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IOT BASED SMART SECURITY SURVEILLANCE SYSTEM FOR REMOTE MONITORING AND CONTROL

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Abstract:

Despite the many benefits of Internet of Things (IoT) based security surveillance systems, existing systems have limitations such as lack of worldwide monitoring and control, high cost, and complexity. There is a need for a cost-effective and easy-to-use system that can offer reliable data storage and worldwide monitoring and control, thereby enhancing security in different homes and offices. This study presents the design and implementation of an IoT-based security surveillance system for easy monitoring and control by the user. The proposed system comprises various sensor components, a raspberry-pi-based controller section, user notification capability, video streaming, and portability as prime features. The system uses Passive Infrared Sensor (PIR) to detect human presence, a Pi camera module to record the event, a Wifi module to upload the event recorded to the user's email address, and an SMS module to send an SMS alert. The system was tested and evaluated for efficiency, power consumption, and ease of use with results showing the system's ability to effectively uploads the recorded video to the user's email while conserving energy. Further extensions and feature enhancements were also proposed for future scope.

Keywords: Internet of Things, security surveillance, Raspberry Pi, wireless fidelity, sensor nodes, intruder detection

INTRODUCTION

The Internet of Things (IoT) is a transformative technology that has revolutionized various aspects of our daily lives. It encompasses a network of interconnected devices, machines, objects, animals, and people, all equipped with unique identifiers and the ability to communicate and share data over a network. With IoT, the physical and digital worlds are seamlessly integrated, enabling unprecedented levels of connectivity, automation, and efficiency (Koohang et al., 2022, Taufik et al., 2021, Vaccari et al., 2019). This transformative technology has facilitated connectivity and interoperability between devices, systems, services, and networks, fundamentally changing the way we interact with technology (Taufik et al., 2021).

One of the key applications of IoT is security surveillance systems, aimed at enhancing safety and security in homes, offices, and public spaces (Rajeshkumar et al., 2023, Andrews et al., 2023, Samuda et al., 2023). Traditional security systems have limitations and are prone to human error and system failures. IoT-based security surveillance systems, on the other hand, offer remote monitoring and control, reliable data storage, and automatic event detection, making them more efficient and effective (Paul et al., 2022).

Intelligent Video Surveillance (IVS) systems have emerged as a response to the limitations of traditional surveillance systems. They utilize analytic software to automatically detect objects and security events of interest within video footage (Kumar et al., 2021). However, existing security systems lack important capabilities such as zone barriers, facial recognition, remote surveillance, and power outage detection. To address this, Lulla et al. (2021) proposed a smart surveillance system that utilizes ultrasonic sensors to detect intrusion attempts, warn unauthorized individuals, and notify owners remotely. The system also includes face recognition for authentication and alerts owners in case of power failures, providing a flexible and reliable security solution for various properties.

In their work, Paul et al. (2022) presented an IoT-based security surveillance system that utilized Node MCUs and Wi-Fi connectivity. The system was composed of sensor nodes and a controller section, offering remote user alerts and mobility as key features. By integrating a Wi-Fi-connected microcontroller with a Passive Infrared (PIR) sensor, the system was able to detect object movements and send alerts to the user through an online cloud platform, ThingSpeak, enhancing its surveillance capabilities.

McBride and Sumbwanyambe (2021) presented a hybrid edge-cloud smart surveillance system that uses a Raspberry Pi, NoIR camera, and cloud computing to provide IoT services while maintaining inference locally at the edge device. The system implements the mobile-first SSD MobileNetV3 model for object detection, which is deployed using AWS services such as IoT Greengrass and Lambda. The system can scale to hundreds of surveillance nodes and send notifications to the user through Amazon Simple Notification Service. Various experiments validate the system's performance, achieving positive detections of people and animals in both day and night conditions. Future iterations will focus on zero-touch provisioning and scaling and reducing resource utilization for more resource-constrained devices.

Based on the reviewed works, one identified gap is the lack of a comprehensive security surveillance system that includes all necessary features such as ultrasonic sensors, facial recognition, and power failure detection, while also being cost-effective, compact, and easy to use. While the previous papers have presented systems that include some of these features, none of them provide a comprehensive solution that includes all of them in a single, integrated system. Additionally, while Raspberry Pi has been used in previous works, there is a need for a more specific focus on the development of a security surveillance system that is specifically designed to be compact, cost-effective, and easy to use while including all necessary features. This current paper aims to address this gap by presenting a comprehensive security surveillance system that meets all of these requirements.

This paper presents an IoT-based security surveillance system using a Raspberry Pi Single Board Computer with network connectivity. The system includes sensor nodes and a controller section, enabling remote user alerts, video streaming, and portability.

Materials and method

System Description

The proposed system consists of a microcontroller, an ultrasonic sensor, a GSM module, and software. The ultrasonic sensor can be installed anywhere around the location of interest, and when a human presence is detected within the configured range of 1 to 70cm, a signal is to be sent to the microcontroller. The microcontroller then sends a command to the GSM module to notify the homeowner via text message or email. The software is used to control and configure the system, allowing users to adjust the detection range and notification settings. The system is powered by a standard 5V DC power supply, making it easy to install and operate.
The system uses embedded systems designed to perform a specific task, and Raspberry Pi is one of the commonly used platforms for IoT applications. The project aims to program a microcontroller to achieve the security surveillance system's goal, and the system uses a passive infrared ray sensor to trigger motion detection. The use of Raspberry Pi eliminates the need for a wireless transceiver module, making the system compact, cost-effective, and easy to use.

Design Specification

The hardware design of the IoT-based Smart Doorbell System consists of four main components: the microcontroller, ultrasonic sensor, GSM module, and power supply. The microcontroller used in the system is an Arduino Uno, which serves as the brain of the system. It is responsible for receiving signals from the ultrasonic sensor and processing them to determine if a human presence has been detected. The ultrasonic sensor is an HC-SR04 model, which emits high-frequency sound waves and measures the time taken for the sound waves to reflect from any obstacle in its range. The sensor is positioned near the door and is configured to detect human presence within a range of 1 to 70cm. The GSM module used in the system is a SIM800L model, which allows the system to send text messages or make phone calls to notify the homeowner when human presence is detected at the door.
The system can be powered by a standard 5V DC power supply or a 9V battery, depending on the user's preference. All components are connected using jumper wires and a breadboard, making the system easy to assemble and modify. The system's hardware design is simple yet effective, enabling it to detect human presence reliably and efficiently. The PIR sensor Gnd and Vcc pin are connected to the 5v and GND pin of the Raspberry Pi. The Dout of the ultrasonic sensor is connected to the 3.3v pin of the microcontroller and the PI camera is connected to the camera slot of the microcontroller. The Camera module is triggered when the PIR sensor detects motion. The 220 ohms resistor will be used to limit the voltage going to the LED.

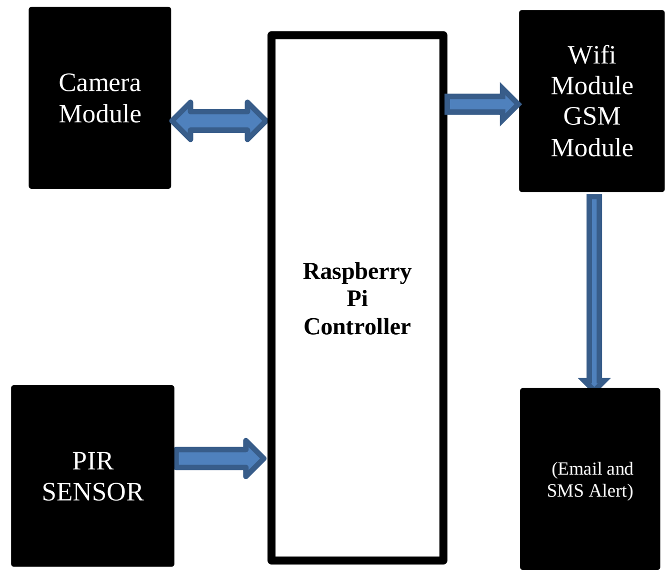

Figure 1. Block Diagram of the system

Table 1: Components Lists

Hardware Component	Pictorial view	Hardware Description
Raspberry Pi		Raspberry Pi is a credit card-sized single-board computer (SBC) that has gained widespread popularity as a versatile and affordable computing platform. It is developed by the Raspberry Pi Foundation as a small but powerful computer and has opened up a world of possibilities for hobbyists, educators, and professionals alike. With its compact size, low power consumption, and wide range of connectivity options, Raspberry Pi has found applications in diverse fields, including home automation, robotics, media centers, and security surveillance systems.
Passive Infra-Red Sensor		The Passive Infra-Red (PIR) sensor is a type of motion detection sensor that operates based on the infrared radiation emitted by objects. It has found wide applications in security surveillance systems, smart homes, and automation systems due to its ability to detect human presence without direct contact or interaction. The PIR sensor can sense changes in the infrared radiation emitted by objects in its detection range, which allows it to detect motion and trigger actions accordingly.
Raspberry Pi Camera		The Raspberry Pi Camera is a versatile and powerful camera module specifically designed for use with the Raspberry Pi Single Board Computer (SBC). It offers a cost-effective and compact solution for capturing high-quality images and videos in a wide range of applications, including security surveillance, robotics, home automation, and multimedia projects. The Raspberry Pi Camera module comes in different versions with varying capabilities, including different resolutions, frame rates, and lens options, allowing users to choose the most suitable camera module for their specific needs.
Sim 800L GSM Module		The SIM800L GSM module is a widely used and affordable module for the Internet of Things (IoT) and embedded systems. It supports quad-band GSM/GPRS communication, has a serial interface for easy integration, and supports standard AT commands for configuration. It is commonly used in various IoT applications such as home automation, smart agriculture, vehicle tracking, remote monitoring, and security systems. However, it requires a valid SIM card with an active data plan and proper handling. In summary, the SIM800L GSM module provides reliable and cost-effective communication over the GSM network for a wide range of IoT applications.
ESP 8266		The ESP8266 is a cost-effective Wi-Fi microchip that features a full TCP/IP stack and microcontroller. This compact module enables microcontrollers to establish Wi-Fi connectivity and establish basic TCP/IP connections using Hayes-style commands.

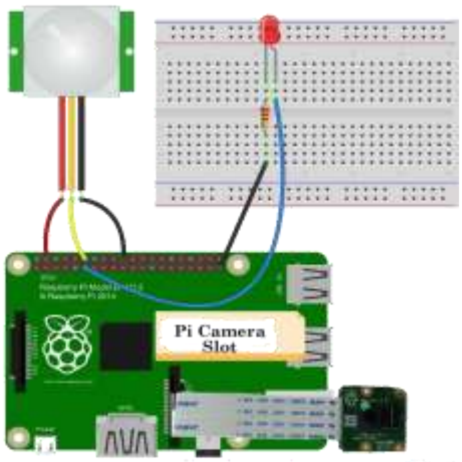

Figure 2. Pictorial Layout for IOT-Based Smart Surveillance System (Saad, 2016)

1.2. PIR Sensor Features

The *PIR Sensor* is designed to accept a wide range of input voltage, ranging from 4V to 12V, with +5V being recommended. The output voltage is in the form of High/Low signals (3.3V TTL). The system is capable of distinguishing between object movement and human movement, with two operating modes - Repeatable (H) and Non-Repeatable (H). It has a coverage distance of approximately 120° and can detect movement up to 7 meters away. Additionally, the system has low power consumption, drawing only 65mA. It is designed to operate in a wide temperature range, from -20°C to +80°C

SOFTWARE DESIGN AND IMPLEMENTATION

The software design and implementation of the IoT-based Smart Doorbell System involve the development of the system's control and configuration software using Python. The software is responsible for controlling the system's components, including the ultrasonic sensor, the Raspberry Pi, and the GSM module. It is written in Python 3 and is designed to run on the Raspberry Pi. The software is divided into two main parts: the initialization function and the main loop. The initialization function is executed once at the start of the program and is responsible for configuring the system's components, including the ultrasonic sensor and the GSM module.

The main loop is executed repeatedly and is responsible for continuously checking for human presence at the door. When the ultrasonic sensor detects human presence within the configured range, the main loop sends a command to the GSM module to notify the homeowner via text message or phone call. The software also allows the user to adjust the detection range and notification settings using a simple menu-based interface. This interface is implemented using the Python curses library and can be accessed via the terminal. The software was developed using the PyCharm Integrated Development Environment (IDE) and was run on the Raspberry PI's Raspbian operating system. The system's low-level hardware interaction was facilitated using the RPi.GPIO library and the TinyGSM library.

SYSTEM FLOWCHART

To start, the system initializes and begins operation by booting the Raspian operating system running on the device. Afterward, the PIR sensor enters a loop that continuously senses motion. If any movement is detected, a short video or snapshot (depending on the predefined configuration) is taken by the attached Raspian Pi camera and saved in a storage device. The system then generates a notification to the user through the preconfigured phone number and email address. During operation, the system continuously monitors its status, including camera status, storage capacity, and communication connectivity, to ensure proper functioning. The system stops operation or goes into standby mode until the next image/video capture event.

Table 2. PIR Sensor Pin Configuration

Pin Number	Pin Name	Description
1	Vcc	The system is designed to operate with an input voltage of +5V for typical applications, but it can also accept a wider range of input voltage from 4.5V to 12V.
2	High Low Output (Dout)	When the system is triggered and motion is detected, the digital pulse goes high at 3.3V. On the other hand, when the system is idle and no motion is detected, the digital pulse goes low at 0V.
3	Ground	Connected to the ground of the circuit

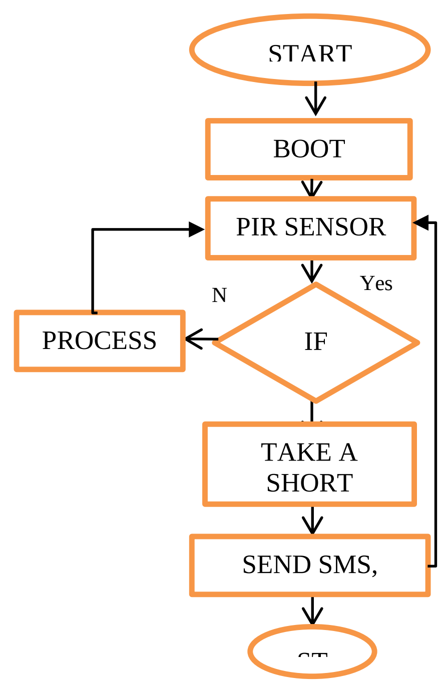

Figure 3. System's Flowchart

RESULTS AND DISCUSSION

Device Interface

The system is made up Passive Infrared Sensor, Pi Camera Module, GSM Module, and Raspberry Pi. The Raspberry Pi controls all other modules within the system. Once the PIR sensor detects a human motion, it will send an SMS to the user and it activates the camera to record a 10 seconds video about the event. Upon completion, it uploads the recorded video to the user's email. Figure 4 shows the device interface upon completion while Figure 5 shows its internal view.

Figure 4. Smart Surveillance System View

Figure 5. Smart Surveillance System Internal View

Functionality Test

To validate the efficiency and ease of use of the proposed system, a functionality test was conducted which comprises the following steps:

i) *Sensor Node Testing*: The Passive Infrared Sensor (PIR) used for human presence detection was tested by simulating human movement in the monitored area and verifying if the system accurately detected the presence and triggered an event.

ii) *Controller Section Testing*: The Raspberry Pi SBC, Wi-Fi module, Pi camera module, and SMS module were tested for their functionality and integration with the system. The Raspberry Pi SBC was programmed to process the sensor-based events, capture video using the Pi camera module, and send alerts via email and SMS using the Wi-Fi and SMS modules respectively.

iii) *Event Recording and Upload Testing*: The system was tested for video recording and uploading functionality. Human presence events detected by the PIR sensor were recorded using the Pi camera module, and the recorded video was uploaded to the user's email address using the Wi-Fi module.

iv) *Alert Testing*: The system was tested for its alerting functionality. Alerts were sent to the user's email and SMS using the Wi-Fi and SMS modules respectively upon detection of human presence events by the PIR sensor.

Based on the functionality test results shown in Figures 6 - 8, the designed system was found to be efficient, reliable, and easy to use. The system successfully detected human presence events, recorded video, and sent alerts via email and SMS.

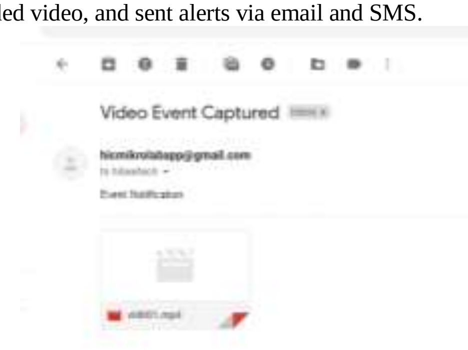

Figure 6: Video Received in the Email

Figure 7. Screenshot of Email Alert in Desktop

Figure 8. Video Interface

Power Consumption Test

A power consumption test was conducted to measure the energy consumption of the proposed system. The purpose of the test was to determine the system's power requirements and assess its energy efficiency during operation over 24 hours. To achieve this, the following steps were performed:

i) Setup and Measurement: The system was set up in a controlled environment with a stable power source and energy meter. All components of the system, including the Raspberry Pi SBC, Wi-Fi module, Pi camera module, SMS module, and PIR sensor, were connected and powered up using a 5V DC power supply. Energy consumption readings were then recorded at regular intervals using an energy meter. The energy meter was connected between the power supply and the system to measure the total energy consumed by the system during the test period.

ii) *Active and Passive State Test*: The system was operated in an active state, simulating real-world usage, with the PIR sensor detecting human presence events, the Pi camera module recording video, and the Wi-Fi and SMS modules sending alerts to the user's email and SMS respectively. The power consumption is recorded at regular intervals. The system was also put in a passive/idle state by ensuring the PIR sensor is not triggered thereby ensuring no video recording or alerts are sent. Power consumption readings are also recorded at regular intervals. Figure 9 presents a comparison of the two sets of results. In the active state, where the PIR sensor detects human presence events, and the system is actively recording video and sending alerts, the power consumption is shown to be higher than in the passive state where no recording and transmission activity is taking place. The PIR sensor, Pi camera module, Wi-Fi module, and SMS module are largely responsible for the power consumption in this active state.

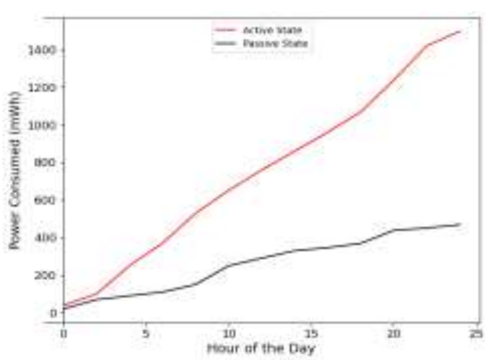

Figure 9. Power Consumption Test Graph

Conclusion

This paper presents an IoT-based surveillance camera system to address the limitations of traditional surveillance systems. Depending on how the system is configured, the proposed system can provide real-time motion detection and automatic uploading of video content to the owner's phone via text messages or email. The system can enhance security by reducing the need for human monitoring, minimizing response time to potential threats, and improving overall surveillance efficiency. Furthermore, the paper highlights the potential of using IoT technology for security purposes and paves the way for further development and implementation of similar systems in various settings. With further refinement and expansion of its capabilities, this system can be an effective tool for ensuring safety and security in a range of applications, including homes, offices, and public spaces. In summary, the proposed system has made a significant contribution to the field of surveillance technology and represents a promising step toward a safer and more secure future.

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