Modern CCTV Surveillance System for Consistent Security Surveillance

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Abstract— Safety and security are now of utmost importance. People employ security systems to safeguard their possessions, including their homes and companies. Cameras are used for image capture and video monitoring in perimeter intrusion detection systems, and a range of sensors are used for motion detection in real-time and object detection. This work aims to present one such idea that ensures the security and safety of an individual's personal property using ESP32-CAM. In this proposed work, we recommend providing a smart CCTV surveillance system with intrusion detection for monitoring and live streaming using face detection, this will be low-cost image recognition solution. By using the ESP32 camera, it is made easy and will be possible to apply everyone by using the time and how fast it is detecting in front of the camera. Speed is observed from the resolution specification utilized for face recognition with the help of format QVGA and ESP32CAM analysis.

Keywords— Security, face recognition, CCTV, Detection, Smart Cameras, ESP32-CAM.

I. INTRODUCTION

Town center surveillance is one of the many applications in which closed-circuit video surveillance is commonly used. The fundamental element of a CCTV system is the accurate assessment of images by a human observer, which depends on several factors. Effectiveness optimization is a complex issue that involves both technical and human factors. From a technical standpoint, proper use of contemporary technology is essential. People must possess aptitude and drive. When technical performance is high, the human observer is the most crucial link in the chain. An operator's productivity is greatly influenced by their workstation, presentation style, and the caliber and preparation of the video content [1].

In the realm of embedded systems and the Internet of Things (IoT), the ESP32-CAM Wi-Fi module emerges as a pivotal component, playing a crucial role in diverse applications [2] [3]. This research explores the integration and utilization of the ESP32-CAM module in a project focused on real-time video streaming. The work is developed through the Arduino Integrated Development Environment (IDE), showcasing the versatility and ease of use associated with this popular opensource electronics platform [4] [5].

As the demand for IoT applications continues to grow, the significance of robust and user-friendly development platforms becomes increasingly apparent. The integration of the ESP32-CAM module in conjunction with the Arduino IDE exemplifies a synergistic pairing that empowers developers to realize sophisticated projects, such as live video streaming applications. This research contributes valuable insights into the capabilities of the ESP32-CAM module and serves as a guide for enthusiasts and professionals alike seeking to harness the potential of this powerful combination in their IoT endeavors [6].

II. OBJECTIVES

This research project is dedicated to the development of a state-of-the-art Closed-Circuit Television (CCTV) surveillance system, aiming to meet contemporary security demands. The primary objectives encompass the implementation of cutting-edge features, including facial recognition, motion detection, and object tracking, to enhance the precision and efficiency of the surveillance system. Additionally, a resilient network infrastructure will be established to enable seamless remote monitoring and realtime access to surveillance footage, ensuring consistent security surveillance across various locations. The system design prioritizes scalability and flexibility, allowing for easy expansion to accommodate additional cameras and adapt to evolving security requirements. Cloud integration is explored to enhance data management and accessibility, while mobile accessibility ensures remote monitoring through smartphones or tablets. The development emphasizes a userfriendly interface for live monitoring and historical playback, promoting efficient system operation. Robust security measures are integrated to protect the integrity and confidentiality of surveillance data, ensuring compliance with privacy regulations.

Automated alert mechanisms will be implemented to trigger responses to predefined events, enhancing the system's overall effectiveness. Optimization efforts will focus on video compression, bandwidth utilization, and storage efficiency without compromising the quality of surveillance footage. Comprehensive documentation and guidelines will be provided for deployment, configuration, and maintenance, and thorough testing will be conducted to validate the reliability and accuracy of the surveillance system under various conditions. This holistic approach aims to create a modern CCTV surveillance system that not only addresses current security needs but also paves the way for future advancements in surveillance technology.

III. Literature Review

The study conducted by Prasetyo Adi and Wahyu [1] titled "Performance Evaluation of ESP32 Camera Face Recognition for Various Projects" thoroughly explores the

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integration of the ESP32-CAM with additional components like the UFL Antenna and FTDI Programmer. This examination provides a detailed understanding of the ESP32CAM's functionality in terms of communication and data transfer. The UFL Antenna plays a crucial role as a signal amplifier, enhancing the wireless communication capabilities of the ESP32-CAM.

The research underscores the significance of the ESP32 camera in the realm of facial recognition technology. Prasetyo Adi and Wahyu [1] highlight the cost-effectiveness of the ESP32 camera as a viable solution for image recognition, ensuring accessibility for a wide audience. The primary focus of the investigation revolves around achieving a balance between user-friendly applications and analytical precision. Key aspects such as the time required for object detection, the covered distance, and the speed of detection measured in milliseconds are thoroughly examined. Furthermore, the study delves into the integration of the ESP32-CAM with other essential components like the FTDI Programmer, elucidating the functional aspects of communication and data transfer. The UFL Antenna's role as a signal amplifier is highlighted, emphasizing its contribution to enhancing the ESP32-CAM's connectivity in various scenarios.

Additionally, the research provides detailed configurations for the connections between the ESP32-CAM and both the FTDI Programmer and Arduino, showcasing the versatility of the ESP32 camera across diverse applications.

Akwinder Kaur et. al. [3] shows Convolutional Neural Network is developed to predict whether someone is wearing a mask or not. It is deployed on a self-made server and can be monitored remotely. The camera used to capture the video is ESP32. Peng Lean Chong et. al.[7] proposed smart surveillance system creates a comfortable and safe environment for households to initiate immediate recording of the surrounding upon triggering of sensors assemble at the specific entrance or exit points at home. Pertab Rai et. al. [8] Authors proposed the hardware as well as software employment of smart surveillance system using the Espressif's with latest ESP32. The projected implementation captures continuous video, and transmits using integrated WiFi capabilities of above-mentioned microcontroller and display on TFT Module connected on other end. [9] [10] This study shows with install a room security system by freezing the contrast configuration problem on the ESP 32 Cammera and transmitting notifications to the telegram.

IV. Components Required

Table I. Components required

Sr. No.	Components Required
1.	ESP-32 CAM Wi-Fi Module
2.	OV2640 Camera (2MP)
3.	USB to UART TTL 5V 3.3V FT232RL
4.	5V Adapter
5.	Custom Built Box as per requirement

A. ESP32 CAM Wi-Fi Module with OV2640 Camera Module 2MP

Fig. 1. ESP 32 CAM

The ESP32 CAM Wi-Fi Module with OV2640 Camera Module table II shows the specifications of OV2640 camera, designed for Face Recognition applications, boasts a remarkably compact camera module with a footprint of only 40 x 27 mm, making it suitable for independent operation as a minimum system. With a deep sleep current of up to 6mA, this module is exceptionally power-efficient, a crucial feature in IoT applications [3] [5] [6].

The ESP32-CAM is powered by a Xtensa dual-core 32-bit LX6 microprocessor, operating at 240 MHz and delivering a performance of up to 600 DMIPS. Its memory configuration includes 520 KB SRAM, 4MB external PSRAM, and 4MB internal flash memory. In terms of wireless connectivity, it supports Wi-Fi (802.11 b/g/n) and Bluetooth (v4.2 BR/EDR and BLE). The camera component features a 2 Megapixel OV2640 sensor with a UXGA array size of 1622×1200 and an image transfer rate ranging from 15 to 60 fps. Security measures include secure boot, flash encryption, OTP, and cryptographic hardware acceleration for various algorithms [2].

Power management is optimized with an internal lowdropout regulator, individual power domain for RTC, and an impressively low 5 microAmp deep sleep current. The ESP32-CAM is a versatile and powerful solution widely used across diverse IoT applications.

Table II. OV2640 Specification

No	Parameters	OV2640 Specifications
1	Array of Size	1600 x 1200 (UXGA)
2	Power Supply	Analog: 2.5~3.0V DC I/O: 1.7V to 3.3V
3	Consumption of power	Free running: 125mW Standby:600µA

4	Image Format	Type 1/4″

B. ESP32-Cam FTDI (USB to UART driver FT232RL)

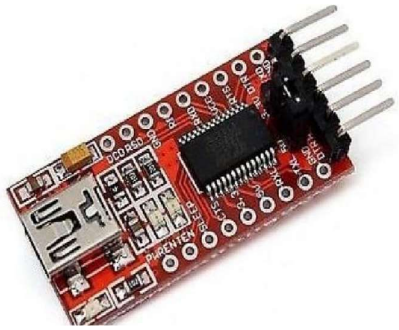

Fig. 2. FT232RL

The module exhibits a standard interface layout, ensuring compatibility with various Arduino models, including the Pro Mini. Notably, it incorporates the reliable FTDI FT232 chip, ensuring stable and consistent performance. The USB power function is equipped with current protection, incorporating a 500MA self-restore fuse for added safety. The module features RXD/TXD transceiver communication indicators, along with power, sending, receiving, and working status LED indicators, providing users with clear visual cues. Additionally, it offers versatile supply options with both 3.3V and 5V TTL Level support. Serving as a USB to serial TTL module, it facilitates the download of STC SCM, and its Mini USB Port Connection enhances convenience in various applications [1].

V. Methodology

The comprehensive design and implementation of a ClosedCircuit Television (CCTV) system involve a systematic approach encompassing ten key components. Firstly, a clear objective is established, defining the purpose of the CCTV system, whether for security, monitoring, or safety. Subsequently, a meticulous site assessment is conducted, optimizing camera placements by considering angles and identifying critical areas. A strategic plan for camera placement is then developed to ensure optimal coverage. The selection of CCTV cameras follows, with a focus on meeting specific needs, such as choosing between fixed or flexible Pan-Tilt-Zoom (PTZ) options. The network infrastructure is carefully planned, addressing connectivity through wired or wireless setups while considering bandwidth and security requirements. Recording parameters and suitable storage solutions are defined for effective data management. Methods for real-time monitoring, such as central stations or mobile access, are outlined, and privacy concerns are addressed, ensuring legal compliance and defining access policies. A routine maintenance plan is developed to conduct camera checks, updates, and resolution of potential issues. Lastly, personnel training is provided, awareness is raised, and comprehensive documentation covering system design and procedures is maintained to facilitate efficient system operation.

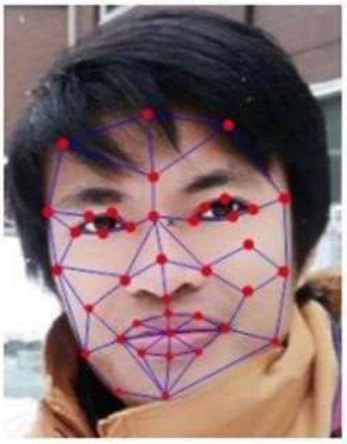

Fig. 4. Face Detection use ESP32-CAM[1]

Fig. 4 shows the face recognition Stages, which involved Capturing, Extracting, Comparing, and Matching of face images. This method is used to govern the Face that is the key by going through various Face Comparing and Matching progressions [1].

VI. Flowchart

Figure 5 shows the flowchart for ESP 32 webserver. Initialization of webserver required to include all necessary libraries for setup of Wi-Fi credentials. Need to create the web server instances to monitor. Connect the device to wi-fi and define the routes for capturing the information through web cam. Start web server and monitor the instances and upload the data in SPIFFS format i.e. serving static files.

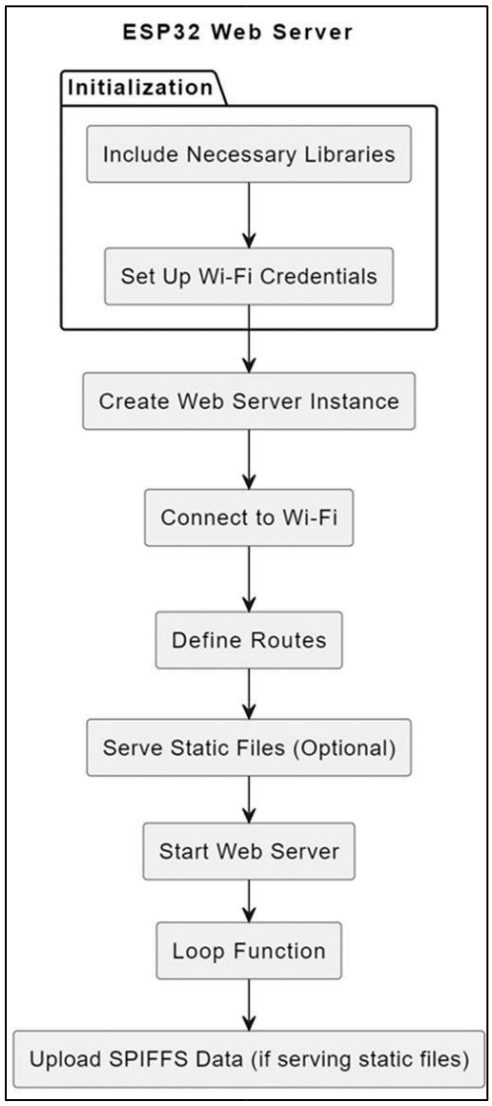

Fig. 5. Flowchart ESP32 Webserver

VII. HARDWARE SETUP

Fig. 6. Custom built frame for camera. In our CCTV surveillance hardware setup, as shown in figure 6, simplifies installation by combining power supply and data transmission in one cable. T The entire system is securely housed, ensuring the reliability of our single-camera CCTV surveillance solution

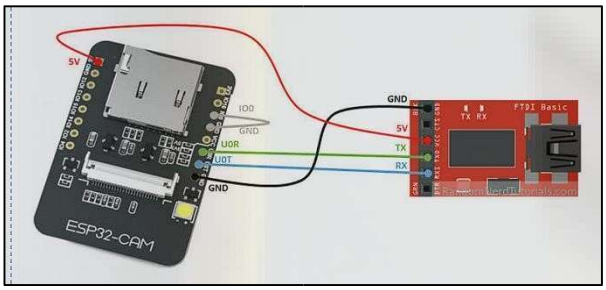

Fig. 7. ESP 32 CAM connection with FT232RL

The hardware is all about ESP32 CAM (Wi-Fi Module Bluetooth with OV2640 Camera Module 2MP For Face Recognition) which contains a camera module from which a web server can be hosted which has an option of live streaming. For programming the ESP32 cam module we require an FTDI232 serial to UART communication cable which acts as a bridge for transferring data it also plays a major role in maintaining the power supply of the module (5V or 3.3V) as per requirement. The connection of ESP32 CAM setup shown in fig. 7. And the monitoring through webcam as shown in fig. 8.

Fig. 8. Camera monitoring

VIII. APPLICATIONS

Closed Circuit Television (CCTV) camera surveillance systems serve diverse purposes in real-life scenarios, enhancing security, safety, and efficiency across different sectors. Here are some common applications:

Closed-Circuit Television (CCTV) systems play a pivotal role in diverse applications across public and private sectors. In the realm of public safety and security, city surveillance utilizes CCTV to monitor public spaces, streets, and crucial areas for the prevention and investigation of criminal activities.

Transportation hubs, including airports, train stations, and bus terminals, employ CCTV to ensure passenger safety and prevent unauthorized activities. In commercial and industrial settings, retail stores utilize CCTV to reduce theft and fraud, while warehouses and factories enhance security by monitoring access points and production processes. Residential security is bolstered through home monitoring for burglary deterrence, and gated communities secure their premises through surveillance at entrances and common areas. Educational institutions, such as schools and universities, employ CCTV for the safety of students and staff, and healthcare facilities monitor critical areas to enhance patient and staff safety.

Traffic monitoring employs CCTV for traffic flow management and accident detection, and in banking and finance, ATMs and bank branches are safeguarded against robberies and fraud. Critical infrastructure, including power plants and utilities, relies on CCTV for preventing unauthorized access, and event security ensures attendee safety at public events and large gatherings. Additionally, remote monitoring and surveillance are extended to locations such as oil rigs, construction sites, and vacation homes to enhance security when owners are away.

IX. Results

CCTV surveillance systems serve as a robust tool for security enhancement, actively deterring criminal activities by their visible presence. The recorded footage provides crucial support for investigations, offering valuable evidence for law enforcement agencies. Real-time monitoring capabilities empower immediate responses to events and potential threats, with the system designed to record only when motion is detected, optimizing storage efficiency. The preventive aspect is reinforced as CCTV cameras act as a visible deterrent, discouraging unauthorized activities in monitored areas. Continuous monitoring not only improves safety in public spaces, commercial areas, and residences but also ensures comprehensive coverage through features like pan-tilt-zoom and wide-angle lenses. The incorporation of clear alert protocols contributes to proactive incident prevention and management. Furthermore, a commitment to legal compliance, privacy protection, and well-defined access policies is prioritized to maintain ethical standards. Regular maintenance, personnel training, and meticulous documentation practices collectively contribute to the longevity and reliability of CCTV systems.

X. Conclusion And Future Scope

CCTV surveillance stands as a crucial cornerstone in contemporary security measures, effectively discouraging criminal activities and contributing to the creation of safer environments. The integration of cutting-edge technologies, such as real-time monitoring and expansive coverage, enables proactive incident management. Beyond its preventive function, CCTV systems play an invaluable role in investigations by supplying essential evidence. Achieving a delicate equilibrium between legal compliance, privacy safeguards, and system reliability, CCTV surveillance emerges as an indispensable asset for ensuring safety in public spaces, commercial hubs, and residential areas. Its enduring significance lies not only in augmenting security but also in fostering confidence within communities, making it an essential tool for safeguarding individuals and properties alike.

Surveillance systems using CCTV cameras have bright futures ahead of them. We can use higher configurations cameras also. Anomaly detection is improved by integrating AI with facial recognition and behavior analysis. Real-time monitoring will be enhanced by body-worn cameras, smartphone surveillance applications, and advanced analytics. Remote access and expandable storage are made possible via cloud integration. System integrity is guaranteed by cybersecurity measures. Urban planning and safety are improved by environmental sensors and integration with smart cities. System efficiency is enhanced via user-friendly interfaces, energy-efficient technologies, and drones for aerial observation. Global cooperation in tackling security issues is a crucial component of these initiatives' future scope.

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