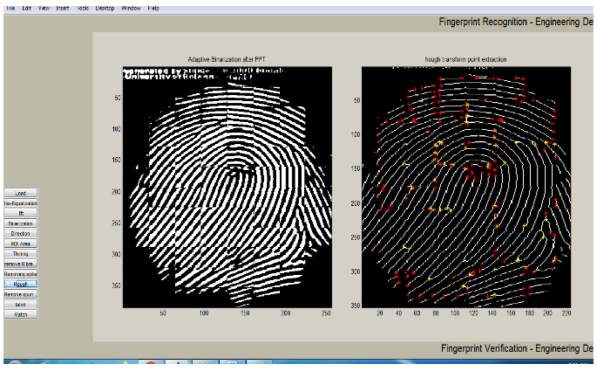


Figure 10: Removing H breaks

Figure 11: Removing spike



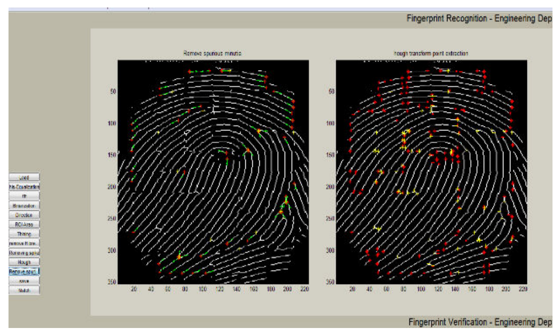


Figure 12: Hough transform

Figure 13: Remove spurious

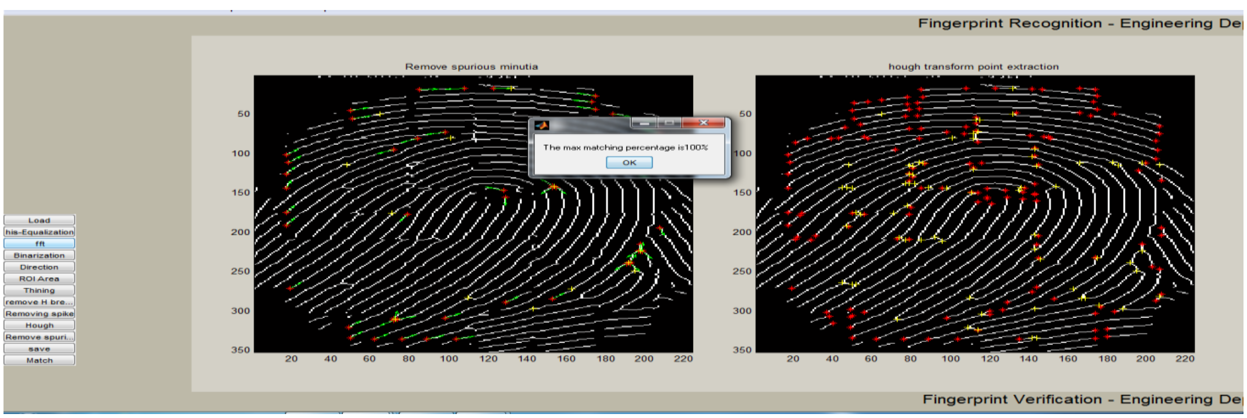


Figure 6.14: Matching Accuracy

Conclusion

A novel approach to fingerprint recognition is proposed, which involves extracting minutiae points from fingerprint images and comparing them to determine matches. This technology has far-reaching implications for security and identity verification. To improve the accuracy of fingerprint matching, a recognition system is developed that utilizes preprocessing, enhancement, and segmentation techniques to extract high-quality minutiae points from noisy images. The system's performance is evaluated, and future research directions involve refining the approach to achieve even higher accuracy and exploring advanced techniques for minutiae extraction and matching.

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