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IMPLEMENTATION OF IOT ON LOW POWER CONSUME SECURITY SURVEILLANCE SYSTEM WITH REAL-TIME ALERT

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ABSTRACT

The rate of security threat around the globe have been of the increase in recent time, the activities ranges from theft, kidnapping and among others. In cooperating image and video recorder on surveillance system can help to enhance the security system round the globe. Over the years, some researcher have carried out some researcher on security surveillance system by deploying motion detection, video and image recorders, application of Internet of Things (IoT) but much work have not be done on power consumption and real time alert system. This research work focuses on the development of an IoT based low power consume security surveillance system for real time monitoring and notification of footages. The surveillance system has the ability to provide real-time image of any criminal activities and send the information to the appropriate authorities without human interference. The research work consists of an ESP32 Camera module, Passive Infrared (PIR) sensor, Arduino nano, servo motor, and a power supply from a Universal Serial Bus (USB) source for efficient and portable operation. From the results obtained from the research work, it shows that the developed security surveillance system is robust, energy-efficient, and cost effective with a motion detection false alarm of 3%, and response time for image capturing of 300ms and data transfer accuracy of 97.8%. This device is suitable in environment that required real-time monitoring and video recording in order to improve the security system in that location.

Keywords: Security, Image, Video recorder, ESP 32 Camera Module, Passive Infrared (PIR) sensor

INTRODUCTION

The needs of effective security solutions in residential, commercial, and public spaces has driven the development of surveillance technologies. The level of insecurity around the world has increase in recent time, the activities of insecurity ranges from kidnapping, theft and so on. Surveillance system can be image capturing alone, video recording alone or combination of both. The surveillance system can operate as a manual, partial-automated and fully-automated system. Conventional security systems often rely on continuous recording and monitoring, which can be resource-intensive and inefficient (Chen, 2019). The advent of the Internet of Things (IoT) has opened up new possibilities for creating smarter, more efficient security systems that can operate autonomously and provide real-time data to users (Gubbi et al., 2013.).One of the key advancements of IoT-based security systems is the ability to integrate image capturing and video recording devices with motion detection capabilities.

The major problems with the conventional security system, it is the continuous recording, large storage consumption, and limited field of view (Muhammad et al., 2018). In order to address these problems, the integration of ESP32-CAM module of high-resolution image and video capture ability with a wireless transmission system, a PIR sensor for motion-activated recording, a servo motor for adjusting the camera orientation, and a USB connection which provides a reliable power source will be deployed in this research work.

The authors in Amad et al., (2019) addresses challenges of a traditional security systems that deployed Sum of Absolute Differences (SAD) algorithm to detect motion in real-time. Whenever motion is detected, the system only records the relevant footage and triggers the alarming system. The research work only focuses on software-based motion detection algorithm without transmitting real-time data or camera control. In sharma et al., (2021), the authors highlight the important of IoT in connection with various sensors and how they can be applied in the design of smart applications. In lee et al., (2020), the authors investigate the use of PIR sensors and servo motors for dynamic surveillance. The research work demonstrates the effectiveness of motion detection and servo control in enhancing security systems but fail to address the issues of power management and its influence in the reliability and durability of IoT-based security systems. A smart home automation system using IoT with Raspberry Pi for surveillance system was implemented in Patchava et al., (2015). The system uses 14 Computer Vision techniques to control home appliances and perform surveillance activities. Whenever motion is detected, the camera takes record of the intruders' identities while the Raspberry Pi is use to send SMS and alarm call to the home owner. In garcia (2019), the author conducted a comparative analysis for an analog CCTV systems and digital IoT-based surveillance systems. The advantages of digital systems were highlighted which ranges from improved image quality and remote accessibility. The research work fails to address the recent advancements in IoT components such as ESP32-CAM for image recording. The authors in (Ganiyu et al., 2020), design an improved digital video surveillance camera, the device was able to monitor the footages of a particular environment and transmitted the output signal via the internet. Muthusenthil and Kim,(2018) reviewed past and present research work for Closed Circuit Tele-Vision (CCTV) video surveillance system in terms of technology deployed and operational strength. The author (Chyan, 2019), design an intelligent security camera with image enhancement support. The device has the ability to intercept and provide real-time information of any criminal activities without human interference; it uses PIC184522 microcontroller and Universal Asynchronous Receiver/Transmitter to interface with other hardware devices. (Sultana and Wahid, 2019) design and implemented an IoT-guard for real-time management system to prevent and predict crime event in a smart home. Artificial intelligent (AI) was deployed to detect and confirm crime event and event-driven method was used to send information to the appropriate authority. In (Muhammad et al., 2018), the authors design a secure surveillance framework for IoT systems using video summarization and image encryption techniques. Probabilistic and lightweight algorithm was used to reduce image losses during transmission and processing of the encrypted images.

The focus of this research work is to develop an IoT based energy efficient security surveillance system for real time monitoring. The surveillance system has the ability to provide real-time image and video of any criminal activities and send the information to the appropriate authorities without human interference.

MATERIALS AND METHODS

The Design and the Hardware Components for the IoT Based Surveillance System

In developing the IoT-based security surveillance system, the discussion of the circuit design and the selection of the appropriate components are essential in order to achieve the required functionality of the system.

The Circuit Design

The design circuit for the implementation of the proposed system is presented in figure 1. The circuit consists of power supply unit through a Universal Serial Bus (USB) source for efficient and portable operation, Camera unit; which provides wireless image and video capturing with transmission capabilities, PIR sensor that detects motion, triggering the ESP32 Camera module to capture images and videos, initiating the recording process. In addition are servo motor which is employed to adjust the camera's orientation for optimal coverage, and an Arduino nano which serves as the central controller, initiating command for the operation of the servo motor and ESP32 camera module as depicted in figure 2. The microcontroller sends a command to the GSM module to notify the Administrators through text message or email. The software is used to control and configure the system, enabling user to adjust detection range and notification settings. The system is powered by a standard 5V DC supply, making it easy to install and operate.

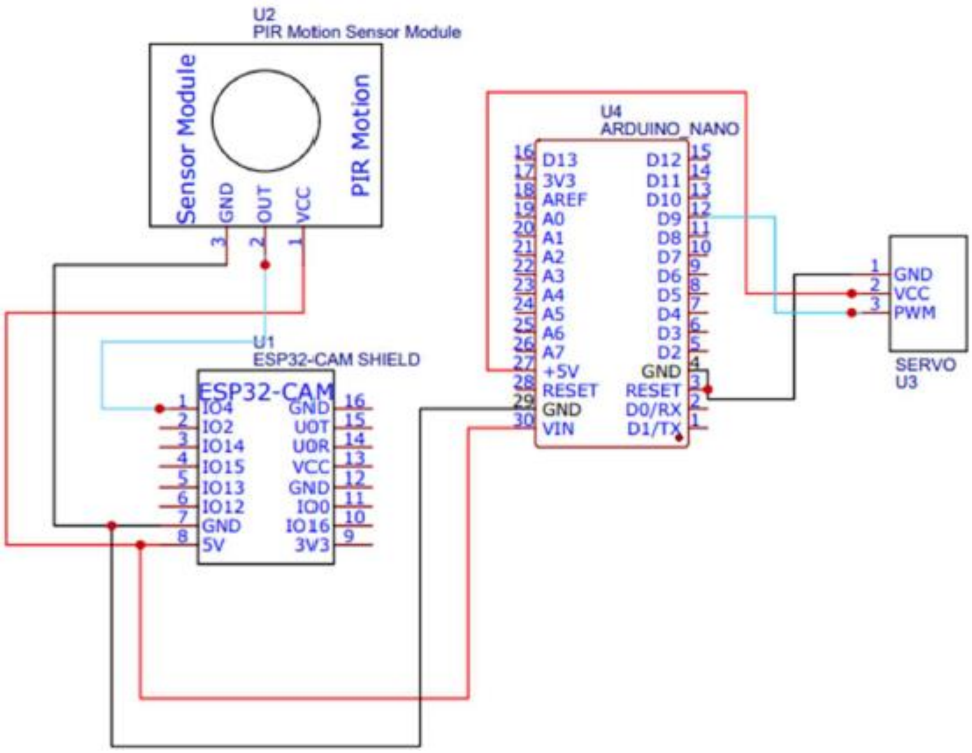

Figure 1: Circuit design for the proposed system

ESP32 Camera Module

The ESP32-CAM is a microcontroller with an in-built Wi-Fi and Bluetooth functionality, designed to capture and process high-resolution images. It features a powerful dual-core processor and integrated camera module, which supports resolutions up to 1600x1200 pixels. The ESP32-CAM is valued for its compact design and low cost, making it ideal for IoT applications that require image capturing and wireless data transmission. Its integrated Wi-Fi capability allows for remote access and real-time image streaming, which is crucial for modern security applications. The picture of ESP32-CAM is shown in figure 2.

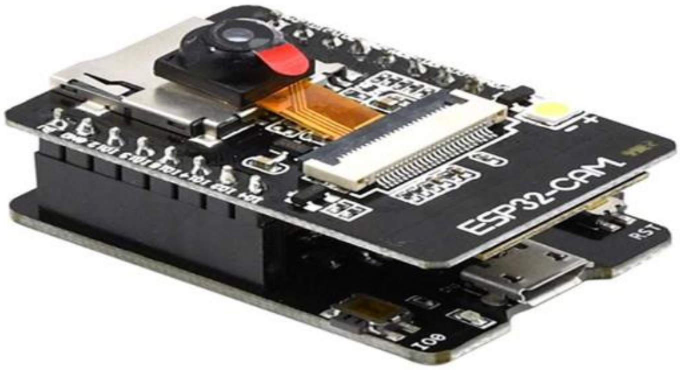

Figure 2: Picture of ESP32-CAM microcontroller

Passive Infrared (PIR) Sensor

The Passive Infrared (PIR) sensor shown in figure 3 is designed to detect motion by sensing changes in infrared radiation, typically emitted by warm objects such as humans and animals. PIR sensors are known for their low power consumption and high sensitivity, which make them well-suited for battery-powered devices in security systems. the PIR sensor is employed to detect motion within the surveillance area. When motion is detected, it triggers the ESP32-CAM to start capturing images. This motion-triggered recording approach helps to conserve battery life and storage space by ensuring that the camera only operates when movement is detected.

Figure 3: Passive Infrared (PIR) Sensor

Servo Motor

Servo motors are used to provide precise control over the movement of mechanical components. They are capable of accurate positioning, making them ideal for applications where controlled movement is required. In this research work, the servo motor is used to adjust the orientation of the ESP32-CAM, allowing it to pan and tilt to cover a larger area. The integration of the servo motor enables dynamic adjustment of the camera's field of view, which is crucial for eliminating blind spots and improving surveillance coverage. The ability to remotely control the servo motor adds flexibility to the system, allowing users to respond to specific security events by adjusting the camera's position as needed. Figure 4 shows the image of a servo motor.

Figure 4: Servo motor (McRuer & Krendel, 2005)

Arduino Nano

Arduino Nano is a compact microcontroller board used for a variety of applications due to its small size and versatility, the image is shown in figure 5. It is commonly used for prototype projects, embedded systems, and educational purposes. The Nano is ideal for electronics projects such as home automation, robotics and so on. It is very good for integrating sensors, controlling motors, and facilitating communication between devices. In this research work, the Arduino Nano is use to control the servo motor operation and ESP32 camera module.

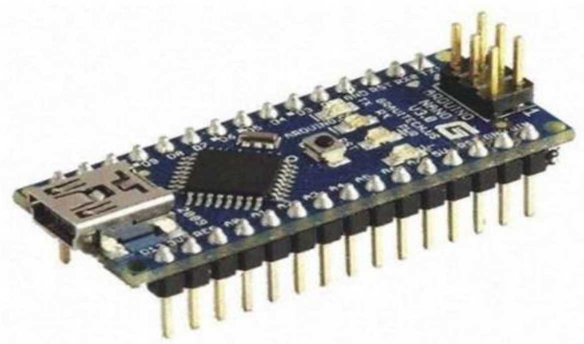

Figure 5: Arduino Nano board (Cameron, 2018)

Universal Serial Bus (USB) Cord

The USB power source cord shown in figure 6 is use to provide regulated electrical power through a USB port, typically delivering 5V Direct Current (DC). It includes devices like wall chargers, power banks, and USB ports on computers. USB power sources are portable, compatible with many devices (such as smartphones and microcontrollers), and ensure stable and reliable voltage for efficient operation. The USB port serves as the primary power source for this research work.

Figure 6: Universal Serial Bus (USB) Cord (Gookin, 2017)

Methodology

The section presents the components specification, methodology and evaluation of the proposed system. The algorithm for the operation of the proposed system was also presented.

Components Technical Specifications

The design specifications for the surveillance system were outlined and presented in Table 1, which include the specifications for ESP32 camera, servomotor, PIR sensor, and Audino-nano. The ESP32-CAM module

Table 1: Design specification for the proposed system

S/N	Parameters	Specification
EPS32-CAM		
1	Microcontroller	ESP32-D0WDQ6 chip
2	Camera	OV2640 camera module
3	Lens	2.8mm focal length
4	Wi-Fi	802.11 b/g/n protocol
5	Operating Voltage	5V DC
PIR Sensor		
1	Detection Range	5-7 meters
2	Detection Angle	120o horizontal /90o vertical
3	Operating Voltage	3.3V - 5V DC
4	Output Signal	Digital Output (High/Low)
Servomotor		
1	Operating Voltage	4.8V - 6V
2	Torque	1.8 kg/cm (at 6V)
3	Speed	0.1 sec/60° at 4.8V
4	Rotation angle	180 degrees
Arduino nano		
1	Chip	ATmega328P
2	Clock Speed	16 MHz
3	Operating Voltage	5V
4	Input/output Pins	14 digital I/O pins and 8 analogue inputs
Power Supply		
1	Voltage	5V DC
2	Current	5Ma

Algorithm for the Proposed System

The algorithm for the operation of the proposed system was developed using Python software package, and the code was burnt into ATmega328P Audino Nano to initiate the command for servo motor, ESP32 camera and the GSM module. The flow chat for the algorithm is presented in figure 7.

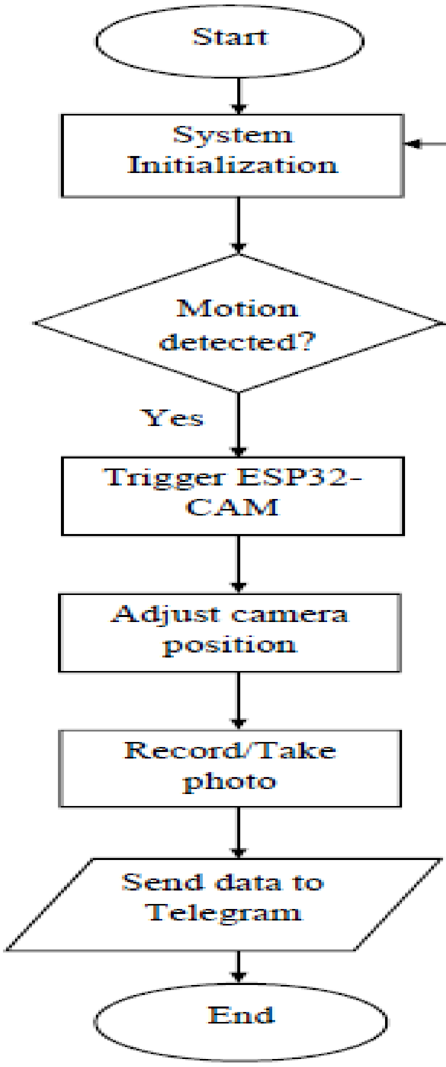

Figure 7: The flow chat for the proposed system

Implementation and Packaging

The GND of the PIR sensor was connected to the GND of ESP32 CAM which in turn connected to the GND of the ATmega328P. The VCC terminal of the PIR is supplied with the required 5V through ESP32 CAM connected to the input terminal of the ATmega328P. The servomotor is also connected to the ATmega328P GND and supplied with 5V through the ATmega328P voltage terminal, and initiated through its PWM signal terminal as depicted in figure 1. The Assembling of all components were done using a weather-resistant enclosure suitable for outdoor such as Plastic. The choice of the enclosure is due to its lightweight, cost effectiveness, and ease of customization.

RESULTS AND DISCUSSION

The functionality and the performance of each component of the proposed system is assessed in this session, ensuring output of each component meet the design specification. The testing involves measuring various parameters and recording numerical values, were used for plotting graphs to visualize the performance of the system.

Testing of the Various Component Functionality

The different component deployed for the surveillance system tested based on their functionality as follows:

ESP32 Camera Module: The tests focus on the image resolution, frame rate, and the reliability of wireless data transfer. The parameters were tested at 600 x 480 resolutions and recorder. The media quality is rated 7/10, and the frame rate were 25, 8, 2 (fps), while transmission latency and reliability of 300 milli-seconds (ms) and 97.8% respectively were obtained.

PIR Sensor: The PIR sensor used in this research work was tested on motion detection range, sensitivity, response time, and tendency to trigger false alarms. The tests were conducted in a medium-sized indoor space with the sensor positioned at a height of 1.2 meters. A human subject walked across various distances and angles to determine the effective range and field of view. Results showed that the sensor reliably detected motion up to 7 meters, with an effective detection angle of 45-120 degree respectively. The average response time was measured at 100ms from the point of motion to system activation. To assess false alarm rates, four non-human moving objects (a rotating fan, toy car, blowing curtain, and plastic bag moved by breeze) were introduced across 20 total trials. Only one false detection occurred, resulting in a 5% false alarm rate. Overall, the PIR sensor demonstrated fast response, good range, and minimal false positives, making it well-suited for real-time motion-triggered surveillance.

Servo Motor: The servo motor was tested to evaluate its movement accuracy, response time, and rotational range in positioning the ESP32-CAM during motion tracking. The motor was programmed to rotate between 0° and 180° in 15° increments, simulating various camera angles. A total of 35 test cycles were conducted, during which the actual position was compared to the intended position using a protractor mounted beneath the rotating camera arm. The observed deviation per movement ranged from 0.5° to 1°, indicating good angular precision. The response time was measured using a stopwatch, recording the time taken for a full 180° rotation, which consistently averaged around 500 milliseconds. Efficiency was calculated based on the number of successful rotations completed without overshooting or stalling; 33 out of 35 cycles were smooth and accurate, resulting in an estimated 85% operational efficiency.

Power supply unit: The dc output voltage and current measured from the power supply unit were 5V and 1A respectively. The output power is stable with minimal fluctuations, and was used to power all component of the system as required. This is supplied to the ATmega328P where it is distributed to the servomotor and PIR sensor.

The system's low false alarm rate of 5% plays a critical role in enhancing practical security system by ensuring that alerts are credible and not ignored due to frequent false triggers, as is common with less accurate systems. This reliability allows for more precise tracking of suspicious or unauthorized activity, enabling quicker identification of genuine threats. Furthermore, the use of a stable USB power source means the system can run continuously for extended periods, which is especially valuable in remote, difficult-to-access, or off-grid locations where frequent maintenance or recharging is impractical. This increases surveillance coverage in areas like isolated buildings, rural environments, or undeveloped sites. Additionally, the low response time, approximately 300 ms for capturing images and 500 ms for full camera movement ensures that motion is detected and acted upon in near real time. This speed is crucial in real-world security situations, as it allows for timely footage delivery and potentially faster mobilization of security personnel before an intruder escapes or a crime is completed. Together, these results suggest the system is not only accurate and energy-efficient but also practical and responsive enough to support real-time threat detection and intervention.

The system was also tested under different scenarios by adjusting motion levels, light conditions and camera angle. It could be observed that the image quality, detection accuracy, and response time remain the same at low motion-bright light, higher motion-low light, as well as variable motion-fixed light conditions. However lower frame rate during fast motion was observed, and this could be fixed by using a better camera. The system's performance in low light condition could also be improved by adding infrared sensors or stronger lighting system.

The time response for system components is shown in figure 9, while figure 8 depict the pictorial views of the proposed system during and after implementation. It could be observed from figure 9 that the PIR sensor have the lowest time responds of 100ms,

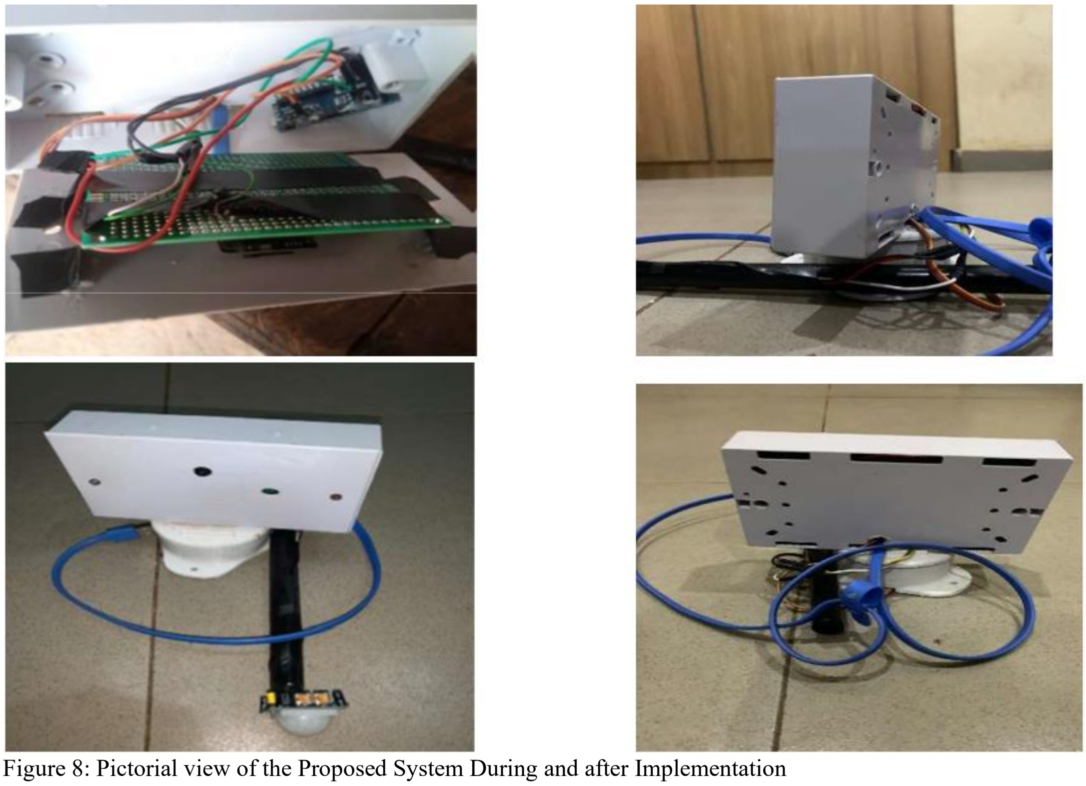

Figure 8: Pictorial view of the Proposed System During and after Implementation

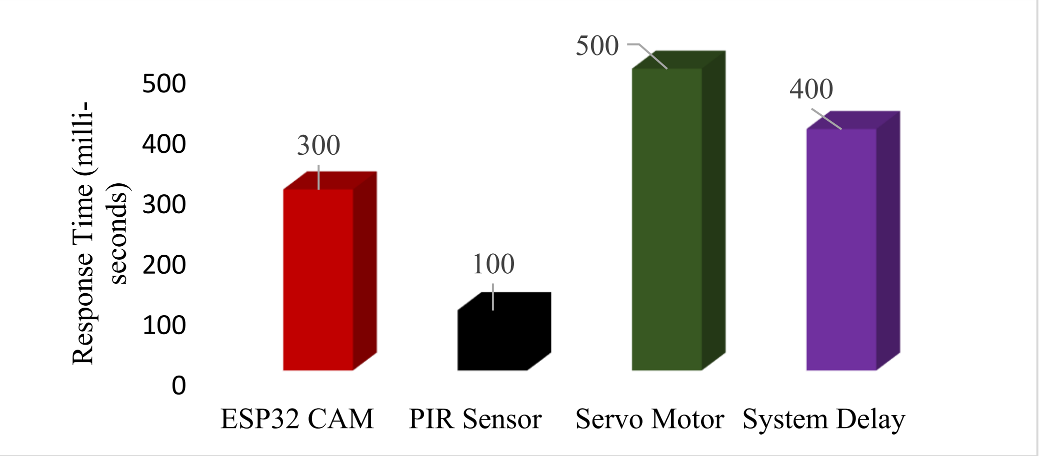

Figure 9: Time response of the system components

CONCLUSION

There is a spark of insecurity around the globe due to activities such as theft, kidnapping and so on. There is need to develop a surveillance system that required less electrical power to operate. The research was carried out using IoT technology, microcontroller, and image and video recorder to report real time footage with low power consumption and enhanced the security system. The key findings from this research work shows that the system performs was efficient across various scenarios, providing reliable real-time motion detection and automated camera control for capturing images and videos. The surveillance system proved to be reliable with minimal system delays, energy efficient, cost effective and adaptable to different environmental conditions, such as varying lighting and motion levels.

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