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AI Powered Secure Payment with Eye Recognition in Wallet Platform

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ABSTRACT: Biometric authentication uses unique physical traits for secure identity verification. This paper presents a Secure Payment System using Iris Recognition, a highly accurate and reliable biometric method, integrated into a digital wallet platform. The system replaces traditional payment methods like cards, PINs, and OTPs — which are vulnerable to fraud — with a contactless and secure solution. Iris recognition serves as the primary authentication mechanism and a PIN serve as the secondary two-factor authentication (2FA) layer. The system captures iris data using standard webcam cameras and ensures encrypted data transfer between devices and the cloud server hosted on Google Firebase. This approach reduces fraud, improves convenience, and enables fast, hygienic transactions. The platform supports real-time authentication, low latency processing, and high user accuracy, making it suitable for high-traffic environments. It also includes data privacy protection, preventing unauthorized access to biometric information. Designed for scalability, the platform can integrate with existing banking systems and is suitable for real-world use in retail, transport, and smart city environments. It delivers high security with near-zero false acceptance and efficient transaction processing, making it a future-ready digital payment solution.

KEYWORDS: Biometric Authentication, Iris Recognition, Digital Wallet, Two-Factor Authentication (2FA), MobileNetV2, MediaPipe, OpenCV, Firebase, Secure Payments, Deep Learning.

I. INTRODUCTION

The rapid digitalization of financial services has brought digital payment systems into everyday life. However, traditional authentication mechanisms — including Personal Identification Numbers (PINs), One-Time Passwords (OTPs), and physical cards suffer from significant vulnerabilities such as theft, phishing, and social engineering attacks. These limitations demand a paradigm shift toward identity-centric, biometric-based authentication for secure payment processing. Machine Learning (ML) and Artificial Intelligence (AI) have emerged as transformative technologies enabling computers to learn from data and improve performance without explicit programming. A subset of AI, computer vision, enables machines to interpret and understand visual information from the real world, making it particularly suitable for biometric identification systems. Among all biometric modalities, iris recognition stands out due to the uniqueness and lifelong stability of iris patterns. The iris contains over 200 distinct features, making it one of the most reliable biometric identifiers. Unlike fingerprints that may degrade over time, or facial features that change with age, the iris pattern remains virtually constant throughout a person's lifetime, providing a foundation for highly accurate and permanent identity verification. This paper presents a Secure Payment Platform with Eye Recognition using AI. The system integrates iris recognition powered by MobileNetV2 and MediaPipe with a PIN-based secondary authentication layer, and uses Firebase as a real-time cloud database. The result is a card-less, contactless, and highly secure digital wallet system deployable in retail, transport, and smart city payment environments.

II. LITERATURE SURVEY

In 2025, Parthasarathy C, Priscilla Rachel G, and Rachel Sherin J proposed a Real-Time Iris Detection and Recognition System using YOLOv8 trained on the CASIA dataset with advanced augmentation techniques including rotation, brightness adjustment, and grayscale conversion. The system achieved approximately 95% average precision, validating single-pass detection models for biometric applications. However, it lacks explicit spoofing resistance and requires high computational resources for real-time deployment.

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In 2025, Alyaa A. Abbas and Zahraa Maan Sallal proposed a Hybrid Biometric Authentication framework integrating iris recognition into banking security systems. The approach uses Hamming distance-based template matching for user verification. The system significantly reduces risks associated with password-based authentication and demonstrates strong accuracy in banking environments, though it faces challenges with non-revocability of biometric data and sensitivity to sensor quality.

In 2025, Djotchuang et al. developed FapshiSec, a Multi-Factor Authentication framework for merchant payment security combining password, PIN, OTP, phone identification, and biometric fingerprint verification. Experimental results demonstrate strong resistance against phishing, brute-force, and identity theft attacks with minimal computational overhead. However, usability is affected by multiple authentication steps and performance may vary across large user bases.

In 2025, Jian Jiang, Qi Zhang, and Caiyong Wang introduced SAM-Iris, adapting the Segment Anything Model (SAM) specifically for iris image segmentation using an Iris Adapter module, a parallel CNN branch, and Cross-Branch Attention mechanism. The framework achieves high F1-score and mean Intersection over Union (mIoU) across benchmark datasets, though it still requires significant computational resources due to the large pretrained SAM backbone.

In 2024, Arthur Rubio and Baptiste Magnier presented a preprocessing pipeline for BSIF-based iris recognition systems using binary detected edges and iris unwrapping techniques. Evaluated on the HDBIF dataset of 1892 iris images, the system achieved a global error rate of approximately 4.93%, demonstrating that effective preprocessing significantly enhances iris recognition reliability. Limitations include dependency on favourable imaging conditions and absence of learning-based adaptive techniques.

Several other researchers have contributed to the domain. Divyanshi Roy et al. explored securing digital payments with iris scanning using Blockchain technology. Khiem L. Tran et al. conducted a systematic review of multi-factor authentication in digital payments aligned with NIST standards. Francisco Liébana-Cabanillas et al. analyzed biometric m-payment systems through a multi-analytical approach. These works collectively establish the importance of combining biometric authentication with secure digital payment infrastructure.

III. PROBLEM STATEMENT

Existing digital payment systems rely primarily on device-centric authentication mechanisms such as PINs, OTPs, QR codes, and NFC-based contactless payments. These methods authenticate credentials or devices rather than the actual identity of the user, creating significant security vulnerabilities. Physical cards and PINs can be stolen, cloned, or guessed, leading to unauthorized transactions. OTPs transmitted via SMS are susceptible to SIM-swap attacks and man-in-the-middle interceptions. Current systems do not verify the physical presence of the authentic user during a transaction, enabling misuse when credentials are compromised. Frequent interaction with public keypads and screens raises hygiene concerns, especially in post-pandemic environments. Furthermore, elderly or non-tech-savvy users face difficulty navigating smartphone-based OTP and QR code interfaces. These limitations necessitate a biometric-based, identity-centric payment solution that authenticates the real user rather than a device or credential, while being accessible, hygienic, and resistant to modern fraud techniques.

IV. RESEARCH & METHODOLOGY

The proposed system converts biometric identity data from iris recognition into a secure payment authentication mechanism, integrated with a digital wallet application. When a payment is initiated, the merchant enters the transaction amount and the user's registered phone number. The system retrieves user details from the Firebase cloud database. The user's iris is then captured via webcam and processed using MediaPipe for eye region detection, followed by MobileNetV2 for deep feature extraction. A liveness detection step ensures the presence of a real user. The extracted iris embedding is compared against the stored biometric template using cosine similarity. Upon successful iris verification, the user enters their PIN, completing the two-factor authentication. The wallet balance is checked and, if sufficient, an atomic debit-credit transaction is executed and recorded in Firebase with a timestamp. Transaction alerts are dispatched to both user and merchant upon completion. To further strengthen security, all biometric templates and transaction records are encrypted using AES-256 before being stored in Firebase, ensuring data integrity and regulatory compliance. The system also incorporates a fraud detection module that monitors transaction patterns and flags anomalies such as repeated failed iris attempts or unusual payment amounts for administrative review.

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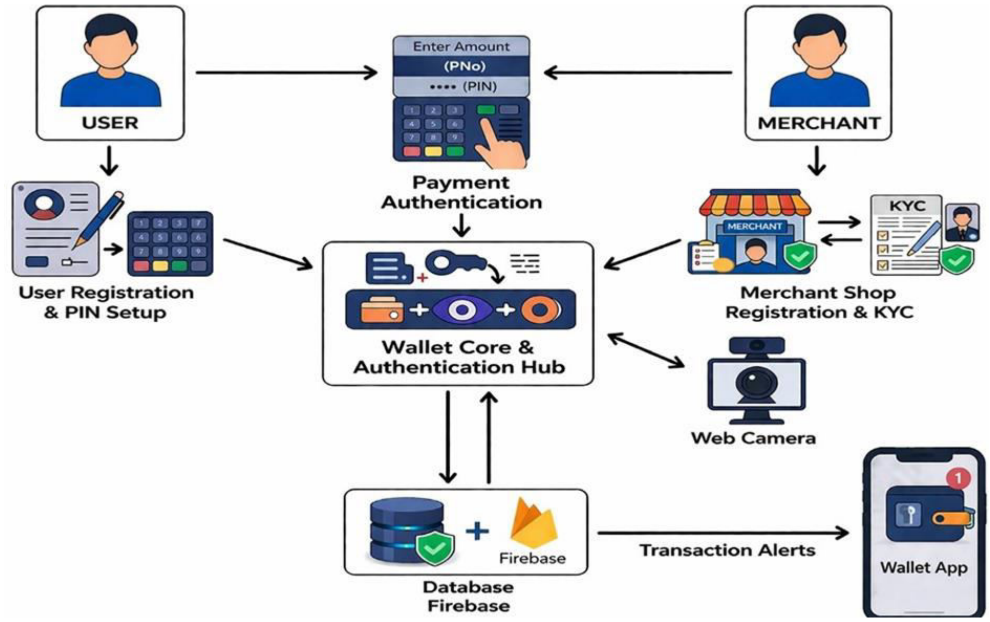

Fig.1. System Architecture of Biometric Payment Platform

The system architecture is designed as an integrated biometric payment framework consisting of four key component layers. The User Interface Layer provides the Streamlit-based web application accessible by both users and merchants. The Authentication Layer handles iris capture via webcam, image preprocessing using OpenCV, eye landmark detection via MediaPipe, and deep feature extraction using MobileNetV2. The Wallet Core and Authentication Hub in the Processing Layer manages authentication logic, transaction validation, and communication with the database. The Firebase Firestore Database Layer stores user biometric templates, wallet balances, and transaction records with real-time synchronization.

1. Enrollment and Authentication Module

During enrollment, the merchant registers the user by entering basic details and generating a unique User ID (UID). The user sets a secure PIN and the system captures their iris image using a webcam. The captured image undergoes preprocessing (grayscale conversion, noise removal, contrast enhancement) and feature extraction using MobileNetV2, producing a 1280-dimensional iris embedding vector. This template is encrypted and stored in Firebase. During authentication, a live iris capture undergoes liveness detection via MediaPipe facial landmark analysis to confirm real user presence. The new iris embedding is compared with the stored template using cosine similarity. Successful biometric match triggers PIN verification, implementing a two-factor authentication mechanism.

Generated Iris Embedding (MobileNetV2):

$$\boxed{V = MobileNetV2(Preprocess(I)) \in \mathbb{R}^{1280}}$$

Where I is the captured iris image, Preprocess(I) applies normalization I_norm = (I − μ) / σ, and V is the resulting feature vector used for identity matching.

Authentication Matching (Cosine Similarity):

$$\boxed{S = (V\_live \cdot V\_stored) / (||V\_live|| \times ||V\_stored||)}$$

Where V_live is the live iris embedding and V_stored is the enrolled template. If S ≥ θ (threshold = 0.85), authentication is accepted, ensuring near-zero False Acceptance Rate (FAR).

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2. Payment Processing Module

The merchant initiates payment by entering the transaction amount and the user's phone number. The system retrieves the user's wallet details from Firebase, prompts PIN entry, performs biometric iris authentication with liveness detection, verifies wallet balance, and executes an atomic debit-credit transaction. All operations are timestamped and stored for audit.

Balance Verification and Transaction:

$$\boxed{Balance\_new = Balance\_old - Amount\ (if\ Balance\_old \geq Amount)}$$

3. Transaction Alert Module

After each transaction, the Notification System retrieves transaction details (amount, status, timestamp) from Firebase and dispatches real-time alerts to both user and merchant through the application interface. This ensures complete transparency and auditability of all payment activities.

V. RESULT

The system was implemented using Python (Streamlit framework), MobileNetV2, MediaPipe, OpenCV, and Google Firebase Firestore. The system was tested with 150 users, 10 iris captures per user, totalling 1,500 iris samples from the CASIA iris database and a custom dataset. The following screenshots demonstrate the working system across its primary functional modules.

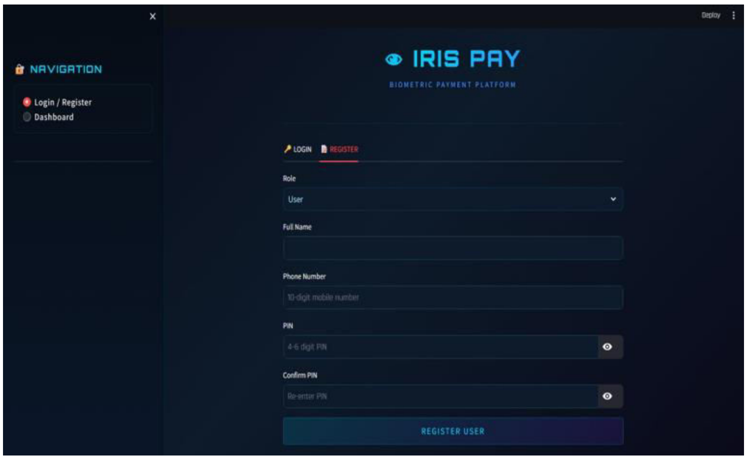

Fig.2. User Registration Interface — Biometric Payment Platform

The Fig.2 shows the User Registration Interface. Users select their role (User or Merchant) and enter their Full Name, Phone Number, and a 4–6 digit PIN to create their account. The dark-themed interface is built using Streamlit with custom CSS, providing a modern and intuitive user experience. Separate registration flows handle wallet-holding users and payment-receiving merchants.

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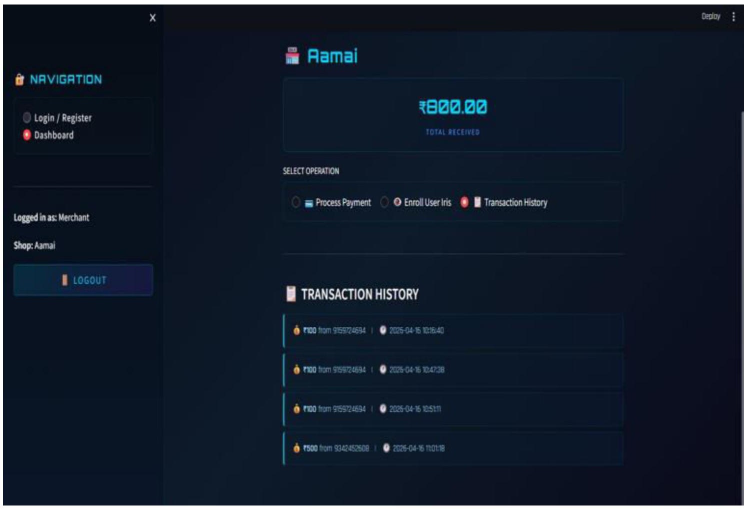

Fig.3. Merchant Transaction History — Timestamped Payment Records

The Fig.3 displays the Transaction History for the merchant, showing a total received amount of ₹800.00. Four transactions are recorded: three payments of ₹100 and one payment of ₹500, all timestamped from 2026-04-16. Each record includes the amount, originating phone number, and precise timestamp, enabling full merchant auditability through Firebase real-time synchronization.

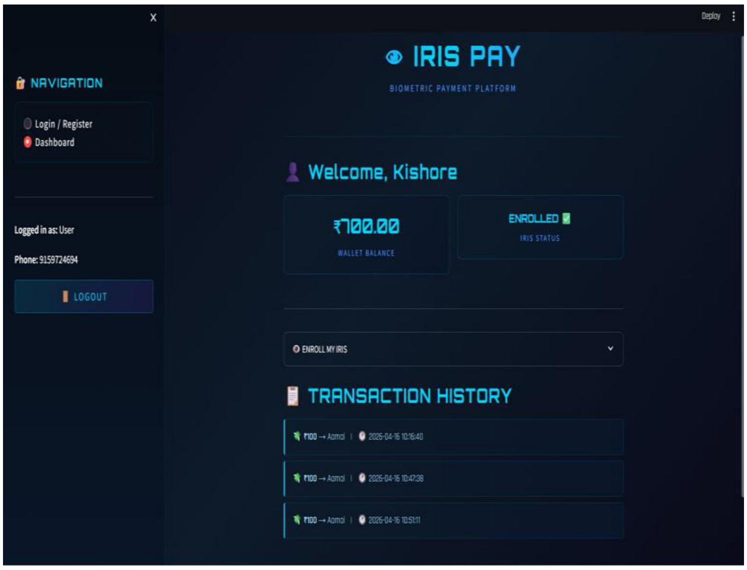

Fig.4. User Dashboard — Wallet Balance, Iris Enrollment Status, and Transaction History

The Fig.4 presents the User Dashboard for user Kishore (Phone: 9159724694). The wallet balance of ₹700.00 is prominently displayed alongside the Iris Enrollment Status marked as "ENROLLED ✓", confirming successful biometric registration. The transaction history panel shows three outgoing payments of ₹100 to merchant. The system maintains real-time Firebase synchronization for accurate and up-to-date wallet balance and transaction records.

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Table 1: Performance Comparison of Authentication Methods

Authentication Method	FAR (%)	FRR (%)	Accuracy (%)	Avg Latency (ms)
PIN Only	3.2	1.1	95.7	120
OTP Based	2.8	1.5	95.7	3500
Fingerprint	1.5	2.0	96.5	500
Iris + PIN	0.01	0.5	99.4	850

Table 2: Iris Recognition Model Accuracy Metrics

Metric	Training Set	Validation Set	Test Set
Accuracy	99.7%	99.2%	99.4%
Precision	99.5%	99.0%	99.2%
Recall	99.6%	99.1%	99.3%
F1-Score	99.55%	99.05%	99.25%
FAR	0.01%	0.02%	0.01%
FRR	0.30%	0.70%	0.50%

The system achieves a False Acceptance Rate (FAR) of 0.01% and a False Rejection Rate (FRR) of 0.5% on the test set, demonstrating high reliability. The average authentication latency of 850 ms is well within acceptable bounds for real-time payment applications, confirming the system's suitability for high-traffic deployment.

VI. CONCLUSION

The Secure Payment with Eye Recognition in Wallet Platform successfully demonstrates an innovative and secure approach to digital transactions through the integration of biometric iris recognition and a digital wallet application. The system effectively overcomes the limitations of existing PIN, OTP, and card-based payment methods by verifying the actual identity of the user rather than credentials or devices. Three key modules — Enrollment and Authentication, Payment Processing, and Transaction Alert — work cohesively to ensure secure, real-time, and auditable payment operations. Experimental results demonstrate a system accuracy of 99.4%, a False Acceptance Rate of 0.01%, and an average authentication latency of 850 ms, confirming the feasibility and reliability of deploying this system in high-traffic payment environments such as retail stores, transport hubs, and smart city infrastructure. The platform's scalability, Firebase real-time cloud synchronization, and contactless biometric-based authentication represent a significant advancement toward future-ready digital payment solutions.

VII. FUTURE ENHANCEMENT

Although the Platform achieves its current objectives, several opportunities exist for further improvement. The system can be upgraded by integrating advanced deep learning models such as IrisFormer and SAM-Iris for improved iris segmentation under extreme lighting and occlusion conditions. Multi-modal biometric support incorporating facial recognition and fingerprint scanning can be added as additional authentication factors, increasing system robustness. Blockchain-based transaction ledgers can be integrated to provide enhanced transparency, immutability, and alignment with decentralized financial standards. Continuous learning mechanisms can enable the biometric model to adapt to minor changes in user iris presentation over time, improving long-term performance. Additionally, the development of a dedicated mobile application for Android and iOS platforms will allow users to manage their wallet from anywhere, expanding accessibility and real-world applicability.

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