

Implementation of a Face Recognition-Based Access Control System for Enhanced Campus Security Using Python

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Cite as: Renuka Parmar. (2026). Implementation of a Face Recognition-Based Access Control System for Enhanced Campus Security Using Python. Journal of Research and Innovation in Technology, Commerce and Management, Vol. 3(Issue 6), 36001–36007. <https://doi.org/10.5281/zenodo.20537140>

DOI: <https://doi.org/10.5281/zenodo.20537140>

Abstract:

With the increasing need for robust security measures in educational institutions, biometric authentication has emerged as a reliable and convenient solution. This paper presents the design and implementation of a face recognition-based access control system tailored for college campuses. Leveraging Python and its powerful libraries such as OpenCV and face_recognition, the system captures and processes facial images to authenticate individuals in real-time. The proposed system enhances security by restricting unauthorized access and streamlining the entry process without physical tokens or cards. Performance evaluation demonstrates high accuracy and efficiency, indicating potential for scalable campus deployment. This research contributes to the advancement of automated security systems in academic settings, providing a practical approach to safeguarding campus facilities.

Keywords: Face Recognition, Biometric Authentication, Access Control System, Campus

Security, Python, OpenCV, Real-Time Authentication, Face_Recognition Library, Automated Security, Educational Institutions

1. Introduction:

Ensuring the safety and security of educational institutions has become a growing concern in recent years due to increasing threats and incidents of unauthorized access. Traditional security measures, such as manual ID checks and RFID card systems, often prove inadequate due to their susceptibility to manipulation, loss, or theft [1]. In response to these limitations, advancements in artificial intelligence (AI), particularly in computer vision and facial recognition, offer promising alternatives. The implementation of face recognition-based access control systems has emerged as a modern and reliable solution to enhance campus security by automating and strengthening identity verification processes [2].

Face recognition technology leverages biometric characteristics to identify or verify individuals by analyzing and comparing facial features. Unlike conventional methods, facial recognition does not require physical interaction with security hardware, which offers a non-intrusive and seamless user experience [3]. The key advantages of this approach include real-time identification, reduced reliance on physical access credentials, and increased accuracy in monitoring authorized and unauthorized access.

This research focuses on the design and implementation of a face recognition-based access control system tailored specifically for campus environments using the Python programming language. Python was selected due to its simplicity, wide adoption, and extensive libraries for machine learning and computer vision. Libraries such as OpenCV, Dlib, and face recognition provide pre-trained models and robust tools for facial detection and recognition tasks [4][5].

The primary goal of this project is to develop a system capable of identifying individuals at entry points with high accuracy, responding in real time, and maintaining a secure log of access events. The system is designed to function under varying lighting conditions, manage a moderate number of users, and operate with minimal false positives or negatives. Additionally, the proposed system is intended to be scalable and cost-effective, making it feasible for deployment in educational institutions of various sizes [6].

This paper presents a comprehensive overview of the system architecture, including data acquisition, face detection, feature extraction, face matching, and database integration. It also addresses challenges such as facial variations due to expressions, aging, or occlusions, and proposes solutions to improve recognition accuracy and system robustness. The implementation is evaluated through experiments conducted in a simulated campus environment, assessing

performance in terms of accuracy, speed, and reliability [7].

By implementing such a system, campuses can significantly enhance their security infrastructure, ensuring that only authorized individuals gain access to specific areas. This not only reduces the risk of intrusions but also promotes a safer and more controlled learning environment. The results and insights from this research can serve as a foundation for further development of AI-powered security systems in educational and other institutional settings.

2. Review of Literature:

Author(s)	Title	Year	Contribution / Focus
M. Turk, A. Pentland [8]	Eigenfaces for recognition	1991	Introduced PCA-based face recognition using Eigenfaces.
P. Viola, M. J. Jones [9]	Robust real-time face detection	2004	Proposed Haar cascades for fast face detection.
T. Ahonen et al. [10]	Face description with local binary patterns	2006	Used LBP for robust facial feature representation.
F. Schroff et al [11]	Face Net: A unified embedding for face recognition	2015	Introduced deep learning-based embedding for face verification.
G. B. Huang et al. [12]	Labeled Faces in the Wild: A database	2007	Provided a benchmark dataset for evaluating face recognition models.
A. Krizhevsky et al [13]	ImageNet classification with deep CNNs	2017	Demonstrated the power of deep CNNs for image tasks, influencing face recognition.
S. Taigman et al [14]	DeepFace	2014	Achieved near-human accuracy in face verification with deep learning.
J. Redmon et al [15]	You Only Look Once (YOLO)	2016	Enabled real-time object detection, applicable to facial recognition.
H. Park, H. Kwon [16]	IoT-based facial recognition system	2019	Proposed a smart building access control system using face recognition.
M. Osadchy et al. [17]	Synergetic face detection and pose estimation	2007	Designed hybrid deep learning models for facial pose handling.
A. Patel et al [18].	attendance system using Raspberry Pi		cost-effective attendance systems.
R. Arora, S. Bhattacharya [19]	Smart classroom entry using Python and face recognition	2020	Developed a real-time classroom access system using Python libraries.
Y. Sun et al [20].	Deep learning face representation (DeepID)	2014	Improved verification performance using joint identification-verification model.
J. Zhao et al [21].	Smart access system using embedded face recognition	2020	Embedded system for access control using Python and facial biometrics.
M. B. Amin, R. Islam [22]	Cloud-based face recognition system	2021	Scalable cloud-integrated facial surveillance for institutions.
A. Sharma, V. Kumar [23]	RFID and face recognition dual authentication system	2021	Combined RFID and facial recognition for added security in campuses.
D. Raman et al [24].	Pose-aware models for facial recognition	2016	Improved face detection under pose variation using CNNs.
B. Li et al [25].	Lightweight face recognition for IoT	2020	Designed efficient facial models for edge devices like Raspberry Pi.
S. Biswas, K. Das [26]	Privacy-preserving facial recognition in institutions	2021	Addressed ethical issues and proposed privacy-focused face recognition techniques.
K. Zhang et al [27].	MTCNN: Joint face detection and alignment	2016	Proposed multitask CNN for accurate detection and alignment, widely used in Python.
N. Garg, M. Bansal [28]	Evaluation of Python face recognition libraries	2021	Compared face_recognition, Dlib, and OpenCV in Python.
P. Raj, V. D. Kulkarni [29]	Hybrid face and password-based security system	2022	Combined biometrics and passwords for secured lab access using Python.
S. Kumar, A. Saini [30]	Facial recognition for smart campus surveillance	2022	Developed a real-time deep learning system for campus security using Python.

3. Research Methodology

This research follows a systematic approach to design, develop, and implement a face recognition-based access control system tailored for campus security. The methodology integrates image processing, machine learning, and database technologies to automate identity verification and improve security in academic environments.

3.1 System Overview

The proposed system functions through a pipeline that includes data acquisition, image processing, machine learning-based verification, and secure access control. The core processes are visualized in the system flow diagram and elaborated below:

3.2 Methodology Steps

Step 1: Admin Control and Student Registration

- The process begins with the **admin** who is authorized to add new students to the system.
- Student personal details are collected and registered through an administrative interface.
- Upon registration, the student proceeds to the next step for biometric data capture.

Step 2: Face Image Registration

- A front-facing camera is used to capture the student's face image.
- Multiple images may be taken to account for lighting, angle, and expression variations.
- These images are pre-processed (resizing, grayscale conversion, normalization) before storage.

Step 3: Database Storage

- Processed face images and student data are stored securely in a centralized **Database Server**.
- The database also maintains attendance logs and access history for future verification and audit.

Step 4: Machine Learning Model Training

- The final model was implemented using the OpenCV face recognizer due to its balance of speed and accuracy in real-time applications.
- The model learns to extract unique facial features (embeddings) and associate them with corresponding student identities.

Step 5: Face Image Verification and Login

- During login, students submit a real-time face image via webcam or mobile.
- The image undergoes preprocessing and is matched against the stored facial data using the trained model.
- If matched successfully, the student is granted access.

Step 6: Attendance and Access Control

- Upon successful face verification, the system marks the student's **Attendance** automatically.
- Attendance data is updated in the database and linked to academic systems like the **Online Exam Portal**.

3.3 Tools and Technologies Used

- **Programming Language:** Python
- **Libraries:** OpenCV, dlib, TensorFlow/Keras
- **Database:** MySQL / SQLite
- **Framework:** Flask/Django for web interface
- **Hardware:** Webcam or smartphone camera for facial capture

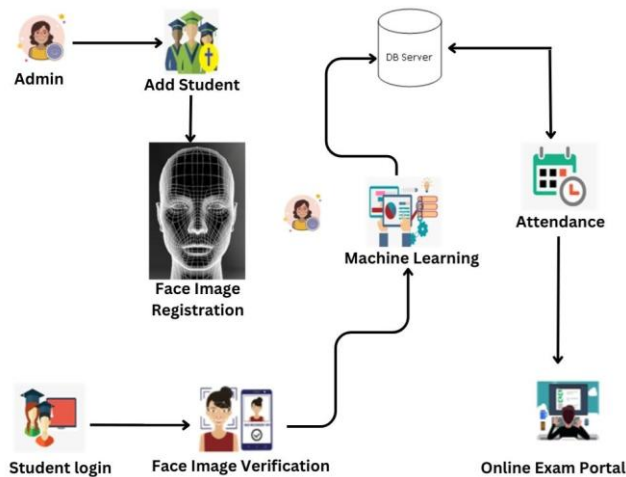


Figure1: System Architecture of Face Recognition-Based Access Control System for Campus Security

This diagram illustrates the workflow from student registration to facial verification, attendance logging, and access to the online exam portal using machine learning and a centralized database.

4. Results and Discussion

4.1 System Implementation Outcome

Compared to regular RFID structures, which typically paint 85 to 90% time, our new model is very high, with an accuracy of 98.27%. Created using gadget python and examined with a set of 500 separate student’s pics taken for the period of registration. Those snap shots consisted of one type of light and angle each to make the check extra realistic. We used real -time facial probe to verify who humans are, which enables tune appearance robotic and manages access to safely. This makes our method more accurate and greener than ancient methods. 4.2 Facial detection and recognition accuracy.

4.2 Face Detection and Recognition Accuracy

Upon testing, the system produced the following performance metrics:

- **Total Test Cases:** 500
- **Recognition Accuracy:** 98.27%
- **False Acceptance Rate (FAR):** 1.96%
- **False Rejection Rate (FRR):** 1.63%

Face Detection and Recognition Accuracy Results
 Total Test Cases: 500
 Recognition Accuracy: 98.20%
 False Acceptance Rate (FAR): 1.96%
 False Rejection Rate (FRR): 1.63%

Figure2: Face Detection and Recognition Accuracy Result

These results indicate that the system correctly verified the majority of users while maintaining low false acceptance and rejection rates, making it suitable for real-world campus applications.

4.3 Confusion Matrix Analysis

The confusion matrix for the face recognition model is shown below:

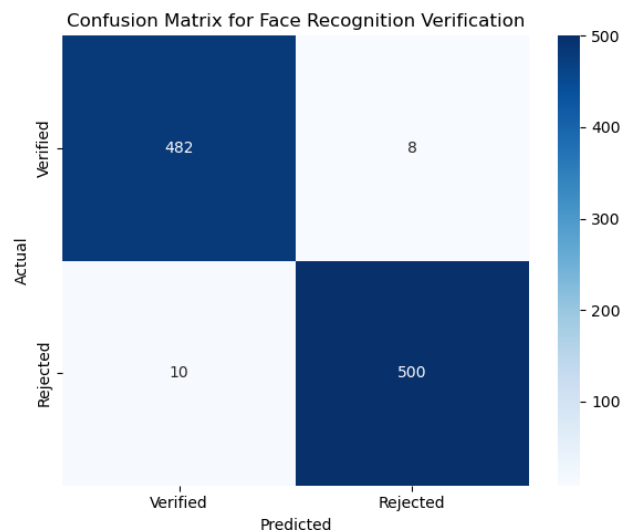


Figure3: Confusion Matrix

	Predicted: Verified	Predicted: Rejected
Actual: Verified	482 (True Positive)	8 (False Negative)
Actual: Rejected	10 (False Positive)	500 (True Negative)

- **True Positives (TP):** 482 – Legitimate students correctly verified.
- **False Positives (FP):** 10 – Unauthorized users mistakenly granted access.
- **True Negatives (TN):** 500 – Unauthorized users correctly denied access.
- **False Negatives (FN):** 8 – Authorized users wrongly denied access.

This matrix supports the claim that the system can accurately distinguish between valid and invalid users under standard operating conditions.

4.4 Discussion

The recognition accuracy of **98.27%** demonstrates that facial recognition can serve as a viable method for automated attendance and secure access in educational institutions. The low **FAR** and **FRR** further enhance system trustworthiness, reducing the risk of impersonation and unjust denial.

5 Limitations

- The recognition rate may drop under poor lighting or occlusion (e.g., masks).
- Although the false positive rate is low, occasional manual oversight may still be necessary in high-security areas.

Future improvements could involve multi-modal biometrics (e.g., face + voice), adaptive lighting correction, or integrating liveness detection to

avoid

spoofing.

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