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Automated Door System with Thermal Scan

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Eric Redding

Abstract

The worldwide Covid-19 pandemic has created opportunities in the public health and safety sector along with a demand for solutions that address the public health issues that have been exposed. The need to create safe environments for the public has drastically increased over the past year and a half. One identified need has been for systems that provide for constant temperature checks for individuals prior to entering federal and public buildings.

This paper discusses the design of an Automated Door System with Thermal Scan that was developed as part of a Senior Capstone Design Projects course at Kennesaw State University (KSU).

The design of the Automated Door System with Thermal Scan was tested to verify the functionality of the design, and most of the objectives for the design project were met. However, this is an ongoing project and recommendations for further research and development work will be documented. Some specific recommendations for future work include more rigorous testing in different outdoor environments, designing a housing unit to house the components to create a more controlled environment for the system, and testing the performance at different distances with the thermal scanner.

Background

The project was undertaken to fulfill the requirements for the Senior Capstone Design course in the BS in Electrical Engineering Technology (EET) degree program. The Senior Capstone Design course at KSU is a one semester course where students are expected to integrate knowledge from across the core Electrical Engineering Technology curriculum, and apply engineering principles to formulate, design, construct, and demonstrate the functionality of a project that serves to address a contemporary problem or improves on a previous design solution. Students are encouraged to be the main drivers of the Capstone Design Project and are expected to come up with their own projects as much as possible, and to work in teams no larger than four people to develop their projects. The chosen projects must address the solution to a real-world problem or need. The main deliverables are a demonstrably working project prototype, a written project report, and an oral presentation of project results to an audience of students, faculty, and industry partners when available.

The requirement for this project was to design a Thermal Body Temperature scanning system that allows door access for individuals based on a successful temperature reading between 97 to 99 degrees Fahrenheit. The purpose of the design was to ensure the public health and safety in public buildings, such as federal buildings, schools, courthouses, state capitals etc.

This work in progress paper provides background information, and describes the tools used to build the Automated Door System with Thermal Scan. The design process is described along with the detailed system layout and a discussion of results.

Design Procedure

During preliminary research for the project, multiple distance sensors were considered. The first consideration was an ultrasonic distance sensor, which was the cheapest option. The ultrasonic distance sensor being considered could measure distances from 3cm-350cm, which was far more than enough for the task. The ultrasonic sensor's shortcoming was that they could not measure fast moving objects or objects with extreme shapes. This was not considered to be an issue for the project. The specific ultrasonic sensor that was researched was easily accessible and easily installed onto a Raspberry Pi circuit.

The second distance sensor considered was infrared based. The infrared distance sensor was more expensive than the ultrasonic distance sensor, but it was still within an affordable range. The infrared distance sensor had a much lower reading range of 10cm-80cm, which could have been an issue for the project.

The third and final distance sensor considered was a LiDAR sensor. The LiDAR sensor performs better than both the ultrasonic and infrared sensors, but the price of the sensor was also much higher, and the price would have raised project costs well above the desired range.

The design chosen consists of a thermal camera, a Raspberry Pi 4, ultrasonic sensor, a linear actuator, and motor driver to power the actuator. In addition to the discrete components, a voltage divider circuit was constructed that consists of an array of resistors to bring down the voltage from 5V to 3.3V to safely provide continuous power to the Raspberry Pi without damage.

The Raspberry Pi was programmed to take an array of temperatures that were then compared with a spread of acceptable temperature ranges. If the temperature is within an acceptable range, then the linear actuator opens and closes for a preset duration. Once that process is complete, the raspberry pi diverts back to the scanning process for the next person to be scanned. If a temperature is scanned that is NOT within the acceptable range, the actuator will not open. The design test set up schematic is shown in Figure 1.

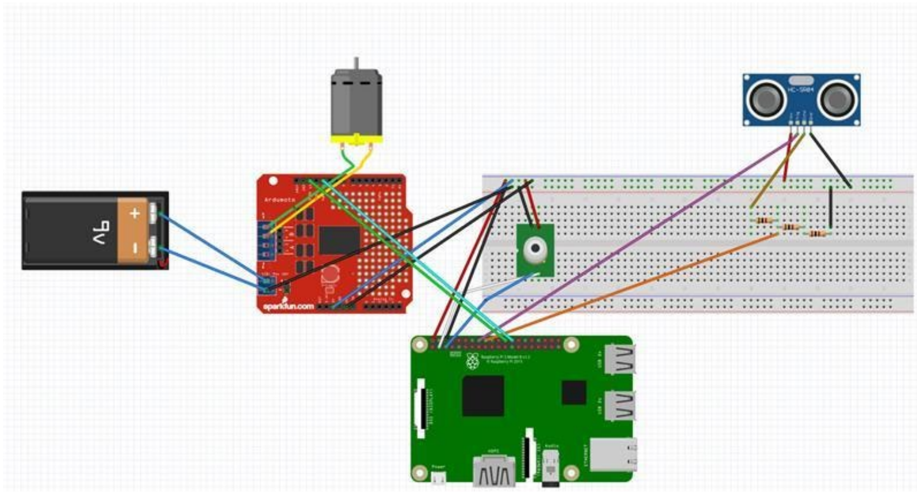


Figure 1 - Design Test Setup Schematic

Coding and Interfacing

The code for this project is written in Python. A flowchart for the program can be found in Figure 2. In the code, initially multiple libraries such as board, Busio, time, NumPy, DigitalIO, MLX90640, and PWMIO are imported for the program's function. The choice of using the board library rather than other substitutes was due to the board library being usable with both I2C and PWM inputs and outputs. Other libraries, such as RPi.GPIO, are not able to incorporate both communication types.

The code for this program was designed to be an infinite loop that utilizes "while True". The program cycles between scanning for both temperature and distance through the respective sensors, filtering the data gathered by the sensors based on the known external factors, and then comparing each value to the conditions required for the actuator to start.

The program uses the initial unfiltered array to create a thermal image of what the thermal camera views. The code then filters the array into a secondary array based on the parameters set and averages the values within the secondary array. These values are then compared, alongside the distance calculated using the HC-SR04 Distance Sensor, to see if the criterion for energizing the actuator is met.

The linear actuator is controlled by a Cytron 10A DC Bi-Directional Motor Driver. The motor driver uses a simple true or false signal to determine the direction of the actuator and uses a PWM signal to control the duty cycle of the actuator. The actuator itself is specified to have a duty cycle of 25%, so in all instances where the PWM signal is enabled, the duty cycle is set to 25%. For all instances where it must be disabled, it is returned to zero. As for the directional pin, the actuator will extend when the pin is set to false and retract when the pin is set to true. The program also utilizes the "sleep ()" command to allow the actuator enough time to fully extend, pause when opened, and be able to fully retract. Once the actuator is fully retracted, the loop reaches its end and returns to the beginning of the loop.

Costs

One of the goals of the project was to minimize the cost of designing and implementing the Thermal Body Temperature scanning system. The cost for designing and creating this project mainly lies in the cost of labor rather than the actual parts. The overall cost of the parts for the project was $335.22, which could be sharply reduced if the MLX90640 Thermal camera can be acquired at the manufacturer's price. That would reduce the total cost of the hardware by $120, resulting in a new parts cost of $215.22.

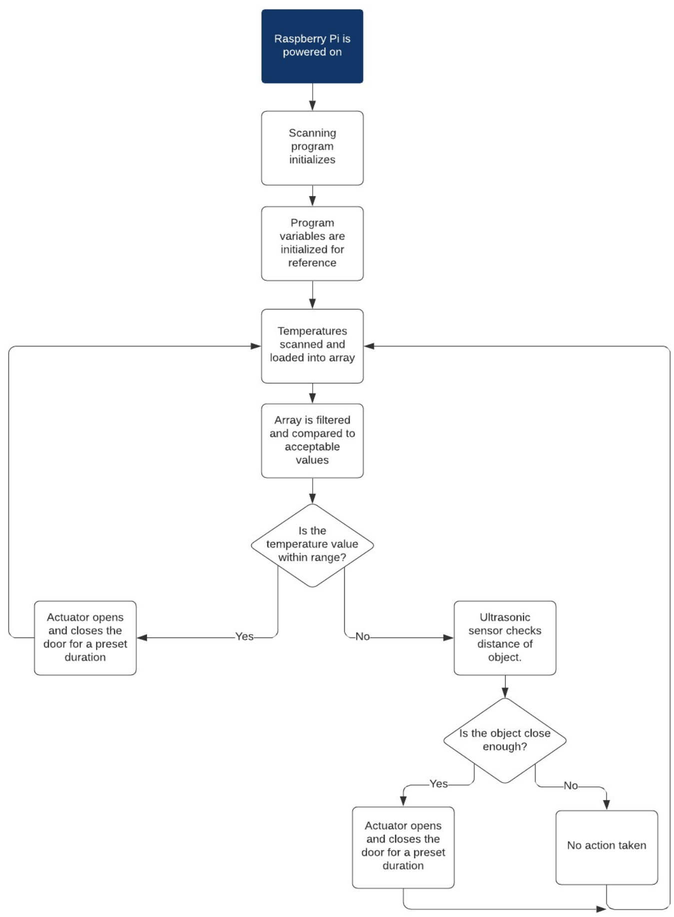


Figure 2 - Code Progression Flowchart

Verification/Results

The testing portion of the project focused on adjusting the readings of the thermal camera based on the external factors present, such as the distance of the reading and the ambient temperature. Testing for the changes in temperature based on the distance of the scan was the least difficult to accomplish, as different positions can be tested on demand. Initial testing was conducted in laboratory environment where the ambient conditions were stable and controlled.

Other variables, such as the effect of sunlight on skin temperature, or the effect of the wind blowing cannot be tested easily due to the lack of independent variables [1]. Testing for the effects of sunlight, wind, or other factors depends on weather conditions and time did not permit testing under all possible conditions.

The temperature decrease as distance increases is nearly a linear line, with the average drop in temperature being around four degrees Fahrenheit per foot. The figure below illustrates this drop.

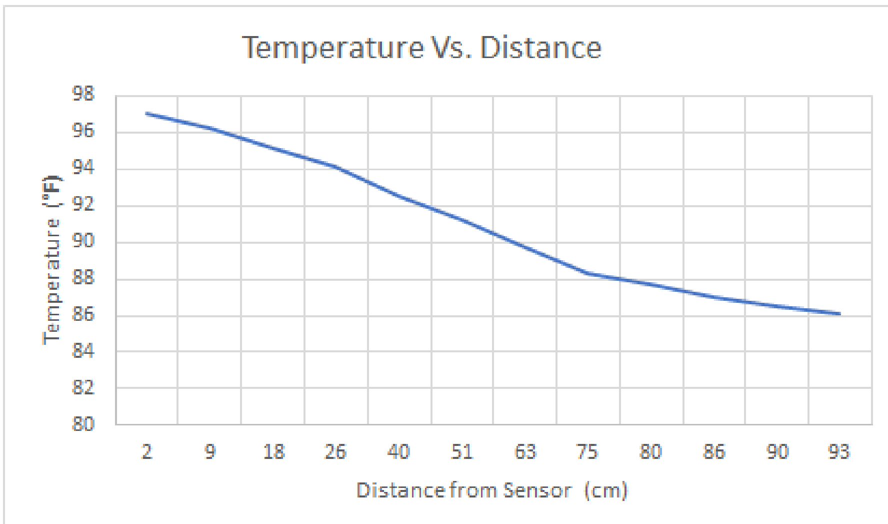
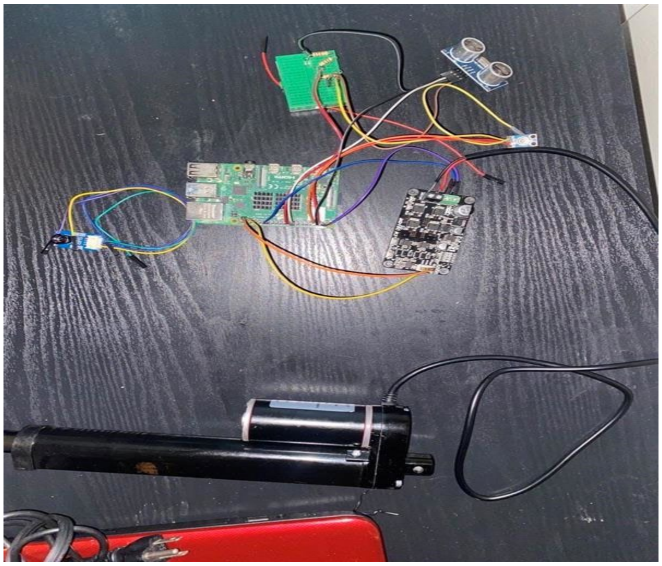
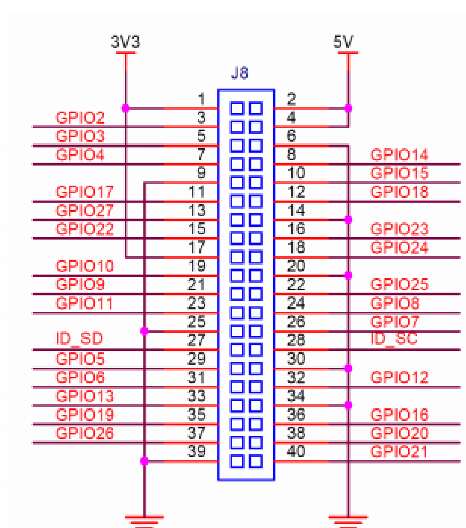


Figure 3 - Temperature Vs. Distance Graph

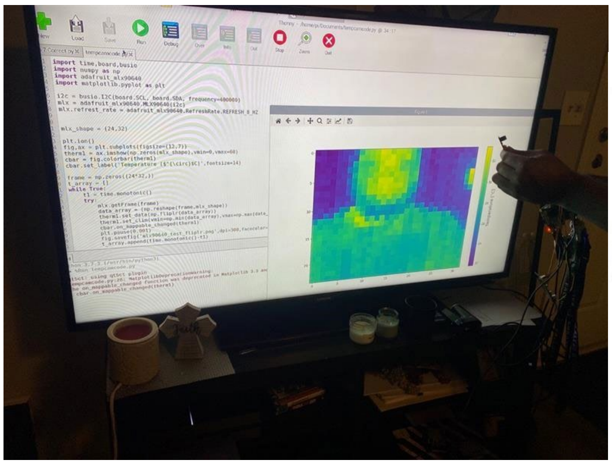
The project consistently responded well to temperature tests while in a controlled indoor environment. However, the project began to falter when the project was moved outside. The main source of problem for the project was that there was no object detection used in tandem with the thermal camera. By using a secondary sensor for object detection, the possibility of selective measurement is greatly increased. The secondary sensor could potentially outline the person in frame and filter the temperature array to only include values that were scanned within the outlines of the detected object. With the setup listed, the array containing the temperature values is filtered by removing temperatures that cannot be considered human. These temperatures have both an upper and lower bound so that factors such as someone holding a cup of hot or iced coffee will not influence the temperature calculation.

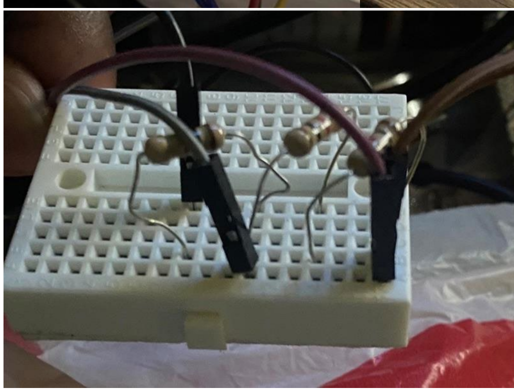
The project has multiple shortcomings that can potentially be fixed in future revisions. These problems include the actuator extension/retraction speed, the lack of object detection previously mentioned, and the lack of a climate-controlled environment.




3V3
5V
J8
1 2
GPIO2 3 4
GPIO3 5 6
GPIO4 7 8 GPIO14
9 10 GPIO15
GPIO17 11 12 GPIO18
GPIO27 13 14
GPIO22 15 16 GPIO23
17 18 GPIO24
GPIO10 19 20
GPIO9 21 22 GPIO25
GPIO11 23 24 GPIO8
25 26 GPIO7
ID_SD 27 28 ID_SC
GPIO5 29 30
GPIO6 31 32 GPIO12
GPIO13 33 34
GPIO19 35 36 GPIO16
GPIO26 37 38 GPIO20
39 40 GPIO21

The Raspberry Pi 4 Model B (Pi4B) is a single board computer with open design applications. In this project we will be utilizing the Thonny Python application to develop a working code for the Automated Door System. The Pi4B model board consists of two 5V pins, two 3V3 pins, and 7 ground pins (0V) [2]. The Pi4B has enough input ports and output ports to support the number of devices needed to complete the design.



A voltage divider is a simple circuit which turns a large voltage into a smaller voltage. By using three resistors and a supply voltage or input voltage to create a smaller output voltage that is about a fraction of the input source voltage [3].

The voltage divider served as a crucial component in order to reduce the amount of current being supplied to the DC motor driver and the actuator itself. By using three one kilo-Ohm resistors in a series configuration we took a 5v supply and reduced it down to 3.3v using this simple circuit configuration.

Conclusion

The intention of this project was to automate a system which would be able to provide a safe and reliable way for small businesses to reduce health risks by denying entry to people with fevers. This project is a failure in that the system cannot reliably measure temperatures in a non-climate-controlled setting. This means that in a setting where the system would have to be outside, which would be the scenario for most small businesses, the project will struggle to act as intended under some conditions. Given that there is not a large margin for error for detecting whether people have a fever, the project cannot be said to be a safe product for deciding whether someone is a health risk or not. It would be unethical to advertise this project to small businesses as it would not perform as intended.

If this project were to be revised, there are many different possibilities that can allow for better performance and reliability of the design. A potential change would be to change the target audience of the project. Many businesses have their offices located in large buildings that are shared with other offices. If the target consumers are these businesses, the door system can be placed inside which eliminates the problem of having a non-climate-controlled environment. Other changes would be to acquire a faster linear actuator so that the process of opening and closing the door can be sped up.

The project can also be revised to not actuate a door but rather enhance another door system, such as a RFID system. The thermal camera could be used in tandem with the RFID system to create a secure system.

Overall, the project is not reliable enough in its current iteration but has the potential to be successful in different iterations.

References

[1] W. Redisch, E. Sheckman, J. M. Steele, "Skin Temperature Response of Normal Human Subjects to Various Conditions" in Circulation, Volume VI, December 1952. Available at: https://www.ahajournals.org/doi/pdf/10.1161/01.CIR.6.6.862. Accessed: April 2021.

[2] Raspberry Pi 4 GPIO Pinout, Specifications and Schematic (etechnophiles.com)

[3] Voltage divider (article) | Circuit analysis | Khan Academy