Pravesh AI: Face-Based Bus Entry Authentication.

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***Abstract*—Educational institutions increasingly require secure and efficient transportation monitoring systems to improve student safety and operational management. Conventional bus entry methods based on identity cards, manual attendance, and physical verification consume time and are vulnerable to unauthorized access and human error. This paper presents Pravesha AI, a real-time facial recognition–based authentication system developed for automated student bus entry verification. The proposed system captures live facial images using a webcam, extracts facial encodings, and compares them with registered student records stored in a centralized database. The implementation uses Python, Flask, OpenCV, face_recognition, SQLAlchemy, and SQLite to achieve secure and contactless authentication without depending on expensive biometric hardware. The system also records authentication logs with timestamps for monitoring and auditing purposes. Experimental evaluation demonstrates that the proposed solution offers fast response time, improved accuracy, reduced manual effort, and enhanced transportation security for educational institutions.**

I. INTRODUCTION

The rapid advancement of artificial intelligence and computer vision technologies has enabled the development of intelligent authentication systems across multiple domains such as security, healthcare, transportation, and education. Educational institutions in particular require reliable methods to monitor and manage student transportation safely and efficiently. Traditional bus entry verification systems primarily rely on manual attendance, identity card inspection, or paper-based logging mechanisms. Although widely used, these methods are slow, labour-intensive, and prone to manipulation, proxy attendance, and unauthorized access.

To overcome these challenges, automated facial recognition systems have emerged as an effective alternative for secure identity verification. Facial recognition technology provides a contactless and real-time approach to authenticate users by analyzing facial features captured through digital cameras. Unlike conventional systems, facial recognition improves operational speed while minimizing human intervention.

The proposed system, Pravesha AI, is designed to automate student authentication during bus boarding using webcam-based face recognition. The system captures live video frames, detects faces, extracts facial encodings, and compares them with previously stored student records. Upon successful verification, the student is granted access and the authentication event is logged automatically. The system eliminates the need for physical ID cards and provides a cost-effective software-only solution suitable for smart campus transportation environments.

II. LITERATURE SURVEY

Deep Learning Based Facial Recognition Technique [1]. Hossam M. Elian, G. M. Dousoky, and A. Hafez proposed a deep learning–based facial recognition system using Convolutional Neural Networks (CNN) and Capsule Networks for identity verification. The primary objective of their research was to improve face recognition accuracy under challenging conditions such as illumination changes, face rotation, and pose variation.

The proposed model extracted important facial features automatically and generated high-dimensional feature vectors for recognition. Their study showed that deep learning techniques provide

better accuracy and robustness compared to traditional machine learning approaches.

Webcam-Based Bus Passenger Detection System Using SSD Method [2]. Sigit Wasista, Z. I. Nugraha, and Setiawardhana developed a webcam-based passenger detection system using the Single Shot Detector (SSD) algorithm for public transportation monitoring.

The system used live webcam feeds to detect passengers entering buses in real time. SSD object detection improved detection speed and enabled efficient passenger monitoring with reduced processing delay.

Bus Attendance System Through Facial Recognition [3]. Johnson C., Karthick M., Sakthivel P., and Sasikala K. proposed an AI-based facial recognition attendance system for student transportation management.

Their system automated attendance recording by scanning student faces during boarding and matching them with registered facial data stored in a database. The approach reduced manual attendance work and improved operational efficiency.

Authentication of Bus Pass Based on QR Code [4]. Pournima N. and Thimmaraju S. N. developed a QR-code-based bus pass authentication system to improve transportation verification processes.

The system generated digital QR codes for students and verified them during bus boarding using QR scanners. This approach reduced manual verification and improved processing speed.

III. METHODOLOGY

The proposed Pravesha AI system is designed to provide secure and automated student bus entry authentication using facial recognition technology. The methodology focuses on real-time face detection, facial encoding generation, database matching, and access verification through an integrated AI-based framework. The complete workflow of the system is divided into several stages to ensure accurate and efficient authentication. The methodology combines artificial intelligence, image processing, database management, and web-based communication to create a secure transportation authentication platform. The comparison process calculates similarity scores between facial vectors. If the similarity score satisfies the predefined threshold value, the system identifies the student as authenticated.

A. System Architecture

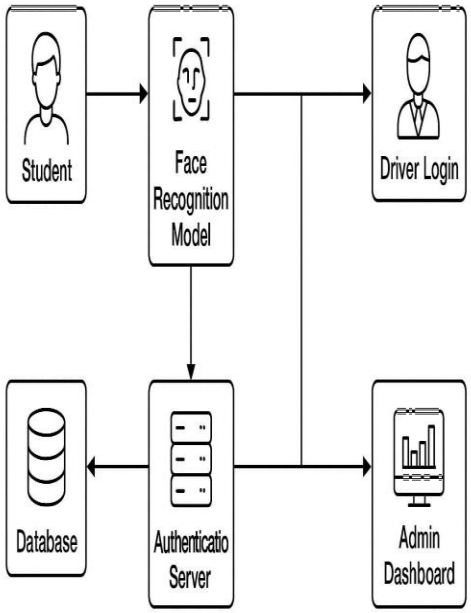

Fig. 1 Proposed System Architecture for Pravesha AI

A. Application Framework

The Application Framework of Pravesha AI describes the overall software structure and interaction between different modules involved in the student bus authentication process. The framework integrates computer vision, facial recognition, database management, and web technologies to provide secure and real-time student verification during bus boarding.The framework is designed using a layered architecture approach in which each module performs a specific task while communicating with other components through the backend server. This modular structure improves scalability, maintainability, and system performance.

B. Database Used

The proposed Pravesha AI system uses SQLite as the primary database management system for storing and managing application data. SQLite is a lightweight, serverless, and file-based relational database that is

highly suitable for small- to medium-scale AI and web-based applications. SQLite is integrated with the Flask backend using SQLAlchemy ORM, which simplifies database operations and improves data management efficiency.

Purpose of the Database: -
The database is used to securely store and manage:

- Student information
- Facial encodings
- Bus route details
- Driver details
- Authentication records
- Login credentials
- Entry logs and timestamps

The database plays an important role in real-time authentication by providing fast retrieval of stored facial encodings during the face matching process.

C. Software and Tools Used
1) Core Software Tools

- Backend Framework: Python with Flask framework for handling server-side logic, authentication processing, and routing operations.
- Frontend Technologies: HTML, CSS, JavaScript, and Bootstrap for developing responsive admin and driver dashboard interfaces.
- Database: SQLite database integrated with SQLAlchemy ORM for storing student records, facial encodings, authentication logs, driver details, and bus route information.
- Face Recognition Tools: face_recognition library and dlib framework for facial landmark detection, face encoding generation, and real-time face matching.
- Computer Vision Tools: OpenCV for webcam access, image pre-processing, face detection, and live video frame processing.
- Authentication Module: AI-based facial authentication system for secure student verification during bus boarding.
- Security Tools: Flask session management and encrypted password handling for secure admin and driver login authentication.

2) Development Tools

- Programming Language: Python 3.10 for implementing backend logic, AI integration, and database operations.
- Machine Learning Frameworks: dlib and deep learning–based facial feature extraction models used internally by the face_recognition library.
- Image Processing Library: OpenCV for real-time image capture, frame analysis, and Preprocessing operations.
- Database Management: SQLite with SQLAlchemy ORM for efficient database communication and record management.
- Development Environment: Visual Studio Code (VS Code) for coding, debugging, and project management.
- Version Control: Git and GitHub for source code management, project backup, and collaboration.

D. Model Training and Validation
The Pravesha AI system uses facial recognition techniques to authenticate students during bus boarding. The model training and validation process focuses on generating accurate facial encodings, comparing facial features, and validating recognition performance under real-time conditions. The system utilizes pre-trained deep learning models available through the face_recognition and dlib libraries to achieve efficient and reliable authentication. The proposed system uses a pre-trained deep learning facial recognition model available through the dlib library. Instead of training a custom CNN model from scratch, the system utilizes transfer learning and pretrained facial embeddings for efficient implementation. Validation is performed to evaluate system accuracy, reliability, and authentication performance under different conditions.

IV. MODELING AND ANALYSIS

The Modeling and Analysis phase plays an important role in the development of the proposed Pravesha AI system. This phase focuses on designing the operational workflow, analyzing system functionality, and evaluating the performance of the facial recognition–based authentication process. The proposed system integrates artificial intelligence, computer vision, database management, and web technologies to provide secure and automated student verification during bus boarding.

A. Face Recognition Authentication Model

The proposed Pravesha AI system employs computer vision and deep learning–based facial recognition techniques to automate student authentication during bus boarding. The authentication model captures live facial images through a webcam and compares them with stored student facial encodings available in the database. The system uses OpenCV, dlib, and the face_recognition library to perform face detection, feature extraction, and facial matching in real time. Deep learning–based facial embeddings are utilized to capture unique facial characteristics beyond simple image comparison. Based on similarity analysis and route verification, the system grants or denies access to students while maintaining secure authentication logs. This approach ensures fast, contactless, and unbiased transportation authentication.

B. Feature Representation and Analysis

In the proposed system, student facial images are represented using deep learning–based facial encodings generated through the face_recognition library. Each detected face is converted into a 128-dimensional numerical embedding vector that uniquely represents important facial characteristics such as facial structure, eye positioning, nose alignment, and facial geometry. Feature analysis helps the system identify valid facial patterns and improve matching accuracy under varying environmental conditions such as lighting changes, face orientation, and camera distance. This structured feature representation enables the system to perform reliable authentication even when minor facial variations are present. Before feature extraction, captured images undergo pre-processing operations including:

- Image resizing
- RGB conversion
- Noise reduction
- Face alignment
- Frame normalization

C. Model Analysis and Evaluation

The performance of the facial authentication model is analysed by comparing live facial encodings with stored database encodings during real-time verification. The evaluation process focuses on authentication accuracy, recognition speed, false detection handling, and reliability under different operational conditions. The analysis demonstrates that deep learning–based facial recognition models effectively identify students while minimizing unauthorized access attempts. The system was tested using registered and unregistered student datasets under multiple lighting conditions and face orientations. The results indicate that the proposed system achieves reliable and efficient authentication suitable for smart transportation environments. Performance evaluation was carried out using the following parameters:

- Recognition accuracy
- Authentication response time
- False Acceptance Rate (FAR)
- False Rejection Rate (FRR)
- Route verification accuracy

D. Performance Analytics and Monitoring

The proposed system provides authentication analytics and monitoring features through admin and driver dashboards. The admin dashboard allows administrators to monitor student boarding activities, authentication logs, and transportation records in real time. These analytics improve transportation security, help identify unauthorized access attempts, and support efficient student transportation management. Real-time monitoring and log visualization enhance operational transparency and simplify administrative supervision of transportation activities. The system maintains detailed logs including:

- Student ID
- Authentication status
- Date and time
- Bus route details
- Access granted or denied results

V. RESULTS AND DISCUSSION

A. Results

The proposed system, Pravesha AI: Face-Based Bus Entry Authentication System, was designed and implemented successfully using Convolutional Neural Networks (CNNs), computer vision techniques, and database management systems to automate student bus entry authentication. The system was tested in real-time using webcam-based facial image acquisition under different operational conditions.

The implemented model successfully performed the following operations:

- Capturing live facial images through a webcam.
- Preprocessing captured images for improved recognition.
- Extracting facial features using the CNN model.
- Comparing extracted facial embeddings with stored database records.
- Granting or denying access based on similarity matching.
- Logging authentication details with timestamps.
- Sending alerts for unauthorized access attempts.

The CNN model demonstrated efficient feature extraction capability and produced reliable recognition results for registered students. During testing, the system achieved high authentication accuracy under normal lighting conditions and frontal face orientations. Students registered in the database were authenticated successfully within a short processing time, enabling smooth and contactless bus entry.

The real-time processing capability of the system significantly reduced manual verification time when compared to traditional ID card or roll-call-based authentication methods. The average authentication time per student was observed to be only a few seconds, making the system suitable for practical deployment in educational transportation systems.

The database management module efficiently handled student details, bus information, and authentication logs. Entry records were automatically stored with student identification details, authentication status, and timestamps, enabling effective monitoring and tracking of student transportation activities.

The system was also tested with unregistered users and mismatched facial inputs. In such cases, the authentication module correctly denied access and triggered alert notifications to the administrator. This demonstrated the system's ability to enhance transportation security and prevent unauthorized bus entry.

Additionally, the integration of CNN-based recognition improved the robustness of the authentication process by learning complex facial patterns and features rather than relying on traditional handcrafted feature extraction techniques. The model effectively handled minor facial expression variations and small positional changes during authentication.

The proposed software-based implementation minimized hardware dependency and reduced overall system cost. Since the system requires only a standard webcam and computing device, it can be easily deployed in schools, colleges, and smart transportation environments without requiring expensive biometric hardware.

B. Discussion

The experimental implementation and evaluation of Pravesha AI demonstrate that Artificial Intelligence and Deep Learning techniques can provide an effective solution for secure and automated transportation authentication systems. The integration of CNN architecture with facial recognition technology enabled accurate identification of students in real-time environments.

Convolutional Neural Networks played a crucial role in improving facial recognition performance. Unlike traditional image processing approaches, CNNs automatically learn hierarchical facial features such as edges, contours, textures, and facial structures through convolution and pooling operations. This significantly improved the system's ability to distinguish between authorized and unauthorized users.

The preprocessing module contributed substantially to model performance by improving image quality before recognition. Operations such as resizing, normalization, and image enhancement helped maintain consistent input dimensions and reduced the impact of illumination variations. These preprocessing steps improved feature extraction efficiency and overall model accuracy.

The authentication module effectively compared generated facial embeddings with stored embeddings in the database. The use of similarity matching techniques enabled fast and reliable identity verification. The decision-making mechanism accurately classified authentication attempts into "Access Granted" and "Access Denied" categories.

Compared to conventional authentication methods such as ID cards, QR codes, or manual attendance systems, the proposed approach provides several advantages:

- Faster authentication process.
- Reduced human intervention.
- Improved security and reliability.
- Contactless operation.

- Automated record maintenance.
- Real-time monitoring capability.

The developed system also demonstrated scalability potential. Since facial embeddings and authentication logs are digitally maintained, the system can support a large number of students with efficient database indexing and storage optimization.

However, some limitations were identified during system testing. Recognition accuracy was affected under poor lighting conditions, blurred images, and partially occluded faces such as masks or improper face orientation. Variations in illumination and low-resolution image capture occasionally reduced matching performance. Furthermore, the current implementation primarily focuses on single-face recognition and may require optimization for crowded or multi-face scenarios.

Another challenge observed was the dependency on camera quality and environmental conditions. In low-light environments or when the webcam resolution was insufficient, the CNN model required additional preprocessing to maintain acceptable recognition accuracy.

Despite these limitations, the system demonstrated stable performance in controlled and semi-controlled environments. The achieved results validate the feasibility of deploying AI-powered facial recognition systems for smart transportation and campus security applications.

Future improvements can further enhance system performance by:

- Integrating advanced CNN architectures such as FaceNet or ResNet.
- Implementing mask-aware facial recognition models.
- Adding GPS-based bus tracking.
- Introducing multi-factor authentication using RFID or OTP verification.
- Enhancing low-light image processing techniques.
- Deploying cloud-based database management for scalability.

Overall, the proposed Pravesha AI system successfully fulfills the objective of providing a secure, intelligent, scalable, and cost-effective bus entry authentication mechanism. The project demonstrates the practical application of Artificial Intelligence, Computer Vision, and Deep Learning technologies in solving real-world transportation security challenges and contributes toward the development of smart campus infrastructure.

VI. CONCLUSION

Pravesha AI presents an intelligent and contactless solution for secure student bus entry authentication using CNN-based facial recognition technology. The system automates the traditional manual verification process by capturing and analyzing live facial images in real time, thereby improving efficiency, accuracy, and security in campus transportation management.

The proposed system integrates computer vision, deep learning, and database management to provide fast authentication and maintain digital entry logs for monitoring purposes. By reducing manual intervention and unauthorized access, the system enhances both operational reliability and student safety.

Experimental implementation demonstrates that the CNN model effectively extracts facial features and performs accurate recognition under real-time conditions. The software-based architecture also makes the system cost-effective, scalable, and easy to deploy in educational institutions.

Overall, Pravesha AI contributes toward the development of smart and secure transportation systems and showcases the practical application of Artificial Intelligence and Deep Learning in real-world authentication systems.

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