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Research Paper

THE WIRELESS IDENTITY DISPLAY SYSTEM

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ABSTRACT

This project demonstrates an innovative facial recognition system that integrates wireless communication with personalized greetings. Using an ESP32-CAM as the primary camera, the system captures facial images and uses facial recognition algorithms to identify individuals in real-time. Once identified, the system displays a personalized greeting on a connected LCD 16x2 display with I2C. The system also includes an alert buzzer for notification and utilizes a battery charge controller to ensure continuous operation.

This project has various applications in retail, smart homes, and events, where personalized interactions are vital to enhancing user experience. This project not only highlights the integration of facial recognition and wireless communication but also showcases the potential of combining advanced technologies for seamless, real-time, personalized interactions.

The ESP32-CAM,a cost-effective yet powerful microcontroller with built-in Wi-Fi and Bluetooth capabilities, acts as the brain of the system, processing facial recognition data. The camera captures and sends images to a remote server or cloud, where the recognition algorithm, based on machine learning or a pre-trained model, identifies the individual.

Once the system recognizes a face, it triggers a personalized greeting displayed on an I2C-enabled 16x2 LCD screen, providing a unique experience to the user.

This greeting could vary based on the user's preferences or profile data, adding an extra layer of personalization. The system's alert buzzer provides audio feedback when a person is detected or identified, serving as both a notification mechanism and an attention-grabber. This could be useful in applications like entryway security or customer engagement in retail stores.

Keywords — ESP32-CAM, LCD 16x2 Display with I2C Module, Battery Charge Controller, USB to TTL Programming Module, Buzzer, Rechargeable battery

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I. INTRODUCTION

Road Facial recognition technology has become a key innovation in modern security, automation, and personalized interaction systems. This project presents a **real-time facial recognition system** using the **ESP8266 microcontroller** integrated with an **external camera module**. The system is designed to capture images, recognize faces using machine learning algorithms, and display personalized greetings on an **LCD screen**. Additionally, a **buzzer** provides an alert when a face is detected, making it useful for security and access control applications.

The system is **IoT-enabled**, allowing real-time data processing and monitoring through a **web server**. The ESP8266 facilitates **wireless communication**, enabling users to access facial recognition logs and system updates remotely. This cost-effective and power-efficient solution is ideal for applications such as **smart homes, automated attendance systems, personalized retail experiences, and security monitoring**.

By integrating **facial recognition with IoT**, this project highlights the potential of low-cost microcontrollers in advanced automation. The system can be further enhanced with **cloud storage, AI-based improvements, and multi-factor authentication**, making it a scalable solution for various real-world applications.

II. PROBLEM STATEMENT

With the rapid growth of smart technologies and the Internet of Things (IoT), there is a strong demand for intelligent systems that can recognize individuals and interact with them in a personalized and automated way. Traditional identification systems such as RFID tags, fingerprint scanners, or password-based access are often limited by cost, user inconvenience, physical contact, or lack of scalability. Additionally, these systems often lack the ability to personalize user experiences in real time.

In environments like smart homes, retail outlets, educational institutions, and secure facilities, there is a need for a solution that can:

- Recognize individuals instantly without physical input.
- Greet them with personalized messages.
- Alert or notify relevant stakeholders.
- Operate wirelessly with minimal maintenance.
- Be implemented at a low cost using readily available hardware.

Most existing facial recognition systems are either too expensive, rely heavily on cloud processing, or are complex to implement at a small or medium scale. Moreover, they often lack real-time feedback mechanisms such as audio alerts or user-specific visual displays.

To address these gaps, this project proposes the development of a **low-cost, standalone facial recognition and greeting system** using the **ESP32- CAM module**, which offers built-in Wi-Fi, camera support, and edge computing capabilities. The system should:

- Detect and recognize faces in real time.
- Display personalized greetings on an LCD (16x2 with I2C)
- Trigger a buzzer when a face is detected or identified.
- Operate wirelessly and remain powered using a battery management system.
- Optionally, provide real-time monitoring or updates via a web interface

This project aims to bridge the gap between facial recognition technology and personalized IoT-based interactions, making it accessible for small businesses, smart homes, and public spaces without requiring heavy infrastructure or high costs.

III. METHODOLOGY

The methodology for this project involves designing a real-time facial recognition system using the ESP32- CAM microcontroller, which has an inbuilt camera and Wi-Fi capabilities. The system begins with hardware integration, connecting the ESP32-CAM to peripheral components such as a 16x2 LCD display (using I2C communication), a buzzer for alerts, and a rechargeable battery with a charge controller to support uninterrupted operation. Once the setup is complete and powered, the ESP32-CAM captures live video frames and processes them using onboard face detection and recognition algorithms. These algorithms are lightweight and optimized to run on embedded hardware, making them suitable for real- time applications.

To recognize a person, the system requires initial enrollment of facial data. During enrollment, the ESP32-CAM captures multiple images of a face and extracts unique features that are stored in flash memory with an associated name or ID. During operation, the system continuously scans for faces.

When a face is detected, it is compared against the stored dataset. If a match is found, a personalized greeting is displayed on the LCD screen, and the buzzer provides an audio cue. If the face is not recognized, a notification is sent to the web interface.

The ESP32-CAM also functions as a web server, hosting a live video stream and offering a WebSocket- based interface where users can remotely interact with the system—for instance, to enroll new users, initiate recognition, or clear saved data. Wi-Fi connectivity allows seamless communication between the device and the interface. This setup ensures that the system is user- friendly, responsive, and capable of delivering personalized interactions in real-time environments like smart homes or commercial entry points.

CIRCUIT DIAGRAM

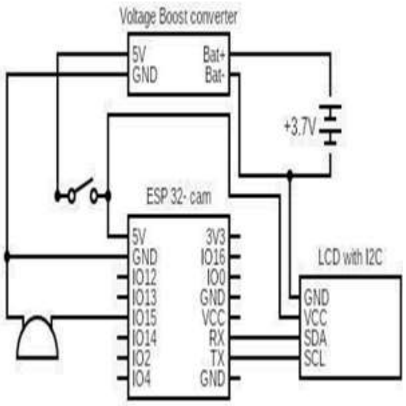

Fig.1: Circuit Diagram

The given The given circuit diagram illustrates a battery-powered ESP32-CAM system with an I2C LCD display and a voltage boost converter. The 3.7V battery supplies power to the boost converter, which steps up the voltage to 5V for stable operation of the ESP32-CAM. The ESP32-CAM module, a microcontroller with built- in Wi-Fi and camera capabilities, controls the system and communicates with the LCD module via I2C protocol (SDA, SCL pins). The LCD display provides a user interface to show data such as sensor readings or status updates. A switch is included to control the power supply, ensuring energy efficiency. The circuit ensures proper grounding to avoid signal issues. The LED indicator can be used to show power status or device activity. The ESP32-CAM operates at 3.3V logic level, so compatibility with peripherals is important. This setup is suitable for IoT applications, portable monitoring systems, and wireless surveillance projects. Proper power management is crucial for optimizing battery life and performance.

IV. INTERFACES

This facial recognition system involves multiple hardware and software interfaces to ensure seamless interaction between components and the end user. The key interfaces used in the project are:

Camera Interface (ESP32-CAM):

The ESP32-CAM module comes with an onboard OV2640 camera which captures real-time images or video. This forms the primary interface for face detection and recognition. The camera is directly integrated into the ESP32 board and controlled through ESP-IDF or Arduino-based camera libraries.

LCD Display Interface (I2C Protocol):

A 16x2 LCD screen is used to show personalized greetings. It uses the I2C communication protocol to minimize wiring and simplify communication. The ESP32 communicates with the LCD via SDA and SCL lines using the Wire library, sending text-based messages.

WebSocket/Web Interface:

The ESP32 hosts a basic web server that supports a WebSocket-based interface. Through this interface, users can view live video streaming from the camera, enroll faces, recognize individuals, and delete or manage the face database. This interaction happens over Wi-Fi, making it accessible through any web browser connected to the same network.

Buzzer (Digital GPIO Interface):
A buzzer is used for audio feedback when a face is recognized or detected. It is connected to a digital GPIO pin on the ESP32 and controlled via simple HIGH/LOW signals to indicate recognition or alerts.

Power Interface (Battery and Charge Controller):
The ESP32-CAM is powered using a rechargeable battery supported by a charge controller module (such as TP4056). This interface ensures that the system is portable and continues operation even during power interruptions.

Face Recognition Software Interface:
Internally, the ESP32 runs face detection and recognition algorithms using libraries such as fd_forward.h and fr_forward.h. These form software-level interfaces that enable detection, feature extraction, and matching of facial data.

Wi-Fi Interface:
The ESP32's built-in Wi-Fi enables network communication. It allows the module to host a web server and send/receive commands over the local network, enabling remote interaction and live streaming

These interfaces work together to build a robust, interactive system capable of identifying individuals and responding in real-time with visual and auditory feedback. Let me know if you want a block diagram or a table format too!

V. COMPONENT DESCRIPTION

1. **ESP32-CAM**
The ESP32-CAM is a small, powerful microcontroller with a built-in camera and Wi-Fi/Bluetooth capability. It captures images and streams live video. It also processes face recognition tasks and connects to the internet to display output on a web page. It acts as the "brain" of your project.

2. **LCD 16x2 Display with I2C Module**
This display shows messages like greetings or status updates. It can show 2 lines with 16 characters each. The I2C module reduces the number of wires needed, allowing the display to connect to the ESP32 using just two pins (SDA & SCL).

3. **Battery Charge Controller (e.g., TP4056)**
This module is used to safely charge your rechargeable battery. It controls how much power flows into the battery and prevents overcharging, ensuring long battery life and safe operation.

4. **USB to TTL Programming Module**
Since the ESP32-CAM doesn't have a built-in USB port, this module is used to upload code from your computer. It connects the ESP32 to a USB port using serial communication and helps in flashing the program.

5. **Buzzer**
The buzzer produces sound as a form of alert or notification. In your project, it sounds when a face is detected or recognized, giving an audible response to users.

6. **Rechargeable Battery**
This battery powers the whole system when it's not connected to a computer or power supply. It's used for portability so that your system can work anywhere without needing to plug it in.

VI. Modelling and Analysis

This project revolves around real-time **facial recognition** using an ESP32-CAM microcontroller. The modeling begins with identifying the system's **inputs**, **processing unit**, and **outputs**.

- The **ESP32-CAM** is the central processing unit. It captures facial images through its built-in camera. The model assumes sufficient lighting and a clear view of the face for optimal recognition.
- Once the image is captured, it goes through a **face detection and recognition algorithm**. This algorithm either runs directly on the ESP32 (for lightweight models) or sends the image to a server/cloud for processing.
- The **face data** is matched with the enrolled faces stored in memory. If a match is found, the system proceeds to respond.

Output Modeling:

- Upon successful recognition, the **LCD 16x2 display** (connected via I2C) shows a personalized welcome message with the recognized person's name.

- Simultaneously, a **buzzer** is activated to give a sound alert.
- The system also has a **web interface** over Wi-Fi, allowing live monitoring and face enrollment or deletion remotely.
- Power supply modeling is managed via a **rechargeable battery and charge controller**, ensuring portability and continuous operation.

Analysis:

- The system's **efficiency** depends on the accuracy of face detection and recognition. Lighting conditions, camera angle, and face clarity play a major role in the success rate.
- The **response time** between face detection and message display is also analyzed to ensure smooth user experience.
- The use of I2C reduces wiring complexity, making the hardware layout more compact and efficient.
- Real-time performance is tested by measuring the frame rate, recognition speed, and network latency when accessing the web interface.

Overall, this modeling approach helps in predicting how each part of the system will behave, and the analysis ensures the system operates reliably under different real- world conditions.

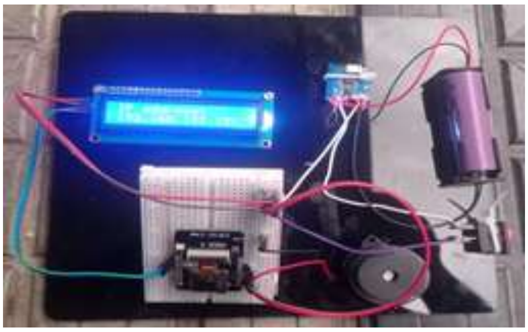

Fig.3: Circuit Without Supply

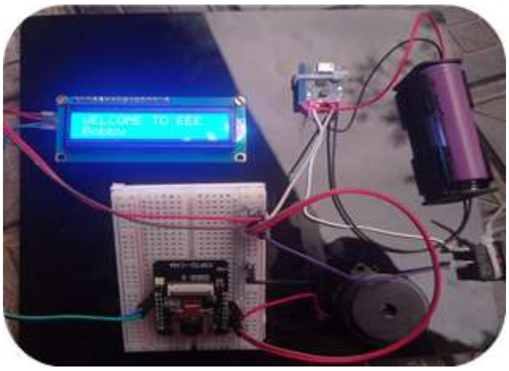

Fig.4: Circuit With welcoming in display

VII. ADVANTAGES AND DISADVANTAGES

ADVANTAGES:

- **Cost-Effective**:

The ESP32-CAM is a low-cost microcontroller with built-in Wi-Fi, Bluetooth, and camera support, making the project affordable.

- **Real-Time Recognition**:

The system can detect and recognize faces in real- time, providing immediate feedback via buzzer and LCD.

- **Wireless Control & Monitoring**:

Using Wi-Fi, you can access the camera stream, control the device remotely, and manage face data without physical access.

- **Personalized Experience**:

The system greets recognized users with custom messages, enhancing user interaction in places like homes, offices, or events.

- **Portability**:

A rechargeable battery and charge controller allow the device to be used in areas without constant power supply.

- **Compact Design**:

The use of an I2C display and ESP32-CAM ensures minimal wiring and space requirements.

- **Easy Programming**:

It supports the Arduino IDE, making development easier for students and hobbyists.

DISADVANTAGES:

- **Limited Processing Power**:

ESP32-CAM has limited memory and CPU speed, which can affect recognition speed and accuracy with complex models.

- **Lighting Sensitivity**:

Face detection performance decreases

significantly in poor lighting conditions or with poor camera angles.

- **Low Image Resolution**:

Compared to dedicated cameras, the image quality of ESP32-CAM is lower, affecting recognition performance.

- **Limited Storage**:

The onboard storage may not be sufficient to store many facial profiles or logs unless external storage is added.

VIII. FUTURE SCOPE

- **Cloud Integration:**

Offload facial recognition to cloud platforms like Google Cloud Vision, AWS Rekognition, or Microsoft Azure for faster and more accurate identification.

- **Mobile App Integration:**

Create Android/iOS apps for remote monitoring, alerts, face management, and user logs.

- **AI & Deep Learning Models:**

Incorporate TensorFlow Lite or MobileNet models on the ESP32 or cloud to improve face detection accuracy and learn over time.

- **Edge Computing:**

Use more powerful edge devices (like NVIDIA Jetson Nano or Raspberry Pi 4) for advanced processing alongside ESP32.

- **Voice Assistant Integration:**

Combine facial recognition with Google Assistant, Amazon Alexa, or custom voice control for smart home applications.

- **Smart Lock Integration:**

Link the system with electronic door locks for real- time face-based access control in homes or offices.

- **Emotion & Gesture Detection:**

Add models to analyze facial expressions or gestures for more personalized user experiences.

- **Night Vision Enhancement:**

Integrate IR LEDs or thermal imaging sensors for facial recognition in low-light or nighttime conditions.

- **Real-time Alerts & Notifications:**

Send SMS, email, or app-based notifications when an unknown face is detected using Twilio, Firebase, or IFTTT.

- **Data Logging & Analytics:**

Store face recognition logs with timestamps in databases like Firebase, MySQL, or Google Sheets for review and analytics.

- **Multi-Camera System:**

Expand the system with multiple ESP32-CAMs for wider surveillance coverage with centralized control.

- **Integration with RFID/Biometric Modules:**

Add additional layers of authentication for more secure access (e.g., fingerprint + face).

- **Face Mask Detection (Post-COVID use cases):**

Add models to identify if a user is wearing a mask and take appropriate actions.

- **Wearable Integration (like smart glasses):**

Implement in AR-based wearable devices for real- time recognition in smart environments.

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