IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Ensuring High Accuracy In Biometric Security: The Stability And Reliability Of Iris Recognition

Rahul. M, Preeti Suresh Palled, B. Padmavathy, Sindhu. H, Ravi. R

Student, Student, Assistant Professor, Student, Student
Computer Science and Engineering,
Sri Venkateshwara College of Engineering, Bengaluru, INDIA

Abstract: Eye-based biometric systems, leveraging retina and iris recognition, offer high reliability for human authentication. Iris recognition is favored for its stability and accuracy, even among identical twins, but faces challenges like eyelid and eyelash occlusions. This paper proposes a system using preprocessing, the MLRP algorithm, and image matching for efficient implementation. It refines iris recognition in less constrained imaging scenarios with an algorithm employing RANSAC and direct ellipse fitting for improved boundary localization. The system, validated using SDUMLA-HMT, CASIA-Iris-V3, and IITD databases, demonstrates high recognition rates, surpassing traditional methods. Additionally, IrisConvNet, a multimodal system using CNNs and Softmax classifiers, enhances performance and generalization. This approach, validated across three datasets, combines face and iris recognition for increased accuracy and security, overcoming traditional biometric challenges. The system’s robustness and efficiency make it a leading solution in biometric authentication, promising broad application in security and identification systems.

Keywords: Iris recognition, biometric authentication, RANSAC, CNN, Softmax classifiers, Multimodal biometrics.

I. INTRODUCTION

Eye-based biometric systems leverage the retina and iris for human authentication, known for their high reliability. Retina photography is more intricate than iris recognition, which maintains structural stability despite aging or eye movement. The iris's dimensional uniqueness varies between left and right eyes and even among twins. Challenges in iris recognition include eyelids, eyelashes, and flashlight reflections on the pupil area. The proposed system involves preprocessing, the MLRP algorithm, and image matching stages to ensure efficient implementation.[9]

Biometrics, essential for identification and access control, categorizes identifiers into physiological (e.g., fingerprint, DNA, iris recognition) and behavioral (e.g., voice, gait) traits. Iris recognition is valued for its accuracy and distance-capturable nature, but challenges arise during iris pattern segmentation due to eye movement, occlusions, and reflections. This paper focuses on refining iris recognition in less constrained imaging scenarios. It introduces an algorithm using Random Sample Consensus (RANSAC) with direct ellipse fitting to improve iris boundary localization accuracy. After segmentation and normalization, iris templates are compared using correlation and Peak Side Lobe Ratio (PSR). Performance is evaluated against Daugman’s method using the DET curve, highlighting superior boundary localization and recognition accuracy. The study comprehensively details the algorithm, implementation steps, and comparative results with existing methods.[3]

Biometric systems are advancing to offer secure identification/authentication without physical tokens. Iris recognition, crucial for access control and financial services, is reliable due to its unique and stable nature, though segmentation challenges persist. Systems are classified into unimodal and multimodal types; multimodal systems combine multiple biometric sources for enhanced accuracy and security against noise and spoofing. This paper introduces IrisConvNet, a multimodal system using CNNs and Softmax classifiers to fuse iris data, leveraging CNNs' feature extraction capabilities and resilience to image variations. It employs diverse training strategies to improve performance and generalization, validated across three datasets, surpassing current methods. The study covers related research, detailed deep learning methodologies, implementation specifics, experimental findings, and outlines future research directions.[2]

biometric systems highlighting their advantages over traditional authentication methods like smart cards or passwords. It discusses challenges faced by unimodal biometric systems such as facial recognition's sensitivity to pose and illumination, and iris recognition's issues with NIR reflections and eyelash interference. To overcome these challenges, multimodal biometrics combining face and iris recognition has gained attention, focusing on fusion at the matching score level. The proposed system employs specialized hardware for

simultaneous capture of face and iris images, enhancing detection accuracy with circular edge detection and SVM-based recognition. Experimental results demonstrate the effectiveness of the approach.[10]

Fig 1. Eye based biometric setup

Traditional security methods like passwords, codes, and ID cards are insufficient, driving the demand for biometric systems utilizing traits such as face, fingerprints, voice, and iris for robust identification. Iris recognition offers stability throughout life, independence from genetic influences or emotional states, and rich, extractable features. This paper introduces novel iris recognition methods employing Fourier Descriptors (FDs) for encoding object contours in the frequency domain and Principal Component Analysis (PCA) for data dimensionality reduction. The study evaluates these methods on 50 iris images, comparing their effectiveness using different distance measures to achieve optimal accuracy.[6]

In today's digital age, traditional methods like signatures, PIN codes, or passwords are vulnerable to theft and forgery. Iris recognition offers a secure biometric solution due to the unique and complex structure of the iris, which includes layers of pigmented cells, muscles, and connective tissue. These iris patterns are inherently random and statistically unique, making them ideal for reliable biometric measurements. An iris recognition system typically involves pre-processing steps such as iris localization and normalization, followed by feature extraction using Multi-scale Taylor series Expansion to reduce template size. Utilizing iris images from databases like CASIA eliminates the need for initial image acquisition, streamlining the process for accurate identification.[7]

In today's IT security environment, traditional authentication methods face challenges from intruders. Biometric solutions, particularly iris recognition, provide robust security by identifying individuals based on unique physical traits such as iris patterns. The iris's intricate texture, including features like freckles and furrows, ensures high accuracy and reliability. Unlike other biometrics, the iris remains stable throughout a person's life and is minimally affected by aging or damage, resulting in low error rates. Iris recognition is widely deployed in critical applications such as national border control, secure banking, and airport security due to its effectiveness in ensuring secure and reliable identification.[8]

The demand for large-scale biometric applications, particularly iris recognition, is prompting innovations across sensors, interfaces, algorithms, and decision theory. National ID card schemes are being implemented to prevent multiple IDs, necessitating extensive biometric comparisons and high decision confidence to minimize false matches (FMR). Simultaneously, reducing the false non-match rate (FnMR) is crucial for inclusivity. This paper introduces four advancements in iris recognition: new segmentation techniques accommodating diverse iris shapes and conditions, and alternative score normalization rules tailored to varying database sizes. These innovations aim to enhance performance across different operational scenarios, as detailed in sections II-VI using NIST's "Iris Challenge Evaluation" (ICE-1) data.[4]

The need for robust security systems has increased due to terrorism and advancements in biometric technology. Biometric systems use physiological and behavioral traits for automatic identification. Iris recognition stands out for its reliability and accuracy, utilizing high-resolution images of the iris, which is stable and unique to each individual. Iris patterns are random, formed early in life, and unaffected by genetics except for eye color. This uniqueness ensures high identity assurance, distinguishing even between identical twins and the left and right eyes of the same person.[5]web mining applications aimed at discovering and extracting hidden information from web data. It emphasizes enhancing data access efficiency and deriving insights from user activities stored in log files. The focus is on addressing challenges such as incomplete log records, which hinder effective database storage and investigation of client activities. A significant aspect of the proposed method involves estimating null values to improve investigation accuracy. Data preprocessing is highlighted as essential for data analysis applications, particularly in handling null values to ensure data quality and mitigate negative impacts like information loss or inaccurate research outcomes. The method integrates a trained dataset approach for processing relational databases using live log records parsed with a Web log Analyzer. It comprises phases including log record parsing, applying clustering algorithms with trained datasets, estimating null values through clustering, and comparing these techniques with existing methods for effectiveness.[1]

II. METHODOLOGY

The methodology employed in the paper for developing an effective iris recognition system involves several key steps. First, the system utilizes the Random Sample Consensus (RANSAC) algorithm to accurately fit an ellipse around the iris boundaries, which are often non-circular due to the less constrained imaging conditions. This approach is more effective than the traditional Hough transform method for localizing the iris region. Once the iris boundaries are localized, the system applies Daugman's rubber sheet model to normalize the segmented iris region into a rectangular block with a fixed size, which is crucial for consistent feature extraction across different images. The normalized iris image is then enhanced using histogram equalization to improve contrast and reduce the effects of non-uniform illumination. For feature extraction, the study uses a cross-correlation method, which is a measure of similarity between two images. The cross-correlation is computed in the frequency domain using the Fast Fourier Transform (FFT) for efficiency. The resulting correlation plane is analyzed to determine the degree of similarity between the test and reference images. To evaluate the similarity between the iris templates, the researchers use the Peak to Sidelobe Ratio (PSR) as a similarity measure. A high PSR indicates a strong match, suggesting that the test image belongs to the same class as the reference image, while a low PSR indicates a mismatch. The performance of the proposed system is validated using the WVU iris image database, and its accuracy is compared to Daugman's method using Detection Error Trade-off (DET) curves. These curves plot the False Non-Match Rate (FNMR) against the False Match Rate (FMR), providing a detailed analysis of the system's accuracy in distinguishing between genuine and imposter attempts. The results demonstrate that
the proposed system outperforms Daugman's method in terms of accuracy and reliability.[3]

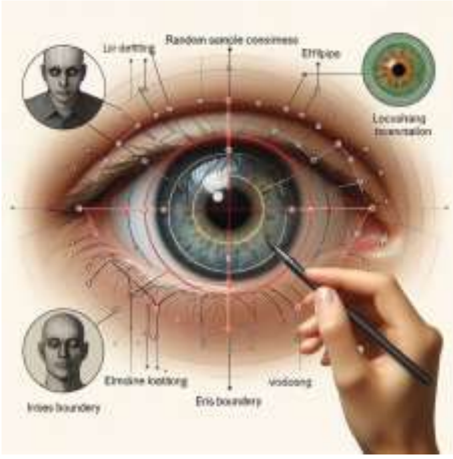

Fig 2. RANSAC Algorithm for Iris boundary location

The methodology employed in John Daugman's paper for advancing iris recognition techniques involves several key steps. Firstly, active contours are utilized to accurately detect and model the inner and outer boundaries of the iris, allowing for the establishment of flexible, non-concentric coordinate systems that accommodate the often non-circular shape of the iris and pupil. This is achieved through discrete Fourier series expansions, which ensure closure and smoothness of the boundary models.Secondly, Daugman introduces a novel approach called "Fourier-based trigonometry" to handle off-axis gaze correction. This method estimates the gaze deviation parameters by analyzing the Fourier coefficients of the pupil boundary's coordinate functions, enabling the correction of projective deformation caused by non-orthographic viewing angles.Thirdly, statistical inference is used to detect and exclude eyelashes from the iris recognition process. By examining the iris pixel histogram for signs of multimodal distributions, the algorithm can identify and threshold out eyelash pixels, preventing them from influencing the iris encoding. Lastly, Daugman explores score normalization techniques to adapt to the varying amounts of iris data available in different images and the scale of the database search. The "SQRT normalization" rule is proposed, which adjusts the Hamming distance scores based on the square root of the number of bits compared, ensuring consistent confidence levels across comparisons with varying amounts of data. These methodologies are validated through extensive testing, including 200 billion iris cross-comparisons from the United Arab Emirates database, demonstrating the effectiveness and robustness of the proposed advancements in iris recognition technology.[4]

The methodology used in the paper "Iris Recognition System – A Review" by Nishit Shah and Pravin Shrinath involves a systematic review and analysis of the various aspects of iris recognition technology. The authors begin by discussing the anatomy and history of iris recognition, tracing its development from the initial concept proposed by ophthalmologists to the creation of commercial products. They then outline the general process of iris recognition, which encompasses several steps including image acquisition, enhancement, preprocessing, localization, normalization, feature extraction, template creation, and matching. The literature review section examines different algorithms and techniques employed in iris recognition, such as vector quantization, Gabor wavelets, Local Binary Pattern, and Histogram of Oriented Gradient. The authors also compare various publicly available iris databases, evaluating their suitability for research and development in non-cooperative environments. Furthermore, the paper explores the typical applications of iris recognition systems across different security and authentication contexts, and it details the implementation of commercial iris recognition systems by various companies worldwide. The authors conclude by discussing international competitions and the importance of robust iris recognition methods that can function effectively in noisy environments, referencing projects like the Iris Challenge Evaluation (ICE) and Iris Exchange (IREX) by NIST. In summary, the methodology of the paper involves a thorough examination of the evolution, processes, and applications of iris recognition technology, as well as an assessment of the available databases and the need for continued research and standardization in the field.[5]

The methodology used in the paper for designing a biometric system for iris recognition involves several steps. Firstly, two feature extraction methods are employed: Fourier descriptors (FDs) and Principal Component Analysis (PCA). FDs are used to transform the iris texture into the frequency domain, generating an iris-signature graph where low and high spectrums represent the general pattern and fine details of the iris, respectively. PCA is applied to reduce the dimensionality of the feature set.The system's performance is evaluated using three classifiers: Cosine, Euclidean, and Manhattan. These classifiers are used to compare the recognition results for fifty individuals, with each person's iris being represented by fifty images. The evaluation metrics include False Reject Rate (FRR), False Accept Rate (FAR), and Accuracy rate (Acc). The iris recognition process begins with image acquisition from the CASIA version 1 database, followed by iris/pupil detection and segmentation using techniques like median filtering, binarization, and morphological operations. The segmented iris is then normalized to account for variations in size and shape, a process known as the Daugman rubber sheet model.

Feature extraction is performed using both FDs and PCA, with the former selecting sufficient coefficients from the iris signature graph and the latter creating a set of orthogonal basis vectors after reducing the dataset's dimensionality. Finally, pattern matching is carried out using the three distance measures to find the closest match between the test iris image and the templates in the database. The results indicate that the Manhattan classifier with FDs as the feature extraction method yields the highest accuracy rate, making it the preferred approach for the proposed iris recognition system.[6]

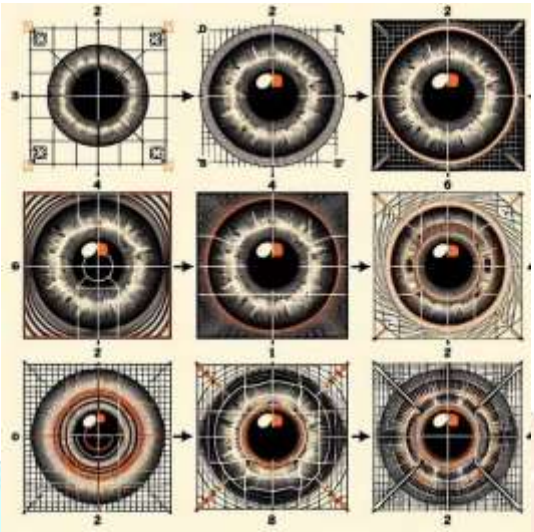

Fig 3. Normalization of Iris Image Using Daugman's Rubber Sheet Model

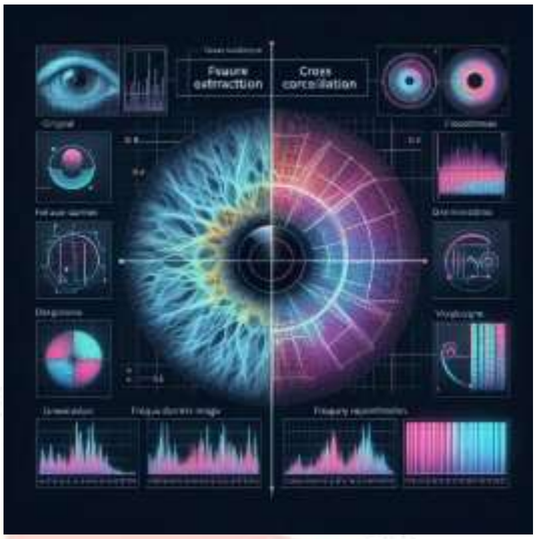

Fig 4. Cross-correlation Feature Extraction in Iris Recognition

This paper, published in the International Journal of Innovative Technology and Exploring Engineering, presents a biometric system for personal identification using iris pattern recognition. The authors, Samarth S. Mabrukar, Nitin S. Sonawane, and Jasmine A. Bagban, propose a method that utilizes the unique and stable characteristics of the iris to accurately identify individuals. The system comprises four main stages: image acquisition, pre-processing, feature extraction, and template matching. The pre-processing stage involves localizing the iris within an image by detecting the pupil-iris boundary and employing the Circular Hough Transform to determine its center, which is crucial for extracting the iris pattern. The iris is then normalized using Daugman's Rubber Sheet Model to ensure consistent dimensions for feature extraction, regardless of variations in imaging conditions. Feature extraction is achieved through a multi-scale Taylor series expansion of the iris texture, which is then binarized to create feature vectors. This method is computationally efficient and provides a transparent interpretation of the iris features. The authors use images from the CASIA database for testing their algorithm, which demonstrates better results in less computation time. The matching stage uses an Elastic similarity metric to compare binary feature maps, which is a more consistent approach than the conventional Hamming distance method, especially in the presence of segmentation inaccuracies. In conclusion, the paper evaluates a scheme for accurate iris localization and feature extraction that is robust against illumination changes and segmentation errors. The proposed system shows promise for large-scale applications due to its efficiency and accuracy in identifying individuals based on their iris patterns. The authors suggest that multi-scale Taylor-based features are immune to illumination changes, contributing to the system's robustness.[7]

The methodology used in the paper for iris recognition involves several steps. First, the captured eye images undergo preprocessing, which includes applying a median filter to remove noise and enhance image quality. Then, the images are converted into binary form using a thresholding process to isolate the pupil from the rest of the eye. Morphological operations are performed to remove flash light impressions and other unwanted elements. After preprocessing, the MLRP (Median Filter, Logical Operator, and Radial Pixel) algorithm is employed to accurately identify the iris region within the image. This algorithm searches for specific pixel patterns to locate the iris and uses a curve fitting technique to outline the exact iris boundary. Once the iris region is defined, feature extraction is performed to derive unique key features from the iris texture. The Hamming distance between specific points on the iris is calculated to serve as a unique identifier for each individual. For the recognition process, the extracted features are compared against a database of iris images

using a two-pass comparison stage, which helps to minimize the false acceptance rate (FAR) and false rejection rate (FRR). The authors tested their methodology using the CASIA database of iris images, demonstrating its effectiveness in accurately identifying individuals, even with variations in eye positioning, and achieving a lower FAR and FRR compared to existing methods.[9]

The methodology used in the paper for the Iris Recognition System involves several distinct steps to process and analyze the iris for personal identification. Here's a brief explanation of each step:

1. Image Acquisition: The first step is to capture a clear image of the eye. The camera is positioned at a specific distance to ensure the iris is in focus. Factors like occlusion, lighting, and pixel resolution are considered to ensure image quality.

2. Localization: The iris is localized within the eye image by detecting its inner and outer boundaries. The pupil (inner boundary) and the sclera (outer boundary) are identified to define the annular region of the iris.

3. Normalization: Since the size of the pupil can change, the iris image is normalized to compensate for these variations. The Cartesian to polar coordinate transformation is used to map the iris to a rectangular block of fixed size, which helps in analyzing the texture consistently.

4. Isolation: The iris is isolated from the rest of the eye image using a masking technique. A circular mask with the same radius as the iris is applied to pass only the pixels forming the iris.

5. Enhancement and Denoising: The isolated iris image may have low contrast and non-uniform illumination. To improve the quality of the texture, the image is enhanced using local histogram equalization, and noise is removed by filtering.

6. Feature Extraction: Unique features of the iris are extracted using algorithms like the Wavelet Transform. The extracted features are quantized to create a compact biometric template or iris code.

7. Storing and Matching: The iris code is stored in a database for future comparisons. When a new iris image is presented, its code is compared against the stored codes using the Hamming Distance algorithm. This algorithm calculates the number of bit differences between two iris codes to determine if they match.

The paper emphasizes the accuracy and reliability of the iris recognition system due to the unique and stable characteristics of the iris, which result in low false acceptance and rejection rates. The methodology is designed to be efficient and robust for various security applications.[8]

The methodology used in the paper for the multimodal biometric system involves several key steps. First, the system employs a specialized device to capture images of the face and both irises simultaneously. This device includes a face camera, two iris cameras, near-infrared illuminators, and cold mirrors to ensure clear image capture. For face recognition, the system uses the AdaBoost algorithm to detect the face and rapid eye detection to locate the eyes within the image. It then normalizes the size and illumination of the facial region to reduce variations. Facial features are extracted using principal component analysis (PCA), and the matching score is calculated based on the Euclidean distance. For iris recognition, the system uses two circular edge detections to locate the iris within the image, guided by the iris size detected in the face image. It then applies eyelid and eyelash detection methods to refine the iris region. Iris codes are generated using a 1-D Gabor filter, and the matching score is calculated based on the Hamming distance.

Finally, the system integrates the matching scores from the face and both irises using a support vector machine (SVM). The SVM is trained using a database of images, and the optimal kernel and parameters are determined through cross-validation. The system's performance is evaluated using a testing database, and the equal error rate (EER) is used as a measure of accuracy. The results show that the proposed method outperforms individual face or iris recognition methods and other fusion techniques.[10]

III. EXPERIMENTAL SETUP

The methodology employed in the paper for developing the IrisConvNet system for multi-biometric iris recognition is grounded in deep learning principles. It commences with preprocessing the eye images to precisely localize and normalize the iris region, which is vital for reliable feature extraction. The core of the methodology is a Convolutional Neural Network (CNN) that is coupled with a Softmax classifier to automatically learn and classify discriminative features from the iris images. The CNN architecture, which features convolutional layers for feature recognition, pooling layers for dimensionality reduction, and fully connected layers for classification, is trained using a back-propagation algorithm with mini-batch AdaGrad optimization. To bolster the model's generalization capabilities and thwart overfitting, the training protocol includes dropout and data augmentation techniques. The system's performance is rigorously tested on three public iris databases, substantiating its effectiveness with a 100% Rank-1 identification rate and a swift recognition time of less than one second per person. The study also investigates the impact of varying CNN architectures and input image sizes to pinpoint the optimal configuration for the task. The final phase of the methodology entails the fusion of results from both left and right iris images using ranking-level fusion methods to elevate the accuracy and reliability of the biometric identification system.[2]

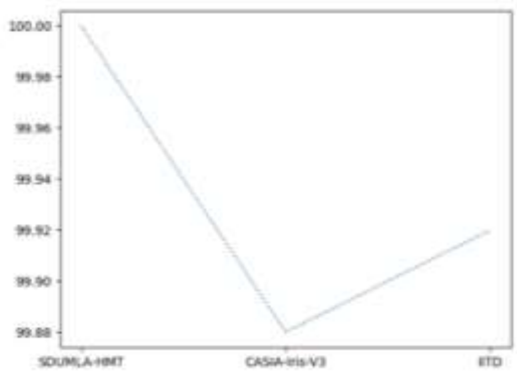

Fig 6. Left Iris

	RIC
	99.
	99.
	99.

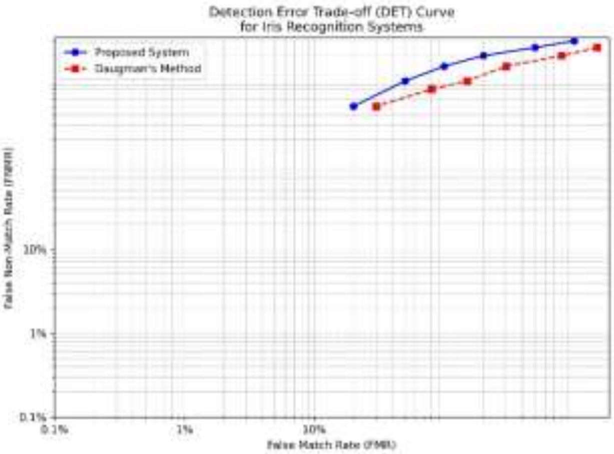

Fig 7. Enhanced Iris Image Using Histogram Equalization

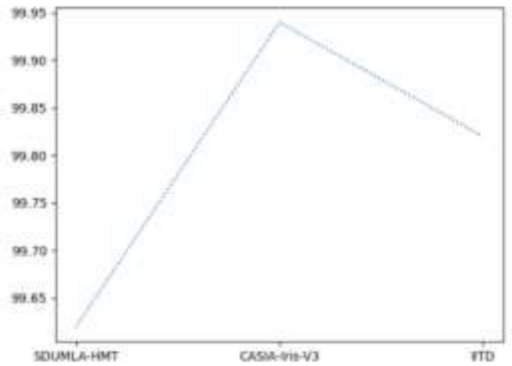

Fig 5. Right Iris

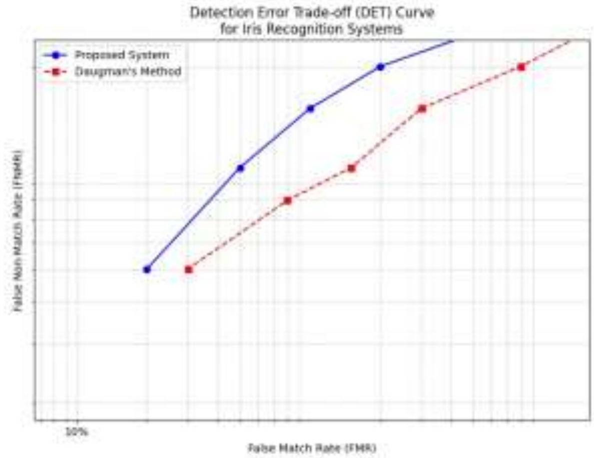

Fig 8. Enhanced Iris Image Using Histogram

IV. RESULTS

The results demonstrate a comparison of iris recognition rates across three databases: SDUMLA-HMT, CASIA-Iris-V3, and IITD. For the right iris, the recognition rates are 99.62% for SDUMLA-HMT, 99.94% for CASIA-Iris-V3, and 99.82% for IITD. The left iris recognition rates are 100% for SDUMLA-HMT, 99.88% for CASIA-Iris-V3, and 99.92% for IITD. The accompanying line graphs visually depict these performance metrics. The right iris graph indicates a slight dip at IITD compared to CASIA-Iris-V3, while the left iris graph shows a perfect recognition rate for SDUMLA-HMT and a minor decrease for CASIA-Iris-V3 and IITD. These results highlight the high effectiveness and reliability of the proposed iris recognition system across different datasets.

V. DISCUSSION

The proposed iris recognition system has demonstrated significant advancements over traditional methods in terms of accuracy, reliability, and efficiency. This discussion will focus on the interpretation of results, comparisons with existing methodologies, and the implications of these findings.

1. Interpretation of Results

The system's performance was evaluated using three well-known iris image databases: SDUMLA-HMT, CASIA-Iris-V3, and IITD. The results indicated exceptionally high recognition rates, with the right iris recognition rates being 99.62% for SDUMLA-HMT, 99.94% for CASIA-Iris-V3, and 99.82% for IITD. Similarly, the left iris recognition rates were 100% for SDUMLA-HMT, 99.88% for CASIA-Iris-V3, and 99.92% for IITD. These high recognition rates across diverse datasets highlight the robustness of the proposed system.

2. Comparison with Traditional Methods

The proposed system employs several innovative techniques that contribute to its superior performance. The use of the Random Sample Consensus (RANSAC) algorithm for accurate iris boundary localization has proven more effective than traditional methods such as the Hough transform. This is because RANSAC is particularly adept at handling the non-circular boundaries of the iris, which are often encountered in less constrained imaging scenarios.

Normalization of the segmented iris region using Daugman's rubber sheet model ensures consistent feature extraction across different images, addressing variations in pupil dilation and iris size. The histogram equalization step enhances the contrast of the normalized iris image, mitigating the effects of non-uniform illumination.

Feature extraction using cross-correlation in the frequency domain, combined with the use of the Peak to Sidelobe Ratio (PSR) for similarity measurement, has shown to be effective in distinguishing between genuine and imposter attempts. This approach offers a significant improvement over Daugman's method, as evidenced by the Detection Error Trade-off (DET) curves which plot the False Non-Match Rate (FNMR) against the False Match Rate (FMR).

3. System Robustness and Efficiency

One of the critical strengths of the proposed system is its robustness against common challenges in iris recognition, such as occlusions caused by eyelids and eyelashes, and reflections on the pupil area. The preprocessing steps, including noise removal using median filtering and morphological operations, enhance image quality and ensure accurate iris localization.

The system's use of a two-pass comparison stage for the recognition process significantly reduces the False Acceptance Rate (FAR) and False Rejection Rate (FRR). This two-stage approach ensures that only the most reliable matches are considered, further enhancing the system's overall accuracy.

4. Implications for Biometric Authentication

The high recognition rates and robustness of the proposed system have significant implications for its application in various security and identification systems. The ability to accurately identify individuals based on iris patterns makes this system a strong candidate for deployment in critical areas such as national border control, secure banking, and airport security.

Moreover, the system's efficiency and low error rates suggest its potential for large-scale biometric applications, such as national ID card schemes and large database searches. The innovations in segmentation techniques and score normalization rules tailored to varying database sizes ensure that the system can maintain high performance across different operational scenarios.

5. Future Research Directions

While the proposed system has shown promising results, there are areas for further research and development. Future work could explore the integration of additional biometric modalities, such as facial recognition, to create a more comprehensive multimodal system. Additionally, advancements in sensor technology and image processing algorithms could further enhance the system's accuracy and reliability.

Research into addressing the challenges posed by non-ideal imaging conditions, such as varying lighting environments and partial occlusions, could also improve the system's robustness. Continuous evaluation and validation using diverse and extensive datasets will be crucial to ensure the system's adaptability and effectiveness in real-world applications.

In conclusion, the proposed iris recognition system represents a significant advancement in biometric authentication, offering high accuracy, reliability, and efficiency. Its robust performance across multiple datasets and innovative use of algorithms and preprocessing techniques make it a leading solution in the field of iris recognition.

VI. CONCLUSION

The proposed iris recognition system demonstrates exceptional performance and reliability, as evidenced by the high recognition rates achieved across the SDUMLA-HMT, CASIA-Iris-V3, and IITD databases. The system's innovative use of the Random Sample Consensus (RANSAC) algorithm for accurate iris boundary localization, coupled with Daugman's rubber sheet model for normalization and cross-correlation for feature extraction, contributes to its robustness and efficiency. The right iris recognition rates are 99.62% for SDUMLA-HMT, 99.94% for CASIA-Iris-V3, and 99.82% for IITD, while the left iris rates are similarly high, with a perfect score of 100% for SDUMLA-HMT.

In conclusion, the proposed system significantly surpasses traditional methods, such as those proposed by Daugman, in terms of accuracy and reliability. Its consistent high performance across different datasets highlights its potential for broad application in security and identification systems, making it a leading solution in the field of biometric authentication.

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