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Intelligent Vision-Based Classroom Attendance and Student Engagement Monitoring System

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ABSTARCT - The Advancement in computer vision and artificial intelligence technologies have enabled the development of intelligent systems capable of automating educational processes and enhancing classroom management. The conventional method of marking attendance is known to be time-consuming and vulnerable to proxy attendance; moreover, it only tracks whether the student is present in the classroom. The constant monitoring of the student's level of attentiveness becomes a subjective process in modern times when all classes take place in the virtual mode. Therefore, this paper introduces an Intelligent and efficient solution that combines attendance management and engagement analysis.

The proposed method uses facial recognition techniques based on facial embeddings and Euclidean distance matching to automatically identify registered students and record the attendance. Additionally, behavioural indicators including head pose analysis, eye gaze estimate, and drowsiness detection utilizing Eye Aspect Ratio (EAR) are used to track student attentiveness. To offer centralized access to attendance data, engagement analytics, and administrative features, a Flask-based web application is created. In order to make it easier to analyze student participation and attentiveness during class, the system also includes event logging and engagement score computation.

With an accuracy of 85.00%, experimental evaluation showed that the facial recognition module performed reliably. Teachers can learn more about student's presence and attentiveness by combining engagement monitoring and attendance management into a single framework. The suggested method facilitates data-driven decision-making in online learning environments and provides a workable and affordable alternative for intelligent classroom monitoring.

Keywords: Intelligent Classroom Systems, Face Recognition, Computer Vision, Student Attendance Management, Face Embeddings, Euclidean Distance Matching, Eye Aspect Ratio (EAR), Drowsiness Detection, Gaze Estimation, Head Pose Estimation, Student Engagement Monitoring, Educational Analytics.

I.INTRODUCTION

Attendance is a big sign of how involved, disciplined, and committed students are. Studies show that showing up regularly boosts grades, improves learning, and ramps up interaction in the classroom. For teachers, keeping track of who's here also helps spot students struggling because of too many absences. On top of that, having good attendance records aids the institute with decisions, meeting rules, and managing resources well. As educational environments continue to evolve, there is an increasing demand for reliable, efficient, and automated attendance management systems that can minimize manual effort while ensuring accuracy and

transparency. Maintaining attendance is an important way for all institutions to keep an eye on their student's performance. Each institution achieves this in a unique manner. Some of these institutions still employ outdated paper-based or file-based systems, while others have implemented biometric approaches for automatic attendance [1].

The traditional method of recording attendance is a time-consuming task in many educational institutions. These approaches pose a number of difficulties in contemporary educational settings, despite being easy to use and requiring little in the way of technology infrastructure. The procedure is also prone to human mistake, including data duplication, missed records, and inaccurate entries. The faculty's workload is further increased because they must call each student by name in order to record attendance, which could take up to few minutes of class time. Traditional attendance systems face another key issue that is students can cheat by marking attendance for others [2]. Also, keeping all those records is no small task; admins spend lots of time storing, finding, and making reports. Plus, paper logs might get damaged, lost, or even tampered with, putting data integrity at risk. With schools aiming for smarter, more efficient management, the limits of traditional methods show why we need automated and reliable tracking systems instead [2].

To tackle old attendance issues, schools are now using biometrics more. They use things like RFID, fingerprints, and iris scans. Facial recognition is popular too. It helps them track who's there and makes things way more precise. By allowing students to register their presence via RFID cards or tags, RFID-based solutions streamline attendance gathering and cut down on the time and effort needed for attendance management. These systems are still susceptible to proxy attendance, though, since students can share or exchange RFID cards, which makes it possible to record attendance for people who aren't there in person [3].By using distinctive biological traits, fingerprint and iris recognition technologies provide increased authentication accuracy and reduce proxy attendance [4][5]. However, these methods frequently entail direct user contact and call for specialized technology, which might limit scalability in big classroom settings, decrease convenience, and raise deployment costs [4][5].

Facial recognition is really taking off for managing attendance because it's non-intrusive and contactless. You don't need any special scans or physical touch, like with other biometrics. With face recognition, a system can spot you using just images or video while classes are going on, unobtrusively. These advantages have led researchers to increasingly explore facial recognition as an efficient, scalable, and user-friendly solution for automated attendance systems in educational environments [2].The quick development of computer vision and artificial intelligence technology has created new opportunities for smart classrooms that are data-driven and intelligent, replacing conventional educational settings. A crucial component of assessing teaching efficacy and enhancing learning is keeping an eye on student's attention during lectures, while traditional methods rely solely on teacher's subjective assessments, which is time-consuming and uneven in large classroom environments [6].

Even while attendance is a crucial measure of student involvement, being physically present in the classroom does not ensure that students are actively engaged in the learning process. During lectures, a student may be marked present yet still be disengaged, preoccupied, or inattentive. As a result, keeping an eye on students focus and involvement has grown in significance in contemporary learning settings. Academic performance and learning outcomes are strongly correlated with student engagement, which measures the degree of focus, attention, and interaction displayed during class activities [12]. To tackle these issues, researchers are now looking more into using computer vision to watch how students behave and stay engaged [6]. By tracking things like when someone blinks or looks away, we can learn a lot about their attention levels [7]. Because of this, there's a bigger push for smart systems that can track not just attendance, but also how involved students are in real time. This helps teachers get a clearer picture of how well their students are participating and learning in class.

Considering the increasing demand for advanced intelligent systems for monitoring classes, this research will focus on creating a vision-based web application which combines automated attendance management and real-time assessment of student engagement. For achieving this purpose, facial recognition algorithms will be used to determine who the student is and record the attendance, while face landmarks analysis will be used to estimate the engagement level by assessing behavioural characteristics such as drowsiness, direction of gaze, and head pose. Furthermore, the proposed system will also store data related to attendance and engagement and provide useful information that can help instructors monitor how engaged their students are and how well they behave inside the classroom.

II.LITERATURE SURVEY

A thorough investigation of literature is crucial to get acquainted with the existing situation regarding automated attendance tracking and student engagement monitoring techniques. During years, several methods were proposed as solutions to the problems that exist when manual attendance tracking is carried out along with assessing student attentiveness. These technologies range from RFID and biometric authentication systems to advanced computer vision and deep learning-based approaches. In this part, selected relevant studies in the areas of attendance automation, face recognition, student engagement analysis, and classroom monitoring will be analyzed.

Traditional attendance management systems commonly use manual paper-and-pen methods in educational institutions. Although widespread, these methods are time-consuming, error-prone, and inefficient for managing attendance records. They require an additional data-entry step to generate reports, increasing administrative workload. Furthermore, these systems are vulnerable to unauthorized practices like proxy attendance, compromising record accuracy and integrity. As a result, conventional attendance methods are considered inefficient and insecure. To address these issues, many researchers have developed various attendance management frameworks to enhance efficiency, accuracy, and security [8].

In [3] the authors developed an Attendance Management System using RFID and web-based information service platforms for educational institutes. They used RFID cards and programmable logic control to manage and track student attendance. Apart from managing the attendance of students, the proposed system offered a variety of other services such as providing students with their grades, class timings, lecture timings, classroom information, and notifications by the teachers. The researchers stated that there were remarkable reductions in the documentation process and increased efficiency in attendance management. However, because the system uses RFID cards to identify users, attendance verification depends on card possession rather than direct biometric authentication, which could lead to opportunities for proxy attendance.

As an alternative to RFID-based attendance systems, biometric technologies such as fingerprint recognition have been investigated to improve user authentication and attendance accuracy. For example, in [4] the authors provided a detailed overview of fingerprint-based attendance systems and examined the application of such systems for overcoming the drawbacks of conventional attendance systems. According to the analysis conducted by the authors, fingerprints provide a robust and effective method for accurate identification, thus ensuring accurate attendance tracking and minimizing any risks related to unauthentic attendance records. However, fingerprints can be applied for attendance tracking and management due to the uniqueness of fingerprint patterns only through specialized scanners, thus entailing increased costs and complexity.

Contactless authentication through iris recognition has recently received much consideration as a means of achieving both reliability and precision. In the research described in [5], an attendance management system based on iris recognition was designed for educational organizations with specific focus on mitigating the impact of the pandemic. The framework relied on machine learning techniques to perform iris detection and recognition, incorporating functionality like student enrollment, identification, attendance recording, examination qualification assessment, and maintenance of defaulter database. The non-contact nature of the system ensured that the guidelines associated with the pandemic were adhered to while automating the attendance process. Experimental results indicated higher accuracy as compared to other iris recognition methods.

Although fingerprint and iris-based recognition systems have been found to be more accurate in terms of verifying the identity of an individual, their use of sophisticated biometric scanners may result in increased costs of implementing such systems. Due to these reasons, there is a growing tendency among research scholars to develop facial recognition systems as a cost-effective way of managing attendance at educational institutions. These facial recognition systems recognize users on the basis of features on their face detected by cameras.

A facial recognition-based attendance tracking system for educational institutions utilizing Python and OpenCV was proposed by Dr. V. Suresh et al. in [9]. In order to automatically identify people and track

attendance, the system used facial recognition techniques and kept a database of registered student faces. Electronically maintained attendance records were distributed to faculty members via automated reporting systems. The study showed that using facial recognition technology increased the efficiency of attendance management, decreased manual intervention, and improved attendance accuracy. However, the suggested solution lacked functionality to track student's interest or concentration during class activities and instead concentrated on automating attendance.

Khawla Alhanaee et al. presented a deep transfer learning-based facial recognition smart attendance system in [10]. Three pre-trained convolutional neural network (CNN) models - SqueezeNet, GoogleNet, and AlexNet—were used in the study to monitor attendance through facial recognition. Transfer learning was used to shorten training times while increasing recognition performance. The efficacy of deep learning approaches for automatic attendance systems was proved by experimental findings, which showed high validation accuracies of 98.33%, 93.33%, and 100% for SqueezeNet, GoogleNet, and AlexNet, respectively. The authors came to the conclusion that the suggested method might be used for access control and attendance management applications in a variety of settings, such as businesses, colleges, and schools.

Attendance alone is insufficient to assess student involvement and learning behavioural, despite the fact that facial recognition-based attendance systems have greatly increased the automation and accuracy of attendance management. Even while a student is physically present in the classroom, they may still be disconnected from the learning process, preoccupied, or inattentive. As a result, academics have been investigating computer vision and artificial intelligence methods for tracking student involvement and attentiveness using behavioural indicators including head posture, eye movements, gaze direction, and facial expressions. These methods give teachers more information about student participation than just attendance statistics.

A real-time drowsiness detection system based on Eye Aspect Ratio (EAR) and facial landmark detection algorithms was proposed by the authors in [11]. The system identified 68 face landmarks and extracted eye-region information for tracking eye closure using Dlib's pre-trained facial landmark predictor. The technology was able to identify indicators of drowsiness in real time from live video broadcasts by computing the EAR and comparing it to a predetermined threshold. According to experimental findings, the suggested method accomplished accurate drowsiness detection with minimal processing cost, making it appropriate for real-time applications. The study highlighted the usefulness of EAR and face cues as markers of human attention. The system did not take into account other behavioural cues that can offer a more thorough evaluation of student participation, such as gaze direction, head movements, or facial expressions, because its primary purpose was to detect tiredness.

The authors of [12] suggested a real-time student engagement detection system for online learning environments that makes use of head movement analysis, eye tracking, and emotion analysis. Without the need for specialized gear, the system assessed student interest and focus using data obtained from a typical camera. The suggested methodology created a concentration index and divided student participation into three groups: "very engaged," "nominally engaged," and "not engaged at all" by integrating facial emotion recognition, eye movement patterns, and head posture data. The system's capacity to precisely detect different levels of student participation in real-time learning settings was shown by experimental results. Additionally, the study found a good association between students' academic achievement and their concentration indicators, demonstrating the usefulness of behavioural analysis in evaluating the efficacy of learning.

The authors of [6] introduced EduVision, a real-time classroom engagement monitoring system that measures student attentiveness objectively using MediaPipe Face Mesh and OpenCV. In order to calculate an attention score for every student, the system identified 468 face landmarks and used geometric head pose analysis based on yaw, pitch, and facial visibility. Students were categorized as attentive or inattentive using a weighted grading system, and engagement information was captured using timestamped logs for additional examination. The suggested framework was implemented using a Streamlit online dashboard and an OpenCV-based monitoring interface, offering an affordable and inconspicuous solution that just needed a regular webcam. The study highlighted the potential of computer vision technology in smart classroom environments and showed how effective head posture estimation is for real-time engagement monitoring.

To overcome the drawbacks of conventional attendance management systems, the authors of [13] suggested an AI-based smart attendance and behavioural monitoring system that combined real-time behavioural analysis with facial recognition. The methodology used a convolutional neural network to categorize engagement-related emotional states, FaceNet to create 128-dimensional facial embeddings, and Multi-task Cascaded Convolutional Networks (MTCNN) for face detection. To enable analytical reporting and real-time monitoring, a Flask-based online dashboard was created. The results of the experimental evaluation showed an accuracy of 96.8% for attendance recognition and almost 90% for engagement-related emotion detection. The study emphasized the advantages of integrating behavioural analytics with attendance management to enhance classroom productivity and enable data-driven educational interventions. However, low lighting and partial facial occlusions caused the suggested system's performance to deteriorate because it mostly depended on emotion identification for involvement assessment. Concerns about ongoing behavioural monitoring and implementation expenses were also noted as obstacles to widespread deployment.

According to the literature review, significant advancements have been made in the fields of student engagement tracking and automated attendance management. To increase the effectiveness and precision of attendance recording, previous research has suggested RFID, fingerprint, iris and facial recognition-based systems. Similar to this, a number of academics have investigated the use of behavioural indicators such eye closure, facial expressions, gaze direction, head movements, and emotion analysis in the measurement of student engagement. The majority of current solutions concentrate on a small number of engagement indicators and offer limited analytical capabilities, despite a few recent studies attempting to combine behavioural monitoring and attendance management.

Additionally, while engagement monitoring systems frequently function independently without establishing student identity or keeping track of attendance, many attendance systems are primarily meant to record student presence. There are currently few comprehensive frameworks that can integrate facial recognition-based attendance management with other engagement indicators, including head pose analysis, gaze estimation, and tiredness detection. Furthermore, there are currently not many web-based tools that offer educators engagement and attendance metrics.

This paper suggests an Intelligent System that combines real-time student engagement analysis with facial recognition-based attendance management in order to overcome these drawbacks. In addition to using eye aspect ratio (EAR), gaze estimation, and head pose analysis to assess student attentiveness, the suggested system uses facial recognition for automatic attendance tracking. Additionally, a web-based dashboard is created to offer analytical data, engagement metrics, and attendance records, giving teachers a thorough grasp of student participation and learning behavioural in both real-world and virtual learning contexts.

III.METHODOLOGY

The approach used to create the suggested Intelligent Vision-Based Classroom Monitoring System is described in this chapter. The suggested framework combines computer vision-based real-time student engagement analysis with facial recognition-based attendance management. Face detection and recognition, attendance management, behavioural cue analysis, engagement monitoring, data logging, and analytics visualization are some of the associated modules that make up the system. Students are identified, their level of attention is evaluated, and attendance and engagement reports are produced by processing live video streams that are taken by a camera. The technology facilitates intelligent classroom monitoring in both conventional classroom settings and online learning contexts by integrating behavioural analysis and attendance verification into a single framework.

A. Face Detection and Recognition

The face detection and recognition module detects the registered students and automatically marks the attendance in the class room. This module uses methods of computer vision and facial recognition to analyze live frames of video through a webcam interface. The captured frames are subjected to preprocessing operations for initially processing. It is to improve the efficiency of the facial feature extraction and recognition.

- **Image Acquisition and Preprocessing**

By using a webcam to capture real-time video frames, the system can be used in both traditional classroom settings and online learning situations where students can engage virtually. In order to lower computational complexity and increase the effectiveness of feature extraction, the collected colour frames are transformed into grayscale images. While preserving real-time speed, this preprocessing stage makes it easier to identify facial features.

- **HOG-Based Face Detection**

The Histogram of Oriented Gradients (HOG) method is used to recognize faces [14]. To detect facial regions in an image, HOG examines local gradient orientations and edge patterns. The technique is appropriate for real-time classroom monitoring applications because it offers precise and efficient face localization with minimal computing overhead.

- **Facial Embedding Generation**

Following the detection of a face, the facial region is converted into a 128-dimensional facial embedding that depicts each person's distinct traits. A deep metric learning technique based on triplet loss is used in the embedding generation process to guarantee that embeddings from the same person are placed closer together in the feature space while embeddings from different people are kept well apart[15].

- **Euclidean Distance-Based Face Recognition**

The extracted face embeddings are matched with that of enrolled faces using Euclidean distance similarity matching method.

The threshold set for identifying the individual is 0.5. If the distance measured is found to be lesser than the set threshold, the face will be identified as one of the enrolled students, and attendance process is completed.

B. Attendance Management

- **Student Registration**

The student registration module. Stores pictures of students faces for future identification and attendance verification. During registration the pictures are processed using OpenCV and Dlib to create facial codes, which are stored in the database for later recognition.

- **Automated Attendance Verification**

Facial recognition is used by the attendance system to automatically authenticate student identity based on the feed received from webcams. Facial embeddings that are created are then compared with the embeddings stored in the system, and attendance is recorded accordingly.

- **Attendance Database Logging**

Attendance records with student details, the date, and the time are automatically saved in the database after a successful identification verification. The administration dashboard provides access to these records for the purposes of monitoring, creating reports, and managing attendance.

C. Behavioural Cue Analysis

- **Drowsiness Detection**

The level of drowsiness among the students is determined using the Eye Aspect Ratio (EAR)[7]. The EAR is obtained from the measurements derived from the facial features within the eye area. The equation for EAR is defined as follows:

$$\text{EAR} = \frac{||p2 - p6|| + ||p3 - p5||}{2(||p1 - p4||)}$$

Here, p1, p2, p3, p4, p5, and p6 are the coordinates of the eye landmarks. The ratio of the eye's height to its width is effectively captured by this formula [11].

To detect eye closure, the threshold of 0.23 is used. If the EAR falls below the threshold for more than 2 consecutive seconds, then the student is declared to be drowsy. Else, the student is considered alert.

- **Head pose Estimation**

OpenCV-based posture estimation methods and Dlib's 68-point facial landmark detector are used to estimate head pose [16]. The orientation of the head in three dimensions is estimated using facial markers that correlate to the nose, eyes, chin, and mouth. Looking Left, Looking Right, Looking Up, Looking Down, and Looking Forward are some of the categories into which the system divides head orientation. During class activities, head posture is a crucial measure of students' concentration.

- **Eye Gaze Estimation**

By examining eye movement patterns, the eye gaze estimation module assesses students' level of attentiveness. Dlib's face landmark detector is used to extract eye areas, which are then processed using OpenCV image processing methods. The ratio of pixel intensities within the thresholded eye region is used to assess the gaze direction. For classification, the average gaze ratio from both eyes is utilized. Pupils are deemed attentive if their gaze ratios fall between 0.8 and 1.6; values outside of this range suggest possible distraction.

- **Engagement Analysis**

The combined study of head posture, gaze direction, and sleepiness status is used to gauge student interest. In order to assess students' levels of attentiveness during class, several behavioural markers are regularly observed. The approach offers a more thorough evaluation of student participation than attendance data alone by incorporating a variety of engagement markers.

D. Data Logging and Engagement Analytics

- **Real-Time Data Logging**

The proposed system uses a custom module to log multimodal behavioural data in real time while monitoring virtual classes. The system employs a CSV-style logging system to document observations of students that include identity data gathered from facial recognition, time and date of the log, and behavioural data that includes a student’s level of focus, drowsiness, pose, computed engagement score, engagement level, and any behavioural events that were logged during the class. Organized and structured logging of data makes it easier to store and access behavioural data for future analysis.

- **Analytics Visualization**

A web-based dashboard created with Flask displays engagement metrics and attendance data. The dashboard supports data-driven decision-making in educational settings by allowing administrators and teachers to see attendance summaries, engagement statistics, behavioural trends, and session reports.

E. Performance Evaluation Metrics

Standard classification measures were used to assess the effectiveness of the suggested facial recognition attendance system. The assessment was conducted in a variety of classroom settings, including poor light, side posture variation, normal face orientation, and unknown face detection.
Based on these values, Accuracy, Precision, Recall, and F1-score were calculated to evaluate the performance and reliability of the proposed system.

Accuracy:

$$Accuracy = \frac{TP+TN}{TP + TN + FP + FN}$$

Precision:

$$Precision = \frac{TP}{(TP + FP)}$$

Recall:

$$Recall = \frac{TP}{(TP + FN)}$$

F1-Score:

$$\frac{2 \times Precision \times Recall}{Precision + Recall}$$

IV.IMPLEMENTATION

The implementation process of the proposed system comprises different modules, which take care of different tasks, such as managing data, making analytics, registration of the students, attendance tracking, engagement evaluation. The whole system was created using Python programming language, and the web interface was built using Flask framework.

A. Software and Development Environment

The Intelligent Vision-Based Classroom Attendance and Student Engagement Monitoring System suggested in this paper was created using Python because of its strong capabilities in computer vision, machine learning, and web application development. OpenCV was used to process images and handle live streaming of videos, while Dlib and the Face Recognition library were used to detect facial landmarks and generate facial encodings respectively. Flask was used to create the web interface and handle the communications between the front-end and back-end elements.

For the storage of student's data, attendance records, and observations related to engagement, Excel was used as the database management system. The creation of the web-based interface was performed using HTML, CSS, and JavaScript languages. Data analysis and report creation features were provided by means of Pandas and Matplotlib libraries. Testing of the suggested system was performed on a computer with a standard camera**.**

B. Student Registration and Dataset Preparation

The creation and upkeep of the facial database needed for attendance verification falls under the purview of the student registration module. Student's faces are photographed at registration using the webcam interface and linked to the relevant student data. Multiple facial samples are collected for each student to improve recognition performance under varying facial orientations and lighting conditions. Facial encodings are created from the processed photos and saved in the database for further identification. When verifying attendance, the generated facial encodings are utilized as the reference dataset.

C. Attendance Verification

This module is used to verify the attendance by processing real-time images using the webcam. When an image is taken from the video, the system processes that frame to identify any of the registered students. Once an identity match is successfully verified, attendance will be automatically recorded along with the date and timestamp. The database stores the attendance records, which are then made accessible for administrative inspection via the reporting dashboard.

D. Engagement Assessment

The engagement assessment module uses a variety of behavioural indicators taken from live video broadcasts to gauge how attentive students are. The module continually monitors student behavioural during the learning session and runs concurrently with attendance verification.

Three behavioural indicators are considered during engagement assessment:

- Eye activity analysis for drowsiness detection.
- Eye gaze tracking for determining visual attention.
- Head orientation monitoring for evaluating focus direction.

The student's level of participation is ascertained by combining the observations produced by these indicators. The generated data is captured and used to create analytics relating to engagement.

E. Session Monitoring and Data Logging

A system for continuous monitoring was established during each learning process to log information relating to attendance and participation. Student identities, attendance records, timestamps, instances of drowsiness, head orientation, gaze direction, and attention levels are all recorded by the system. Automatic logging of every data makes it easy to track student engagement in the future. The logging system is important when evaluating performances of the students and generating historic reports.

F. Analytics and Report Generation

To turn attendance and interaction data into insightful data, an analytics module was created. The module creates engagement statistics, student-specific participation reports, and attendance summaries by processing saved data. Charts and graphs are examples of visual representations that are used to enhance the interpretation of gathered data. These analytics let teachers spot patterns in attendance, keep an eye on student's focus, and assess classroom engagement over time.

G. Web Application Development

The proposed system was implemented as an online application by using the Flask framework. The online interface provides centralized access to features for tracking engagement, attendance management and student registration.

The application consists of the following user facing components:

- Registration Interface: Collects and stores student facial data for student enrolment and creation of facial datasets.
- Punch Attendance Interface: Students punch their attendance with real time facial verification. Each attendance record is automatically saved with the date and time.
- Monitoring Interface: Shows live webcam feeds and constantly monitors student engagement by analyzing behavioural cues and attention during the class.
- Database Management Interface- Provides management with details of the registered students, attendance and engagement. The interface enables the administrator to access the entire database system.
- Student Engagement Dashboard- Shows visualization of attendance data, engagement indicators, and behaviour through graphical representations. The dashboard facilitates monitoring of student engagement and attendance by teachers.

Because of its web-based architecture, the system is appropriate for both online learning environments and traditional classroom settings.

H. Testing and Performance Evaluation

In relation to the assessment of the performance of the face recognition system, testing of the system was done in different classes according to the available lighting and placement of the faces. The accuracy of the system was measured using such performance metrics as accuracy, precision, recall, and F1-score. From the results, it can be seen that the face recognition system is quite effective in creating automated attendance systems and identifying the students.

V.RESULTS AND DISCUSSION

Experimental results of the system proposed in this research are discussed in this section. The efficiency of the face recognition system was evaluated by considering the standard criteria for classifications while the operation of the engagement system was analyzed in real time. The following results have shown the efficiency of the proposed system regarding the automation of attendance monitoring as well as determining the level of a student's attention during online learning.

A. Face Recognition Performance Evaluation

For testing purposes, the face recognition algorithm was run on 100 test cases consisting of both recognized and unregistered facial images. For testing purposes, various conditions were used including changing the illumination of the facial image, changing its position, and detecting an unrecognized face.

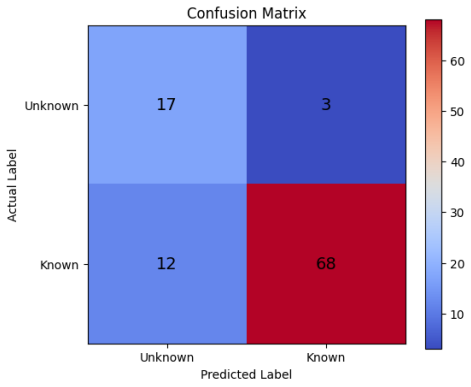

Fig.1 Confusion Matrix for Face Recognition Model

The confusion matrix shows that the system correctly identified 68 registered students and correctly rejected 17 unknown individuals. Misclassifications were primarily observed under challenging lighting conditions and facial pose variations.

Based on the confusion matrix, Accuracy, Precision, Recall, and F1-Score were computed. The obtained performance metrics are presented below.

Table 1 Performance Metrics

Metric	Value (%)
Accuracy	85.00
Precision	95.77
Recall	85.00
F1-Score	90.06

B. Attendance Management Results

The attendance module enabled us to automate attendance using facial recognition. After detecting a registered student's face, the attendance was automatically entered into the system, along with the date and time of attendance. This data about the attendance was then saved in the database and could be accessed via the administrator's dashboard for further use.

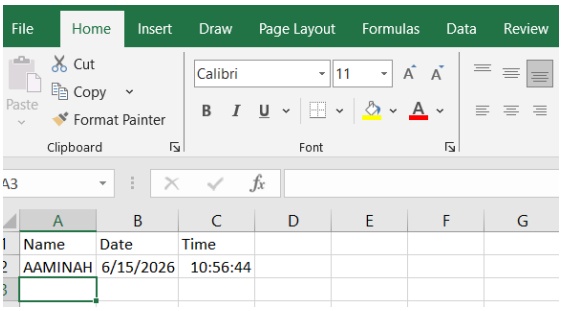

Fig.2. Sample Attendance Records

C. Student Engagement Monitoring Results

The proposed system continuously monitored the attentiveness of students through the use of a combination of drowsiness detection, eye gaze estimation, and head pose estimation. All three behavioural patterns were processed concurrently using input from webcam feeds to measure their engagement levels.

Data collected from the detected behavioural patterns was stored for evaluation purposes. An Excel report was created to document the detected behavioural patterns, including drowsiness, gaze estimation, and head pose estimation throughout the process.

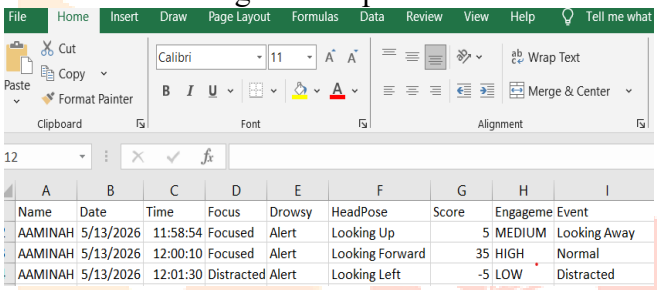

Fig.3. Sample behavioural observations and engagement data recorded

D. Web application Interface

An attendance management and engagement monitoring tool was created using the Flask framework to enable centralized access to attendance management and engagement monitoring, among other features. The web application allows the student to register, authenticate attendance, manage attendance records, and display engagement analytics through an easy-to-use interface. The efficient running of the web application highlights the viability of the proposed system.

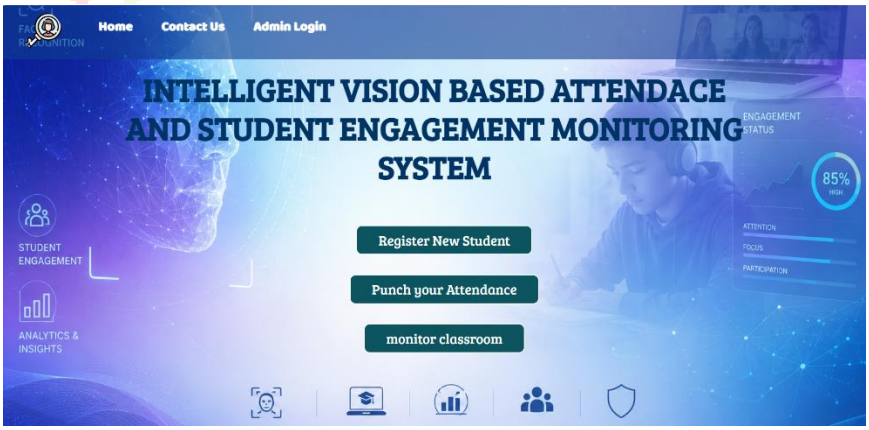

Fig.4. Web Interface

E. Dashboard and Analytics Results

To offer centralized access to attendance records and engagement analytics, a Flask-based dashboard was created. Through graphical and tabular visualizations, the dashboard presented attendance summaries, engagement statistics, and behavioural observations. The dashboard can help the teachers to view changes in engagement levels as well as monitor the participation of students.

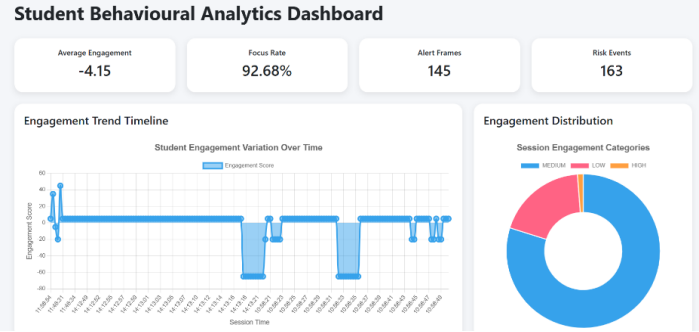

Fig. 5. Student Engagement Dashboard

F. Discussion

The experimental results show that the proposed model works effectively in integrating attendance authentication and monitoring of students' engagement using a single platform. Identification with the face recognition model worked successfully, and the engagement monitoring component managed to analyze engagement through eye gaze tracking, drowsiness detection, and head orientation tracking. While traditional attendance monitoring systems only consider the presence of students, the proposed model helps gain insights about learning behavioural and participation in classes.

Even though the system performed satisfactorily, there are still few constraints. Significant position alterations, facial occlusions, and dim lighting can have an impact on the accuracy of face recognition. Similarly, when facial characteristics are partially hidden, engagement assessment may be less successful because it depends on the presence of facial landmarks inside the webcam broadcast. Despite these drawbacks, the findings show that the suggested method is a workable and affordable option for intelligent classroom monitoring in virtual learning settings.

VI. CONCLUSION AND FUTURE WORK

A. Conclusion

The present paper described a System which aimed at automating attendance management along with monitoring students' attentiveness during learning processes. This work introduced a system that included face recognition, attendance verification, and behavioral analysis through drowsiness detection, eye gaze estimation, and head pose tracking algorithms.

The system also had a web-based application made with the Flask web framework which facilitated access to attendance data, students' engagement analytics, and administration capabilities. Results showed that the face recognition algorithm performed well in recognizing faces as indicated by the obtained recognition accuracy of 85.0%. In addition, the system succeeded in automating attendance recording and minimizing the risk of proxy attendance. Finally, the proposed engagement monitoring algorithm helped analyze students' attentiveness efficiently through combining different behaviors.

Thus, providing attendance management, engagement monitoring, and analytics visualization on one website could be viewed as an efficient and economical way to track student engagement. Contrary to traditional attendance systems that only indicate whether a student is present in class or not, the proposed System provided additional information on learning behavior.

B. Future Work

Possible future improvements can include making the facial recognition module more reliable and accurate by implementing even more advanced face recognition techniques based on deep learning. Moreover, the engagement monitoring technique itself can be improved by taking into account more engagement parameters, which include detecting the behavioral patterns of the students and facial emotion recognition. As for the engagement module, there is also room for improvement, as it is necessary to make it capable of creating more extensive engagement reports and providing learning analytics.

Another area for possible improvement is the use of Learning Management Systems, through which the entire process of attendance tracking and engagement statistics collection would be made much easier and more effective, since all the information could be centralized. Cloud-based solution can also be implemented in order to support scalability and efficient data management.

All of these enhancements will make the proposed approach even more applicable as an intelligent classroom monitoring and educational analytics solution.

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