UNIVERSITY OF SCIENCE AND TECHNOLOGY OF HANOI

Smart home monitoring and security system

From Sensors to Users

Security and Ethics for Data

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1. INTRODUCTION

1.1. Context

In today's technology-driven world, smart home systems are gaining immense popularity, providing enhanced convenience, security, and efficiency. These smart home devices address a variety of issues, particularly in regions like Vietnam, where theft and break-ins are prevalent concerns for many households. Consequently, a robust monitoring and alarm system is highly sought after by numerous families. Additionally, a smart temperature and humidity control system, along with automated LED lighting, can significantly improve the comfort, safety, and energy efficiency of homes.

1.2. Objective

In this project, we aimed to design a smart home system with various automated functionalities aimed at improving home security and convenience. The real-world applications of this system include automated lighting, temperature monitoring, intruder detection, and camera surveillance.

The system is designed to enhance the safety, security, and comfort of a household through intelligent decision-making based on sensor data.

2. System Components and Architecture

2.1. Requirement and Functionalities

The system comprises several key functionalities:

- **Automated Lighting:** Activates lights when motion is detected in low light conditions.
- **Temperature and Humidity Monitoring:** Continuously monitors the house temperature and humidity and displays it on a webpage for remote viewing.
- **Intruder Detection:** Detects unauthorized entry and alerts the homeowner via email while providing the ability to disable the alarm temporarily using an IR remote.
- **Surveillance Camera:** Captures surroundings upon detecting motion, stores it on an SD card, and alerts the homeowner via email.

Importance of Data Collection and Processing

Effectively collecting and processing data from sensors is crucial in this project to ensure accurate and timely responses to environmental changes and potential security threats. Reliable sensor data is necessary to trigger the appropriate actions, such as turning on lights or sending alerts, thereby enhancing the system's functionality and reliability.

2.2. Components

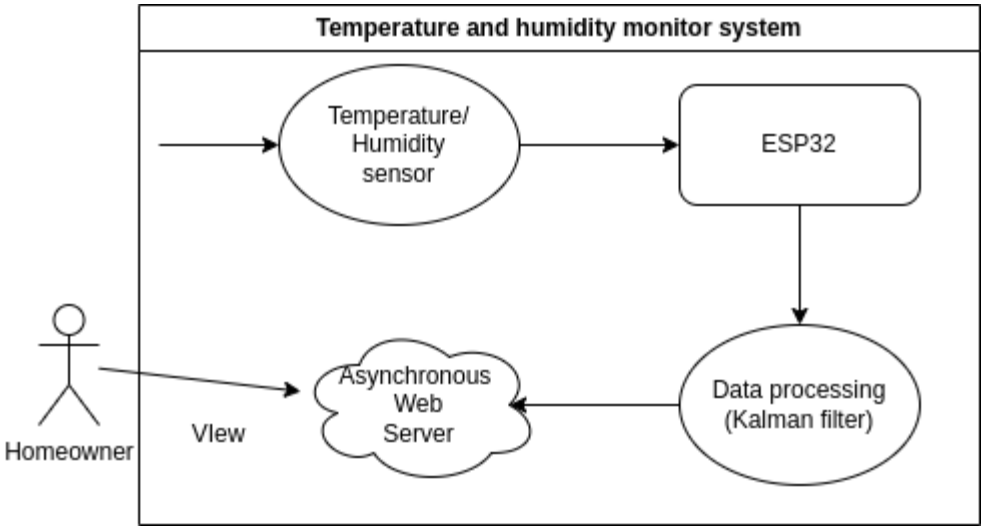
1. **PIR Sensor/Microwave radar sensor**: Detects motion for the automated lighting system and security camera.

2. **Photoresistor**: Measures light levels to determine when to activate the lights.
3. **Temperature Sensor**: Monitors the house temperature.
4. **Hall Sensor and magnet**: Detects door opening for the intruder detection system.
5. **IR Remote and Receiver**: Acts as a key to disable the intruder alarm.
6. **Buzzer**: Sounds an alarm when an intruder is detected.
7. **Camera**: Records and streams video footage
8. **SD Card**: Stores recorded footage.
9. **Microcontrollers (Esp32 and Arduino)**: Central unit that processes sensor data and controls other components. The Esp32 enables remote data transmission and control.
10. **AES Encryption**: Secures email and Wi-Fi credentials.

2.3. Architecture

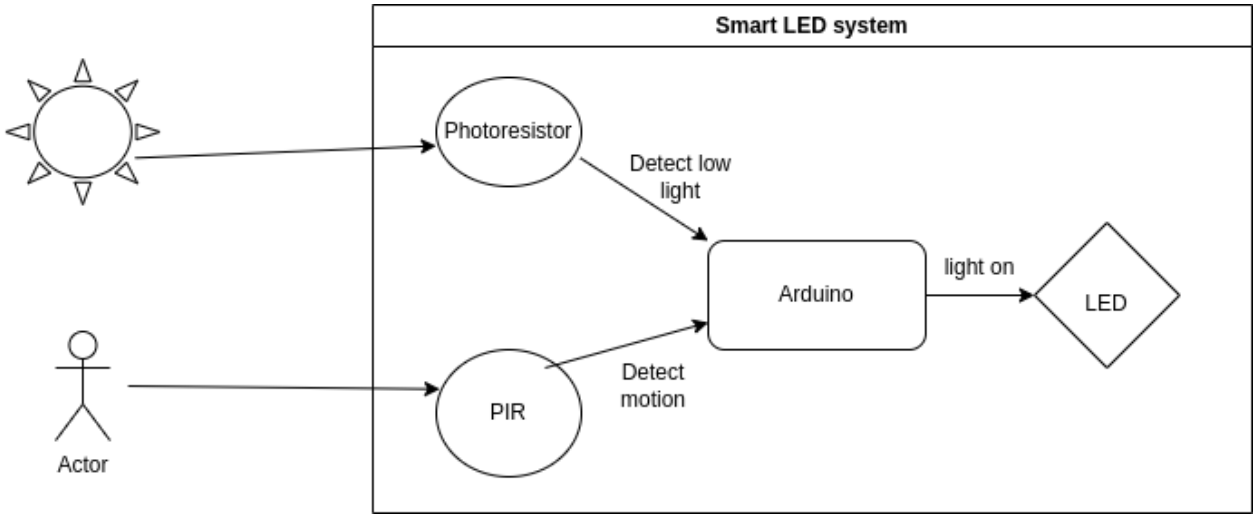
Our project includes the 4 following parts:

1. **Temperature and humidity monitor system**



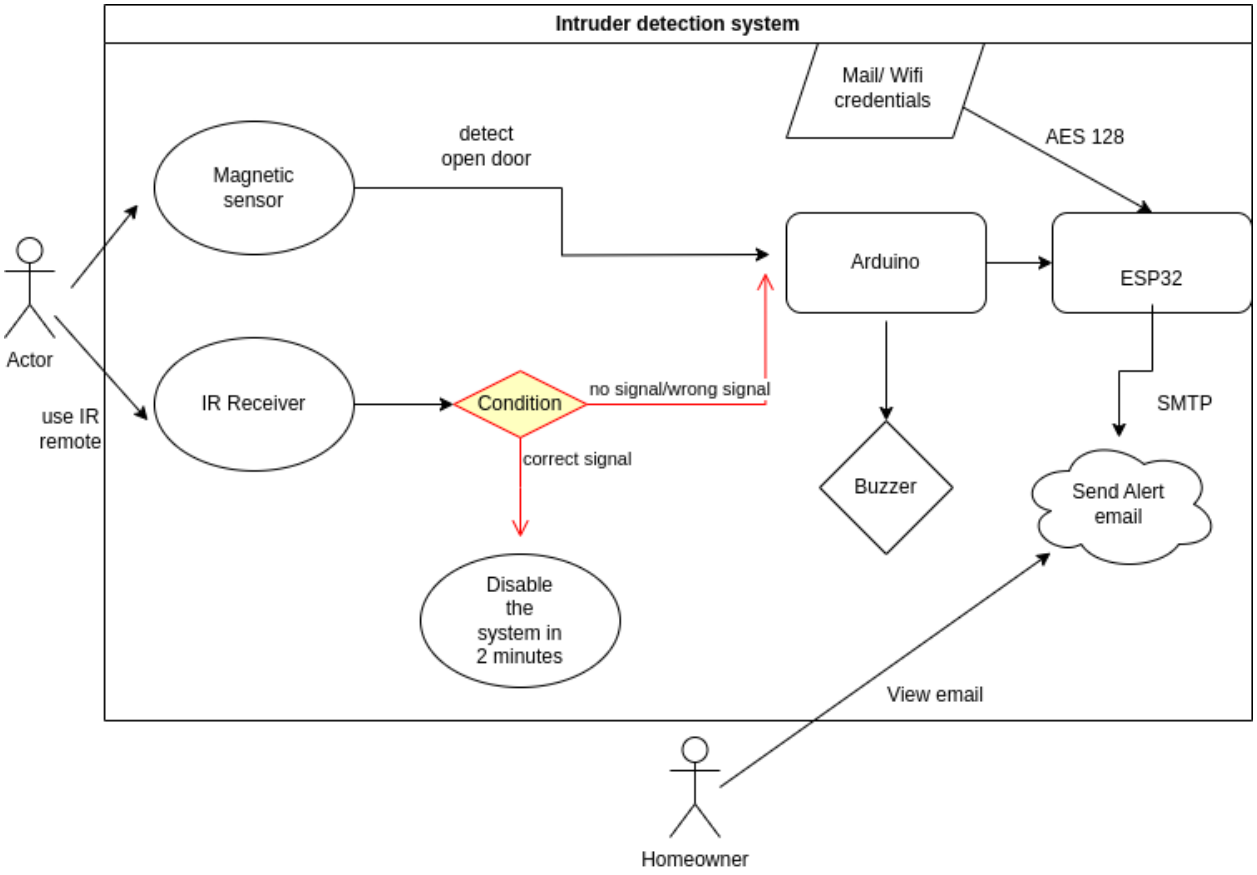
The Temperature and Humidity Monitor System is designed to provide real-time monitoring of the environmental conditions within the home. This system uses sensors to measure the temperature and humidity levels in different rooms.

2. **Smart LED system**



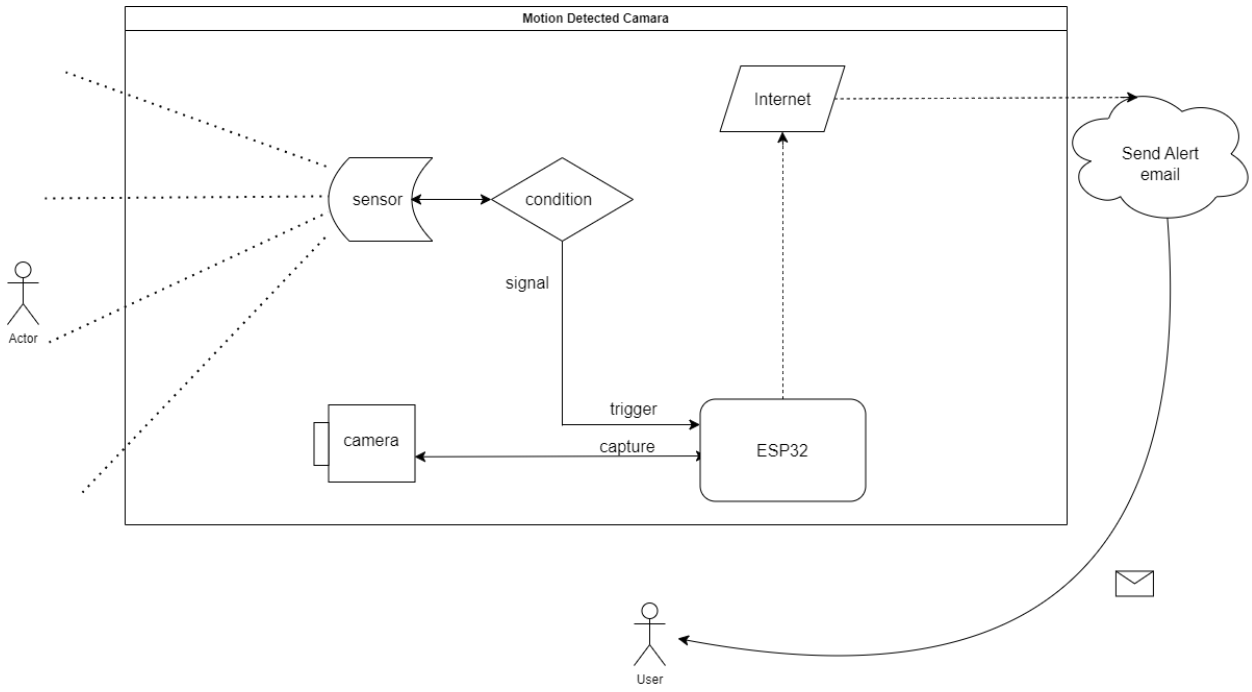
The Smart LED System revolutionizes home lighting by offering customizable and energy-efficient solutions by using sensors to manage the lights.

3. Intruder detection system



Security is a top priority for any homeowner, and the Intruder Detection System provides a robust solution to protect the property. Motion sensors and door/window sensors are strategically placed around the house to monitor for any suspicious activity. When an intrusion is detected, the system triggers an alarm and sends notifications to your smartphone, allowing you to take swift action.

4. Motion detected camera



The Motion Detected Camera is an essential component of any smart security system, providing real-time surveillance of any movement within its field of view. This camera is equipped with motion detection technology that activates the camera when movement is detected, and capture images; the footage is then stored locally on an SD card, and send instant alerts via email services.

3. Implementation

3.1. Smart LED system

Choice of sensor:

- **PIR Sensor**: Selected for its ability to detect motion, crucial for automated lighting. The sensor works by detecting the change in infrared lights generated by living beings/heat sources like humans. The sensor model HC-SR501 is affordable and is quite sensitive, therefore is a very cost-effective option for this task.

- **Photoresistor (LDR)**: Chosen to measure ambient light levels, ensuring lights are only activated when necessary. The resistance of the LDR decreases with an increase in light intensity, therefore with proper wiring, it can help the microcontroller measure the brightness of a room.

How the system works:

The sensor collects the output of the photoresistor and passive infrared sensor. The sensitivity of the PIR is manually adjusted to work as intended. There is a predefined threshold for the light intensity. When the microcontroller detects a signal from PIR that there is motion, together with a signal that the room is currently darker than the threshold, it will turn on the LED for a predefined time period.

Usage:

For convenience, and to help the security camera system work at night with adequate light.

3.2. Temperature and Humidity Monitor

Choice of sensor:

- **Temperature and Humidity Sensor:** Used to monitor and display house temperature/humidity for comfort and safety. The DHT11 sensor is a popular and inexpensive sensor used for measuring both of these values.

How the system works:

The system will collect the temperature/humidity in real time, and then the data is sent to ESP32. The ESP32 module processes the data by applying a Kalman filter to the raw value. The purpose of this is to smoothen out the readings from noises. The filter is initialized with the estimated value for process noise, measurement noise and estimated error.

The ESP32 then connects to the local wifi to get access to the internet. It then sets up an HTTP server to serve web pages and handle client requests. An asynchronous web server is created that listens for HTTP requests and serves responses. A web page can then be accessed with a generated IP address that displays the sensor reading dynamically.

Usage:

To view the temperature/ humidity status of the house remotely with multiple possible devices. The sudden surge in temperature can mean there is a fire that occurs.

3.3. Intruder alert system

Choice of sensor:

- **Hall Sensor:** Essential for detecting door status, a key component of the intruder detection system. In our project, we use the KY-003 which is cheap and works well together with a piece of magnet attached to a door. Its mechanism is simple: by just

sensing the change in the magnetic field, it can output a digital signal indicating the status of a door.

- **IR Remote/Receiver:** Acts as a secure and convenient method to disable the intruder alarm.

How the system works:

We utilize the Arduino Uno microcontroller for the sensors because of its more stable library support for our components. When someone opens a door, the hall sensor detects such a change, it will give a signal to a buzzer to output very loud noise to alert the homeowner/ scare away possible intruders. The Arduino controller then communicates with an ESP32 board via UART (with the TX, RX pin). The ESP32 has already connected to the Wifi network, when it receives instruction, it will automatically compile and send an urgent email to a specific address of the homeowner, therefore alert of possible threat. The mechanism in which the email is sent is via SMTP (Simple Mail Transfer Protocol). The alert emails are programmed to be sent at least more than 5 minutes away from each other to avoid unnecessary spam.

When the homeowner entered his house, to avoid triggering the alarm system, he could press a button from an IR remote, with the frequency of the signal already programmed. When the correct signal is received by an IR receiver connected to the Arduino board, the system will be disabled for 2 minutes, in which time the homeowner can enter the house freely.

To safely store the data about wifi and email credentials, we put them in EPROM memory of the ESP32 by AES 128 encryption. The key was provided in the code and it decrypts that information at runtime, allowing the module to send email.

3.4. Motion detected camera

Choice of sensor:

- **Microwave motion sensor:** Unlike traditional passive infrared (PIR) sensors, microwave sensors emit microwave signals and detect motion based on the changes in the reflected signals. This allows for more accurate and reliable motion detection, even though certain materials like glass and thin walls.

How the system works:

The security system operates through a seamless integration of a microwave motion sensor and an ESP32-CAM module, designed to provide robust and efficient monitoring. The microwave motion sensor continuously scans its environment, emitting microwave signals and detecting motion based on changes in the reflected signals. This sensor is highly sensitive and can detect movement through certain materials, making it more reliable than traditional PIR sensors. When motion is detected, the sensor sends a signal to the ESP32-CAM module, which is initially in sleep mode to conserve power.

Upon receiving the signal, the ESP32-CAM wakes up and activates its OV2640 camera module to capture an image of the detected motion. This image is then saved to an SD card inserted into the ESP32-CAM, ensuring local storage of the visual data. Simultaneously, the system uses the ESP_Mail_Client library to send the captured image to a predefined email address. This involves configuring the email client with the necessary SMTP server details and authentication credentials. The email, with the image attached, is sent to the predetermined email address, providing real-time alerts and visual evidence of any detected motion.

After the image is captured and the email is sent, the ESP32-CAM returns to sleep mode to minimize power consumption. This cycle repeats each time motion is detected, ensuring continuous monitoring and efficient power usage. The system's design makes it suitable for various applications, including home security, office surveillance, remote property monitoring, wildlife observation, and construction site security. Its ability to provide accurate motion detection, real-time alerts, and efficient power management makes it a versatile and effective solution for enhancing security and monitoring in different environments

4. RESULTS

4.1. Examining process

We examined various scenarios to ensure each component functioned correctly. For instance:

- Simulating motion in different lighting conditions to test the automated lighting system.
- Monitoring temperature/humidity readings and test if they are updated in real time in the webpage.
- Testing the intruder detection system by opening a door and ensuring the buzzer sounded and email alerts were sent. Test that the IR remote to temporarily disable the system works.
- Receiving the scene from the camera to verify the system work.

4.2. Evaluation

4.2.1. Effectiveness

The smart home system effectively meets its goals of enhancing security and convenience through intelligent automation and remote monitoring capabilities. The integration of multiple sensors and components allows for comprehensive home management and security.

4.2.2. Advantages, Limitations, and Scalability

Advantages:

- Improved home security with real-time alerts and surveillance.
- Energy efficiency through automated lighting.

- Enhanced convenience with remote monitoring and control.

Limitations:

- Dependency on a stable internet connection for remote functionalities.
- Potential challenges with sensor calibration and false positives in motion detection.

Scalability:

- The system can be expanded to include additional sensors and functionalities, such as smart locks, smoke detectors, and voice control.
- Integration with other smart home ecosystems and platforms could further enhance its capabilities.

5. CONCLUSION

In this project, we have developed four integrated systems: the Temperature and Humidity Monitor System, the Smart LED System, the Intruder Detection System, and the Motion Detection Camera. These systems collectively enhance the functionality and security of any living space.

To further improve these systems, future developments could include the implementation of machine learning algorithms for advanced motion and anomaly detection, enhancing the user interface for better usability, adding battery backup and offline capabilities for continuous operation during outages, and integrating additional sensors such as smoke detectors and air quality monitors. These enhancements would make the smart home systems even more robust, user-friendly, and reliable, further elevating the quality of life and security in any living environment.