Design and Implementation of the IoT Surveillance System using Electronic Appliances with Raspberry Pi

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Abstract

The importance of security and surveillance systems in today's society cannot be overstated. The monitoring system can send out early alerts in an emergency. This study investigates an IoT surveillance system that can detect movement, record video footage by the camera module in real-time, and count the recorded video footage. The video footage is sent to the user via Mail. In addition to sending notification messages, "WARNING! Motion is detected, and the video is sent to Gmail for playback" immediately to the mobile phone using the Telegram application via Wi-Fi (Wireless Fidelity). It is worth mentioning that the microcontroller for this system is the Raspberry Pi 3 Model B. Additionally, the Passive Infrared (PIR) sensor detects any movement by measuring the changes in Infrared (IR) radiation. The Light Dependent Resistor (LDR) sensor is also used to check whether daylight or darkness exists. Furthermore, if the movement is detected, the Light Emitting Diode (LEDs) and the Lightbulb will be lit up/down depending on the state of the Light Dependent Resistor (LDR) sensor. The buzzer will activate to provide the emergency sound, and a power bank will be used as a power source to avoid interruptions in electrical power for the surveillance system.

Keywords- Raspberry Pi 3 board, Raspberry Pi Camera Module, Infrared PIR sensor, Mobile phone, Mail.

I. INTRODUCTION

Nowadays, many incidents occur, like stealing, and people remain busy with their work throughout the day. So, security is the first attention everyone wishes to have everywhere at every point in human life. Therefore, they need a surveillance system to ensure the safety of their property. Human and technological mechanisms work together in surveillance systems to keep our homes and communities safe[1][2]. Many devices are available to do that work, But making your own is fantastic and less expensive [3]. Many researchers proposed security systems using Raspberry Pi devices like N. Surantha and W. R. Wicaksono [4], designed as home security systems using Raspberry Pi3 and connected to Arduino. In this system, if human movement is detected, the web camera captures the picture, and the system warns the house owner by activating the alarm. S. Tanwar et al. [5]introduced a security alert system for the smart home to detect any unusual event at home. This system uses a PIR sensor and Raspberry Pi to reduce the delay during the warning by email. M. N. Chowdhury et al.[6] created a system to connect any door to the Internet for monitoring. P. Vigneswari et al. [7] invented a high-level security system that sends pictures of suspicious movement to the user by SMS using a GSM modem and controls the fans and lights. T. Ahmed et al. [8] developed a monitoring system to find any movement and coordinates, measure its distance, and take a picture. A. N. Patil et al. [9] designed a secure automated locking system for the door by capturing video and sending a security warning through the GSM module. The device has a secure face recognizer for automatic door opening. A. F. Symon et al. [10] presented a baby monitoring system that can detect the baby's motion and sound by recording video footage of the baby's motion and displaying it on a display monitor. The most reliable security systems are often the most expensive to maintain because of the high initial investment, ongoing maintenance and monitoring, and any accompanying warranties. The present technological race is to develop a monitoring system that is both simple and inexpensive to operate. This study aims to provide users with an effective IoT surveillance system at a low price and focus on designing and implementing the IoT surveillance system using electronic appliances compatible with Raspberry Pi. The Internet of Things (IoT) is a network comprising physical objects like devices and other items[11]. These entities are embedded with electronics, software, sensors, and network connectivity, allowing them to collect and exchange data [12][13]. The most basic surveillance system components are the Raspberry Pi 3 and the motion and light detectors. The state of the Internet Network Connection influences the speed of sending the alert to the Mail. Due to immediate notice, which enables immediate action, remote monitoring, and the surveillance system can lower the theft rate [14]. Consequently, this system can be moved to homes or offices, companies, factories, or any other place where it must be monitored for monitoring and security [15].

II. DESIGN OF THE SURVEILLANCE SYSTEM

The IoT surveillance system is created with devices engineered to work seamlessly with the Raspberry Pi 3 Model B. The Raspberry Pi 3 is a single-board mini-computer and the system's microcontroller[16]. In addition, a Raspberry Pi 3 server setup with Wi-Fi internet access has been implemented. Raspbian Bullseye operating system from Linux-based operating systems is preinstalled on Raspberry Pi 3. Figure 1 is a block diagram of the monitoring infrastructure. There are two primary components in the overall block diagram for this study. The first part is the hardware requirements consisting of a PIR sensor, LDR sensor, camera module, buzzer, LEDs, and relay connected to Raspberry Pi 3 GPIO pins using jumper wires (male to male and male to female). Furthermore, a Raspberry Pi board can utilize a power bank to fulfill the power requirements of an external device and ensure a stable power source for the IoT surveillance system. The second section covers the essential software, comprising the Telegram application for mobile phones and Gmail accounts. Telegram is a program that must be installed and configured on a Raspberry Pi 3 and a mobile phone. The required details of hardware and software are as follows:

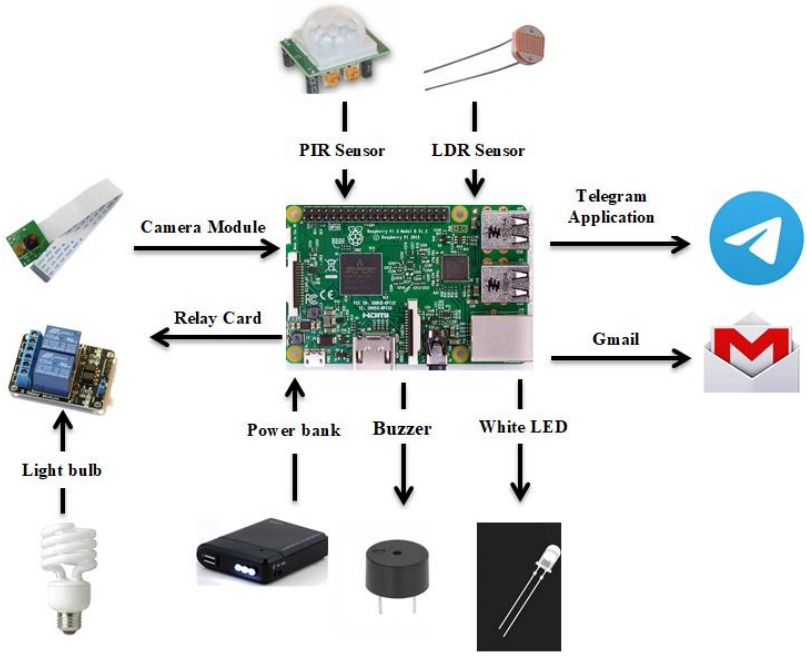


Figure 1, The block diagram for the surveillance system

A- Raspberry Pi 3 Model B

Single Board Computers (SBC) include the Raspberry Pi 3 Model B, which is a reasonably priced, credit card-sized computer that uses HDMI to connect to a TV or computer monitor. It takes input from a regular keyboard and mouse[17]. It was created in the UK by the Raspberry Pi Foundation and has a quad-core 1.2 GHz ARM Cortex-A53 processor, a Broadcom BCM2837 System on Chip (SoC), and 1 GB of RAM[18][19]. The microprocessor and microcontroller characteristics are combined in the Raspberry Pi's processor[20]. The Raspberry Pi 3 is a great option for reliable connected solutions because it has wireless LAN and Bluetooth connectivity (BLE)[21]. Notably, Windows 10 Core may be downloaded and installed without charge from the Raspberry Pi website and is compatible with the Raspberry Pi 3[18][22]. The gadget has multiple connectors for attaching peripherals and a connector for the power supply; it needs 5v - 2.4 A[23]. The Raspberry Pi3 model b is shown in Figure 2.

Figure 2, Raspberry Pi 3 Model B board

B- Raspberry Pi Camera Module

The high definition Camera Module is a small PCB (Printed Circuit Board) containing a camera alongside the power LED of it. It is manufactured specifically for Raspberry Pi Model A and Model B. In addition to that, it provides high sensitivity, lightweight design, 5-megapixel resolution image, and low noise image capture[24]. It is worth mentioning that "Picamera" is a Python programming library made especially for the camera module. The camera module must also be activated in the Raspberry Pi settings[25]. In addition, as shown in Figure 3, the camera module connects to the Raspberry Pi board using a CSI (Camera Serial Interface) connector designed for interacting with the camera. The connection is established via a 15cm ribbon cable to a 15-pin CSI connector.

Figure 3, The connection between Raspberry Pi 3 board and Camera Model

C- PIR Sensor

The important hardware for this system includes passive infrared detectors. A passive infrared (PIR) sensor is a digital electronic device that detects motion by capturing the IR radiation emitted by any movement in its vicinity. Therefore, the sensor periodically checks the IR radiation's strength to see if there has been any change. High-impedance input pins are monitored for a change in voltage to determine if an object is moving[22][26]. It is worth mentioning that the PIR sensor is highly reliable, has high sensitivity, consumes low voltage power, and is widely used in various auto-sensing electrical equipment. It's worth mentioning that the detection range goes up to 6 meters[27]. The PIR sensor device also has three GND, OUT, and VCC pins, which connect with GND, any input/output pin, and 5V from GPIO pins, respectively. In this system, the OUT pin connects with pin 16, as illustrated in Figure 4**.**

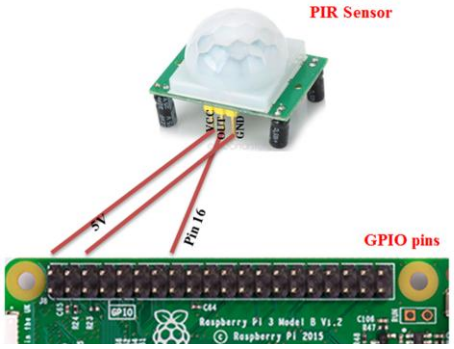


Figure 4, The connection between Raspberry Pi 3 board and PIR sensor

D- LDR Sensor

An LDR (Light Dependent Resistor) is a resistor whose resistance varies with the brightness of the light striking its surface. This means the resistance value decreases with increasing light intensity in an incident on its surface, as shown in Figure 5[28][29]. It works by measuring the change in light falling on the sensor. In contrast to other cards, the Raspberry Pi lacks analog input/output GPIO pins or an ADC (Analog-to-Digital Converter) pin. Therefore, to ensure compatibility with the Raspberry Pi, the output of the LDR sensor must be converted from analog to digital. The conventional method involves connecting the LDR sensor with a fixed resistor (10k ohm) to establish a voltage divider., as shown in Figure 6.

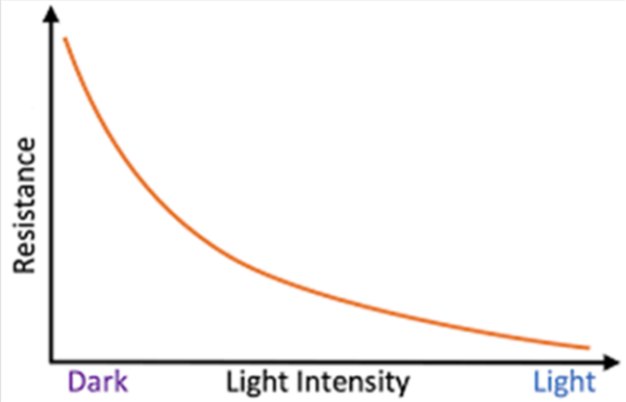


Figure 5, The relationship between resistance and light intensity

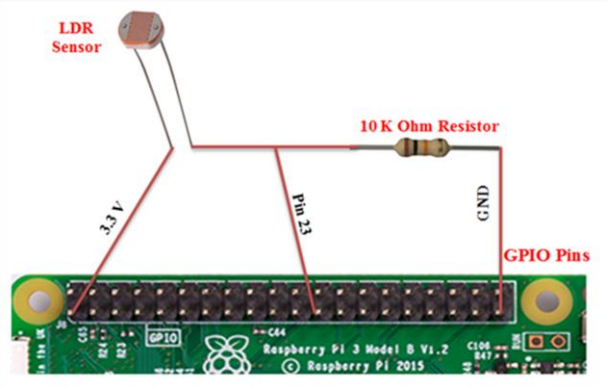


Figure 6, The connection between Raspberry Pi 3 board and LDR sensor

E- Relay card

A relay card is an electrical switch that controls high voltage, such as a load device(light bulb), using very low voltage, such as input GPIO pins[30]. It is worth mentioning that the relay card consists of two groups of pins. The first group includes GND, VCC, and IN1 or IN2, which connect to GPIO pins. The second group comprises NC (Normally Closed), COM (Common), and NO (Normally Opened), which connects to the external electrical device such as a load device[31], as illustrated in Figure 7.

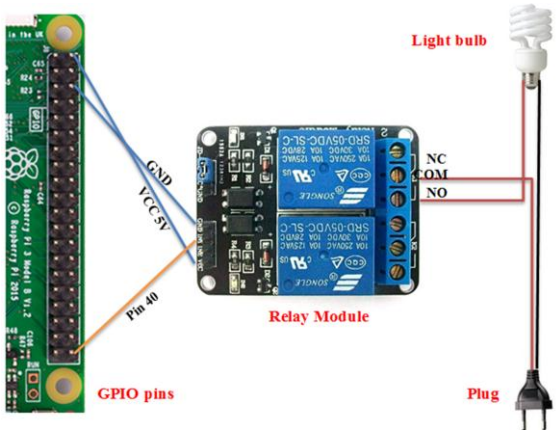


Figure 7, The connection between Raspberry Pi 3 board and Relay Card

F- Buzzer

A buzzer is an electronic device that generates a buzzing or beeping noise and is designed to assist in alerting someone of emergencies[32]. Besides that, buzzers can be categorized as active buzzers and passive buzzers. The active buzzer only needs an electric current to generate a buzzing noise[33]. Unlike active ones, passive buzzers are silent when powered by direct current (DC), instead requiring square waves in the frequency range of (2K-5K) to generate an audible tone. The active buzzer is used in this system, and the Raspberry Pi 3 supplies the current needed to create buzz noise, as shown in Figure 8.

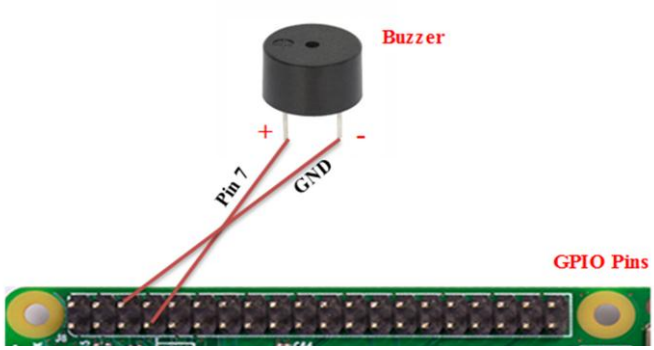


Figure 8, The connection between Raspberry Pi3 board and Buzzer alarm

A light-emitting diode (LED) is an electronic component that produces visible light of a particular color when an electrical current is sent through it[34]. Each LED has a two-party, anode(more extended party) and cathode. The cathode party must be connected in series with a small resistor (220 ohms) to prevent the destruction of the LED[35], as illustrated in Figure 9. In this system, six pieces of 5MM white LEDs are used to improve lighting for video recorded by the camera module in the dark.

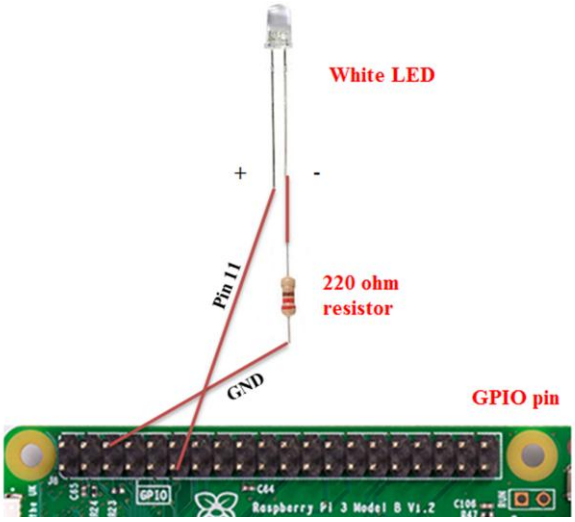


Figure 9, The connection between Raspberry Pi3 board and LED

H- Telegram Application

By the end of 2023, Telegram had more than 800 million monthly users and is the most popular instant messaging service in Europe, Asia, and Africa[36]. For the suggested approach to work, the Raspberry Pi must deliver WARNING messages to mobile devices via the Telegram application. The Telegram application must be installed from the Play Store on a mobile device and set up to meet system requirements for users to access this functionality. Additionally, the Python "telepot" package makes it easier to integrate Telegram with the Raspberry Pi[37].

I-Gmail

Gmail (Google Mail) is a free service introduced in 2004 by Google that allows users to send and receive email over the Internet[38].

III. IMPLEMENTATION OF SURVEILLANCE SYSTEM

The surveillance system was implemented by executing the program written in Python to configure the Raspberry Pi 3 for the proposed system. The program is written based on the following algorithm in the steps respectively:

1. Start the program by turning on the power bank.
2. The counter for the video footage is recorded equal to 1.
3. Check if the PIR sensor detects the motion.

4. If the motion is not detected:
    - The LEDs will be turned off.
    - The program will wait for 1 second.
    - Then loop the process from step 3.
5. If the motion is detected, check if the LDR sensor is True.

1-If the LDR sensor is True:

- The LEDs and the Light bulb will be turned off.
- Start recording the video for 5 seconds and send it to Gmail with the message "WARNING! Motion is detected!".
- It will be sent a notification message to the Telegram application on mobile.
- Increment the counter by 1.
- After that, the buzzer will start ringing to provide an emergency sound.
- The program will wait for 10 seconds.
- Then loop the process from step 3.

2-Else the LDR sensor is False:

- The LEDs and the Light bulb will be turned on.
- Start recording the video footage for 5 seconds and send it to Gmail with the message "WARNING! Motion is detected!".
- It will be sent a notification message to the Telegram application on mobile.
- The LEDs and the Light bulb will be turned off.
- Increment the counter by 1.
- After that, the buzzer will start ringing to provide an emergency sound.
- The program will wait for 10 seconds.
- Then loop the process from step 3.

Figure 10 shows the flow chart for the above algorithm.

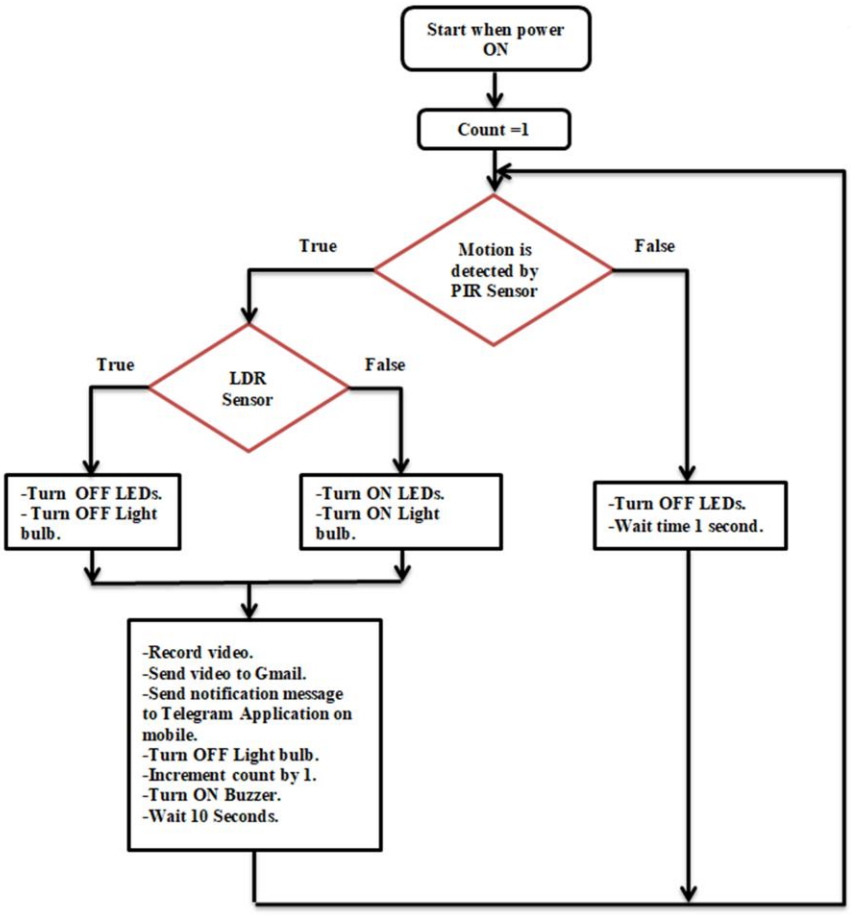


Figure 10, The flow chart for survillence system

IV. RESULTS

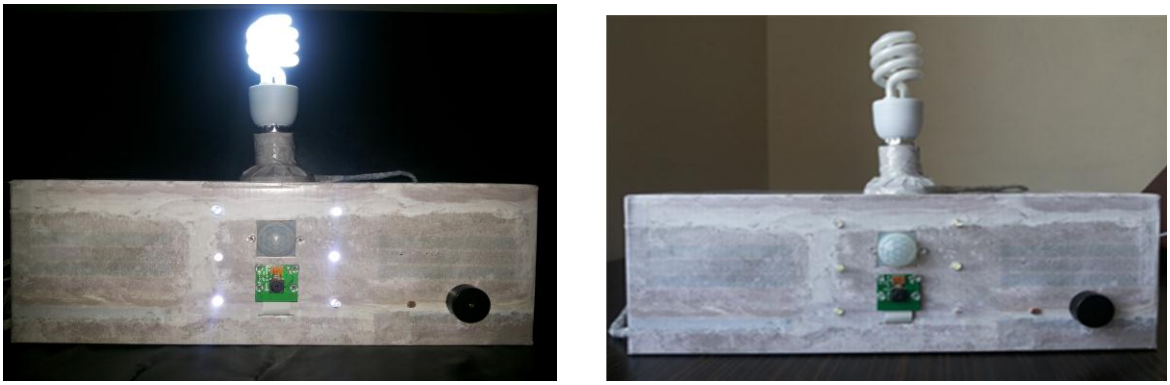
There are three cases for results:

A- Case I

Figure 11 depicts the surveillance system box during video recording if the motion is detected:

a. If the light is unavailable, turn the LEDs and light bulb ON.

b. If the light is available, turn off the LEDs and light bulb.



(a) (b)

Figure 11, The surveillance system box during recording video if the motion is detected when (a) in the dark or (b) in the light.

B- Case II

The notification message "WARNING! Motion is detected, and the video has been sent to Gmail for playback" has been effectively delivered to the Telegram application on the mobile phone upon detecting motion, as shown in Figure 12.

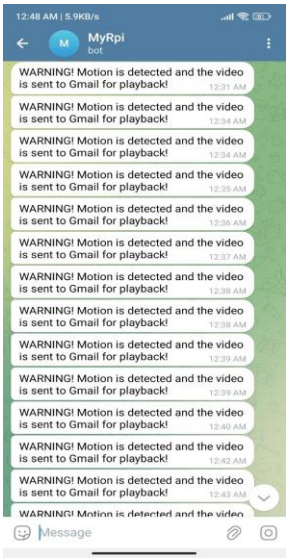


Figure 12, The notification message has been successfully sent to Telegram Application

C- Case III

The email containing the recorded video was sent successfully upon detection of motion, as illustrated in Figure 13.

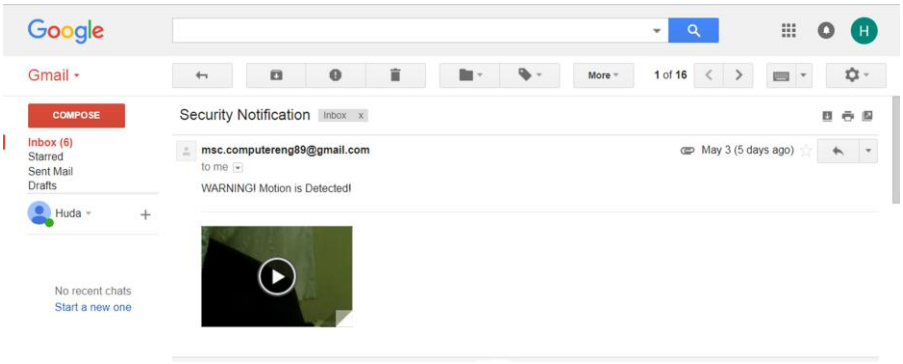


Figure 13, The content of the received email notification

This paper aimed to develop and deploy a surveillance system using the Raspberry Pi 3 Model B microcontroller. By integrating various devices, it ensures robust security measures. The experimental work was conducted meticulously. The study introduces a novel surveillance system capable of monitoring movement in real-time, offering alerts through an alarm buzzer and streaming tracking data such as video and notice messages. Leveraging mobile phone technology enhances its convenience. The system is characterized by reliability and specificity across mobile phones and Raspberry Pi 3 platforms. Tailored for specific monitoring needs in private home offices, public parking garages, and bank vaults, it is a comprehensive solution boasting user-friendly security features. Its affordability, low power consumption, simple circuitry, efficiency, advanced technology, and adherence to high-security standards make it an appealing choice.

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