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Enhancing Classroom Attendance Systems by Face Recognition Using OpenCV and ESP32-CAM

Vishal Kumar Pandey,Vishal Jaiswal, Vishal Yadav, Shilpee Patil
Department of Electronics and Communication Engineering Galgotias College of Engineering & Technology, Greater Noida

Abstract— Classroom attendance tracking was a fundamental task in educational institutions, traditionally managed through manual roll calls or sign-in sheets. These methods were time-consuming, error-prone, and susceptible to manipulation. With advancements in computer vision and embedded systems, there was an opportunity to automate this process. In this research paper, a novel approach to classroom attendance management was presented, utilizing OpenCV and face recognition technologies, implemented on the ESP32-CAM microcontroller. The proposed system was designed to automatically identify and record student attendance, offering enhanced accuracy and efficiency. Comparative results demonstrated that the face recognition-based approach significantly outperformed traditional manual methods and other automated systems in terms of accuracy and processing speed. The system's architecture, implementation, and evaluation were outlined, showcasing its potential to transform attendance tracking in educational settings.

Keywords- Face recognition, Face detection, OpenCV..

I. INTRODUCTION

The Attendance Systems by Face Recognition is a technological solution for the classroom designed to automate and streamline the process of tracking and managing student attendance within an educational institution. Traditionally, attendance in classrooms has been recorded manually, posing challenges such as time inefficiency, errors and difficulties in data analysis. The introduction of an automated Attendance System addresses these issues, providing a more efficient, accurate, and transparent way to monitor student attendance.

II. LITERATURE REVIEW

This system utilizes advanced technologies to replace the conventional manual methods of taking attendance, offering a range of benefits to both educators and students.Several studies have explored automated attendance systems using various technologies. Biometric methods such as fingerprint and iris recognition have been considered but face recognition offers a non-intrusive and convenient alternative. Previous research has demonstrated the feasibility of using face recognition for attendance systems, but challenges remain in ensuring accuracy under different conditions. Bradski and Kaehler provide a comprehensive overview of computer vision techniques and their applications, highlighting the potential of OpenCV for various image processing tasks [1]. King discusses the Dlib machine learning toolkit, which includes tools for face recognition, demonstrating its effectiveness and efficiency [2]. Huang et al. introduce the Labeled Faces in the database, which has become a standard benchmark for evaluating face recognition systems under unconstrained conditions [3]. These studies provided us a foundation for the development of an automated attendance system using face recognition. However, the integration of such systems into real world applications, such as classroom environments, requires addressing specific challenges related to hardware limitations, environmental variations, and data management.

III. OPERATING RECOGNITION SYSTEMS FOR ATTENDANCE

Fingerprint Based recognition system: In this recognition system, fingerprint-based recognition is used for recording classroom attendance. In which a portable fingerprint device needs to be pre-configured with each student's fingerprint and name respectively. And then verification is also needed. Before or during lecture hours, students need to record their fingerprint on the configured device to confirm their attendance for the day or for a specific lecture. However, a challenge with this approach is that students may not always have clean, dry fingers – water or oil on fingers can damage the device and slow down verification. This process can also be time-consuming and may disrupt students' focus during class. [4].

RFID (Radio Frequency Identification) Based recognition system: In the existing Radio Frequency Identification (RFID) card-based system, students need to carry their RFID or ID card and place it on the card reader to record their attendance for the day or a specific lecture. This system can connect via RS232

and record attendance in the classroom's attendance management database. However, there are potential issues with this approach: students may misuse the system by using another student's ID card to mark attendance for someone who is absent, leading to unauthorized access. This misuse undermines the integrity of the technology and its intended purpose.

Iris Based Recognition System: In an iris-based student attendance system, each student's iris is scanned and stored in advance. During attendance, students stand in front of a camera that scans their iris, matching it in real-time with the stored data in the database to mark their presence in the classroom. This method reduces the paper-and-pen workload for faculty and minimizes the chances of proxy attendance, keeping student records safe and secure. However, this approach requires a large database and allows students to attend any lecture due to centralized data. Additionally, some students may be reluctant to share their iris data, as it is highly sensitive.

Face Based Recognition System: Face recognition technology can be used to record attendance through a high-resolution camera that detects and recognizes students' faces. The system (using machine learning) compares the recognized face with stored images in the database and marks attendance for that specific lecture or class. If the captured image doesn't match any face in the database, an error or alert is triggered, indicating that the student may be in the wrong class or lecture. This approach is time-efficient, paper-free, proxy-free, and transparent. It also provides real-time attendance data for each class or lecture.

Comparison of Operating Recognition Systems for Attendance is shown in Table I.

System	Description	Challenges
Finger print-Based	Students scan their fingerprints to mark attendance.	Wet/dirty fingers slow down verification, time-consuming.
RFID-Based	Students use an RFID card on a reader to record attendance.	Misuse by swapping cards, compromising system integrity.
Iris-Based	Iris is scanned and matched with stored data to confirm attendance.	Privacy concerns, large databases needed, students may attend any class.
Face-Based	Uses facial recognition to mark attendance by comparing images with stored ones.	Potential privacy issues, errors in image capture.

Table I: Operating systems and their description and challenges

IV. System Architecture

The proposed system comprises the following components:

ESP32-CAM Module: Captures images of students.The ESP32 CAM module is a development board based on the ESP32 system on chip (SoC) with an in-built camera module. Developed by Espressif Systems, the ESP32 CAM board combines the powerful features of the ESP32 micro-controller with a camera, making it suitable for various Internet of Things (IoT) & camera-related projects.

USB-to-Serial Converters: FTDI is perhaps best known for its USB-to-serial converter ICs, such as the FT232R and FT232H. These chips enable devices without native USB support to communicate with a computer via USB.

- Face Detection: Uses OpenCV to detect faces in the captured images.
- Face Recognition: Matches detected faces against a database of known faces to identify students.
- Attendance Logging: Records identified students' attendance in a database.
- Connections of the circuit are shown in Fig I.

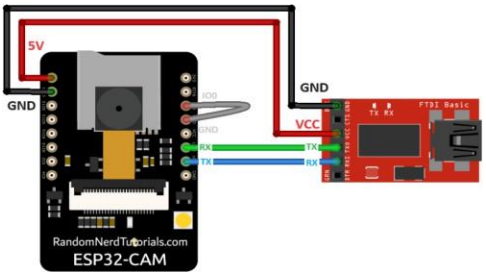
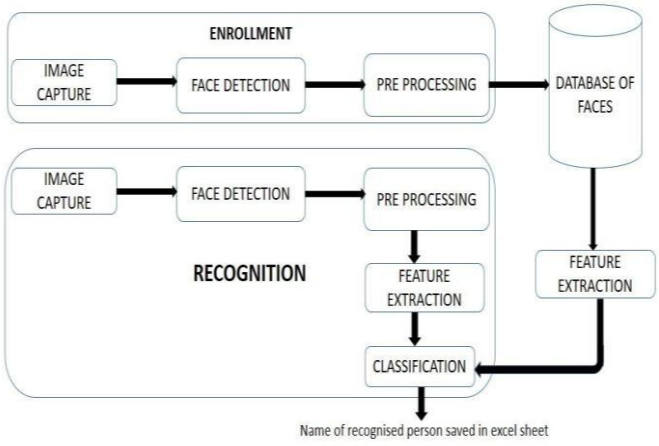


Figure I: Connections of the circuit

Flow Chart Of System Architecture



V. FEATURE EXTRACTION AND CLASSIFICATION

In this system, the performance of face recognition for student attendance in a classroom depends on effective feature extraction and classification to achieve precise and accurate results. For feature extraction, holistic techniques such as Principal Component Analysis (PCA), Linear Discriminant Analysis (LDA), and Local Binary Pattern Histogram (LBPH) are used. In classification we are using Distance-Based Classifiers, Support Vector Machine (SVM), Naive Bayes Classifier techniques and some machine learning algorithms. For better results, we compared the performance of different techniques used for classification and feature extraction in a real-time scenario [5]. Table II provides the holistic comparison of all techniques in detail. Principal Components Analysis (PCA) was a holistic technique or an algorithm which represents faces economically. PCA creates Eigen faces & projects them onto a small subspace of all Eigenfaces, retaining only the most meaningful dimensions. It reduces the complexity of the face image because it keeps only meaning details. the mathematical formula is used for an image using PCA is represented as

$$x = W Y + \mu$$

Where x represents the face vector, W represents the feature vector, Y represents the vector of Eigen faces & μ represents the average face vector. Linear Discriminant Analysis (LDA) improves upon PCA by maximizing the ratio between class scatter to within-class scatter.so, it captures more discriminative information in data than PCA. It performs well but struggles under the poor lightning conditions [6]. Local Binary Pattern Histogram (LBPH) was a holistic technique or an algorithm which captures local texture details by dividing the face images into smaller regions & creating histograms for each image and these histograms are combined to make or form a complete face descriptor of a student. It is effective across all ranges of lighting conditions [7]. The holistic techniques like PCA and LDA often use the distance measure, like Euclidean distance, to classify faces which involves comparing the features of new faces with those students faces or known faces which are saved into a database. If the distance is below the threshold, then the attendance system recognizes the faces of the students [8]. Support Vector Machine (SVM) is a classifier which is used to separate different classes of images by finding the optimal hyperplanes. It is used for multi class classification tasks. It is effective in all separations i.e. linear or nonlinear. Naive bayes classifier is a technique that assumes independence between the features and computationally light weight, requiring minimal training data. But its simplicity would lead to less precise and accurate results in complex, real world scenarios [9]. OpenCV also offers strong face detection capabilities with its Haar Cascade and DNN-based face detectors. So, the classroom attendance system by face recognition involves two stages (feature extraction and classification). Above mentioned feature extraction methods or holistic techniques combined with classification techniques are compared in various real-world scenarios like lightning condition, expressions, unintentional facial feature changes. The performance of the system is also checked or evaluated in terms of distance of object recognition, training time, false positive rate, recognition rate (static images and real time video), occluded faces. It has been observed that LBPH technique or algorithm provides good recognition rate and least or minimum false positive rate, training time. It is also correctly differentiating the known and unknown faces of the students. LDA provides the least recognition rate in both static images and real time video. The camera captures the face region around 4-7 feet and provides better results for all the techniques or algorithms like LDA, LBPH, PCA. Training time is calculated by taking 150 images or faces as training data in the database. SVM and Bayes classifiers take more time for training than others and LBPH and distance classifiers take less or minimum time. SVM does better classification than another classifier.

Performance Evaluation Conditions	PCA + Distance Classifier	LDA + Distance classifier	PCA + SVM	PCA + Bayes	LBPH + Distance classifier
False Positive Rate (In %)	55	53	51	52	25
Distance of object for correct recognition (In feet)	7	7	7	7	4
Training time (In m.sec)	1081	1234	24570	29798	563
Recognition Rate (Static Images) (In %)	93	91	95	94	95
Recognition Rate (Real time video) (In %)	61	58	68	65	78
Occluded Faces (In %)	2.5	2	2.8	2	2.3

TABLE II: Comparison of Holistic Face Recognition Algorithm

VI. IMPLEMENTATION AND RESULT

Implementation

The implementation involved setting up the ESP32-CAM module, configuring the software components, and integrating the system into the classroom environment. The system captured images of students, processed them to detect and recognize faces, and logged attendance in real time.

- First of all, the person(s)/student(s) were registered in the database. Also, the name and registration number of each individual were provided and stored in the database accordingly.
- Recent pictures of the individuals/students were captured using available cameras, such as a mobile phone camera in this case.
- After running the project, the ESP32-CAM module was activated and captured images of students who came in front of it, recognized them, and saved the data in Excel format (database) along with real-time date and time.
- The data was then stored in the institute/college's database.
- The faculty of the college/institute could then access the data and mark the attendance of the students.

Result

- Data Collection: A database of student faces was created by capturing images and encoding them using the face recognition model.
- Real-Time Processing: During each class session, the system captured images at regular intervals and processed them in real time to detect and recognize faces.
- Attendance Recording: Recognized faces were matched with the database, and attendance records were updated accordingly.
- The system was tested in a controlled classroom environment. The performance was evaluated based on accuracy, speed, and reliability under various conditions, such as different angles and occlusions.

The experimental evaluation of the ESP32-CAM-based face recognition system revealed several key performance constraints along with opportunities for optimization. The limited processing power and resolution of the device posed challenges to real-time recognition performance. These limitations, however, can be addressed through the integration of cloud-based processing, optimized image pre-processing techniques, and edge computing strategies. To enhance security and protect against potential data breaches, it is crucial to implement robust encryption protocols, utilize secure local storage, ensure compliance with data privacy standards, and adopt multi-factor

authentication. Network reliability issues, such as unstable Wi-Fi connections, can be mitigated using MQTT or WebSockets for communication, along with local data caching and the deployment of lightweight edge AI models. Additionally, concerns related to scalability and system maintenance—including model updates and hardware failures—can be effectively managed through centralized server architectures, automated update mechanisms, and the provision of backup hardware components..Result is shown in Fig II (a),(b).

Figure.II: (a)-Result on Screen

	A	B	C
1	Name	Time	Date
2	YADAV	10:28:47	01-02-2024
3	YADEV	10:28:48	01-02-2024
4	PANDEY	10:28:49	01-02-2024
5	PANDEY	10:28:49	01-02-2024
6	PANDEY	10:28:50	01-02-2024
7	JAISWAL	10:29:07	01-02-2024
8	JAISWAL	10:29:07	01-02-2024
9	JAISWAL	10:29:09	01-02-2024

Figure.II:(b)-Result on Excel Sheet

VII. CONCLUSION AND FUTURE WORK

Conclusion

This paper presents a novel approach to classroom attendance management using OpenCV, face recognition, and the ESP32-CAM module. The proposed system demonstrates a significant improvement over traditional manual methods, offering a more efficient and accurate way to track student attendance. Comparative results indicate that our system outperforms traditional roll-call methods in terms of both accuracy and processing speed, while providing a reliable and automated solution. With further refinement, this technology has the potential to be widely adopted in educational institutions, contributing to more effective administrative processes and improved student monitoring. It represents a progressive step towards modernizing educational administration, enhancing operational efficiency, and fostering a culture of responsibility and accountability among students and educators.

Future work

Future enhancements include integrating fingerprint recognition with face recognition into a standalone Raspberry Pi-based system. This integration aims to improve system security, reduce hardware dependency, and support offline functionality, making the solution more robust and scalable for widespread deployment.

REFERENCES

1. G. Bradski and A. Kaehler, “Learning OpenCV: Computer Vision with the OpenCV Library.” O'Reilly Media, 2008.
2. D. E. King, "Dlib-ml: “A Machine Learning Toolkit,"Journal of Machine Learning Research, vol. 10, pp. 1755-1758, 2009.
3. G. B. Huang, M. Ramesh, T. Berg, and E. Learned-Miller, "Labeled Faces in the Wild: A Database for Studying Face Recognition in Unconstrained Environments," University of Massachusetts, Amherst, 2007.
4. Divya Pandey, Priyanka Pitale & Kusum Sharma,” Face Recognition Based Attendance System using Python” JETIR 2010064 October 2020, Volume 7, Issue 10.
5. Shireesha Chintalapati, M.V. Raghunadh,” Automated Attendance Management System Based On Face Recognition Algorithms”, 2013 IEEE International Conference on Computational Intelligence and Computing Research, 978-1-4799-1597-2/13/$31.00 ©2013 IEEE.
6. W. Zhao, R. Chellappa, P. J. Phillips, and A. Rosenfeld, “Face recognition: A literature survey,” Acm Computing Surveys (CSUR), vol. 35, no. 4, pp. 399–458, 2003.
7. T. Ahonen, A. Hadid, and M. Pietik¨ainen, “Face recognition with local binary patterns,” in Computer Vision-ECCV 2004. Springer, 2004, pp. 469–481.
8. N. A. I. Q. S. Z. Rameez Qasim, M. Mutsaied Shirazi, “Comparison and improvement of pca and lbp efficiency for face recognition,” 2013.
9. M. O. Faruqe and M. Al Mehedi Hasan, “Face recognition using pca and svm,” in Anti-counterfeiting, Security, and Identification in Communication, 2009. ASID 2009. 3rd International Conference on. IEEE, 2009, pp. 97–101.