"Design and Development of Real-Time IoT Based Motion Activated Surveillance System Using ESP32"

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ABSTRACT:

With the rapid Advancement of Internet of Things (IoT) Technology, Smart Camera Systems without wire have become more popular for various applications, including Surveillance, Security, and Wildlife Monitoring. In common, all Camera Systems obviously needs a constant power supply, limiting their deployment in remote or hard to reach areas. This project presents a low-power, the ESP32 Microcontroller based Motion-Activated Camera System. The system integrates a Smart Camera Module, PIR motion sensor, and Real-Time Clock (RTC) to capture images upon detecting motion. The ESP32's deep sleep mode is utilized to minimize power consumption, allowing the system to run for extended periods on a single charge. When motion is detected, the PIR sensor triggers the ESP32 to wake up, capture an image, and save it to a micro-SD card. The system then returns to deep sleep mode, awaiting the next motion event. The RTC ensures that the system maintains accurate time keeping, even during extended periods of inactivity. This project demonstrates a cost-effective and energy-efficient solution for motion- activated photography.

Key words: Internet of Things, Camera Systems, Motion sensor, Surveillance.

1. Introduction:

The rapid Advancement of Technology has led to the Development of various types of surveillance systems. These systems have become an essential component of modern life, providing security and monitoring capabilities for homes, industries, and public spaces. However, most surveillance systems require a continuous power supply and do not have the capability to capture images at specific intervals.

Recent years have seen a significant increase in the use of Internet of Things (IoT) devices, which have enabled the development of more efficient and cost-effective Surveillance Systems. One such device is the ESP32 microcontroller, which has built-

This project aims to Design and Development an ESP32-based surveillance camera that uses a Real Time Clock (RTC) and Motion Sensor to capture images at specific intervals. The system will conserve power by only capturing images when motion is detected, making it an energy-efficient solution for surveillance applications. The proposed system has more advanced application such as Home Security, Industrial Surveillance, Wildlife Monitoring, and Traffic Monitoring. The system's low power consumption and ability to capture images at specific intervals make it an attractive solution for applications where power efficiency and image capture are critical.

This project will provide a comprehensive overview of the Design and Development of the ESP32 - based Surveillance Camera, including the hardware and software components, System Architecture, and Testing and Validation Procedures. The project will also discuss the advantages and limitations of the proposed system and provide recommendations for future improvements.

2. Literature Survey:

In this section, the existing models on the Motion Sensor Camera are addressed.

2.1 N. Aishwarya et al., [1] developed a Motion Detector where the ESP32 CAM with external wake up enabled, is in deep sleep mode. The PIR Motion Sensor sends a signal to wake up the ESP32 as the motion is detected. In the micro-SD card the photo is taken and saved in the ESP32- CAM. A new signal from the PIR motion sensor is send to wake up from the deep sleep mode.

2.2 Filantropi Yusuf Aji Cahyono et al., [2] created a device that is able to increase the security of the room at home by utilizing the ESP32 Cam as a Microcontroller and the PIR sensor as a detector of movement when crossing the corner area of the sensor and also the Fire Sensor key as a detector of fire. The test results have been running in accordance with the designed system. So that pictures taken and notifications of fire can be sent to the telegram application with a 100% success percentage.

2.3 Pradeep Palkar et al., [3] created a project that presents an Internet of Things (IoT)-based Home Monitoring System intended to improve Home Security by providing Real-Time Image capture and immediate alerts. The system offers a quick and easy way to remotely monitor activity at home by taking pictures when motion is detected and sending them straight to the user through a Telegram bot. This method is lightweight and economical because it does not require complicated interfaces or cloud storage. Users can receive real-time visual updates on their smartphones from any location thanks to the integration of Telegram, which guarantees secure and instant communication.

2.4 Vijay Gaikwad et al. [4] created a project that integrates an ESP32-CAM module, PIR Sensors, and a Servo Motor to create an Automated Surveillance System. The PIR Sensors Detect Motion in their respective directions, prompting the servo motor to rotate towards the detected motion. Simultaneously, the ESP32-CAM captures an image as soon as the servo motor adjusts its position. The captured image is then promptly sent and stored on a designated Google Drive account through the Google Drive API, providing a Real Time Security Monitoring Solution.

2.5 Kennedy Okokpujie et al., [5] created a study that introduces a cost-effective, real-time surveillance system, integrating the ESP32 microcontroller with an OV2640 (OV) camera and a Pyroelectric Infrared (PIR) sensor, leveraging Internet of Things (IoT) technology. The system is designed to detect motion, alert users via SMS in the event of an intrusion, and transmit real-time video using the TWILIO Application Programming Interface (API), which facilitates global communication through SMS, voice, and wireless services. Upon deployment and testing, it was observed that the system effectively corresponds the visual images on the Ismart platform with the actual real-time video captured within the coverage area.

2.6 Aniket Patil et al., [6] created a project that focuses on the Design and Implementation of an efficient and cost-effective Security Camera System utilizing the ESP32-CAM Microcontroller and Blynk, a popular Internet of Things (IoT) platform. The primary objective is to monitor the Motion Activated Surveillance System that not only captures and records video footage but also sends real-time notifications to the user's mobile device. The core component of this security system is the ESP32-CAM, which has a motion sensor and a camera module.

3. Proposed Methodology

The system captures images or records video when motion is detected and timestamps the event using a Real- Time Clock (RTC). The ESP32-CAM with OV2640 module, equipped with a PIR motion sensor, serves as the core component for detecting movement and capturing images, displaying the status of the circuit on the OLED display and storing the captured images in the SD card.

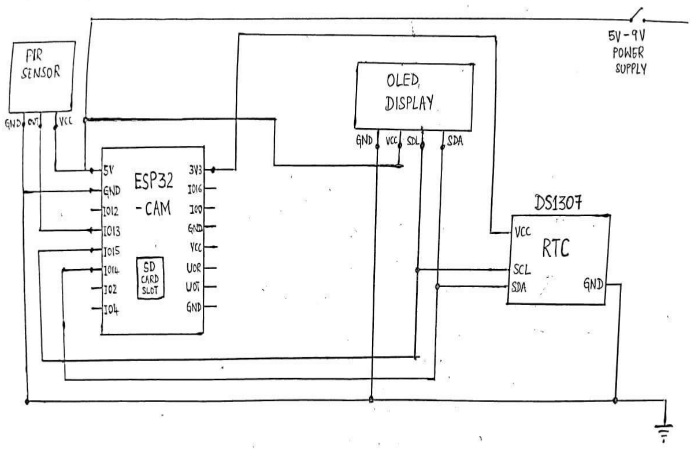


Fig. 3.1: Circuit diagram of ESP32-CAM motion sensor camera

3.1 Key components

ESP32-CAM Module – A low-power microcontroller with a built-in OV2640 camera.

PIR Motion Sensor – Detects motion based on infrared radiation[7].

RTC Module (DS1307) – Keeps track of the date and time even when power is off.

MicroSD Card Module – Stores captured images or video.

Li-ion Battery with Charging Circuit – Provides power for standalone operation system

Wi-Fi Connectivity – Sends images to a server, cloud, or email.

4. Implementation:

4.1 Setup and Configuration : The ESP32 board is connected to the computer using a USB cable. The necessary libraries and board support package in the Arduino IDE are installed. The ESP32 board is configured to use the OV2640 camera module, DS3231 RTC module, and PIR motion sensor module.

4.2 Camera and RTC Setup : The OV2640 camera module is initialized and the resolution and frame rate is set. The DS3231 RTC module and the current date and time is set. The RTC module is used to synchronize the camera's timestamp with the current time.

4.3 Motion Sensor Setup : The PIR motion sensor module is initialized and the sensitivity and trigger mode is set. The motion sensor is used to detect movement and trigger the camera to take a photo.

4.4 Image Capture and Storage : When motion is detected, the OV2640 camera module is used to capture a photo. The captured image is stored on the ESP32's internal storage or an external SD card.

4.5 Time stamping and Logging : The DS1307 RTC module is used to timestamp each captured image with the current date and time. The captured images and their corresponding timestamps are logged to a file or database[8].

4.6 Power Management: Power-saving features are implemented to minimize power consumption when the camera is not in use. The ESP32's deep sleep mode is used to reduce power consumption when the camera is not triggered.

4.7 Formatting micro SD: The ESP32-CAM has an integrated SD card interface that allows us to connect an SD card directly to the module. The ESP32-CAM uses the SPI (Serial Peripheral Interface) to communicate with the SD card.

4.8 SD Card Type: a standard SD card is ensured to be used (not microSD) and it is formatted with FAT32. Most SD cards (up to 32GB) are formatted with FAT32, which is required for use with the ESP32 -CAM.

4.9 Capacity: While the ESP32-CAM can support SD cards with capacities up to 32GB, FAT32 is typically the recommended file system. Higher capacity cards (e.g., 64GB) might not work unless formatted in FAT32.

4.10 Setting up of Arduino IDE: Arduino IDE is used to program the ESP32-CAM board. Arduino IDE installed ie required along with the ESP32 add-on. First Arduino IDE was set up and installed. The code starts by including the necessary libraries to use the camera. The libraries is needed to interact with the microSD card.

4.11 ESP32 Camera: For controlling the camera module.

5. Uploading of code

The ESP32-CAM board is connected to the computer using an FTDI programmer

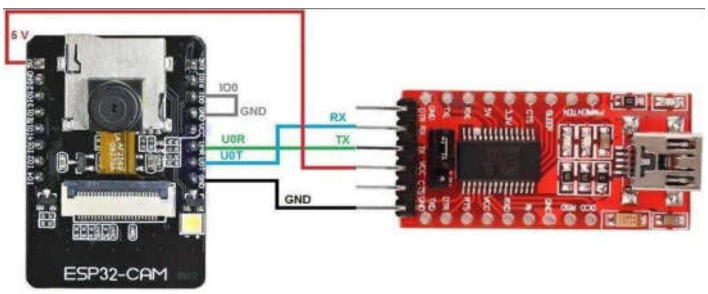


Fig. 5.1 Connections between ESP32 and TTL converter

To upload the code, the next steps were followed:

5.1 Tools > Board and AI-Thinker ESP32-CAM was selected.

5.2 Tools > Port and the COM port the ESP32 is connected to was selected.

5.3 Then, the upload button to upload the code was clicked

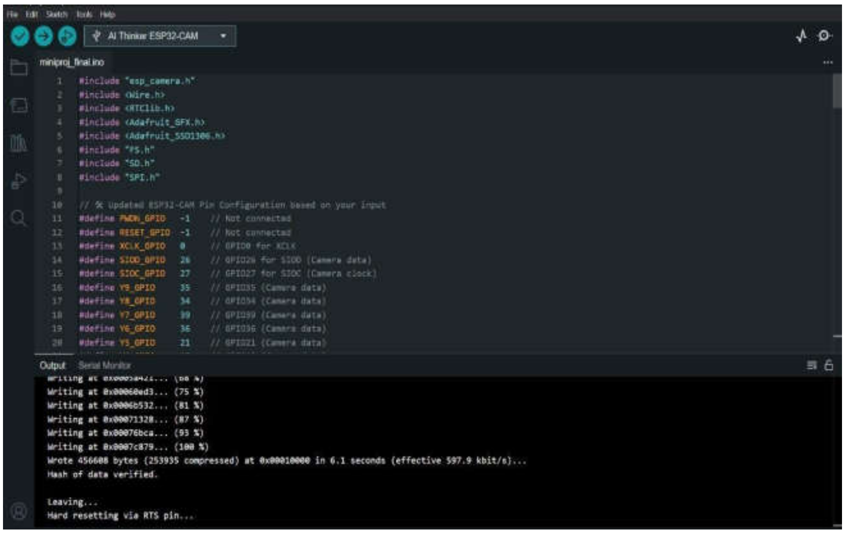


Fig. 5.2: Code Upload

After a few seconds, the code was successfully uploaded to the board.

After uploading the code, GPIO 0 is disconnected from GND. The Serial Monitor was opened at a baud rate of 115200. The ESP32-CAM on-board Reset button was pressed. The code starts running and the status of the circuit and output can be monitored on the serial monitor.

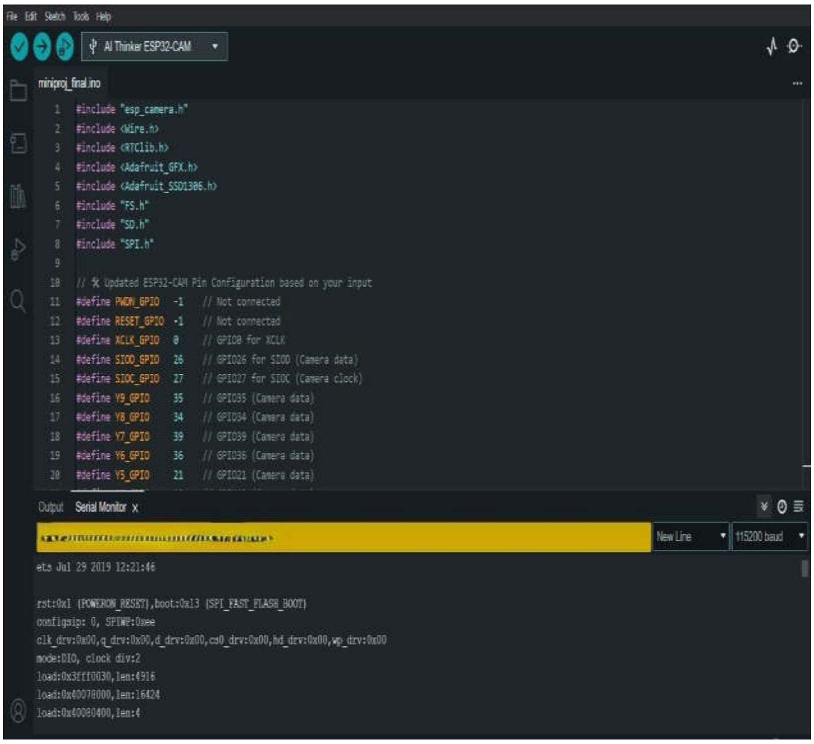


Fig.5.3 : Serial Monitor

The code is written in C++, specifically tailored for the ESP32 CAM microcontroller. It utilizes Arduino libraries to interact with the ESP32 hardware, camera, PIR sensor, OLED display and real -time clock (RTC).

6. Results, Analysis and Discussion

This circuit is designed to create a motion-triggered camera system that captures images with timestamps and displays the current status using an OLED display. The power supply is managed by a TP4056 module that charges a Li-ion battery (connected to the circuit) through the laptop's USB port. In the end, the captured image is stored in the SD card which we then accessed through the computer.
After uploading the code, the jumper that connects GPIO 0 from GND is removed.
Serial Monitor at a baud rate of 115200 is opened. The ESP32-CAM reset button is pressed. The PIR sensor detected the object. This initializes the camera and takes a photo. When it takes a photo it turns on the flash (GPIO 4) as shown in the image below.

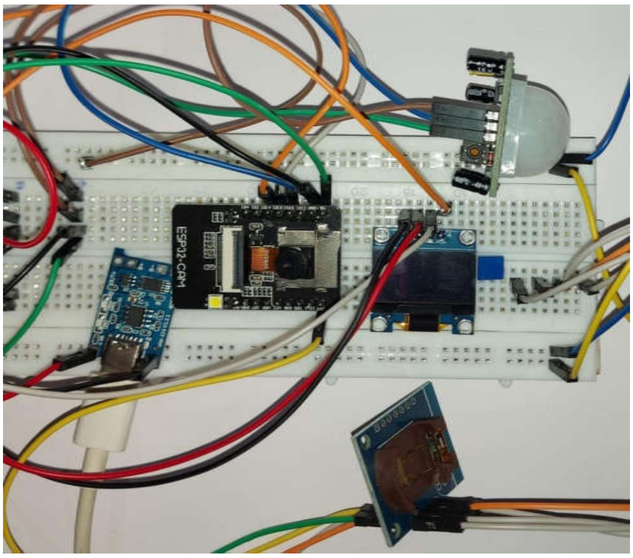


Fig. 6.1: Implemented Circuit

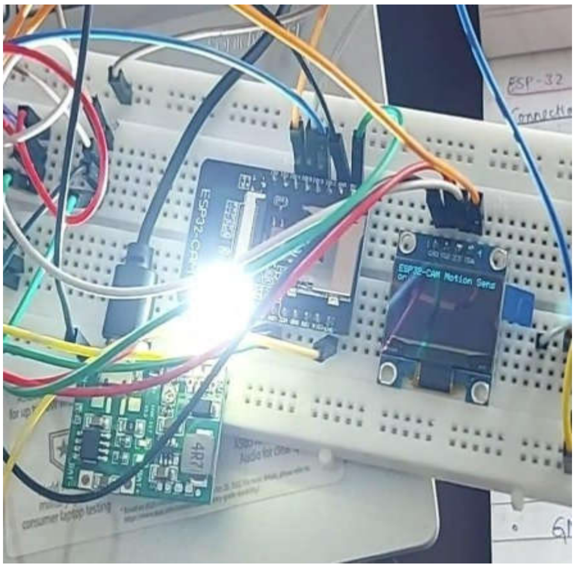
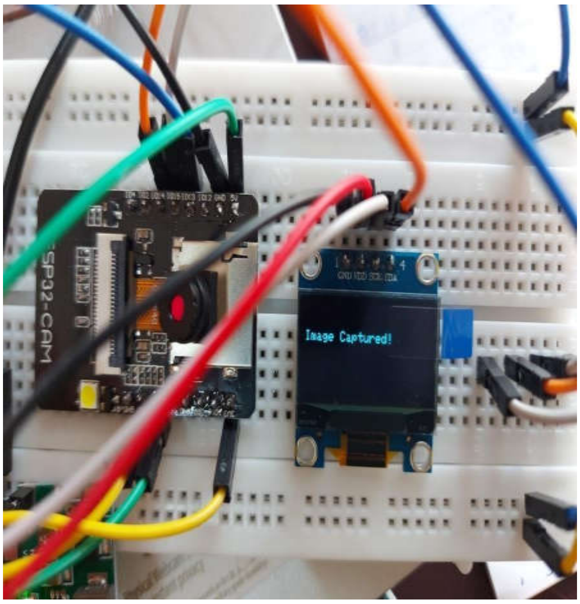


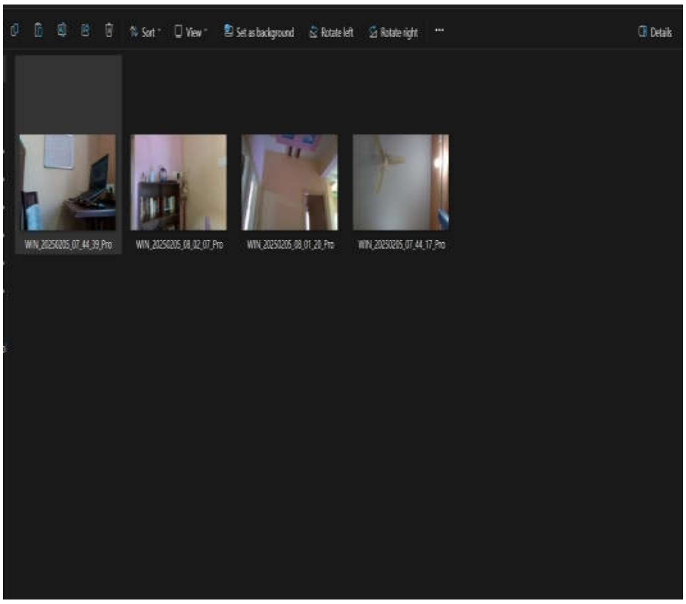
Fig.6.2: Flash LED on ESP32 CAM

The working of Arduino IDE Serial Monitor window is checked to monitor if every thing is as expected. The picture is successfully saved in the microSD card with the OLED display showing “Image Captured” as shown in the image. After monitoring monitoring and confirmed that everything is working as expected, the ESP32-CAM is powered using an independent power supply and disconnected from the FTDI programmer.

Fig. 6.3: OLED displaying the status

Fig. 6.4: Accessing saved images from the SD card





To check the photos status from the microSD card slot the microSD card is removed and inserted into the computer. The saved photos are accessed as shown above in 6.4.

7. Conclusion and Future Scope

The ESP32-CAM-based motion detection system is a cost-effective, low-power, and scalable solution suitable for various surveillance and monitoring applications. By combining an ESP32 microcontroller, PIR motion sensor, RTC module, and camera, the system can efficiently capture images or videos upon detecting motion, providing valuable insights for security, wildlife monitoring, and industrial surveillance. The system's low power consumption is especially advantageous for battery-powered applications. The ESP32 can operate in deep sleep mode to conserve energy, The inclusion of the RTC ensures accurate time-stamping, while the ability to store captured data on a microSD card or upload it to cloud storage enhances the system’s usability and flexibility.

Overall, this project demonstrates the effectiveness of combining low-cost, widely available components for creating a practical and efficient surveillance system, making it a valuable tool for home security, wildlife research, and industrial monitoring.
In the future, it can be used in enhanced camera modules, advanced image processing, cloud storage integration, alert system expansion, robotics and autonomous vehicles and traffic monitoring .

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