SCURE ACCESS

July 11th, 2021

Dr. Craig Scratchley
School of Engineering Science
Simon Fraser University
Burnaby, BC V5A 1S6

Re: ENSC 405W/440 Design Specifications for DoorID™ by SCURE Access

Dear Dr. Scratchley,

Please find the attached document, "DoorID™ Design Specifications" produced by SCURE Access, as to fulfil the requirement of the ENSC 405W Capstone A course. Our product is an automatic door access system that will utilize facial recognition to allow eased entry for disabled individuals entering their homes.

Within the document, we will define the design specifications of our product to be expected from the proof-of-concept prototype and the possible design choices for the beta and production phase. Note that it also includes appendices regarding the UI and appearance design and the supporting test plan.

Our company comprises of six senior engineering students. Majority of the company stems from Computer Engineering, including Taranpreet Kaur, Manmeet Singh, Siavash Rezghi and Arshdeep Bhullar. Laura Vargas and Mena Shalaby are contributing from the Systems Engineering program.

Thank you for taking the time to consult our design specifications documentation for the DoorID™. If there are any questions concerning our product functionality or requirements, please contact Siavash Rezghi at 604-441-6361 or srezghig@sfu.ca.

Sincerely,

Siavash Rezghi

Siavash Rezghi
Chief Executive Officer
SCURE Access

DoorID Design Specifications

SCURE Access' Automatic Door Access System Using Facial Recognition

July 11th, 2021

Simon Fraser University

School of Engineering Science

ENSC 405W

SCURE ACCESS

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Glossary

CW/CCW: Clockwise/Counter-Clockwis
Face Detection: Detect a face in the frame captured by the camera
Face Recognition: Determine if the face detected matches an authorized user or not
GPIO: General Purpose Input/Output
MCU: Micro Controller Unit
MTCNN: Face Detection Algorithm
PIR sensors: Passive infrared sensor
TEE: Trusted Execution Environment [26]
Transfer Learning: To take a model trained on a large dataset and transfer its knowledge to a smaller dataset [1]
VGG Face: Face Recognition base model
WCAG: Web Content Accessibility Guidelines

Abstract

The simple and frequent act of entering one's home can cause great discomfort and difficulty to individuals living with a disability. DoorID™ by our company SCURE Access aims to ease this task by providing an automated system that will analyze a user's face upon entry, and perform a sequence to unlock, open, close, and lock a door.

The automatic door access system will consist of three main subsystems: image capturing, image processing, and a door opening/closing system. The DoorID™ will utilize a camera positioned near the front entrance, which will track and identify individuals approaching the door. Once individuals are identified, their image will be used in our facial recognition system to allow access into the house once matched with an approved user in the database. The user will also have access to our application in following phases (engineering prototype and final product), where images and videos of themselves can be added into a database and cloud services used by the product. Within this document, design specifications essential to meet all the requirement specifications and standards for our product will be specified, along with a justification for the final design component. This document also includes user interface and appearance design in Appendix A followed by supporting test plans for DoorID™ in Appendix B.

Version History

Version #	Produced by	Revision Date	Approved by	Approval Date	Reason
1.0	Arshdeep Bhullar Laura Vargas Manmeet Singh Mena Shalaby Siavash Rezghi Taranpreet Kaur	Jully 11th 2021	Siavash Rezghi	Jully 11th 2021	Initial Design Specifications draft

1. Introduction

Accessibility for individuals with a disability has always been a topic of large importance. However, for those not frequently interacting with this demographic, it may be easy to dismiss the difficulty and inconvenience of simple tasks such as entering one's home. In Canada alone, over 6 million people identified as having at least one type of disability in 2017 [2]. Majority of the people studied claimed to have a disability relating to pain, mobility, flexibility and mental health, but sight, hearing, dexterity, learning, memory and developmental disabilities are also commonly reported.

What is accessibility? Explicitly, Accessibility Services Canada (ASC) defines accessibility as, "the design of products, devices, services, or environments for people who experience disabilities". Contrasting with accessibility are the barriers, specified by ASC as, "a circumstance or obstacle that keeps people apart". These barriers can include physical, social, transportation, communication and social barriers [3]. The simple task of opening doors in such environments can be a large barrier for those with a disability [4].

1.1 General Project Overview

The DoorID™ by SCURE Access is taking accessibility one step further, to ensure that people of all abilities have a comfortable, convenient, efficient and secure means of entering their homes. As disability types can vary in complexity, severity, and age demographics, the DoorID™ aims to provide a simple solution to opening and entering doors, without any discrimination based on ability. The product can be generally explained through its three stage implementations The first stage consists of an image capturing subsystem that uses an exterior camera near one's front door. Once an individual's face is detected by the camera, their image is sent into a facial recognition system. The second stage consists of an image processing subsystem, where the facial recognition algorithms are used to verify if a person is an authorized user. Real time image data will be sent through the algorithm and compared against pictures from the database of authorized users. When a face is successfully matched, the door mechanisms of the final stage begins. Here, specialized locks will be triggered to unlock the door, and prompt a connected motor to open a sliding door for the proof-of-concept prototype. Finally, when the individual/s are safely inside the home, the DoorID™ will be signaled to close and lock the door.

1.2 Intended Use

The DoorID™ is intended to be used on house doors, particularly helping those having disabilities enter their homes. For the proof-of-concept prototype, the DoorID™ will be operating on a lockable sliding door, but the final product would also support swinging doors.

1.3 Intended Design Label Scheme

Throughout this specification document, the convention applied to requirement labels will be as follows:

[Des-X.Y.Z-W].

X displays the section number.
Y displays sub-section number.
Z displays the requirement number.
W displays the priority as alpha, beta, and pilot phase (‘a’, ‘b’, and ‘p’).

- Alpha phase corresponds to the proof-of-concept prototype: a
- Beta phase corresponds to the engineering prototype: b
- Pilot phase corresponds to the production prototype: p

2. System Overview

This section provides a brief overview of the product’s main components and the high-level functionality of each component.

Figure (1) gives a high-level overview of how the system would work from the outside world.

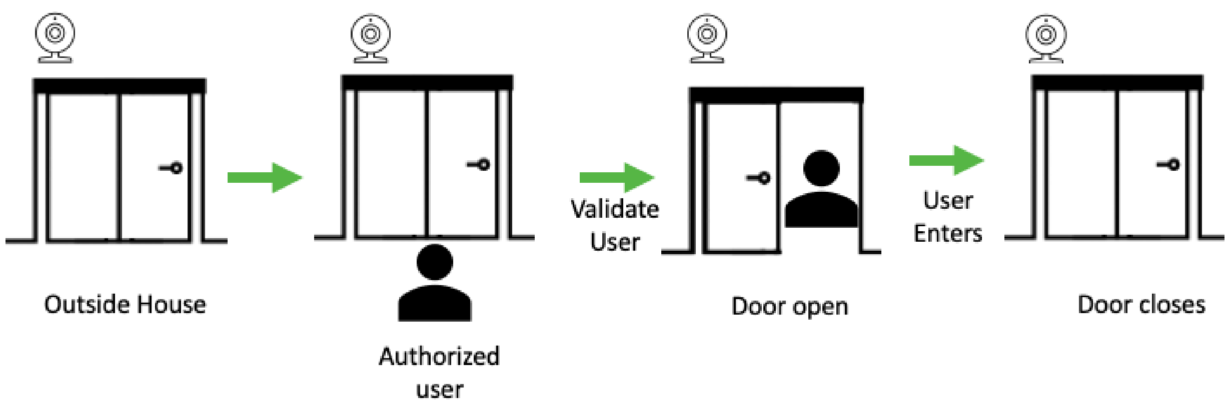

Figure 1: A quick overview how system would work from outside.

Figure (2) displays the three main connected subsystems within DoorID™. This includes the initial image capturing system to detect a human face, followed by the image processing system to authorize user entry. The last system in the pipeline controls the door mechanisms used to open and close a door.

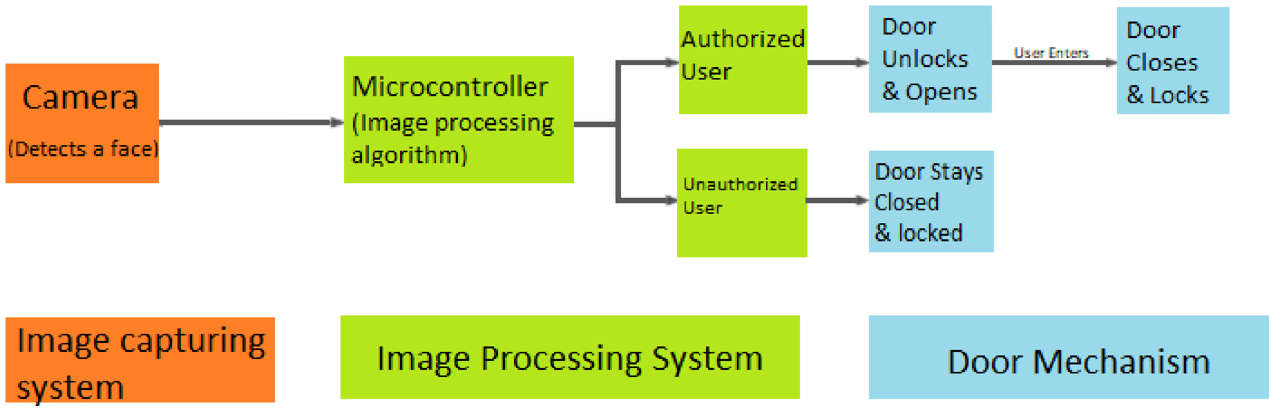

Figure 2: Implementation Pipeline

2.1 Image Capturing System

The image capturing system would consist of a camera which detects and locates the image of a face in real time. The camera would be carefully chosen so that it can also gather the depth data of an object along with traditional 2D image statistics.

2.2 Image processing System

The image processing system would be responsible to receive and analyze the data received from the camera/image capturing system. The analog data, that is, the image of a person, would be converted to digital data based on the facial features of the person [5]. The image processing algorithm would then look for a match in the database for that corresponding image/face detected by the camera. "In the presence of illumination, expression and pose variations, traditional 2D image-based face recognition algorithms usually encounter problems. With the availability of three-dimensional (3D) facial shape information, which is inherently insensitive to illumination and pose changes, these complications can be dealt with efficiently." [6].

2.3 Door Mechanism

The door mechanism carries one of the important roles in the whole system and provides the second layer of security by the lock. The door mechanism can be divided into four sections: door opening, door closing, door lock and unlocking sections. The microcontroller would communicate to the door mechanism that the user was authorized which would trigger the unlocking mechanism.

Safety measures have been considered while designing the door mechanism part. To avoid any collision or hit by the door mechanism in the door closing action, the design includes PIR sensors. The sensors should check for clear surroundings between the door and the door frame before triggering the closing mechanism. If any user, item or obstacle is between the door and the door frame, the PIR sensors keep the door open until closing is safe.

At last, the door mechanism includes the automatic lock and unlocking feature. The auto lock comes to play twice in a cycle of door opening and closing. Once at the very beginning step to unlock the lock, and then in the last step of locking the door after closing.

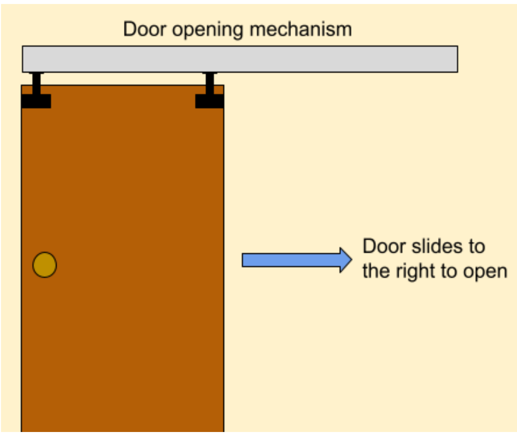

Figure 4: Door opening phase.

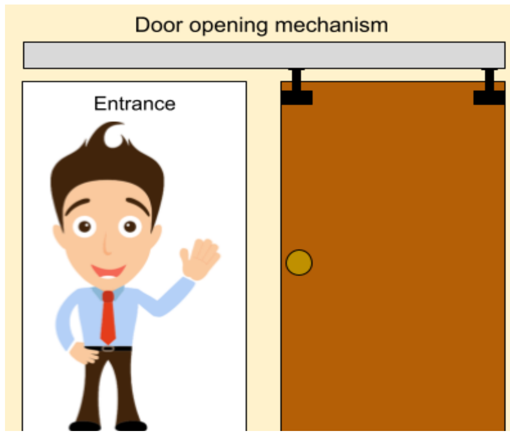

Figure 5: Clear entrance.

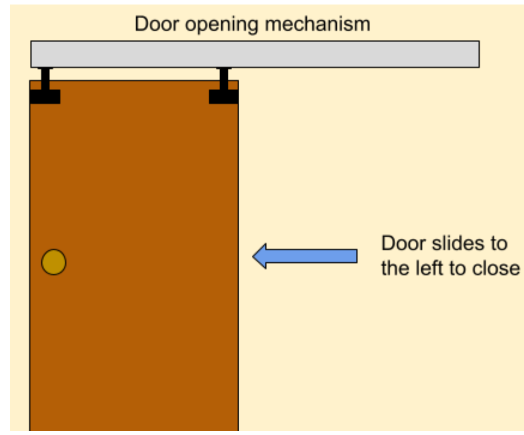

Figure 3: Door closing phase.

3. Mechanical Design

3.1 Camera mounting

Camera is part of the first pipeline Image Capturing algorithm for DoorID™. Camera has a big responsibility in figuring out whether the person is really present through depth sensors present in the camera. The camera used is the same for POC, Engineering Prototype and Production Phase. Details about specifications about the camera used can be found at section 4.1 Camera.

Figure 6: Camera mount part 1

For POC we would mount the camera to wall using the corner brace as shown in the figure (7). The tripod connector will connect to the camera and mount through the bottom of the bracket.

Figure 7: Carner brace, camera mount part 2

The table below shows design specifications for physical requirement for camera for the system:

Design Requirement	Requirement Description	Corresponding Requirements
Des-3.1.1-a	Camera weighs ~0.16lb.	PR-3.1.1-a
Des-3.1.2-a	Camera should be mounted outside and above the door ~10 -12 ft above the ground.	PR-3.1.2-a PR-3.1.6-a PR-3.2.3-b
Des-3.1.3-b	Camera should have a tampering switch to detect tampering and tampering evidence to confirm tampering.	PR-3.1.3-b PR-3.1.4-b

Figure 8: Camera Physical Requirements Design Specification

3.2 Door Lock

In order to lock the door and sync the opening and closing signals with the MCU, an electric door lock compatible with a sliding door will be utilized. A simple, yet strong drop bolt lock with 12V input will be used for proof-of-concept prototype. The lock will be connected to a 12V source as well as to a relay switch, signaled by the MCU. Once activated, a drop bolt will insert into a steel lock buckle that is mounted to the door frame. Figure 9 displays the lock and buckle to be used on the following page.

Figure 9: Electric Lock Dimensions [7]

Figure 10: Steel lock buckle [7]

Design Requirement	Requirement Description	Corresponding Requirements
Des-3.2.1-a	An Electric Door Lock will be used to unlock the door.	PR-3.4.2-a
Des-3.2.2-p	The lock must be able to withstand shear pulling of at least 150kg (1470 N).	n/a
Des-3.2.3-a	The lock will have dimensions small enough to integrate into a wooden or metal door.	PR-3.2.1-a PR-9.2.5-b

Figure 11: Door Lock Physical Requirements Design Specification

3.3 Door Opening and Closing Mechanism

An essential element of the DoorID™, product is the door opening and closing mechanism. This module includes different components that have the responsibility of unlocking, opening, closing, and locking the door. The door lock explained in section 3.2 would be taking care of unlocking and locking the door.

The mechanism is small in size and very elegant. For the sake of POC, we will be having a smaller version of a real-world door and door frame which reduces the size of the mechanism on the POC. The mechanism could be assembled and mounted on top of a door frame of any sliding door, whether a slide door to access the backyard or even as the main entrance.

The POC version of the mechanism will be made from lightweight lumber and timber to be able to carry it around. Initially, after taking all the required measurements, we need a strong piece of wood to use as the track board. All the hardware elements of the door opening and closing mechanism will be screwed and attached to the track board, as well as the sliding door track. For illustration purposes, we have the following mechanism breakdown that would also help the reader with better understanding of the design.

As can be seen below, we have the base which is the track board. The sliding door track is attached to the track board using hanging brackets. The design has two notched pulleys located at both ends of the track. The notched pulleys are hanging from the door track using jamb hangers.

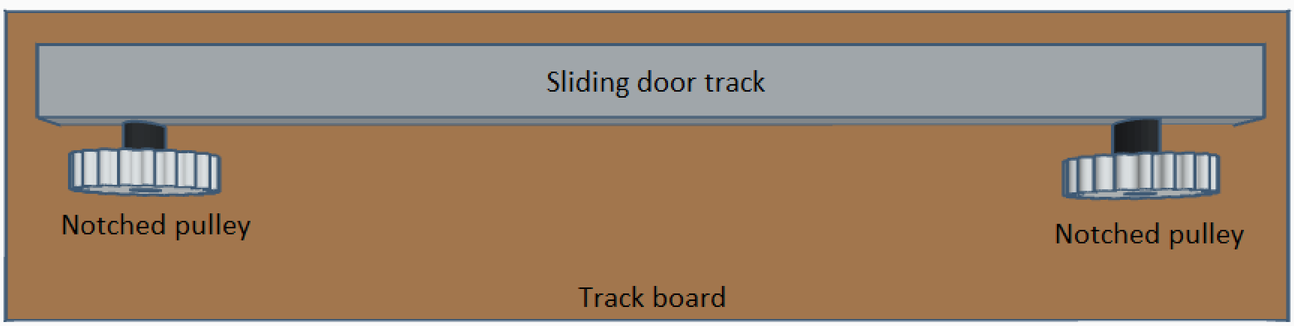

Figure 12: Door mechanism breakdown #1

Moving on to the next breakdown, figure (13), here we can see that our Raspberry PI is added to the right-hand side of the board. The 3V DC motor with 45 RPM is assembled on the lower side of the right pulley and the motor itself will be mounted to the board using mounting tools or a hanging bracket. Next item is the notched (timing) belt that goes around both pulleys of the mechanism. Since the length of the belt is very specific in this scenario, we have planned to use a larger size belt so we can cut it down to the desired size of ours. The two ends of the belt would get connected to each other using the top side of the belt clamp (connector). The two ends of the belt are going to get screwed to the top of the clamp and the bottom will be screwed to the top of the sliding door.

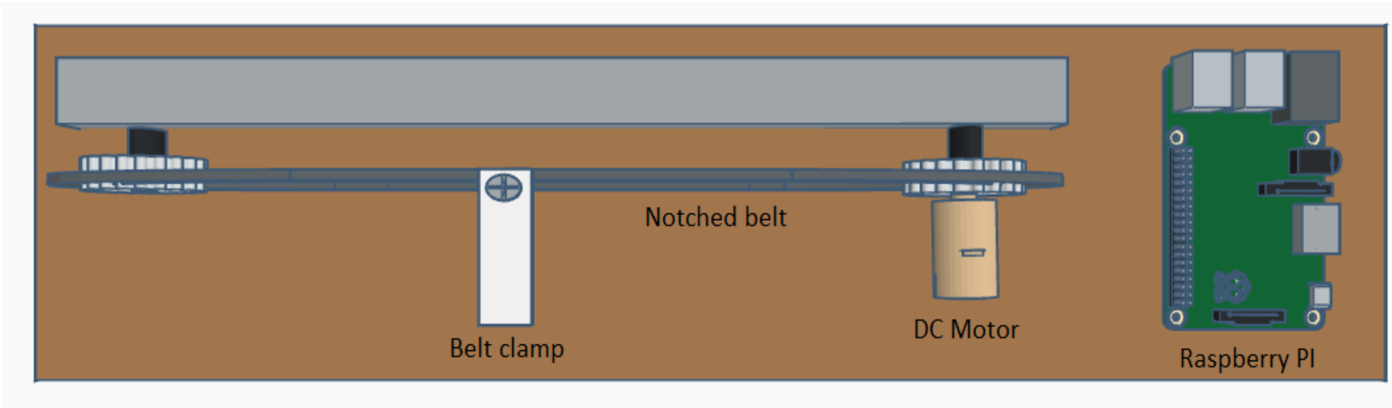

Figure 13: Door mechanism breakdown #2

On the next breakdown, 2 door hanger roller brackets have been added to the system. The figure (14) below shows how the overall positions of the roller brackets look like. The yellow rollers in the figure (14) are basically inside the door track and adjusted on the rails located in the internal part of the door track. A great point to consider is the fact that the whole weight of the door would be on the door track and hanger roller brackets. As shown below, the bottom of the hanger roller brackets is where the top of the sliding door will get screwed to. Figure below shows the clear demonstration.

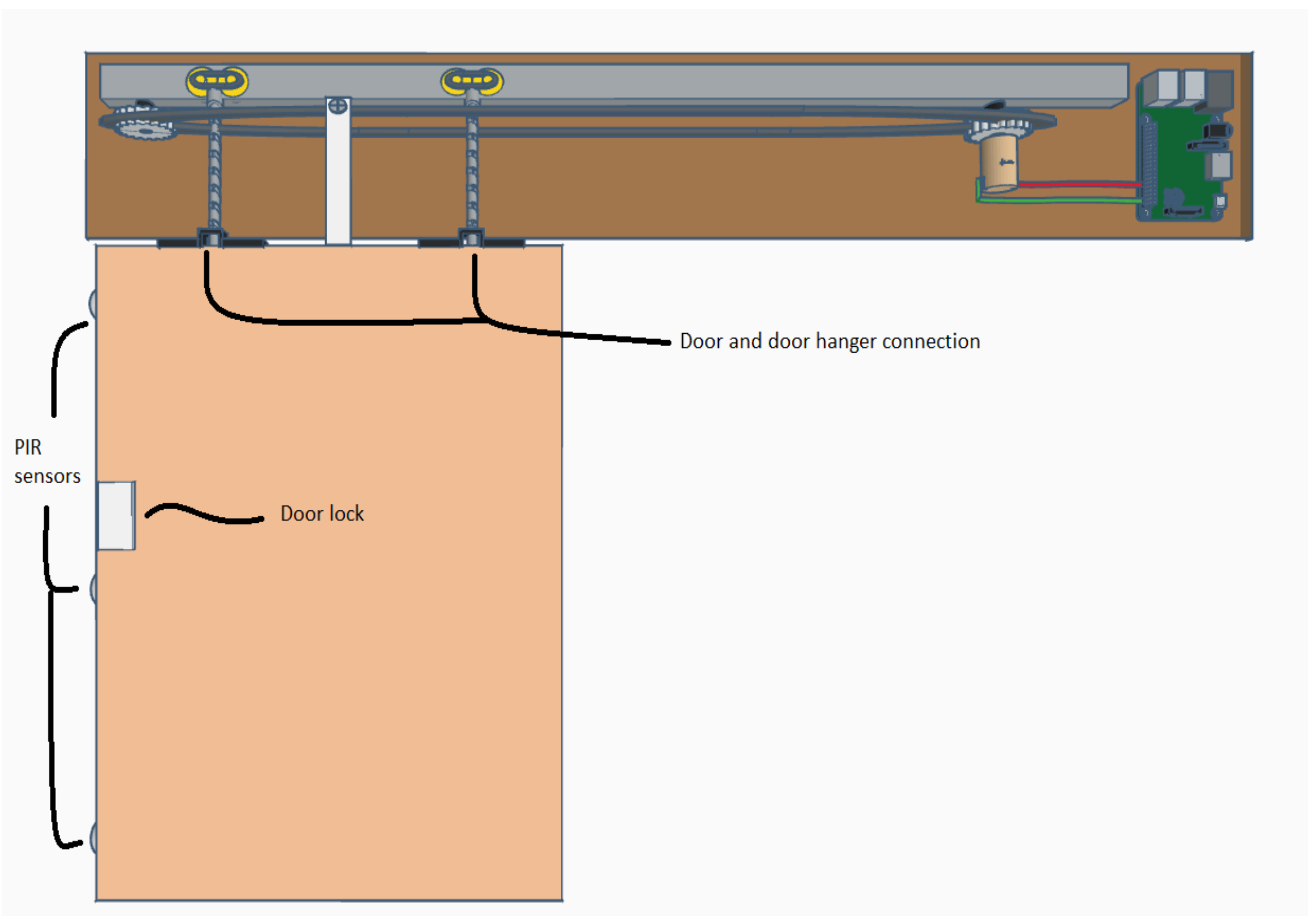

Figure 14: Door mechanism breakdown #3

Lastly, we have added the PIR sensors located on the interior edge of the sliding door. The connection of the PIR senators and DC motor have also been added. Sliding door is also screwed to the door hanger and the locking mechanism is now attached to the door. There will be tinny door stopper rubber inside the left side of the door track between the roller hanger and the pulley to prevent any strike to the pulley. We may be adding another sliding door track for the bottom side of the door to make sure the door is moving solid without any extra moves. This will be monitored and tested later in the POC process.

If time allows, we are considering adding a cover for the whole mechanism in order to have a more pleasing and elegant look by hiding all the hardware underneath it.

Design Requirement	**Requirement Description**	**Corresponding Requirements**
Des-3.3.1-a	The door employs an Electric Door Lock.	PR-3.2.1-a
Des-3.3.2-b	A standard door height is ~ 6ft -8ft with ~ 2.6ft of width. For POC and demo the height is ~ 1.3 - 2ft with ~ 1ft.	PR-3.2.2-b PR-3.2.13-b
Des-3.3.3-p	Another sliding door track is added between the ground and door to avoid tampering of the door through outside.	PR-3.2.3-b
Des-3.3.4-a	3x PIR sensors are used to make sure the door closes safely.	PR-3.2.4-a
Des-3.3.5-a	The run time of all 3 pipelines all together should take between 5-25 seconds.	PR-3.2.5-a
Des-3.3.6-a	The door mechanism is inside the house to avoid tampering.	PR-3.2.6-a
Des-3.3.7-a	The door mechanism is easy to implement.	PR-3.2.7-a
Des-3.3.8-a	The door mechanism covering panel should look presentable.	PR-3.2.8-a
Des-3.3.9-a	The door panel weight is approximately between 10-14 Ib and 2-4 Ib in POC.	PR-3.2.11-a
Des-3.3.10-b	The maximum weight of the door component is ~ 10-14 Ib which is under OHS standards for lifting a object by single user which is 51 lb [8].	PR-3.2.12-b
Des-3.3.11-a	In the final product the motor weighs less than ~ 2lb and all the other door mechanism components weigh ~1.5lb or less.	PR-3.2.14-p

Des-3.3.12-a	MCU weighs ~ 0.11lb.	PR-3.1.1-a
Des-3.3.13-a	MCU system is inside the house to avoid tampering.	PR-3.1.3-b PR-3.1.4-b
Des-3.3.14-p	Door mechanism setup does not need any expertise and can be implemented using screwdrivers and drill.	PR-3.2.9-p PR-3.2.10-p

Figure 15: Door and MCU Physical Requirements Design Specification

3.4 Other Non-Functional Requirements

Figure (16) below gives a design specification for other physical requirements.

Design Requirement	**Requirement Description**	**Corresponding Requirements**
Des-3.4.1-a	The ratios and sizes for POC have been mentioned in design specification document with different components.	PR-3.4.3-a
Des-3.4.2-p	DoorID must include a user manual to indicate the usage of the product safely.	PR-3.4.1-p
Des-3.4.2-p	DoorID can be available for standard door size and non-standard doors.	PR-3.4.4-p
Des-3.4.3-p	Users can order custom size DoorID products based on the user's door length.	PR-3.4.5-p

Figure 16: Other non-functional Physical Requirements Design Specification

4. Hardware Design

4.1 Camera

Camera is an integral part of the Image Capturing algorithm. The Intel® RealSense™ depth camera D435 is a stereo solution, offering quality depth for a variety of applications. It's wide field of view is perfect for applications where seeing as much of the scene as possible is vitally important. This small form factor camera can be integrated into any solution with ease and comes complete with Intel

RealSense SDK 2.0 and cross-platform support. Main reason for us to use the Intel Realsense camera is for its ability to generate high quality depth data, which will be used by our image processing algorithm to distinguish between images and real faces. Note that given it has an IR projector it is ideal to use at daytime and nighttime.

The camera in general is not going to change, so it is going to be similar to beta phase and will have similar connections with hardware.

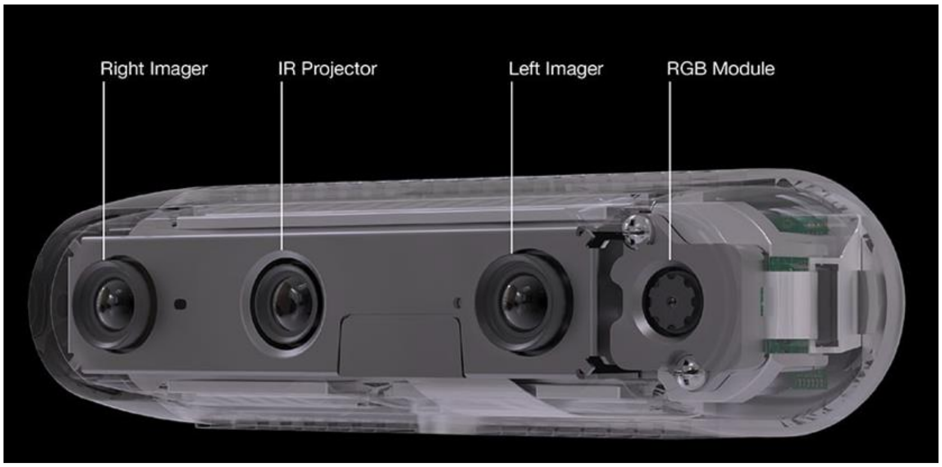

Figure 17: Intel Realsense D435 [9]

Figure (18) below shows design specification for the product followed by physical specifications for the intel's D435 camera.

Design Requirement	Requirement Description	Corresponding Requirements
Des-4.1.1-a	Camera will detect faces in real time.	PR-4.1.1-a
Des-4.1.2-a	Camera will gather depth data of the captured image.	PR-4.1.2-a
Des-4.1.3-a	Camera will detect faces at nighttime using an IR projector.	PR-4.1.3-a

Figure 18: Camera Design Specifications

Parameter	Value
Use Environment	Indoor/Outdoor
Ambient Temperature	0 °C - 35 °C
Ideal Range	.3m to 3m
Depth Field of View	87° x 58°
Depth Accuracy	<2% at 2m
Depth frame rate	Upto 90fps
RGP Frame Resolution	1920 x 1080
RGB sensor field of view	69° x 42°
RGB Frame Rate	30 fps
Length x Depth x Height	90mm x 25mm x 25mm
Weight	72 gr (0.16 lb)

Figure 19: Intel D435 Camera Parameters [9]

4.2 Raspberry PI 4

DoorID™ should be able to support a camera device with a medium sized motor, PIR sensors.

Raspberry PI 4 model B in general allows a large variety of functionalities. With multiple outputs and programmable functions, it is one of the best options for DoorID™. Raspberry pi 4 model B was specifically chosen for its compatibility with the camera and motor as well as it is well defined GPIO output which can be used with PIR sensors. Figure (20) and Tables specify specs as well as layout for Raspberry Pi 4.

Raspberry Pi 4 like camera, will not change as the specification and its purpose are decided. Some problems that we can face is to make sure that all switches are connected properly and may need multiple boards for the beta phase as there might be too many functions for Raspberry Pi 4 to handle.

Design Requirement	Requirement Description	Corresponding Requirements
Des-4.2.1-a	MCU must be able to receive data from the image capturing system, a camera.	PR-4.2.1-a
Des-4.2.2-a	MCU must be able to run image processing algorithm, verify identity of captured user	PR-4.2.2-a
Des-4.2.3-a	MCU must be able to interact with the motor handling door mechanism.	PR-4.2.3-a
Des-4.2.4-a	MCU must be able to communicate with door (using relay switch).	PR-4.2.4-a
Des-4.2.5-a	MCU must be able to connect to internet service or wireless network or Wi-Fi.	PR-4.2.5-a
Des-4.2.6-a	MCU can be coded to support delay for door closing.	PR-4.3.7-a

Figure 20: MCU Design Specifications

Specification type	Value
Dimensions	85.6mm × 56.5mm × 17mm
Weight	50 g (0.11 lb)
Processor	Broadcom BCM2711, Quad core Cortex-A72 (ARM v8) 64-bit SoC @ 1.5GHz
Memory	8GB LPDDR4-3200 SDRAM
Access	Raspberry Pi standard 40 pin GPIO
SD card Support	Micro-SD card slot for loading operating system and data storage
Connectivity	2.4 GHz and 5.0 GHz IEEE 802.11ac wireless, Bluetooth 5.0, BLE + 2 USB 3.0 ports; 2 USB 2.0 ports + Gigabit ethernet
Video and Sound	2 × micro-HDMI ports (up to 4kp60 supported)
Input power	5V DC via USB-C connector (minimum 3A*) 5V DC via GPIO header (minimum 3A*)
Environment	0 - 50 C operating temperature

Figure 21: Raspberry Pi Parameters

GPIO Specifications:
Figure (22) shows input and output for Raspberry PI. Any voltage lower than 1.8 V would be low and any voltage higher than 3.3 V would be high. It should be kept in mind that if a device which intakes more than 3.3V is connected and run with the pins, it will call in a lot of current which will fry the circuit for Raspberry PI.

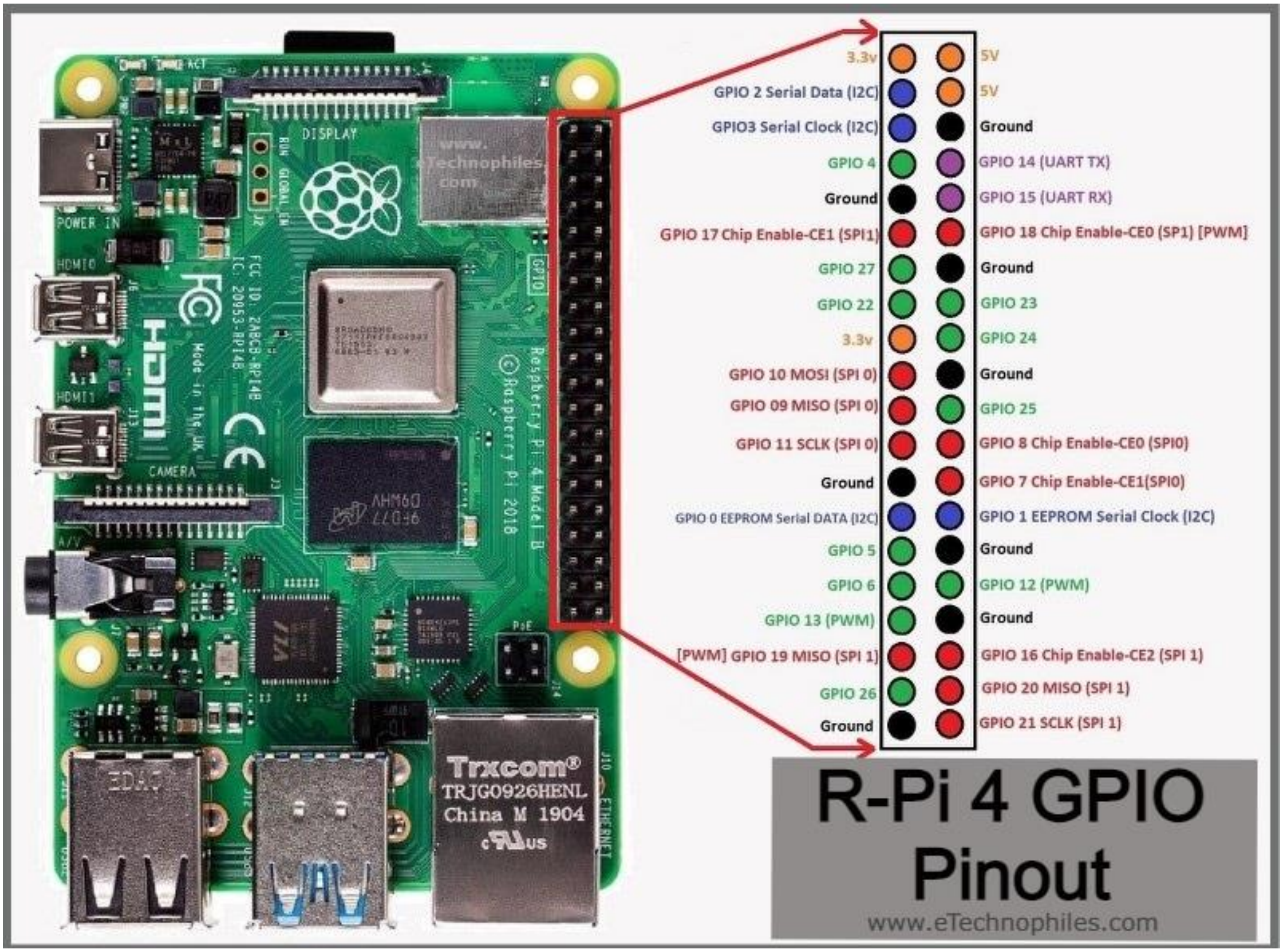

Figure 22: Raspberry PI 4 GPIO Specifications [16]

4.3 Electric Door Lock and Supporting Hardware

An electric door lock will be used to lock and unlock a sliding door, once signaled by the relay module and provided it's required input voltage. The third-party specifications of the electric lock are provided in figure (23). The lock used will follow the design requirements listed in figure (24).

Specification type	Value
Input Voltage/Current	12VDC/2A
Size	80x60x13mm
Lock mode	Fail Secure
Lock strength	150kg
Weight	90.7 g
Operating Temperature	-40 to 60℃

Figure 23: Electric Door Parameters

Design Requirement	Requirement Description	Corresponding Requirements
Des-4.3.1-a	A third-party electric lock used will not cost more than $100.	PR-3.4.2-a PR-6.6.2-p
Des-4.3.2-a	The electric lock and wiring will be able to be integrated safely and effectively into a sliding door.	PR-3.2.1-a PR-9.2.5-b
Des-4.3.3-a	The electric lock will communicate with the Raspberry Pi through a relay switch to lock and unlock the door.	PR-4.2.4-a PR-4.3.1-a PR-4.3.2-a PR-4.3.5-a
Des-4.3.4-a	The electric lock will weigh less than 700g and can be attached to a wooden or metal door frame.	PR-3.2.14-p
Des-4.3.5-p	The electric lock will be locked or unlocked, dependent on user preference, when a power loss occurs. Users will be notified via email or app if the power is low, or completely lost.	PR-4.2.5-p PR-9.2.6-p
Des-4.3.6-a	The electric lock must open for a successful facial recognition or registered key fob scan.	PR-9.2.2-a PR-4.3.1-a PR-4.3.2-a PR-4.3.5-a

Des-4.3.7-a	The electric lock must operate in varying weather conditions (-40 to 60℃).	PR-9.2.6-p

Figure 24: Electric Door Design Specifications

Relay Switch Module:
In order to automate the door unlocking sequences, a relay switch with an adjustable delay will be used to signal 12VDC to the electric door lock. The Raspberry PI will provide 5V from a GPIO pin to power the relay module at VCC. The ground pin from the relay module will also connect to a GND pin from the GPIO. The input pin on the relay will connect to any available GPIO pin. For the output of the relay, the relay switch has normally open (NO), normally closed (NC) and common (COM) modules. NO will connect to the negative terminal of a 12VDC power supply, and the COM will connect to the negative rail of the electric lock. The NC will remain unconnected, to ensure the Fail Secure coordination with the electric lock. A wiring diagram can be seen in figures (26) and (28) to illustrate the connections between the Raspberry PI, the door lock and the relay module.

Specification type	Value
Weight	20g
Dimensions	70×20×18mm
Quiescent Current	10mA
Dynamic Current	45mA/12V; 90mA/5V; 30mA/24V
Load Capacity	10A (AC 0-250V, DC 0-30V）
Delay Ranges	DC5V: 0-30min/ 0-24hr DC12V: 0-120min/0-24hr/ DC24V: 0-15min/ 0-30min

Figure 25: Relay Switch Parameters

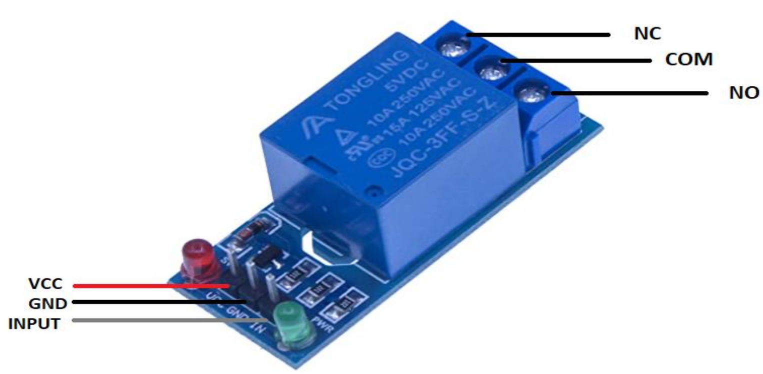

Figure 26: Relay module input/output terminals

Design Requirement	Requirement Description	Corresponding Requirements
Des-4.3.8-a	Relay module will weigh less than 700g and be able to stow away within door mechanism.	PR-3.2.14-p PR-9.2.5-b
Des-4.3.9-a	Relay module must communicate with raspberry pi and not take more than 5V input.	PR-4.2.4-a
Des-4.3.10-p	Relay module can use a delay to allow some time before locking/unlocking of the lock.	n/a
Des-4.3.11-a	Relay module will connect to Raspberry Pi GPIO, electric door lock and external power supply to lock/unlock the door.	PR-4.3.1-a PR-4.3.2-a PR-4.3.5-a

Figure 27: Relay Switch Design Specification

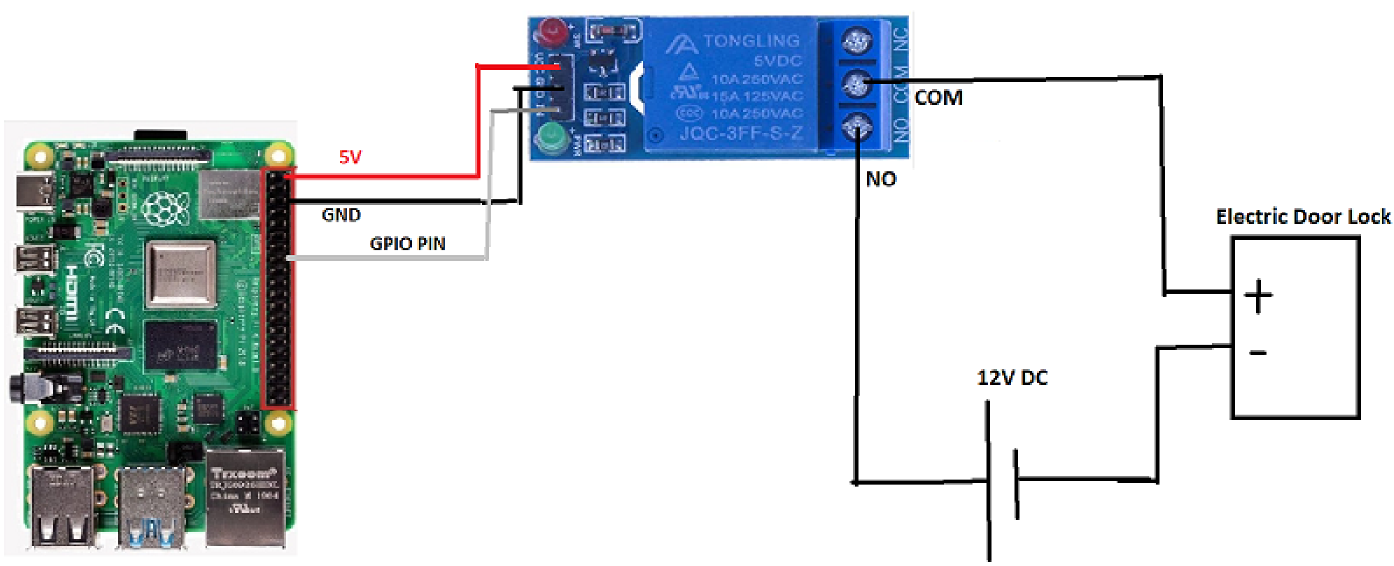

Figure 28: Wiring Diagram of locking/unlocking mechanism

RFID card reader:
An RFID card reader with USB input will be connected to the Raspberry Pi. This will serve as a backup manual entrance via key fob, for the case of a failed facial recognition of an authorized user.

Design Requirement	Requirement Description	Corresponding Requirements
Des-4.3.12-a	The RFID card reader must accept registered key fobs.	n/a
Des-4.3.13-a	The key fobs can be used for authorized users to enter the door, in the case facial recognition fails.	PR-9.2.2-a
Des-4.3.14-a	The RFID reader must connect into a USB port of the Raspberry Pi.	n/a
Des-4.3.15-a	The RFID reader must allow for registered key fobs to be entered into its accompanied UI.	n/a

Figure 29: RFID Card Reader Design Specification

4.4 Sliding Door Motor

For POC purposes, we are using a smaller motor compared to the FP version. POC includes a 3V 45RPM horizontal shaped stainless steel mini gear DC motor. The motor provides high torque which is necessary to make the door hanger roller brackets move. Also, the compact size and light weight of the motor is what we need to keep the door mechanism panel small in size and light in weight.

The DC motor will be connected to a L298N Motor Drive Controller that powers up and controls the motor. Motor drive controller will be connected to the Raspberry PI and we can program it such that the motor rotates in both directions, clockwise and counterclockwise.

Design Requirement	Requirement Description	Corresponding Requirements
Des-4.4.1-a	The motor used is less than ~2lb.	PR-3.3.1-a
Des-4.4.2-b	The motor does not make a loud noise when rotating.	PR-3.3.2-b
Des-4.4.3-a	The motor rotates in both directions to perform opening and closing.	PR-4.3.4-a PR-4.3.5-a

Figure 30: Sliding Door Motor Design Specification

Figure (31) shows an illustration of the DC motor and figure (32) gives some motor data for your reference.

Figure 31: Mini DC gear motor [10]

Voltage	No-load		Rated			At Stall	
V DC	Speed rpm	Current mA	Speed rpm	Current mA	Torque Kg.cm	Torque Kg.cm	Current mA
3	45	35	33	150	0.3	1	350

Figure 32: Motor data [10]

4.5 DC Motor Drive Controller with Dual H Bridge

There are a variety of motor drive controller modules on the market that can be used for controlling DC and servo motors. After researching, we have decided to use the L298n Motor Driver Module with Dual H Bridge to control the motor of the door mechanism. This module includes an L298 motor driver IC, 78M05 Voltage Regulator, resistors, capacitor, Power LED, 5V jumper in an integrated circuit [11]. Figure (33) on the following page shows the L298n module.

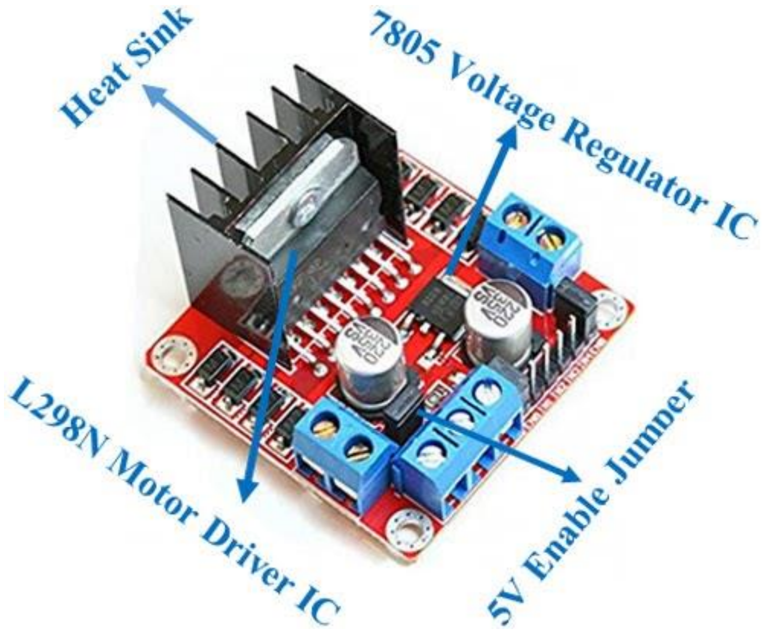

Figure 33: L298n Motor Driver Module [11]

Design Requirement	Requirement Description	Corresponding Requirements
Des-4.5.1-a	L298n is a motor driver controller.	PR-4.2.3-a
Des-4.5.2-a	L298n is capable of communicating with the Raspberry PI.	n/a

Figure 34: DC Motor Drive Controller's Design Specification

The module is powered through 3-pin 3.5mm-pitch screw terminals that consist of pins for motor power supply (Vs), ground and 5V logic power supply (Vss) [12]. The L298N Module can control the rotation direction and the speed of our DC motor. This could be done by employing PWM technique for speed control and H-Bridge for rotation direction control [12]. Figure (35) below shows the circuitry of this driver module.

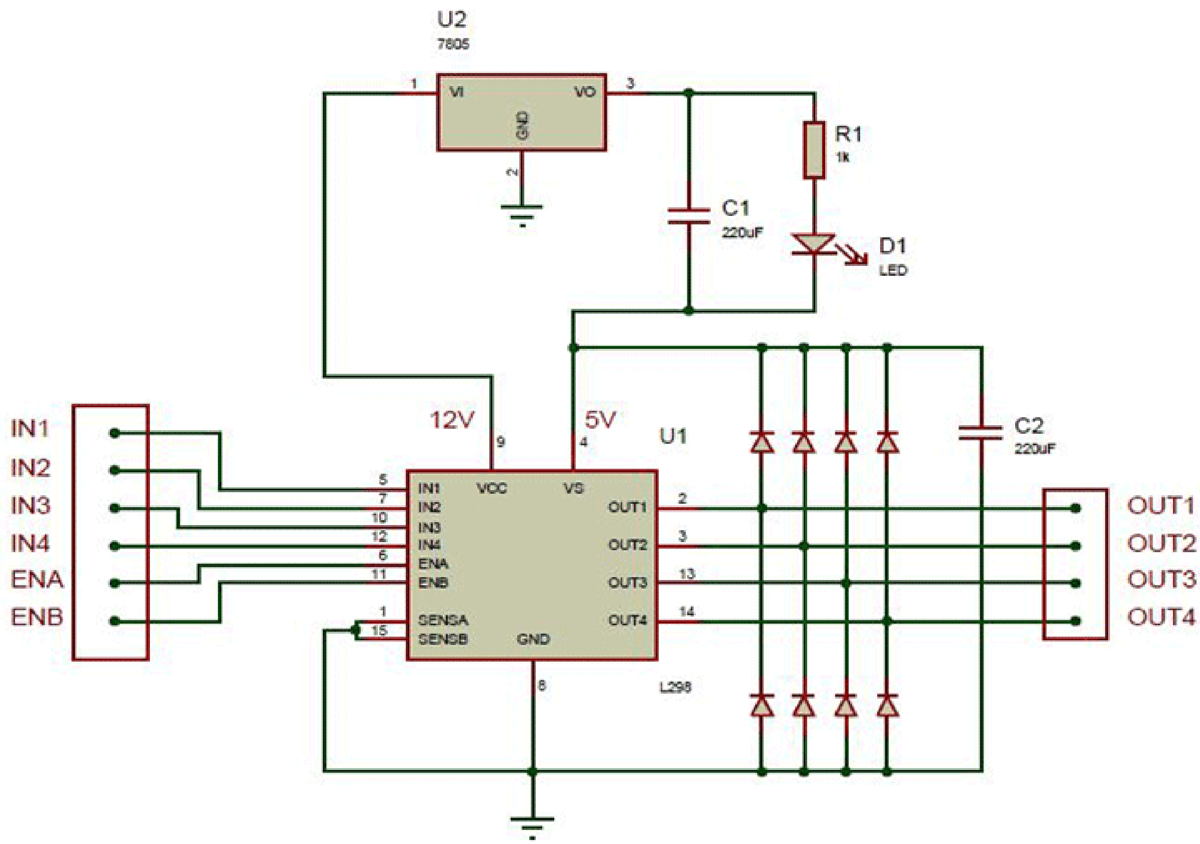

Figure 35: Circuitry of L298n Driver Module[12]

We can control the speed of the DC motor by varying and adjusting its input voltage. To achieve this, we are going to use Pulse Width Modulation technique, known as PWM [12]. This technique adjusts the average value of the input voltage by sending a series of ON-OFF pulses [12].

To control the spinning direction of the DC motor, we can change the polarity of its input voltage where for this common matter, the device includes an H-Bridge [12]. An H-Bridge circuit contains four switches with the motor at the center forming an H-like arrangement [12].

Closing two specific switches at the same time, the H-Bridge reverses the polarity of the voltage applied to the DC motor which leads to change in rotation direction of the motor [12]. The animation on the following page illustrates how H-Bridge circuit works.

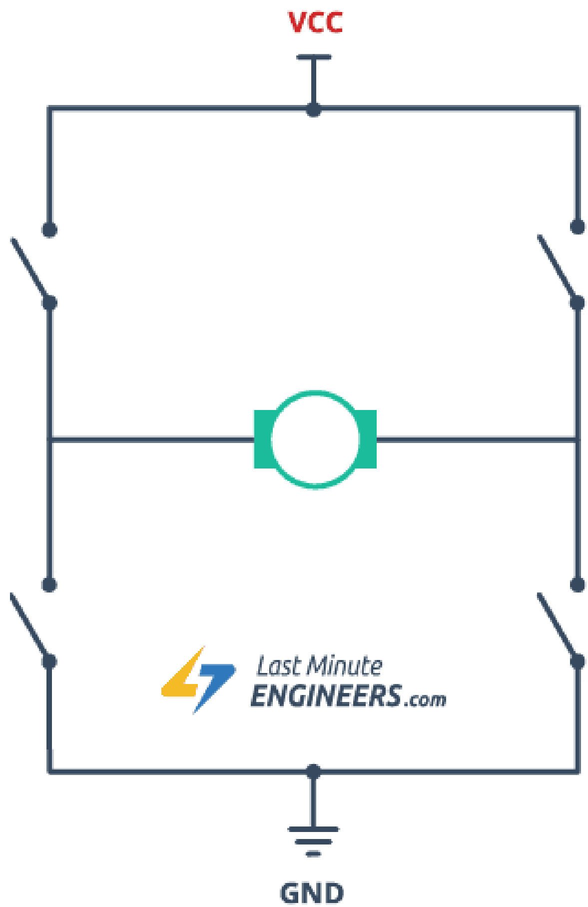

Figure 36: H-Bridge circuit [12]

4.6 PIR Sensor

To ensure the safety of a user during the door closing step, we are going to implement 3x PIR sensors on the sliding door. The PIR sensors will be communicating to the raspberry PI and are responsible for safe door closing.

Design Requirement	Requirement Description	Corresponding Requirements
Des-4.6.1-a	The PIR sensors will check the surroundings before closing the door to avoid any collisions.	PR-4.3.6-b
Des-4.6.2-a	The PIR sensors will be assembled to the outer edge of the sliding door.	n/a

Figure 37: PIR Sensor Design Specification

In general, PIR sensors allow us to sense motion and they are very small in size, low-power and inexpensive. PIR stands for Passive Infrared sensor and it measures infrared light radiating from any object [13]. Figure (38) below shows a typical PIR sensor and its pin configuration.

The PIR sensors are consist of 3 pins:

- Pin1: corresponds to the drain terminal of the device, which is connected to the positive supply 5V DC [13].
- Pin2 corresponds to the source terminal of the device, which connects to the ground terminal via a 100K or 47K resistor. The Pin2 is the output pin of the sensor [13].
- Pin3 of the sensor connected to the ground [13].

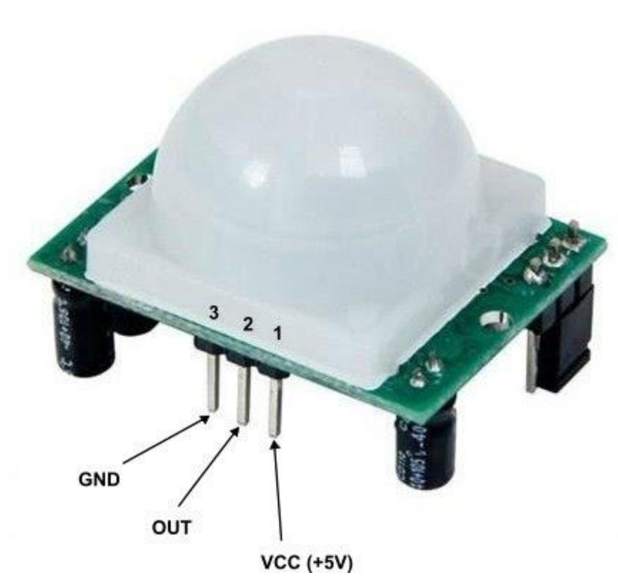

Figure 38: PIR Sensor [13]

The PIR sensors are capable of detecting animals and human movement in a requirement range. The pyroelectric sensor, which the PIR sensor is made from, can detect different levels of infrared radiation [13]. However, the sensor does not emit any radiation or energy but passively receives them [13]. When a human or an animal body passes by, it intercepts the first slot of the PIR sensor which causes a positive differential change between the two bisects [13]. Afterwards, when a human or animal body leaves the sensing area, the sensor generates a negative differential change between the two bisects.

Figure (39) on the next pages shows the how the passive energy and radiation is received by the PIR sensor.

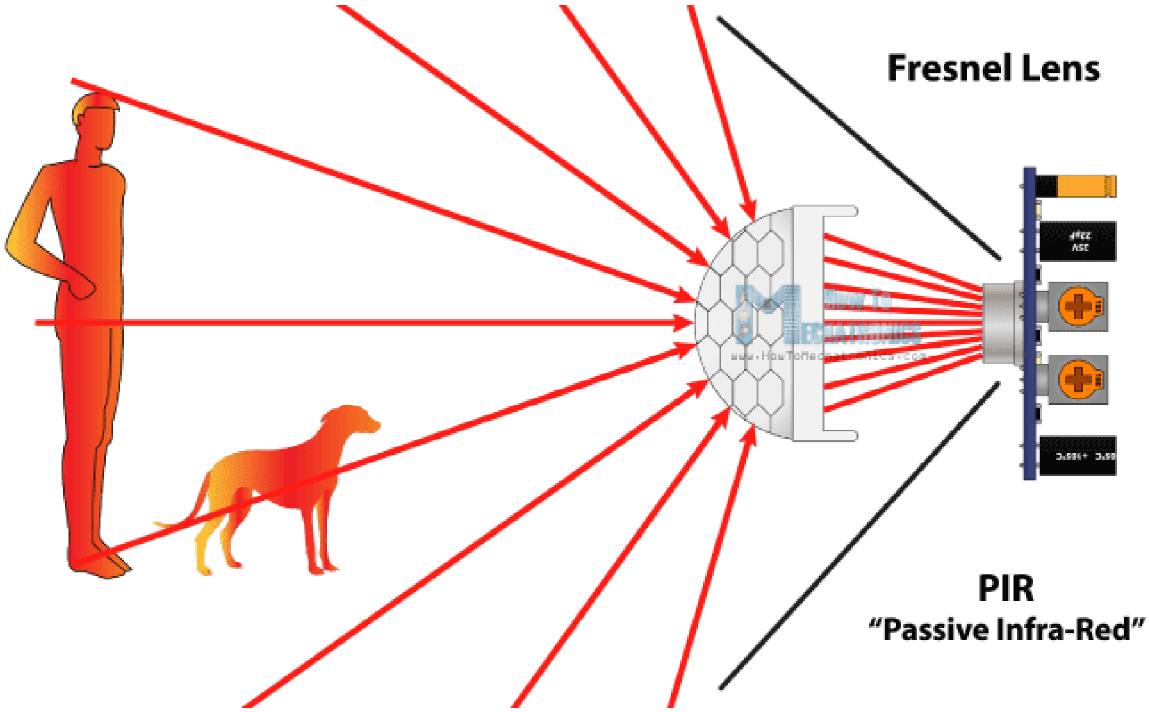

Figure 39: PIR sensor receiving radiations [13]

4.7 Power Supply

We are going to use two 12V DC power supplies, beside the Raspberry PI that has its own adaptor and power brick. One power supply will be used for the door locking mechanism and the second one will be used to power up the L298n Driver Module. The 3V DC motor will get connected to the Driver Module and the module will be powering the motor up.

Design Requirement	Requirement Description	Corresponding Requirements
Des-4.7.1-a	2x power supplies will provide the power that the system needs.	n/A

Figure 40: Power Supply Design Specification

The power supply requirements might get changed later in the beta phase.

Figure 41: 12V DC Power Supply

5. Software Requirements

Software design specifications are divided into three sections: Mobile App, Cloud and Image Processing Algorithm.

5.1 Mobile App

A custom iOS app with a simple user interface will be implemented in the Beta Phase. More details are included in appendix A.

The following table includes the design specifications applicable to this section:

Design Requirement	Requirement Description	Corresponding Requirements
Des-5.1.1-b	The mobile app will be programmed using Swift 5.	n/a
Des-5.1.2-b	The IDE to be used is Xcode 12.	n/a
Des-5.1.3-b	The User Interface will have a simple and coherent design.	PR-5.1.1-b
Des-5.1.4-b	The App will be available for IOS devices.	PR-5.1.1-b

Des-5.1.5-b	The UI will be connected to the cloud and will be able to upload data in order to add new users to the system.	PR-5.1.2-b
Des-5.1.6-b	The UI will be connected to the Microsoft Azure and by removing access to users their corresponding data will be erased from the cloud.	PR-5.1.3-b
Des-5.1.7-b	By means of the camera's SDK the app will be capable of showing a livestream of the frames being captured.	PR-5.1.4-b
Des-5.1.8-p	By means of a remote connection to the Raspberry Pi the user through the app is to be able to remotely lock and unlock the door.	PR-5.1.5-p

Figure 42: Mobile App Design Specifications

5.2 Cloud Storage

SCURE Access has decided to use Microsoft Azure. This cloud service was selected due to its reputation of being one of the most secure working environments.

The integration for the product would be considered in the beta phase, in the alpha phase we do the selection of the cloud storage and calculations of number of users, size of data and therefore the cloud storage needed. The below table shows design choices for cloud components of the software side to store user information.

Design Requirement	**Requirement Description**	**Corresponding Requirements**
Des-5.2.1-a	Microsoft Azure has the ability to store 80 images per person for up to 10 people (subject to change).	PR-5.2.1-a
Des-5.2.2-a	Microsoft Azure has the ability to store images larger or up to 1MB (subject to change).	PR-5.2.1-a
Des-5.2.3-b	Microsoft Azure is able to safely erase user data.	PR-5.2.2-b

Figure 43: Cloud Design Specifications

The cloud design choices related to the safety requirements specifications are included in the table below.

Design Requirement	Requirement Description	Corresponding Requirements
Des-5.2.4-a	The data in cloud will be labeled without containing any personal information.	PR-9.2.3-a
Des-5.2.5-b	The data in Microsoft Azure will have a local backup.	PR-9.2.4-b
Des-5.2.6-p	For the pilot phase we would have an upgraded cloud storage that will ensure we never run out of memory.	PR-9.2.7-p

Figure 44: Cloud Safety Design Specifications

5.3 Image Processing Algorithm

The algorithm is divided into two main architectures. The first architecture is to make sure that the person is in the system or cloud. The second architecture's purpose is to make sure that a person is really present rather than someone else showing that person's image. Figure (45) gives a quick overview of how the architecture is established. Figure (46) gives a quick overview of how the architecture has different technical components.

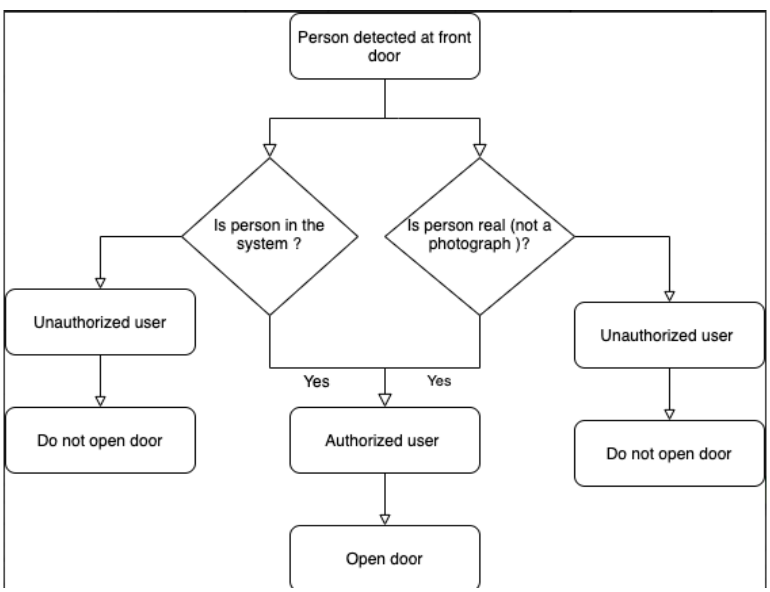

Figure 45: Image Processing Flowchart #1

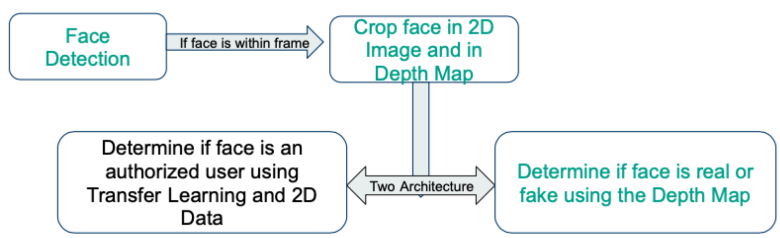

Figure 46: Image Processing Flowchart #1

The first step is to do Face Detection using the MTCNN algorithm [14]. Initially, ModelNet-V2 was considered to do Face Detection, however, testing showed that it was inaccurately classifying human faces as other objects. Testing of the MTCNN algorithm showed that faces are accurately detected even when users had their faces oriented at different angles and when users were wearing hats and face masks. The MTCNN algorithm was selected due to the latter and the fact that it provides useful information that can be cross referenced to the Depth Map (3D data) in order to implement anti-spoofing techniques to make the system invulnerable to pictures of faces of authorized users.

```
>>> detector.detect_faces(img)
[
    {
        'box': [277, 90, 48, 63],
        'keypoints':
        {
            'nose': (303, 131),
            'mouth_right': (313, 141),
            'right_eye': (314, 114),
            'left_eye': (291, 117),
            'mouth_left': (296, 143)
        },
        'confidence': 0.99851983785629272
    }
]
```

Figure 47: Demo of the MTCNN algorithm [14]

Another reason why the MTCNN algorithm was chosen is because of its speed.

Image size	Total pixels	Process time	FPS
460x259	119,140	0.118 seconds	8.5
561x561	314,721	0.227 seconds	4.5
667x1000	667,000	0.456 seconds	2.2
1920x1200	2,304,000	1.093 seconds	0.9
4799x3599	17,271,601	8.798 seconds	0.1

Figure 48: Processing Time of MTCNN given the Image Size using Intel i7-3612QM CPU @ 2.10GHz, with a CPU-based Tensorflow 1.4.1

The 2D and 3D data captured by the D435 Camera are cropped using the bounding box outputted by the Face Detection algorithm. The image is cropped in order to reduce background noise and to narrow the data just to the area of interest which is the face. The Face Detection and cropping will also be performed when adding users to the system.

Note that after cropping the images are resized to 224x224 since it is required by the Face Recognition algorithm. The Face Detection algorithm takes any image as an input regardless of the size.

After a face is detected and the data is cropped and resized the two architectures are triggered in parallel. Another possibility is to merge the two architectures and have one model that does Face Recognition and anti-spoofing. We chose the two architecture models given that it is efficient and given our level of experience in Deep Learning we consider it the most reasonable approach.

Using VGG Face [15] for Transfer Learning was chosen given that we can load only the feature extraction layers and include our own data in the following layers to finish training the model. Another reason this model was chosen is due to the good reputation and the extensive documentation available regarding VGG Face.

For the PoC prototype the trained model will be uploaded into the Raspberry Pi. In the beta phase we will train the model in the Raspberry Pi given that at that stage we will implement the functionality of adding and removing users through the mobile app.

The figure below shows design choices for the image processing component for the product.

Design Requirement	**Requirement Description**	**Corresponding Requirements**
Des-5.3.1-a	The Face Detection and Face Recognition will use python and base models to do Transfer Learning.	n/a
Des-5.3.2-a	The Face Detection algorithm returns the bounding box pixel coordinates of a face detected on the frames captured by the camera.	n/a
Des-5.3.3-a	The Face Detection algorithm returns the confidence level and key point coordinates of the left eye, right eye, nose, left side of the mouth and right side of the mouth.	n/a
Des-5.3.4-a	Face detection accurately detects human faces even if user is wearing an accessory (hat, face mask, between others).	n/a
Des-5.3.5-a	Comparing the cropped face in 2D image and in-Depth Map (3D) to user stored in Microsoft Azure cloud by means of the Face Recognition Deep Learning model.	PR-5.3.1-a
Des-5.3.6-a	Both algorithms will be run ideally in parallel or in series to make sure that the full process of determining if a person is authorized takes no more than 10 sec.	PR-5.3.2-a

Des-5.3.7-a	By implementing Transfer Learning with VGG Face and doing parameter tweaking the algorithm should have sensitivity of at least 90% and specificity of 99%.	PR-5.3.3-a
Des-5.3.8-a	Second algorithm makes sure that the person is real rather than just an image by using Depth Map (3D Data).	PR-5.3.4-a
Des-5.3.9-b	Face detection should be able to detect multiple people by modifying the face detection algorithm from the alpha phase.	PR-5.3.5-b
Des-5.3.10-b	Both algorithms will work with multiple people if one person within the group is authorized.	PR-5.3.5-b
Des-5.3.11-b	By improving the initial implementation using Transfer Learning with VGG Face [1] and further parameter tweaking the algorithm should have sensitivity of at least 95% and specificity of almost 100%.	PR-5.3.6-b
Des-5.3.12-b	The algorithm should work on daytime and nighttime given that it takes as an input the frames captured by the IR camera.	PR-5.3.7-b
Des-5.3.13-b	Data preprocessing would be considered to account for obstacles introduced by capturing frames at nighttime with the IR camera.	PR-5.3.7-b
Des-5.3.14-b	Similar as in Des-6.3.7-B, the algorithm should work under different weather conditions given that it takes as an input the frames captured by the IR camera.	PR-5.3.8-b
Des-5.3.15-b	Data preprocessing would be considered to account for obstacles introduced by capturing frames at weather conditions (such as rain and snow) with the IR camera.	PR-5.3.8-b
Des-5.3.16-p	Multiple anti-spoofing techniques would be implemented to ensure the system is not vulnerable to advanced anti-spoofing techniques such as 3D facial masks.	PR-5.3.9-p
Des-5.3.17-a	The first algorithm is that the person in the system should be able to take information from Microsoft Azure cloud.	PR-5.3.10-a

Figure 49: Image Processing Design Specifications

6. Conclusion

The DoorID™ by SCURE Access gives an ability to enter and exit with ease without any discrimination based on ability. The design specification documentation gives a design overview and details of all components of the DoorID. Corresponding with the Requirement Specification paper, this document entails the design descriptions and requirements of the various components mentioned throughout the paper. The design specification documents have given priorities similar to the requirements document. The specification has three phases: alpha, beta, and pilot phase. To ensure user satisfaction, all components will be tested individually through supporting test plans which are present in Appendix B detailed below.

A Raspberry Pi 4 is used as the MCU of the product, where GPIO and USB provide power and connectivity to various components of the product. An Intel Realsense Depth Camera D435 is utilized for image detection and connected to the MCU via USB port. Image processing algorithms will be carried out using the MCU and Python processing to authorize users. Once authorized, the door mechanism subsystem is signaled.

The door opening mechanism includes the required tools to hang and slide the door. Also, a L298n motor driver module and a DC motor are used for door sliding purposes. The mechanism has employed PIR sensors for safety reasons. Moreover, a 12V electric lock connected to a 5V relay module will be signaled to unlock and lock. GPIO pins provided by the MCU will power a relay module to perform this sequence. Finally, the user will have the backup option of key fob entry. To support this, an RFID card reader will be input via USB port of the MCU.

7. Product Design Specification Approval

Signature		**Date**	July 11, 2021
Print Name	Siavash Rezghi		
Title	Mr.		
Role	Chief Executive Officer		

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9. Appendix A: User Interface and Appearance Design

Introduction

The purpose of this appendix is to provide details and an analysis of the User Interface and Appearance of the overall system. We will analyze how user friendly the system is and will explain the design choices we made for the system to be user friendly. The scope is a user analysis, technical analysis, engineering standards, analytical usability testing, empirical usability testing and a graphical representation of the User Interface that makes part of the DoorID™ system. On one note SCURE Access does not want the user to be able to tamper with hardware to make sure that security provided at houses is not breached.

User Analysis:

This section can be divided into two parts, the analysis regarding the use of the mobile app and the analysis regarding the use of the product excluding the app. Note that DoorID™ has as a main target audience individual with disabilities.

We aim to create an app with a simple and coherent design. The way we designed our app was to minimize the required user knowledge and restrictions. To be able to install our app the user should have an IOS compatible mobile device and be able to type in the device. The user should also be able to read or use an assistance/accessibility setting (external to the DoorID™ app) to be able to understand what is being shown on the screen. The mobile application for the beta phase will have the following functionalities:

1. Verify username and password.
2. Add users (upload pictures and/or videos to the cloud).
3. Delete users.

To use the DoorID™ product (excluding the app) the user's required knowledge is negligible since the system will automatically unlock, open, close and lock the door. The action needed from the user is to position the face at an angle that is fully or partially visible from the camera, wait for the door to open and then go inside the house.

Technical Analysis:

This technical analysis considers Don Norman's "Seven Elements of UI Interaction". The first element, discoverability, tells us that the more visible an element is it is more likely that users know how to use it [17]. Therefore, we made sure that the elements are visible to the user and that they are located in a place that makes sense. For example, in the mobile app the logout button is going to be located in the top left of the screen.

The feedback principle can be described as making clear to the user what action has been taken and what has been accomplished [17]. The app is designed to have a flow which will make sense. The app will also show if an action was completed for example: the photos were uploaded, or if an action is being completed by showing a loading symbol.

The conceptual model is a mental model people use their imagination and experience to complete an action. The app will try to keep the UI consistent with what is seen around the world. For example, the delete button color is usually red, and the upload color button is usually green or blue, or using a universal symbol for deleting stuff, or uploading pictures. This would ensure that users can use applications without any issues as they could use their imagination.

The affordances are a principle which tells the user about how this object can be used. The app would be used to upload pictures and give users an opportunity to lock and unlock doors remotely. These features need to be clearly stated or clearly shown on the application. The app would avoid confusing users by using proper UI, for example avoiding using a shape similar to a button which does not perform any action.

The signifiers reflect what affordance the action has [18]. If multiple users are added in the app, a user might need to scroll through the surface to see all users. Therefore, the app should clearly signify that users can scroll through the page.

The mappings principle reflects a clear relation between control and effect. The app will clearly state which action each button or other interacting platform would perform, for example a delete button would clearly have "DELETE" text or would have the universal symbol of delete on the button, so, this will clearly signify what would the effect be through the particular action.

The constraints can be described as a certain aspect or actions that users are restricted to use or perform [17]. At this moment SCURE Access came up with some constraints as stated below:

- user has to upload a video for a specific time or specific number of photos at different angles.
- user should know how to take video or photos at different angles.

Engineering Standards

Since the app is geared towards users with disabilities the basic user interface design requires a lot less interface interaction and should be easy to set up. The app also needs to be accessible to users where accessibility includes requirements that are technical and relate to underlying code rather than to visual appearance. This includes screen readers that can read aloud content and screen magnifiers that enlarge content. Voice recognition is another form of assistive technology. Also, conceptual design as discussed above is an important factor towards improving accessibility issues. Web Content Accessibility Guidelines (WCAG) is a web standard set for web accessibility for HTML, CSS and more[19]. So, this will be one of the major standards to follow for accessible content for users. Following general guidelines such as proper formatting, adequate css usage etc. for general apps will also fall under standards for app.

For Hardware side we need to make sure that major components are installed inside the house, so that they cannot be tampered with, and make sure that the user understands that hardware tampering could pose security risks to their house.

Analytical Usability Testing:
The analytical usability testing will consist of measuring the performance of the whole system. We will measure the time it takes in between a person being within the frame captured by the camera to the moment the door closes and locks. We will ensure the user can successfully enter the door without interference by the door mechanism by testing entering, leaving, and standing in the doorway. The door should not close until after the required wait time. Each subsystem will be tested individually and compared to the physical requirements outlined in the Requirements Specifications Document.

Empirical Usability Testing:
For future implementations, users will be able to have more interaction within the user interface of the app. More access and options will be enabled, to allow users to remotely unlock and lock the doors within the app. As well, they will have the option of adding new users to the database. Testing required for these future phases will include adding one or more new potential users to the database and ensuring the facial recognition process will still be successful and meet the design requirements. Additionally, testing from the user interface for various locking and unlocking sequences remotely will be conducted, to ensure that the door mechanisms will still open and close without the need for an external facial recognition. To support accessibility measures for people with disabilities, Assistive Speech will be tested within the app. All features that would regularly be selected in the user interface could be used with the Assistive Speech commands.

Graphical Representation:
To have a better understanding of the design choices made for the User Interface is necessary to look at the graphical representation of the mobile app. The arrows indicate the flow of the UI and figure (50) can be found in the following page.

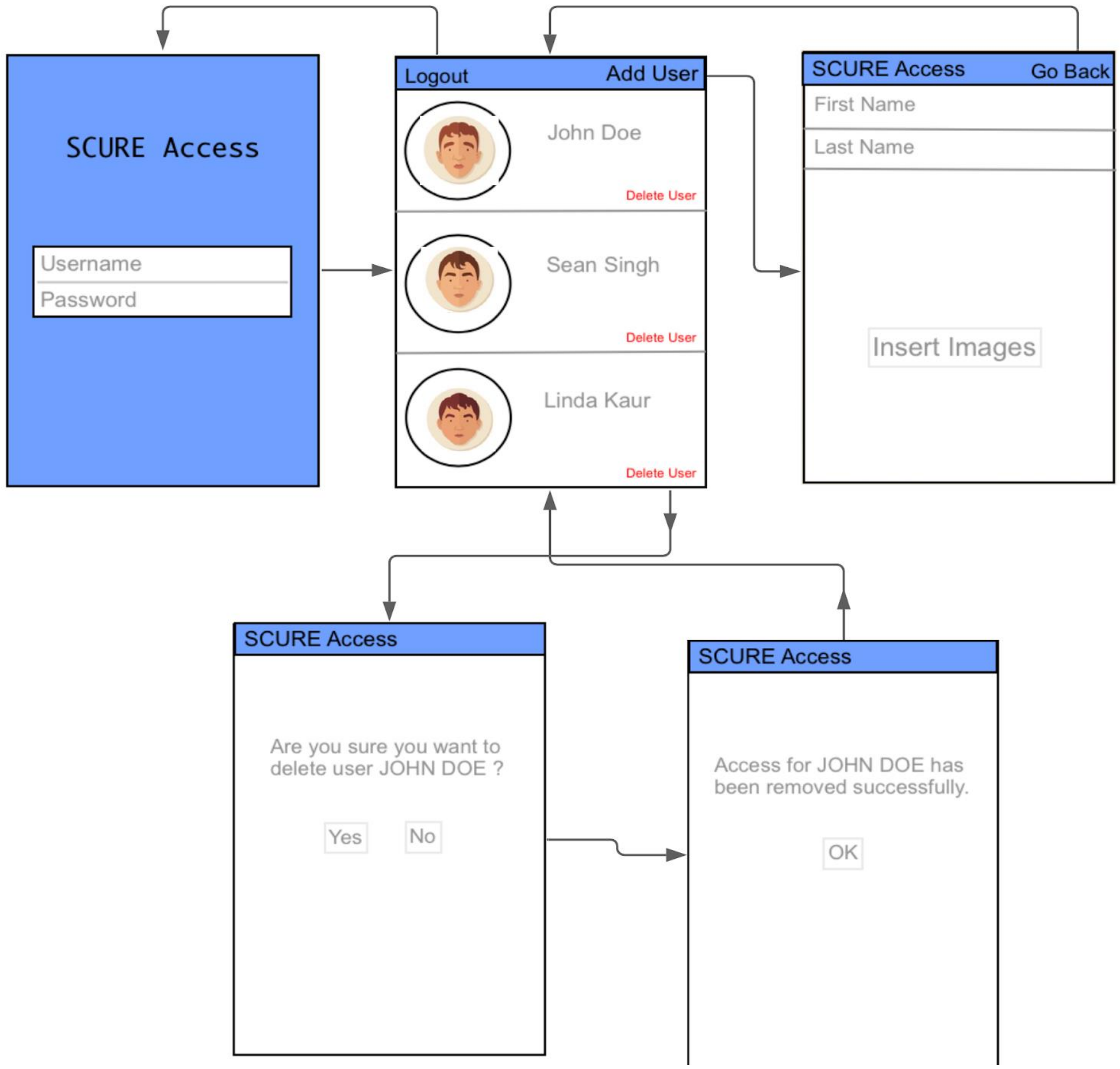

Figure 50: UI Design

Conclusion:

This UI appendix talks about detailed analysis of User Interface for DoorID™, which is based more on software rather than hardware. For hardware, SCURE Access needs to make sure that product cannot be tampered with by user or outsider. This is made sure by providing guidelines to users about hardware and making sure main components of our hardware cannot be reached from outside. For the software part for DoorID™, the main focus is on application. Since applications would be developed in beta phase these UI specifications are subject to change. SCURE Access is trying to provide its users best user experience by making sure that the application is made for the targeted audience, that is, individuals with disabilities. Furthermore, the company is making the mobile app under Don Norman's “Seven Elements of UI Interaction'' and also following WCAG engineering guidelines. Finally, SCURE Access has also mentioned some future features that its users will find helpful and could look forward to.

10. Appendix B: Supporting Test Plan References

10.1 B.1 Hardware and Mechanical Test Plan

For hardware and mechanical test plans, we need to test the compatibility with Raspberry Pi and make sure that interaction is proper. All the test plans stated below would be for the POC phase.

Camera:

Test	Description	Pass/Fail
Detecting faces	Making sure camera detects faces in under 3-5 seconds.	
3D dataset rendering	Camera should be able to render 3D dataset and send it to MCU for processing of videos.	
Depth image	Camera is able to capture z coordinates for depth image.	
Working in different conditions	Make sure camera's IR sensor is able to take clear videos with different weather conditions, daytime, and shadows.	
Connecting properly	Able to connect the camera properly with Raspberry PI 4 and run it inside the values.	
Camera wide view	Perform exercise to make sure camera docking system is where camera can have a wide view of area.	
Camera	Perform exercise to make sure Camera should be mounted securely.	

Figure 51: Camera Test Plan

Door Mechanism:

Test	Description	Pass/Fail
Locking/unlocking of doors	Perform two exercise to make sure that the lock is working with Raspberry PI 4 as its MCU.	
Locking Door	Perform one exercise to make sure door does not lock before it closes.	
Motor IEC standards	Perform four exercise to make sure that motors work according to IEC Standards it should always be viewed from driven side meaning that the motor should move clockwise to open door and anticlockwise to close door.	
Motor power	Perform exercise to make sure motor is able to slide the door.	
PIR sensor sensing objects	Perform exercises to make sure the PIR sensor is able to check for objects when placed in between them, among few exercises should have no object.	
PIR sensor and door together work properly	Following ANSI/CAN/UL 325 standards for automatic door, must remain open if it detects an object in between for at least 10 seconds.	
Far away from Tampering	Make sure that product is anti-tampering proof according to ISA -62443-4-2 standard.	

Figure 52: Door Mechanism Test Plan

Raspberry PI 4:

Test	Description	Pass/Fail
Connected Properly	Making sure all components connected together run properly with Raspberry PI 4 as its MCU.	
Time allocation	Making sure Raspberry PI 4 is able to run values in right time, and parallelly enough if necessary.	
Different ports run properly	Make sure all products run properly with USB-C and DPIO ports individually.	

Figure 53: Raspberry PI 4 Test Plan

10.2 B.2 Software Test Plan

Mobile App:

The test plan for the mobile app is reserved for the beta phase.

Cloud:

Test	Description	Pass/Fail
Storage	Storage should be sufficient to meet the design and requirements specifications.	
Data Removal	Able to safely delete data from Microsoft Azure.	
Handle multiple users	Following IEEE std 1686-2013 standards for intelligent systems, must be able to handle at least 10 different users.	

Figure 54: Cloud Test Plan

Image Processing System:

Test	Description	Pass/Fail
Individual Face Detection	Face Detection of single individuals is successful at different angles, lighting conditions, obstructions, between others.	
Individual Face Recognition	Face Recognition of single individuals is successful at different angles, lighting condition, obstructions, between others.	
Sensitivity (90%)	Calculate sensitivity using Scikit Learn metrics.	
Specificity (99%)	Calculate specificity using Scikit Learn metrics.	

Figure 55: Image Processing System

11. Appendix C: Supporting Design Options

11.1 Hardware Design

This section would compare different components for different pipelines for DoorID and state the reason for final component selection by SCURE Access.

Camera:
The camera used for the DoorID product was an important aspect. There are wide ranges of cameras available in the market. However, SCURE Access was looking for specific features in a camera as stated below:

1. infrared sensor projection to detect users in day or night.
2. have depth sensor present to make sure a person is present, and SCURE Access does not have to implement depth sensor with camera.
3. Able to work in different environments and has wide field view.
4. 3-D image object capturing: for image analysis algorithm to check if the person is really present rather than a photograph.
5. 2-D image object capturing: for image analysis algorithm to check if the person is in the cloud storage.
6. Able to connect with the MCU.
7. Weigh less so it is able to mount easily outside the door.

The different product options considered for camera are stated in figure below:

Products	Parameters	
Intel D435 Camera [9]	Infrared Sensor	Yes
	Depth Sensor	Yes, with depth accuracy of <2% at 2m
	Work in different environment	Yes
	Field view	87° x 58°
	3-D image	Yes
	2-D image	Yes
	Connect to MCU	Yes
	Weigh	72 gr (0.16 lb)
	Price	CD$189.00

Azure Kinect [21]	Infrared Sensor	Yes
	Depth Sensor	Yes, robust depth accuracy [not specified]
	Work in different environment	Does not work properly in ambient condition
	Field view	Yes 120° x 120° or 75° x 65° depending on modules being used [20]
	3-D image	Not specified
	2-D image	Not specified
	Connect to MCU	Yes
	Weigh	440 g (~0.97 lb)
	Price	CD$399.00

Figure 56: Product options for Camera

From figure (56), SCURE Access decided to use Intel D435 Camera as, Intels D435 camera weighs less than Azure Kinect and also cost. Additionally, Intel D435 Camera also works better in ambient condition than Azure Kinect. Lots of inconsistency and no specification about some sections for Azure Kinect needed for the camera made SCURE Access lean towards Intel D435 Camera.

MCU:

Microcontroller acts as the brain of our system, coordinating and performing most of the functions of the DoorAccess system. Main objective of our system was to:

1. A programmable microcontroller must be able to receive data from the image capturing system, a camera.
2. The microcontroller must be able to run the image processing algorithm and verify the identity of the captured user.
3. The microcontroller must be able to interact with the motor handling door mechanism.
4. The microcontroller must be able to communicate with the third-party smart lock.
5. The microcontroller must be able to communicate with the app to notify someone is at the door.
6. The microcontroller must be able to connect to internet service or wireless network or Wi-Fi.
7. Able to use python.

Analysis and Decision for the products options for MCU:

Three product options were considered for MCU: Toradex, Arduino and Raspberry Pi. Raspberry Pi was considered to be most optimal option by SCURE Access due to the following reasons:

- Toradex:
  Toradex devices by Nvidia, although incredible for software and hardware functionality, does not have much documentation for Intel D435 camera. Because of the limited resources online and lack of installation experience among the team. Additionally, unable to find any chip that would be compatible with Intel Realsense Camera, SCURE Access decided not to go with Toradex.

- Arduino:
  Arduino has a good hardware system but lacks in the advanced software side as for DoorID image analysis algorithm SCURE Access decided to use python language, but Arduino has its own language (similar to C, C++). Additionally, Arduino hardware have smaller size of microchips than required for DoorID. Hence, making Arduino not the most optimal option.

- Raspberry Pi:
  Raspberry pi provided SCURE Access with an optimal solution with both software and hardware specs the company was looking for. Since python language can be used with this hardware, it also has a larger size of microchips, it also works well with Intel D435 camera and last but not the least has a lot of documentation (including Intel's own specific documentation) and resources online.

Motor:
When considering motors to power the door opening mechanism, various considerations took place. Namely, choosing the type of motor was the major task. servo motors, stepper motors as well as DC motors were first compared. In order to meet the requirement specifications needed by the project, the following must be considered:

1. The motor must not cost more than $80.
2. The motor must have clockwise and counterclockwise rotation
3. The motor cannot weigh more than 5lbs.
4. The motor should not be unreasonably loud.
5. The motor should have enough torque to move a door and should not have too much speed in order to ensure stability of door mechanism.

Products	Parameters	
DC Worm Gear Motor [22]	Input Voltage	3V
	Speed	33RPM
	Rated Torque	0.3 Kg.cm
	Shaft Length	8mm
	Gear Ratio	1/238
	Stall Torque	1.0 Kg.cm
	CW and CCW	Yes
	Weight	<2lbs
	Price	CAD $11.62
Brushless DC gear motor [23]	Input Voltage	24V
	Speed	41RPM
	Rated Torque	6 kg.cm
	Shaft Length	24mm
	Gear Ratio	1/217
	Stall Torque	10 Kg.cm
	CW and CCW	Yes
	Weight	<5lbs
	Price	CAD $17.43

Figure 57: Product options for motor

After comparing these two DC motors, the DC Worm Gear motor is chosen as the design option. This is due to the smaller RPM, as speed too fast will cause instability with the door mechanisms (pulley and door hangers). It is also smaller in size which makes it more easily integrated into the indoor door mechanism. Finally, it is more inexpensive and smaller in weight, which are both major requirements to be met.

Locks:
Locks in our system are supposed to make sure that users do not get affected too much by it, while being able to be powered by the face recognition system. Some features of the lock include:

1. Electric lock and wiring are integrated safely and effectively.
2. Electric lock can communicate with MCU through a relay switch to lock and unlock the door.
3. Lock should weigh less than 700g and can be attached to different door frames.
4. Electric lock can be locked or unlocked dependent on user preference, when power loss occurs (Fail secure or Fail safe).
5. Electric Lock can be accessed through successful facial recognition or registered key fob.
6. Lock should be compatible with a sliding door for the proof-of-concept prototype.

Looking at these requirements, including requirement specifications where our locks cannot cost more than $100, we decided on ordering a lock with relay switch module with single channel. We also made sure to order a relay module which can interact with GPIO pins rather than USB-C. Various locks and lock types were compared, in order to verify which module would be compatible with our project.

Products	**Parameters**	
Electric Strike [24]	Voltage Input	12VDC
	Simple wire connectivity	Yes
	Work in extreme temperatures	Yes
	Fail Secure/Fail Safe	Fail Safe
	Size	150x28.5x3mm
	Compatible with sliding doors	No
	Delivery Time (Estimated)	2-3 weeks
	Weight	0.29kg
	Holding Strength	500kg
	Price	CAD$41.00

Electric Drop Bolt [25]	Voltage Input	12VDC
	Simple wire connectivity	Yes
	Work in different environment	Yes
	Fail Secure/Fail Safe	Fail Secure
	Size	80x60x13mm
	Compatible with sliding doors	Yes
	Delivery Time (Estimated	1 week
	Weight	90g
	Holding Strength	150kg
	Price	CAD$16.99

Figure 58: Product options for lock

After comparing these two similar locks, and also considering the required specifications to be met, the electric drop bolt is preferred. This is primarily due to its smaller size, compatibility with sliding doors, expected delivery time, and more inexpensive price.

11.2 Software Design

Mobile App:
Since the application would be implemented in beta phase a simple user application has been implemented in User Interface Appendix (Appendix A). Given our skill set SCURE Access the application would be built for iOS users for starters.

Cloud:
Users' images or videos would be stored on a cloud server. Since the server would store user's personal data the server or the environment the data is stored needs to be secure. Therefore, SCURE Access tried to find cloud servers with TEE. TEE is a Trusted Execution Environment. In TEE the code execution of code is under a highly trusted environment [26]. Since images and videos would also be stored on cloud SCURE Access needs a server which could store big files without any issues. The list for different Product options for cloud are stated in figure (59).

Products	Parameters	
Microsoft Azure	TEE	Yes [27]
	Price per user	CAD$11.52 user/month*: with advanced security system [28]
	Encrypt data during transmission	Yes [29]
	Encrypt own file within own environment	Yes [29]
iDrive	TEE	Not specified
	Price per user	CAD$74.62/year for 5 users [30]
	Encrypt data during transmission	Yes [31]
	Encrypt own file within own environment	if private key program Yes, otherwise No [32]

Figure 59: Product options for Cloud

From the above table, SCURE Access decided to use Microsoft Azure as, Microsoft Azure has TEE environment whereas, iDrive did not specify if TEE environment is used. Additionally, Azure allows users to encrypt their files in their own environment so individuals behind the scenes to maintain servers cannot see data.

Image Processing Algorithm:

Image Processing Algorithm is part of the second pipeline for DoorID™. The algorithm is one of the major components of DoorID™ as it determines if a user is authorized or not. The training model selected should easily be able to detect a face with a high confidence rate from a 2D image. The model should also be able to detect faces even if the users wear any accessories or if users are not facing directly towards the camera in the image. The list for different models options which were tested by SCURE Access team for image processing algorithm are stated in figure below.

Models	**Parameters**	
MobileV3	Detect face correctly	No, detected as follows: a/imagenet_class_index.json 40960/35363 [=============== - spotlight (31.86%%) - matchstick (3.37%%) - digital_clock (3.31%%) - theater_curtain (2.53%%) - lampshade (2.15%%)
	Detect face with a side view	-
	Detect face with an accessory	-
	Not able to detect face if no face is present	-
VGG Face model	Detect face correctly	Yes
	Detect face with a side view	Yes with a high confidence rate 'confidence': 0.999996542930603
	Detect face with an accessory	Yes, with a high confidence rate confidence': 0.9993757605552673
	Not able to detect face if no face is present	Yes, returns nothing

Figure 60: Model options for Image Processing

From the above table, SCURE Access decided to use the VGG model since the VGG model accurately detects faces. This model also returns a high confidence rate when the image shows a side view face for the user and the user is wearing an accessory. The model returns nothing when it detects that no face is present. Thus, making it a better suited model for DoorID™.