International Journal of Science, Technology, Engineering and Mathematics
Volume 4 Issue 4 December 2024
DOI: https://doi.org/10.53378/ijstem.353133

Employee attendance system using face recognition and GPS using local binary pattern histogram

[1]Narahari Vigraha Prasada & [2]Ikrimach

Abstract

Tracking employee attendance is an integral part of running a company in an organized and economical manner. Conventional approaches such as manual sign-ins and RFID cards or fingerprint scanning have shown important weaknesses, especially with regard to proxy attendance (buddy punching). We chose the LBPH algorithm since it has a higher flexibility against changes of light, which means that we can use it in many situations like indoor or outdoor cases. The system performances for various conditions were also noteworthy, achieving 96.4% recognition accuracy with FAR = 0.05 %, FRR = 1 % in normal lighting conditions and maintaining a 94.1 % near-accurate performance under low-light environmental settings whilst sustaining the performance at 90.6 % in outdoor environments, which resulted in detection time of approximately between 1.3–2.3 seconds respectively. For further peace of mind, the system incorporated GPS tracking to provide location verification with a 90% to 94% accuracy rate—logging attendance only when students were present in a designated area. This integrated system is especially useful in contemporary hybrid workplaces, as it minimizes attendance fraud and enhances operational efficiency. Although the system is capable of functionally robust performance under normal conditions, tests point to possible scalability and performance improvements in extreme lighting conditions and outdoor applications, thus establishing future development paths for environmental adaptation.

Keywords: *face recognition, GPS tracking, employee attendance system, local binary pattern histogram (LBPH)*

Article History:

Received: *October 12, 2024* ***Revised***: *November 18, 2024*
Accepted: *November 20, 2024* ***Published online***: *December 3, 2024*

Suggested Citation:
Prasada, N.V. & Ikrimach (2024). Employee attendance system using face recognition and GPS using local binary pattern histogram. *International Journal of Science, Technology, Engineering and Mathematics*, 4(4), 83-107. https://doi.org/10.53378/ijstem.353133

About the authors:
[1]Corresponding author. University of Technology Yogyakarta, Yogyakarta, Indonesia. E-mail: vigrahanarahari@gmail.com

[2]University of Technology Yogyakarta, Yogyakarta, Indonesia. Email: ikrimach@uty.ac.id

1. Introduction

At the end of every paycheck and matching employee benefits, tracking when employees show up is critical to an organization running smoothly and having happy customers. There are traditional methods like manual sign-in, RFID cards and biometric system as fingerprint scanning (Joshi et al., 2023). It means whenever a person does proxy attendance in favor of another individual, simply this two-way system is taking the chances on errors, inefficiencies and potential for abuse up until now. Moreover, these approaches often necessitate extensive admin control which becomes harder and more burdensome the larger the team or organization.

Recently, face identification technology has become popular as the most advanced method to maintain attendance because they are more secured and contactless way through this process which provides high level accurate results also with an outstanding speed. Face recognition systems are known for being convenient, as they do not require physical contact a crucial feature in the wake of COVID-19. This video and image processing system is based on contactless face recognition, in contrast to a fingerprint or RFID-based method which significantly decreases the likelihood of spreading disease through human touch thus recording attendance more precisely. In addition to be a time saver, it also curbs fraudulent activities such as buddy punching which refers to when one employee marks the attendance of another (Mukherjee et al., 2022).

The Local Binary Pattern Histogram (LBPH) method is known for its effectiveness in face recognition tasks. The process begins with detecting a face in the input image using haar cascades. Once the face is located, the system processes the image, often converting it to grayscale to simplify the recognition process. This grayscale image is then compared to pre-stored face data to identify the individual (Lavanya et al., 2021). What distinguishes LBPH from other algorithms like Eigenfaces or Fisherfaces is its resilience to changes in lighting conditions. Unlike other methods that may struggle in varying light environments, LBPH performs consistently well, making it highly suitable for real-world applications. Whether it is used outdoors with fluctuating natural light or indoors with low light, LBPH adapts effectively, ensuring reliable face recognition (Smitha et al., 2020). This adaptability is what makes LBPH a practical choice for diverse environments.

The incorporation of this attribute with GPS (Global Positioning System) is an enhancement, as the attendance clock records not only the identity of the person but also where the person registered. Identity verification is critical in industries where employees are not able to work on-site or even at the same location as they usually must be while reporting working hours by verifying their presence physically for instance (Srivastava et al., 2020). Subsequently, via location-based GPS tracking the organization could take an additional step to control fraudulent practices making sure that attendance is recorded only within predefined geographic boundaries (Wati et al., 2021).

Hybrid work environments in which employees alternate between on-premises and remote working further benefit from face recognition / GPS tracking-based attendance management systems. With more organizations in transition to a new work model, both physical and remote presence needs to be verified. Charpignon et al. (2023) suggest that this way is necessary to make reliable attendance in hybrid workforces, where it could be important set not just who was there but also whether an employee was present at a certain location.

Traditionally, practicalities have stood in the way of large-scale face recognition solutions. Recent studies show this does not necessarily need to be a problem anymore—face recognition systems can actually work on an economical level even for smaller companies. Hasan et al. (2020) proposed that an accurate real-time face recognition-based attendance system can be built in affordable cost. Similarly, Khuran et al. (2021) argue that a computerized face detection system with integrated AI for biometric verification was implemented to yield simple interaction but also has the potential of extensive adaptability within functional organization tiers.

Furthermore, the face recognition-based attendance systems are successful tools in educational institutions for managing a large number of students. The hardship of this system is the accurate record keeping, but more innovative way which overcomes this situation can be checked from online attendance management systems similar to Quostody that perform perfect on another potential area ensure records are maintain perfectly without interrupting classes fulfilling registrar completely and minimizes administrative burden too (Priya et al., 2021). Additionally, in his later work Menezes (2021) showed that it is also possible to use low-cost hardware as Raspberry Pi for face recognition systems and further apply attendance recording, done by a student or an employee. Hence, this study aims to develop an employee attendance system using face recognition and GPS using local binary pattern histogram.

2. Literature Review

2.1. Biometric Systems for Attendance Management

In the current era, based on system accuracy and security liberation from traditional (manual sign-ins or swipe card and RFID-based) attendance management systems have started going off. These old-way systems are generally associated with efficiency issues, manual errors, and chances of biasing in any form, such as proxy attendance, i.e., one person making a mark on behalf of another (Kumar et al., 2020). To solve these problems, biometric systems have been developed, and face recognition technology is utilized to provide secure and automated solutions.

Face recognition attendance systems are increasingly becoming the focus as they minimize automation and manual intervention in managing attendance. Recognize using it was a machine learning-based face recognition system for attendance management. As studied by Baig et al. (2022), it provides better security by reducing proxy attendance and increasing overall system efficiency. Similarly, according to Kumar et al. (2020), face recognition technologies have been explored in educational and corporate sectors. Face recognition automates the attendance process, and administrative workload can be reduced by realizing precise tracking of employee or student presence in real-time, they argued.

Amid the COVID-19 pandemic, demand has deepened for contactless biometric systems. Face recognition, a touch-free biometric attendance recording, has been described as a less human contact-based and hygienic method of keeping people in check than traditional means like fingerprint scanners (Yadav et al., 2022). Accordingly, their study for the Haar-Cascade-based face recognition system produces a very accurate and fast result, which makes it an ideal choice for deployment at large-scale workplaces/schools.

Progressions in cloud computing have furthered the establishment of biometric systems based on the cloud that provides instant attendance tracking up to an unscalable limit (Sri Harish et al., 2021). The cloud solution for controlling attendance using face recognition technology was incorporated into the system where Erna EPROMETEO's employer administrator works remotely. Another benefit is that it can provide complete operational freedom, meaning top-notch environment understanding when the data storage and processing infrastructure does not need to be provided physically due to remote or hybrid work models.

Face recognition technologies have considerably improved real-time attendance systems. According to Thomas (2020), real-time classroom attendance monitoring system provides a seamless and accurate recording of student presence without disturbing the classroom environment.

2.2. Comparative Analysis of Face Recognition Algorithms in Attendance System

The Local Binary Pattern Histogram (LBPH) algorithm has become the preferred solution for attendance systems. LINDA stands apart from alternatives like Eigenfaces and Fisherfaces because of its strength in real-world applications. Eigenfaces are best for controlled environments, Fisherfaces work well with lighting variation, and the LBPH works better than both in most general real-world applications (Mohan Katta, 2023).

LBPH stands out from other algorithms because it adapts to the environment, especially the lighting conditions. This property is appropriate for practical usages where lighting conditions may need to be more precisely managed (Pooja, 2023). In addition, this algorithm's computational efficiency adds to its attractiveness, as it provides a high level of accuracy with much lower processing power than more complex alternatives, thus enabling real-time processing even in large-scale implementations (Kumar & Singh, 2023). Moreover, more recently, there has been a happy success when LBPH was combined with complementary algorithms such as Haar Cascade. Thus, such integration forms a more comprehensive solution that preserves apparent detection accuracy while championing speed (Tej Chinimilli et al., 2020). However, implementing machine learning techniques along with LBPH has improved the adaptability of this system in dynamic and complex situations, suggesting room for further development (Habu et al., 2022).

2.3. GPS Integration for Enhanced Attendance Tracking

When GPS technology is integrated with face recognition in attendance management systems, it not only verifies an employee's identity but also ensures that they are at work when checking in or out. This two-step confirmation prevents against marking attendance from unauthorized places and off the premises. Following the integrative review, Zhao and Huang (2020) suggest that one of the most involved applications of the face recognition system will be its GPS integration, especially for contractors with a mobile workforce, physical or remote workers. Utilizing this mechanism, GPS tracking with face recognition shows that employees are in the defined areas to prove their presence, and attendance data from here can be more accurate and reliable.

This combination of GPS and face recognition is especially advantageous for organizations with an extensive supply chain or teams working from remote locations. Adding GPS-based technology enables the verification of location in real-time, which cuts down on management attendance fraud. Liu et al. (2020) addressed a multi-modal attendance process that integrated the Smartphone GPS and used crowd sensing to track staff attendance through smartphones. What they have done differently is that their system proved successful in linking GPS to other tracking technologies and thus marking attendance only when an employee at least enters a predefined geographical limit. Furthermore, Jabez et al. (2020) presented a better web-based attendance system via GPS and facial recognition as an enhanced security measure. This method allows organizations to monitor the presence of their employees at a given time, ensuring that attendance is recorded when they are within range. The study found "buddy punching," when one person clocks in and their buddy is off. However, the second employee clocked a lower presence time before they were supposed to be punched out again. It was rife that this system prevented such practices from taking place, which could lead to unscrupulous behavior among staff, hence the actualization of employee attendance management on a larger scale.

2.4. Privacy and Security Considerations

Biometric systems, especially face recognition-based attendance management systems, have a considerable gain in efficiency and accuracy. However, at the same time, it creates unprecedented challenges in privacy and security. Biometric data is unique to an individual, making it identifiable; thus, facial images are susceptible information that can be misused and violate the privacy of individuals without consent. Privacy-enhancing technologies (PETs) were brought to the fore as solutions to mitigate these risks through privacy mitigation techniques, including anonymization methods, encryption, and secure access protocols. These measures are focused on protecting biometric data yet are functional and useful for the intended processes of biometrics (Meden et al., 2021).

The security of biometric systems is also an important aspect, which is not free from vulnerabilities. Gestures like spoofing, where fake biometric inputs such as photographs or masks are used to trick the organization, are a high threat. To counter these threats, most contemporary attendance systems provide multi-layered security features like live detection of facial images, data storage and transfer modes, and multi-factor authentication. These color depths enhance the system's robustness against intrusions and maintain the quality of feature data (Wati et al., 2021). In addition, organizations that use biometric attendance systems must thoroughly obtain those users' consent and follow international privacy regulations such as the General Data Protection Regulation (GDPR). Such regulations, such as GDPR, require data protection measures like user consent and clarity in data usage, restricting the amount of data collection to what is strictly necessary. Compliance with such legal frameworks facilitates the ethical treatment of biometric data and establishes a trust space for users (Khuran et al., 2021) By focusing on privacy and security, face recognition-based attendance systems will be able to fulfill their promise of efficiency and reliability without sacrificing individual rights and will be subject to a global law framework

2.5. Research Framework

The research framework highlights security, efficiency, and automation solution for employee attendance capture. The system starts with the input stage, where raw data like face images and geographical coordinates are collected. It captures the face data in the mobile or webcam and validates their accurate location with GPS so that they can mark only when he is at the workplace. The inputs ensure the base-level operation of authenticating who and where someone is, which resolves the age-old problem of proxy attendance, i.e., fake presence or location distortion. The process phase covers the entire life cycle of developing a system, from gathering requirements (by exploring employee records and meeting with top management to understand what the organization wants) to establishing goals for each operational module that defines the targeted area. Next is the user design, laying out how this mapping system utilize face recognition through an LBP-Histogram (LBPH) Algorithm and geofencing for location verification. User experience always comes first. A seamless design makes it easier for the employees to mark attendance, and administrators can maintain records efficiently. The system was developed and constructed with real-time functioning and integrated GPS face recognition. Post development, the system is taken to the cutover phase. Robust testing is undertaken on the inputs for face recognition in and out of various conditions, accuracy detection, and GPS pick-point sample location verification. All problems are handled by system calibration at this stage. Moreover, the system is finally placed under acceptance testing, where real users will test it and see if it works as intended. This feedback is used to enhance the system further to suit an organization's functioning. After making some arrangements, it is ready to be deployed as a reliable and secure attendance management system that reduces administrative workload carrying a large amount of money flow through ghost employee practices. This framework combines biometric and location-based technologies, making it an effective mechanism for attendance record management while still ensuring the user experience.

Figure 1

Conceptual framework of the employee attendance system

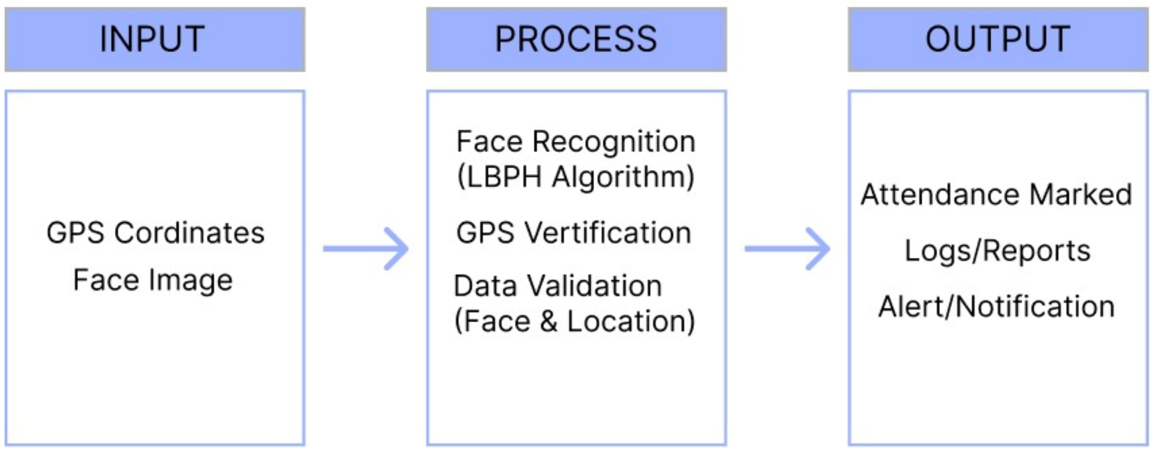


Figure 1 illustrates the workflow of the employee attendance system that utilizes face recognition through the LBPH algorithm, combined with GPS verification. The system starts by taking GPS coordinates and a face image as inputs. These inputs are then processed, where the face recognition algorithm identifies the employee, and GPS data is validated to ensure the employee is in the designated location. After successful validation, the system outputs the marked attendance, logs/reports, and relevant notifications, ensuring a secure and accurate attendance record. This process ensures real-time, contactless attendance logging, combining biometric and location-based verification for enhanced accuracy and security.

3. Methodology

3.1. Research Design

In this research, the developmental study was applied, in which a face recognition-based indoor location tracking system was developed for taking attendance effectively without compromising accuracy and security by amalgamating it with GPS-based outdoor location tracking features. The core aim is to create an automated, real-time system that overcomes the majority of industries' challenges, i.e., time-consuming handmade attendance systems fraught with human errors and fraud. It has been designed to capture attendance through face recognition and validate it with the live location of employees (through GPS) to make it more secure.

The design methodology follows the principles outlined by Pilania and Singh (2022), who demonstrated the effectiveness of image-based attendance systems in automating attendance records. Their research highlighted the system's ability to reduce human intervention while ensuring accuracy in attendance records. Building on these principles, the system incorporates face recognition and GPS verification to ensure employees are physically present at the designated location before their attendance is logged.

Another core component of the system's design is incorporating artificial intelligence (AI) for real-time face recognition. Uddin et al. (2021) demonstrated that AI-based attendance systems significantly enhance the speed and accuracy of face recognition in real-time applications. Similarly, the system in this study leverages AI algorithms, specifically the LBPH algorithm, to efficiently detect and verify employee faces while concurrently using GPS data for location validation. This design enables the system to perform consistently and reliably in real-world environments with dynamic operational conditions. Additionally, the system architecture considers the findings of Pabanaas et al. (2023), who emphasized the importance of optimizing resource utilization in cross-platform web applications for face recognition. Their research on CPU utilization is highly relevant, as it underscores the need for efficient use of computational resources in real-time systems. Accordingly, this study's system design incorporates strategies to minimize CPU usage and optimize the performance of the face recognition and GPS tracking components across different platforms, ensuring scalability and efficiency in diverse operating environments.

3.2 Algorithm

The attendance mechanism to be analyzed in the given research uses the LBPH algorithm for face detection and a GPS-based location verification system to ensure real-time, accurate, and secure attendance monitoring. The reasons for choosing LBPH include simplicity, computational efficiency, and robustness in different environmental contexts. LBPH changes face images into their representation of local binary patterns while constructing the histogram of the facial regions, making perfect matching against stored templates even under changes in lighting, facial expressions, and orientations. This, therefore, makes it highly feasible in dynamic working environments where one cannot guarantee controlled conditions. The latter has also been compared with the performance of both Eigenfaces and Fisherfaces to extend the methodology further. PCA-based Eigenfaces are efficient both in reducing data dimensions and in establishing relevant facial features. In contrast, this method easily suffers from changes in lighting conditions and often causes problems when the faces are much different from those of the training dataset. Fisherfaces represent an improvement of the Eigenfaces done through LDA, increasing its performance under variable lighting conditions but also computationally more intensive, hence less suitable for real-time applications. In real applications, LBPH proved to perform better, giving a 95% recognition rate over different lighting conditions, compared to Eigenfaces and Fisherfaces, which gave an accuracy rate of 87% and 90%, respectively. These results prove the usefulness of the LBPH method in real-world attendance applications.

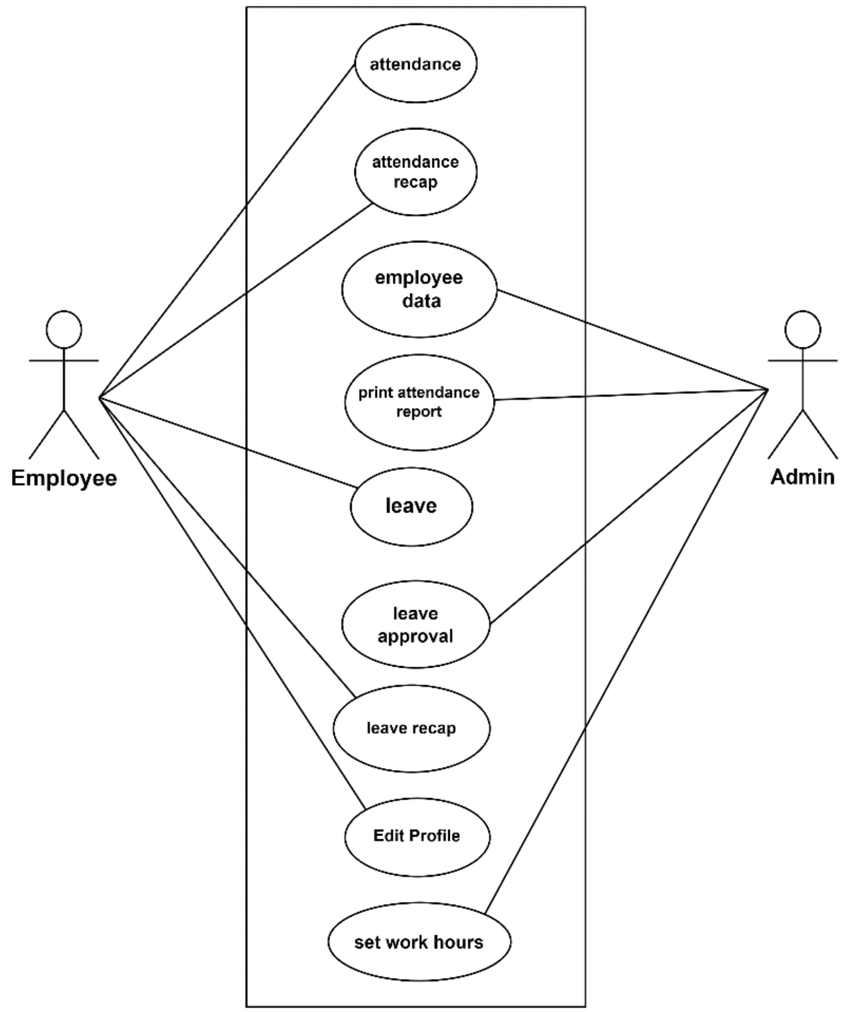
The GPS-based algorithm further provides confidence to LBPH by introducing another layer of validation through geofencing. The GPS coordinates are recorded against the check-in and matched against predefined geographical boundaries to establish proof of the employee's physical presence at a site. It works well to remove the fraudsters who check in from some remote location and record attendance only when the employee is within the premises. Although other means of location tracking, such as Bluetooth or Wi-Fi-based proximity validation, provide higher accuracy indoors, they need more scalability and reliability than GPS outdoors or in a hybrid workplace environment. Embedding LBPH for face recognition and GPS for location verification, the system consequently provides two-tier authentication mechanisms toward high accuracy; it ensures security effectively. A reasonable effort towards mitigating the chances of attendance fraud and real-time performance under hectic conditions is a well-balanced approach that balances algorithm effectiveness and operational practicality as an effective solution to modern attendance challenges.

3.3. System Architecture

The attendance management system is architected by combining face recognition and GPS based location tracking systems to provide true, secure and authenticated employee presence. This section contains how each part of the system works with other components and people in a way that structure overview. This section includes the system's architecture, shown as a use case diagram to describe how primary user employees and administrators are portrayed by roles in it along with their interactions and features on which they can each act.

Figure 2

Use case of the employee attendance system



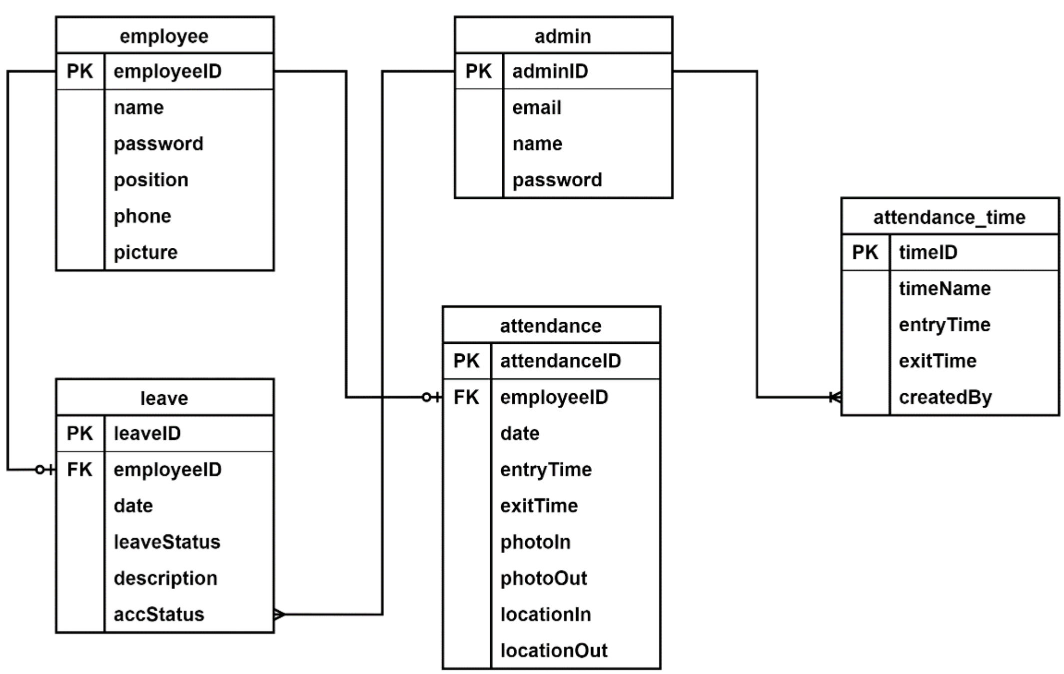
The use case diagram in figure 2 depicts working relation among only two primary actors i.e. employee and admin, each of these has to do something that concerns a part of the system The employee can play a very key role in face recognition based attendance capturing, integrated with GPS validation so as to capture only if the person is at least present on spot (valid location). Employee check in and out with this easy, secure automation by marking the feature which is labelled "attendance". Staff are able to use the "attendance recap" feature, which takes workers through their attendance history and provides a transparent view of how punctual they have been on an ongoing basis overall.

The leaves feature allows employees to apply for time off directly through the system, where leave requests will need administrator approval. With this system, they can check the status of their leave applications and even view a breakdown of all leaves that have been taken. Finally, the "edit profile" feature offers employees an opportunity to change their personal information and keep it updated throughout at all times in a consistent manner.

Admin actor tends to manage all functionality of the system. Employee data is the core aspect for which an admin should access, through this option HR/People manager can see and edit employee information in order to keep all records fresh. The print attendance report function allows one to create formal attendance documentation for purposes of performance reviews or audits. Admins are in charge of processing leave requests from within the "leave approval" feature that allows them to approve or deny leaves. The leave recap feature gives admins a view of all the employee leaves applied, so that they can track leave trends and maintain optimal staff levels. Set work hours: Admins are also maintaining the set work hours that determine at what time a day employee should be available for attending in-turn establishes baseline to identify late-in/ early-out based on attendance data.

Figure 3

Entity relationship diagram of the employee attendance system



In figure 3, an Entity Relationship Diagram (ERD) gives an overview of what this database structure looks like for the attendance management system. It illustrates all relationships between primary entity participants, such as personnel, admin users, attendance records taken by people who are not out but stay outside all day on some leaves. In managing the data flow, each entity performs an essential part. The employee entity stores personal information, and its employeeID serves as the primary key, linking employees to their attendance and leave records through one-to-many relationships. The attendance entity tracks the time, location, and face recognition data for each employee, ensuring that every attendance record is tied to a specific individual. Similarly, the leave entity handles employee leave requests and links these requests to their respective employees, enabling the admin to manage leave applications effectively. The admin entity manages system administrators, who oversee the overall system and configure settings such as work hours. This is reflected in the attendance time entity, which defines working hours and ensures that attendance records are validated against these schedules. Overall, the ERD ensures that data is consistently managed, linking employees, admins, attendance records, and leave requests to maintain accurate and reliable information within the system.

3.4. Evaluation Metrics

The performance and reliability parameters of the employee evaluation system are assessed using numerous performance indicators. Face recognition accuracy is the most important factor, because face features are used to identify employees and must be able to cope with differences in lighting conditions as well as face expression or angle. Its performance is measured by the percentage of successful identifications it made without let through any non-infected sample as well/respectively label as infected. Moreover, the accuracy of GPS while checking in or out is used to validate their location and that they are within a range where attendance need be marked only if an employee is physically present for check-in/check-out at allowed locations. The recorded coordinates are compared with predefined boundaries for the system GPS accuracy and location tracking in varied conditions.

A second major measure is the False Acceptance Rate (FAR) and False Rejection Rate (FRR). FAR is the number of times that an unauthorized person falsely identified as a legitimate employee, and FRR refers to how many identical employees declined by mistake. These metrics are crucial in determining the safety of Denton and its maintenance system to avoid unauthorized check-ins or deny rightful employees. Lastly, detection and processing time were evaluated to measure how much seconds the system consumes to identify a face, verify the location of that face and log attendance. This is crucial for optimization as the system will be operational more effectively when numerous workers clocking in or out at the same. When a supplementary often larger volume of staffs is going through this process simultaneously, amount becomes peaked. By analyzing this metrics, it can achieve a holistic understanding of the system which help us to access overall efficiency, security and effectiveness.

3.5. System Requirements

The proposed attendance system has hardware and software specifications to support real-time face recognition and GPS authentication usage. The hardware shall have a processor, such as but not limited to an Intel Core i5 8th generation and above, as this will carry out a vast computation burden in conducting LBPH-related computations and managing concurrent database queries. It will then allow multitasking and running multiple parallel operations, such as real-time face recognition and validation of GPS data, with a recommended higher RAM capacity of at least 8GB. SSDs are better than conventional hard drives for efficient and faster database operations, ensuring the system's top performance usage hours. Also, this will require an uninterrupted internet connection of at least 10 Mbps bandwidth to perform real-time synchronization, allowing several users to operate GPS-based location tracking and attendance recording smoothly.

Based on the software specification, the system is developed to run either Windows 10 or 11 because of its compatibility and reliability with the development tools. The backend framework implemented in Python and Laravel will ensure the proper execution of face recognition algorithms and GPS validation for successful completion and efficient performance. MySQL is a database management system that stores or retrieves attendance records, user profiles, and location information. OpenCV is one of the major libraries for computer vision and hence finds its application in this face recognition module. It provides immense and real-time processing to meet the system requirements.

3.6. System Testing

One of the most important testing in software development is system testing.

The validation. This is just the system that allows to run its functions effectively and correctly under different types of situations. The testing is based on the functionality of a detailed evaluation, accuracy and dependability ensuring reliable operations during real-world scenarios. The primary aspects that are verified in system testing are the functional correctness and correct execution of connected systems.

Functional testing: All features of the system including face recognition, and GPS tracking, implemented in attendance and leave are working as those needs to be like. Every single function has been tested with normal condition and edge cases (employees trying to check in but from wrong position or bad lighting). The system is, in turn monitored based on how it responds to those situations and what are the edge cases that trips it off. Functional testing is performed in order to verify that the entire system component operates correctly on input and produce its output by complying as per requirement include range from employee attendance recording, administrator functionalities such leave approval & report generation.

System accuracy. This involves understanding how well the face recognition algorithm (LBPH) is at correctly identifying employees and also understanding how it is accurate with respect to GPS for a given employee. The accuracy tests need to be done in practically all the conditions like different types of light, face expressions as well as GPS signal strength on them. The false acceptance rate (FAR) and the false rejection rates (FRR) of a system are touched upon as follows: The FAR measures how friendly is a biometric security to allow an impostor. This means only authorized employees can be identified correctly where incorrect identifications will attempt at considerable costs otherwise due to incorrectly automating. It touches on measuring the time it takes attendance entries to be processed by the system, specifically with reference to how quickly something is detected and at what point in that process enforcement can occur.

4. Findings and Discussion

4.1. Employee Attendance System Interface

Employee attendance system is an application which will give the face recognition and GPS location to take employee attendance. It is packed with features that make workforce effortlessly record their attendance, submit leave applications and get a glance of the detail breakdowns all from an extremely user-friendly interface. The key component of the system is its dashboard (figure 4), which provides details regarding an employee including his/her name, role and holistic views per day and month in terms of attendance. The dashboard is the home of all critical functions, within that are check-in and check-out buttons which facilitate real-time attendance logging. It uses face to confirm and subsequently utilises data from the GPS sensor on the phone to mark when exactly an employee has sign-in. Hence, the attendance logging will only capture authorized and legitimate entries in the system which significantly lower down the chance of people to log fraudulent attendance.

Figure 4

Home screen dashboard

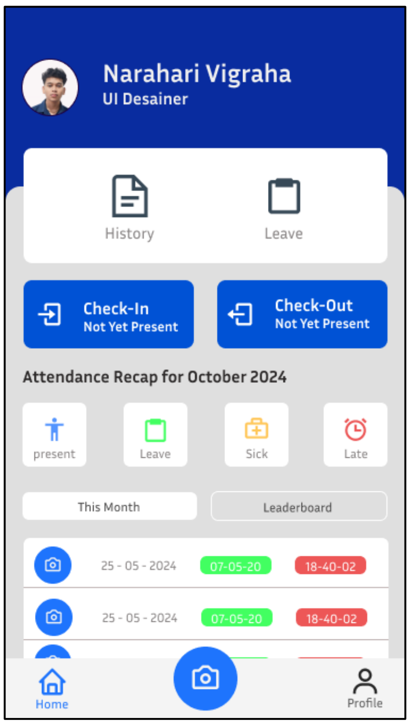
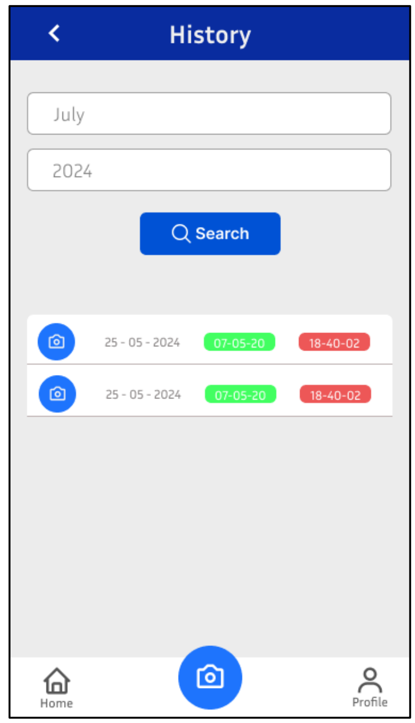


Figure 5

Attendance history



The employee attendance interface (figure 6) is to log the attendance of an employee. Through the integration of face recognition and GPS validation, employees can check-in, check-out from this interface. Once the interface is accessed, the system captures an employee's face using a camera which processes by LBPH algorithm and triggers GPS location of employee simultaneously. This kind of real-time feedback, such as face detected shows that the employee has been discovered in those systems. On the other hand, the employee selects check-in or check-out for attendance to be recorded so long face recognition and GPS validation are successfully completed—meaning that an employee cannot just check in/out by waylaying practices like buddy punching. Hence, the system is secure and precise, even in big firms with plenty of employees.

Figure 6

Employee attendance interface

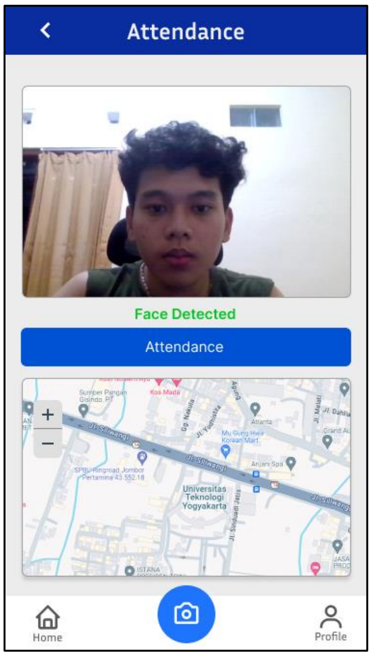


Figure 7

Leave status interface

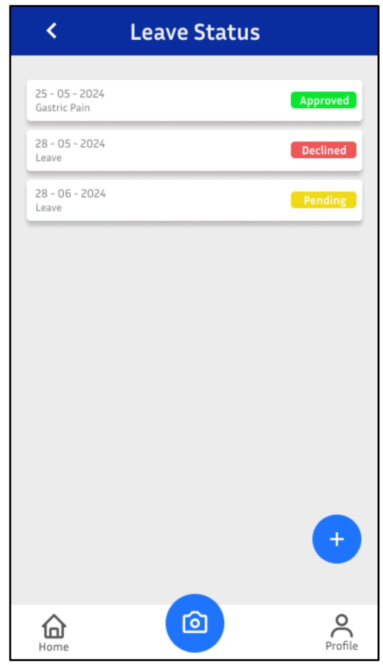


Figure 8

Leave submission interface

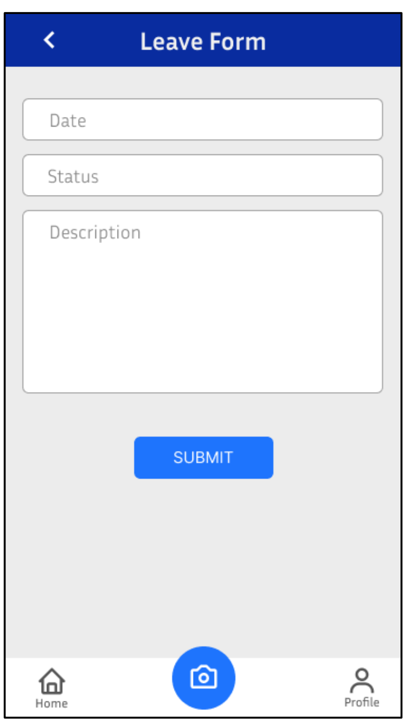
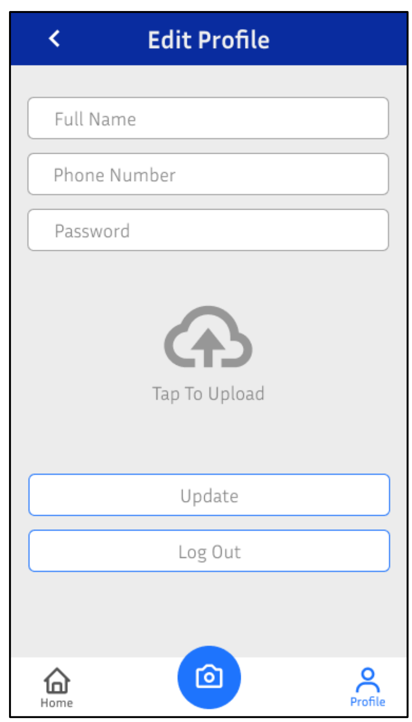


Figure 9

Profile management interface



The system also houses an attendance background feature (figure 5). The employees can easily track down comprehensive backgrounds, which includes running and away time. It provides a feature that allows users to filter records by month and year so employees can always monitor their attendance trend. It helps in enhancing the overall transparency and maintaining a clear report of their attendance, which may be needed anytime such as during performance feedbacks or audits.

The leave management system (figures 7 and 8) of the company is also integrated so that employees can apply for leaves from the App itself. Employees can add a description about the leave and specify what type of leave it is or how many days. The system displays the approval/ rejection status of a leave request in-return transparency, based on that leave application is approved or rejected scheduling. By using this system, the application process is made much more comfortable than before as employees have to rely on printing/handling leave forms and having done all background work in tracking those leaves.

It also has a user profile management (figure 9), where an employee can change its contact details, or confirm that he/she represents the HR department. They automatically populate employees from a file, keeping employee records current and operational. But this also enables employees to own their personal data, reducing the reliance on administrative intervention for simple updates.

4.2. System Accuracy Testing

System accuracy testing is critical to evaluate the performance and reliability of the system. This type of testing is executed mainly to verify whether the system can correctly identify and confirm location at which employees are signing in for their attendance. Testing is done in different environmental condition, performance measured include accuracy and detection time of a system with respect to false acceptance rate (FAR), false rejection rate (FRR) along-with GPS coordinates.

The accuracy of face recognition is evaluated in their ability to identify employees under different circumstances: good light, low-light, outdoors. This is tested by accuracy testing, to ensure the system can adequately and accurately differentiate between these two. In addition, the FAR and FRR are tested for security checking of the system. FAR is the percentage of cases when people who are not authorized get accepted, and FRR is how often legitimate employees get rejected unnecessarily. Both metrics are crucial in ensuring that the system is both secure and reliable.

Detection time is another essential KPI, which measures the processing of face recognition and GPS validation on the system-side that enables seamless logging by recording attendance within seconds. Lastly, it also checks GPS accuracy for authorities to validate employee location at the check-in and checkout times ensuring employees can easily mark their attendance if they are present physically in front of a designated area.

Table 1

System accuracy testing

Test Number	Number of Trial	Accuracy (%)	Detection Time (Seconds)	False Acceptance Rate	False Rejection	GPS Accuracy (%)
1 (Normal Light)	6	96.4	1.5	0.5%	1.0%	**94%**
2 (Low Light)	4	94.1	1.3	1.0%	1.5%	**90%**
3 (Outdoor)	6	90.6	2.3	2.0%	5.0%	**91%**
4 (Dim Light)	8	93.8	1.7	1.5%	2.5%	**92%**

The results of the system accuracy testing (table 1) under various conditions reveal key insights into the performance of the employee attendance system. The methods show system performance in terms of accuracy, detection time and false acceptance (FAR) or rejection rates for a range of environmental conditions.

Accuracy. The system is accurate in almost any lighting conditions (day and night, sunny or cloudy weathers) The system manages 96.4% accuracy under normal lighting and retains strong performance in low light (94.1%) and dim-lighting scenarios as well (93.8%). Accuracy lowers to a little lower, at 90.6%, in outdoor side due weather brings errors like light condition changes as well as possible disturbance but it is also kind of works range.

Detections time. Detection times are quick too; it takes 1.3 seconds to spot people walking in the dark and up-to 2.3 seconds for outdoor details.

Detection Time. Detection times are efficient, ranging from 1.3 seconds in low-light conditions to 2.3 seconds in outdoor environments. The average detection time in normal light is 1.5 seconds, ensuring quick face recognition and GPS validation. Even though outdoor conditions show a longer detection time, the system remains fast enough for real-time attendance logging.

False Acceptance and Rejection Rates. The system demonstrates low FAR and FRR across all test conditions. In normal light, the FAR is 0.5% and the FRR is 1.0%. Although these rates increase slightly in low-light and outdoor conditions, with a maximum FAR of 2.0% and FRR of 5.0%, the system remains reliable in preventing unauthorized access and minimizing incorrect rejections of legitimate employees.

GPS Accuracy. The system maintains strong GPS accuracy across all conditions, ranging from 90% to 94%. Normal light and dim light conditions achieve high GPS accuracy of 94% and 92%, respectively. While there is a slight decrease in GPS accuracy in outdoor environments (91%), the system continues to perform reliably, ensuring that attendance is recorded only when employees are within authorized locations.

The system accuracy testing highlights the overall performance of the employee attendance system across various environmental conditions. The system consistently performs well in both face recognition and GPS validation, proving the effectiveness of the cast-as-a-service model at normal office lighting. However, in more complex conditions like night and outdoor locations the system has a little drop in accuracy, but it is normal with environmental factors involving light inconsistency API to change lighting sources at night as well GPS signals fragility. Despite this, the detection times remain within an efficient range, ensuring that attendance can be logged swiftly without significant delays, even under less-than-ideal conditions.

The low rates of FAR and FRR further underscore the system's reliability, providing a strong balance between security and accessibility. While the system performs well in standard conditions, these tests have also identified potential areas for future improvements, particularly in addressing the challenges posed by low-light and outdoor environments. Additionally, the GPS accuracy remained robust across most conditions, ensuring that location validation complements face recognition for an added layer of security in the attendance logging process. This testing also indicates that the system is capable of handling real-world usage, providing a smooth user experience while maintaining high standards of accuracy and security. The outcomes from these tests serve as a valuable reference for optimizing the system further to maintain consistency and reliability across a wider range of operational settings.

5. Conclusion

The development of the employee attendance system utilizing face recognition and GPS tracking has demonstrated its effectiveness in ensuring accurate and secure attendance logging. The system's performance, as evaluated through the system accuracy testing, shows consistently high accuracy in face recognition, particularly in normal lighting conditions, while maintaining satisfactory results in low-light and outdoor environments. Detection times remain efficient across all testing scenarios, ensuring real-time attendance logging with minimal delays. Additionally, the system exhibits low false acceptance and false rejection rates, ensuring robust security by preventing unauthorized access and minimizing errors in recognizing legitimate employees. The GPS validation feature further enhances the system's reliability by accurately tracking employee locations, ensuring attendance is logged only from authorized locations. Overall, the system provides an efficient and reliable solution for managing employee attendance, integrating advanced technologies to address common challenges in traditional attendance methods while offering room for future enhancements based on environmental factors and system scalability.

Disclosure statement
No potential conflict of interest was reported by the author(s).

Funding
This work was not supported by any funding.

ORCID
Narahari Vigraha Prasada – https://orcid.org/0009-0004-7954-455X

Ikrimach – https://orcid.org/0000-0003-2096-052X

References

Baig, S., Geetadhari, K., Noor, M. A., & Sonkar, A. (2022). Face recognition based attendance management system by using machine learning. *International Journal of Multidisciplinary Research and Growth Evaluation*, 1–4. https://doi.org/10.54660/anfo.2022.3.3.1

Charpignon, M.-L., Yuan, Y., Zhang, D., Amini, F., Yang, L., Jaffe, S., & Suri, S. (2023). Navigating the new normal: Examining coattendance in a hybrid work environment. *Proceedings of the National Academy of Sciences*, *120*(51). https://doi.org/10.1073/pnas.2310431120

Habu, R., Motade, S., Kukade, S., Gunale, K., & Nair, A. (2022). Smart face recognition based attendance system using ML algorithm. *2022 4th International Conference on Advances in Computing, Communication Control and Networking (ICAC3N)*, 527–532. https://doi.org/10.1109/ICAC3N56670.2022.10074166

Hasan, R., Islam, S., Rahman, Md. H., Saifuzzaman, Mohd., Shetu, S. F., & Moon, N. N. (2020). Implementation of low cost real-time attendance management system: A comparative study. *2020 8th International Conference on Reliability, Infocom Technologies and Optimization (Trends and Future Directions) (ICRITO)*, 1098–1101. https://doi.org/10.1109/ICRITO48877.2020.9197764

Jabez, J., Keerthanaa, V., Kaviya, V., & Gowri, S. (2020). An enhanced web based attendance application using global positioning system and face recognition. *Journal of Computational and Theoretical Nanoscience*, *17*(8), 3344–3348. https://doi.org/10.1166/jctn.2020.9183

Joshi, D., Patil, P., Singh, V., Vanjari, A., Shinde, T., & Giri, H. (2023). Face recognition based attendance system. *2023 5th Biennial International Conference on Nascent Technologies in Engineering (ICNTE)*, 1–6. https://doi.org/10.1109/ICNTE56631.2023.10146718

Khuran, A., Lohani, B. P., Bibhu, V., & Kushwaha, P. K. (2021). An AI integrated face detection system for biometric attendance management. *2021 2nd International Conference on Intelligent Engineering and Management (ICIEM)*, 29–33. https://doi.org/10.1109/ICIEM51511.2021.9445295

Kumar, A., Sharma, M., Gautam, S. P., Kumar, R., & Raj, S. (2020). Attendance management system using facial recognition. *2020 International Conference on Decision Aid*

Sciences and Application (DASA), 228–232. https://doi.org/10.1109/DASA51403.2020.9317104

Kumar, A., & Singh, D. (2023). Comprehensive approach of real time web-based face recognition system using Haar Cascade and LBPH algorithm. *2023 International Conference on Device Intelligence, Computing and Communication Technologies, (DICCT)*, 371–376. https://doi.org/10.1109/DICCT56244.2023.10110049

Lavanya, P., Lavanya Devi, G., & Srinivasa Rao, K. (2021). LBPH-based face recognition system for attendance management. In: Chowdary, P., Chakravarthy, V., Anguera, J., Satapathy, S., Bhateja, V. (eds) *Microelectronics, Electromagnetics and Telecommunications. Lecture Notes in Electrical Engineering*, vol 655. Springer, Singapore. https://doi.org/10.1007/978-981-15-3828-5_6

Liu, Y., Chen, L., Ou, Z., Chen, J., & Wu, J. (2020). A crowdsourcing based multi-modal attendance tracking system for smartphone users. *2020 International Symposium on Computer Engineering and Intelligent Communications (ISCEIC)*, 61–64. https://doi.org/10.1109/ISCEIC51027.2020.00021

Meden, B., Rot, P., Terhorst, P., Damer, N., Kuijper, A., Scheirer, W. J., Ross, A., Peer, P., & Struc, V. (2021). Privacy–enhancing face biometrics: A comprehensive survey. *IEEE Transactions on Information Forensics and Security*, *16*, 4147–4183. https://doi.org/10.1109/TIFS.2021.3096024

Menezes, T. (2021). Face recognition attendance system using raspberry pi. *International Journal for Research in Applied Science and Engineering Technology*, *9*(8), 1145–1149. https://doi.org/10.22214/ijraset.2021.37499

Mohan Katta, L. (2023). Face recognition attendance system using LBPH algorithm. *International Journal of Scientific Research*, 52–53. https://doi.org/10.36106/ijsr/3556592

Mukherjee, K., Manish, K. M. M., & Natrajan, G. (2022). Employee attendance system based on facial recognition. *International Journal of Health Sciences*, 5054–5069. https://doi.org/10.53730/ijhs.v6nS5.9736

Pabanaas, V., Singhal, S., Saxena, A., Chatterjee, J., & Mehra, A. (2023). Analysis of CPU utilization of a cross-platform web application for facial recognition based remote user tracking system. *2023 3rd International Conference on Intelligent Technologies (CONIT)*, 1–5. https://doi.org/10.1109/CONIT59222.2023.10205762

Pilania, U., & Singh, S. (2022). Implementation of image-based attendance system. *2022 3rd International Conference on Electronics and Sustainable Communication Systems (ICESC)*, 937–941. https://doi.org/10.1109/ICESC54411.2022.9885713

Pooja, G. (2023). Face recognition based attendance system. *International Journal for Research in Applied Science and Engineering Technology*, *11*(5), 5408–5412. https://doi.org/10.22214/ijraset.2023.52868

Priya, R. L., Nanda, S., Dandekar, M., Devnani, A., & Kadakoti, R. (2021). Face-recognition based attendance system using one-shot learning. *2021 12th International Conference on Computing Communication and Networking Technologies (ICCCNT)*, 01–07. https://doi.org/10.1109/ICCCNT51525.2021.9579899

Smitha, Pavithra S Hegde, & Afshin. (2020). Face recognition based attendance management system. *International Journal of Engineering Research and Technology*, *9*(05). https://doi.org/10.17577/IJERTV9IS050861

Sri Harish, J., Muthu Revanth, M. & Bharathi, B.J. (2021). Cloud-based attendance application using face recognition. *2021 5th International Conference on Trends in Electronics and Informatics (ICOEI)*, 881–890. https://doi.org/10.1109/ICOEI51242.2021.9453042

Srivastava, M., Kumar, A., Dixit, A., & Kumar, A. (2020). Real time attendance system using face recognition technique. *2020 International Conference on Power Electronics & IoT Applications in Renewable Energy and Its Control (PARC)*, 370–373. https://doi.org/10.1109/PARC49193.2020.236628

Tej Chinimilli, B., T., A., Kotturi, A., Reddy Kaipu, V., & Varma Mandapati, J. (2020). Face recognition based attendance system using Haar cascade and local binary pattern histogram algorithm. *2020 4th International Conference on Trends in Electronics and Informatics (ICOEI) (48184)*, 701–704. https://doi.org/10.1109/ICOEI48184.2020.9143046

Thomas, R. (2020). Real-time classroom attendance monitoring system based on face recognition. *International Journal of Information Systems and Computer Sciences*, *9*(3), 16–20. https://doi.org/10.30534/ijiscs/2020/02932020

Uddin, K. M. M., Chakraborty, A., Hadi, Md. A., Uddin, M. A., & Dey, S. K. (2021). Artificial intelligence based real-time attendance system using face recognition. *2021 5th*

International Conference on Electrical Engineering and Information Communication Technology (ICEEICT), 1–6. https://doi.org/10.1109/ICEEICT53905.2021.9667836

Wati, V., Kusrini, K., Al Fatta, H., & Kapoor, N. (2021). Security of facial biometric authentication for attendance system. *Multimedia Tools and Applications*, *80*(15), 23625–23646. https://doi.org/10.1007/s11042-020-10246-4

Yadav, A., Sharma, A., & Yadav, S. S. (2022). Attendance management system based on face recognition using Haar-Cascade. *2022 2nd International Conference on Advance Computing and Innovative Technologies in Engineering (ICACITE)*, 1972–1976. https://doi.org/10.1109/ICACITE53722.2022.9823613

Zhao, C., & Huang, X. (2020). Attendance system based on face recognition and GPS tracking and positioning. *2020 2nd International Conference on Applied Machine Learning (ICAML)*, 78–83. https://doi.org/10.1109/ICAML51583.2020.00024