Ambient Intelligence, Alameda, Group 14

Home Security Monitoring

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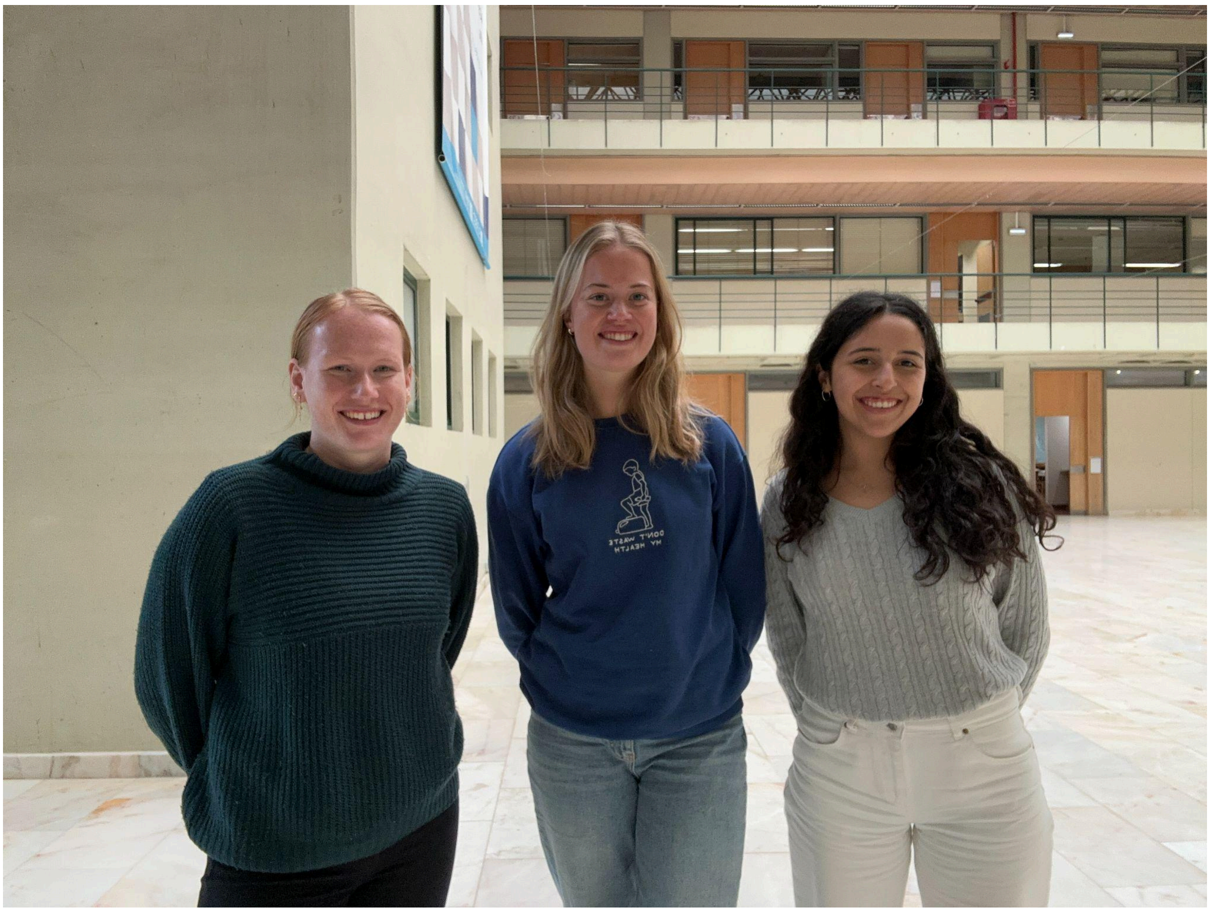


1 Introduction

Ambient Intelligence (AmI) is a technology that enables simplification and automation of our everyday lives through the use of sensors embedded in our environment. One specific use area for this technology is to allow at-risk individuals to live independently and safely at home for longer. For our project, we have chosen to focus on individuals with memory impairments or attention deficit disorders.

Our solution focuses on home appliance monitoring. Since we have limited time for the project, we restricted the task to implementing two parts of this monitoring system. The first part involves a stove monitoring system. This system will alert the user or caregiver through a website if the stove remains on for an extended duration. It will then be possible for the user or caregiver to activate a kill switch to turn off the heat source. For demonstration purposes, our killswitch consists of a motor which drives a fan that will blow out a candle representing the stove top. In a real application, the killswitch would be connected to an electrical stove top and turn it off.

The second part we implemented for the prototype is a door monitoring system. Its purpose is to alert the user/caregiver if the front door remains open for an extended period of time. The status for this system is displayed on the same website as the first part, to provide real-time updates on the status of the door.

2 Literature Review

For our literary review, we have chosen two studies relevant to our project's focus on improving home security for the elderly using IoT technologies. The first paper, "IoT Supported Smart Home for the Elderly", details an IoT-based home monitoring system aimed at improving safety at home for the elderly, particularly those with dementia (Sokullu, Akkaş, & Demir, 2020). The system uses ambient environmental sensors and an emergency wristband to monitor the safety of its users.
The paper describes an ambient sensor system that is directly relevant to the environmental monitoring we envision for our system. Particularly, the use of alerts for abnormal activities are a useful insight that could be included in our system as well. In addition to this, the paper also uses a noise alarm to alert residents of potentially dangerous events.

While the paper prioritizes health aspects of safety, through detecting events like prolonged inactivity or falls, our project is geared more towards appliance safety. Key functionalities for our system are the visual monitoring and killswitch capabilities. This extends the appliance security functionalities by enabling automatic action to avoid dangerous events, instead of requiring the inhabitant to perform the action themselves. The above paper also does not focus on the user-friendliness of its user interface, but rather the simplicity of setup. We intend to create a user-friendly and accessible dashboard, to make it easier for users to monitor and control appliances, to improve the effectiveness and accessibility of the system.

The second paper chosen for our literary review, "Design of a Smart Home Environment Monitoring System Based on STM32", presents a detailed explanation of the implementation of an IoT-based system focused on enhancing home safety through environmental monitoring (Zhang et al., 2023). This paper focuses more on the practical implementation

part of the project than the previous paper. They also improve on the user interface by using a simple mobile app, and by utilizing application notifications for effective alerts.
This paper's approach to environmental monitoring, especially the detailed descriptions of the sensors and alert system, is valuable for how we can implement our own system. We can incorporate these same concepts for our stove-focused prototype. The mobile app and notification functionality is also a good addition, and something we would recommend for further development of our system.

Similarly to the first paper, our project differs from the second paper by having a larger focus on appliance safety in particular, including a killswitch, and by including visual monitoring as well as sensor-based.

3 Problem

The specific problems being addressed in our project are the safety and security concerns faced by individuals with memory problems and attention deficit disorders who live alone at home. These individuals may struggle to remember to lock doors, turn off electrical equipment, or switch off stove tops, putting themselves at risk of accidents or intrusions. Uncertainty connected to the safety of these residents and their homes might also be a daily stressor for both the residents themselves, and their caregivers.

The proposed solution aims to provide real-time monitoring of a stove top, which is a potentially dangerous home appliance, and ensure locking of exterior doors, through the use of sensors and cameras. The purpose is to give a way to monitor important parts of the home, to reduce risk of damages and alleviate anxiety for both the primary user and their caregivers. By enabling remote killswitch functionality of the stove, and alarms for monitoring both stove top and front door, the system offers increased safety and reassurance.

Stakeholder	**Description**	**Major value**
Residents (*Primary users*)	Individuals with memory impairments or attention deficit disorders	Increased security at home. Reduced anxiety about forgetting potentially dangerous home appliances.
Caregivers (*Secondary users*)	Professional or non-professional caregivers of the resident, such as nurses, family, or friends	Reduced anxiety on behalf of the resident. A simple way to check dangerous appliances. A simple way to interfere with a dangerous event like a stove top being left on.
The healthcare system	Healthcare providers and regulators connected to the patient	Increased security for patients. Reduced costs connected to caring for patients. Reduced demand for home care.

3.1 Solution Requirements

Stove monitoring system:
R1.1: The system must be able to detect a heat source.
R1.2: The system must be able to produce sound signals to alert users of a possible issue.

R1.3: The system must be able to provide real-time camera updates to monitor appliances.
R1.4: The system must be able to deactivate an appliance upon detection of a possible issue.
R1.5: There should be a user-friendly dashboard to allow users to see monitoring information.
R1.6: The user interface should let the user set the specific parameters for system alarms.
R1.7: Sensor information must be correctly and effectively communicated to the dashboard.
R1.8: The user must be able to activate the kill switch through the user interface.

Door monitoring system:
R2.1: The system must be able to detect whether a door is open or not.
R2.2: The system must be able to produce sound signals to alert users of a possible issue.
R2.3: The system must be able to provide real-time camera updates to monitor a door.
R2.4: There should be a user-friendly dashboard to allow users to see monitoring information.
R2.5: The user interface should let the user set the specific parameters for system alarms.
R2.6: Sensor information must be correctly and effectively communicated to the dashboard.

3.2 Assumptions

- The primary users of our system have the digital competency to be able to turn off notifications before activation of killswitch
- Home environments have an existing internet connection, power connection, and a smartphone or computer for accessing the system dashboard
- Assume the oven can be turned off based on an electrical signal

4 Proposed Solution

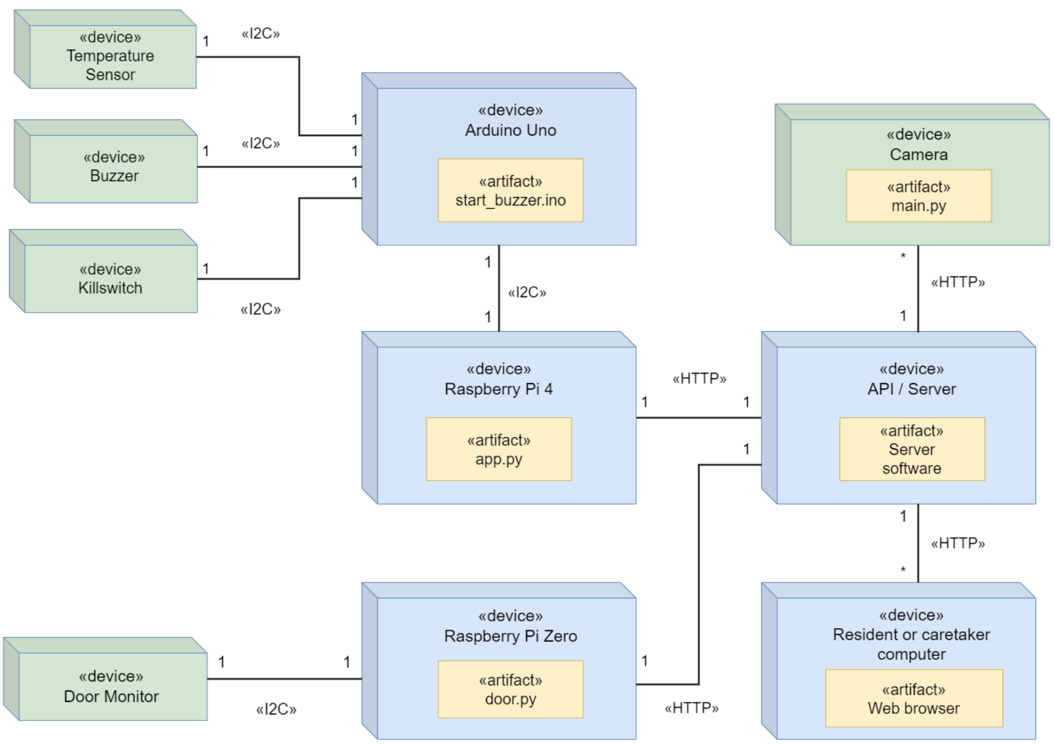
4.1 Overview

The components included in the solution are visible in the diagram below. The main processors of the system are the Raspberry Pi 4 model B (RPi), and the Raspberry Pi zero 2W. Both use Wi-Fi to exchange messages with our frontend dashboard. The RPi4 is also connected over USB to an Arduino uno, which handles the buzzer and temperature sensor.

Raspberry Pi 4	Handles application logic based on the Arduino information, and communicates with the dashboard. Sends temperature and alert status to dashboard, receives updated alert times and eventual killswitch activation on user input.
Arduino Uno	Processes signals from the sensors and sends to the RPi.
Raspberry Pi zero 2W	Processes signals from the door system, and sends the state of the door over Wi-Fi to a dashboard. Receives updated alert times from dashboard on user input.
Camera	The camera is connected by a camera serial interface (CSI) port.
Heat sensor	The heat sensor is connected to the Raspberry Pi through GPIO pins.

Kill switch	To turn the heat source off. Demonstrated with a small motor.
Buzzer	For sending audible alarm signals.
Web Dashboard	A dashboard implemented as a web page. Works as a user interface, to let the user see and interact with the state of the door and stovetop.

See the following deployment diagram for an illustration of the system setup. The green devices are the devices that directly gather data, while the blue devices handle system logic and communication.

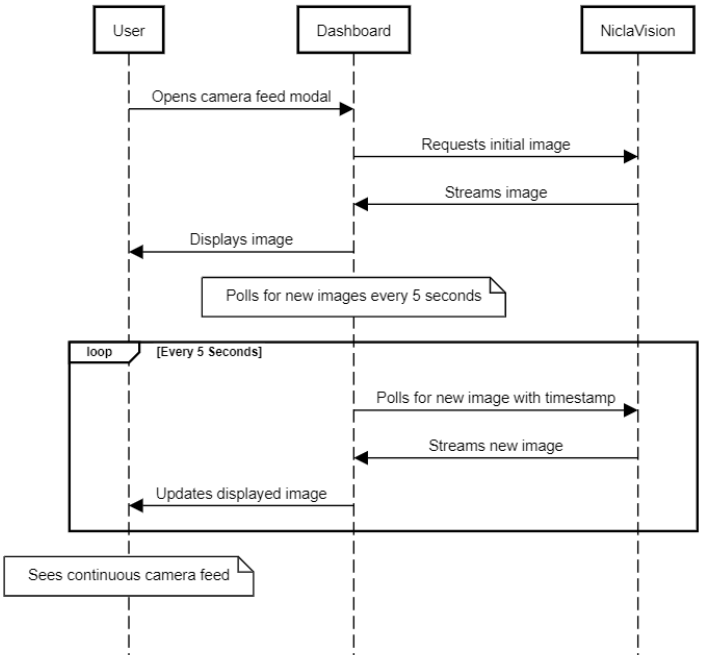


4.2 Logical Design

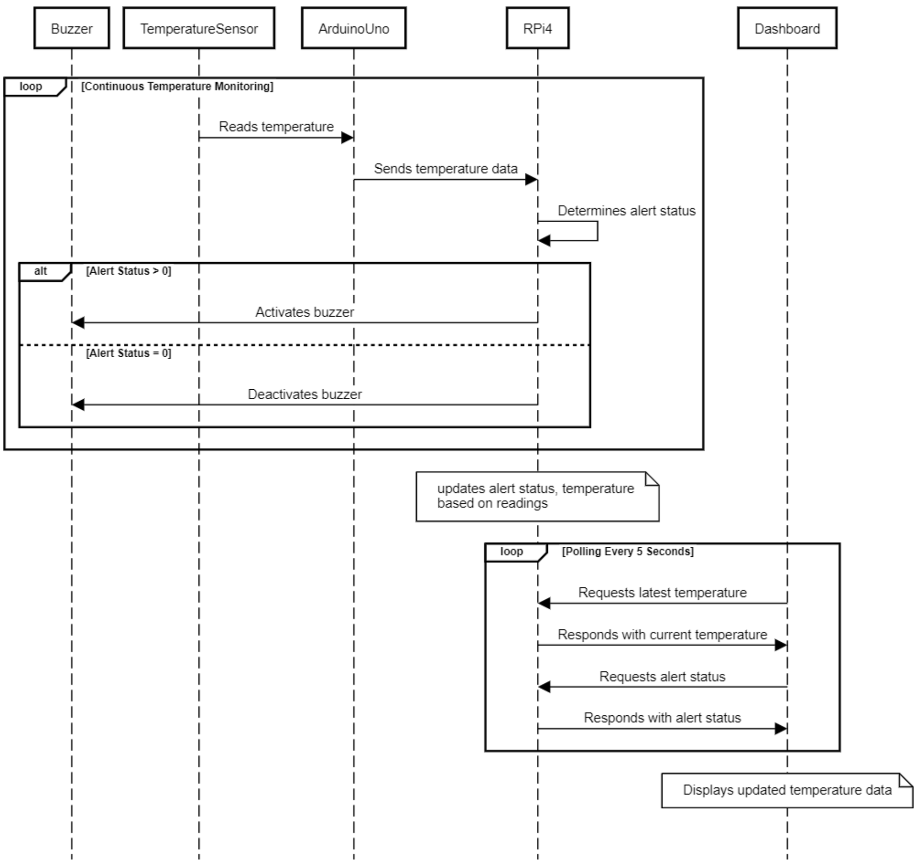
The Raspberry Pi 4 periodically gathers data from the sensors via the Arduino. It also uses a timer to keep track of how long the heat source has been active. If the heat source has been on for longer than the alert time, an “alert” event will be triggered. This event is displayed on the dashboard, and sounds an alarm through the buzzer. The user then has the option to activate a killswitch from the web dashboard, to turn off the stove top. In the real system, the kill switch would be connected to the electrical oven to turn it off, but for demonstration purposes we use a small motor with a fan to show that the signal is received.

See the following sequence diagrams for an illustration of system communication.

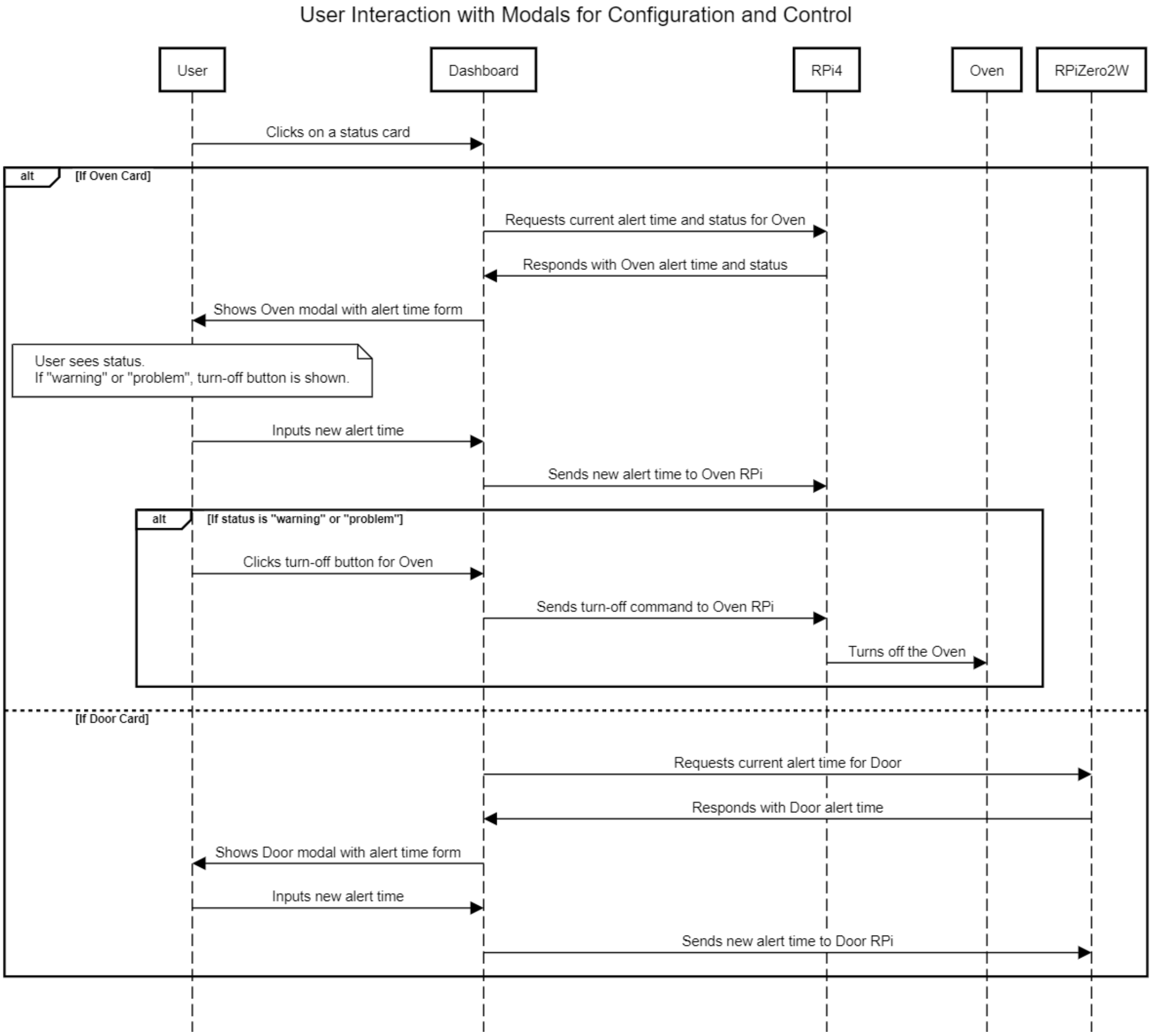
4.2.1 Camera to Dashboard Communication



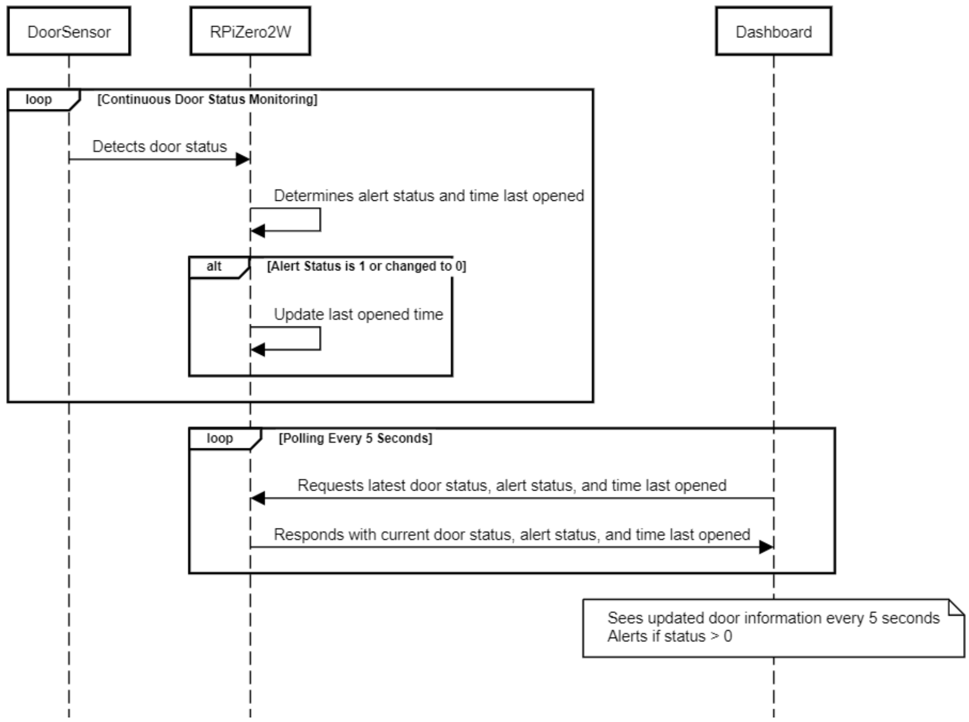
4.2.2 Temperature updates



4.2.3 Modal System



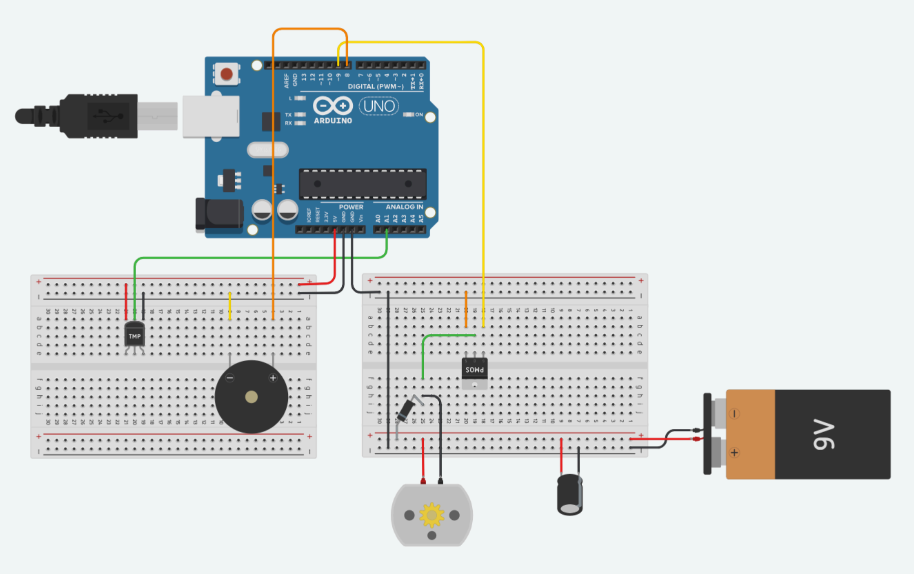
4.2.4 Door Monitor System



4.3 Technology Selection

The main programming language used in this project is Python. We decided to go with this language as it is well documented, and has several libraries and frameworks that are suited for Raspberry Pi development. In addition to this, it is a language that the group is familiar with. For the code that is uploaded to the Arduino we use Reference. The camera is programmed in MicroPython. For the dashboard we selected the web-framework React for the frontend, combined with Tailwind to simplify the styling of the page.
We used HTTP as a communication protocol between the web dashboard and the Nicla Vision and Raspberry Pi's, as this is a simple protocol that most browsers support. On the Nicla vision we created the HTTP requests, while we used Flask for simpler request and endpoint handling for the Raspberry Pi communications.

For the project development, we connected to both RPis using SSH over Wi-Fi. This way, the system only requires a stable connection to power and to the network. All components that connect through the network must be connected to the same SSID. Their IP addresses on this access point should be stored in a network config file, which is accessed by all components that communicate over the network. The RPi 4 runs a program which handles both the exchange of information and all the processing of sensor data. The Nicla Vision needs Wi-Fi and a power connection. For our system we power it through the RPi, but the camera is only connected to the dashboard through HTTP messages. The Arduino is connected to the RPi4 using a USB cable. It uses the USB connection to send readings over the serial terminal, and receive inputs from the RPi4. The Arduino has three main circuits: temperature monitoring (TMP36 sensor), alarm sound generation (Piezo), and the activation of the killswitch. The first two are very simple and require only connection to ground and to their respective (analog) input and (digital) output pins. Our demonstration of the killswitch uses a motor to blow out a candle, illustrating the stovetop. This motor requires additional components and connections, including a diode to prevent current flowing in the incorrect direction, a transistor to act as a switch to turn the motor on or off depending on the input, a 9V battery to provide more power to the system, and a capacitor to manage fluctuations in voltage. A diagram of the circuit can be found in the following image:



5 Bill of Materials

5.1 Hardware

- **Raspberry Pi 4 Model B**: Central control unit.
- **Raspberry Pi zero 2W:** Door monitoring system.
- **TMP36 Sensor**: Monitors temperature
- **Nicla Vision camera**: For visual monitoring.
- **Buzzer (Piezo)**: Audible alerts.
- **Breadboard & Jumper Wires**: Prototyping connections.
- For a simplification of the killswitch:
    - **Small motor, Transistor MOSFET, Diode, 9V Battery and battery snap, Capacitor**

5.2 Software

- **Raspberry Pi OS**: Operating system.
- **Python:** Programming language for the RPi's.
- **Micropython**: Programming language for the Nicla Vision.
- **Reference:** Programming language for the Arduino.
- **Arduino-Cli:** CLI to compile and upload Arduino code.
- **React and Tailwindcss:** Web-frameworks, used for building the frontend.
- **Flask & HTTP**: Web interface and real-time communication.

6 Conclusion

Our finished product meets all requirements for both parts of the system. For simplification, we did not implement R2.3: "The system must be able to provide real-time camera updates to monitor a door”, as this would require an additional Nicla Vision camera, but the implementation would be the same, so it would be simple to extend this solution for a real implementation.

We managed to successfully implement a prototype of a stove system and door monitoring system. We provide a simple web page as a user interface, which provides real time updates on the heat source and the door circuit and displays alerts if we register potentially dangerous behavior. For the stove top, we monitor the temperature, and provide buzzer alarms, a camera feed, and a killswitch. For the door system, we monitor whether it is opened or closed and keep track of when it was last opened or closed. We have no automatic closing of the door, so this must be done manually. The intention here is just to serve as a reminder while the resident is likely close enough to manually fix the issue. It is possible for the user to change the timer on the alerts. This gives each user the opportunity to personalize the system to their needs.

One of the biggest strengths of our system is the user-friendly and visually appealing web interface, which clearly communicates the status of each part of the system. We think the killswitch functionality, although just illustrated through a motor here, is a big advantage of a system like this, as it allows users to fix the issue remotely. The option for real-time visual monitoring of each appliance through a camera is also important, since it increases system reliability and the user’s trust in the system, as it allows the user to visually confirm the sensor readings and avoid false alarms. Finally, the system provides customizability by allowing users to adjust alert times according to their own needs. In a more complete system, this could be extended to adjust the timer automatically based on user habits.

One weakness of the system is the lack of automatic door closure functionality. What differentiates this system from the monitoring system we looked at in our literature review is the killswitch functionality of the oven, and the ability to remotely solve the issues that might arise. That is currently not possible for the door system. Another potential issue is the cost of the system, as the cameras are relatively expensive, which would make the system inaccessible for many. Finally, the current implementation requires the user to actively monitor the dashboard web page to get alerts if they are not at home to hear the buzzer. In a final implementation, it would be beneficial to implement some form of automatic notification through messages or an app with notifications.

In summary, our project fulfills the requirements we set at the beginning of our development, and we believe it succeeds in increasing the safety of users, and relieving possible anxiety about home appliances. This prototype can be further developed to make a more complete home monitoring system that would allow at-risk individuals to live home longer, with less need for attention from caregivers.

7 Bibliography

Sokullu, R., Akkaş, M. A., Demir, E. (2020). "IoT supported smart home for the elderly". Internet of Things, 11, 100239. Available online 6 June 2020, Version of Record 16 June 2020. https://doi.org/10.1016/j.iot.2020.100239

Zhang, H., Zuo, X., Jiang, W., Jiang, Q., Yin, G. (2023). "Design of Smart Home Environment Monitoring System Based on STM32". In: 2023 3rd International Symposium on Computer Technology and Information Science (ISCTIS), Chengdu, China, 07-09 July 2023, IEEE Xplore, 16 August 2023. https://doi.org/10.1109/ISCTIS58954.2023.10213174