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Biometric Smartphone Attendance System

Prof. Dr H R Divakar
Associate Professor
Department of CS&E
PESCE, Mandya, Karnataka

Kavana S, K P Renuka Prasad, Manoj Kumar S R, Lipika K
4PS22CS075 | 4PS22CS072 | 4PS22CS096 | 4PS22CS088
Department of CS&E
PESCE, Mandya, Karnataka

Abstract—The traditional attendance system used in educational institutions is often time-consuming, error-prone, and vulnerable to proxy attendance. Existing hardware-based attendance solutions such as RFID systems require additional infrastructure, maintenance cost, and dedicated devices, making them less flexible and expensive for large-scale deployment. To overcome these limitations, this paper presents a Biometric Smart Attendance System that combines biometric verification, AI-based face verification, and GPS location validation to ensure secure, accurate, and reliable attendance management without using dedicated hardware components. The proposed system uses multi-factor authentication to verify student identity before marking attendance. Face verification technology identifies and authenticates students, while biometric authentication provides an additional layer of security. GPS-based location verification ensures that attendance can only be marked when the student is physically present within the authorized classroom premises. The system is developed using React, TypeScript, FastAPI, Python, DeepFace, OpenCV, and Supabase. Test results show face verification accuracy of 96% under normal lighting and overall attendance accuracy of 95%.

Keywords: Smart Attendance System, Face Verification, Biometric Authentication, GPS Validation, AI-based Attendance, Proxy Prevention, Web-based Attendance System.

I. INTRODUCTION

Attendance management plays a vital role in educational institutions for monitoring student participation, maintaining discipline, and ensuring academic transparency. Traditional attendance methods such as manual roll calls consume valuable classroom time and are highly prone to human errors, data manipulation, and proxy attendance. Existing automated systems based on RFID cards or hardware devices require additional infrastructure, maintenance cost, and dedicated equipment, making them expensive and inflexible for institutions with large numbers of students.

With the rapid advancement of Artificial Intelligence, biometric technologies, and web-based applications, modern attendance systems can now provide secure and intelligent authentication mechanisms without relying on separate hardware devices. Technologies such as AI-based face verification, biometric authentication, and GPS location validation can be integrated to ensure that attendance is marked only by authorized students who are physically present inside the classroom premises.

The proposed Biometric Smart Attendance System is a web-based attendance management solution that integrates multiple verification techniques—biometric verification, AI-powered face verification, and GPS-based location validation—to eliminate proxy attendance and improve attendance accuracy. The system supports three user roles: Admin, Teacher, and Student. Teachers can manage classes, monitor attendance records, generate attendance reports, and export attendance data in Excel format. Administrators can manage users, approvals, and system activities through a centralized dashboard.

A. Problem Statement

The main objective is to provide a hardware-free, multi-factor attendance management system that prevents proxy attendance and supports real-time verification. The challenge is to integrate biometric authentication, face verification, and GPS-based geofencing in a unified web-based platform accessible from any standard smartphone without specialized equipment.

B. Objectives

The objectives of this work are to design a secure, automated attendance system using biometric, face, and GPS verification; eliminate dedicated RFID or fingerprint hardware; provide role-based dashboards; achieve high face

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verification accuracy; automate Excel-based reporting; and identify limitations for future improvement.

C. Scope of the Work

The scope is limited to web-based attendance management for educational institutions using WebAuthn biometrics, DeepFace face verification, and browser GPS geofencing. Mobile-native applications, offline synchronization, and ERP integration are outside the current scope.

II. LITERATURE SURVEY

Attendance management systems have evolved significantly from manual registers to digital and automated solutions. RFID-based attendance systems use radio-frequency cards to identify students quickly; however, RFID cards can be exchanged among students, making proxy attendance possible. Biometric systems using fingerprints improve security but require physical contact and specialized hardware devices [1].

Recent research has shown that facial recognition technology provides a more efficient and contactless attendance solution. Research by Sharma et al. (2022) demonstrated that AI-based attendance systems reduced attendance marking time by nearly 70% compared to manual methods. Deep learning models such as Haar Cascade, LBPH, and CNN-based recognition systems achieved high recognition accuracy in classroom environments [2][3].

Web-based attendance systems provide centralized access to attendance data for administrators, teachers, and students. Cloud-based systems enable real-time synchronization, remote access, and scalable deployment. Modern systems also integrate the Web Authentication API (WebAuthn) for passwordless biometric login, eliminating the need for dedicated fingerprint scanners [4][5].

Gaps identified in the literature include: reliance on manual verification, vulnerability of RFID to proxy attendance, dependency on expensive hardware, lack of real-time analytics, and absence of integrated GPS-based physical presence validation. The proposed system addresses all these limitations in a single hardware-free platform.

TABLE I: Comparison of Existing Approaches

Approach	Capability	Limitation
Manual Attendance	Simple roll call	Proxy-prone, time-consuming
RFID-based System	Fast card-based ID	Card sharing enables proxy
Fingerprint Biometric	Secure identification	Requires dedicated hardware
Face Recognition Only	Contactless verification	No location validation
Proposed System	Multi-factor, hw-free	Requires stable internet

III. PROPOSED SYSTEM

The proposed system is a complete, hardware-free attendance management platform with four major layers: a React-based presentation layer, a FastAPI application layer, a DeepFace and OpenCV AI verification layer, and a Supabase PostgreSQL database layer. Each layer can evolve independently, ensuring maintainability and scalability.

A. System Architecture

The architecture contains four major modules: the React frontend, the FastAPI backend, the DeepFace AI verification service hosted on Hugging Face Spaces, and the Supabase database. API-based communication between all layers ensures modularity. The frontend handles biometric, camera, and GPS data collection; the backend coordinates verification and database operations.

B. Attendance Marking Workflow

Step 1 – Session Verification: Student enters the unique class code. Step 2 – GPS Verification: Haversine distance to classroom computed; access allowed within 150 m. Step 3 – Biometric Verification: WebAuthn fingerprint prompt validated via hardware security. Step 4 – Face Verification: DeepFace extracts embedding and performs cosine similarity comparison. Step 5 – Attendance Storage: Verified attendance recorded in Supabase with logs.

C. Functional Requirements

The system must allow students to mark attendance through multi-factor verification, enable teachers to generate sessions and export Excel reports, and allow administrators to manage users and approve biometric registrations. The application must handle GPS failures, camera errors, and biometric mismatches gracefully.

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IV. METHODOLOGY

The methodology follows five stages: requirements definition, system design, AI integration and testing, module integration, and real-classroom evaluation. Data preprocessing uses OpenCV to detect, crop, resize, and normalize face images. Feature engineering produces DeepFace embedding vectors and Haversine-based GPS distances.

A. Data Preprocessing

Face images captured during student registration are preprocessed using OpenCV before embedding extraction. The pipeline detects the face region, crops, resizes, and normalizes pixel values. Images where no face is detected are rejected. The same preprocessing is applied during attendance marking for consistency.

B. Feature Engineering

The core feature is the DeepFace facial embedding vector. GPS coordinates are processed using the Haversine formula. Biometric authentication uses the WebAuthn API, producing a cryptographically signed assertion verified by the backend.

C. Model and Algorithm Selection

DeepFace wraps multiple pre-trained models including VGG-Face, Facenet, and ArcFace. Cosine similarity is used for embedding comparison. WebAuthn FIDO2 provides hardware-level biometric security. The Haversine formula provides accurate GPS distance at short ranges.

D. Evaluation Metrics

Performance is evaluated using face verification accuracy across lighting conditions, GPS validation success rate, biometric authentication response time, and overall attendance accuracy compared to manually verified ground truth.

V. IMPLEMENTATION

The implementation is divided into frontend, backend, and AI modules. The React and TypeScript frontend provides role-based dashboards and handles camera, GPS, and WebAuthn in the browser. The FastAPI backend exposes RESTful endpoints for all verification and reporting operations. Supabase provides the PostgreSQL database, real-time subscriptions, and authentication.

TABLE II: Technology Stack

Component	Technology	Purpose
Frontend	React + TypeScript	User interface
Build Tool	Vite	Build and bundling
Styling	Tailwind CSS	Responsive UI
Backend	FastAPI / Python	API and AI logic
Database	Supabase PostgreSQL	Data storage
Face Verification	DeepFace	Facial recognition
Image Processing	OpenCV	Face detection
Biometric Auth	WebAuthn API	Fingerprint auth
Vector Search	pgvector	Embedding storage
Excel Export	SheetJS (XLSX)	Report export
Frontend Deploy	Vercel	Frontend hosting
AI Backend	Hugging Face Spaces	AI service hosting

A. Algorithm

Step 1: Student enters class code. Step 2: GPS coordinates captured; Haversine distance computed and compared to 150 m threshold. Step 3: WebAuthn fingerprint prompt validated cryptographically. Step 4: Camera capture preprocessed; DeepFace embedding extracted and compared via pgvector cosine similarity. Step 5: All verifications pass → attendance recorded in Supabase with timestamp. Step 6: Teacher dashboard updates in real-time; Excel export available on demand.

TABLE III: Module Description

Module	Responsibility	Output
React Frontend	UI, GPS, camera, WebAuthn	Verification data
FastAPI Backend	Auth, session, attendance	API responses
DeepFace Service	Embedding & similarity	Similarity score

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Supabase DB	Storage & real-time sync	Persisted records

VI. RESULTS AND DISCUSSION

The experimental results demonstrate that the proposed multi-factor verification approach successfully prevents proxy attendance. Face verification achieved 96% accuracy under normal lighting. GPS geofencing blocked all attendance attempts from outside the 150 m radius. WebAuthn biometric authentication validated all registered students without external hardware.

Response times measured under classroom conditions: GPS validation 2–3 s, biometric authentication 2–4 s, face verification 3–5 s, and attendance submission under 2 s after all verifications passed. These are acceptable for practical deployment.

TABLE IV: System Performance Benchmarks

Feature	Avg. Response Time	Remarks
User Login	1–2 seconds	Fast authentication
GPS Validation	2–3 seconds	Depends on device GPS
Biometric Auth	2–4 seconds	WebAuthn based
Face Verification	3–5 seconds	Camera quality dependent
Attendance Submit	< 2 seconds	DB update successful
Excel Export	3–6 seconds	Successful XLSX generation

Face verification accuracy varied with lighting: 96% under normal, 91% under moderate, and 82% under low lighting. Multiple-face frames and unknown-user attempts were rejected in all test cases, confirming robust proxy prevention.

TABLE V: Face Verification Accuracy

Condition	Accuracy
Normal Lighting	96%
Moderate Lighting	91%
Low Lighting	82%
Multiple Faces	Rejected
Unknown User	Rejected

Comparison with traditional and RFID-based systems confirms the proposed system outperforms existing approaches in proxy prevention, hardware requirements, and feature completeness.

TABLE VI: Comparison with Existing Systems

Feature	Traditional	RFID	Proposed
Proxy Prevention	Low	Moderate	High
Hardware Required	No	Yes	No
Face Verification	No	No	Yes
GPS Validation	No	No	Yes
Biometric Auth	No	Limited	Yes
Excel Export	Manual	Partial	Automatic
Scalability	Low	Moderate	High

VII. VALIDATION METHODOLOGY

Validation used unit, integration, system, and user acceptance testing in real classrooms. Integration testing confirmed correct communication across all module pairs: Frontend↔Backend, Backend↔Database, Frontend↔Face Verification, GPS↔Attendance, and Biometric↔Auth.

Security testing confirmed that unauthorized access, duplicate attendance, session hijacking, and invalid biometric submissions were all blocked. Browser compatibility testing verified correct operation on Chrome, Firefox, Edge, and Safari.

VIII. LIMITATIONS

The current system has several limitations. Face verification accuracy degrades significantly under low lighting. GPS accuracy depends on device hardware and may fluctuate indoors. WebAuthn requires a compatible device and

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browser. Stable internet connectivity is required for real-time verification. Offline attendance recording and fallback mechanisms are not yet supported.

IX. CONCLUSION

This paper presented the Biometric Smart Attendance System, a secure, intelligent web-based solution integrating WebAuthn biometrics, DeepFace face verification, and GPS geofencing into a hardware-free platform. Testing demonstrated 96% face verification accuracy, 95% overall attendance accuracy, and successful proxy prevention across all test scenarios.

The system eliminates RFID hardware, reduces teacher workload through automated Excel reporting, and provides role-based dashboards. Future enhancements include mobile application development, AI-based absenteeism analytics, offline synchronization, and ERP integration.

X. FUTURE SCOPE

Future improvements include developing a native mobile application, integrating low-light face recognition models, adding AI-based absenteeism analytics dashboards, implementing offline attendance recording with synchronization, and integrating with existing institutional ERP and LMS systems. Cloud deployment with load balancing would support institution-wide scaling across multiple concurrent classes.

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