IN4300 - Embedded Systems Group Assignment Final Report

Level 4

Smart Home X

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Group Number: 19

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Abstract

This project presents the development and implementation of a smart home system that leverages Internet of Things (IoT) technology to enhance residential living through environmental monitoring and voice-controlled automation. The system utilizes a Raspberry Pi 4 as the central processing unit, integrating DHT11 temperature and humidity sensors, light detection resistors (LDRs), and a relay module to monitor and control the home environment. A distinguishing feature of this implementation is its seamless integration with Google Home, enabling intuitive voice command functionality for controlling lighting systems. The project incorporates a custom-built Sinri Pro dashboard that visualizes real-time environmental data and provides a user-friendly interface for monitoring and controlling the smart home ecosystem. Testing results demonstrate the system's reliability in accurately monitoring environmental conditions while responding efficiently to voice commands through Google Home. This implementation represents a cost-effective and accessible approach to smart home technology that can be readily expanded to incorporate additional functionalities in future iterations.

1. Introduction

The rapid evolution of Internet of Things (IoT) technology has revolutionized how humans interact with their living environments, transforming conventional residences into intelligent ecosystems capable of environmental monitoring, resource management, and enhanced user convenience. This project presents the development and implementation of a comprehensive smart home system centered around the Raspberry Pi 4 platform, integrating environmental sensors and voice-controlled automation through Google Home Assistant.

The modern smart home represents a confluence of various technological advancements, including miniaturized sensors, wireless communication protocols, cloud computing, and artificial intelligence. By leveraging these technologies, this implementation creates an accessible and extensible framework for home automation that addresses the growing consumer demand for intuitive, responsive living spaces.

This smart home implementation distinguishes itself through its balanced approach to technological sophistication and user accessibility, providing advanced functionality while maintaining an intuitive interface that accommodates users regardless of technical proficiency. The system's design prioritizes reliability, responsiveness, and user experience, addressing common barriers to adoption that have historically limited the mainstream penetration of smart home technology.

2. Aim and Objectives

<u>Aim</u>

Development of a Smart Home IOT application using temperature, humidity, and light sensors for reliable environmental monitoring that possess the ability to control light using voice commands in a room.

<u>Objectives</u>

1. To develop a smart IOT application using temperature, humidity, and light sensors for environmental monitoring
2. To integrate voice control functionality through Google Home for intuitive user interaction
3. To create responsive, real-time dashboards for data visualization and system control with Sinri Pro and React.
4. To utilize an LDR sensor for detecting the room's light intensity and automating the operation of the bulb.
5. To integrate a DHT11 sensor for measuring real-time temperature and humidity.
6. To establish a scalable architecture that facilitates future expansion

3. Literature Review

3.1. Introduction to Smart Home Technology and IoT

The integration of Internet of Things (IoT) technology into residential environments has transformed conventional households into intelligent ecosystems capable of environmental monitoring, resource optimization, and enhanced user convenience. Gubbi et al.[1] (2013) defined IoT as the interconnection of sensing and actuating devices providing the ability to share information across platforms through a unified framework. The rapid growth of IoT applications in residential settings has been facilitated by advancements in wireless communication technologies, miniaturization of sensors, and increased computational capabilities of edge devices (Sethi & Sarangi, 2017)[2].

3.2. Environmental Monitoring in Smart Homes

Environmental monitoring constitutes a fundamental aspect of smart home implementations. Sensors for temperature, humidity, and light intensity provide valuable data that can be leveraged for both user awareness and automated decision-making processes. Kelly et al. (2019)[3] demonstrated that continuous monitoring of indoor environmental parameters contributes significantly to energy efficiency, with potential energy savings of 15-30% in residential buildings. The DHT11 sensor, employed in this project, has been extensively utilized in similar implementations due to its cost-effectiveness and reasonable accuracy for non-industrial applications (Kumar et al., 2020)[4].

3.3. Voice Control and Virtual Assistants in Smart Homes

Voice-controlled interfaces have emerged as a transformative technology in smart home ecosystems, offering hands-free interaction that enhances accessibility and user experience. Hoy (2018)[5] examined the evolution of virtual assistants and their integration into smart home environments, highlighting that voice interfaces reduce the cognitive load associated with controlling multiple connected devices. The adoption of commercial virtual assistants such as Google Assistant, Amazon Alexa, and Apple Siri has accelerated the deployment of voice-controlled smart home systems due to their robust natural language processing capabilities and extensive third-party integration options.

3.4. Raspberry Pi as an IoT Platform for Smart Homes

The Raspberry Pi has emerged as a popular platform for IoT implementations due to its computational capabilities, connectivity options, and cost-effectiveness. Vujović and Maksimović (2015)[6] evaluated the Raspberry Pi as an IoT platform, concluding that it offers an optimal balance between processing power and energy efficiency for home automation applications. The GPIO (General Purpose Input/Output) interface of the Raspberry Pi enables direct connection to various sensors and actuators, facilitating the development of integrated smart home systems without requiring extensive additional hardware

4. Analysis and Design

- **Hardware Design**:

  Hardware Components Used

  - Raspberry Pi 4
  - MicroSD Card - 32GB
  - DHT11 Temperature and Humidity Sensor - To detect temperature and humidity
  - Light Sensor - LDR
  - Relay - JQC3FF-S-Z
  - Bulb - 5W
  - Capacitor -1 µF
  - Power Supply for Raspberry Pi
  - Jumper Wires
  - Breadboard

- **Software Architecture**:

  Software Components Used

  - Python 3
  - React
  - GPIO Libraries - For sensor data handling
  - Sinric Pro
  - Sinric Pro Dashboard Interface - For real-time monitoring and automation
  - Visual Studio Code - IDE for development of dashboard
  - Communication protocols (HTTP, WebSocket, etc.)

4.1. Overall System Architecture

The smart home system follows a three-layer architecture that provides a clear separation of concerns while facilitating seamless data flow between components:

1. **Perception Layer**: Comprises the physical hardware components including the Raspberry Pi 4, DHT11 temperature and humidity sensor, light-dependent resistor (LDR), and relay modules connected to lighting fixtures. This layer is responsible for data acquisition and physical control of the environment.

2. **Network Layer**: Handles communication between the perception layer and application layer, utilizing both local network connectivity and cloud services. This layer incorporates WiFi communication for local network access and leverages Google's cloud infrastructure for Assistant integration.

3. **Application Layer**: Consists of the custom-built Sinric Pro Web and mobile dashboard, and a custom made React dashboard for visualization and control, and Google Home integration for voice commands. This layer provides the interfaces through which users interact with the system. Google Home is integrated into the system through the mobile app with the aid of Sinric Pro. The React dashboard is for regular domestic visualization purposes.

4.2. Features of the system

- Displays real time temperature and the humidity of the room in all three dashboards, custom react dashboard, Sinric Pro Web and Mobile.
- Has an automation feature for switching the bulb on and off automatically, by sensing the surrounding environmental lighting.
- Can switch on and off the bulb manually via the dashboards as per the user’s wish.
- The voice commands are taken in from the mobile app and sent through Google Assistant via Sinric Pro to the Raspberry Pi Operating System(OS). It then operates accordingly.

E.g: When the user says " Hey Google, turn on the lights of my living room", it would respond "Turning bulb on" and while switching on the bulb.

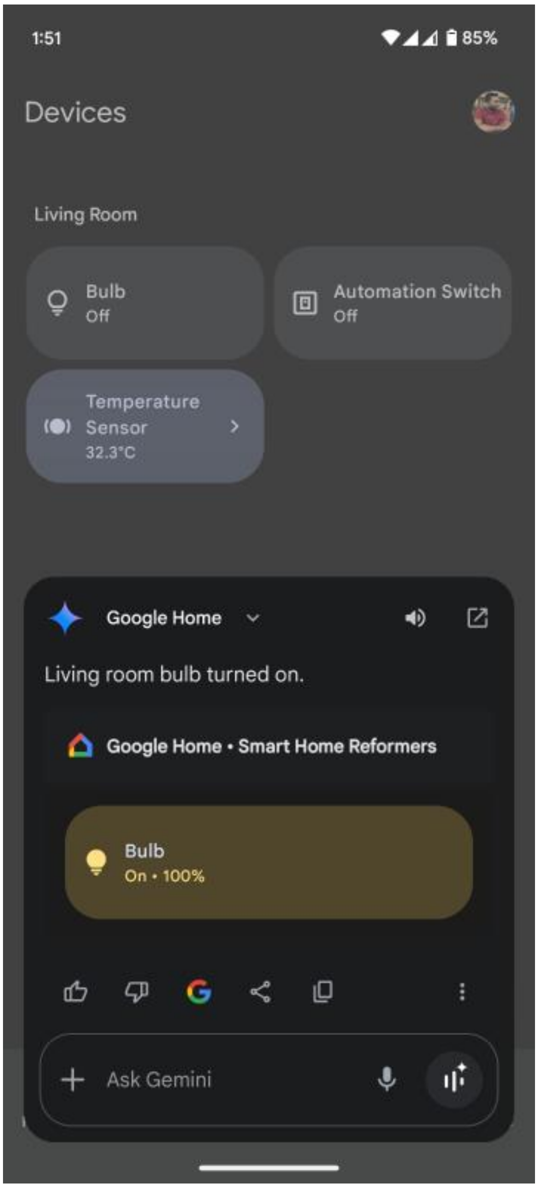

Fig. 1 "Living room bulb turned on" response

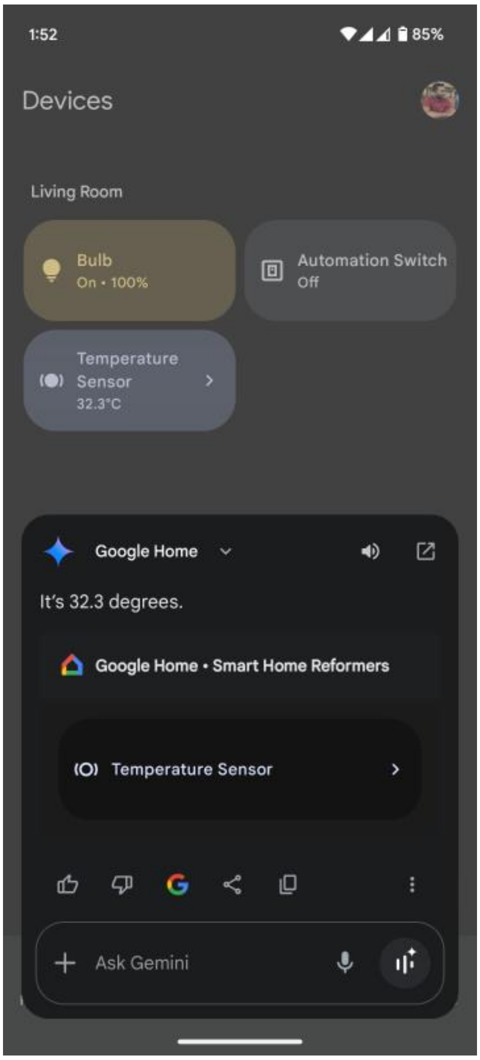

Fig. 2 - Temperature asking scenario

4.3. Block diagram of the system

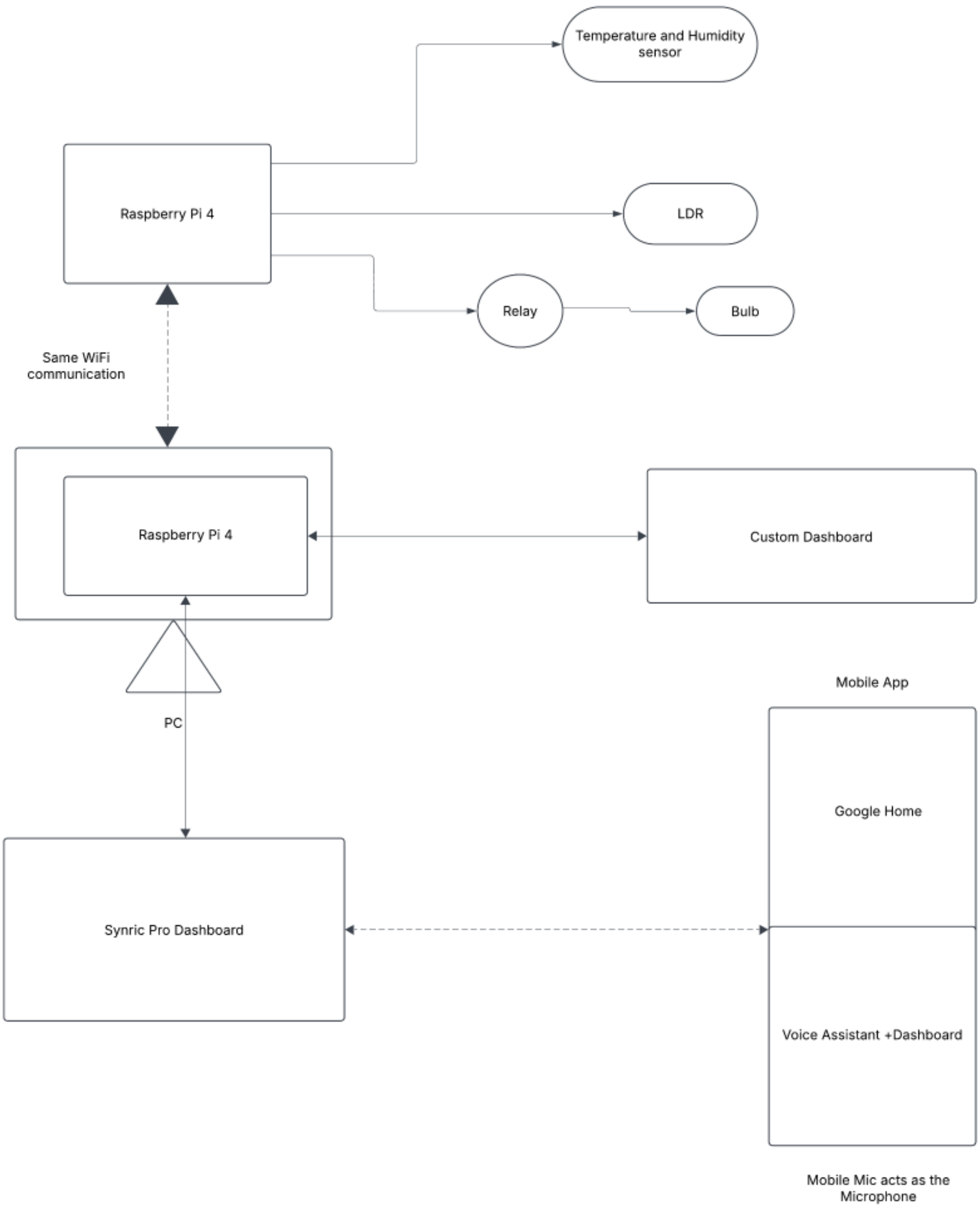

Fig. 3- Block Diagram of the system

8. Physical Design

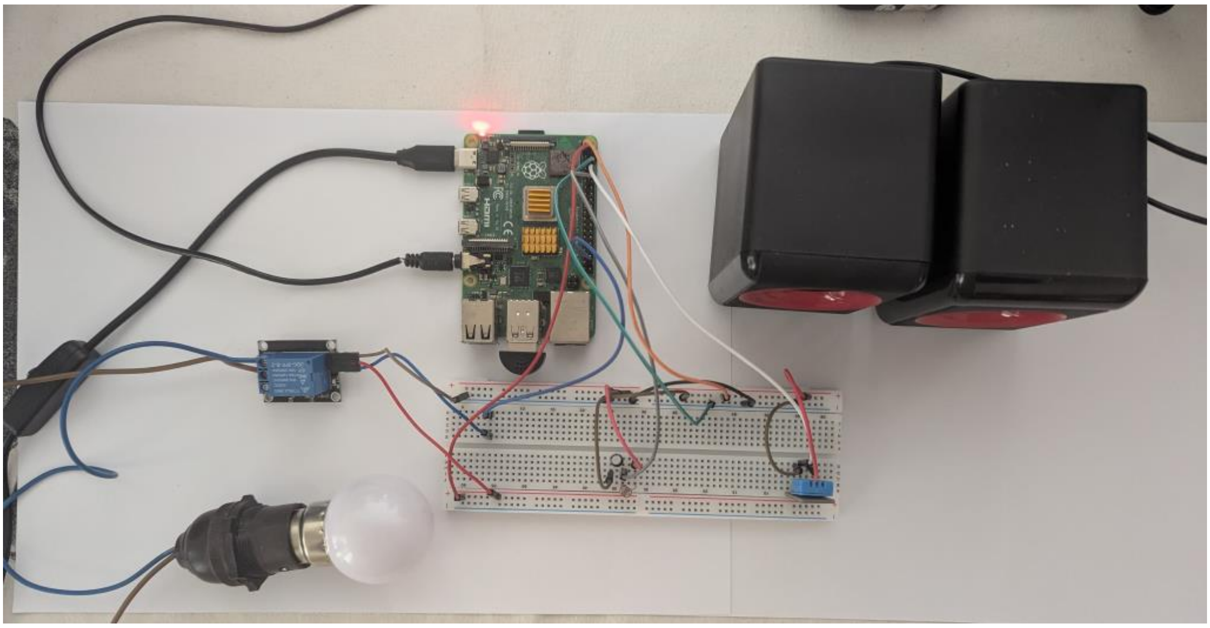

Figure 4-View from top, when the light is off

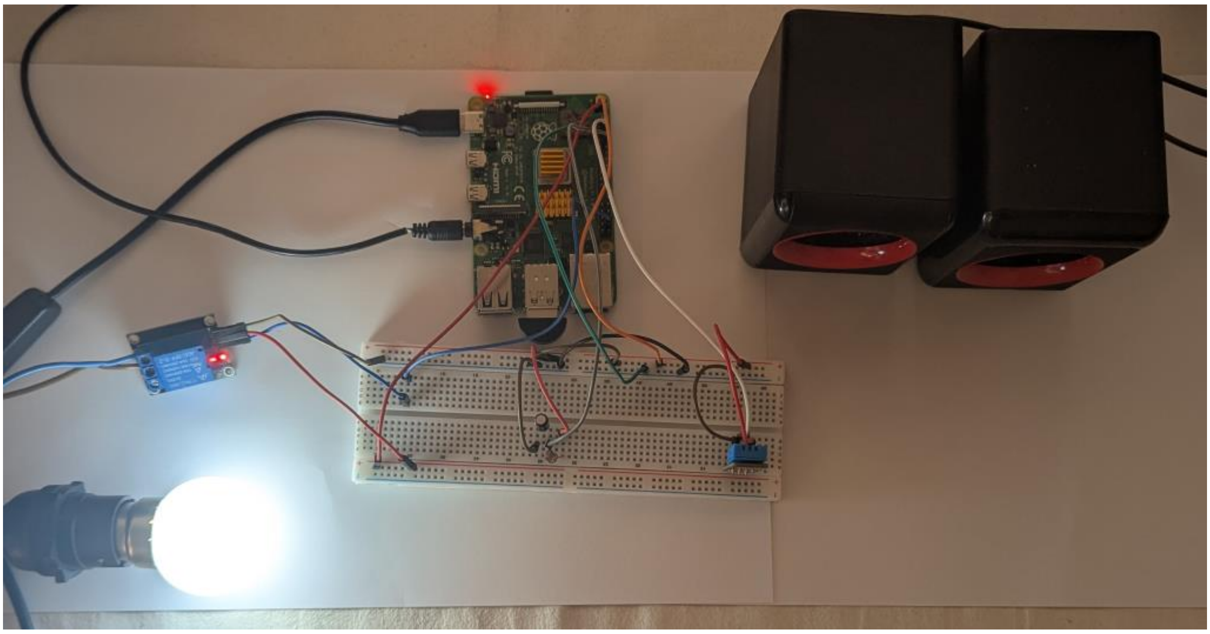

Figure 5 - View from top, when the light is on

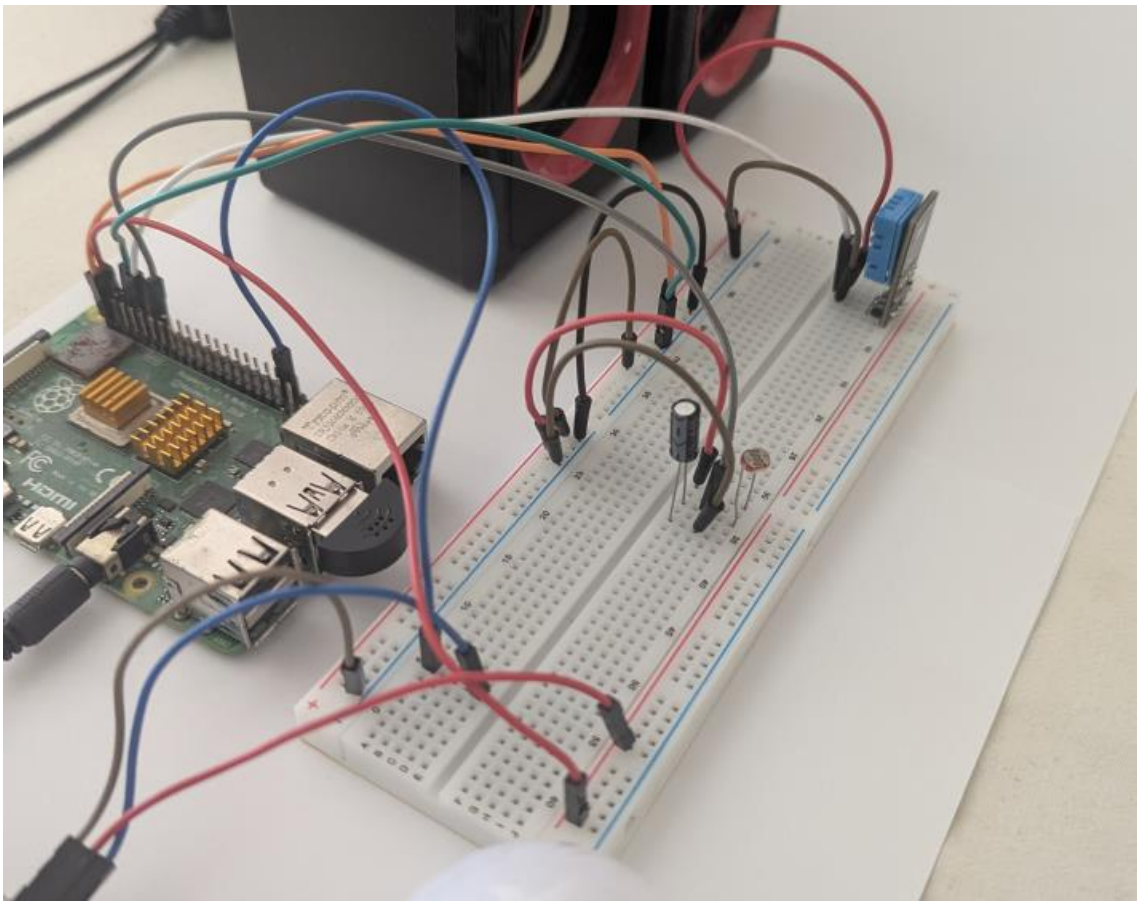

Figure 6 - Breadboard arrangement

9. Circuit Design and Implementation

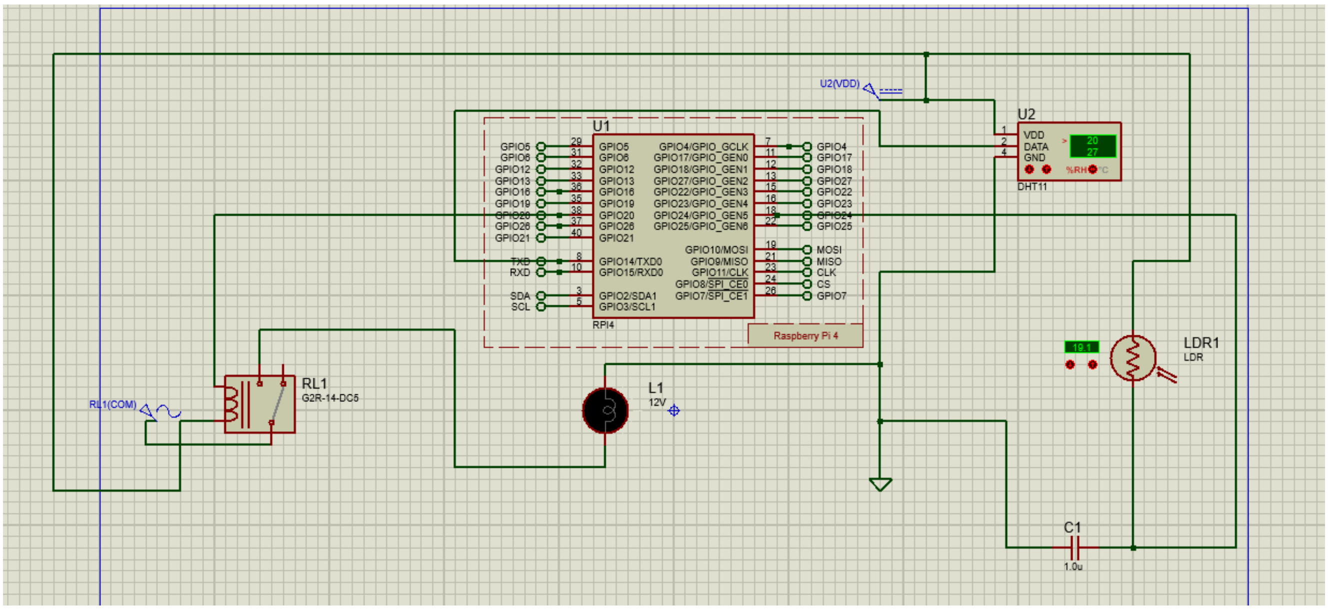

Figure 7 - Basic Circuit Design of the system

Figure 8 - Custom React Dashboard

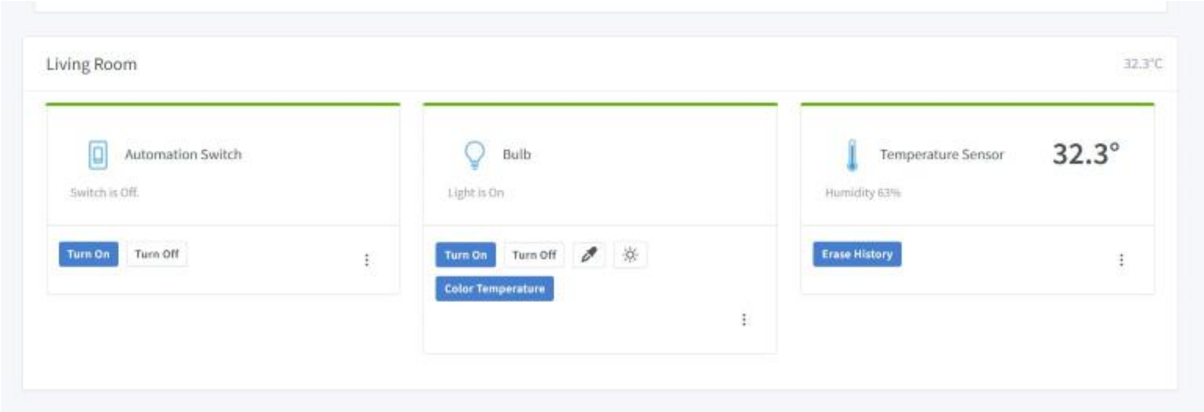

Figure 9 - Sinric Pro Web Dashboard

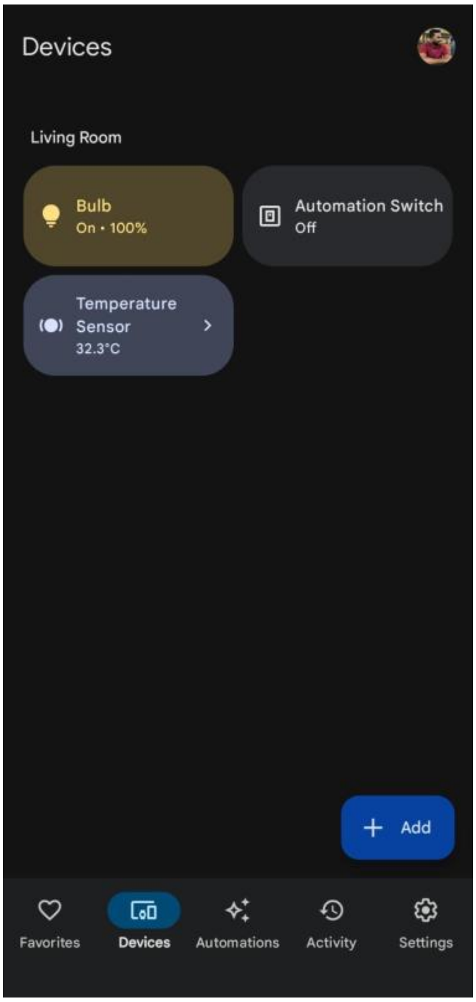

Figure 10 - Sinric Pro Mobile Dashboard

10. Further Work

Future enhancements of this system include:

1. Expansion of the sensor suite to include air quality, motion detection, and energy consumption monitoring
2. Implementation of machine learning algorithms for predictive automation based on usage patterns
3. Integration with additional smart home platforms such as Home Assistant
4. Development of mobile applications for improved remote access and control
5. Enhanced security features including intrusion detection and comprehensive logging

This implementation represents a successful proof-of-concept that bridges the gap between simple sensor projects and comprehensive commercial smart home solutions, providing a foundation for further innovation in residential IoT applications.

13. Conclusion

Key achievements of the implementation include:

1. Successful integration of hardware sensors with the Raspberry Pi platform to create a reliable environmental monitoring system
2. Implementation of two responsive dashboards that visualizes real-time data and facilitates system control
3. Implementation of Google Home integration, enabling natural language voice control of lighting systems
4. Creation of an automation framework that responds to environmental conditions according to predefined rules
5. Establishment of a scalable architecture that can accommodate future expansion and additional functionality

This project successfully demonstrated the development and implementation of an integrated smart home system utilizing Raspberry Pi, environmental sensors, and Google Home voice control. The system effectively monitors temperature, humidity, and light intensity while providing intuitive control mechanisms through both a custom-built Sinri Pro dashboard and voice commands.

14. References

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