INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD)
© 2026 IJNRD | Volume 11, Issue 3, MARCH 2026 | ISSN: 2456-4184 | IJNRD.ORG

# A ROBUST AND SCALABLE CCTV-BASED ATTENDANCE MANAGEMENT SYSTEM USING DEEP LEARNING FOR REAL-TIME FACE RECOGNITION

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**Abstract**
This study proposes an automated Face Recognition-Based Attendance Management System that can be used to substitute the traditional manual roll-call systems in institutions of higher learning. The system uses Deep Face-facial embedding extraction, face detection using open CV, and the Flask Web Framework to offer a smooth and effective workflow of attendance. The capturing of a few face samples provides students with the ability to capture many face samples in order to have robust feature representation. Embeddings are extracted and stored to be compared later with Euclidean distance as a measure of identity during attendance sessions as captured by webcam, image or video uploads. The system is a combination of a SQLite database where student records, subjects and attendance history are stored on a long term basis. It also has the automated email notification feature to notify parents about the student after it is marked absent to enhance transparency and communication. The system helps to enhance accuracy, minimize proxy attendance, minimize human effort, and also makes it more dependable within the classroom set ups hence it has the capacity to be implemented in real time academic usage.

**Keywords-**Face recognition, Deep face, attendance system, Flask, OpenRTS, Embeddings, automation, Image Processing.

## 1.1 INTRODUCTION

Attendance checking is an important aspect in academic institutions so that participation of students is ensured and discipline is maintained. The old system of attendance like manual roll calls or RFID card charters are tedious, easily distorted, and there is no form of verification to ascertain the true identity of the student. In order to overcome these issues, there has been new development adopting the use of face recognition technology to enable automation of attendance. Indicatively, Aisyah highlighted the effectiveness and comfort of a smart attendance system that operated on facial biometrics to minimize the amount of work handled by an administrator as well as eliminating proxy attendance [1]. On the same note, the contemporary organizations are becoming inclined toward digital and AI-enhanced solutions to enhance the operational accuracy and transparency.

Face recognition systems use deep learning models to identify the facial characteristics of people, match them with embedded ones in the storage, and identify them in real time. As pointed out by Paul et al., combining face recognition with web technologies enhances the notion of accessibility and monitoring in real-time by use of online dashboards [2]. Patel et al. further established the fact that with CCTV-based attendance monitoring, dedicated attendance hardware is not necessary and it provides a wide coverage of the classroom [3]. With these innovations, biometric attendance systems are moving towards more scalable and less intrusive and faster systems of academic settings.

In the educational context, accuracy, scalability, and user interaction experience are the main concerns of selecting an appropriate attendance automation framework. Lari et al. highlighted that machine learning-enhanced facial recognition enhances the dependability and cuts the rate of false identifications in colleges [4]. In the meantime, it was shown by Bangare et al. that automated smart attendance systems increase the efficiency of the classroom and decrease manpower cost [5]. The decision support framework and optimised recognition models also add value to the enhanced accuracy and flexibility of identification of the various

student samples [6]. Thus, a facial recognition-based attendance system can help in achieving a lot of benefits to the educational institutions in search of the secure, efficient, and user-friendly attendance management systems

## 1.2 LITERATURE REVIEW

### *A. Face Recognition Smart Attendance Systems.*

To lessen the use of time in the manual roll-call system, Aisyah (2025) came up with a smart attendance system where manual roll-call or the use of proxies is replaced with automated facial recognition to avoid the use of time and proxy attendance instances. The system scans the student and retrieves the facial features and compares them with the stored data to identify identity as a means of guaranteeing that a system is accurate and efficient in the administration. The paper discusses the significance of user-friendly interfaces and integration of systems into the current academic processes. On the same note, Lateef and Kamil (2025) presented an interactive real-time attendance system that was based on human-computer interaction and the ease of use. Their strategy emphasizes fast processing and minimizing errors in terms of recognition in the classroom learning conditions. The conclusion made by both works is that automated biometric attendance systems improve institutional transparency, security, and reliability.

### *B. Live Web-Integrated Check-In Check-Out Tracking.*

Paul et al. (2025) created an entire attendance system based on web technologies, which involves face recognition and emotion detection. Their work refers to the real-time recognition and high mobility based on the models of interaction provided by browsers, which can allow teachers to control the attendance remotely and safely. The architecture of the system provides effective API communication and synchronization of data. Concurrently, Pires et al. (2025) suggested an end-to-end automated attendance system with surveillance cameras feed to record and recognize students at all times. Their solution reduces the use of manual involvement and provides passive surveillance. Both articles prove the importance of web-based attendance programs boosting scalable, distance and instantaneous academic surveillance without interfering with classroom dynamics.

### *C. Deep Learning and CCTV-Detected Classroom Attendance.*

The authors of the study by Patel et al. (2025) examined the optimization of classroom attendance systems with the aid of CCTV cameras and facial recognition made with the deep learning algorithm. Their approach has a comprehensive cover and does not require a particular attendance hardware. The live frame model identifies students and marks their attendance by processing live frames. Meanwhile, the study by Bangare et al. (2025) envisaged a smart automated system of attendance, in which face recognition mainly tracks the attendance effectively in dynamic classroom settings. Their structure makes them eligible to withstand change in angle, and range of lighting and distance. Both articles indicate that CCTV-driven solutions enhance all the convenience and the ability to implement it on a massive scale, and it has great possibilities in terms of automation of a contemporary educational institution.

### *D. Identification and Recognition Models based on machine learning.*

Lari et al. (2025) worked on better attendance in colleges by training machine learning models to identify and identify the faces of students. They minimize manual verification in their system and assist adaptive learning to enhance face matching. The researchers note that the recognition accuracy in the study was better when changing the appearance of students and changing the circumstances of the environment. Santoso et al. (2025) on the other hand proposed a decision support and machine learning models to identify optimal face recognition settings. Their work gives comparative assessments of various classifiers and detection models to obtain more performance. All these studies accentuate the value of optimized model choice and scalable learning approaches in attendance automation.

### *E. Techniques Automated Recognition and Attendance Tracking.*

Margaryan et al. (2025) underline effective face detection and recognition algorithms in managing the attendance of students. Their system is much more concerned with minimization of recognition errors and consistency of performance across rotations of face. Likewise, it is possible to mention the proposal of SM et al. (2025), who offered the automatic attendance system based on a face recognition application, which simplifies the work of recording attendance on a daily basis. Their methodology has shown a holistic end-to-end process of image capture to attendance recording with interest in accessibility and precision. The two works reaffirm the fact that image based systems of biometrics can properly substitute the conventional attendance system since they ensure authenticity, lessen the workload of the teachers, and insure sound academic records.

## 2. PROPOSED METHODOLOGY

### A. *General Prospectus of the Projected System.*

The proposed system is supposed to be used to mark the attendance using face recognition technology as a part of a web interface. The system substitutes old roll-calling and carding-based attendance system with biometric identification in order to achieve accuracy, less time wastage, and proxy attendance. Facial pictures that belong to students are taken when they are registered and transferred into numerical embeddings, and entered into the system database. At the point of attendance, the system receives input in terms of web camera, image, or video feeds, and compares the input to the saved records to obtain face embeddings and compare them to the stored ones. Once identified successfully the attendance will mark automatically and be stored in the database, and the guardians of absent students can be notified automatically. Such approach will increase reliability, transparency and efficiency.

### B. *Data Acquisition and Preprocessing*

The process of collecting student data is done in the stage of enrollment, whereby the several facial images are taken to provide the data with strength when the light, orientation, and expression condition change. The images are saved on the local memory and processed with OpenCV functions, such as grayscale denoising, histogram equalization, face detection and smoothing. Such a preprocessing is useful to clear up and increase the performance of feature extraction. Instead of using all the facial features, a face detection algorithm identifies the area of interest so that only the useful facial features are applied in recognition. The system guarantees that every student possesses a sufficient amount of good face samples to come up with quality embeddings. Data manipulation, e.g., rotation and resizing, can be used to enhance the generalization of the model and recognize stability in the real-life classroom attendance session.

### C. *EXTR Feature Extraction and Face Embedding Generation*

DeepFace is used to create face embeddings with the distinguishing facial features. A deep neural network that has been trained with large datasets of faces is used to extract feature vectors of high dimensions in each image. These embeddings are numerical feature values which permit one to compare dissimilar faces by using mathematical distances. Throughout the enrollment process, numerous embeddings will be created and stashed against every student to take into consideration the differences in appearance. To be recognized, the extracted embeddings on a frame posted online or using the live trader are compared to known baked-in embeddings using the Euclidean distance. A threshold value is used to decide on the match. This will provide high recognition accuracy, ability to overcome pose changes, and withstand spoofing attempts.

### D. *System Architecture*

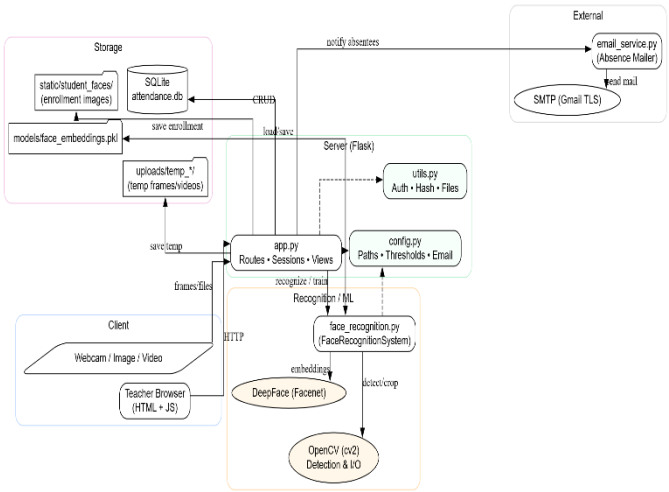



***Fig1: System Architecture***

The architecture of the system has its five key elements which include user interface, server application, face recognition engine, embedded database and attendance logging module. The user interface is created based on Flask templates so that the teachers can register students, start attendance, and see reports. Request processing, image processing and session management are done by the server application. The face recognition engine works on detection, embedding extraction, and matching on Deepface and OpenCV. The facial representations are stored in the embedding database which is associated with student profiles and the status of attendance and confidence is recorded in the attendance module. It has automated email services that alert the parents on absenteeism. This scalable architecture fixes down to an environment, is maintainable and adjustable to different academic settings.

**E. *Attendance Recording and Notification Workflow.***

Upon achieving a face recognition success and a match, the system records them to the attendance database with the details of date, time, student ID, subject and recognition confidence rating. Whenever duplicate entries occur, this is prevented due to the data integrity of the match, which is already present of that particular session. The system also will recognize that students were not identified after each session and will automatically send email messages to their parents, who will know about the absence. Such workflow enhances accountability and promotes regular attendance by the students. The automated system not only has the merit of lessening the workload of teachers, but also shortening the attendant taking time, and enhancing the interaction between the institutions and households, which eventually leads to better academic surveillance and performance management.

## 3. RESULTS AND DISCUSSION

### *A. User authentication/ System accessibility.*

The system gives a user friendly Teacher Login Interface that is clean and only authorized users can visit the platform. The log in form creates an option of Remember Me with the username and password fields to make it easier. Upon a successful authentication, the teachers are redirected to the dashboard. The process ensures their privacy over data and unauthorized persons cannot access their student information. It is easy to use and minimalistic and its design is simple with less training needed on the use of the new system. The process of the log-in is efficient in session management and password validation, meaning that the teachers are registered to be able to access and manipulate attendance and student data in the system.

### *B. Dashboard Overview and System Status Page 1:*

The identified recovery-support tools, such as the ones offered by the Kimono Project[10], and obstacles connected to the identified challenges will be discussed.After signing in, the Dashboard will give a quick look into the statistics of the system, including the total number of students, the number of subjects, among other data, and the number of students who are present on a specific day. Quick action cards allow teachers to access important functions such as registering the students, handling of the records and attendance. The system transparency is enhanced by the fact that there is a notification message informing whether the facial recognition model is trained and is ready to be used or not. The dashboard will enable the teachers to observe the recent lists of attendance, so that there is consistent coverage of classroom activities. Such a structured design will enhance efficiency by minimizing navigation time and also directing immediate accessibility to most essential functionalities of the system.

### *C. Registering and Face Capture of students Process.*

Register New Student Interface enables the teacher to key in student and parent information and have complete records of student identity. This system is a webcam-based multi-angle face capture tool, which captures multiple face images, which enhances global recognition accuracy. Guidance prompts create inconsistency of capture by adjusting light, and angle of descent of the face. The images of the faces are shown below and they can be checked prior to submission and any mistake can be rectified. This procedure guarantees data collection of high quality which is critical in the formation of precise face embeddings. The solution enhances accuracy in the capacity of models and minimizes false identifications during the attendance sessions particularly in actual classroom conditions whereby the lighting and student positions might be dissimilar.

### *D. Student Data and Management Visualization.*

Student Management panel is where you can see all the registered students in card format, with the roll number, department, contact details of the parent and count of images stored. This hierarchical system will enable the educators to monitor the admission of students and update their records when necessary. The student profiles can also be viewed and this helps in ensuring that training data is of high quality as it is checked by viewing student profiles. The recognition process is more accurate because of the ability to review and control individual records. The module enhances transparency and makes the administration work easier as it provides a centralized access to the student data. It enhances the dependability of the consistency in facial recognition accuracy with the maintenance of records and their supervision.

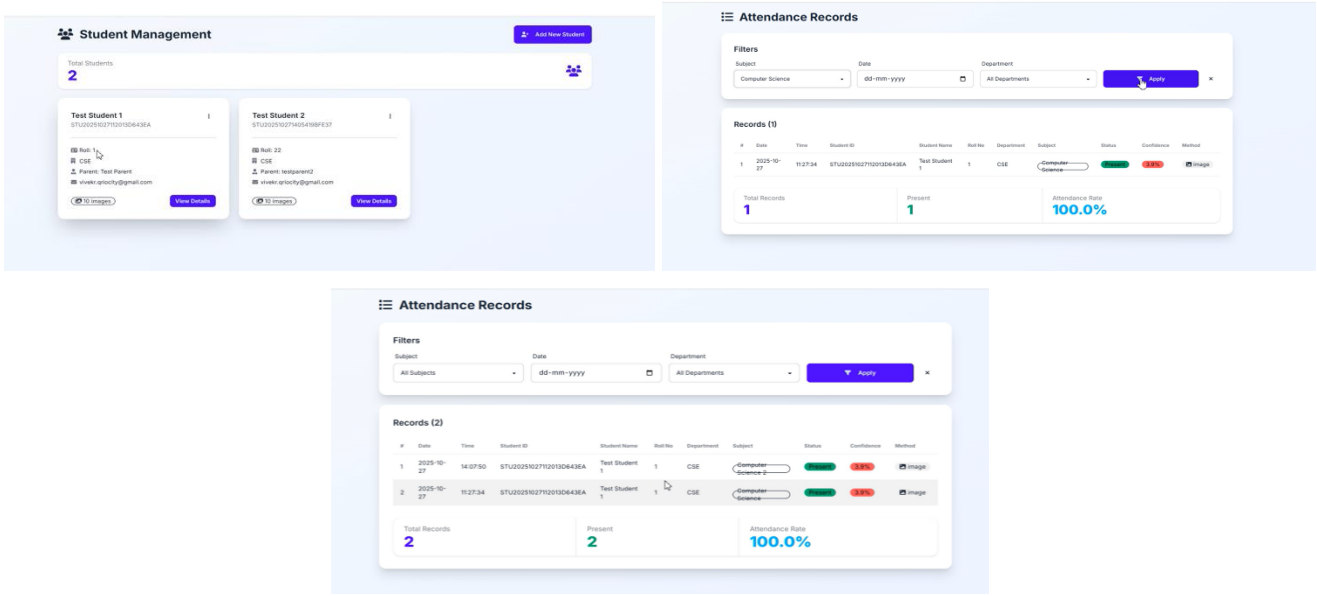
### *E. Naprobilan and Pematuju Hasan.*

Attendance Records page can be filtered with the option of subject, date, and department which can support the detailed analysis of attendance. The attendance records consist of the date, time, student identification, student name, roll number, department, subject, attendance record, confidence level, and mode of attendance (image/webcam/video). The reason why confidence scores are used is to assist teachers to estimate how accurate their recognition is, and to be able to confirm the results when they feel the need to do it. The computer system eliminates repetitive entries and proper daily records. Moreover, some of the attendance records like the total records and attendance rate are automatically generated. This improves monitoring effectiveness and decreases the chances of human input production of errors. The representation of results is clear and enhances decision-making and enhances transparency in the management of academic attendance.

### *F. Discussion*

The system shows a functional and effective way of automating the attendance based on face recognition. The interface is user friendly, thus easy to use even to non-technical users. Multi-angle face capture strategy has a significant contribution to the accuracy of the model due to sufficient training data. Reward recognition performance can however be affected by extreme variations in lighting and also by partial obstruction of faces. The fact that confidence scores are used is advantageous to predictability reliability evaluation. Some of the features that can be improved in the future are incorporation of advanced face detecting algorithms, mobile based attendance and integration with cloud so that it can be expanded to cater to larger populations. Overall, the findings suggest that the solution is effective, reliable and applicable in actual studying settings.

### *G. Output Screenshots:*




## 4.CONCLUSION AND FUTURE SCOPE

Proposed face recognition-based attendance system can be identified as an achievement in automating the normal attendance system since it is accurate and consumes less manual work and eliminates proxy attendance. The system is efficient in offering student management, real-time attendance generated by the DeepFace-made embedding extraction, face detection by using OpenCV, and the implementation of an easy-to-use Flask interface to offer efficient student control in addition to real-time attendance and automatic absence notification to parents. The structured database and multi-angle face capture can increase recognition reliability, and therefore, the system is applicable in the education setting.

The system may be scaled to contain mobile app integration, cloud-based storage, and edge-based processing in the future to enhance scalability and performance. The recognition can be further improved in accuracy and resilience in the real-world through advanced deep learning models, liveness detection and multi-camera tracking of the classroom.

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