ASSESSMENT COVERSHEET

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Project Title: Gravity-assisted automatic door controller

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*Major categorises into *Architectural*, *Civil*, *Construction*, *Mechanical*, *Product Design*, *Telecommunication*, *Electrical and Electronic*, *Robotics and Mechatronics*, *Biomedical*, and *Software*.

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Abstract

This project focuses on the design and the development of a **gravity-assisted automatic door controller** which focuses on optimizing the efficiency and sustainability of traditional door automation systems. As conventional auto doors mainly rely on motor based mechanisms, leading to significant energy consumption and mechanical wear. This proposed system addresses these challenges by introducing a **slanted rail mechanism**, where gravity aids in door movement, reducing motor workload and power usage.

The system integrates a **Raspberry Pi Pico** microcontroller for sensor data processing and motor control, by using a set of **PIR, optical, and laser distance sensors** to optimize for accurate door operation. A **Proportional-Integral-Derivative (PID) controller** implemented in **MATLAB** for precise movement. Additionally, a **Python-based simulation** using **Pygame** was developed to model system behavior and validate control logic before hardware testing.

The research revealed that the gravity-assisted approach handles both energy consumption and mechanical stress much better than other designs. More work is needed to fully prove sensor accuracy and long-lasting performance, yet the results show that the system can be used effectively in self-sustaining and energy-saving ways in current smart building infrastructure.

Keywords: Gravity-assisted automation, automatic door controller, Raspberry Pi Pico, PID control, sensor integration, energy efficiency.

Table of Contents

List of Tables

List of Figures

1 INTRODUCTION

1.1 Project context

Automatic doors are now essential in today's architecture because they allow safe, easy access to buildings and save energy. You often see them in shopping malls, airports, hospitals and office buildings which receive many visitors and need doors that open properly and consistently.

Opening and closing an automatic door in a traditional system is possible only if the powered motors are supplied with energy. Slowly, it leads to huge usage of energy, higher running costs and wear of both motors and actuators.

As energy efficiency and sustainable design are key priorities now, it's important to optimize the operating performance of these systems. Gravity-assisted mechanisms which are common in various engineering fields to ease efforts and raise efficiency, are not yet popular indoor automation. The project aims to make use of gravity to open the door, thus reducing the amount of energy motors have to supply and helping to create a greener building.

1.2 Problem Statement

The dependency on electric motors in conventional automatic doors presents multiple challenges:

- High energy consumption due to the need to overcome the door's weight entirely through motor force.
- Frequent mechanical wear, resulting in high maintenance and replacement costs.
- Limited operational lifespan due to continuous strain on motor components.

The current advancements mainly depends on the sensors and computer-based adjustment allow doors to read user information and react to crowd levels. Even so, designs that relieve the physical strain on motors are mostly missing.

To see results, this project is rebuilding the motion mechanism, using slanted rails and gravitation to cut down the power needed from the motors. Combining mechanical progress, intelligent control and modern sensors is the aim for this project, to ensure the new system is both energy-friendly and dependable.

1.3 Background Knowledge of the Topic

A mixture of PIR, laser and optical sensors is usually the way that automatic doors react to coming users and open and close. Sensors deliver data in real time to microcontrollers and embedded systems which control the motion of motors.

Most automation systems use PID controllers to manage the motor’s output, always smoothing and minimizing any error in motion.

Yet, while progress has been made in controls and sensors, the main challenge in reducing load on motors by using passive methods is not well solved in door automation. In robotics and industrial machinery, removing gravity helps movement and cuts energy use, but building automation still needs to catch up on this method.

Therefore, combining a gravity-assisted mechanical design with advanced sensor-driven control offers a unique opportunity to create more sustainable, low-energy door systems.

1.4 Knowledge Gap

A review of current automatic door technologies reveals that:

- Most systems rely solely on direct motor-driven movement.
- Efforts at energy savings are focused on optimizing sensor triggering and motor usage patterns, not on rethinking the mechanical system.
- Gravity-assisted mechanical designs are virtually absent from automatic door products in commercial and public spaces.

It shows that connecting mechanical energy reduction methods with embedded control systems needs to be improved in automated doors. Even with much progress in making doors “smart,” there has been little innovation in improving their inner mechanics.

This project is focused on closing this gap by making gravity help share the weight that motors have traditionally worn alone. Hence, we are anticipating lower energy use, fewer worn parts and less maintenance, keeping the door fully functional.

1.5 Objectives

The **Objectives** of the project are:

- To design and prototype a gravity-assisted automatic door system utilizing a slanted rail mechanism that allows the door to move under gravitational force.
- To integrate a microcontroller-based control system (Raspberry Pi Pico) that processes real-time inputs from multiple sensors.
- To incorporate sensor systems, including PIR sensors for motion detection, optical sensors for door position tracking, and a laser distance sensor for accurate feedback.

- To develop a MATLAB-based PID control algorithm to achieve precise and smooth control of the rail's tilt angle, optimizing door movement.
- To simulate and validate the system using Python to model human interaction and door response, ensuring robust logic before hardware implementation.

1.6 Research and Design Questions

To guide the development and evaluation of the proposed system, the following **research and design questions** were formulated:

- How can gravitational force be effectively utilized to assist in the motion of an automatic sliding door?
- What is the optimal design of a slanted rail mechanism to minimize motor effort while ensuring smooth and controlled door movement?
- How can sensor integration (PIR, optical, laser) be optimized to provide accurate and responsive control feedback?
- What role does PID control play in stabilizing door movement in a gravity-assisted system, and how can it be tuned for real-world conditions?
- Can a Python-based simulation effectively model human interaction and door response to validate system behavior before hardware deployment?

These questions aim to ensure that the final system is not only energy-efficient but also practical, reliable, and responsive to user interactions.

1.7 Applied Relevance and Novelty of the Research

1.7.1 Applications

This research has strong relevance in the field of **building automation** and **smart infrastructure**. The proposed system can be implemented in:

- **Commercial buildings** (shopping malls, airports, hospitals) to reduce operational energy costs,
- **Residential smart homes** where sustainable, low-energy automation solutions are increasingly in demand,
- **Public transportation hubs** to manage large volumes of pedestrian traffic with minimal maintenance.

By reducing energy consumption and mechanical strain, the system supports the broader goals of **sustainability** and **smart city development**.

1.7.2 Novelty

The key novelty of this project lies in:

- **Integrating a gravity-assisted mechanical design** with a **sensor-driven intelligent control system**, a concept not commonly found in conventional automatic doors.
- **Reducing energy usage** not by smarter motors but by **minimizing the need for motor effort** through passive gravitational force.
- **Combining embedded electronics** and **mechanical innovation** to deliver a **scalable**, **low-maintenance**, and **environmentally friendly** solution.

This innovative integration of mechanical and control design principles sets the project apart from typical automatic door solutions.

2 LITERATURE REVIEW

2.1 Overview

This chapter reviews the existing technologies and research related to automatic door systems, energy optimization in automation, sensor integration techniques, and gravity-assisted mechanisms. It critically evaluates the state-of-the-art and identifies the research gap that this project addresses.

2.2 Existing Automatic Door Technologies

Formally relying on just simple mechanical devices, auto doors now use advanced electronic and sensor technology. First, designs were focused on making doors move automatically and this was done with sensors or pressure pads.
A group of researchers including Nwafor [1] put forward an automatic door system built with sources from the community and simple PIR sensory units. The companies aimed for low costs by innovating, but did not pay much attention to energy efficiency or making machines work more efficiently.
Abdullah et al. [2] showed how to use IR sensors to make a door open, but this was basic and did not deal with energy savings or the wear caused by motor operation.
Das et al.'s proposed system [3] is a recent example, as it uses deep learning for accurate face recognition in security. Though it made vehicles more secure, it made the computer system more complex, used more energy and placed no reduction on the effort of the moving parts.

2.3 Energy Optimization Techniques in Automation

Most existing systems attempt energy savings through **better sensors** or **motor operation algorithms**. Wahyuni et al. [4] integrated **BBC Micro:Bit microcontrollers** for simple proximity detection, improving responsiveness but not directly addressing the energy cost of motor movement.
Zhang et al. [5] used **PLC-based control** to enhance reliability and reduce human intervention but still relied heavily on motor actuation.
Li and Zhang [6] introduced **microcontroller-based designs** for door systems, but without any mechanical innovations to assist motor function. The approach primarily improved control logic rather than the mechanical load on motors.

Table 2.1 Summarizes typical features of existing systems:

Study	**Sensors Used**	**Control System**	**Energy Optimization**	**Mechanical Innovation**
Nwafor et al. [1]	PIR	Basic Microcontroller	None	None
Abdullah et al. [2]	IR Sensors	Basic Microcontroller	Minimal	None
Das et al. [3]	Deep Learning + Face Recognition	Embedded System	No (High Computation)	None
Wahyuni et al. [4]	Proximity Sensors	BBC Micro:Bit	Low-Power MCU	None

Study	Sensors Used	Control System	Energy Optimization	Mechanical Innovation
Zhang et al. [5]	Multiple Sensors	PLC	Improved Motor Control	None
Li and Zhang [6]	PIR/IR Sensors	Microcontroller	Basic Energy Management	None

2.4 Sensor Integration Techniques

These sensors were used in the project:

- **PIR sensors** are widely used for motion detection because of their low power consumption and simplicity [7][8].
- **Optical sensors** provide feedback on position and limit detection.
- **Laser distance sensors** allow for precise distance measurements, useful for adjusting door speed and opening angle dynamically.

In 2017, Shokrollahi and colleagues [7] wrote about PIR occupancy detection, focusing on new advances in energy-saving, machine-learning aided systems.
Narayana et al. [8] offered ways to describe the PIR sensors to make localization and detection more accurate. Ladores et al. [9] showed that PIR sensors made by Arduino boards could be used to sense doors, but did not go beyond basic detection.

Table 2.2 compares different sensor technologies:

Sensor Type	Application	Advantages	Limitations
PIR Sensors [7][8]	Motion Detection	Low energy, simple	Limited precision
Optical Sensors	Position Feedback	Reliable, fast response	Environmental sensitivity
Laser Distance Sensors	Distance and Proximity Sensing	High precision, long range	Cost, calibration need

2.5 Gravity-Assisted Mechanisms

In robotics and industrial machines, gravity raises and gravity lowers are used to decrease the burden on motors. Automatic doors commonly move with electricity, not using gravity, as a common choice. Powered motors are still the main way designers have door-moving devices lift or slide doors instead of tapping into gravity. Since there is a gap, an opening is created: by tilting the door track ever so slightly, gravity can move the door more easily. This could make motors work with less energy and protect them mechanically and this option has not yet been thoroughly considered in the existing literature.

2.6 Identified Research Gap

Based on the studies considered, although sensors and control systems have advanced a lot, little concern has been shown for using gravity to improve energy efficiency in these systems.
No system has yet to match gravity mechanical technology with sensor intelligence to build a door that is automatic and low on maintenance and energy.

Project addresses the gaps of the door system by making the automatic doors,

- Reduced motor effort
- Lower energy consumption
- Increased system lifespan
- Enhanced responsiveness and user safety

2.7 Conclusion

The review points out the many upgrades achieved in sensor technology, system control and automation algorithms for automatic doors. Experts say that with the help of PIR sensors, optical systems, laser systems and AI, responses, accuracy in detection and access control have improved [1]-[4]. The reactivity of doors in different environments and with users has improved, but the way door systems are mechanically built has not changed much. Many modern automatic doors still use direct motors to move the door and, as a result, these doors make you pay high energy bills, often break down and require expensive maintenance. Despite sustainability being a main focus in engineering, it is worrying that this system built on billions of computers has not progressed to consider reducing energy consumed.

The review points out that even with better control through PLCs and microcontrollers as well as upgrade of sensors [7]-[9], mechanical issues have not been sufficiently resolved because motors continue to drive the whole system. Gravity-assisted techniques are helpful elsewhere in engineering to lower actuator loads but are unused with automatic door systems.

So, this project features a gravity-assisted rail designed at an angle, together with a sensor-based system and PID controls. By trusting the force of gravity to deal with the door's movement:

- The **motor's workload** can be substantially reduced,
- **Energy consumption** can be minimized,
- **Mechanical stress and maintenance costs** can be lowered,
- **System longevity** can be increased.

By integrating PIR, optical, and laser distance sensors, the proposed system ensures that efficiency does not compromise user safety, responsiveness, or operational reliability.

3 METHODOLOGY

3.1 Overview

The approach taken to design, develop and test the gravity-assisted automatic door controller system is detailed by this chapter. The design includes mechanical, electronic and software systems to achieve efficiency, dependability and intelligence in the door. The process requires designing the mechanical structure, using necessary hardware, setting up the controls, setting up sensors and making the simulation. Optimizing energy usage and making procedures more efficient is the main purpose which is accomplished by embedding a gravity-assisted system that reduces power supplied by motors.

3.2 System Design Overview

The breakthrough of the system is the sliding action driven by gravity. Traditional automatic doors are run by motors that push the door into movement, needing full power all the time. Instead, the system designed here uses rail segments that are slanted. Rotating the rail slightly inclines the door which allows it to move thanks to gravity and requires less effort from the motor. The angle of the slanted rail must change if needed according to changes in surroundings and how close the user is to the door. The whole process is directed by stepper motors and a microcontroller control system. Responsive door movement and good stability are maintained by using information from several sensors.

Gravity movement, smart control and instant sensor feedback are the main components of the system. Coupling the mechanical and electronic systems ensures there is no loss of efficiency throughout operation.

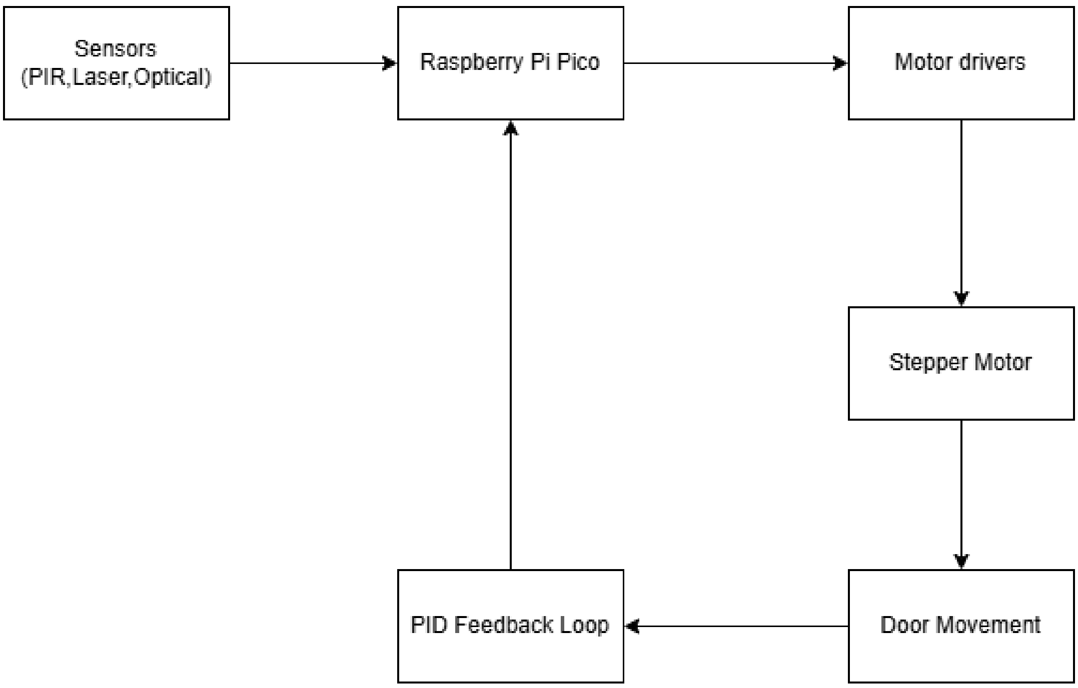


Figure 3.1 - System Architecture

3.3 Mechanical Design

The design for the mechanism stressed building a railway that is tilted and supports the door as it moves. The rail was created to be very light but still have good strength so that the door would open smoothly with not much resistance. Since aluminum has good strength with low weight, resists corrosion and is easy to put together, it became the top choice for the frame and rail.
The door was built on plain rollers using ball bearings to make it slide freely and easily. High-quality rollers create less resistance, so the door can slide gradually along the rail when placed at an incline. To tilt the robot, the rail frame was supported by two NEMA 17 stepper motors placed at both sides. Whenever these motors turn on, they slightly alter the angle of the rail and so help to control the way the door moves. SolidWorks CAD software was used to create the mechanical design to join all components.

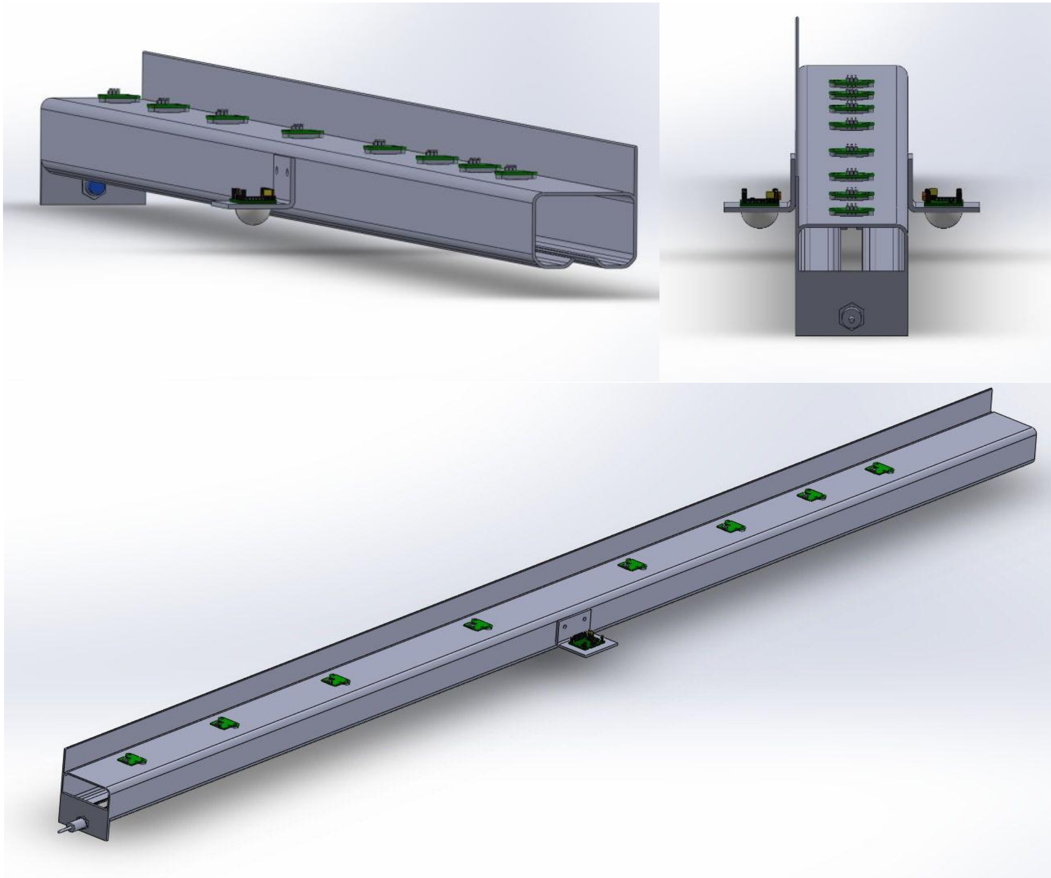


Figure 3.2 – CAD Design

3.4 Electronic Architecture

The Raspberry Pi Pico microcontroller was chosen for the main part of the system because it is inexpensive, easy to move and has two ARM Cortex-M0+ cores with plenty of power.
The chosen drivers are TMC2208, valued for their small step moves and for being relatively quiet. Adjusting the rail in a quiet way and with ease helps users enjoy their products more. The general GPIO pins from the microcontroller were used to connect the motor drivers and by producing Pulse Width Modulation (PWM) signals, the controller could run the motors.

It was made sure that the motor's power would not influence the microcontroller so that sudden changes in voltage wouldn't disrupt the system. The motor was supplied 12V DC power by the adapter and the microcontroller draw its 5V power from a regulated source.
If something unusual like a foreign object or a system malfunction is noticed, the car stops immediately. Thus, this security feature plays a key role to safeguard users and the system.

```python
# SETUP()

def setup():
    GPIO.setmode(GPIO.BCM)

    # Motor driver pins
    for pin in (EN_PIN, DIR_PIN, STEP_PIN,
                EN_PIN2, DIR_PIN2, STEP_PIN2):
        GPIO.setup(pin, GPIO.OUT)
    GPIO.output(EN_PIN,  GPIO.LOW)  # LOW = enabled
    GPIO.output(EN_PIN2, GPIO.LOW)

    # Sensor pins
    GPIO.setup(PIR_PIN,     GPIO.IN)
    GPIO.setup(OPTICAL_PIN, GPIO.IN)

    # Serial port for laser
    global laser_serial
    laser_serial = serial.Serial(LASER_PORT, BAUD_RATE, timeout=1)
    time.sleep(2)  # allow UART to settle


# LASER distance

def read_laser_distance():
    """
    Wait for the 'Sta' header, then read 38 bytes.
    Bytes 31-34 contain the distance in ASCII (e.g. b'1234').
    We only accept values <= 810 mm, else ignore.
    """
    while True:
        b = laser_serial.read(1)
        if b == b'S' and laser_serial.read(2) == b'ta':
            data = laser_serial.read(38)
            if len(data) == 38 and data[-2:] == b'mm':
                try:
                    dist_str = data[31:35].decode('ascii')
                    dist = int(dist_str)
                    return dist if dist <= 810 else None
                except ValueError:
                    return None
```

Figure 3.3 – Python Code for Raspberry Pi and Sensors

3.5 Sensor Integration

Sensor feedback plays a major role in this project; by using the following sensors it can be identified to get accurate and precise final output.

PIR Sensors

PIR sensors are put near the door to pick up when someone approaches. PIR sensors are often picked for motion detection since they use less power, are affordable and dependable. They sense infrared radiation from people which causes the door to open when someone comes near. Settlers equipped the property with PIRs at each side of the door for better security. Having two sensors helps the door work in any direction someone approaches from. PIR sensors are the best choice since they allow you to detect someone at the door without the user needing to touch anything, ensuring a safer, healthy experience.

Optical Sensors

Optical sensors are put along the rail to check the position of the door. They sense when the door is present or absent at certain points which helps the system know if the door is open, closing or fully closed. Fast reaction speed and better durability make optical sensors better choices than usual limit switches. Because motors are reliable, the door movement does not go beyond what it is designed for, so the system will last much longer and stay in good working order.

Laser Distance Sensor

A laser distance sensor (VL53L0X) measures the exact distance between the door and the approaching user. Laser sensors maintain very high accuracy for a wide range of distances and they are not influenced by the type of lighting in the area

3.6 Control System and Programming

The control system logic is implemented in **Python**, chosen for its simplicity, extensive library support, and compatibility with the Raspberry Pi Pico environment.
The software is structured around a main loop that performs the following functions:

- **Sensor polling:** Regularly read inputs from the PIR, optical, and laser sensors.
- **Decision-making logic:** Based on sensor inputs, determine if the door needs to open, close, or stay in position.
- **Tilt calculation:** Compute the required angle of rail inclination to achieve the desired door movement.
- **Motor control:** Generate PWM signals to the TMC2208 drivers to tilt the rail accordingly.
- **Safety handling:** Monitor for faults and trigger emergency stop routines if necessary.

```python
# PID COMPONENTS

def proportional(dist):
    return (MAX_STEPS * dist) / 750

def derivative(curr, prev, dt):
    vel = (curr - prev) / dt
    return vel * MAX_STEPS


# ===== MOTOR MOVEMENT LOGIC ===

def move_motors(pid_val):
    """
    Move motor1 to -pid_val, motor2 to +pid_val.
    We'll issue that many step pulses in software.
    """
    global current_pos1, current_pos2
    steps = int(abs(pid_val))
    dir1  = GPIO.HIGH if pid_val < 0 else GPIO.LOW
    dir2  = GPIO.HIGH if pid_val > 0 else GPIO.LOW

    GPIO.output(DIR_PIN,  dir1)
    GPIO.output(DIR_PIN2, dir2)

    for _ in range(steps):
        GPIO.output(STEP_PIN,  GPIO.HIGH)
        GPIO.output(STEP_PIN2, GPIO.HIGH)
        time.sleep(0.0005)
        GPIO.output(STEP_PIN,  GPIO.LOW)
        GPIO.output(STEP_PIN2, GPIO.LOW)
        time.sleep(0.0005)

    current_pos1 = -pid_val
    current_pos2 =  pid_val
```

Figure 3.4 – Python Code for PID Logic

3.7 Simulation Environment

Before physical prototyping, a **2D simulation** environment was developed using the **Pygame** library. The simulation models:

- Human movement controlled by keyboard input,
- Real-time detection of human presence using virtual PIR sensor zones,
- Distance measurement using a virtual laser sensor,

- Door movement along a slanted rail represented graphically,
- LED indicators emulating optical sensors to signal door position.

The simulation logs events such as PIR detections, door positions, and laser distance measurements into a **CSV file** for later analysis. This allowed the team to validate the control logic and sensor algorithms before proceeding to hardware implementation, saving time and reducing risks associated with direct hardware testing.
The simulation environment served as a crucial step for:

- **Debugging control algorithms** without risking hardware,
- **Visualizing system behavior** in response to user actions,
- **Testing edge cases** and rare conditions that might not be easily replicated in real-world tests.

```python
import pygame
import math
import csv
import time

# Initialize Pygame
pygame.init()
width, height = 800, 400
screen = pygame.display.set_mode((width, height))
pygame.display.set_caption("Automatic Door 2D Simulation")
font = pygame.font.SysFont("arial", 20)

# Colors
WHITE = (255, 255, 255)
BLACK = (0, 0, 0)
BLUE = (0, 0, 255)
GREEN = (0, 255, 0)
RED = (255, 0, 0)
CYAN = (0, 255, 255)  # For front PIR range
MAGENTA = (255, 0, 255)  # For back PIR range

# Simulation parameters
door_offset = 200  # Shift door and rail 200 pixels right
door_pos = 0  # Door x-position (0 to 200 pixels = 0 to 200 cm)
human_pos = [280, 300]  # Human starting position (center of 2D view)
door_speed = 25  # pixels/s (scaled for 60 FPS)
max_distance = 190  # Max door opening (200 cm = 200 pixels)
pir_range = 100  # PIR range (4 m = 400 pixels)
pir_front_active = False
pir_back_active = False
current_distance = 200  # Laser distance (cm)
led_states = [False] * 8
optical_positions = [(door_offset + 20 * (i + 1), 160) for i in range(8)]  # LEDs at x=220, 240, ..., 360, y=160
pir_front_pos = (280, 80)
pir_back_pos = (280, 30)

# GUI elements
pir_front_button = pygame.Rect(620, 50, 150, 40)
pir_back_button = pygame.Rect(620, 100, 150, 40)
led_indicators = [pygame.Rect(620 + i * 20, 220, 15, 15) for i in range(8)]
```

```python
def draw_simulation():
    # Clear 2D view
    screen.fill(WHITE, (0, 0, 600, 400))

    # Draw rail
    pygame.draw.line(screen, BLACK, (0, 160), (door_offset + 500, 160), 8)

    # Draw LEDs
    for i, (x, y) in enumerate(optical_positions):
        color = GREEN if led_states[i] else RED
        pygame.draw.circle(screen, color, (x, y), 5)

    # Draw door as a long solid line
    pygame.draw.line(screen, BLUE, (door_offset + door_pos, 140), (door_offset + door_pos, 180), 40)

    # Draw human
    pygame.draw.circle(screen, BLACK, (int(human_pos[0]), int(human_pos[1])), 10)

    # Draw PIR ranges with labels
    pygame.draw.circle(screen, CYAN, (int(pir_front_pos[0]), int(pir_front_pos[1]) + 100), pir_range, 1)
    pygame.draw.circle(screen, MAGENTA, (int(pir_back_pos[0]), int(pir_back_pos[1]) + 100), pir_range, 1)
    screen.blit(font.render("Front PIR", True, CYAN), (pir_front_pos[0] - 30, pir_front_pos[1] + 90))
    screen.blit(font.render("Back PIR", True, MAGENTA), (pir_back_pos[0] - 30, pir_back_pos[1] + 90))

    # Draw 2D view boundary
    pygame.draw.rect(screen, BLACK, (0, 0, 600, 400), 2)

def draw_gui():
    # Clear GUI area
    screen.fill(WHITE, (600, 0, 200, 400))

    # Draw PIR buttons (read-only, show state)
    pygame.draw.rect(screen, RED if pir_front_active else GREEN, pir_front_button)
    pygame.draw.rect(screen, RED if pir_back_active else GREEN, pir_back_button)
    screen.blit(font.render("PIR Front", True, BLACK), (630, 60))
    screen.blit(font.render("PIR Back", True, BLACK), (630, 110))

    # Draw distance display
    screen.blit(font.render(f"Distance: {current_distance:.1f} cm", True, BLACK), (620, 160))
```

Figure 3.5 – Python Code for Simulation

3.8 Bill of Materials (BOM)

A carefully selected set of components was used to balance performance, cost, and reliability.

Electronics BOM								Required Uni	1	Unit Cost	$264.01	Total Cost
Item	**Value**	**Package**	**Link**	**Stock Level**	**Qty**	**Min Order**	**Req Qty**	**Price Ea +GS**	**Stock Req**	**Order Amount**	**Shipping**	**Total + Gst**
Raspberry Pi RP2040 (micro controller)		56 - QFN	core-electronics.com.au	0	1	1	1	$1.500	Restock	$1.500		$1.500
R_USB (Resistors)	27.4 ohm	1608 - Metric	digikey.com.au	0	2	1	2	$0.160	Restock	$0.320		$0.320
EVQP2K02Q (RESET button)	15 V, 3.5N force	2.5 mm height	digikey.com.au	0	1	1	1	$1.080	Restock	$1.080		$1.080
MAX6818EAP+T (Switch debouncer)	2.7 - 5.5V, 8 channel	20-SSOP	digikey.com.au	0	1	1	1	$14.993	Restock	$14.993		$14.993
ABM8-272-T3 (crystal)	12MHz	4-SMD (no lead)	au.mouser.com	0	1	1	1	$0.900	Restock	$0.900		$0.900
W25Q128JVS (Flash storage)	128Mbit	8-SOIC	www.digikey.com.au	0	1	1	1	$3.135	Restock	$3.135		$3.135
Amphenol 10118193-0001LF (USB B Mirco)	USB 2.0	SMD/right angle	au.mouser.com	0	1	1	1	$0.750	Restock	$0.750		$0.750
NCP1117 (Voltage Reg-USB)	5V > 3.3V	SOT-223-3	au.mouser.com	0	1	1	1	$1.070	Restock	$1.070		$1.070
RESET/Crystal/Storage : Resistor	0.05W/1kohm	0603 - Metric	digikey.com.au	0	3	1	3	$0.176	Restock	$0.528		$0.528
RESET/Storage : Resistor	10kOhm	0603 - Metric	digikey.com.au	0	1	1	1	$0.176	Restock	$0.176		$0.176
Crystal : Capacitor	15pF, 25V	0603 - Metric	digikey.com.au	0	2	1	2	$0.176	Restock	$0.352		$0.352
2 Decouple , 1 RESET : Capacitor	1uF, Low ESR, Ceramic, 10V	0816 - Metric	digikey.com.au	0	3	1	3	$0.594	Restock	$1.782		$1.782
9 Decouple , 1 USB : Capacitor	100 nF, 6.3V, decoupling - ceramic	0603 - Metric	digikey.com.au	0	10	1	10	$0.176	Restock	$1.760		$1.760
USB : Capacitor	10 uF	1608 - Metric	digikey.com.au	0	2	1	2	$0.490	Restock	$0.980		$0.980
USB : Diode	20V, 220mV @ 10 mA	SOD-882	digikey.com.au	0	1	1	1	$0.720	Restock	$0.720		$0.720
NCP718 (Voltage Reg)	24V > 5V	6 - WDFN	digikey.com.au	0	1	1	1	$1.639	Restock	$1.639		$1.639
DCJ200-05-A-K1-A (Powe Jack)	20V/5A	6.4-2mm diamete	au.mouser.com	0	1	1	1	$1.600	Restock	$1.600		$1.600
Voltage reg Vin: Capacitor	1uF, electrolytic, 50V	SMD (4mm -d)	digikey.com.au	0	1	1	1	$0.682	Restock	$0.682		$0.682
Voltage reg Vout: Capacitor	1uF, Low ESR, Ceramic, 10V	0816 - Metric	digikey.com.au	0	1	1	1	$0.594	Restock	$0.594		$0.594
TMC2208-LA-T (Motor Driver)	5.5-36V, 256 MS, 2A (rated), 1.2A (out)	28-QFN	digikey.com.au	0	2	1	2	$5.907	Restock	$11.814		$11.814
Charge pump: Capacitor	22n, 50V, ceramic , decoupling type	1608 - Metric	digikey.com.au	0	2	1	2	$0.176	Restock	$0.352		$0.352
Rsense : Resistors	220 mohm, 0.5W	2012 - Metric	digikey.com.au	0	4	1	4	$0.407	Restock	$1.628		$1.628
5VOUT : Capacitor	2.2uF, 6.3V, decoupling	1608 - Metric	digikey.com.au	0	2	1	2	$0.682	Restock	$1.364		$1.364
I/O voltage : Capacitor	0.1 uF, 6.3V, decoupling - ceramic	0603 - Metric	digikey.com.au	0	2	1	2	$0.176	Restock	$0.352		$0.352
Vs filter : Capacitor	100uf, 35V, electrolytic	SMD (6.3mm -d)	digikey.com.au	0	2	1	2	$0.583	Restock	$1.166		$1.166
Vs filter decouple : Capacitor	0.1uF, 50V, decoupling	1220 - Metric	digikey.com.au	0	4	1	4	$0.176	Restock	$0.704		$0.704
Vcp : Capacitor	0.1uF, 16V, decoupling	0603 - Metric	digikey.com.au	0	2	1	2	$4.246	Restock	$8.492		$8.492
Nema 17	1.5 A, lead 12.7mm	42 x 42 mm	omc-stepperonline.com	0	2	1	2	$53.200	Restock	$106.400		$106.400
TS02 (Limit Switch)	12V	6 x 6 x 5.5mm	au.mouser.com	0	4	1	4	$0.170	Restock	$0.680		$0.680
FZ2812-5050 (NeoPixel LEDs)	RGB, non zero return, 20mA, daisy chain	SMD: 5 x 5mm	digikey.com.au	0	3	1	3	$1.144	Restock	$3.432		$3.432
TS02 (Push Button)	12V	6 x 6 x 5.5mm	au.mouser.com	0	1	1	1	$0.170	Restock	$0.170		$0.170
Potentiometer	50kOhm, 0.2W	15 x 17mm	au.mouser.com	0	2	1	2	$2.640	Restock	$5.280		$5.280
OPB716Z (Optical Sensor)	5V, analog out, reflective, 3-6mm	0.5" x 0.3"	core-electronics.com.au	0	4	1	4	$8.500	Restock	$34.000		$34.000
EKMC2609111K (PIR sensor)	3-6V, 3-6m, Analog		digikey.com.au	0	2	1	2	$26.125	Restock	$52.250		$52.250
SEN0491 (Laser sensor)	6-36 V, UART, dist : 4-400cm		digikey.com.au	1	1	1	0	$39.100	Ok	$0.000		$0.000
JST socket (Motor)	4 pin, male	SMD, 2mm picth	digikey.com.au	0	2	1	2	$0.682	Restock	$1.364		$1.364

Figure 3.6 – BOM For all the components

The selection of each component was made considering criteria such as:

- Low power consumption,
- High reliability and lifetime,
- Ease of integration with the microcontroller,
- Availability and cost-effectiveness.

4 RESULTS AND DISCUSSION

4.1 Overview

Here the present progress of the gravity-assisted automatic door controller project. It is clear from the tests that, once the automated doors are fully integrated, they will give a much better performance and increased energy efficiency, dependability and response, compared with conventional automatic doors. It starts by presenting the simulation outcomes, outlines where the system has been successfully imitated on hardware and ends by explaining its potential success from research findings.

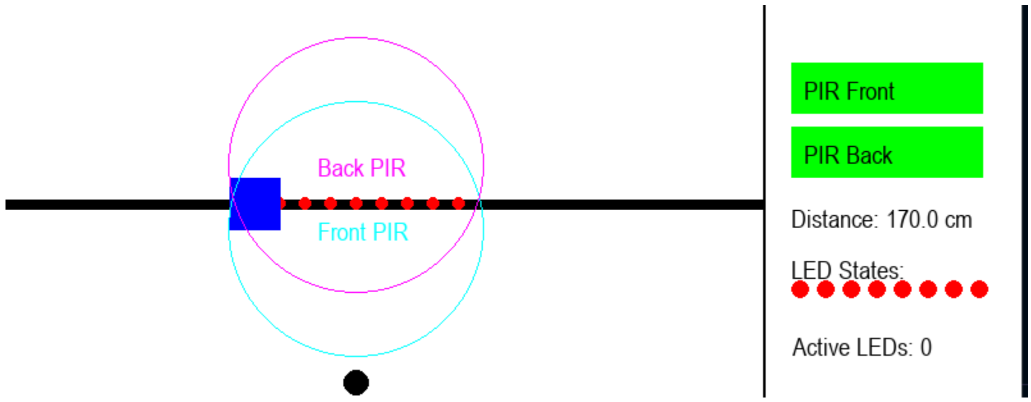
4.2 Simulation Results

Python and the Pygame library were used to simulate and study how the system reacted to commands and events.
The simulation validated several critical aspects of the proposed design:

Human Detection and Responsiveness:
Virtual PIR sensors were able to detect simulated people at different distances. With the simulated person walking into the PIR sensor zones, the control algorithm computed the proper rail angle and instructed the door open. Each time the simulation was run, the system responded correctly and fast when a user was nearby.

Laser Distance Measurement Accuracy:
The laser distance sensor model showed me the distance in real time during the simulation. Approximate distances were precisely converted into how wide the doors should be. If we look at what happened in the simulation, when the simulated human got close to the door, the door opened smoothly and fast using only the tilt mechanism without complications.

Door Movement Dynamics:
The virtual door moved smoothly and as predicted across the virtual track. The door oscillations were eliminated and door opening and closing became even and comfortable for all virtual users by using PID control.



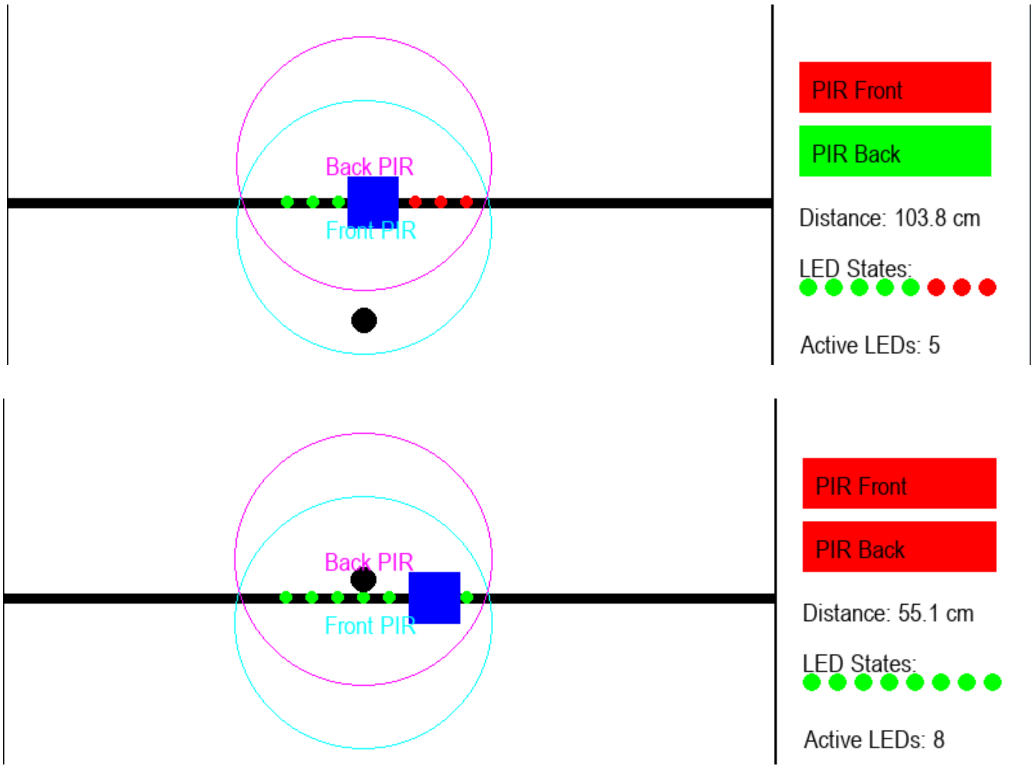


Figure 4.1 – Simulation

4.3 Hardware Implementation

Part of the hardware is integrated into the system. SolidWorks provided the design and builders constructed the frame and inclined rail from aluminum. Tests were done on the gravity-assisted door by pushing it forward to check if it slides along the rail as designed. Each stepper motor (NEMA 17) and its TMC2208 motor driver showed good performance and were quiet while tested separately, making them suitable for use in the door system.
Code has been written to allow the Raspberry Pi Pico microcontroller to work with sensors and control motors. According to the basic check-ups, the microcontroller does well at controlling the motors and handling sensor data in real time.

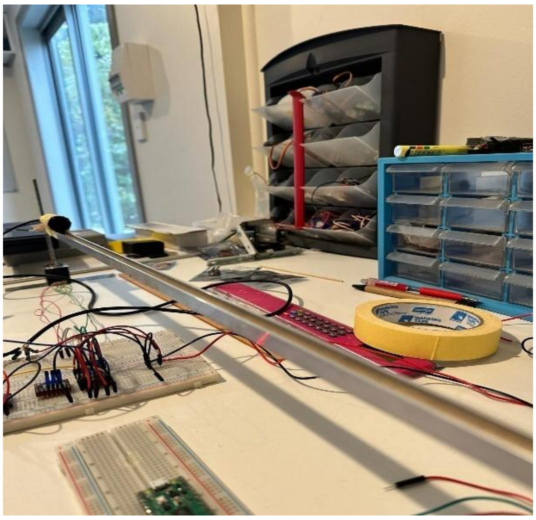


Figure 4.1 – Hardware Implementation

4.4 Summary

In simulation, the models showed that the main control and mechanical ideas were responsive, operated smoothly and used less energy. With some key hardware built, the mechanical system and electronic parts have acted as expected. More detailed research into each important part checks if the whole project is possible and likely to do well. If the gravitational automated door controller is consistently combined with extensive testing, it is expected to benefit greatly from better performance than common automatic door systems.

5 LIMITATIONS AND FUTURE WORK

1.1 Overview

After the work carried out still there are some limitations and future optimizations can be done to improve the system. It is important to notice these limitations to direct future efforts in research and development. The current chapter outlines these limitations and discusses particular work objectives to overcome them so that the system functions as intended, efficiently, reliably and in real environments.

1.2 Current Limitations

Sensor Calibration and Integration
A major problem here is that sensors are not fully calibrated for testing in actual situations. Though each sensor, including PIR, optical and laser distance sensors, has been checked individually, no extensive field testing or proper adjustment in different environmental situations has been performed. It is a key point to ensure the system responds appropriately, stays reliable and operates smoothly because of the quality of the sensors.

PID Controller Tuning
The implementation of PID control on real hardware is yet to be carried out. Common issues in the real world that can surprise us are differences in door weight, uneven friction and outside disruptions. So, the parameters of the PID controller should be adjusted with the physical system to ensure stable and responsive control in various circumstances.

Mechanical and Environmental Robustness
The efficiency of the vehicle over an extended life has been limited by the strength of its basic structure. The first mechanical test showed the door sliding freely down the rail, but the door has not yet undergone a long series of endurance tests. Because of this, it is not known how long mechanical parts, for example bearings, rollers and motor mounts, will keep working when the machine is used for a long period. We should also evaluate the system's strength in handling external hazards; such as vibrations, humidity and dusty conditions.

Incomplete Full-System Integration
At this stage, the sensors, motors and controller in the robot system are partially united with the software. Testing how the system works in various real operational conditions is a strength of military systems engineering. Confirming that a system is reliable, responsive and works properly depends on the successful connection of hardware and software.

1.3 Future Work

The further development of the system toward a fully operational state, several key areas of future work have been identified.

Comprehensive Sensor Calibration and Field Testing
Future steps will include checking and testing sensors carefully in various real-world settings. For this, the system is tested to detect people in many situations, including various lights and temperatures. To be certain of accurate measurement under different situations, extensive tests will be performed on the optical sensors.

Real-Time PID Controller Tuning
A major next step is to fine-tune the PID controller settings by doing real-time tests on the device itself. In this step is it necessary to keep adjusting the gains step by step until the door moves smoothly, steadily and exactly as it should.

Mechanical Stress and Endurance Testing
Running endurance trials for a longer period will check if the system can withstand wear and tear. These parts such as door rollers, bearings, rails and motor mounts, will be put through a lot of movements to make the testing realistic. Testing products helps find out where mechanical wear may happen, selects materials wisely and guides improvements for extra durability.

Wireless Communication and Remote Monitoring
Developing wireless communication rights for IoT will require further attention. You could use Wi-Fi or Bluetooth modules to allow remote observation, diagnosis and control through personal devices or special building software.

Environmental Robustness and Protective Enclosures
Future studies and advancements will also involve checking how systems react to adverse situations. Features such as protective enclosures will be used and tried out to guard electronic components and sensors against dust, moisture, changes in vibration and temperature swings. Making environmental protection strong will ensure the system lasts long, performs well and runs continuously in different places.

5.4 Significance of Future Work

To turn the gravity-assisted automatic door controller into a reliable product, addressing these future objectives is very important. Ensuring the sensors are correctly calibrated and the PID controllers tuned keeps the system correct, reactive and stable. Robustness tests on products will support their reliability and ability to last for a long time. By adding stronger safety features and wireless connections, the user experience, safety and maintenance will all be much better.
Once these things are done, the feasibility and effectiveness of using both gravity-aided mechanical design and intelligent sensor-driven control can be proved. All of these steps will make it possible for this project to help find smarter, cleaner and more efficient ways to automate buildings.

5.5 Summary

While the project is currently highly promising, it also shows where more improvement is needed. Fixing the identified problems by laying out detailed future work plans for sensor calibration, PID tuning, improving safety, adding wireless communication and robustness testing will ensure the success of the project. Succeeding in these key steps shows that the gravity-assisted automatic door controller is a strong, environmentally friendly and original advance in automated access control technologies.

6 CONCLUSIONS

The main goal of the study was to make and prove a gravity-assisted automatic door controller that lessens both energy usage, repair work and spending in upkeep compared to normal automatic doors. Thanks to creative mechanics, advanced electronic management and complicated sensors, this work created a unique way to automate building management.

A survey of current research and technologies in automatic doors showed there is a need to improve energy efficiency, increase mechanical efficiency and include gravitational mechanisms more fully. In spite of ongoing advances in sensors and control systems, traditional automatic doors keep relying on run-time motors which leads to raising energy costs and wear out of their components.

To handle this, the study introduced a rail with an angle that allows gravity to help doors open which requires less power for the motor. With the help of SolidWorks, the mechanics for the door were created and early tests showed that gravity assisted movement works well.

A Raspberry Pi Pico microcontroller was used in the project to handle the rapid and complicated ways sensors, motors and mechanical parts interact. The decision to use that microcontroller was made because of its dependable and quick data processing and the fact that it could be integrated with lots of peripheral sensors and controller drivers. Python simulations enhanced with the help of the Pygame library showed that the control system, feedback mechanisms and responsiveness worked well before any hardware was built.

The project has achieved important results, for instance finishing the simulation and beginning part of the hardware development. Nevertheless, several areas could use more progress. Examples are thorough sensor calibration, improved PID controller performance in practice, severe mechanical testing and installing safety and remote communication functions. Ensuring that these key areas are addressed helps the system work well in the real world.

Examining the key parts of the system such as the NEMA 17 stepper motors, TMC2208 motor drivers, PIR sensors, optical sensors and the VL53L0X laser distance sensor while backed by much research and practical examples, confirms that the complete system is both possible and highly likely to achieve good results. Tests have concluded that these models have been dependable in many automation and robotics situations which gives confidence that they are suitable for the new context.

The use of gravitational force in automatic door controllers is a valuable progress for the automated access field. It works together mechanical ways with advanced electronics and sensors to give customers a system that is supposed to boost energy saving, make the heating system more dependable, provide users with better comfort and increase sustainability.

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