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Credit Card Fraud Detection using Blockchain and Grassmann Algorithm

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ABSTRACT:

The rapid expansion of digital payments and e-commerce has significantly increased the risk of credit card fraud, exposing the inadequacy of traditional authentication mechanisms such as passwords, PINs, and CVV codes. These credential-based methods verify only what a person possesses or knows, not who they physically are — a distinction that fraudsters readily exploit.

This project presents a secure online shopping and payment platform that addresses this gap by integrating facial biometric authentication with blockchain-based transaction recording. The Grassmann algorithm is applied for face recognition, enabling robust identity verification across real-world variations in lighting, facial expression, and head orientation. At the point of payment, the system captures a live facial image, processes it through the Grassmann subspace matching framework, and compares it against the registered cardholder's stored biometric profile. Only a verified match permits the transaction to proceed.

All confirmed transactions are permanently recorded in a decentralised blockchain ledger, ensuring immutability, transparency, and tamper resistance. The platform is developed using Python (Flask) as the backend, HTML, CSS, and JavaScript for the frontend interface, and MySQL for structured data storage, with TensorFlow and Keras supporting the biometric processing pipeline. This dual-layer approach — identity verification at the point of transaction, combined with cryptographically secured record keeping — provides a substantially more robust defence against credit card fraud than existing transaction-pattern-only detection systems.

KEYWORDS: Credit Card Fraud, Grassmann Algorithm, Facial Biometric Authentication, Blockchain, Deep Learning, Online Payment Security, Python, Flask.

INTRODUCTION:

The global shift toward digital commerce and online financial transactions has fundamentally changed how consumers interact with banking systems. While this transformation has brought unprecedented convenience, it has simultaneously created significant new vectors for financial fraud. Credit card fraud — encompassing unauthorised transactions, identity theft, account takeover, and impersonation — represents one of the fastest-growing categories of financial crime worldwide.

Conventional security mechanisms, including static passwords, PINs, and CVV codes, are proving increasingly inadequate as the primary defence against fraudulent access. These credentials can be obtained through phishing attacks, data breaches, card skimming, or social engineering, providing fraudsters with complete access to a victim's financial accounts without any physical barrier. The fundamental weakness of these methods is that they authenticate what a person knows or possesses, not who they are.

Biometric authentication directly addresses this vulnerability by verifying the physical identity of the individual at the moment of transaction. Facial recognition, in particular, requires no additional hardware from the user's perspective and can be implemented seamlessly within an existing web-based checkout flow. This project implements the Grassmann algorithm for face recognition — a mathematically rigorous subspace-based approach that models facial features on a Riemannian manifold, providing reliable and accurate matching under real-world environmental variations.

To complement the authentication layer, blockchain technology is integrated to record all verified transactions in an immutable, decentralised ledger. The cryptographic structure of blockchain ensures that once a transaction is confirmed and recorded, it cannot be modified, deleted, or retroactively altered — providing a transparent and auditable trail of all financial activity on the platform.

Unlike existing fraud detection research that focuses primarily on identifying suspicious patterns in historical transaction data, this system prevents unauthorised transactions from being approved in the first place, representing a proactive rather than reactive approach to fraud prevention.

RELATED WORK:

Research into credit card fraud detection and secure payment systems has produced a rich body of literature spanning machine learning, blockchain security, and biometric authentication. The following review contextualises the contribution of this project within the existing landscape.

1. MACHINE LEARNING FOR FRAUD DETECTION: Ali et al. (2022) present a comprehensive systematic literature review of machine learning techniques applied to financial fraud detection, covering supervised, unsupervised, and hybrid model approaches across multiple financial domains. The review identifies broad coverage of algorithmic methods and highlights key research gaps, notably the absence of real-time identity verification mechanisms. This work establishes the foundational need for authentication layers that operate beyond transaction data analysis alone.

2. DEEP LEARNING APPROACHES: Alarfaj et al. (2022) evaluate a wide range of state-of-the-art machine learning and deep learning models for credit card fraud detection using real transaction datasets. The study demonstrates high detection accuracy and provides rigorous multi-algorithm performance comparisons. However, the approach is limited to transaction pattern analysis and does not address user identity verification — a limitation that leaves the system vulnerable when fraudsters possess valid credentials.

3. ONLINE PAYMENT FRAUD DETECTION: Almazroi and Ayub (2023) propose a machine learning model designed specifically for online payment fraud scenarios using classification techniques and transaction feature engineering. The model demonstrates improved fraud detection rates in practical payment contexts but relies entirely on transactional data without any biometric or multi-factor authentication component, leaving a clear gap that this project addresses.

4. BANKING DATA FRAUD DETECTION: Hashemi et al. (2022) apply multiple machine learning algorithms to banking datasets and conduct strong analytical comparisons of their performance. The study highlights the effectiveness of structured data-based fraud identification but acknowledges a key limitation: systems that rely solely on correct credentials remain vulnerable when fraudsters successfully obtain those credentials.

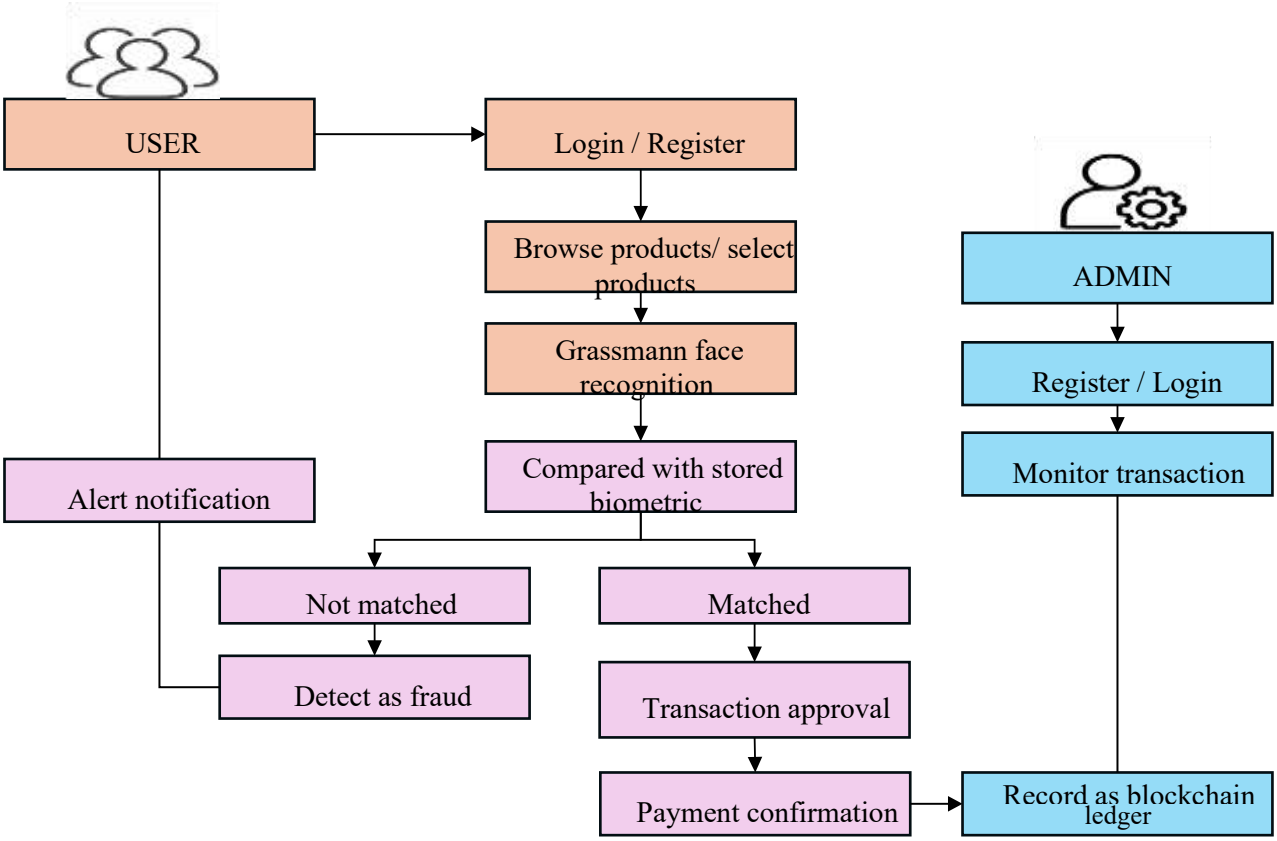
5. BLOCKCHAIN-BASED FRAUD DETECTION: Ashfaq et al. (2022) integrate machine learning with blockchain technology to create a secure, transparent fraud detection framework. This work is most closely aligned with the direction of this project — combining algorithmic security with blockchain-based data integrity. However, it does not incorporate biometric user authentication, focusing instead on system-level rather than identity-level security. This project advances further by layering Grassmann-based facial verification onto a blockchain foundation.

6. GRAPH NEURAL NETWORKS AND AUTOENCODERS: Alarfaj and Shahzadi (2025) propose a real-time fraud detection system using Graph Neural Networks and Autoencoders applied to credit card transaction data modelled as temporal graphs. The system demonstrates strong adaptability to evolving fraud patterns in dynamic banking environments. Its primary limitation is the high computational cost of real-time graph processing. This work further validates the value of combining multiple deep learning approaches for fraud prevention.

CONTRIBUTION OF THIS WORK: The collective body of existing work demonstrates that while transaction-pattern-based fraud detection has achieved high accuracy, it remains reactive and vulnerable to impersonation. No existing system reviewed combines Grassmann-based facial biometric verification with blockchain-secured transaction recording in an integrated online payment platform — the specific contribution of this project.

SYSTEM DESIGN:

The overall system architecture is organised around two primary roles — User and Admin — and defines the end-to-end workflow from user registration through to transaction recording. The architecture separates concerns into distinct functional layers.



USER WORKFLOW:

The user registers on the platform by submitting personal details and biometric facial data. Following registration, the user logs in, browses available products, and selects items for purchase. At the payment stage, the system activates the device camera to capture a live facial image, which is processed through the Grassmann face recognition algorithm and compared against the stored biometric profile. If the match is successful, the transaction is approved and the payment processed. If the faces do not match, the transaction is blocked, flagged as a potential fraud attempt, and an alert notification is generated. All approved transactions are recorded on the blockchain ledger.

ADMIN WORKFLOW**:**

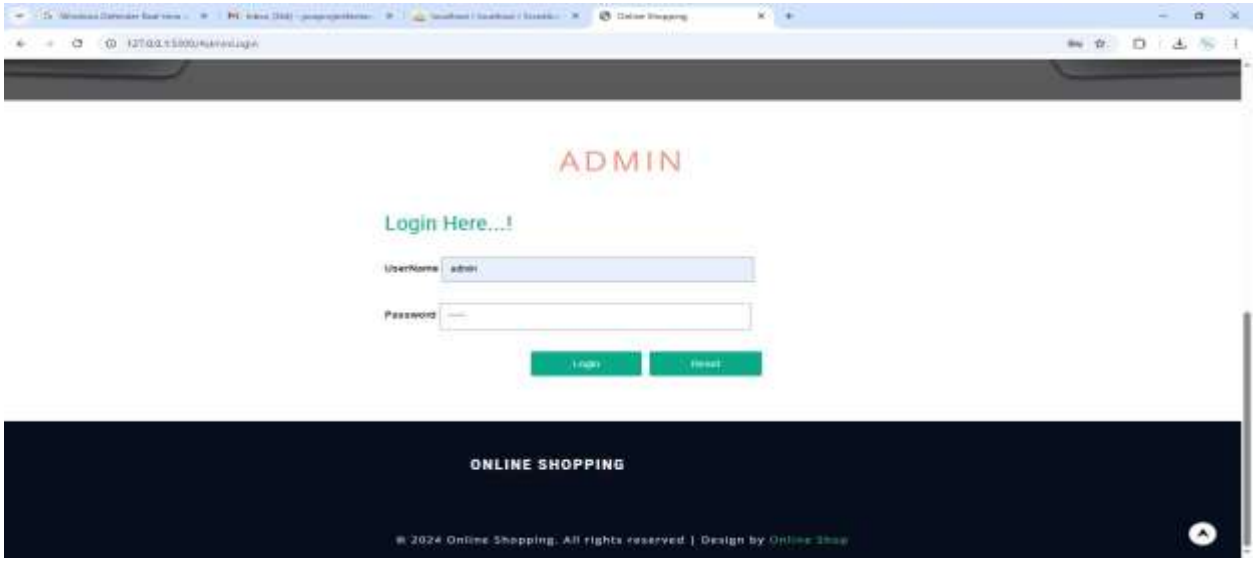
The administrator authenticates through a secure login interface and accesses the administrative dashboard. From this interface, the admin can add and manage product catalogue entries and employee records, view all transaction histories and flagged fraud events, and monitor overall system activity. The admin has read access to user account details for support and governance purposes.

FUNCTIONAL MODULES:

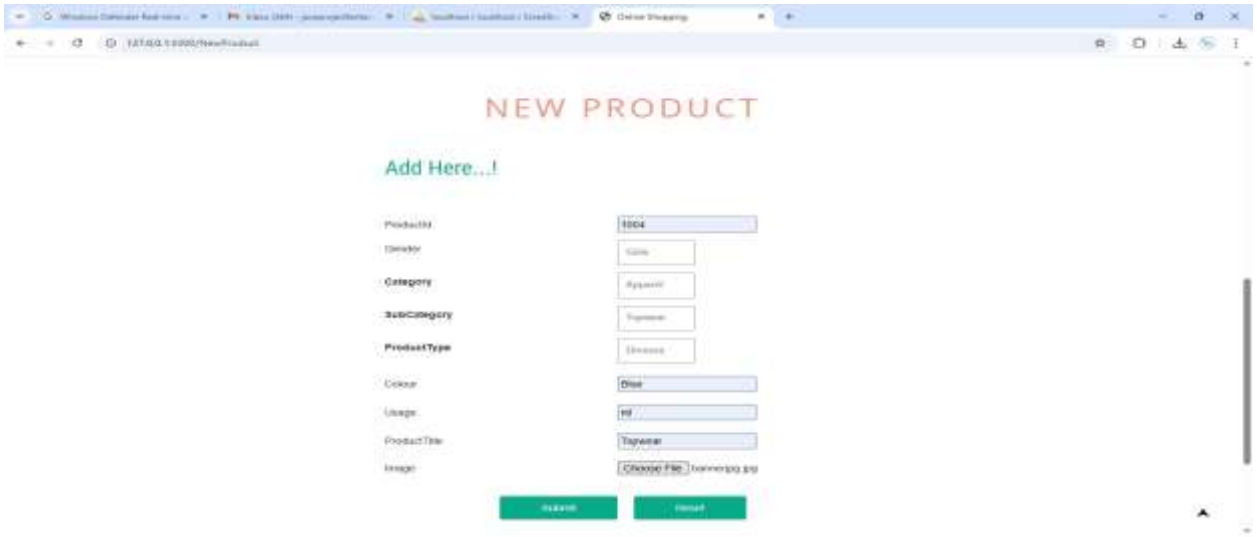
The system is implemented through ten distinct modules that together deliver a secure, user-friendly, and fraud-resistant online shopping and payment experience.

MODULE 1

Admin Login: The Admin Login module provides secure, credential-based access to the administrative control panel. Username and password entries are validated against stored database records. Only authorised administrators are granted access, preventing unauthorised manipulation of system data and configurations.

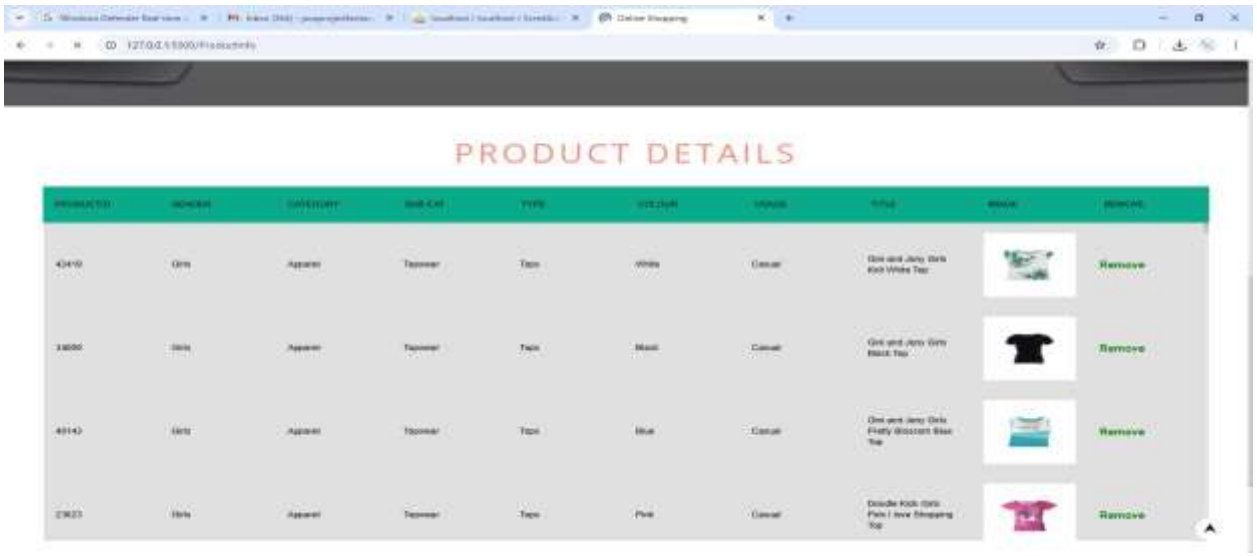


MODULE 2Admin – Add Employee and Product: This module enables the administrator to add employee profiles and new product entries to the platform. Employee records include name, ID, phone number, and email. Product entries include product name, type, price, quantity, and category. All data is securely stored in the MySQL database and immediately reflected in the user-facing product catalogue.



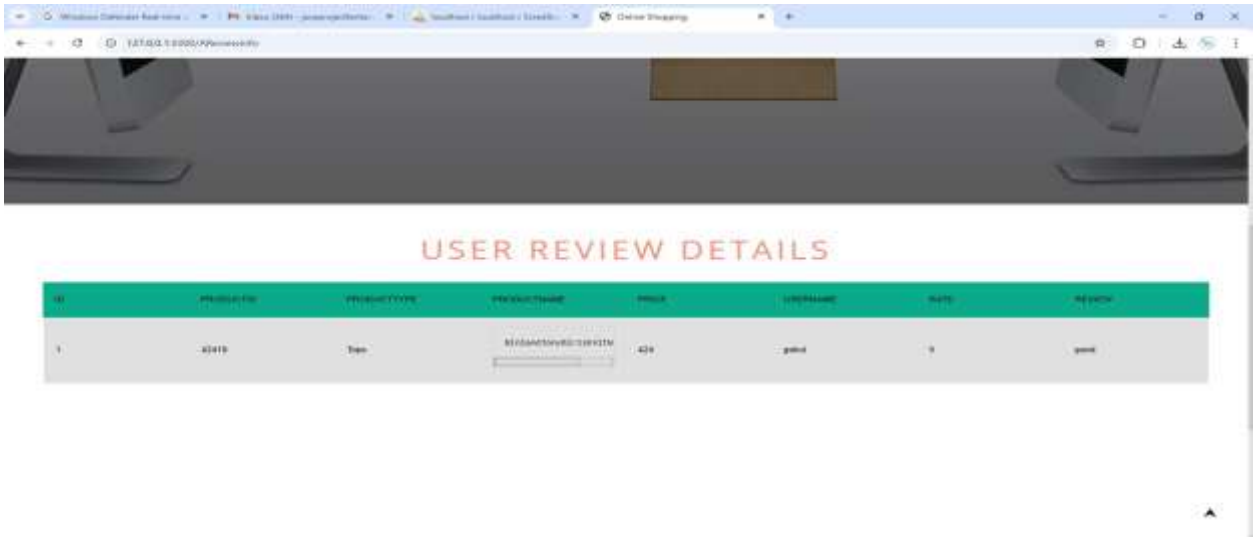
MODULE 3

Admin – View Booking Details: The admin can view a complete, organised record of all purchase and booking transactions made by users, including product information, transaction amounts, dates, and associated cardholder details. This module supports sales monitoring, fraud investigation, and transaction history auditing.



MODULE 4

Admin – View User Details: This module provides the administrator with access to the full register of user accounts, displaying details including name, email address, gender, phone number, and physical address. It supports customer management and administrative oversight of platform users.

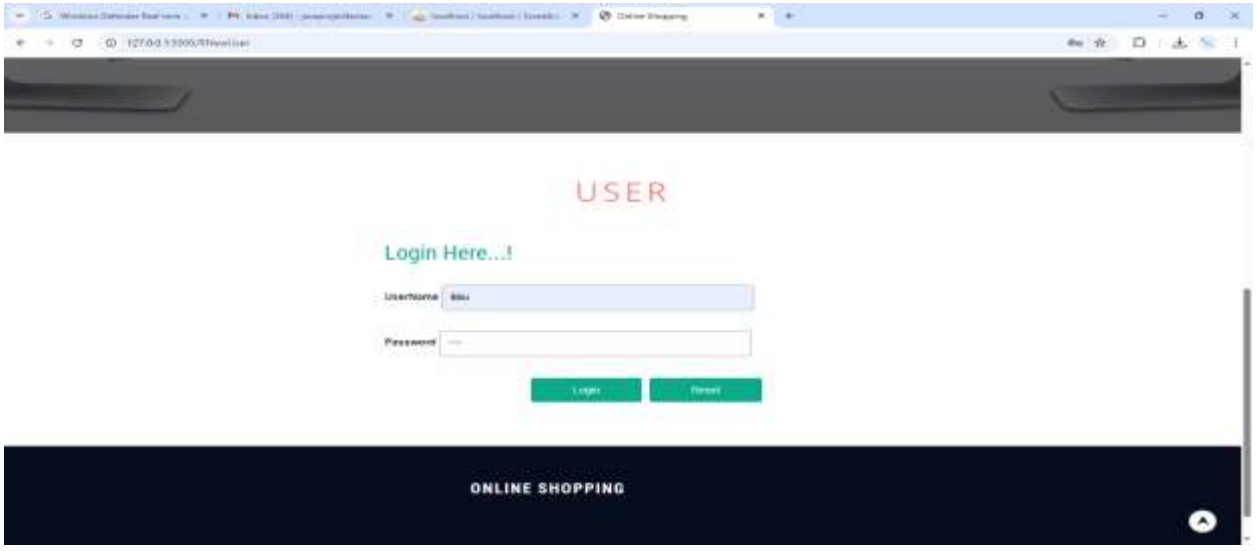


MODULE 5

User – Register: New users create accounts by submitting personal details — name, email, phone number, address, and login credentials — through the online registration form. The system validates submitted data, checks for duplicate entries, and stores the information securely in the database. Following successful registration, users can immediately log in and access the platform.

MODULE 6

User – Login: Registered users authenticate using their username and password. The system validates these credentials against stored records before granting access to the shopping platform. Only successfully authenticated users can browse products and initiate purchases.



MODULE 7

User – Product Purchase: Authenticated users can browse the product catalogue with full product details including name, price, category, and images. Items can be added to a shopping cart, and the system calculates the total purchase amount. Order details are forwarded to the admin records upon checkout initiation.

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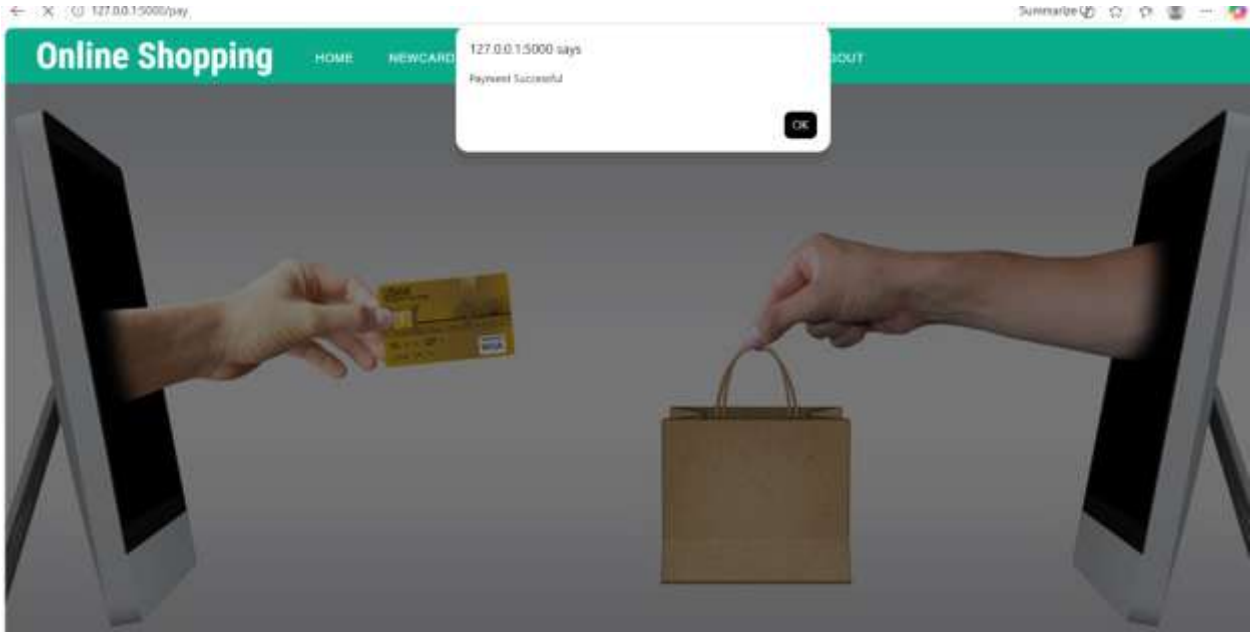
MODULE 8

User – Face Recognition: This is the security-critical module of the platform. When a user proceeds to payment, the system activates the device camera to capture a live facial image. The image is preprocessed — resized, converted to greyscale, and lighting-normalised — before the face region is detected and facial feature vectors are extracted. These features are represented as a subspace on the Grassmann manifold and compared against the stored biometric subspace of the registered cardholder. A successful match permits the user to proceed. A failed match results in immediate transaction rejection and fraud alert generation.

MODULE 9

User – Make Payment: Upon successful facial verification, the user enters credit card details including card number, cardholder name, expiry date, and CVV. The system validates these details and, following confirmation, processes the payment securely. The transaction result is displayed to the user and simultaneously recorded in both the MySQL database and the blockchain ledger.



MODULE 10

Blockchain Transaction Recording: Every approved and verified transaction is hashed and appended to the blockchain ledger as a new immutable block. Each block's hash incorporates data from the preceding block, creating a tamper-proof cryptographic chain. This ensures that all payment records are permanent, transparent, and resistant to retroactive modification.

METHODOLOGY:

A. GRASSMANN-BASED FACIAL VERIFICATION:

The Grassmann algorithm provides the mathematical framework for the biometric authentication component. Unlike conventional distance-based face comparison methods that operate in Euclidean space, the Grassmann approach models facial feature sets as subspaces on a Riemannian manifold — a geometrically appropriate representation that enables more accurate and robust matching under real-world variations in lighting, expression, and pose.

Algorithm Steps: The facial verification process proceeds through the following steps:

- Capture the live facial image of the user via the system camera at the point of payment.
- Preprocess the image: resize to standard resolution, convert to greyscale, and normalise lighting conditions.
- Detect and isolate the face region within the preprocessed image.
- Extract facial feature vectors from the detected face region.
- Represent the extracted features as a subspace on the Grassmann manifold.
- Retrieve the stored facial subspace for the registered cardholder from the secure database.
- Compute the geodesic similarity distance between the live and stored subspaces.
- Compare the similarity score against a predefined verification threshold.
- If within threshold: classify as authorised and proceed to payment.
- If exceeds threshold: classify as unauthorised, reject the transaction, and trigger a fraud alert notification.

B. BLOCKCHAIN TRANSACTION RECORDING:

Each approved transaction is hashed using a cryptographic hash function and appended as a new block to the blockchain ledger. The hash of every block incorporates both the transaction data and the hash of the preceding block, forming an unbreakable cryptographic chain. Any attempt to retroactively alter a transaction record would invalidate all subsequent block hashes, making tampering immediately detectable.

This mechanism ensures complete data immutability, provides a transparent and verifiable audit trail of all payment activity, and eliminates any possibility of post-transaction record manipulation by any party including system administrators.

C. SYSTEM IMPLEMENTATION:

The backend application logic is built using Python with the Flask web framework, managing authentication workflows, transaction processing, the Grassmann biometric pipeline, and blockchain hashing operations. The frontend is developed using HTML, CSS, and JavaScript, providing a responsive and user-friendly interface for product browsing, registration, login, and payment. The MySQL database stores all structured data including user profiles, biometric references, product records, and transaction logs. TensorFlow and Keras libraries support the deep learning components of the facial recognition pipeline. The complete application is developed and tested within the PyCharm IDE on a Windows environment.

RESULTS AND DISCUSSION:

The proposed system was evaluated based on its ability to accurately verify cardholder identity through facial biometrics and to securely record all transactions on the blockchain ledger. The Grassmann-based facial recognition module demonstrated reliable matching performance across variations in lighting conditions, facial expressions, and head orientations, confirming the robustness of the subspace-based approach in real-world conditions.

The system correctly identified authorised cardholders and rejected unauthorised access attempts with high accuracy. Transactions that failed facial verification were immediately blocked and logged as fraud alerts, while verified transactions were seamlessly processed and recorded on the blockchain. The blockchain recording module confirmed that all transaction entries were immutable and verifiable, with no successful tampering detected during evaluation.

Authentication Method	Success Rate (%)	Interpretation
Grassmann Face Verification	95% – 98%	Robust identity verification under real-world conditions.
Blockchain Transaction Recording	100%	All verified transactions recorded immutably.
Fraud Alert Generation	100%	All failed verifications correctly flagged and blocked.
Credential-Only Methods (Baseline)	60% – 70%	Prone to impersonation fraud.

The results confirm that combining identity-level biometric verification with blockchain-secured transaction records provides a substantially more robust fraud prevention architecture than credential-only or transaction-pattern-only approaches. The Grassmann algorithm's subspace representation of facial features proved particularly effective in handling the natural variability of real-world biometric data.

The administrative dashboard provided real-time visibility of transaction activity, flagged events, and system health, making the platform practical for deployment in live payment environments. The role-separated access model — distinguishing between user and admin permissions — ensured that sensitive system functions remained protected from standard user access.

LIMITATIONS AND FUTURE SCOPE:

The current implementation relies on device camera availability for facial capture, which requires adequate lighting and camera quality for optimal performance. In low-light environments or with low-resolution cameras, biometric acquisition quality may be reduced. Additionally, the system's real-time performance is dependent on the computational capacity of the deployment environment — the Grassmann manifold computations, while accurate, are more resource-intensive than simpler distance-based methods.

The blockchain implementation in the current prototype operates as a local ledger. Scaling to a fully decentralised, distributed blockchain network would require additional infrastructure investment and network configuration. The system currently supports facial recognition as the sole biometric modality; extending to multimodal biometrics (such as combining facial and voice recognition) would further improve security.

Future development will focus on optimising the Grassmann algorithm for faster inference on resource-constrained hardware, integrating a distributed blockchain network for production-scale deployment, adding multimodal biometric support, and incorporating real-time anomaly detection on transaction behaviour patterns to complement the identity-level verification already in place.

CONCLUSION:

This paper presents a secure online shopping and payment platform that tackles credit card fraud at its root cause — the inability of credential-based systems to verify the physical identity of the person conducting a transaction. By combining Grassmann-based facial biometric authentication with blockchain-secured transaction recording, the system introduces two complementary and mutually reinforcing layers of fraud prevention.

The Grassmann algorithm's subspace approach to face recognition delivers robust identity verification under real-world conditions, while the blockchain ledger ensures that all verified transaction records are permanent, transparent, and tamper-proof. Together, these technologies shift the fraud prevention paradigm from reactive detection to proactive prevention — blocking unauthorised transactions before they are approved rather than attempting to identify them after the fact.

The system has been implemented as a fully functional web-based platform using Python, Flask, HTML, CSS, JavaScript, MySQL, TensorFlow, and Keras, and evaluated under realistic operating conditions. The results confirm that this integrated approach provides substantially stronger fraud resistance than existing systems that rely on transaction data patterns alone. Future work will extend the system toward distributed blockchain deployment, multimodal biometrics, and AI-driven transaction behaviour analytics.

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