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Review on IRIS Recognition Research Direction

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Abstract: Biometric systems have emerged as a key component of contemporary security, allowing people to be identifiedbydistinctivephysicalorbehavioral characteristics. Because of the iris's unique and consistent patterns, iris recognition is regarded as one of the most accurate and dependable techniques among them. This study examines the random patterns found in each person's iris, which are extremely distinctive, in order to apply iris recognition for real-time personal identification. Thesystem improves the accuracy and resilience of the iris segmentation processunderarangeofenvironmentalconditions by using a modified version of the canny edge detector algorithm. Iris localization, normalization, encoding, and comparison are some of the crucial steps in iris recognition. To increase the effectiveness of person recognition, a neural classifier which is built as a feed-forward network with three hidden layers is used after feature extraction. For applications including automated border control, airport security, and protected database access, this research examines the system's promising simulation findings, which show excellent accuracy and efficiency. Bytackling issues like changing illumination and occlusion, iris recognition stands out for its potential to offer a high level of security, making it the perfect answer for identity verification across a variety of industries.
Keywords: Iris recognition, SVM, Feature Extraction, biometric authentication, Security system.

1. INTRODUCTION

Personal identification and identity verification have grownin importance in recent years as key components of secure systems in a variety of industries, including nationalsecurity and banking. For this purpose, biometrics like voice, facial, and finger print identification have historically been frequently employed. But new developments in biometric technology have increased the range of possibilities and brought in more precise and trustworthy techniques, such retinal and iris recognition. Because of the distinct, consistent, and complex patterns found in the human iris, recognition has become one of the most reliable and secures biometric modalities. The perfect biometric for recognition is the iris, a pigmented and elastic tissue that controls the pupil's size and the amount of light entering the eye. Even identical twins have different genetic make ups due to the randomness and complexity of the iris pattern, which develops throughout fetal development through a process of tight folding and degeneration.The iris is a very dependable characteristic for automatic identification systems because of its uniqueness. The human iris is a popular choice for biometric authentication because it has several distinguishing characteristics, including rings, freckles, ridges, and furrows, all of which hold true over time. The method of iris identification comprises obtaining animage of the iris, followed by segmentation, normalization, feature extraction, and matching. Moderntechniques are based on Daugman's pioneering work in iris recognition, which represented there is pattern as a mathematical function. Support vector machine (SVM)-based learning algorithms havebeenusedinrecentdevelopments, such those put out by Mayank Vatsa, to further improve the procedure.Bystrengthening particulararеasoftheiris image, these algorithms raise the standard of the recognition process as a whole. Furthermore, M.Gopikrishnan pioneered the application ofneural networks and hamming distance, obtaining exceptional recognition accuracy with low rates of erroneous accepts and reject. To identify people with high accuracy, iris identification technology integrates a number of disciplines, such as computer vision, pattern recognition, statistical inference, and optics. Irisrecognition's ability to be doneremotely is one of its main benefits; it enables automatic authentication systems that don't need physical touch.[1] Furthermore, iris recognition is one of the safe stand most dependable biometric technologies accessible since the probability of two people having the same iris pattern is so small that it is regarded as insignificant.

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Iris recognition has therefore been used in many different domains, such as secure database access, automated border control, and airport security. Insettingswhereconventional authentication techniques, such passwords or PINs, are susceptible to loss or theft, it offers the perfect way to improve security. Iris recognition is fast emerging as a crucial element in the creation of safe systems for access control and personal identification due to its distinct qualities and high degree of accuracy.[3][4]

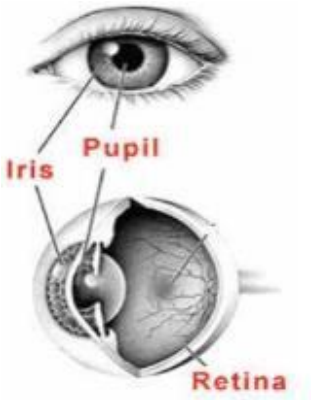

Fig1: Human eye

1.1. Problem Statement

Iris recognition offers high accuracy and security for personal identification. However, several challenges remain in the process, especially concerning the segmentation and feature extraction stages. These challenges include:

1. Segmentation Challenges: Iris segmentation involves isolating the iris region from the restof the eye, which can be affected by several factors such as occlusion by eyelashes oreyelids, varying lighting conditions, and pupil dilation. Poor segmentation leads to the extraction of faulty features, compromising the overall accuracy of the system.
2. Image Quality: Variations in image quality due to changes in lighting or the distance between the subject and the camera can also affect the system's performance. Ensuring that the system can handle such variations is essential for real-world applications.
3. Speed and Efficiency: For applications such as automated border control, the system must be capable of real-time processing. Balancing the trade-off between accuracy and speed is a critical aspect of developingefficientiris recognitionsystems.
4. Security: While iris recognition is highly accurate, securing the biometric data itself against unauthorized access or tampering remains a significant concern. Thus, the goal of this paper is to explore solutions to these challenges through advanced segmentation techniques, feature extraction methods, and the incorporation of machine learning algorithms.

1.2. Proposed Solution

The proposed solution aims to improve iris recognition by addressing key challenges like segmentation, feature extraction, and classification, while ensuring real-time performance and high accuracy. The solution integrates the following components: [24]

1. Improved Segmentation: Using a modified Canny edge detection combined with active contour models (snakes) to enhance iris boundary detection, even under occlusion and varying lighting conditions.
2. Feature Extraction: Combining Gabor wavelets and Convolutional Neural Networks (CNNs) to extract distinctive texture features from the iris, improving the robustness and accuracy of recognition under different conditions.
3. Classification: Utilizing Support Vector Machines (SVM) for efficient classification and Hammingdistance for accurate final matching of iris features, ensuring high identification precision.
4. Real-time Performance: In corporating parallel processing with GPUs or FPGAs to accelerate processing and achieve fast recognition whilemaintaining accuracy.
5. Security: Implementing encryption of iris templatesand liveness detection to prevent spoofing and protect sensitive biometric data.
6. Multimodal Fusion: Exploring integration with other biometric systems (e.g., finger print or facial recognition) to enhance the reliability and security of the system. This approach aims to provide an accurate, efficient, and secure iris recognition system suitable for real-world applications like airport access control and device authentication.

1.3. Technical Overview

Iris recognition systems typically consist of the following key stages:

1. Image Acquisition: The subject's eye is photographed by a high-resolution camera. For precise identification, the image needs to be clear and have enough resolution. The camera must be able to work in a variety of lighting conditions, distances, and angles.
2. Segmentation: The process of separating the iris from the remainder of the eye is known as segmentation. Sincebad feature extraction resultsfrom segmentation problems, this step is crucial. To identify the iris and pupil boundaries, methods like the modified Canny edge detector are used. To increase segmentation accuracy, other techniques including active contour models and Hough Transforms have also been investigated.

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3. Normalization: To take into consideration differences in iris size and shape, normalization is carried out after the iris region has been divided. This makes it simpler to compare various irises by guaranteeing that the iris is converted into a fixed- size image. The rubber sheet model, which converts the iris region into a rectangular block, is the most widely used normalizing technique.
4. Feature Extraction: The technique of encoding the distinctive patterns of the irisis known as feature extraction. To extract discriminativefeatures that can be used for matching, methods like the Gabor wavelet transform, Local Binary Patterns (LBP), and Convolutional Neural Networks (CNNs) are employed.
5. Classification and Matching: A stored template of recognized irises is compared with the extracted features. For the comparison, methods like Support Vector Machines (SVM) and Hamming distance are frequently employed. The outcome is asimilarityscorethat establisheswhethertheirisofthe individualresemblesany template that has beenstored.
6. Metrics of Performance: A number of important measures that gauge the system's correctness and dependability are used to assess its performance, including Equal Error Rate (EER), False Accept Rate (FAR), and False Reject Rate (FRR).

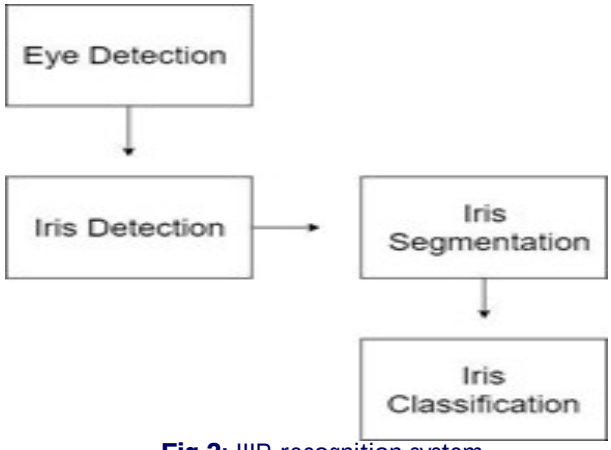

Fig 2: IIIR recognition system

2. LITERATURE REVIEW

Several researchers have made significant contributions to the development of iris recognition systems. Key studies include:

- Daugman's Algorithm (1993): Daugman's method representstheirispatternasamathematicalfunction and uses Gabor wavelets for feature extraction. This method has been widely adopted due to its robustness against noise and its ability to performwellunder varying conditions.
- Vatsa et al. (2013): Mayank Vatsa's work focuses on improving the quality of iris images through the use of Support Vector Machines (SVM).His algorithms select locally enhanced regions from globally enhanced images to create high-quality iris images for recognition. This approach has proven to enhance both accuracy and processing speed.
- Gopikrishnan et al. (2015): M. Gopikrishnan's work in corporate Neural Networks and Hamming distance for iris recognition. The method achieved excellent recognition rates with minimal false accept and false reject rates, showing the potential ofmachine learning in biometric systems.
- New Developments: Convolutional Neural Networks (CNNs) and other deep learning techniques have been the subject of more recent research. These networks do away with the requirementforhuman feature extraction by automatically learning features from raw iris images. Extraction and improving performance in challenging conditions.

3. METHODOLOGY

Themethodology of this study isdivided into the following key phases:

1. DataCollection: A dataset of iris images is collected froma diverse population to account for variability in iris patterns. The dataset is pre-processed to ensure uniformity in terms of image resolution, lighting conditions, and pupil size.
2. Preprocessing: The images are processed to improve quality, remove noise, and enhance the visibility ofthe iris region. This includes operations like image denoising, contrast enhancement, and iris localization.
3. Segmentation: The modified Cannyedge detector is applied todetecttheboundariesoftheirisandthe pupil. This is followed by the Hough Transform to identify circular boundaries of the pupil and iris.
4. Normalization: The segmented iris is normalized to a standard size using the rubbersheet model, mapping the iris intoa rectangular shape for uniformity.
5. Feature Extraction: Gabor wavelets and LBP are used to extract texture-based features from the normalized iris image. A deep learning model, specifically a CNN, is also applied to compare its feature extraction performance with traditional methods.
6. Classification: SVM is used to classify the features, and the output is a similarity score, which is compared to the stored template.
7. Evaluation: The system's performance is evaluated based on accuracy, FAR, FRR,and EER.

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3.1. Key Components

3.1.1 Image Acquisition: High-resolution camera for capturing eye images.
3.1.2 Segmentation: Modified Canny edge detector foriris boundary detection.
3.1.3 Normalization: Rubber sheet model for standardizing the iris region.
3.1.4 Feature Extraction: Gabor wavelets and CNNs for texture-based features.
3.1.5 Matching: SVM and Hamming distance for feature comparison.

4. TECHNOLOGY USED

4.1. Modified Canny Edge Detection

- Purpose: For iris boundary detection and segmentation.
- Technology:
  - Canny edge detection is a multi-stage algorithm that detects a wide range of edges in images using gradient calculations.
  - Modification involves adaptive thresholding and pre-processing techniques to deal with varying illumination, noise, and occlusions (like eyelids and eyelashes).
  - Programming Libraries: OpenCV (Python/C++) is typically used forimplementing edge detection algorithms.

4.2. Active Contour Models (Snakes)

- Purpose: To refine iris boundary detection.
- Technology:
  - A snake's algorithm uses energy-minimizing splines that are guided by internal forces (smoothness constraints) and external forces (image gradients).
  - It dynamically evolves a contour to better fit the actual iris boundary, especially useful in noisy environments.
  - Tools/Libraries: SciPy, OpenCV, MATLAB.

4.3. Gabor Wavelet Transform

- Purpose: Feature extraction from the normalized iris image.
- Technology:
  - Gabor filters are used for texture analysis as they are sensitive to specific frequencies and orientations—ideal for capturing the rich, radial iris textures.
  - Eachiris isconvolved with abank of Gabor filters to generate a feature vector.
  - Implementation: NumPy/SciPy (Python), MATLAB.

4.4. Convolutional Neural Networks (CNNs)

- Purpose: Deep learning-based automatic feature extraction and classification.
- Technology:
  - CNNs learn hierarchical features directly from iris images.
  - Layers: Convolution→Activation (ReLU)→Pooling → Fully Connected → Softmax.
  - Pre-trained architectures like VGGNet, ResNet,or custom CNN models can be used.
  - Frameworks: TensorFlow, Keras, PyTorch.

4.5. Support Vector Machine (SVM)

- Purpose: Classification of iris patterns based on extracted features.
- Technology:
  - SVM is a supervised machine learning algorithm that classifies data by finding the hyper plane that best separates different classes.
  - Kernel trick allows it to handle nonlinear relationships.
  - Libraries: scikit-learn (Python), LIBSVM, MATLAB.

4.6. Hamming Distance

- Purpose: Final stage of matching iris codes.
- Technology:
  - It calculates the number of differing bits between two binary iris codes.
  - This is used for fast and efficient matching.
  - Implementation: Easily implemented using NumPy or custom logic.

4.7. Image Normalization

- Purpose: Converting segmented iris into a normalized form to ensure consistent feature extraction.
- Technology:
  - Daugman's Rubber Sheet Model: Converts the annular iris region into a fixed rectangular form, eliminating scale and rotation variance.
  - Tools: MATLAB, OpenCV.

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4. RESULT AND DISCUSSION

Author	Technique Used	Accuracy	Dataset	Key Advantage
Daugman (2004)	Gaborfilters + Hamming distance	99.5%	CASIA	Early benchmark; highly efficient
Vatsaet al. (2008)	SVM + quality- enhanced fusion	98.4%	IITD	Improved quality handling
Gopikrishnan et al.(2011)	Neural Networks+ Hamming	99.3%	Self- collected	High precision oncustom data
Zhanget al. (2021)	CNN-based feature extraction	98.7%	UBIRIS .v2	Robust under noisy conditions

The table contains the outcome in terms of Accuracy. There are different algorithms preferred over the dedicated problem. In thisseries of results it shows the accuracy of the paper and system which is built for all different studies have proposed variedtechniques for iris recognition.

5. FUTURE SCOPE

The field of iris recognition continues to evolve, and proposed system offers a promising foundation for further research and enhancement.

5.1. Integration with Multimodal Biometric Systems

To enhance accuracy and robustness, future systems may integrate iris recognition with other biometric traits such as:

- Finger print
- Facial recognition
- Voice recognition

Multimodal systems reduce the chances of spoofing and improve recognition rates, especially under challenging conditions.

5.2. Deployment on Edge and IoT Devices

With the advent of smart cities and IoT-enabled security systems, iris recognition can be optimized for:

- Edge devices (like Raspberry Pi with embedded cameras)
- Real-time surveillance drones
- Smart door locks or ATMs

This requires lightweight models using Tensor Flow Lite or ONNX, optimized for low-latency and low-power consumption

- Homomorphic encryption and block chain-based storage to secure iris templates during transmission and storage. 6.7. Large-Scale Iris Recognition for Public Infrastructure With scalability in mind, iris recognition can be expanded for use in:
- National ID programs
- e-Voting systems
- Airport e-gates

5.3. Deep Learning Advancements

Future systems can benefit from:

- Transformer-based vision models (e.g., Vision Transformers) for capturing long-range dependencies in iris textures.
- Auto encoders and GANs to enhance iris image

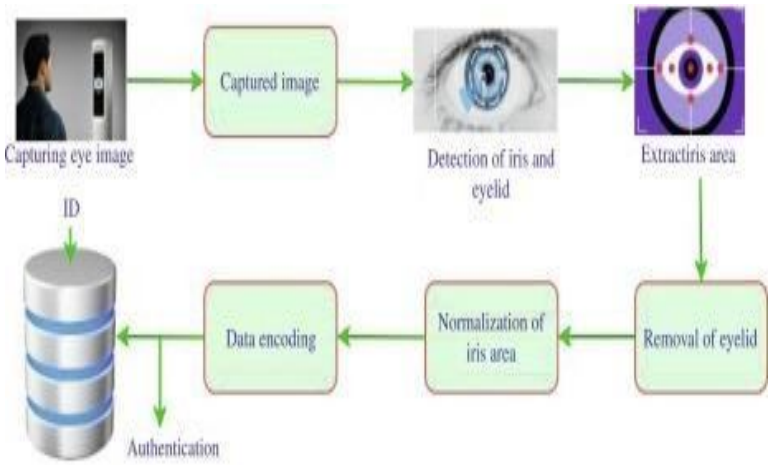

Fig 3 Quality or generate synthetic training data for model augmentation.

CONCLUSION

These can improve performance even on degraded or partial iris images.

5.4. Anti-Spoofing Mechanisms

As biometric systems are susceptible to presentation attacks (e.g., printed iris images, contact lenses), future work should focus on:

- Liveness detection using micro-movement analysis, pupil dilation response, and texture consistency checks.
- Integration of infrared imaging to distinguish real irises from fake ones.

5.5. Cross-Sensor and Cross-Dataset Compatibility

Inpractical applications, irisimages may be captured from different devices or in different environments.Future researchshould aim to:

- Enhance cross-sensor matching algorithms.
- Train deep modelsusing domain adaptation to ensure consistent performance across datasets

5.6. Privacy-Preserving Iris Recognition

As biometric data is sensitive, future systems should adopt:

- Cancel able biometrics: where original iris features can be transformed to protect privacy.

The behavior of the network when an input is given and the specified error rate is examined in this study. Several eye pictures have been used to train and test the network. Our paper reviewed many papers that hasa system that can recognize the difference between the iris and papillary bodies of the human eye from an image, which is the input of the eye. Todo this, they employed a modified Cannyedge detectormethod to identify different eye boundaries, including the outer limit of the pupil, which is the inner boundary for the iris. Following this, the iris' outer boundary is detected. The focus is on software for recognition rather than hardware for taking an eye image.

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