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Microcontroller-Based Face Recognition Attendance System.

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ABSTRACT

Attendance management system is an indispensable system by which every organisation tracks employees or students attendance. The manual process of marking attendance by using a paper-based or file-based system is susceptible to loss, falsification or disaster. One of the most interesting and important ways used in the past two decades in attendance management systems is the face recognition systems.

This paper proposes a face recognition attendance system using ESP32-CAM development board, which is a low-cost microcontroller with built-in camera and Wi-Fi capability. The system captures and registers a facial image of a student, many student images are stored in the ESP32-Cam permanent internal storage. When attendance tracking is enabled, the face of a student in front of the camera will be detected and recognition process is performed where the tested image is compared with the stored images; once recognition is done, the recognized student data is sent wirelessly via http protocol to a MySQL database for further attendance report management.

Keywords: *ESP32-CAM , MySQL, IoT, Face Recognition*

1. Introduction

A face recognition attendance tracking system is a modern and effective way to manage and track attendance at different places, such as schools, companies or events. Unlike traditional attendance methods such as manual records or paper systems, it is very convenient for registering students, especially university students, as it saves time and is safer and more accurate. It is one of the useful methods in the educational aspect in terms of accurate and time-saving recording.

Many face recognition based systems were proposed by a lot of researchers , Kumar et al. [1] proposed IoT-based recognition systems, which Organizations can use to increase their security by integrating smart facial recognition to monitor and track employee attendance, detect and prevent unauthorised access, and quickly spot possible risks. This system uses a cloud server to process the face traits like the position of the mouth, nose, and eyes, and then make its decisions.

A face recognition-based car security system was proposed and developed by Arumugam et al. [2], where only authentic users are allowed to access the car ignition system. The hardware and software system was developed depending on Raspberry Pi 2 incorporated with other components. The system was set up to send a SMS to notify the owner of the car of unauthorised user access.

Gowda et al. [3] presented the management of the attendance system that marks the attendance of students using a live video stream. The proposed system uses library "dlib" is used for face detection and recognition process.

Namrata et al. [4] presented the creation of a door lock system, which is accomplished using facial recognition in conjunction with the ESP32 CAM for more accurate face detection. Also in this paper an application called Face detection Door lock was used. which is predicated on Arduino using Internet of Things technology to watch the status of the door, control the door and increase security.

A wireless access control system designed for a smart home environment was presented by Sahani et al. [5]. The physical components that are needed to be installed for functioning of virtual home security systems are the camera unit and the Raspberry Pi unit. These components are installed in a home through ZigBee. The virtual home security system functions by notifying the house owner about any visitor who confronts the camera unit by SMS or E-mail.

2. Face Detection and Recognition

The face recognition process typically consists of three main stages, enrollment/registration, detection and recognition. Here's an overview of each stage, Kortli et al. [6].

2.1 Enrolment:

During enrolment, a user's face is captured and processed to create a unique representation of their facial features. The detection process, shown in Figure 1, generally involves the following steps:

- Face Detection: Capture an image or video frame containing the user's face. Apply a face detection algorithm to locate and extract the face region.
- Face Alignment: Align the detected face region to a standardised pose for consistency in subsequent recognition steps. This step helps normalise the face's orientation, scale, and position.
- Feature Extraction: Use a feature extraction to extract a compact representation of the face's unique features, often referred to as a face embedding or descriptor.
- Store the Face Template: Save the extracted face embedding or descriptor along with the user's identity information in a database or file system for future recognition comparisons.

2.2 Detection:

In the detection phase, the system captures an image or video frame and identifies the presence of faces within it. The process typically involves the following steps:

- Face Detection: Apply a face detection algorithm or library to locate and extract face regions within the image or video frame.
- Optional Face Alignment: Align the detected face regions for consistency, similar to the enrollment process. This step may not be necessary depending on the face recognition algorithm used.
- Preprocess the Detected Faces: Normalise the detected face regions by adjusting their size, orientation, and illumination to match the enrolled face template's requirements. This step helps improve recognition accuracy.

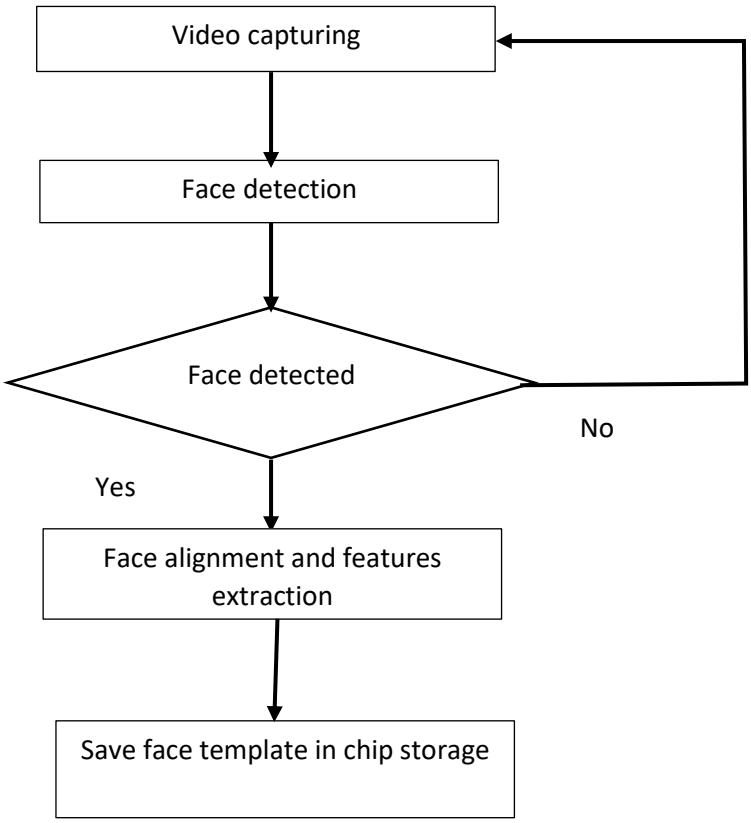

Figure 1. Face enrolment process

2.3 Recognition:

In the recognition phase, shown in Figure 2, the system compares the detected face against the enrolled face templates to determine the identity of the individual, Tolba et al. [7]. The process typically involves the following steps:

- Feature Extraction: Apply the same feature extraction algorithm used during enrolment to extract the face embedding or descriptor from the preprocessed face region.
- Comparison: Compare the extracted face embedding against the enrolled face templates in the database or file system using a suitable distance metric. Calculate the similarity score between the detected face and each enrolled template.
- Thresholding: Define a similarity threshold above which a detected face is considered a match with an enrolled template. If the similarity score exceeds the threshold, the face is recognized as belonging to a registered user.

- Identification or Verification: If the similarity score surpasses the threshold, the system can either identify the person by retrieving their identity information associated with the matched face template or verify the person's identity against their enrolled template.

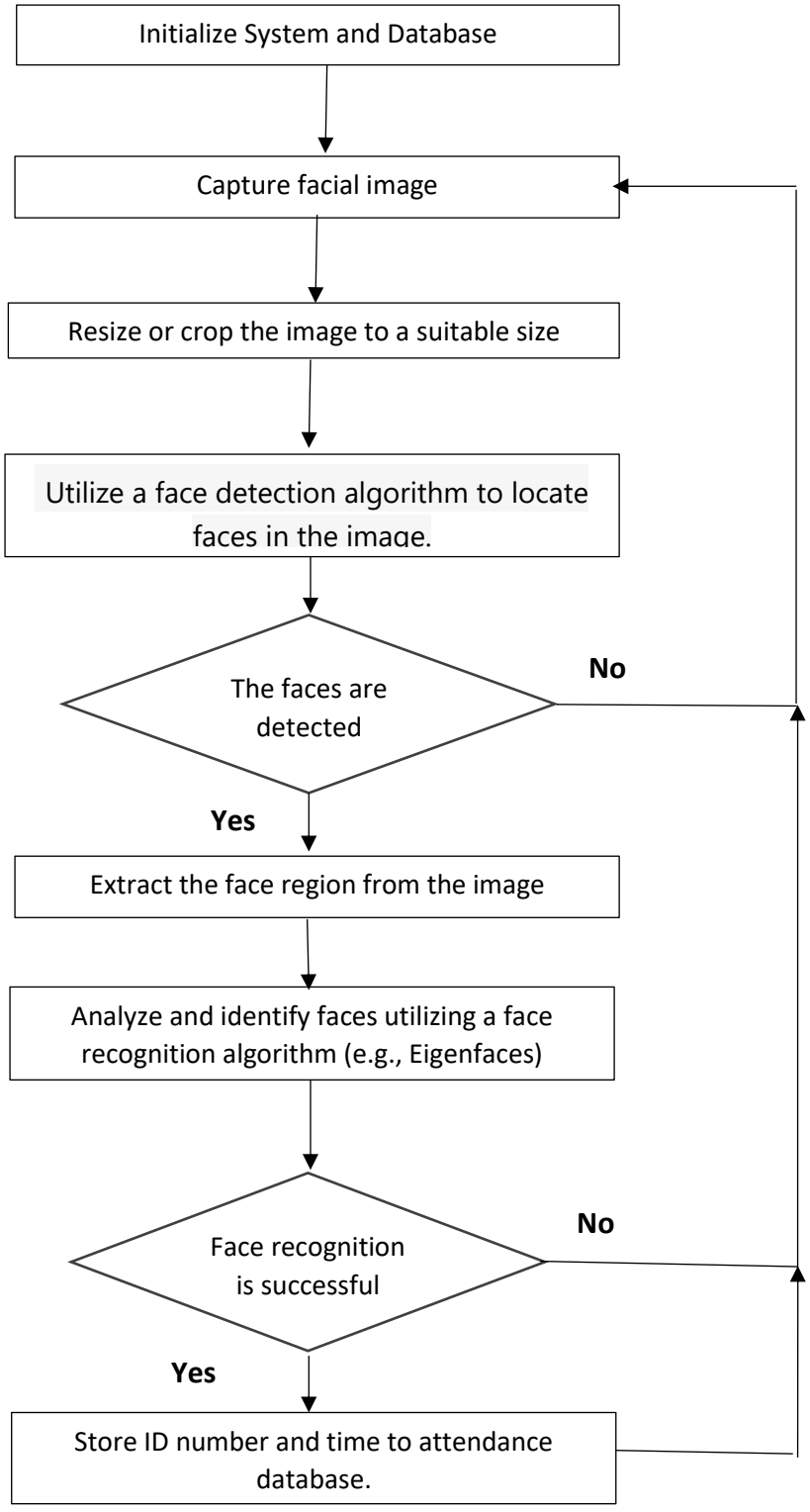

Figure 2. The proposed system operation

3. Design Methodology

The system uses a camera to capture video of individuals entering a specific area. Once a face is detected a facial recognition algorithm is used to identify and verify individual identity and then the identified face ID is sent to a local web server through WiFi connection to be saved in a database system

The proposed system is composed mainly of two modules, the first is the ESP32-CAM module which is a microcontroller with a camera, and will be referred to as the camera module throughout this paper.

The second module is a database module, which can be a cloud based database or local database system running on a desktop OS. Database module will be responsible for storing the recognized face IDs, which can be used later with any web app or desktop app for generating an attendance tracking report.

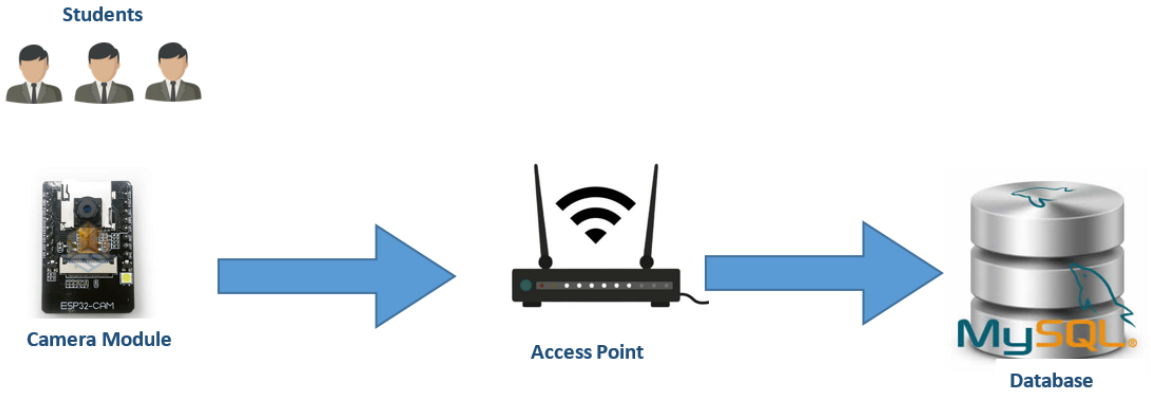

Figure 3. System Basic Configuration

The two modules typically communicate through Wi-Fi connection. The basic configuration of the system is shown in Figure 3. The attendee data is sent wirelessly to a desktop and stored in a MySQL database for further management and analysis. The data can be transmitted to the database module via communication protocol like HTTP or MQTT. The http protocol is adopted in the proposed system. Figure 3.1 shows the components of the system

3.1 The Camera Module:

The camera module is the main component of this system where the processes of capturing, detecting and recognizing the face take place.

The ESP32-CAM module shown in Figure 4, is a small-sized, low-power Wi-Fi and Bluetooth-enabled camera module based on the ESP32 microcontroller. It combines the ESP32 chip with a camera module, allowing you to capture images and video, and transmit them wirelessly over the internet or to other devices.

The ESP32-CAM module is popular for various applications, including security systems, home automation, remote monitoring, and IoT applications that require image or video capturing and wireless connectivity. Its compact size and low power consumption make it suitable for systems where space and energy efficiency are important factors.

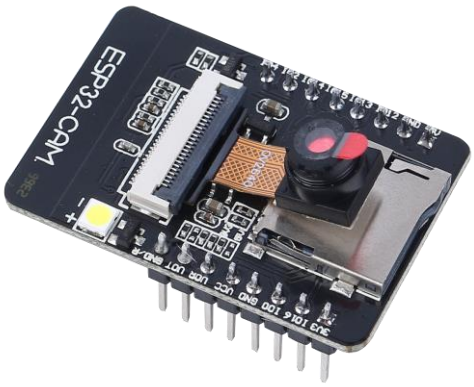

Figure 4. ESP32-CAM board

Here are some key features of the ESP32-CAM :

- The module is built around the ESP32 SoC microcontroller, which is a powerful dual-core microcontroller with integrated Wi-Fi and Bluetooth capabilities. It offers a wide range of GPIO pins, ADC channels, and other peripherals for various applications.
- The module comes with an OV2640 camera that allows you to capture images and video. The camera supports resolutions up to 2 megapixels and can be controlled programmatically.
- The module also includes an SD card slot for external storage, which allow for more faces to be registered.
- Programming the ESP32-CAM module typically performed using the Arduino IDE development platforms.

3.2 The Database Module:

The database module proposed for this system is a MySQL database installed on a desktop along with a webserver. The web server receives http requests from the camera module, then a web service handles the request and saves the recognized face id in the database along with the time of recognition. PHP programming language is used to implement this web service.

XAMPP package is used to test the system, which includes a web server, MySQL database engine and PHP interpreter. A simple database is created with two tables, the "students" table and the "attendance" table.

The "student" table contains a record for each student with two columns, the student "name" column besides the "id" column. In fact, this table can have more columns that holds student-specific information, but that is outside the scope of this paper.

The attendance table is the one that the camera module interacts with, where the recognized face id is sent to the database module and inserted into the "student_id" column. This column is a foreign key that refer to the "id" column in the "student" table. The time of attendance is automatically saved in the "created_at" column. The data base schema is shown in Figure 5.

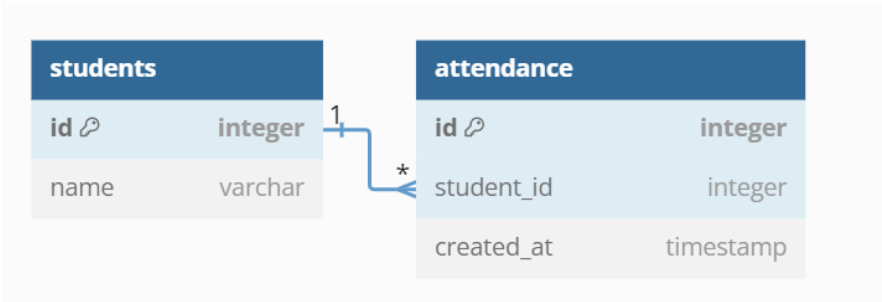

Figure 5. The Database Schema

4. Conclusion

The ESP32-CAM face recognition attendance system offers a convenient and automated solution for tracking attendance based on facial recognition technology. By leveraging the capabilities of the ESP32-CAM module, such as its built-in camera and Wi-Fi connectivity, the system can capture and process images in real-time. The integration of a trained face recognition model into the ESP32-CAM firmware enables accurate detection and identification of individuals, eliminating the need for

manual attendance tracking.

This system provides several advantages. Firstly, it eliminates the manual effort and potential errors associated with traditional attendance tracking methods. The automated nature of the system reduces administrative burden and saves time for both staff and attendees. Additionally, the real-time processing capability allows for immediate attendance updates, enabling better monitoring and management of attendance records

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