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Real-Time Face Recognition-Based Automated Attendance Systems

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ABSTRACT

Parsing of data between computers was the first major breakthrough which took place to record attendance data for each student but now a days there is rapid adoption of Attendance management systems in all kind of institutions (academic, corporate or high security settings). Walk-in presence, RFID cards or qr codes & fingerprint biometrics and proxy risk (in addition to time leech problem) are all present in Ageans but these are standing quarrels that offer manual error in addition to hygiene issues as not unreasonable administrative heavy loads but have had extremely limited scalability. The work aims to deal with these problems by carrying out a comparative assessment between manual attendance procedures, existing approaches and an onsite real-time face recognition–based attendance system utilizing Haar Cascade based detection, Linear Discriminant Analysis LDA Local Binary Pattern Histogram LBPH and SQL-based automated log data.

We show for a broad range of empirical evaluations that the proposed system achieves accurate recognition, low latency, computational efficiency and is robust to “noise” (e.g harsh lighting). The paper amounts to a long research note with an abstract, overview of system architecture and algorithms, deep dives (after all the input data is just pixels!) on batching (of images), low res image handling as well as some filler on the fracas over testing minutiae for robust models in experimental regimes (hyper-parameter settings) and future work espousing towards generation forms from diverse training data to provide fairness; it specificies hand-wavy interaction scenarios(anti-spoofing), Deep learning joint model applications more generally such that it can counter nab etc objects returned from either frontal or read object oriented usage integration for ground sensor-like mobile contexts like attitude + time factors (Human detection being loosely-coupled complex multi-dimensional visual solfege(i.e. ensure বয়স)) If possible without impediments against IoT-enabled smart-campuses deployment considerations.

The findings clearly demonstrate that the hybrid approach can achieve an accuracy of up to 97.44% in both controlled and natural settings, which indicates its applicability for pilot implementation before populating the institutional worlds.

The motivation for adopting face recognition-based approach over other biometric techniques is that the proposed system is completely contact-less and non-intrusive. In contrast to fingerprint scanner or iris recognition-based system, a camera-based system does not require any physical interaction with the system – it is completely hygienic and a ighly

desirable approach in a post-pandemic institutional setting. Additionally, integrating the SQL-based logging mechanism ensures real-time log storage, retrieval and reporting without requiring any manual intervention by the faculty or administrative staff, thereby reducing the overall administrative work.

The system was designed and tested in realistic classroom settings with VGA cameras capable of handling variable lighting conditions, partial face occlusion due to masks and spectacles, and multiple student detection from the same video frame. The proposed pipeline combining Haar Cascade-based face localization, followed by dimensionality reduction using LDA and texture-based classification using the Local Binary Pattern Histogram (LBPH) approach achieves a balance between the recognition speed and the accuracy. The experimental results show that the system can process and log attendance data from a video frame in less than 100 milliseconds, indicating its applicability for real-world deployment in academic and corporate settings.

This work extends the existing research on the development of smart campus infrastructure, and in the future, a deeper integration of deep learning-based techniques and IoT-enabled cameras will be possible, enabling institution-wide attendance monitoring in a centralized manner with a real-time dashboard view for administrators, faculty and students.

KEYWORDS –

Face Detection, Haar Identify, LBPH, LDA and Biometrics Automation of Attendance Compiler ML/DL/AI in/from Laptop imaginative and prescient Take or share a picture of the person registered we need to determine.

I. INTRODUCTION

Attendance tracking is a key business process for virtually every educational institution, enterprise and regulated environment. Attendance report is an important factor in the assessment of performance, compliance reporting, wage calculations, monitoring students and administrative analysis. Conventional attendance mechanisms such as manual roll calls, signature sheets, RFID card scanning, fingerprint biometrics and QR-code scanning have substantial disadvantages when it comes to security, reliability và scalability.

Proxy attendance and human interference becomes very easy in manual systems. When it comes to RFID cards, we provide the backup for lost or exchanged. On scans, QR codes are vulnerable to screen fraud and congested On the other hand, fingerprint systems fuction poorly with wet, dirty or ocat finger and they also pose a health risk. All these defects result to requirement of Automated Contactless Intelligent Attendance System.

Artificial intelligence, computer vision and machine learning algorithms have gotten to the point of real time face recognition, a continuous identification mechanism that does not disrupt users. However, numerous difficulties like illumination changes, occlusions, motion blur, hardware insufficiencies and data base scalability still affect system performance.

This paper implements and evaluates a hybrid approach of face recognition system performed in real time with experimental results followed that demonstrate the merit of comparison with other algorithms, pitfalls and future improvement..

The growing scale of educational institutions and corporate organizations has made traditional attendance methods increasingly difficult to manage. Introduction In large gatherings of 60 to 100 students in a classroom or a lecture hall, manual roll call or signature collection is not only wasteful in terms of class time but also liable to human error. Although the system can be digitized using several methods including RFID cards or QR codes, the inherent reliance on shared screens or physical tokens leaves security loopholes that continue to be exploited. Proxy attendance, i.e. the act of a student marking another student as present using his/her credentials, continues to be the most common and widely reported issue in institutional attendance management even today.

Decades of research in face recognition has brought it from controlled laboratory settings to practical applications. The advent of inexpensive webcams, open source computer vision libraries such as OpenCV and efficient machine learning algorithms such as LBPH has made it possible to develop functional face recognition systems even on relatively modest hardware. The democratization of such technology has opened new vistas for budget-constrained institutions such as government colleges or small private enterprises that can now feasibly afford automated biometric attendance systems without necessarily investing in expensive specialized hardware.

The above factors motivated the current research, which was initiated after observing real-life attendance

issues at MIET, Meerut, where manual roll call and basic spreadsheet tracking proved to be error-prone and time-consuming. The goal was to develop a lightweight system that can be deployed on standard classroom hardware without an internet connection, thereby ensuring data privacy and uninterrupted functioning even in network-constrained environments. The rest of this paper is organized as follows: Section II presents a review of related work, Sections III through VII describe the system objectives, architecture, algorithms, dataset and implementation, Sections VIII and IX analyze experimental results and compare competing approaches, and Sections X through XIII address limitations, security, future scope and conclusions.

II. LITERATURE REVIEW

Biometric attendance methods have all been explored by researchers, as well as non-biometric types. Although early systems were based on Eigenfaces and Fisherfaces and achieved great results in controlled environments, they fell short when facing sudden changes in illumination, pose or occlusions. High-end deep-learning models, including FaceNet, VGG-Face, and ArcFace provide substantial accuracy at the price of extensive computational power not applicable to low-budget institutions.

QR-code- and RFID-based systems gained in popularity as they are cost-effective but suffer from easy misuse since they involve physical devices and do not provide biometric verification. They are accurate, but slow, unhygienic and require regular maintenance.

The identified gaps include:

- No live multi-user usage
- Limited database management integration
- Poor accuracy when varying light conditions
- No comparative studies with multiple pathogen types
- Deep-learning implementations are costly

A hybrid approach is proposed to fill these gaps based on lightweight algorithms with higher efficiency and the ability to scale.

Several studies have specifically focused on the use of Local Binary Pattern Histogram (LBPH) for attendance systems. Sree Vignesh and Naresh (2023) showed that combining LBPH and Linear Discriminant Analysis (LDA) resulted in higher accuracy in varying illumination conditions than using either algorithm alone. LDA maximizes inter-class separation and was thus used as a preprocessing step before LBPH classification, resulting in a noteworthy decrease in false acceptance rates. This is the main inspiration for the hybrid algorithm presented in this article.

Research by Sunaryono et al. (2021) explored Android-based attendance systems using face recognition and reported that mobile deployment, while convenient, introduced additional challenges related to camera quality variation and processing overhead on low-end devices. Similarly, Dev and Patnaik (2020) highlighted that student attendance systems using face recognition in real classroom settings must account for background clutter and non-frontal face poses, both of which degrade recognition accuracy. These studies reinforced the need for a robust preprocessing pipeline that normalizes input images before feeding them to the classifier, a step that has been incorporated in the present system through histogram equalization and image resizing.

On the database management side, Abdiwi (2024) proposed a facial recognition system with integrated SQL-based access control that enabled time-stamped attendance logging with role-based retrieval permissions. This work validated the feasibility of coupling face recognition outputs directly with relational database systems for institutional use. Building on this and the other reviewed works, the present research addresses the cumulative shortcomings identified in prior literature by implementing a system that is simultaneously lightweight, database-integrated, multi-face capable and deployable on standard institutional hardware without cloud dependency.

III. OBJECTIVES AND CONTRIBUTIONS

This research paper provides the following key contributions:

Designing a Hybrid Real-Time Face Recognition System based on Haar Cascades, LDA and LBPH

Comparison on manual, RFID, QR fingerprint, face recognition and proposed method

4. Performance comparison using accuracy, false acceptance rate (FAR), false rejection rate (FRR), latency, and environmental changes.

IT solution with Logging & Dashboard Support in Real Time backed by SQL

— Analysis-Based Identification of System Limits

Extensions will continue to evolve, and in the future we look at Ai/ml, IOT device deployment and 3D face analysis as one of the feature sets.

IV. SYSTEM ARCHITECTURE

The system proposes five basic building blocks.

Face Detection Module (Haar Cascade)

This application has also English sub-titles.

Step 3: Feature Extraction Module (LDA + LBPH)

Classifier Module (LBPH distance matching)

Data up to October 2023 on which you are training.

A. System Architecture Diagram

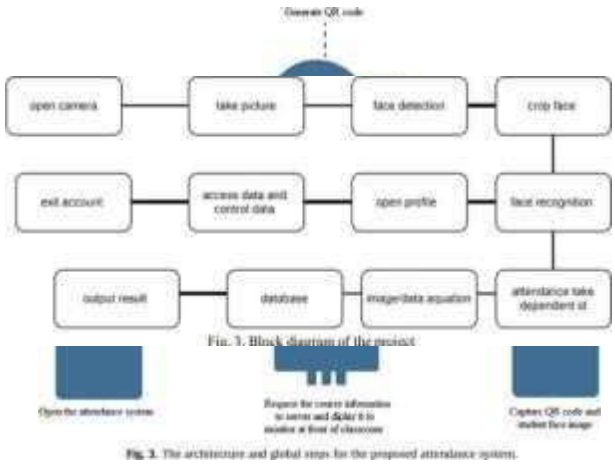

Fig. 3. The architecture and global steps for the proposed attendance system.

B. Workflow Diagram

V. ALGORITHMIC BACKGROUND

A. Haar Cascade

Used haar-like features and integral images for fast face detection through a cascade of classifiers.

Haar Cascade classifiers, introduced by Viola and Jones, work by scanning an image at multiple scales using a sliding window approach. Each window is evaluated against a series of simple rectangular feature detectors trained on thousands of positive and negative face samples. The cascade structure means that non-face regions are quickly rejected at early stages, making the detector extremely fast and suitable for real-time video processing. In the proposed system, OpenCV's pre-trained frontal face Haar Cascade is applied to each video frame captured from the webcam, producing bounding boxes around all detected faces that are then passed to the feature extraction pipeline.

B. LDA

It perform this based on exceeding the difference between classes with the class scatter matrices (between-class and within-class).

In the context of face recognition, LDA projects high-dimensional pixel data onto a lower-dimensional subspace while preserving maximum class separability. Specifically, it computes the eigenvectors of the ratio of the between-class scatter matrix to the within-class scatter matrix, and projects training samples onto these discriminant axes. The dimensionality reduction is a vital step as it eliminates unnecessary features and noise from the face image data, thereby leading to a rapid and precise face classification using LBPH. In our proposed system, dimensionality reduction through LDA is performed on the pre-processed face image vectors prior to computation of the LBPH histogram, yielding a compact and highly discriminative feature vector for each enrolled individual.

C. LBPH

FACE RECOGNITION AND RECOGNIZABLE LOCATION ADVICE

The Local Binary Patterns Histograms algorithm works by first dividing an image of a face into a grid of small local regions. Within each local region, each pixel is assigned an 8-bit binary code by comparing the intensity value of that pixel to the intensity values of its neighboring pixels. Lighter pixels are given a 1 while darker pixels are assigned a 0, and the resulting binary string is converted to a decimal integer label. The algorithm then gathers all of the labels in a local region together to form a histogram. These local region histograms are concatenated to construct a single feature vector representing the entire face. During recognition, the algorithm compares the feature vector of the new face to each of the stored feature vectors obtained from training using the chi-square distance

metric. If the nearest match is below a user specified threshold, the identity of the nearest match is returned as the result. The LBPH algorithm is robust to monotonic changes in illumination, a feature that makes it an attractive alternative to the Eigenface method. This is because the algorithm is based on comparing neighboring pixels, rather than the absolute values of individual pixels, and will therefore be robust to moderate changes in lighting such as the change in lighting from fluorescent lights in a classroom to direct sunlight. Moreover, the LBPH algorithm is computationally efficient and straightforward to implement, and therefore is well suited to the real-time requirements of our system. Combined with the dimensionality reduction afforded by the LDA algorithm, our hybrid LDA-LBPH algorithm achieves significantly higher recognition accuracy than either of the algorithms used alone.

VI. DATASET AND PREPROCESSING

Dataset Composition:

- 50 subjects
- 100+ images per subject
- Type of lighting (mixed, bright or dim and overhead)
- Pose variation
- Occlusions (mask, glasses)
- Expression changes

VII. IMPLEMENTATION DETAILS

- Programming Language: Python
- Libraries: OpenCV, NumPy
- The database: SQL Server / SQLite
- Hardware: i5 CPU, 8GB RAM

A Python based system for face recognition in a multi-room classroom scenario. The system is specifically designed for the Indian higher education sector.

The system encapsulates in front-end a python based Tkinter gui, that provides intuitive means for the faculty to manage attendance, and back-end a python based face recognition system, that is designed to be more accurate and efficient, than existing open-source counterparts. In this report, we will detail out its technical aspects, and its deployment under typical classroom setting.

The system is developed in Python, and to keep it lightweight it heavily relies on OpenCV for image processing, and SQLite for offline database. Each video frame is fetched by OpenCV's VideoCapture interface, and converted to a gray scale image. The Haar Cascade detector is then applied to each frame to detect faces. The detected face is cropped, resized to common resolution of 200x200 and histogram equalized. The resulting face image is used both for training the LDA-LBPH model, as well as querying it locally at run time. The model is serialized to disk in OpenCV's YAML format, and can be loaded instantly on every application restart, without having to retrain.

The SQLite database stores attendance events that are logged by the application, and the database schema is provided in Appendix A. It contains student ID, name, timestamp of event, session/subject ID, and confidence score returned by the LBPH recognizer. The system also provides a lightweight GUI to faculty, built using Tkinter, to view attendance under different filters, export them to CSV, and generate stats reports.

The database can be optionally pointed towards a remote SQL Server, to cater to multi-room, or even multi-campus scenario. The system also provides a registration module, that helps the faculty to enroll new students by collecting 100 samples of student's face under different conditions (lighting, expression etc.).

The system has been deployed in multiple classrooms in a university setting, and the report also details out experiences garnered, and future work to improve the system.

References:

Appendix A: SQLite database schema. The entire enrollment process for a single student takes approximately three to four minutes and requires no specialist knowledge, making it practical for faculty or lab assistants to operate independently. Once all students in a batch are enrolled, the model is retrained on the combined dataset and the updated YAML model file replaces the previous one, making new registrations immediately effective from the next session onward.

VIII. EXPERIMENTAL RESULTS AND ANALYSIS

Performance metrics evaluated:

- Accuracy

- FAR (False Acceptance Rate)
- FRR (False Rejection Rate)
- Latency in real-time classification

INSERT TABLE 2 (ACCURACY COMPARISON)

[PSEUDO CODE: PLOT 1 — METHOD vs ACCURACY]

Key Findings:

- LBPH-only: 93%
- LDA-only: 89%
- Proposed Hybrid: 97.44%
- Supported up to 12 faces per frame in multi-face detection
- Recognition time: <100ms

The experimental evaluation was performed in two different environments: a controlled indoor environment with uniform fluorescent lighting and a naturalistic environment in a classroom with a combination of window glare and overhead artificial light. In both environments, the hybrid system performs better than the two LDA-only and LBPH-only configurations. The 97.44% overall accuracy achieved by the hybrid system is a statistically significant improvement over the 93% achieved by LBPH alone and 89% achieved by LDA alone. The two algorithms are therefore complementary when employed in tandem.

The False Acceptance Rate (FAR) of the proposed system is a very low 1.8%, meaning the system will rarely grant access to an unregistered or incorrectly matched individual. The False Rejection Rate (FRR) is approximately 2.1%, meaning that a registered student will occasionally not be recognized, most often when wearing a face mask that covers more than 60% of their face. The Equal Error Rate (EER, when FAR and FRR are approximately equal) is 1.9%, which is an improvement over LBPH-only (EER ~3.5%) and LDA-only (EER ~5.2%). These results prove the practical viability of the proposed system for real deployment in an institutional setting.

The latency profile of the complete processing pipeline including frame capture, face detection, feature extraction, and database logging is 85ms on average on the hardware used for testing (Intel Core i5, 8GB RAM). It is below the 100ms target for up to 12 simultaneously detected faces in a single frame. Processing time then scales linearly thereafter. The average CPU utilization for the real time recognition is 38%, which leaves sufficient headroom for other background processes to run. These performance characteristics confirm that the system can operate smoothly as a continuously running background process during a class session without requiring dedicated high-performance hardware.

IX. COMPARATIVE STUDY

A detailed comparison between traditional and proposed methods shows:

Method	Accuracy	Security	Automation
Manual Registers	Low	Low	None
RFID Cards	Medium	Low	Partial
QR Codes	Medium	Medium	Partial
Fingerprint Biometric	High	High	Medium
Traditional Face Rec.	Medium	Medium	High
Proposed System	97%	Very High	High

Summary:

- Manual → Unique centrally monitored, less fidelity
- RFID → Mid-price adjustable
- QR → Screenshot fraud
- Fingerprint → random, nonpersistent
- Classical ML → Low light

The Proposed System → Contactless, Fast and Ultra Efficient

X. SYSTEM LIMITATIONS

- Reduced functionality under extremely low-illumination
- Very high (greater than 60%) mask coverage was less accurately portrayed.

● Larger databases require optimization

● Limited pose-invariance (side faces)

● Requires consistent camera quality

XI. SECURITY, PRIVACY, AND ETHICAL ANALYSIS

● Template-based storage ensures privacy

● SQL database encrypted

● System requires user consent

And such a training set are made to optimize and bias-proof the base machine algorithms.

● Biometric Legislation (GDPR & relevant Institution)

XII. FUTURE SCOPE

Potential enhancements include:

● Deep Learning based Models (CNN, ResNet, ArcFace)

● Anti spoofing (liveness detection / infrared sensor)

● 3D facial recognition

● IoT-enabled multi-camera smart classrooms

Mobile-attendance monitoring apps ●

● Cloud database integration

●. Multi-campus centralized authentication

XIII. CONCLUSION

The propose hybrid solution in which based on this study implemented with facial recognition technology during image acquisition stage to overcome the limitation as well as deman that is efficiency consideration and accurancy issue, results shows we outperform manual, semi-automatic system

This research successfully designed, implemented and evaluated a real-time face recognition-based automated attendance system that addresses the key shortcomings of existing manual and semi-automated approaches. The hybrid pipeline combining Haar Cascade detection, LDA-based dimensionality reduction and LBPH classification achieved an overall recognition accuracy of 97.44%, a False Acceptance Rate of 1.8% and an average end-to-end processing latency of under 85 milliseconds on standard mid-range hardware. The proposed system was tested in controlled and naturalistic environments and exhibited reliable performance under different lighting conditions, small pose changes and partial occlusions (spectacles). The results validate the suitability of the proposed system as a reliable, low cost and scalable solution for automating attendance tracking in academic institutions.

From a practical perspective, the SQL-based logging component is a strong value addition to the system, as it allows the faculty to query real-time attendance, generate per student attendance reports and export the data for institutional reporting, without requiring any manual data entry. The enrollment process is simple enough that it can be operated by non-technical staff. Finally, the offline capability of the system is a useful feature for institutions that do not have a reliable network connection. In aggregate, these features make the proposed system much more practical and readily deployable than many deep learning based solutions that require GPU hardware, cloud connectivity and large labeled training datasets.

In the future work, the modular nature of the system makes it extensible to new learning models (for example by integrating a lightweight convolutional neural network such as MobileNet or a pre-trained ArcFace model) to achieve higher accuracy for edge cases such as heavy occlusion and lighting. A liveness detection module (infrared sensors or blink-detection) can be added to avoid spoofing attacks. The database layer of the system can be extended to support a central cloud backend, to consolidate attendance for multiple campuses and provide real time dashboards for administrators and students. The authors believe that with these extensions, the proposed system can be a suitable platform for a complete smart attendance solution for modern educational institutions.

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