Computer Engineering Department

Project U33: AuraTherm/Aura

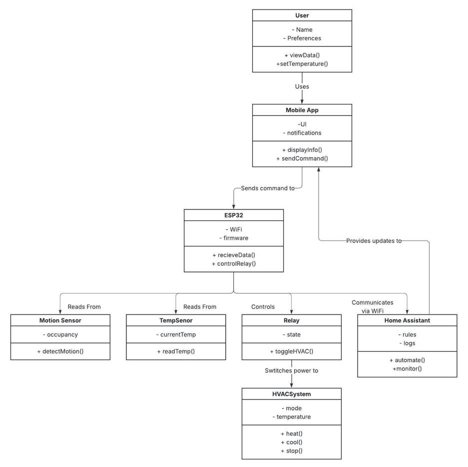
Project Advisor: Dr. Daphne Chen

Huynh, Roger (BS Computer Engineering)
Montepalco, Jeric (BS Computer Engineering)
Quach, Sabrina (BS Computer Engineering)

Introduction

Traditional and smart thermostats control temperature for the entire house, wasting energy when rooms are unoccupied. This inefficiency can shortec HVAC lifespan, increase utility bills and increase carbon emissions. Lower income households are disproportionately affected due to high energy costs [1].

AuraTherm is a motion sensing smart thermostat designed to optimize HVAC usage by adjusting temperature only unoccupied rooms. This system lowers energy usage, reduces utility costs and promotes environmental sustainability.



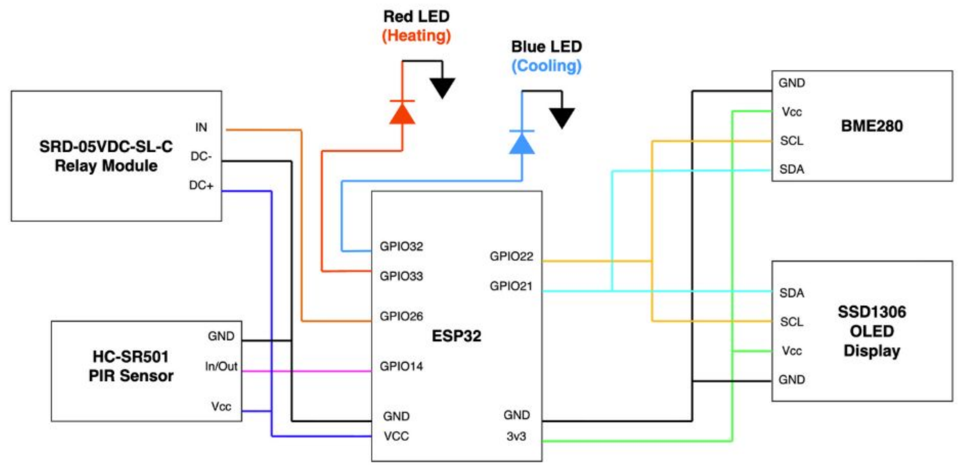
System Overview

- ESP32 microcontroller for Wi-Fi connectivity and hosting a lightweight HTTP server
- PIR motion sensor to track room occupancy
- BME280 for temperature sensing
- Relay module for simulated HVAC control
- Aura mobile app for real time monitoring and settings

Methodology

Hardware

AuraTherm was developed using an iterative hardware-software integration workflow:



- Microcontroller Platform - ESP32:
  - Select for its dual-core processing, built-in Wi-Fi, lower power usage, and strong support for real-time sensor polling and REST API communication
- Environmental Sensing - BME280
  - Integrated over I2C to collect temperature, humidity and pressure. Wiring was optimized for stability using pull-ups and verified using multimeters

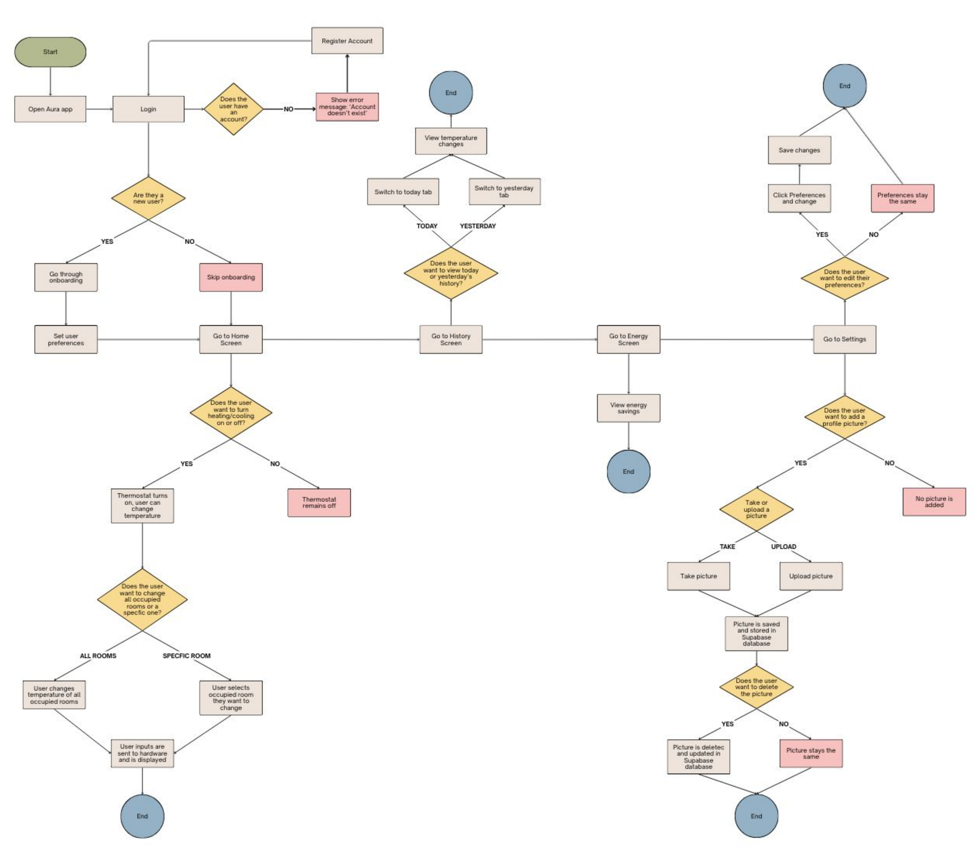
Methodology

- Occupancy Detection -PIR Motion Sensor:
  - Added to detect room movement and trigger when motion is detected, 90-second hold occurs. Warm-up timing and false-trigger reduction were tested through repeated motion trials.
- OLED Display - SSD1306:
  - Connected via I2C to provide real time display of sensor data and device status. Custom UI pages were written to fit the resolution.
- Relay Module Integration:
  - A 5V relay module allows AuraTherm to switch HVAC systems or heaters. Hardware isolation and flyback protection were ensured.
- Prototyping and Wiring
  - Built on a breadboard with jumper wires, then test continuously for stability, reliability, and noise reduction.

Software

The data flow diagram illustrates how users interact with the Aura app and how their actions flow through the system. When a user logs in, the app checks if they are a new or returning user where they can either go through the onboarding and set their initial preferences or go directly to the home screen. After, users can control heating and cooling, adjust temperatures, and view energy saving data. Each user decision flows into the next step to ensure a smooth user experience [2].

Behind this interface, the system processes each user input and updates the thermostat and backend appropriately. Temperature changes are sent to the ESP32 in real time which ensures that the HVAC system immediately responds. When users modify their temperature preferences or take, upload, and delete a profile picture, those updates are stored through Supabase.



Overall, the Aura app successfully translates user actions into synchronized, real time behavior across both the app and the hardware.

Analysis and Results

HTTP Request Latency

HTTPRequest Type	ESP processing	Wifi Transmission	App Update	Total RTT
GET /status	2 - 5ms	1 - 5ms	<2ms	3 - 12ms
POST /motion/set	2 - 5ms	1 - 5ms	<2ms	3 - 12ms

Temperature Sensor (BME280) Accuracy

BME280 Test #	Issue (If any)	Temperature reading accuracy	Pass/Fail
T1 (Device #1)	Faulty device and sensor. Sensor read static value	±x°F	Fail
T2 (Device #2)	Faulty device	N/A	Fail
T3 (Device #3)	Larger pinholes require pins to be at certain angle.	±1.0°F	Pass (Conditionally) Sensor be secure. Readjust to fix.

PIR Motion Sensor Detection Timing and Behavior

Test Case	Scenario	Sensor Triggered	Time for raw = 1 (Motion detected)	Time for raw = 0 (No motion)	Observations	Pass/Fail
T1	Human body enters detection zone, stays, then leaves	Yes	100-500ms (instant)	5 - 10s	Reliable/real time detection	Pass
T2	Human passes through zone.	Yes	100-500ms (instant)	5 - 10s	Detects entry, then remains HIGH for hold time after exit	Pass
T3	Inanimate object moves	No (should not)	N/A	N/A	No false triggers from inanimate objects	Pass

Analysis

The communications between the ESP32 and the app have a total round trip time (RTT) of 3-12ms, providing real time responses. This is due to the small payload size, where each JSON field is about <10 bytes. Our ESP32 has 4 JSON hearts, so the payload is ~40 bytes, not including HTTP headers and trailers

The BME280 testing ran through three separate devices. Devices 1 and 2 were faulty, where device 1 provided a static value and 2 did not connect to the ESP32. Device 3 works conditionally, as the larger pinholes require the temperature sensor to be at a certain angle. Nonetheless, the device works consistently, providing real time temperature sensing with an error margin of ±1.0°F.

For the PIR motion sensor, we tested with the following constraints. Only human/living beings, as the PIR sensor senses heat, should activate the sensor. Raw, where HIGH signals motion and LOW signals no motion, should not instantaneously change from 1 to 0 to avoid multiple on and off triggers. We set the timing from 1 to 0 at 5 to 10s for demonstrating functionality. For real use cases, it would be 20-60s.

The sensor provides real time and practical timing for tests, ONLY sensing human body heat. It does NOT trigger HIGH when inanimate objects move in the detection range.

Summary/Conclusions

AuraTherm demonstrates how low-cost IoT hardware paired with mobile app control can significantly enhance thermal comfort and energy management. Through environmental sensing and occupancy detection, the system intelligently adjusts HVAC behavior to reduce waste. The project showcases strong integration between embedded systems, cloud-free networking, and user-interface design

Key References

[1] Ayan, Onur, and Belgin Turkay. “Smart Thermostats for Home Automation Systems and Energy Savings from Smart Thermostats.” 2018 6th International Conference on Control Engineering & Information Technology (CEIT), Oct. 2018, pp. 1–6, ieeexplore.ieee.org/abstract/document/8751790, https://doi.org/10.1109/ceit.2018.8751790. Accessed 19 Mar. 2025.

[2] Carli, Raffaele, et al. “IoT Based Architecture for Model Predictive Control of HVAC Systems in Smart Buildings.” Sensors, vol. 20, no. 3, 31 Jan. 2020, pp. 781–781, www.mdpi.com/1424-8220/20/3/781, https://doi.org/10.3390/s20030781. Accessed 19 Mar. 2025.

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