CNT6156 Advanced Python Programming in ECE

Final Project Report

Smart Home security system using Raspberry Pi

Maria Diaz 6529918

Yulin Jing 6505343

Dr. Yu Du

10/07/2024

Executive Summary

The home security system is a monitoring system used to monitor house intrusion or abnormal event warning. This project implements a smart home system based on Raspberry Pi, which can monitor the home environment in real time and improve home safety and comfort. The system is mainly divided into three parts: motion detection, temperature monitoring, and remote monitoring and alarm. It uses a variety of sensors and modules, including temperature and humidity sensors, PIR sensor, camera, I2C LCD1602, active buzzers, LED light control module, etc., to achieve multiple monitoring and control functions of the home environment. At the same time, the data is stored and visualized through a simple Web interface, which is convenient for homeowners to manage the security system of the house.

TABLE OF CONTENTS

1.0 Introduction

1.1 Purpose

In today's world, ensuring the safety and security of our homes has become increasingly important. With the rise of urbanization and increasing concerns about burglary, intrusions, and safety threats, having a reliable and efficient home security system is no longer a luxury but a necessity. Traditional security systems, while useful, often lack the flexibility and adaptability required to address modern security challenges.

1.2 Background

According to statistics, with the continuous advancement of technology and the accelerated development of digitalization, home security systems have become an important device for more than 39 million American households. According to a study, 60% of thieves will give up their crimes and look for easier targets when they see that the family has installed a security system. In addition, another similar study shows that families without security systems are 300% more likely to be burglarized. The global home security market is expected to grow to $84.4 billion, and more and more people are installing smart security systems to ensure safety.

As AI technology continues to advance, we can expect to see further integration and connectivity of devices in home security systems that are powered by AI. This includes hardware devices such as cameras, motion detectors, sensors, and smart locks, as well as software such as digital applications. This enhanced connectivity will not only make it easier for homeowners to manage their security systems, but also customize their home security settings based on their changing needs.

The home security monitoring system proposed by Desnanjaya et al. is based on Raspberry Pi as the control center, combined with PIR sensors, cameras, temperature and gas sensors, and uses Telegram as a communication platform. It can monitor intruder activities, ambient temperature and gas concentration in real time and send alarm notifications to users. Madupu and Karthikeyan used a Raspberry Pi-based automation system to remotely monitor home security through the Internet of Things (IoT) and cloud servers, using multiple sensors to collect data, such as smoke, PIR, vibration, and humidity sensors to detect abnormal conditions. When an abnormality is detected, the system dynamically sends a service request through an ARM controller and has been successfully applied to actual home security scenarios. Tanwar et al. proposed an IoT-based smart home security alarm system, which used PIR modules and Raspberry Pi to detect intrusion or abnormal conditions when no one was at home and quickly sent alerts via email. Anwar and Kishore proposed an energy-efficient and economical Raspberry Pi-based system. When a visitor is detected indoors, the camera module takes a picture and sends an email alert via TCP/IP. The system also allows the camera's video stream to be viewed using a smartphone and triggers an audible alarm by sending a command when an intruder is detected.

1.3 Scope

This project focuses on building a Smart Home Security Alert System, leveraging the power of smart devices and the Internet of Things (IoT). Smart home technology provides innovative solutions that allow for real-time monitoring, automation, and remote control, making it possible to create intelligent security systems tailored to specific needs.

By integrating various sensors—such as motion detectors, cameras, and environmental monitors—this project aims to provide enhanced security measures, offering features such as:

- **Motion detection** that triggers alarms and records video when suspicious activity is detected.
- **Temperature monitoring** to detect and respond to fire hazards or unusual environmental conditions.
- **Remote monitoring and alerts**, ensuring homeowners can monitor their security system from anywhere using a simple web interface.

1.4 Methodology

The system is designed to monitor both environmental conditions, such as temperature, and security threats, such as motion detection. It operates using a combination of sensors, alert mechanisms, and a camera module, all controlled by a Raspberry Pi. The system's logic is divided into two parallel branches: **temperature monitoring** and **motion detection**, as demonstrated in the block diagram and flowchart provided.

1.4.1 Hardware and software requirement

The development of the Smart Home Security Alert System required a combination of hardware and software components. Below is a detailed list of the materials used:

Hardware:

1) Input Devices (Sensors and Interfaces):

These components gather data from the environment or allow the user to interact with the system.

- PIR Sensor: Detects motion, which triggers alerts and video recording.
- DHT-11 Sensor: Measures temperature and humidity, monitoring environmental conditions.
- Joystick: Provides manual control and input, potentially used for navigation or system interaction.

2) Output Devices (Alerts and Display):

These components are used to display information or alert the user.

- 2 Active Buzzers: Audible alarms triggered by input data from sensors of the system
- LED: Visual indicator for system status or alerts.
- I2C LCD1602: Displays real-time information like temperature or system messages.

3) Processing and Control Components:

These components handle the processing and execution of the system's tasks.

- Raspberry Pi: The core controller of the system, running all the logic for monitoring, alerts, and recording.

• T-Extension Board: Simplifies GPIO pin connections for multiple sensors and devices.

• 40-Pin Cable: Connects the GPIO pins of the Raspberry Pi to the extension board.

• GPIO Extension: Expands the available GPIO pins for more device connections.

• Transistor: Amplifies current for controlling higher-power devices like the buzzers.

• Resistors (220Ω, 1kΩ, 10kΩ): Protect components by limiting the current in various parts of the circuit.

• ADC0834: Converts analog signals from sensors into digital signals that the Raspberry Pi can process.

4) Recording and Storage:

These components handle the video recording triggered by the motion detection system.

• Camera Module: Captures video when motion is detected, providing evidence of events.

5) Power Supply:

• Voltage Charger: Provides stable power to the Raspberry Pi and connected components.

Software:

• Raspberry Pi OS: Operating system running on the Raspberry Pi.

• Thonny: Python IDE used to write and test the system's code.

• Visual Studio Code: An advanced editor used for developing and managing the project’s codebase.

1.4.2 Design and system architecture

The block diagram illustrates the main components involved in the system, highlighting how they interact with the central control unit (the Raspberry Pi) and their respective roles within the system.

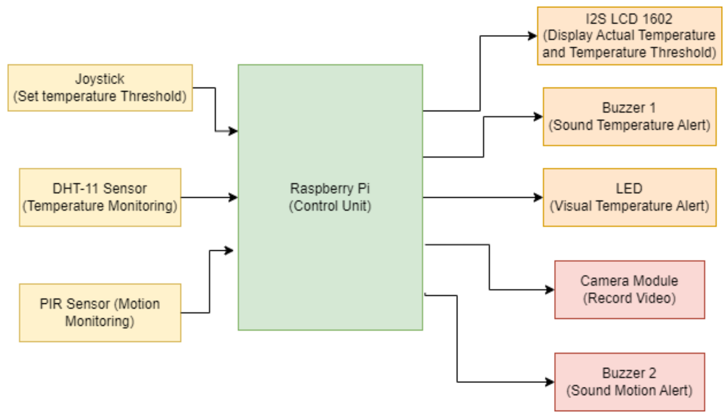

Figure1 System Block Diagram

The flowchart provides a step-by-step breakdown of the system's operational logic. The system operates in two parallel branches: temperature monitoring and motion detection.

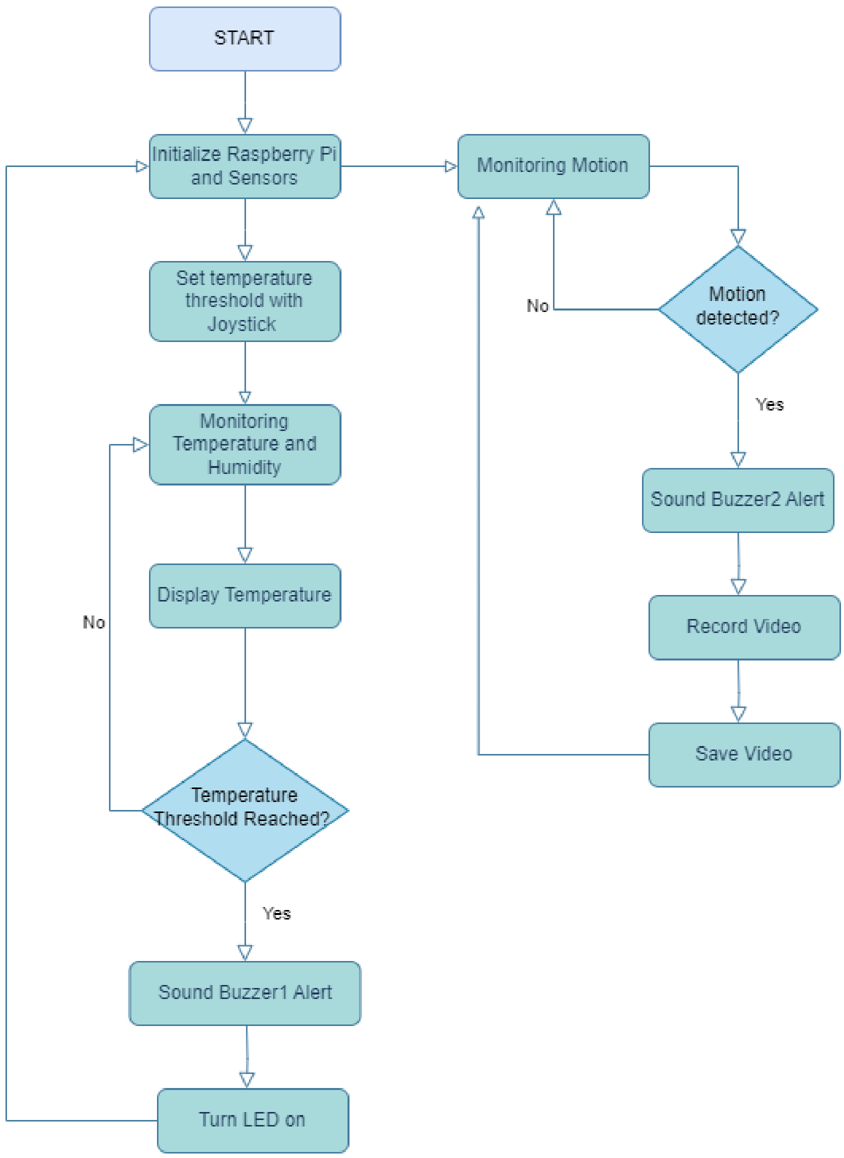

Figure2 System Flowchart

2.0 Procedure and Findings

The Smart Home Security Alert System operates efficiently by running two critical processes in parallel: environmental monitoring and security surveillance.

System Operation:

The system starts by initializing the Raspberry Pi and all connected sensors. In parallel, the system monitors both temperature and motion.

- Temperature Monitoring: Once the user sets a threshold, the system continuously compares the current temperature to the threshold, triggering alerts if necessary.

- Motion Detection: The system monitors for movement and triggers alerts and video recording if motion is detected.

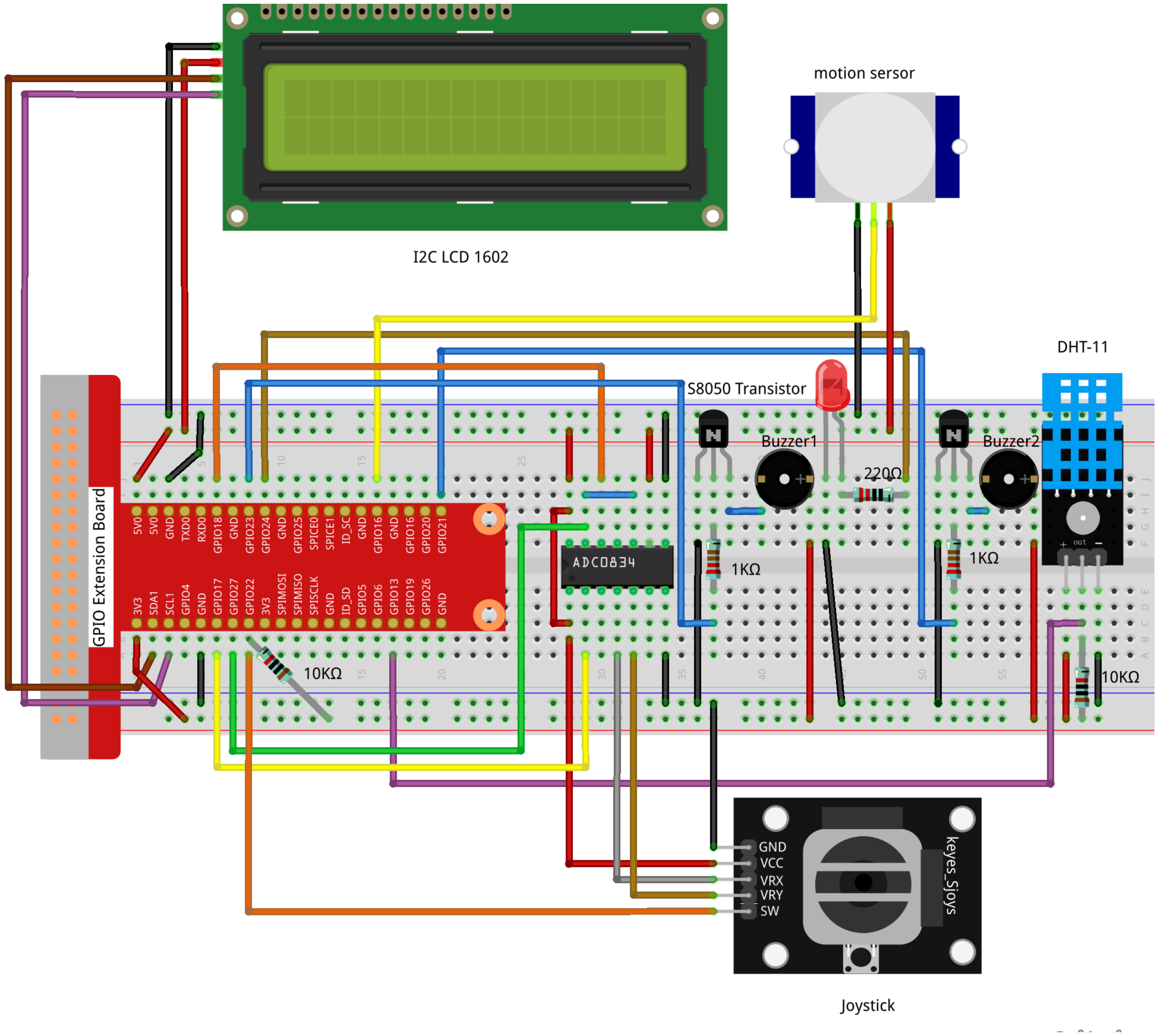

Figure3 system circuit

2.1 Temperature Monitoring

This system uses DHT11 to monitor the indoor temperature in real time. DHT11 is a digital temperature and humidity sensor suitable for environmental monitoring. It uses a single bus protocol, can measure temperature and humidity at the same time, is suitable for 5V power supply, has simple wiring and low power consumption. The system uses I2C LCD1602 to display the current temperature and the upper limit temperature, and uses joystick to adjust the upper limit temperature. It also activates buzzer and LED as alarm signals.

When the system is running, DHT11 monitors the indoor temperature and humidity. he current temperature and the high-temperature are displayed on I2C LCD1602. If the current temperature is larger than the threshold, the buzzer and LED are started to alarm you. At the same time, the system will also send an email reminder, which contains the current temperature and the best temperature threshold.

Press the Joystick can adjust the high-temperature threshold. Toggling the Joystick in the direction of X-axis and Y-axis can adjust (turn up or down) the current high-temperature threshold. Press the Joystick once again to reset the threshold to initial value. If the alarm temperature threshold is raised, the system alarm will stop and the LED light will turn off. In the actual implementation process, more people will connect the system to the mobile phone to control and close the alarm information through the mobile phone. This method is more convenient and intelligent.

2.2 Motion Detection

The system continuously monitors motion using a PIR (Passive Infrared) sensor, which is specifically designed for detecting human movement. This sensor is preferred over an ultrasonic sensor because it provides superior performance for detecting human presence. Unlike ultrasonic sensors, which detect any object based on sound waves, PIR sensors detect infrared radiation emitted by warm objects, such as the human body. This makes PIR sensors more accurate and reliable in home security applications, as they are less likely to be triggered by non-human objects, ensuring fewer false alarms.

When motion is detected, the buzzer 2 will sound to indicate an intrusion or movement in the monitored area. An active buzzer is used in this system instead of a passive buzzer primarily because of its simplicity and ease of use, especially in security systems like this one. Active buzzers have a built-in oscillator, they only require a simple ON/OFF signal to operate, while passive buzzers need a PWM signal to produce sound, requiring more complex control. The goal is to emit a clear and consistent sound alert when motion is detected, and the active buzzer provides this immediate, reliable sound with minimal effort, making it ideal for this application.

A transistor is placed between the GPIO pin and the buzzer to act as an amplifier, as GPIO pins on the Raspberry Pi may not be enough to power devices like buzzers, so it allows the GPIO pin to control devices that require more current or voltage. Also, it prevents damage to the GPIO pin, acting as an intermediary, preventing the GPIO pin from being overstrained.

However, different tone durations are used to create distinct sound patterns or "melodies" for different alerts. This helps differentiate between the alerts triggered by the temperature branch and those by the motion detection branch.

At the same time, the camera module will record a video for a predefined duration, in this case 5 seconds. The recorded video is stored locally on the Raspberry Pi for later review.

2.3 Flask Server

As part of the Smart Home Security Alert System, a Flask server was created to provide a simple web interface for accessing the videos recorded by the system's camera, as well as viewing system logs. This allows the user to remotely monitor the system's actions and check recorded videos when motion is detected. Additionally, the user can track the system's history through logs, providing a complete overview of the security measures taken by both the motion detection and temperature monitoring systems.

General Workflow of the Flask Server:

1. The Flask application is initialized to listen for incoming HTTP requests from users. This setup allows users to access the system's web interface by entering the Raspberry Pi's IP address in a web browser.

2. Flask uses routes to map specific URLs to functions within the application. For example, when a user visits the home page or requests to view a list of recorded videos, Flask processes these requests and serves the appropriate content.

3. When users visit the root URL, they are directed to the index page, which acts as the system's main dashboard. This page serves as a gateway for users to explore other features.

4. When users navigate to the videos page (/videos), the Flask server retrieves the list of recorded video files from a designated folder on the Raspberry Pi. This list is sorted chronologically so users can view recordings in the order they were captured. The video files are displayed as clickable links on the videos page, allowing users to stream or download the recordings directly from their browser.

5. When users visit the logs page (/logs), they can view logs generated by both systems. These logs contain important information such as the time of motion detection, temperature readings, and any actions taken by the system. This section provides users with a full overview of the security system's operation, giving insight into both recent and past events that have occurred at home.

3.0 Conclusions and Recommendations

The Smart Home Security Alert System developed in this project demonstrates the effectiveness of leveraging smart devices to enhance home safety and security. By integrating motion sensors, a camera module, and a simple notification system, the project highlights how IoT technology can create a robust, real-time security solution for homeowners.

Furthermore, the system is customizable and scalable, it opens the door to numerous possibilities for future improvements:

• Integration with Additional Sensors: Adding more sensors such as door/window contact sensors, smoke detectors, or even glass break sensors could enhance the system's capabilities, making it even more comprehensive in detecting threats.

• Mobile App Integration: Developing a dedicated mobile application could provide real-time alerts and remote control, allowing users to monitor their home security from anywhere with ease.

•Cloud Storage for Video: Storing video recordings in the cloud would make the system more robust, ensuring that even if the local system is compromised, video evidence remains secure and accessible.

• AI-Powered Detection: Incorporating artificial intelligence for facial recognition or object detection could further refine the system, helping to differentiate between false alarms, such as pets, and actual intruders.

• Voice Assistant Integration: Integration with voice assistants could allow for hands-free control and automation, making the system more user-friendly.

References

Anwar, S., & Kishore, D. (2016). IOT based smart home security system with alert and door access control using smart phone. *International Journal of Engineering Research & Technology (IJERT), 5*(12), 504-509.

Desnanjaya, I. G. M. N., & Arsana, I. N. A. (2021). Home security monitoring system with IoT-based Raspberry Pi. *Indones. J. Electr. Eng. Comput. Sci, 22*(3), 1295.

Madupu, P. K., & Karthikeyan, B. (2018, March). Automatic service request system for security in smart home using IoT. In *2018 Second International Conference on Electronics, Communication and Aerospace Technology (ICECA) (*pp. 1413-1418). IEEE.

Tanwar, S., Patel, P., Patel, K., Tyagi, S., Kumar, N., & Obaidat, M. S. (2017, July). An advanced internet of thing based security alert system for smart home. In *2017 international conference on computer, information and telecommunication systems (CITS)* (pp. 25-29). IEEE.