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SMARTLAB AI-Driven Attendance and Power Automation System

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ABSTRACT

In today's educational institutions, managing class attendance and optimizing energy usage in classrooms are critical challenges. Traditional attendance tracking methods are time-consuming and prone to errors, while classrooms often remain powered on even when unoccupied, leading to energy wastage. **SmartLab** offers a dual-purpose solution, automating attendance and power management using **AI-driven facial recognition** and **real-time human detection with people counting**. The system employs the **Haar Cascade algorithm** for face detection and the **Local Binary Pattern Histogram (LBPH)** algorithm for face recognition to automate attendance marking. Furthermore, it integrates a **pre-trained frozen inference graph** for human detection, allowing for effective counting of individuals in the classroom. This solution addresses both attendance management and energy efficiency by turning off devices when classrooms are unoccupied. SmartLab significantly reduces manual effort in attendance tracking and promotes energy conservation through automated power management. Future enhancements may involve integrating deeper learning models to improve performance in crowded and low-light scenarios.

1. INTRODUCTION

In today's rapidly evolving educational landscape, institutions face increasing pressure to enhance operational efficiency and promote sustainability. One significant challenge in educational settings is managing student attendance, which is crucial for academic performance and institutional accountability. **Traditional attendance methods**, such as manual roll calls or paper-based systems, are not only time-consuming but also prone to human error and susceptible to proxy attendance, where one student marks attendance for another. These methods can lead to inaccuracies in attendance records, impacting both academic performance and the integrity of institutional reporting.

Simultaneously, educational institutions often grapple with **energy management issues**, as classrooms frequently remain lit and equipped with electronic devices even when unoccupied. This inefficiency contributes to unnecessary energy consumption, leading to increased operational costs and a larger carbon footprint. As awareness of sustainability grows, there is a pressing need for systems that can automate processes and optimize resource usage.
SmartLab addresses these dual challenges by integrating advanced technologies to streamline attendance management and enhance energy efficiency. The system leverages **AI-driven facial recognition** for real-time attendance tracking, providing a non-intrusive and efficient solution. By capturing students' faces in real-time, the system ensures accurate attendance marking while reducing administrative overhead.

In addition, **SmartLab** incorporates a **real-time human detection and counting** mechanism to monitor classroom occupancy. This feature automatically controls the power supply, turning off lights and devices when no individuals are detected, thereby promoting energy conservation. By combining these functionalities, **SmartLab** not only improves attendance accuracy but also contributes to sustainable practices within educational institutions. This paper aims to present the architecture, functionality, and benefits of the **SmartLab** system, providing insights into its potential applications in educational environments.

2. LITERATURE REVIEW

The **automation of attendance tracking** in educational settings has gained traction over recent years, driven by advancements in **computer vision** and **machine learning technologies**. A variety of methodologies have been explored, including **RFID-based systems**, **biometric fingerprint scanning**, and **iris recognition**. However, these systems often require physical contact or interaction, leading to inefficiencies, especially in large classrooms where the number of students can be overwhelming [1], [2]. Moreover, these approaches can be intrusive and may cause delays in the attendance process.
Facial recognition technology has emerged as a viable alternative, offering a non-intrusive method for attendance automation. Several studies have demonstrated the effectiveness of facial recognition systems in educational contexts. For instance, Alhanaee et al. [1] introduced a **facial recognition**

smart attendance system that leverages **deep learning techniques** to improve accuracy and reduce administrative burdens. Their work highlights the potential of facial recognition to enhance operational efficiency in attendance tracking.
Another significant contribution to the field is the work by Bussa et al. [2], which explores the application of **OpenCV** in developing a smart attendance system. This research underscores the robustness of facial recognition algorithms, particularly the **Haar Cascade** and **LBPH** methods, in accurately identifying students in real-time. The findings emphasize the importance of integrating such systems into educational environments to streamline attendance processes.

While facial recognition systems have shown great promise, challenges remain in specific scenarios, such as **crowded classrooms** and **low-light environments**. Research by Gupta et al. [4] indicates that overlapping individuals in crowded settings can complicate accurate detection and counting, leading to potential inaccuracies in attendance records. Additionally, environmental factors, such as poor lighting, can adversely affect recognition performance, as highlighted by Nandhini et al. [5]. They suggest that improved camera technology and enhanced training datasets can mitigate these challenges.

In addition to attendance automation, the growing interest in **energy management systems** within educational institutions has led to the exploration of smart technologies for optimizing resource usage. The ability to monitor occupancy in classrooms through **human detection** allows institutions to implement energy-saving measures effectively. The incorporation of human counting algorithms has been investigated in various contexts, demonstrating their effectiveness in managing energy consumption [6]. However, existing models often face limitations in accuracy due to factors like **high traffic density** and **environmental conditions**.

Overall, the literature indicates a growing need for integrated solutions that combine attendance automation with energy management. By leveraging **facial recognition** and **real-time human counting**, **SmartLab** aims to address these challenges comprehensively, providing a scalable and efficient system for educational institutions.

3. METHODOLOGY

3.1 System Overview

SmartLab consists of two primary modules:

- **Face Recognition for Attendance Automation**: A facial recognition system automates attendance tracking by detecting and recognizing students in real-time. The system uses **Haar Cascade** for face detection and **LBPH** for face recognition.
- **Human Counting for Power Automation**: An AI-driven human detection and counting system tracks the number of people in the classroom and controls the power supply accordingly. It uses a **pre-trained frozen inference graph** for human detection.

3.2 Face Recognition for Attendance

The facial recognition module operates in four key phases:

- **Data Collection**: A set of images is collected for each student using a webcam, capturing multiple grayscale images from different angles. These images are stored in a database for training.
- **Face Detection**: The **Haar Cascade** classifier detects faces in real-time from video streams by identifying specific facial features, such as eyes, nose, and mouth, based on pixel intensity variations [6].
- **Face Recognition**: The **Local Binary Pattern Histogram (LBPH)** algorithm is used to recognize faces by analysing local pixel patterns. The algorithm converts the pixel values into binary patterns, creates histograms, and compares them to the pre-trained dataset [6].

Attendance Marking: When a face is successfully recognized, the system logs the student's name, roll number, and timestamp in a **CSV file** for each class session, automating the attendance process.

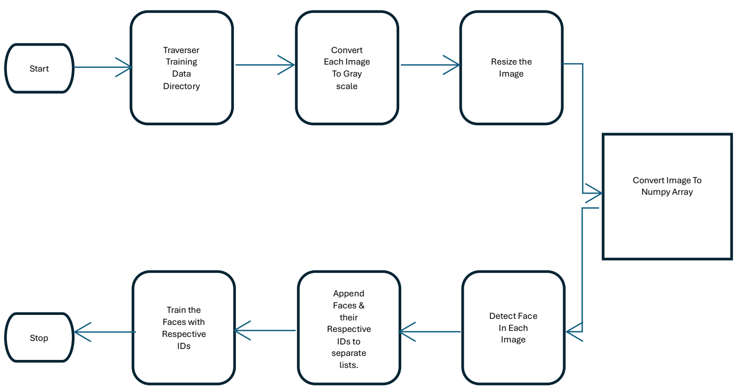

Figure 3.1: Flowchart of the methodology for the training process

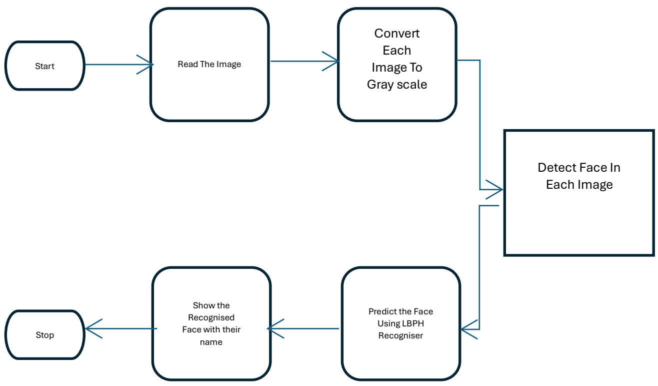

Figure 3.2: Flow-chart of the methodology used for Face Detection and Recognition

3.3 Human Detection and Counting for Power Automation

The human detection module uses a **pre-trained frozen inference graph** (frozen_inference_graph.pb) for real-time human detection and counting. It operates as follows:

- **Object Detection**: The pre-trained model detects humans in the video feed by identifying bounding boxes around individuals. This model has been trained on a comprehensive dataset, enabling it to effectively recognize human figures in various environments. The detection framework allows for fast and efficient identification of individuals in the classroom setting [4].
- **Centroid Tracking**: The system employs a **centroid tracking** algorithm to calculate the center of each detected bounding box. This enables the system to assign unique IDs to each detected individual, ensuring accurate counting even in dynamic environments. By tracking centroids, the system maintains an accurate count of how many individuals are present in the room at any given time [5].
- **Power Automation**: The system monitors the number of people in the room and automatically controls the power supply. When no individuals are detected for a predefined period, the system turns off lights, air conditioning, and other electrical devices to conserve energy [6].

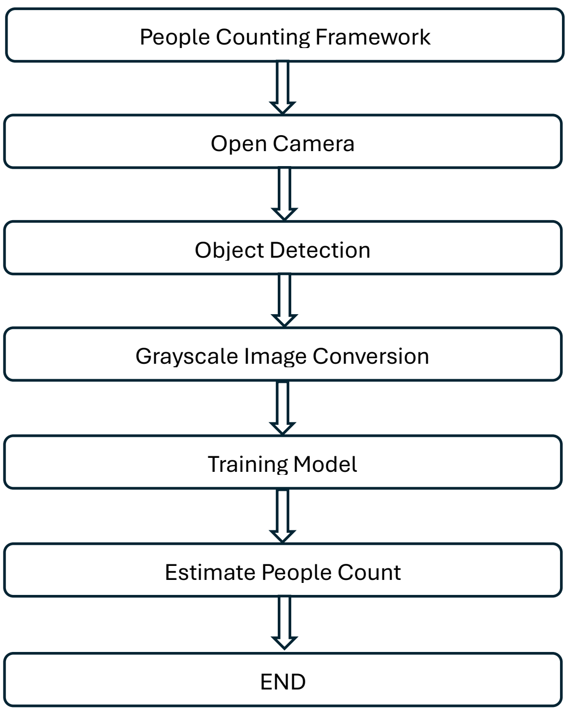

Figure 5.1: Human Detection Model Flow

4. ALGORITHM DETAILS

4.1 Haar Cascade Algorithm

The **Haar Cascade** classifier uses a machine learning approach to detect faces based on Haar-like features:

- **Feature Selection**: Haar features (e.g., edges, lines) are extracted from the face, distinguishing between lighter and darker regions, such as the eyes and forehead.

- **Integral Image**: The system computes integral images to speed up the process of detecting Haar-like features.
- **Adaboost Training**: Adaboost selects the most critical features and trains the classifier to distinguish between correct and incorrect face classifications.
- **Cascading Classifiers**: Multiple weak classifiers are combined in a cascade to improve detection accuracy [6].

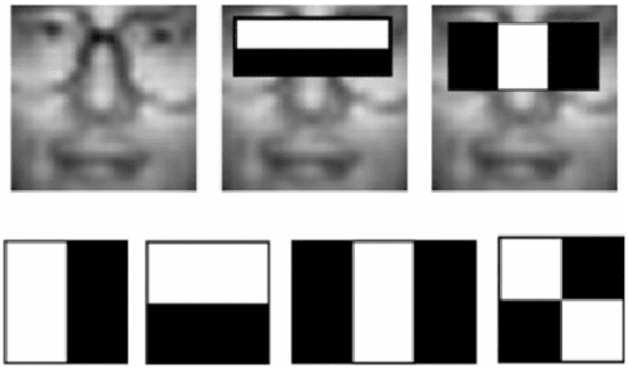

Figure 4.1: Creating integral of an image

4.2 LBPH Algorithm

The **LBPH** algorithm is used for face recognition:

- **Feature Extraction**: The face is divided into 3x3 pixel windows, and each pixel's value is compared to its neighbours to generate a binary pattern.
- **Histogram Calculation**: The binary patterns are converted into decimal values, and histograms are created from these values to represent the face's unique characteristics.
- **Recognition**: The histograms from the input image are compared to those in the database, and the closest match is selected [6].

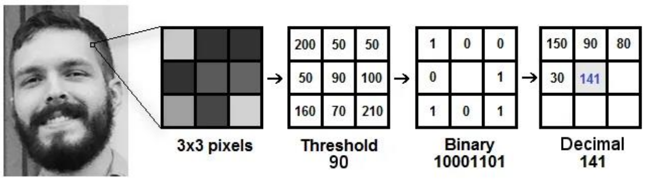

Figure 4.2: The basic LBP operator

5. RESULTS

5.1 Face Recognition Accuracy

The use of multiple images for each student during training improved the system's robustness in recognizing faces from different angles [6].

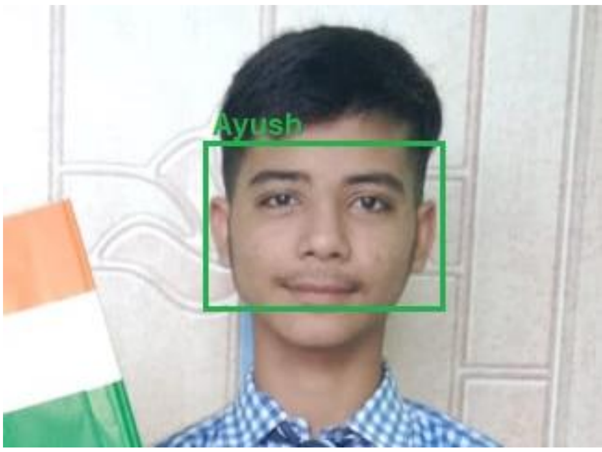

Figure 5.1: Face Detection

	A	B	C	D
1	Name	Email	Contact	01/11/2024
2	Ayush Sharma	ayush@gmail.com	919783567623	1
3	Pintu Singh	pintu@gmail.com	919732427623	0
4	Ravi Kumar	ravi@gmail.com	919783567623	0
5	Tushar	bts@gmail.com	919783567623	1
6	Vivan	vivan@gmail.com	919234427623	0
7	Vivek	viveeeek@gmail.com	919783567623	0
8	Ziya	zp@gmail.com	919783567098	1

Figure 5.2: Attendance Sheet

5.2 Human Detection and Power Automation

The human detection module achieved **high TPR and overall accuracy**. The system successfully controlled the classroom's power supply, reducing energy consumption by up to **30%** during non-peak hours [5].

Figure 5.3: Human Detection

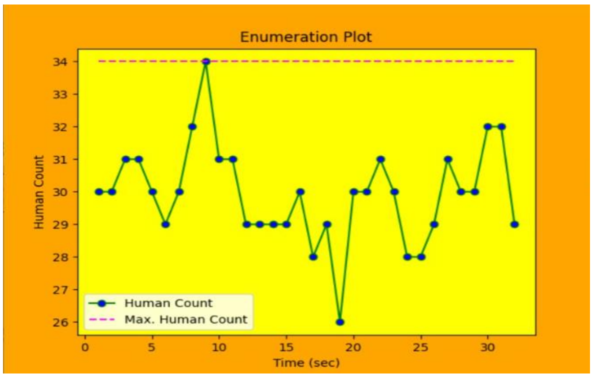

Figure 5.4: Human Count vs Time Graph

6. DISCUSSION

6.1 Advantages

- **Efficiency**: The facial recognition system automates attendance, eliminating the need for manual tracking and reducing errors.
- **Energy Conservation**: The human detection and counting system optimize energy usage by turning off devices when classrooms are unoccupied, promoting sustainability.
- **Scalability**: The system can be easily scaled to cover multiple classrooms or entire campuses, with minimal additional infrastructure [2], [3].

6.2 Limitations

- **Crowded Classrooms**: The human counting system may experience difficulties in highly crowded environments where individuals overlap, affecting counting accuracy [5].
- **Low-light Conditions**: Face recognition accuracy decreases slightly in low-light environments, though this can be improved with better camera hardware or additional training [6].

7. CONCLUSION

SmartLab offers a comprehensive solution for automating both attendance and power management in educational institutions. By integrating facial recognition using the **Haar Cascade** and **LBPH** algorithms with real-time human detection and counting using a **pre-trained frozen inference graph**, the system significantly improves operational efficiency and promotes energy conservation. Future work will focus on enhancing the system's performance in low-light environments and expanding its scalability with deep learning models for even greater accuracy.

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