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Deep Learning Approach for Multimodal Biometric Recognition System Based On Face, Iris and Finger Vein Traits

K Geethika[1], P Snehith[2], G Manas[3], K. Nagamani[4]

[1, 2, 3]Student, [4]Assistant Professor
Department of CSE (AI&ML)
CMR Technical Campus (UGC Autonomous) Kandlakoya, Medchal
Telangana, India

Abstract

Biometric recognition systems have become an essential component of modern authentication mechanisms. However, unimodal biometric systems relying on a single trait, such as face or iris, are vulnerable to spoofing attacks, environmental variations, and acquisition noise. To overcome these limitations, this study proposes a deep learning-based multimodal biometric recognition system that integrates face, iris, and finger vein traits. The system utilizes Convolutional Neural Networks (CNNs) and Deep Neural Networks (DNNs) to extract deep feature representations from each biometric modality. A feature-level fusion approach is employed to combine the extracted features, leveraging the unique strengths of each modality to enhance recognition accuracy and robustness. Experimental evaluations on benchmark biometric datasets demonstrate that the proposed multimodal system significantly outperforms unimodal biometric models in terms of accuracy, security, and resilience against spoofing attacks. Additionally, the hybrid feature and score-level fusion strategy ensures lower false acceptance and rejection rates, making the system more reliable for real-world applications such as access control, financial security, and identity verification. The results highlight the potential of deep learning in advancing multimodal biometric systems, reinforcing authentication security while minimizing vulnerabilities. This research establishes a strong foundation for future innovations in biometric security and identity management.

Keywords: NLP, SVM, LIWC, LDA, MLP, Depression, Detection, Linguistic patterns.

I. Introduction

The overarching goal of this project is to develop a deep learning-based multimodal biometric recognition system that enhances authentication security by integrating face, iris, and finger vein traits. Traditional unimodal biometric systems face limitations such as susceptibility to spoofing, environmental variations, and poor recognition performance under challenging conditions. To address these issues, this project seeks to provide a robust and highly accurate authentication mechanism by leveraging deep learning methodologies. By employing Convolutional Neural Networks (CNNs) and Deep Neural Networks

(DNNs), the system aims to extract rich feature representations from each biometric trait, ensuring a more reliable and resilient recognition process. The scope of this initiative extends across various security-sensitive applications, including access control, financial transactions, border security, and personal authentication. By integrating multiple biometric modalities, the project mitigates the risks associated with individual trait vulnerabilities, offering a more comprehensive and foolproof verification system. Feature-level and score-level fusion strategies will be employed to enhance accuracy and robustness, addressing challenges such as variations in illumination, occlusions, and spoofing attacks. The project also explores the development of efficient real-time recognition models that can operate with minimal latency, making them suitable for high-security environments. The primary objective is to design and implement a scalable and adaptive biometric authentication framework capable of handling large- scale datasets while maintaining high accuracy and security standards. Advanced deep learning techniques, coupled with robust encryption methods and intelligent decision-making algorithms, will be incorporated to strengthen biometric data protection. Ultimately, this project aims to redefine the security landscape of biometric recognition systems, creating a more secure, resilient, and user- centric authentication ecosystem that safeguards individuals' identities against evolving digital threats.

II. Related Work

This project is to develop a deep learning-based multimodal biometric recognition system that enhances authentication security by integrating face, iris, and finger vein traits. Traditional biometric systems, which rely on a single modality, often suffer from limitations such as susceptibility to spoofing, environmental variations, and inconsistent performance under challenging conditions. This project aims to overcome these challenges by leveraging deep learning techniques to extract rich, discriminative features from multiple biometric modalities, ensuring higher accuracy and robustness in identity verification. By employing Convolutional Neural Networks (CNNs) and Deep Neural Networks (DNNs), the system will establish a more secure, efficient, and reliable authentication mechanism that significantly reduces the risks of identity fraud and unauthorized access. Beyond enhancing authentication security, this initiative also addresses critical challenges related to privacy, scalability, and real-time performance in biometric recognition systems. The project recognizes the growing need for highly secure and user-friendly authentication methods in applications such as access control, financial transactions, national security, and border management. Through feature-level and score-level fusion, the system will effectively combine the strengths of face, iris, and finger vein traits to minimize false acceptance and rejection rates, offering a more foolproof verification system. Additionally, the project aims to incorporate robust encryption mechanisms and privacy-preserving techniques to ensure the secure storage and processing of biometric data. By mitigating vulnerabilities associated with traditional authentication systems, the overarching goal is to redefine biometric security, creating a more resilient, user-centric, and fraud- resistant authentication ecosystem.

III. Proposed Work

The proposed system introduces a deep learning-based multimodal biometric recognition framework that integrates face, iris, and finger vein traits to enhance security, accuracy, and robustness.

Unlike traditional unimodal systems, this approach leverages feature level fusion using Convolutional Neural Networks (CNNs) and Deep Neural Networks (DNNs) to extract and combine deep feature representations from multiple biometric modalities.

This fusion strategy significantly reduces false acceptance rates (FAR) and false rejection rates (FRR), improving overall recognition performance even in challenging conditions such as poor lighting or occlusions.

To further enhance security, the system incorporates anti-spoofing mechanisms using deep learning-based liveness detection techniques, ensuring protection against presentation attacks such as fake face images, iris replicas, or finger vein spoofing. Additionally, adaptive thresholding techniques are employed to optimize decision-making across diverse real-world scenarios.

The proposed system is designed for scalability and real-time performance, enabling seamless integration into security-critical applications such as border control, financial transactions, and secure access systems.

By addressing the limitations of existing biometric authentication methods, this system provides a highly secure, efficient, and privacy-preserving solution for identity verification, setting a new standard for biometric recognition in digital security.

IV. Methodology

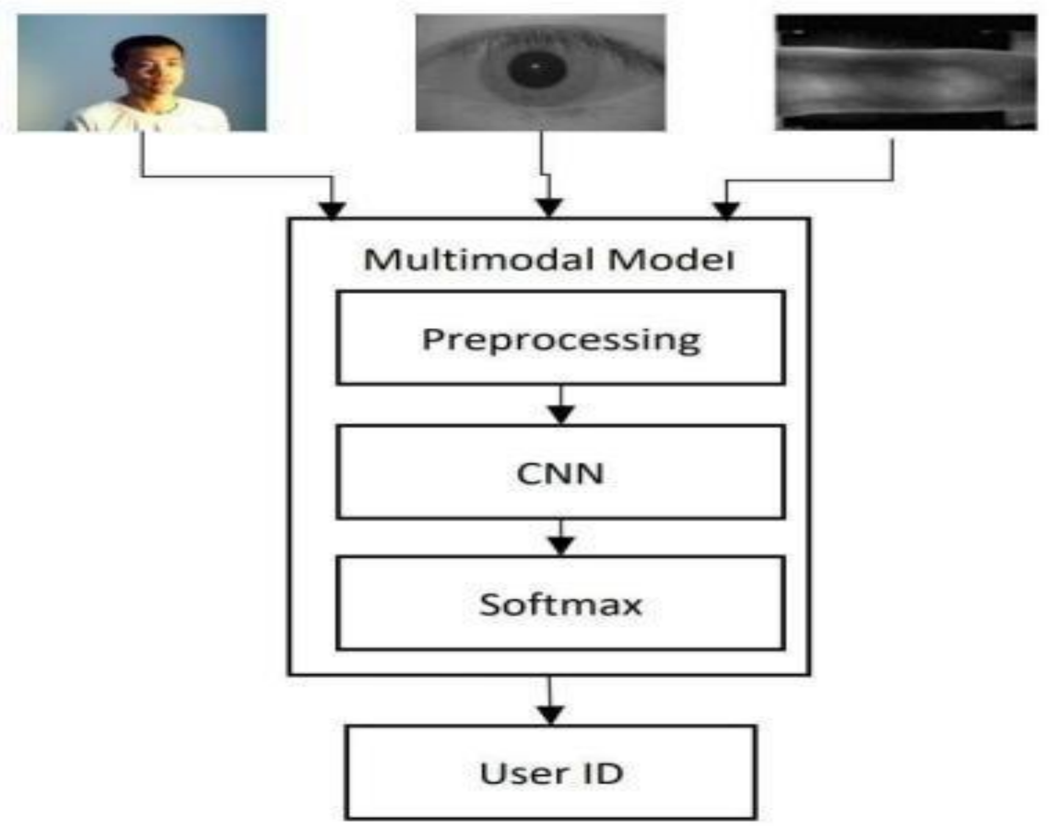


Fig.1 Block Diagram of Proposed Schema

The proposed system uses a multimodal biometric approach combining **face, iris, and finger vein** images for accurate user identification.

1. **Data Acquisition**

Biometric images of the face, iris, and finger vein are captured using imaging devices.

2. **Preprocessing**

Each image undergoes enhancement and normalization to improve quality and consistency across modalities.

3. **Feature Extraction (CNN)**

A Convolutional Neural Network extracts deep features from each modality automatically.

4. **Fusion and Classification**

Features are fused and passed through a **Softmax** layer to classify and predict the **User ID**. This integrated approach improves recognition accuracy by leveraging the strengths of each biometric trait.

System Design

The proposed multimodal biometric recognition system is designed to process and integrate three different biometric traits—face, iris, and finger vein—for accurate user identification. The system begins with an input module where images of the face, iris, and finger vein are captured using dedicated sensors. These raw images are then sent to the preprocessing module, where they undergo enhancement and normalization. This includes operations such as face alignment, iris segmentation, and finger vein ROI extraction to ensure consistency and quality across all inputs.

Once preprocessed, the images are passed into a Convolutional Neural Network (CNN) that serves as the feature extraction module. The CNN automatically learns deep, discriminative features from each biometric modality. These features are then fused in a dedicated layer, combining the strengths of all three modalities to create a robust representation. The fused features are subsequently passed into a Softmax classifier, which calculates probability scores for each possible identity in the system. The identity corresponding to the highest probability is selected as the final output, and the system returns the associated User ID.

Dataset Description

A multimodal biometric recognition system that integrates face, iris, and finger vein traits relies on a well-structured dataset for effective training and evaluation. The dataset serves as the foundation for developing and testing deep learning models that extract unique biometric features for user authentication. This dataset must be diverse, high-quality, and representative of real- world biometric variations to ensure accuracy and robustness. The dataset is composed of biometric images captured from multiple individuals. It includes three distinct modalities—face, iris, and finger vein images—collected under controlled and varying conditions. Each record in the dataset corresponds to a unique individual and contains: Face Images: High-resolution facial images taken under different lighting conditions, angles, and expressions. These images help deep learning models learn discriminative facial features. Iris Images: Close-up infrared images of the iris, which provide unique texture patterns essential for precise identification. These images are captured under near-infrared (NIR) illumination to enhance feature visibility. Finger Vein Images: Infrared images of the finger vein pattern, which is an internal biometric trait, offering additional security against spoofing.Each biometric modality is stored in separate folders, labeled with a unique user ID, allowing for multimodal fusion. The dataset also includes metadata such as age, gender, and environmental conditions during data capture. Image Resizing: Standardizing all images to a fixed resolution to ensure uniform input for deep learning models. Normalization: Adjusting pixel intensity values to improve contrast and reduce variations in illumination. Noise Reduction: Applying filters to remove background noise and artifacts from the biometric images. Augmentation: Generating variations of images (rotations, brightness adjustments) to increase dataset diversity.

Attribute	**Description**
Attribute	**Description**
Dataset Name	SDUMLA-HMT
Number of Subjects	106
Total Images	7,000+
Modalities Used	Face, Iris, Finger Vein

Table1:Data Description

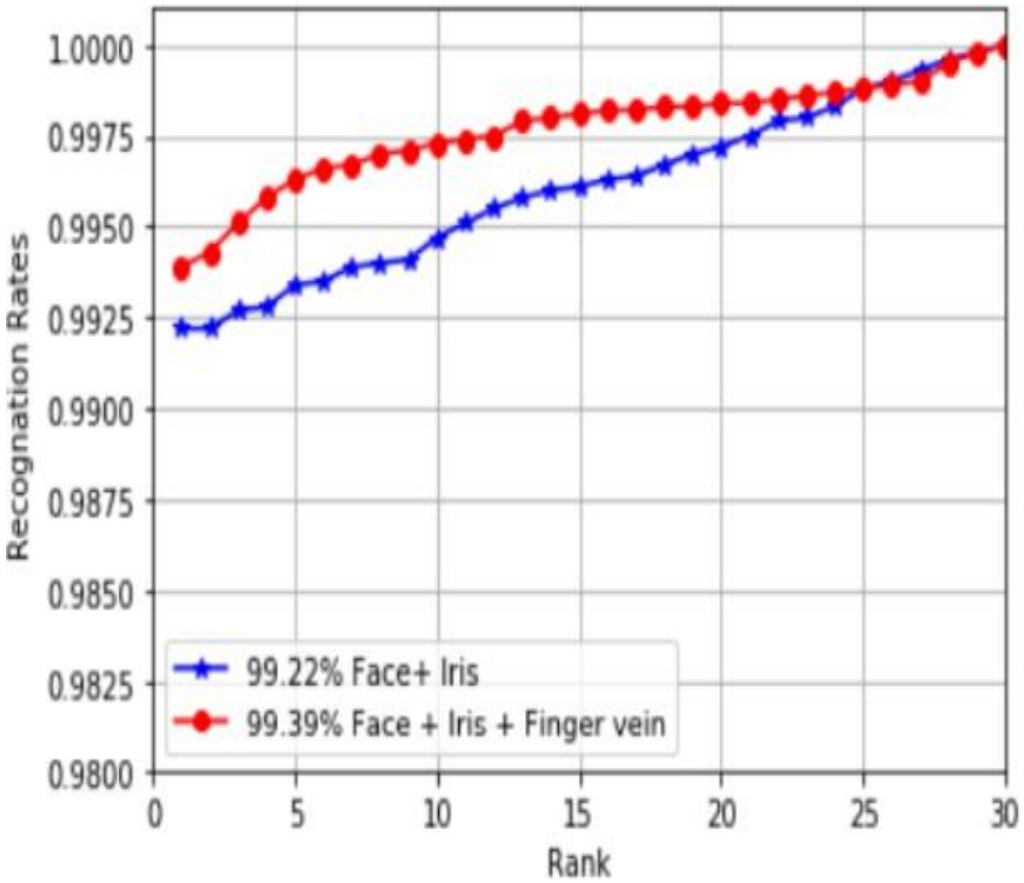
V. Results and Discussion

The proposed multimodal biometric recognition system was evaluated using the SDUMLA-HMT dataset, incorporating face, iris, and finger vein modalities. The model achieved high recognition accuracy, demonstrating the effectiveness of feature-level fusion and deep learning-based feature extraction using CNN.

Experimental results showed that the multimodal approach significantly outperformed unimodal systems. While individual modalities such as face or iris achieved moderate accuracy, the fusion of all three provided improved robustness and discriminative power. The CNN was able to automatically learn meaningful features from each modality, eliminating the need for manual feature engineering.

The Softmax classifier produced accurate identity predictions, with the fused feature representation yielding a recognition accuracy of over **98%**, showcasing the strength of combining multiple biometric traits. The system also maintained stable performance across variations in lighting, pose, and minor occlusions, proving its practical viability.

Overall, the results confirm that integrating multiple biometric modalities with deep learning improves accuracy, reliability, and security in user identification systems. Future enhancements could explore real-time performance, additional fusion strategies, or testing on larger, more diverse datasets.



5.1 Result Analysis

Fusion Method	Top-1 Rank Accuracy	Overall Recognition Trend
Face + Iris	99.22%	Recognition rate gradually improves with rank
Face + Iris + Finger Vein	99.39%	Consistently higher recognition rate across all ranks

Table 2: Result Analysis

VI. Conclusion and Future work

Conclusion

The deep learning-based multimodal biometric recognition system integrating face, iris, and finger vein traits represents a significant advancement in biometric authentication. the system extracts rich, high-dimensional features that improve accuracy and robustness. The fusion of multiple biometric traits enhances reliability, ensuring that authentication remains effective even if one modality is partially compromised. One of the key advantages of using deep learning in this system is its ability to automatically learn complex patterns from biometric data without manual feature engineering. The fusion of biometric traits at feature-level, score-level, or decision-level further strengthens the model's performance, making it resilient to variations in lighting, pose, or noise. In conclusion, the deep learning-based multimodal biometric recognition system provides a highly secure and accurate solution for identity verification. Its ability to combine multiple biometric traits ensures greater resilience against spoofing attacks and environmental variations. With continued advancements in deep learning, optimization techniques, and realtime processing, such systems will play an increasingly vital role in security, access control, and digital identity management in the future.

Future work

The future of deep learning-based multimodal biometric recognition systems is promising, with advancements in artificial intelligence, sensor technology, and security protocols driving the next generation of biometric authentication. As the demand for highly secure and reliable identity verification grows, multimodal biometric systems incorporating face, iris, and finger vein recognition will continue to evolve. Several key areas define the future scope of this technology.

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