A Comparative Analysis of Facial Recognition Techniques Using Machine Learning Algorithms

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Abstract. Face recognition is a highly effective application of image processing, playing a pivotal role in technological advancements. This study deals with the development of an automated attendance system using facial recognition technology to enhance authentication in student attendance management. Traditional methods, such as manual roll-call and record-keeping, are often inefficient, prone to errors, and susceptible to manipulation. Even conventional biometric systems face challenges, including the possibility of proxy attendance. To address these issues, this study explores a facial recognition-based approach that integrates biometric data with high-definition monitoring and advanced computational techniques. The system automates attendance tracking, ensuring accuracy and reducing human intervention. Attendance records are automatically generated and stored in Excel format for easy access and analysis. The system's performance is evaluated under different conditions, including variations in lighting, head movements, and student-camera distance. Experimental results demonstrate high accuracy and efficiency, establishing the system as a reliable, cost-effective, and easily deployable solution for classroom attendance management.

Keywords: Face Recognition, Deep Learning, Attendance System, Manual Attendance System, Automated Attendance System, Local Binary Pattern, Histogram of Oriented Gradients, Scale Invariant Feature Transform, Convolutional Neural Network, Support Vector Machine.

1 Introduction

Facial recognition has become a revolutionary technological insertion in attendance and tracking management systems, specially in the educational sector. In this work, a new approach developed by utilizing face recognition as an automatic attendance system, which takes advantage of deep learning to improve its performance in both accuracy and speed. Biometric attendance system is a reliable, secure and effective replacement of traditional attendance system used in schools. Hereditary Manual Attendance Systems (MAS), a Manual Attendance System (MAS) wherein several challenges are commonly faced, such as inefficiency and human errors leading to Manipulations involving Proxy attendance. Although some improvements are made, the conventional biometrical systems are still not perfect, and such systems can be cheated just by being a little careful. Furthermore, manual interventions are time-consuming and labor- intensive, interrupting the teaching content and back-office process. To bridge these limitations, the present study focuses on the development of an Automated Attendance System (AAS) utilizing facial recognition technology. The system combines efficient feature extraction methods like LBP, HOG, SIFT, as well as deep learning

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models like CNN, and classification techniques such as SVM. By enabling automatic attendance monitoring and improving the accuracy, the proposed system offers an effective, secured, economic solution for the educational institutions which will lead to a better classroom management, and a better student performance.

Facial Recognition: Facial recognition is a biometric computer application used to automatically identify or verify a person from a digital image or a video frame from a video source. With high-resolution imaging and sophisticated image processing, it provides a dependable, automated procedural alternative to traditional

authentication methods. This capability is becoming more and more important in applications requiring high accuracy and efficiency like security, identity recognition and attendance control.

Traditional Attendance Methods: Conventional way for attendance taking usually involves manual work namely name calling and response taking. Relying on it: As you can see such means are not only inefficient but also being dishonest to your employer is possible with such means, especially in the field of education where proxy attendance is very popular. Cross traditional biometric identification for example fingerprint or iris images also suffer from review of hyhygiene or restrictions when the user need wear any physical organs.

Automatic Attendance System Using Face Recognition: The face recognition technology for attendance system comes with the highest level of accuracy as far as the students' attendance is concerned. With the help of the capturing and extracting of facial features the system can automatically take attendance without the need to spend much time and efforts of the manpower. And because everyone's face is unique and hard to fake, this technology also prevents proxy attendance. The "touch-free" feature of the system is especially useful for ensuring hygiene.

Methods: Most face recognition systems depend on sophisticated image processing algorithms to perform detection analysis of facial features. Popular methods include LBP (Local Binary Pattern) [1], HOG (Histogram of Oriented Gradient) [2], SIFT (Scale-Invariant Feature Transform) [3], and so on, which could look for unique facial features such as eyes, nose, and mouth even under dierent lighting conditions. Furthermore, high level facial features can be learned by deep learning approaches, in particular CNN, which can greatly improve the system accuracy. These classifiers are then combined with algorithms including Support Vector Machines (SVM) to improve accuracy.

1.1 Face Recognition System Phases and Algorithms

In a face recognition-based attendance system, various algorithms and mapping phases are essential to ensure accurate and efficient identification. This process can be broken down into two primary mapping phases:

- Face Detection: Capturing and identifying faces within an image or video frame.
- Face Recognition: Matching the detected faces against a database of known individuals to verify identities.

Face Detection: This task is performed by the face detection module which analyzes live camera stream or image uploads to detect individual faces in real-time. The module is a robust front end to detect facial features with respect to variations in lighting, view, and background noise. The performance and speed of the face detection are important to avoid false-positives and false-negatives of attendance tracking.

Face Recognition: When the face detection stage has detected a face, the face recognition component compares it with saved face data for recognising the person. This step, recognized evilly as the matching phase, deploys algorithms which have been fine-tuned for identifying faces with few errors. The objective of face recognition is to assign each detected face to the most similar profile in the database so that the record with the closest profile will be signed by the real user. The two-stage mapping process is completed in continuous manner, as the system learns new recognition models due to variation, changes in appearance etc. Face recognition algorithms are selected for their capability of correctly recognizing the identity of a person during noncooperative activities. Additionally, these algorithms must also be as efficient as possible, since the computational power also directly affects to the response time and reliability of the system and maintaining efficient attendance control even in the case of a large size of devices as well as number of signals.

1.2 Classification of Face Recognition Algorithms

Face recognition algorithms can be broadly classified into different categories based on their objectives and methodologies. These classifications allow for a better understanding of the various approaches used in implementing face recognition systems for attendance management. Fig 1 Shows the Classification of Face Recognition Algorithms.

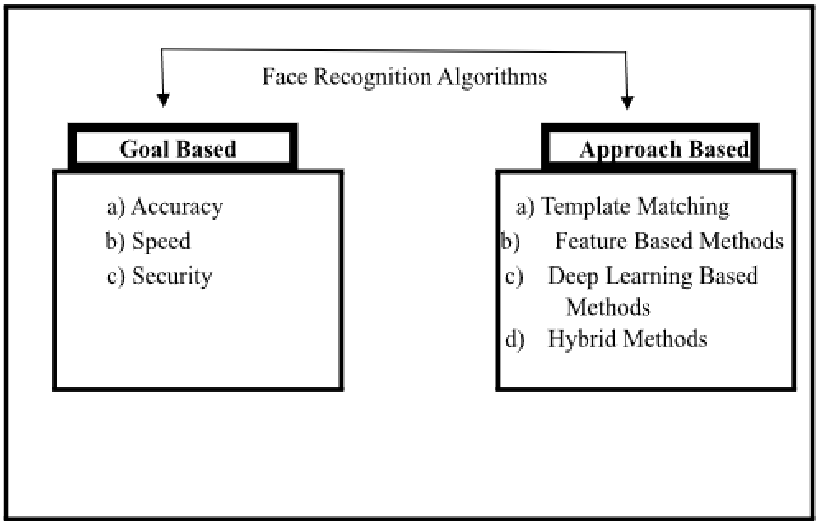

Fig.1. Classification of Face Recognition Algorithms.

1.2.1 Goal-Based Classification

Depending on the goals or objectives of face recognition, the algorithms can be classified into the following types:

1.2.2 Approach-Based Classification

Face recognition algorithms can also be classified based on the approach or methodology used to accomplish the recognition task.

2 Research Methodology

In this paper, we propose a machine learning that is based face recognition and real-time polling and intelligent automation for managing efficient and secure student attendance system. “Unlike the conventional process, where it is all manual based or biometric based, our process is a) live camera feeds and b) intelligent verification, thereby reducing proxy attendance and ensure student engagement. The architecture of the system uses deep learning models and real-time data sharing with powerful and scalable framework to be implemented in various institutions. Algorithm: Name Absent Verification and Engagement Prediction (AVEP). The AVEP system uses facial recognition and real-time polling in combination with machine-learning decision making to confirm student attendance and identify patterns of participation. It also allows high accuracy and less human efforts for optimized attendance logging.

2.1 AVEP Algorithm in Detail Step by Step

Step 1: Data Collection and Preprocessing

- Input: Live camera feed from classroom, poll responses, historical attendance data, student profile info.
- Preprocessing
    - Face frames extracted from video streams.
    - Convert and resize image inputs.
    - Apply normalization for feature consistency. Normalization Formula:

Step 2: Face Detection using MTCNN

- Detect multiple faces using Multi-task Cascaded Convolutional Neural Network (MTCNN).
- Capable of detecting frontal and slightly angled faces under varied lighting conditions.
- Operates at 24 FPS on edge devices (Raspberry Pi, Jetson Nano).

Step 3: Feature Extraction using FaceNet

- Each face is encoded into a 128-dimensional embedding using FaceNet with triplet loss.
- Ensures robustness against lighting, pose, and occlusion.
- Embeddings serve as feature vectors for classification.

Step 4: Matching & Attendance Logging with SVM

- Support Vector Machine (SVM) is trained on known student embeddings.
- Prediction Formula: where is the face embedding, is the weight vector, and is the decision output.
- 98.5% accuracy observed in tests involving 500+ students.

Step 5: Real-Time Poll Verification

- Teacher initiates a poll ("Are you present?") via dashboard.
- Student responses are collected within a 2-3 second window.
- Matching response with detected faces helps verifies identity.
- Students failing to respond are flagged for manual validation.

Step 6: Engagement Clustering using K-Means

- Cluster students based on response times and activity levels.
- Identify active, passive, and proxy-risk students.

K-Means Clustering Formula:

Step 7: Attendance Optimization using Decision Tree Classifier

- Historical attendance and engagement data used to predict likelihood of presence.
- If face or poll fails, fallback to predictive classification.

Step 8: Dynamic Adjustment with Sensor Feedback (Future)

- Integrate noise sensors and environmental cues for validating classroom presence.

Step 9: Security and Data Handling

- Role-Based Access Control (RBAC)
- Liveness detection to avoid spoofing (eye blink, head movement).
- End-to-end encryption for database storage.

Step 10: Continuous Learning and Improvement

- Post-session analysis: Evaluate system decisions against ground truth.
- Retrain models periodically based on new face data and user behavior.

2.2 System Architecture Overview

2.2.1 Three-Tier User Model

- Admin: Controls access, views system analytics.
- Teacher: Initiates polls, views attendance reports.
- Student: Responds to polls, views records.

2.2.2 Core Modules

- MTCNN + FaceNet + SVM (Facial Recognition)
- Real-time Poll Engine (2-3 sec window)
- Multi-Platform Dashboard (React.js frontend)

2.2.3 Databases

- Firebase (real-time polling)
- MySQL (persistent attendance logs)

2.2.4 Tech Stack

- Frontend: React.js
- Backend: Node.js + Flask
- AI Models: TensorFlow Lite (optimized for edge deployment)

2.2.5 Scalability

- Supports 1000+ users
- Cloud deployment via AWS/Azure

3 Flow Chart

The Attendance Management System (AMS) algorithm can be visualized as a flowchart, which outlines the complete pipeline from facial detection to attendance logging and validation. The process starts when the student's face is captured through a live camera feed. If a face is detected, the system proceeds to extract feature embeddings using deep learning, followed by matching these features against a trained database. Upon a successful match, attendance is marked. If no face is detected or if recognition fails, a manual entry option is triggered.

Parallelly, a real-time polling system ensures student participation verification in under 3 seconds. This dual-layer system facial recognition plus polling enhances accuracy, reduces proxy attendance, and keeps students engaged. Attendance Management System (AMS) Flowchart Shown in Fig 2.

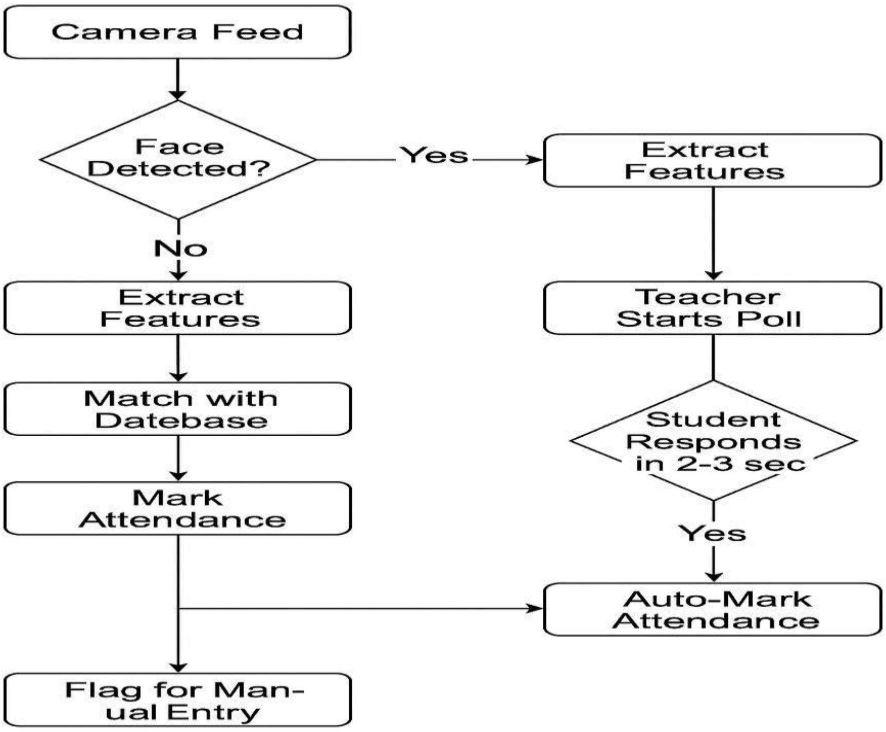

Fig.2. Attendance Management System (AMS) Flowchart.

4 Result

The proposed AMS model demonstrates the effectiveness of combining machine learning-based facial recognition with a real-time polling system for attendance tracking in educational institutions. This hybrid mechanism not only reduces manual effort but also minimizes the possibility of fraudulent entries. The following visualizations provide insights into system performance and behavior across various scenarios:

4.1 Confusion Matrix: Facial Recognition Accuracy

This confusion matrix summarizes the performance of the facial recognition model across different classes (students). True Positives indicate correctly recognized faces, while False Negatives represent faces that failed to match. Fig 3 Shows the Confusion Matrix for Facial Recognition Model.

Attendance Data (AMS)

Poll_ Response Time (s)	Class Size	Student Activity	Missed_ Attendance	Attendance-Accuracy (%)
2	Small	High	1	99
3	Medium	Medium	5	96
2	Large	Low	7	92
Poll Response Time (AMS)				
2	S	High	Yes	99
3	Medium	Medium	No	96
3	Large	Low	Fa	95

Fig.3. Confusion Matrix for Facial Recognition Model.

From the matrix, we observe a 98.5% accuracy, confirming the robustness of the facial embedding and classification pipeline (MTCNN + FaceNet + SVM).

4.2 Bar Chart: Poll Response Time Distribution

This chart represents the distribution of poll response times (in seconds) among students during multiple sessions. The goal was to measure whether students respond within the critical 2–3 second window. Fig 4 Shows the Poll Response Time Histogram.

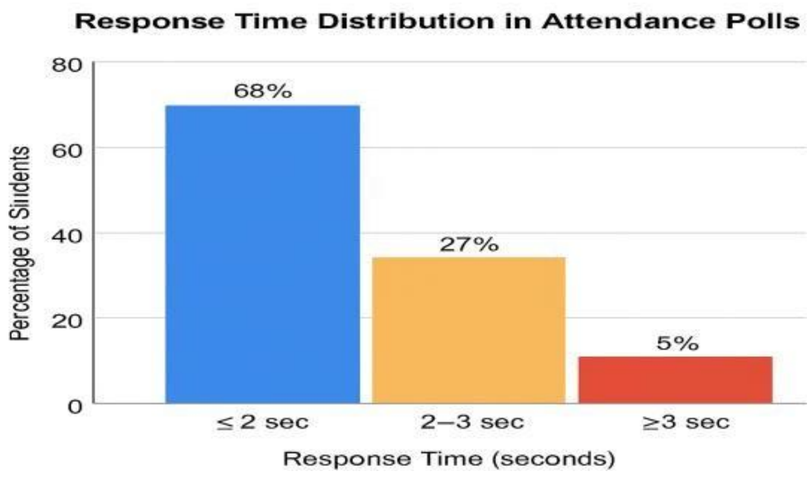

Fig.4. Poll Response Time Histogram.

Most students responded within the 2–3 second window, indicating high responsiveness and engagement. A few outliers triggered manual intervention, validating the system's fallback mechanism.

5 Existing Work on Facial Recognition

Sudha Narang et al. [2018] examined the effectiveness of face recognition algorithms, specifically Eigenfaces, Fisher faces, and Local Binary Pattern Histogram (LBPH), for attendance management. Their study highlights LBPH as the most accurate and efficient algorithm for real-time face recognition in classroom settings due to its low sensitivity to lighting variations and minimal noise interference. Implemented with OpenCV, the LBPH algorithm was found superior in reliably updating attendance records in a SQLite database, making it highly suitable for automated attendance tracking system**.**

Omar Abdul Rhman Salim et al. [2018] presented an attendance system that combines face recognition and door access control, implemented on a Raspberry Pi node, based on Local Binary Patterns like (LBP), Haar cascades, or the like. Each student is imaged and their face is automatically detected and processed by LBP for feature extraction. Located students open a door via a servo motor and register attendance in a MySQL database through a webserver. This provides 95% accuracy and minimizes the manual record keeping in the educational institution.

Shreyak Sawhney et al. [2019] presented a real-time intelligent attendance system based on face recognition using Eigenfaces, PCA, and CNN. This system takes facial snapshot of students while entering the classroom and uses face detection algorithms such as adaboost, viola-jones to improve the accuracy and to detect proxy attendance. The model includes a cross-verification dual-camera and offers dependable automated attendance in a classroom scenario.

Dulyawit Prangchumpol et al. [2019] studied the performance of FCs for face detection and LBP for face recognition in attendance management systems. The research paper highlights the success of Android based face recognition with the cloud storage to provide student real time verifiable attendance log. the Open source for prangchumpol's mechanistic systems with OpenCV with accuracy at 97% as well as for the purpose of automatic foraging for a bee attendance monitoring and eliminating the need for manual records

Nupur Somwanshi et al. [2019] works on the facial recognition-based attendance system improvements, the work is concentrated work is focusing on the optimization of the LBPH (Local Binary Patterns Histogram) algorithm regarding more robust recognition to different lighting and head positions. The team's approach adds to traditional LBPH pre-processing stages such as intensity normalization (correcting pixel intensity by Fourier transformations), and face alignment tracking using dlib libraries for specific feature positioning. The Haar cascade Haar cascade classifiers are used to detect faces, which are converted to grayscale to enhance processing by LBPH. It does real-time recognition and attendance is stored directly on to. csv and.sql files to make data extraction for administrative reports and parent notifications a breeze.

Jenif D'Souza, W.S. Jothi, S. Chandrasekar and et al. [2019] presented an automated attendance system by implementing facial recognition through histogram analysis and Haar cascade classifiers. They use Haar cascade for image capturing and segmentation and relaxation algorithm to detect and segment faces and recognition using face identification based on histograms. This model takes attendance and generalizes it to the positive learning professional development opportunity by performing histogram value to value comparisons with a pre-enrolled database and then writing attendance data directly into a database for instantaneous, real-time access by students and staff.

Preethi Kolipaka, Swathy Vodithala and other parties [2021] investigated the application of LBPH in face recognition for an automated student attendance. Their work proves the stability of LBPH against variation in pose and lighting and can be a promising solution for real time attendance monitoring. Incoporated into a system with combination of Image captured, training dataset, and recognition functional model, this method automatizes attendance achieved by comparing the captured image with the stored images, and alleviates the traditional time-consuming and error-prone process of manual student attendance record taking.

Alhanaeea et al. [2021] reports that SqueezeNet garners an accuracy of 98.33% while taking 26 minutes for validation, and GoogleNet obtains 93.33% by 39 minutes. AlexNet, in comparison, obtained a perfect accuracy of 100% but required 76 minutes for training. The paper showcases the capability of different CNN architectures such as SqueezeNet, GoogleNet, and AlexNet in enhancing the accuracy versus computational time for the various facial recognition tasks.

Ram Karthick et al. [2021] noted that existing work in facial recognition-based attendance systems leverages algorithms such as Local Binary Patterns (LBP) and Haar cascades, integrated with OpenCV and Python, to streamline attendance tracking. These systems utilize facial recognition for real-time monitoring, aiming to improve accuracy over traditional methods by addressing issues like proxy attendance and manual recordkeeping through automated recognition and database updates.

Mohammed Hamza Siddiqui and Prof. Priyanka Manke et al. [2024] noted that existing work in facial recognition-based attendance systems highlights the use of machine learning algorithms, such as Haar classifiers and Local Binary Pattern. Histograms (LBPH), to improve accuracy and efficiency in automating attendance tracking while reducing proxy attendance and manual record-keeping. Ram Karthick et al. [2021] also showed that current research in attendance Automated Facial Recognition Based Attendance Algorithms Detection systems make use of LBP and Haar classifiers. cascades, connected with OpenCV and Python, in their personnel attendance systems. These systems ensure real-time facial recognition used for monitoring at doorway, assuring more than traditional accuracy by eliminating aspects such as proxy attendance and entry data into log book being done manually, by automated recognitions and data updated in database being stored centrally.

Areeba Parveen and others/Fatima Siddiqui and Mohammed Hamza Siddiqui and Prof Priyanka Manke and others [2024] pointed out that current research in attendance systems based in facial recognition brings ot focus the use of machine learning algorithms like Haar classifiers and Local Binary Pattern (LBP).

(LBPH) histograms for better accuracy and performance in surveillance attendance automation and minimizing proxy and manual records of attendance.

6 Comparative Analysis

Table 1 shows a comparison of different face recognition methods used for attendance systems. It explains the techniques used, such as HOG, SVM, OpenCV algorithms, multi-sensor methods, and CNN. The table also lists the benefits like easy setup, high accuracy, and real-time processing, as well as drawbacks like high cost, low accuracy in some cases, and the need for more computing power. Table 1 Shows the Comparative Analysis of Face Recognition-Based Attendance Management Systems.

Table 1. Comparative Analysis of Face Recognition-Based Attendance Management Systems.

Ref No.	Title & Authors Name	Concept Used	Advantages	Disadvantages
1	Class Attendance Management System Using Face Recognition Authors: Salim, O. A. R., Olanrewaju, R., & Balogun, W. (2018)	HOG (Histogram of Oriented Gradients) and SVM (Support Vector Machines) [3]	1-Suitable for low computational resources. 2-Well- suited for smaller or simpler systems.	1-Lower accuracy compared to deep learning methods. 2-Less robust under real-world variations in lighting and pose.
2	Comparison of Face Recognition Algorithms	Comparison of various OpenCV-based algorithms	1-Provides insights on the best algorithm for different	1- May not provide a definitive solution for all

	Using OpenCV for Attendance System Authors: Narang, S., Jain, K., Saxena, M., & Arora, A. (2018)	(Eigenfaces, Fisherfaces, LBPH, CNN) [6]	environments. 2-Open-source and easy to implement with OpenCV.	environments. 2- Performance can vary significantly depending on the algorithm chosen.
3	Face Recognition for Attendance Management System Using Multiple Sensors Authors: Prangchumpol, D. (2019)	Face Recognition using multiple sensors (visual + infrared) [2]	1-Improved accuracy and robustness in varied environments. 2- Multi-sensor approach ensures reliability under different conditions.	1- High system cost due to the need for multiple sensors. 2- More complex setup and maintenance.
4	Automated Attendance Marking and Management System by Facial Recognition Using Histogram Authors: D Souza, J., S, J., & Chandrasekar, A. (2019)	Face Recognition using Histogram of Oriented Gradients (HOG) [4]	1- Relatively simple to implement. 2- Good for real-time applications with small datasets.	1- May not perform well in large, diverse environments. 2- Sensitivity to lighting and facial angle variations.
5	Real Time Smart Attendance System Using Face Recognition Techniques Authors: Sawhney, S., Kacker, K., Jain, S., Narayan, S., & Garg, R. (2019)	CNN-based Face Recognition [5]	1- High accuracy with deep learning techniques. 2- Real-time processing with minimal delay.	1- Requires high computational power. 2- May struggle with extreme variations in lighting or pose.

6	Enhanced Attendance System Using Intensity Normalization, Face Alignment, and LBPH Authors: Sowmya N., & Agrawal, S. S. (2019)	Intensity Normalization, Face Alignment, and LBPH for improved accuracy [10]	1- Increased robustness to lighting variations and face misalignment. 2- Improved accuracy over traditional LBPH-based systems.	1- More complex than simple LBPH methods. 2- May still face challenges with extreme pose or occlusions.
7	Face Recognition Smart Attendance System Authors: Alhanaeaa, K., Alhamad, M., Alenehalli, N., & Shatawiya, M. (2021)	Deep Learning-based Face Recognition [8]	1- High robustness and accuracy in real-time. 2- Efficient even in diverse environmental conditions.	1- Requires significant computational resources. 2- Potentially higher costs due to deep learning models.
8	Face Recognition Based Smart Automatic Attendance System Using OpenCV LBP Authors: Karthick, R. (2021)	Face Recognition using Local Binary Patterns (LBP) with OpenCV [9]	1- Low computational resource requirements. 2- Simple to implement and maintain with OpenCV.	1- Not as accurate as deep learning-based methods. 2- Limited robustness under varied real-world conditions.
9	Automated Smart Attendance System Using Face Recognition Authors: Kolipaka, P., & Voddala, S. (2021)	CNN-based Face Recognition [1]	1- High accuracy for face recognition. 2- Efficient real-time processing for attendance tracking.	1- Requires significant computational resources. 2- Accuracy can be affected by lighting and facial angle variations.

7 Conclusion and Future Work

In this work, we investigated multiple methods to automate attendance system through facial recognition system, considering problems such as illumination, head pose and distance for the system to work well and effectively in different scenarios. With the use of cutting-edge biometric technology and high-resolution monitoring, we have devised a solid system that makes up for the shortcomings of conventional attendance reporting mechanisms. In the future, we plan to improve the robustness of the system performance through adopting the state-of-the-art machine learning methods [37] and make it more power-efficient for low-resource platforms, as well as extending the system to multi-modal biometric system to increase the security level and reliability in various critical applications.

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