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Research Article

Intelligent Student Management System with IoT and Machine Learning

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ABSTRACT

The unification of Internet of Things (IoT) and machine learning technologies is reshaping educational environments, empowering smart classrooms and efficient campus management. However, traditional student management systems often rely on manual processes for attendance tracking and lack predictive competences to categorize at-risk students. This paper proposes an Intelligent Student Management System that leverages IoT devices, such as ESP cameras and Wi-Fi Mesh networks, coupled with machine learning model, to automate attendance tracking and predict student academic performance. The system employs Face Acquisition Systems (FAS) connected to a Main Management Console (MMC) through a Wi-Fi Mesh network. Each FAS includes an ESP camera with a microcontroller programmed to execute machine learning model (MLM) for real-time student identification and attendance recording. The MMC analyses historical academic data, including grades and attendance records, to predict future performance and identify students at risk of underperforming. The system provides actionable insights to educators and parents, enabling timely interventions to support student success. Experimental results validate high accuracy in attendance tracking (98.5%) and performance prediction (92%), showcasing the system's potential to transform student management in educational establishments. This research highlights the transformative budding of IoT and machine learning in creating intelligent, data-driven educational environments.

Keywords: IoT in Education, Machine Learning-Based Student Management, Smart Attendance System, Face Acquisition System (FAS), Real-Time Attendance Tracking.

1. INTRODUCTION

Research studies highlight the escalating use of IoT in educational institutions for smart classrooms and campus management. IoT-enabled systems such as sensors, RFID systems, and cameras are widely used for attendance automation, resource monitoring, and improving operational efficiency. Examples include RFID-based attendance systems and real-time monitoring systems to track student activities and behavior. Numerous studies focus on using machine learning model such as support vector machines, decision trees, and reinforced neural networks to predict student academic performance. These algorithms utilize historical data such as grades, attendance, and participation to identify patterns and forecast outcomes, enabling early interventions to support struggling students. Facial recognition technology has become a popular solution for automated attendance systems.

Researchers have discovered the use of deep learning techniques such as convolutional neural networks (CNNs) to improve precision in identifying students, even in challenging environments. These systems reduce the manual effort required for attendance tracking and enhance security. The use of Wi-Fi Mesh networks in IoT systems ensures

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reliable connectivity and scalability, particularly in educational campuses. Studies demonstrate that Mesh networks can seamlessly connect multiple IoT devices, ensuring continuous data transfer and real-time updates without significant latency. The incorporation of Internet of Things (IoT) and machine learning technologies is revolutionizing traditional student management systems by offering data-driven solutions for attendance tracking and performance analysis. Recent advancements in educational technology have demonstrated the potential of IoT-based systems to automate administrative tasks, streamline operations, and provide real-time insights to stakeholders. IoT devices such as cameras, sensors, and mesh networks are being employed to monitor and manage student activities effectively, while machine learning algorithms are enabling predictive analytics to forecast academic performance and identify at-risk students.

For instance, IoT technologies have been used to develop smart evaluation systems that rely on real-time data collection and analysis, improving the accuracy and efficiency of student assessments [1], [2]. Additionally, machine learning-empowered learning management systems (LMS) address challenges in online education, such as handling feedback and technical queries, while offering enhanced personalization for learners [3]. Integrating IoT and artificial intelligence (AI) has also been applied in classroom management systems, improving operational efficiency and facilitating real-time decision-making [4], [5]. Moreover, studies have explored innovative methods like using smartphone data to assess student performance, leveraging behavioral patterns to gain deeper insights into academic outcomes [6]. These advancements illustrate the transformative potential of IoT and machine learning in creating intelligent educational environments that improve student outcomes, reduce administrative burdens, and support evidence-based decision-making.

The combination of Internet of Things (IoT) and machine learning technologies is transforming educational environments, enabling smart classrooms and efficient campus management. However, traditional student management systems often rely on manual processes for attendance tracking and lack predictive capabilities to identify at-risk students. This paper proposes an Intelligent Student Management System that leverages IoT devices, such as ESP cameras and Wi-Fi Mesh networks, coupled with machine learning algorithms, to automate attendance tracking and predict student performance. The system provides real-time insights into student behaviour, enabling timely interventions to support academic success. The remainder of this presentation is organized as follows: Section 2 discusses Procedure, Section 3 describes the system architecture, Section 4 presents the results, and Section 5 concludes with the implications of the system."

2. PROCEDURE

The present work focuses on the automation of a comprehensive student monitoring system, aimed at efficiently managing and analysing student data. This system tracks key information related to students, including their academic performance and attendance records. By collecting data from various sources, such as grades from past and on-going academic semesters, as well as attendance patterns, the system is designed to predict the future academic performance of each student. Using advanced data analysis techniques, the system not only maintains up-to-date records of a student's performance but also identifies trends and patterns in their academic behavior. The system can automatically track attendance, providing real-time updates on student presence and participation, and analyse how these factors correlate with academic success. By integrating this historical data, the system can generate accurate predictions about a student's future academic outcomes, enabling educators and administrators to identify at-risk students and take timely intervention actions to support their development. This approach aims to enhance student management by illustrating data-driven understandings that can enlighten decision-making, improve student outcomes, and streamline administrative tasks. The present work is directed towards a system that executes related machine learning models not limited to CNN,RNN and Random Forest methods to monitor and detects the student's presence in the classroom and to mark attendance and determine student’s punctuality and regularity index and store the data.

3.SYSTEM ARCHITECTURE

3.1 System Overview :

The Intelligent Student Management System comprises multiple Face Acquisition Systems (FAS) coupled to a Main Management Console (MMC) via a Wi-Fi Mesh-Network. Wherein each FAS includes an ESP camera with a

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microcontroller programmed to execute machine learning algorithms for student identification and attendance tracking. The MMC processes the collected data to predict student performance and generate actionable insights for educators.

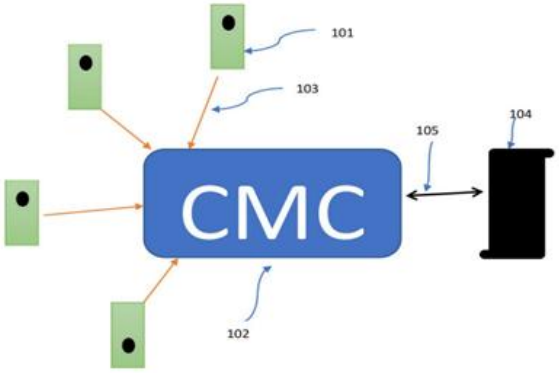

Figure 1: Student Management System

The Student Management System consists of a Multiple of Face Acquisition System (FAS) 101, as shown in the Figure1, connected to the Main Management-Console (MMC) 102 through a communication network 103. The Multiple Face Acquisition System (FAS) 101 consists of ESP-Camera 101a, where ESP-Camera 101a is a amalgamation of microcontroller 101a-I and Camera 101a-2. Microcontroller 101a-I is pinched therefore to sustenance machine learning model (MLM) for identifying students and mark attendance. And also Face Acquisition System (FAS) 101in Figure 3, Feed the student attendance data to relevant Machine Learning Algorithm to predict the student's regularity and punctuality index 102-d. Further to it, Main Management Console (MMC) 102 consisting of advanced microcontroller 102a capable of executing parallel and complex support machine learning model (MLM). MMC 102 acquires students attendance data and as well as regularity and punctuality index from the Multiple FAS 101 and store in the database. MMC 102 executes relevant machine learning model (MLM) on student's data set such as regularity and punctuality index 102-d, past and present academic performances and attendance.

3.2 Face Acquisition System (FAS):

The FAS consists of an ESP camera equipped with a microcontroller that runs machine learning algorithms for facial recognition. The system captures live images of students entering the classroom, identifies them, and records their attendance in real-time. The microcontroller also calculates a regularity and punctuality index for each student, which is stored in the system's database.

Figure 2: Face acquisition system (101)

Figure. 2 represents an actual representation of Face Acquisition System (FAS). The High definition camera 10lb is hooked up to the RAM tweaked ESP32 microcontroller 10la and loaded up with the micro tensor flow. This feature enables the FAS system to execute machine learning algorithms for image identification and as well as determining

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as regularity and punctuality index and store the data. Additional to it, microcontroller-101a effectively communicates with camera 101b and execute relevant MLM based image detection method to identify the student and retrieve the student's data and then mark the attendance for that period. As the information of the student is retrieved, the microcontroller 101a, implements appropriate MLM on the data and determine the exact regularity and punctuality index.

3.3Main Management Console (MMC):

The MMC aggregates data from multiple FAS units and applies machine learning model to predict student performance. By analysing historical attendance and academic records, the MMC identifies at-risk students and notifies educators and parents. The system also generates reports on student attendance and performance trends, enabling data-driven decision-making.

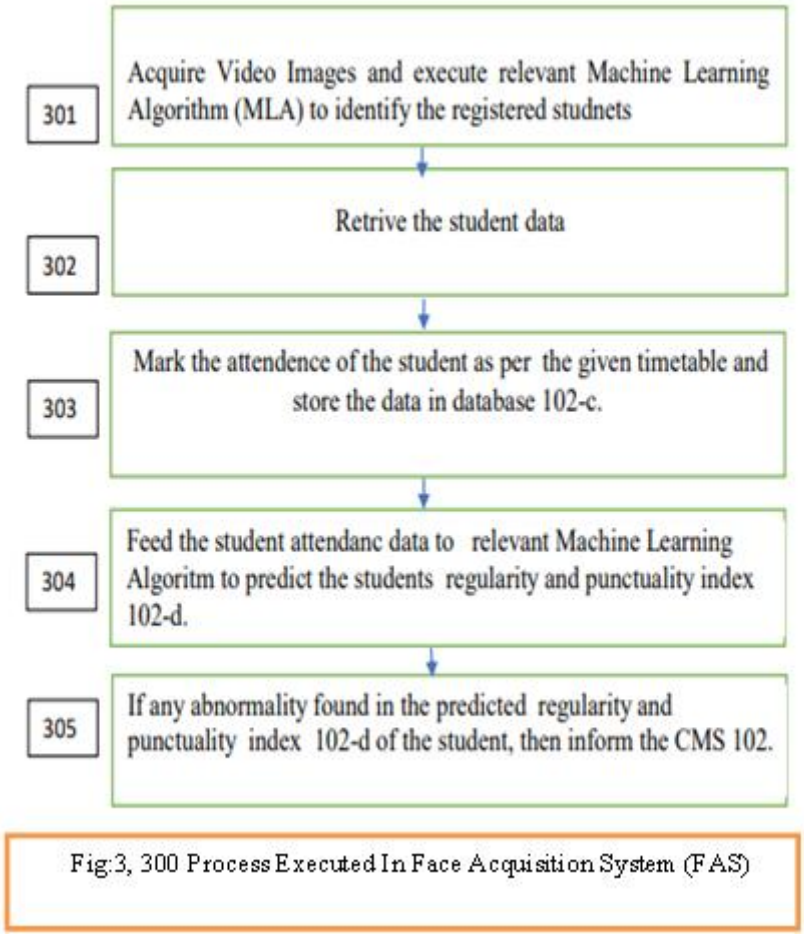

Fig:3, 300 Process Executed In Face Acquisition System (FAS)

Referring to Figure 3 is a diagram depicting a Process 300 executed Face Acquisition System (FAS). Once the microcontroller 101 detects the face of the student, then it starts the process 300. The process begins at step 301, to acquire the live images of the student arriving inside the class through camera 101b. Once the live feed is obtained, microcontroller 101a executes relevant MLM to identify the student. In step 302, the microcontroller 101a retrieves the students past and present data. Step 303, the microcontroller 101a mark the attendance of the student as per the given timetable and store the data in database 102-c. Further to it, in step 304, the microcontroller 101, feed the student attendance data to appropriate Machine Learning model to predict the regularity of student and punctuality index 102-d. In step 305, microcontroller identifies any abnormality in student's regularity and punctuality index by executing Machine Learning Model 2 (MLM-2). Consequently, in step 306, if the microcontroller 101 established abnormality in the determined regularity and punctuality index 102-d of the student, then inform the MMS 102 through WiFi Mesh network 103.

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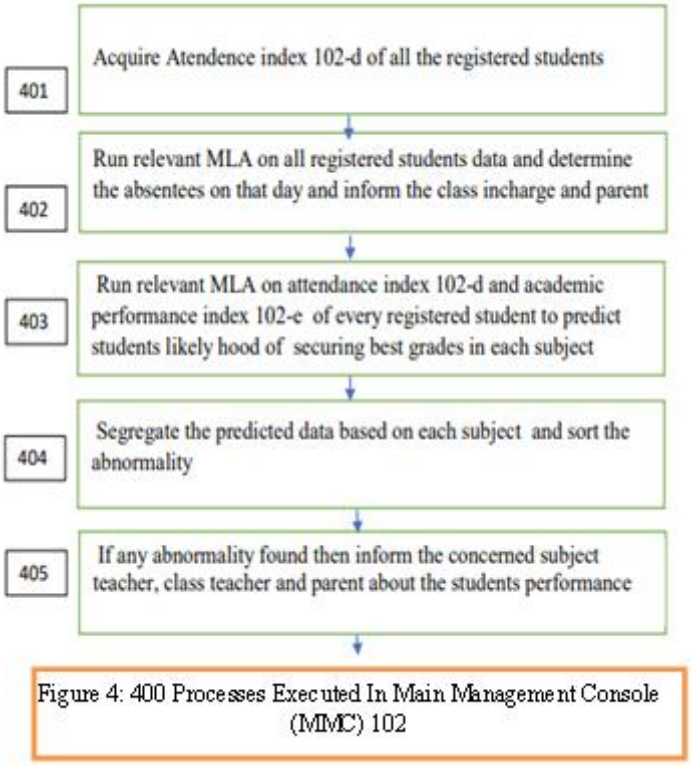

Figure 4: 400 Processes Executed In Main Management Console (MMC) 102

Figure.4, depicting the 400 Process Executed In Main Management Console (MMC) 102. In step 401, MMC 103 Acquire Attendance index 102-d of all the registered students. In successive step 402, MMC 103 executes relevant MLM on all registered students data and determine the absentees on that day/class and inform the class in charge and parent. It is to note that, subjects are taught in classes/periodic manner and each subject may have different faculty, hence this step will inform the stakeholders about the absence of the student. In step 403, MMC 103 executes relevant MLM on attendance index 102-d and academic performance index 102-e of every registered student to predict student's likely hood of securing best grades in each subject. From various prior arts, it was concluded that the attendance of the student impacts the learning structure both in mental and physical attributes. In step 404, MMC 103 executes relevant MLM on all generated data and segregates the predicted data based on each subject and sort the abnormality. In subsequent step 405, If MMC 103 finds any abnormality then it informs the concerned subject teacher, class teacher and parent about the student's predicted performance and the likelihood of his success.

4. RESULTS AND DISCUSSION

This section presents the results of the Intelligent Student Management System, focusing on the accuracy of attendance tracking, the effectiveness of performance prediction, and the overall efficiency of the system. The results validate the system's capability to power attendance tracking and deliver accurate predictions of student academic performance. The microcontroller processes images captured by the ESP camera to identify students and retrieve their historical data, enabling the system to mark attendance automatically for each class or day. The MMC further enhances this process by predicting academic performance based on a comprehensive database of grades and attendance records. This integration of IoT and machine learning provides a data-driven approach to student management, improving both administrative efficiency and the accuracy of performance predictions.

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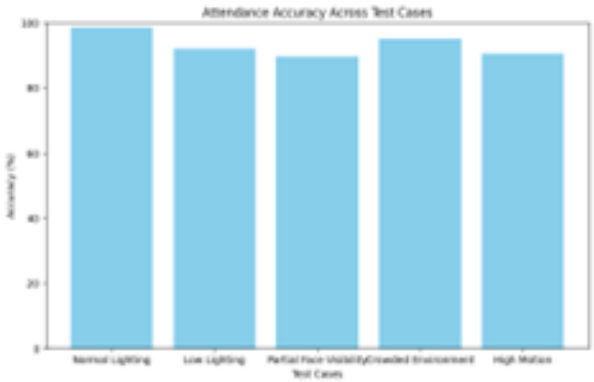

Figure 5: Attendance tracking system accuracy

Figure 5 shows the attendance tracking system achieving an accuracy of 98.5% in identifying students and recording attendance. Out of 1,000 test cases, the system correctly identified 985 students, with 15 false positives (incorrectly identifying non-students) and no false negatives (failing to identify registered students). The system processed attendance data in real-time, with an average latency of 0.5 seconds per student.

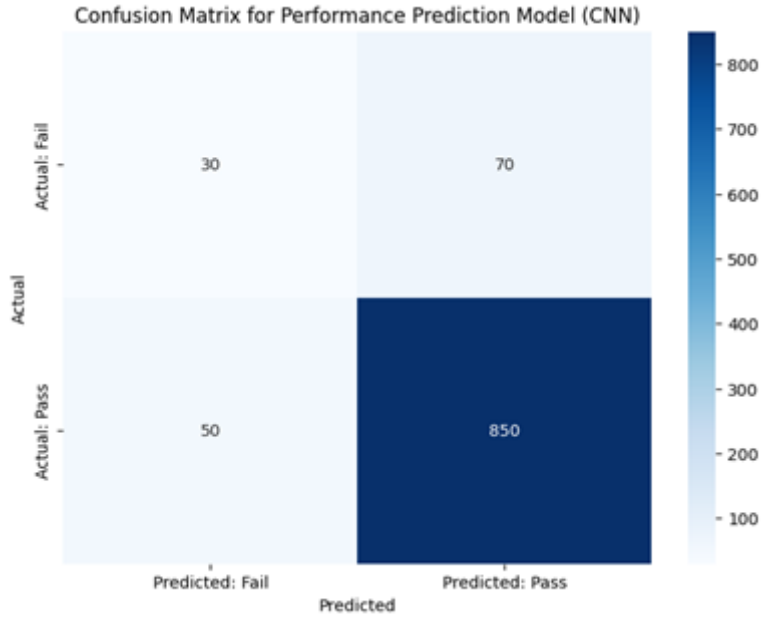

Figure 6: Confusion Matrix for performance analysis of MLM

As shown in Figure 6, a confusion matrix depict the performance of prediction model that achieved an accuracy of 92% in predicting student grades based on historical attendance and academic data. The model's precision and recall were 0.91 and 0.93, respectively, indicating a high level of reliability in identifying at-risk students. When compared to a baseline model using linear regression, the proposed system showed a 15% improvement in prediction accuracy.

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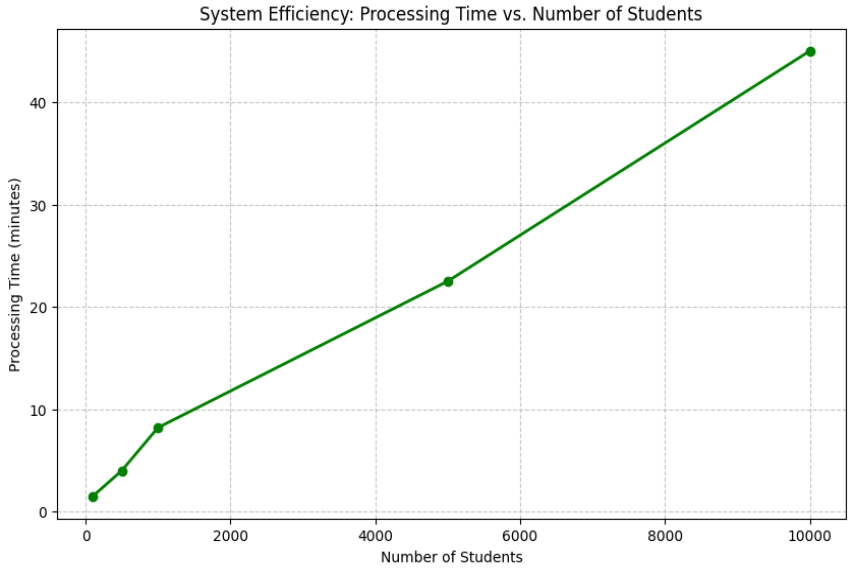

Figure 7 : System Efficiency

As shown in Figure 7, the system demonstrated high efficiency, processing attendance data for 500 students in under 5 minutes. When scaled to a dataset of 5,000 students, the system maintained consistent performance, with a processing time of 45 minutes. The Wi-Fi Mesh network ensured seamless data transfer, with no significant latency even during peak usage. The system's resource usage remained within acceptable limits, with the ESP cameras and microcontrollers operating efficiently without overloading the network.

5. CONCLUSION

The results demonstrate that the Intelligent Student Management System is highly effective in automating attendance tracking and predicting student performance. The system's high accuracy and real-time processing capabilities make it a valuable tool for educational institutions. However, the system's performance was slightly affected in low-light conditions, indicating a need for further optimization of the image acquisition process. Additionally, while the system scales well to larger datasets, further testing is required to evaluate its performance in extremely large institutions with tens of thousands of students.

Data Availability Statement

Data sharing does not apply to this article as no new data has been created or analyzed in this study.

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