MIDDLE EAST TECHNICAL UNIVERSITY

FORCULUS

Project Title: Automatic Door Access System via Vision-based Person Detection and Intention Analysis

Company Name: FORCULUS

Project Members:

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# 1)Executive Summary

Forculus, a pioneering enterprise, is devoted to enhancing safety, health, and energy conservation in communal environments. The onset of the COVID-19 pandemic has amplified the need for touch-free interactions, thereby escalating the demand for automatic doors. However, traditional sensor-based systems often lead to energy wastage and pose security risks, particularly in private spaces.

To address these challenges, Forculus has embarked on an ambitious project to develop an Automatic Door Access System that employs Vision-Based Person Detection and Intention Analysis. This innovative system utilizes a camera to capture visual data, which is then processed through advanced computer vision algorithms. These algorithms are designed to identify the object and interpret its intent. If the object remains within the system's range beyond a predetermined duration, the embedded system triggers the DC motor, thereby opening the door.

This unique approach of discerning and understanding an individual's intention ensures that the door operation is not only secure but also energy-efficient. The driving force behind Forculus is a team of four senior students specializing in Electrical and Electronics Engineering. These individuals bring a wealth of knowledge, enthusiasm, and a deep understanding of the technologies involved in this project.

The team has conducted rigorous research into the project's specifics, gaining a comprehensive understanding of the technologies to be employed. The development environment for the embedded system will be Atmel Studio and Proteus, while Visual Studio Code will serve as the Integrated Development Environment (IDE). The team intends to utilize the OpenCV Library and the Haar Cascades Algorithm for the software component of the project. Simulations and circuit designs for power will be executed on Proteus.

The Raspberry Pi 3 B+ will serve as the communication hardware, facilitating Wi-Fi communication between itself and the main computer. This ensures seamless data transmission and real-time responses.

In essence, Forculus's Automatic Door Access System Via Vision-Based Person Detection And Intention Analysis is a groundbreaking project that seeks to offer effective solutions to the challenges associated with automatic doors in both public and private spaces. By harnessing cutting-edge technologies and leveraging the team's expertise, Forculus is committed to fostering safer, smarter, and more energy-efficient environments for everyone. This project is a testament to Forculus's dedication to innovation and the team's unwavering commitment to excellence in engineering.

# 2)Introduction

Forculus, a forward-thinking company, is dedicated to enhancing security, health, and energy efficiency in public spaces. Our mission is to provide innovative solutions that address the challenges of our rapidly evolving world. In response to the increased demand for contactless interactions due to the COVID-19 pandemic, we have developed the Automatic Door Access System via Vision-Based Person Detection and Intention Analysis.

Our vision is to create safer, smarter, and more energy-efficient environments. The Automatic Door Access System is a testament to this vision. It uses advanced computer vision algorithms to detect and understand the intention of an object or person approaching the door. If the object's duration time exceeds a certain threshold, the system activates the door to open, ensuring a contactless and efficient entry.

This system not only enhances security by preventing unauthorized access but also promotes energy efficiency by preventing unnecessary door operations. Our team of dedicated Electrical and Electronics Engineering students has leveraged their expertise and innovative thinking to design this system, embodying Forculus's commitment to creating effective solutions for public and private spaces.

# 3)System Description

Our project is segmented into four individual units, each equipped with its own apparatus, prerequisites, and hurdles. The initial unit is focused on computer vision. Here, we analyze incoming images to ascertain if there is a demand to open the door. The door remains unopened if we move from the door's right side to the left; it opens only when approached head-on. The second unit involves communication. This segment facilitates the interaction between the computer vision component and the embedded system. Once images are captured through an isolated network, the detection of a person within initiates a decision process about door operation, communicated to the embedded system by this unit. The third segment is the embedded system itself. Within this system, we forward incoming signals to the motors and regulate the comprehensive system via the embedded system. The final unit revolves around the power system. In this segment, signals from the embedded system are relayed to the motors to enable the door closure.

## 3.1)Embedded Systems

Firstly, let's clarify the concept of an embedded system. An embedded system represents a fusion of hardware and software, custom-built to execute a certain function within a broader system, such as a television or a smartphone. We see these systems in routine gadgets where

they control various operations and characteristics. They are pervasive in smartphones, TVs, appliances, cars, and industrial controls, to list a few examples. For this capstone project, an embedded system will function as the central management entity.

Arduino is an open-source platform that allows the creation of electronic projects using a microcontroller, which is a small programmable computer capable of operating diverse electronic elements like sensors, motors, and displays. Arduino boards are user-friendly, thus they are a preferred choice for novices and instructors alike. In contrast, Raspberry Pi is a complete computer capable of running operating systems such as Linux or Windows. Its powerful processor, larger memory, and the ability to run several programs simultaneously make it stand out. Raspberry Pi can control electronics, and be utilized for a range of projects, such as home media centers, gaming consoles, and desktop computers. As a group, we opted for Raspberry Pi over Arduino due to its ability to function as a computer, providing us more versatility with its components.

Moreover, Raspberry Pi possesses a superior processor and additional ports compared to Arduino. After deciding on Raspberry Pi, we selected the best model for our needs. The Raspberry Pi 3 B+ was chosen as the most appropriate and cost-effective option due to its Bluetooth and Wi-Fi functionalities. This model aligned with our needs efficiently since we will be receiving signals via Wi-Fi from other parts.

Moving onto the coding aspect, we plan to enhance the code written in the previous term by adding new elements this term. This is due to changes made in the communication and power sections. We will substitute the proximity sensor with an infrared (IR) sensor. As a result of these alterations, we will revise the embedded system code we developed last term and incorporate it into the system.

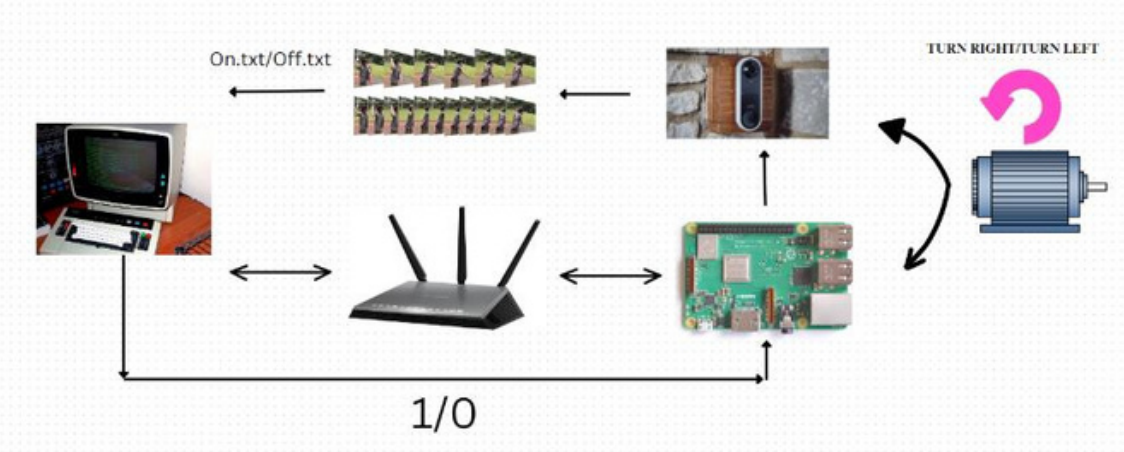
## 3.2)Communication

Our project employs wireless communication (Wi-Fi) to facilitate data exchange between our Raspberry Pi 3B+ and the main computer. Wi-Fi, a technology that enables devices to communicate via radio signals, necessitates a Wi-Fi network. Fortunately, the Raspberry Pi 3B+ comes with built-in Wi-Fi hardware, eliminating the need for an external adapter.

After extensive deliberation, research, and discussions, we decided to establish a local network for the connection between our Raspberry Pi 3B+ and the main computer. This is achieved using a modem router, to which both the Raspberry Pi 3B+ and the main computer are wirelessly connected. This setup creates a local network that operates independently of the internet, thereby not being influenced by internet connection speed or latency.

The choice to use a local network was driven by several factors. Firstly, it offers faster transfer speeds due to its higher bandwidth and lower latency. Secondly, it provides increased security as the data remains within the network and is not exposed to potential security risks associated with internet transfers. Thirdly, it is more cost-effective as there are typically no data transfer fees associated with local network transfers. Lastly, it offers more control over the transfer process, including the transfer speed, file format, and transfer settings.

By using a local network and File Transfer Protocol (FTP), we can ensure that images are transferred swiftly and securely without incurring high data transfer fees or exposing sensitive data to potential security risks. This approach aligns with our commitment to efficiency and security, making it particularly suitable for our system's requirements.




## 3.3)Computer Vision

For the Computer Vision aspect, I imported the "cv2" and "os" libraries to incorporate their functionalities into my software. To identify a person's frontal face, I utilized the "haarcascade_frontalface_default.xml" file. In case the frontal face detection fails, I also included the "haarcascade_fullbody.xml" file as a backup plan to detect the person's body. Additionally, I established an FTP Server connection to utilize images in my project.

To initiate the face and body detection process, I prepared the software by retrieving frames from the server file. I decided to retrieve a specific number of frames per second via the FTP Server, where each frame is sent from the client (a Raspberry Pi 3B+) to the host (my computer). Once received, the program begins the face and body detection process. Initially, the program reads the image using cv.imread() and converts it from BGR to grayscale for easier processing. Then, the grayscaled image is analyzed, and if a face and body are detected, a rectangle is drawn around them, and the result is displayed using the cv.imshow() function. Afterward, the counter is incremented by 1, and the program is configured to send an output.

In the final stage of the program, it sends either a 1 or 0 output to the main.txt file on the FTP Server. This output triggers the embedded system to activate the motor in the power system component. Assuming the server sends 5 frames per second, each containing one face, the program counts the number of faces in the frames. I set the threshold at 13, meaning that if 13 or more faces are detected, the program infers that someone has been waiting for the door to open for 3 seconds. Consequently, the program writes a 1 to the main.txt file, initiating the opening of the door through the FTP Server.

During this semester, I incorporated a body detection component into my algorithm to improve the program's efficiency. If any issues arise with face detection, the body detection component synchronously counts the frames and indicates that there are sufficient frames to confirm the presence of a human being.

## 3.4)Power Systems

In this project, the main components of the power system are a 6V DC Motor, L293D Motor Driver, 5 Volt Regulator, IR Sensor, 9 Volt Battery, and Gearwheel set. The goal is to examine the power distribution in the system.To ensure the safety of the microcontroller unit (MCU), a motor driver is necessary to control the DC motor without damaging the MCU. The L293D Motor Driver is chosen for this purpose as it is smaller and suitable for the 6V DC Motor. It provides the necessary control signals to the motor and protects the MCU from back electromotive force generated by the motor.A 5 Volt Regulator is used to regulate the 9V battery voltage down to 5 volts. This regulated voltage is then sent to the DC Motor through the motor driver, providing the electrical energy required for the motor to operate.To achieve axial movement of the motor (forward and backward), a gearwheel set is mounted on the door. The logic outputs of the sensor and camera determine the direction of motor movement, causing the door to move accordingly.IR Sensor is employed to detect when the door reaches its fully open position. Once the door reaches this point, the IR sensor sends a signal to the microprocessor, instructing the motor to stop.To prevent jams during door closing, a 3-pin IR sensor capable of detecting obstacles between 2 and 30 cm is utilized. This sensor ensures that any obstacles within the range of 2-30 cm are detected, allowing for the safe closing of the door. In summary, the power system for the automated door project consists of a 6V DC Motor, L293D Motor Driver, 5 Volt Regulator,IR Sensor, 9 Volt Battery, and Gearwheel set. The motor driver protects the MCU, the regulator provides regulated voltage, and the IR sensors ensure safe operation by detecting the door's position and obstacles.

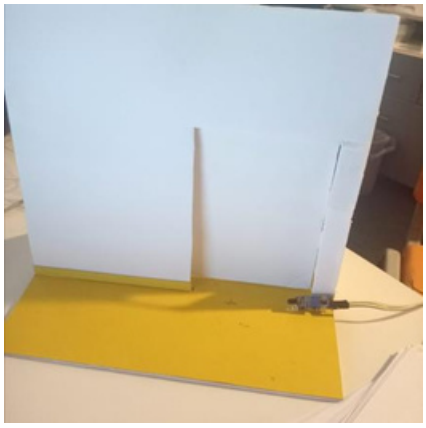


Figure 1

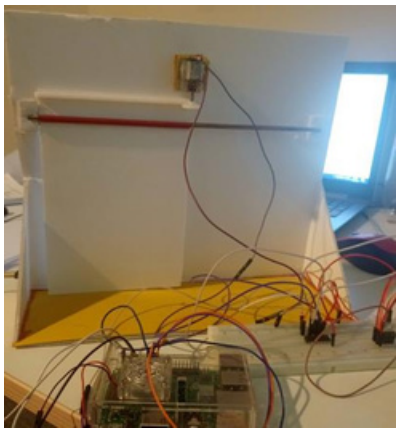


Figure 2

L293D Motor Driver and Motor:

It is used for rotating to motors according to microprocessor signal and it is feeded with 5 volt power supply.As you can see from the figure 3 and 6 pins of L293D connected to motors pins and also power supply is connected to 8 pin of L293D motor driver. 2 and 7 pins of L293D connected to microprocessor in order to get HIGH and LOW signals.

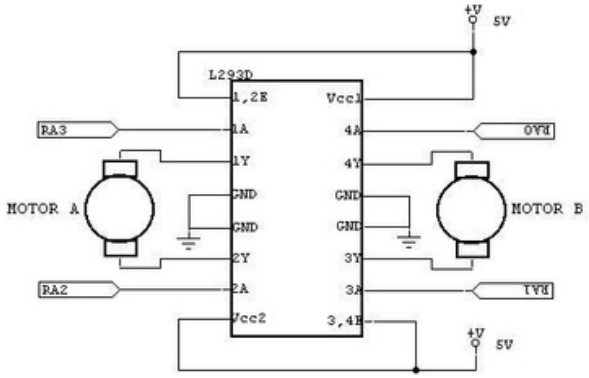



Figure 3

Motor Gear: We need to have motor gear in order to move the gate upwards and backward.With the rotation of the motor, the gear wheel applies a constant force to the door, allowing the door to move forward or backward.

Figure 4

IR sensor:

After the door is opened with the face recognition system, if the person has not fully passed the door, the infrared sensor will hit the obstacle and will stop the engine and enable it to open again.

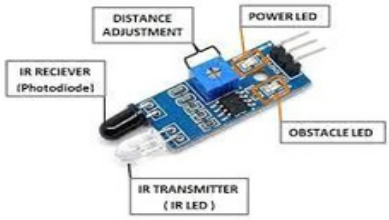



Figure 5

5 Volt Regulator:

I provided energy to the motor by using a 5 volt regulator to convert 9 volts to 5 volts. In this way, I prevented the motor from breaking down by reducing excessive power draw. By

connecting the middle end of the regulator to ground, the other end of the regulator to 9 volts and the output voltage to the 8th pin of the motor driver circuit.

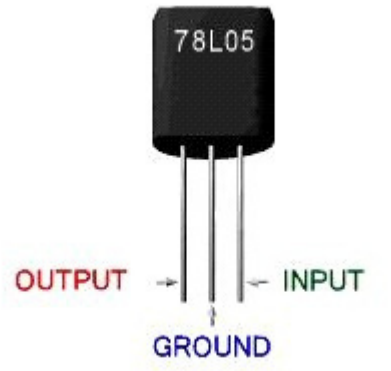



Figure 6

## 3.5)Safety Measures

In the development of the Automatic Door Access System via Vision-Based Person Detection and Intention Analysis, we prioritized safety at every stage. We ensured that the area in front of the door is always clear and unobstructed for smooth operation. We conducted regular maintenance checks on all system components, including the camera, Raspberry Pi 3B+, and DC motor, to ensure they are functioning optimally. We also committed to regular software updates to maintain the highest level of security and performance. Furthermore, we provided a comprehensive user manual and emphasized its importance to prevent misuse or mishandling, thereby reducing the risk of accidents or system failure.

# 4)Cost Analysis

| Component | Quantity | Price/Component (USD) |
|---|---|---|
| Microprocessor | 1 | 116 |
| Camera | 1 | 30 |
| Power Supply | 2 | 6 |
| Battery Holder | 1 | 1.5 |
| TCRT IR Sensor | 2 | 0.5 |
| Motor Driver | 1 | 1.5 |
| Voltage Regulator | 1 | 1 |
| DC Motor | 2 | 7.5 |
| Brass Rod | 1 | 2.5 |

| | | |
|---|---|---|
| IR Sensor | 2 | 3 |
| Gearwheel Set | 1 | 3.5 |
| Basic Circuit Components | - | 6 |
| Other Components | - | 8 |
| Total Cost | | 187 |

## 4.1)Engineering Infrastructure and Cost

Equipment and Components includes the cost of the automatic door system components such as the DC motor, motor driver, sensors, regulators, gearwheel set, microcontroller unit (MCU), wiring, connectors, and other hardware which is presented cost analysis part. In addition, Engineering and design cost is about 4000 dollars for four person it is very high value because this cost includes the design and engineering services required to plan the system, create the schematics, and develop the control algorithms. It involves electrical engineering staff and software skills. Further, Testing cost is about 50 dollars. It is necessary to ensure proper functionality and performance. This costs involve calibration, adjustment, and verification of the system's operation, which causes additional costs. In addition, To present and explain the project well, we had to prepare a poster that cost $8. This is necessary for a better understanding and aspiration of the project.

# 5)Conclusion

The critical design report reveals that FORCULUS is dedicated to utilizing technology to improve security and create safer, smarter, and more peaceful environments. The team's passion and commitment to innovation are evident in their meticulous planning and execution of the project titled "Automatic Door Access System Via Vision-Based Person Detection And Intention Analysis." They strategically assigned tasks based on each member's strengths and interests, ensuring efficient and effective project implementation. The team's meticulous attention to detail, time management skills, and well-structured timetable will be instrumental in completing the project within the specified timeline. Additionally, their collaborative spirit and ability to exchange ideas facilitated the development of innovative solutions to potential challenges. Overall, FORCULUS's project represents a significant advancement in enhancing security and safety in public spaces, showcasing the team's exceptional technical skills, creative thinking, and commitment to excellence

# 6) USER’s MANUAL

## 6.1)General

Closely review the guidance provided in this manual, as it imparts crucial details for the accurate, efficient, and safe installation, operation, and maintenance of the automatic door access system. Retain this manual in an easily accessible location for any other system operators who may require it in the future. The installation of this system should strictly adhere to Forculus's directives and local regulations. The system's connectivity to power supplies and the integration of the Wi-Fi network should only be conducted by individuals who are adequately qualified. Users of this system should be specifically trained in its operation. In the event of a system failure or malfunction, promptly power off the system. The periodic function checks suggested in the manual should be performed according to the instructions. When servicing is required, it should only be done by a technically qualified person authorized by Forculus and should utilize original spare parts. Failure to comply with these directives could potentially jeopardize the safety and integrity of the Automatic Door Access System Via Vision-Based Person Detection And Intention Analysis.

## 6.2)Safety Instructions

### 6.2.1) General

Forculus's Vision-Based Person Detection and Intention Analysis Automatic Door Access System strictly follows necessary safety requirements. Nonetheless, inappropriate handling could potentially lead to personal injuries and damage to the system. To ensure user safety and preserve the functionality of the system, it is mandatory for all users to abide by the following safety procedures prior to utilizing this system.

### 6.2.2) Instructions for use

Before engaging with the automatic door access system, ensure that you carefully peruse these guidelines. This will not only safeguard users but also prevent any inadvertent harm to the system. Adhere to the instructions in the order provided, and ensure this guide is readily available near the system for immediate consultation.

### 6.2.3) Usage

• Regularly perform visual inspections of the system for any possible damage or malfunctions.

• Do not expose the system to water or other liquids as this could damage the electronic components.

• Avoid using sharp objects to interact with any part of the system.

• Maintain the cleanliness of the system, particularly the control components, to prevent malfunctions.

• Disconnect the power supply when the system is not in use to conserve energy.

• Ensure the camera used for vision-based person detection and intention analysis is not obstructed or covered.

• Regularly test the door's safety features, such as its ability to stop when an obstruction is detected.

• Remember that the door will only open when the object's duration time exceeds a certain threshold, ensuring energy efficiency and security.

• Ensure clear Wi-Fi communication between the Raspberry Pi 3B+ and the main computer for optimal system performance.

## 6.3)Functional Description

The Forculus Automatic Door Access System is designed to enhance security, efficiency, and energy savings in public spaces. By utilizing computer vision algorithms and intelligent person detection, the system ensures safe and contactless operation of automatic doors. This user manual provides comprehensive instructions for the installation and operation of the system

### 6.3.1)System Overview

The Forculus Automatic Door Access System consists of four subsystems: computer vision, communication, embedded system, and power systems. The computer vision subsystem processes images using computer vision algorithms to detect faces and bodies. The communication subsystem enables communication between the computer vision and embedded systems. The embedded system acts as the controller, managing the entire system's operations. The power systems provide the necessary power and control for the door opening mechanism.

## 6.3.2)Installation

Follow these steps to install the Forculus Automatic Door Access System:

- Step 1: Identify a suitable location for the system components, including the camera, Raspberry Pi, and power supply.

- Step 2: Mount the camera securely, ensuring a clear view of the door area.

- Step 3: Connect the Raspberry Pi to the camera, power supply, and Wi-Fi network as per the provided instructions.

- Step 4: Install the necessary software on the Raspberry Pi, including the required

libraries

and algorithms.

- Step 5: Configure the communication settings between the Raspberry Pi and the

main

computer using the local network.

## 6.3.3)Operation

The aim of the project is to establish communication between the raspberry and the computer first and to enable the door to be opened and closed thanks to the face recognition code.By using the face and body identification code with the camera, we provide the opening and closing of the door by giving high or low voltage to the motor.Thanks to the modem, it provides the communication between the microprocessor and the computer by using the common IP address, and after the camera detects the face, it sends the on txt file to the raspberry and converts the on txt file to high voltage thanks to the embedded software system, the motor is energized and the door is opened for a while and turn off again.The establishment of a shared network connection, along with the configuration of a common IP address and network protocols, enables seamless communication between the Raspberry Pi and the computer, facilitating reliable data transmission.By utilizing a camera module connected to the Raspberry Pi and implementing a face and body identification algorithm with the help of computer vision libraries like OpenCV, the captured frames are processed to detect and recognize faces and bodies.By establishing a connection between the motor driver and the Raspberry Pi, the door's opening and closing mechanism can be controlled. The decision to grant or deny access based on the output of the face and body identification algorithm is converted into specific actions by providing high or low voltage signals to the motor driver, facilitated by the embedded software running on the Raspberry Pi. This ensures that the motor is energized appropriately to open or close the door according to face detection.

## 6.3.4)Maintanance

Regular maintenance is essential to ensure the optimal performance of the Forculus Automatic Door Access System. Follow these maintenance guidelines:

- Keep the camera lens clean and free from dust or obstructions.

- Regularly check the connections of the system components for any loose connections.

- Monitor the system's power supply and ensure it is functioning correctly.

- Perform software updates as recommended by Forculus to benefit from the latest enhancements and improvements.

## 6.3.5)Technical Specifications

- Computer Vision: Utilizes "cv2" and "os" libraries, "haarcascade_frontalface_default.xml" and "haarcascade_fullbody.xml" for face and body detection.

- Communication: Wireless communication via Wi-Fi network between Raspberry Pi 3B+ and the main computer.

- Embedded System: Raspberry

# 6.4)Troubleshooting

| Issue | Symptoms | Possible Causes | Actions |
|---|---|---|---|
| **The door doesn't open** | The door remains closed despite a person standing in front of it | Computer vision algorithm or communication issue | Check camera feed, algorithm parameters, and Wi-Fi connection |
| **The door opens randomly** | The door opens without any person in front of it | False detection by the computer vision algorithm or embedded system glitch | Check algorithm parameters and inspect the embedded system |
| **System doesn't respond to environment** | System doesn't adjust its operation based on changes in lighting or weather | Algorithm not correctly calibrated | Adjust algorithm parameters |
| **System doesn't communicate with main computer** | System doesn't send or receive data from the main computer | Wi-Fi connection disrupted or Raspberry Pi 3B+ issue | Check Wi-Fi connection and Raspberry Pi 3B+ setup |
| **Computer vision algorithm not accurately detecting people** | System either fails to detect people or falsely detects non- | Incorrect algorithm parameters or non-diverse training data | Review and adjust algorithm parameters, consider retraining the algorithm |

| | | | |
|---|---|---|---|
| | human objects as people | | |
| **System not correctly interpreting intention** | Door doesn't open when a person intends to enter, or opens when a person is just passing by | Incorrect setup of intention analysis part of the algorithm or incorrect interpretation of duration time | Review intention analysis part of the algorithm, check system's interpretation of duration time |
| **Embedded system not correctly activating door** | Door doesn't open even when system detects a person intending to enter | DC motor not correctly connected or issue with power supply | Check connection between embedded system and DC motor, inspect power supply |
| **System not correctly processing images or videos** | System fails to detect people even in clear images or videos | Incorrect setup of image or video processing part of the algorithm or camera not capturing clear images or videos | Review image or video processing part of the algorithm, check camera feed for clarity |

# References


https://vector4engineering.com/product/ir-sensor/

https://thinkrobotics.com/products/l293d-ic-motor-driver-datasheet

https://www.litchfieldstation.com/product/integrated-circuit-voltage-regulator-5-volt-100-ma/