FH AACHEN
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System specification document

For

Project: Security Lock system

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Contents

1 Project Drivers

1.1 Purpose of the project

1.1.1 Project Effort

- The project is to develop a product that demonstrates the integration of a Light Barrier sensor with IO Device and communicates with I/O link Master
- The project was started at the request of Prof Wollert

1.1.2 Project Goals

- The project consists of a Light Barrier sensor, Key-Pad, Servo-Motor, ESP-32, IO-Shield & IO-master
- The light barrier sensor gives digital output, Key-pad has 10 numbers, 4 alphabets and 2 special character as input options, Servo motor rotates 0-360 degrees and the ESP-32 communicates to the I/O link Master via the I/O link Device shield
- The light barrier sensor detects when a card is entered in the system and enables the Key-Pad to enter the password. Upon password validation the Servo-motor opens the door

1.2 Client, Customers and Other Stakeholders

- Clients: The Project head Prof. Wollert is our main client
- Customers: The product is developed in-house so the customer is also Prof Wollert and Victor Chavez
- Stakeholders: The groups involved in the development of the project are the main stakeholders

1.3 Users of the Product

- The Hands-on users of the project: Students, professors and testing engineers are the primary users of the product
- Priorities Assigned to Users:
  - The Professors are the Key users of the product
  - The students and testing engineers are Secondary users
- Maintenance Users: The students developing the project are responsible to maintain the product

2 Project Constraints

2.1 Mandated Constraints

2.1.1 Solution Constraints:

- Constraint 1:
  - Description: The project must use the ESP-32 microcontroller for system controls
  - Relational: Client will not pay for new controller /control system
  - Fit criteria: All functional requirement must be delivered along with no response delay

- Constraint 2:
  - Description: I/O link communication protocol must be used to for communication
  - Relational: Client has specific requirement for the use of I/O link communication protocol
  - Fit criteria: The logic and hard wire connections must be compatible with IEC 61131-9 I/O link communication standards

- Constraint 3:
  - Description: Transmission speed of I/O link is 50 ms
  - Relational: The communication between I/O link device and master has response time of 50ms
  - Fit criteria: The software logic must consider the transmission rates in subsequent steps while writing the logic

- Constraint 4:
  - Description: Graphical User Interface (GUI) must be developed to indicate real-time status and failure responses
  - Relational: I/O link master must have communication with GUI over TCP/IP interface
  - Fit criteria: I/O link master must communicate with GUI via access point with TCP/IP communication protocol, real-time status along with failure modes must be displayed on GUI to the operator

2.1.2 Implementation environment of the current system:

- Block diagram illustrating the correlation between the controllers, I/o link device and I/O link master:

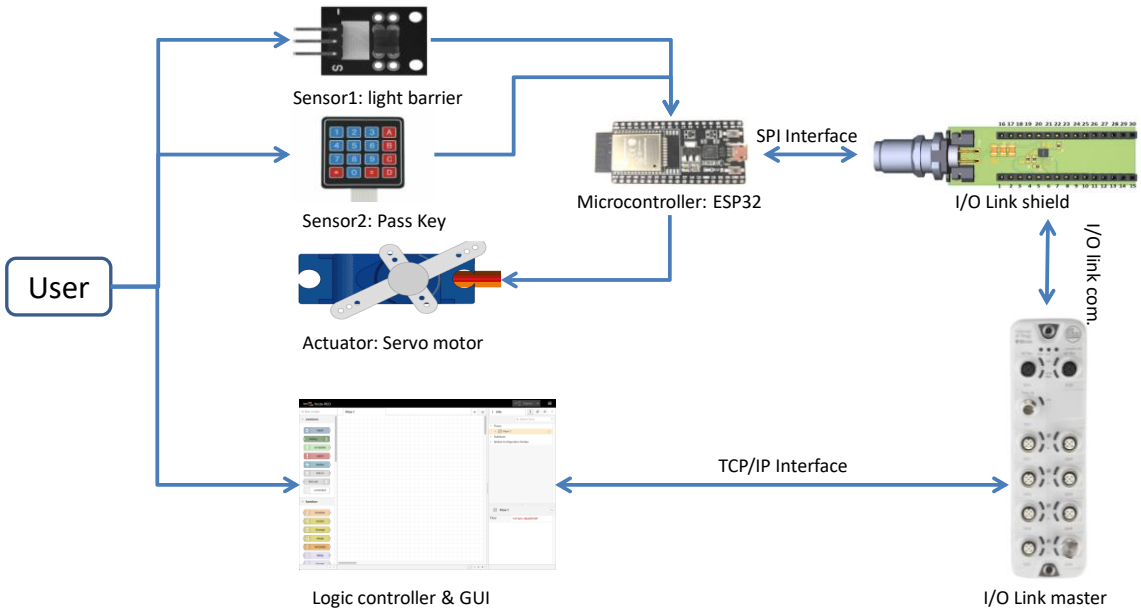

Fig.1 Block diagram: System Architecture

- ESP32 Microcontroller: A controller to control the complete system, It communicates with I/O link shield with SPI communication interface. It interacts with all the sensors and the actuators of the system
- I/O link shield: It communicates with ES32 microcontroller via SPI communication interface and with I/O link master over a I/O link communication protocol
- I/O link master: It is an intermediate link between the PLC controller and I/O link device. It receives and transmit the data from I/O link over a I/O link communication protocol and with GUI (Node red) with TCP/IP interface

- Node red (Controller and GUI): It receives the sensor data and transmits the actuator command over TCP/IP interface with I/O link master. It also represent the real-time status of the system along with warning and failure messages to the operator

2.1.3 Partner or Collaborative Applications

- Visual Studio Code: An open source software by Microsoft which is being used in this project for the software development
- Star UML: An open source system modelling software which is used for the system engineering diagrams (ex.: Sequence diagram, Parametric diagram and state machine diagram)
- Node-red: It's an open source software which is being used to create a GUI interface and programmable logic control for the system

2.1.4 Off-the-Shelf Software and hardware:

- ESP32 – It is an open source hardware which is being used as a microcontroller for the development of this project using open source Arduino libraries
- I/O link shield: The IO-Link shield is the physical layer that sets the appropriate voltage levels for communication with the IO-Link master, it is used along with ESP32 microcontroller to create I/O link device
- I/ link master AL1350: A I/O link maser device of make IFM is being used to establish the I/O link communication with I/O link device and TCP/IP communication with GUI(Node-Red)

2.1.5 Anticipated workplace environment:

- Final product could be a portable locker for individuals or it can be build up to a large array lockers for the organizations or institutions
- Product casing should not get damaged easily to prevent the failure of theft by breaking the locker

2.1.6 Schedule Constraints:

- The final product must be delivered within the three weeks after the product kick-off

2.2 Naming Conventions and Definitions

Definitions of All Terms, Including Acronyms, Used in the Project:

- SPI: Serial Peripheral Interface
- ESP32: Microcontroller developed by Espressif Systems-32

2.3 Relevant Facts and Assumptions

2.3.1 Facts:

- The passkey for security lock system is limited to four character
- User can use any card to have detection over a light barrier sensor

2.3.2 Assumptions:

- It is assumed that there will not be any changes in functional and non functional requirements of the product as considered earlier in the scope of this project

2.4 Norms and related documents

- The scope of this projects includes I/O link communication protocol to between I/O link device and I/O Link master
- The scope of this projects includes SPI communication interface between the I/O link shield and ESP-32
- The scope of this project includes the norms and guidelines of SysML to derive structural, behavioural and requirement diagrams along with the initial operating conditions

3 Functional Requirements

3.1 Scope of the work

3.1.1 The current situation

We are developing a security lock system using light barrier sensor to detect presence of Id card, A pass key sensor to accept and verify the pass key from the user. After successful authentication an actuator will automatically open the locker

3.1.2 Scope and context of the work

The scope of this project consists of the conceptual development; prototyping and proving out the functionalities of security lock system. The end product could be a portable device which can be used by an individual as a personal locker or can be implemented on large array lockers to be used by the employees of organizations and institutions. Detailed description about the scope of work as follow:

- **Drawing project functional and non-functional requirement:**

  In this phase of the project a conceptual model was developed along with the systematic documentation to understand the functional and non-functional requirements. A systematic structure of system along with subsystem was drawn to elaborate the internal and external communication sequences.
- **Prototype development for validation (VP):**

  In this phase of the project a prototype was made to demonstrate the functions of the security locker system. A prototype was developed using the open-source hardware and software system which are in line with the customer requirements and constraints. A simulator was used to test all the functions of the joystick.

  In this phase of the project, all used cases of the product were tested Ex. Opening a locker and closing the locker
- **Proposal for improvement of the product:**

  In this phase all open issues were listed and collected together to present the customer along with the possible solutions (Just a brief explanation about the possible solutions) to improve the product functionality and appearance

  Ex.: Product can be improved further by including the RFID tags, which will be a unique identification for every individual for better functionality

3.2 Functional and Data Requirements

3.2.1 Use-Cases

Different use cases are prepared and analyzed to understand the functional requirements and different modes of operations. Use cases elaborate all possible operation modes along with the functional dependencies on internal and external parameters.

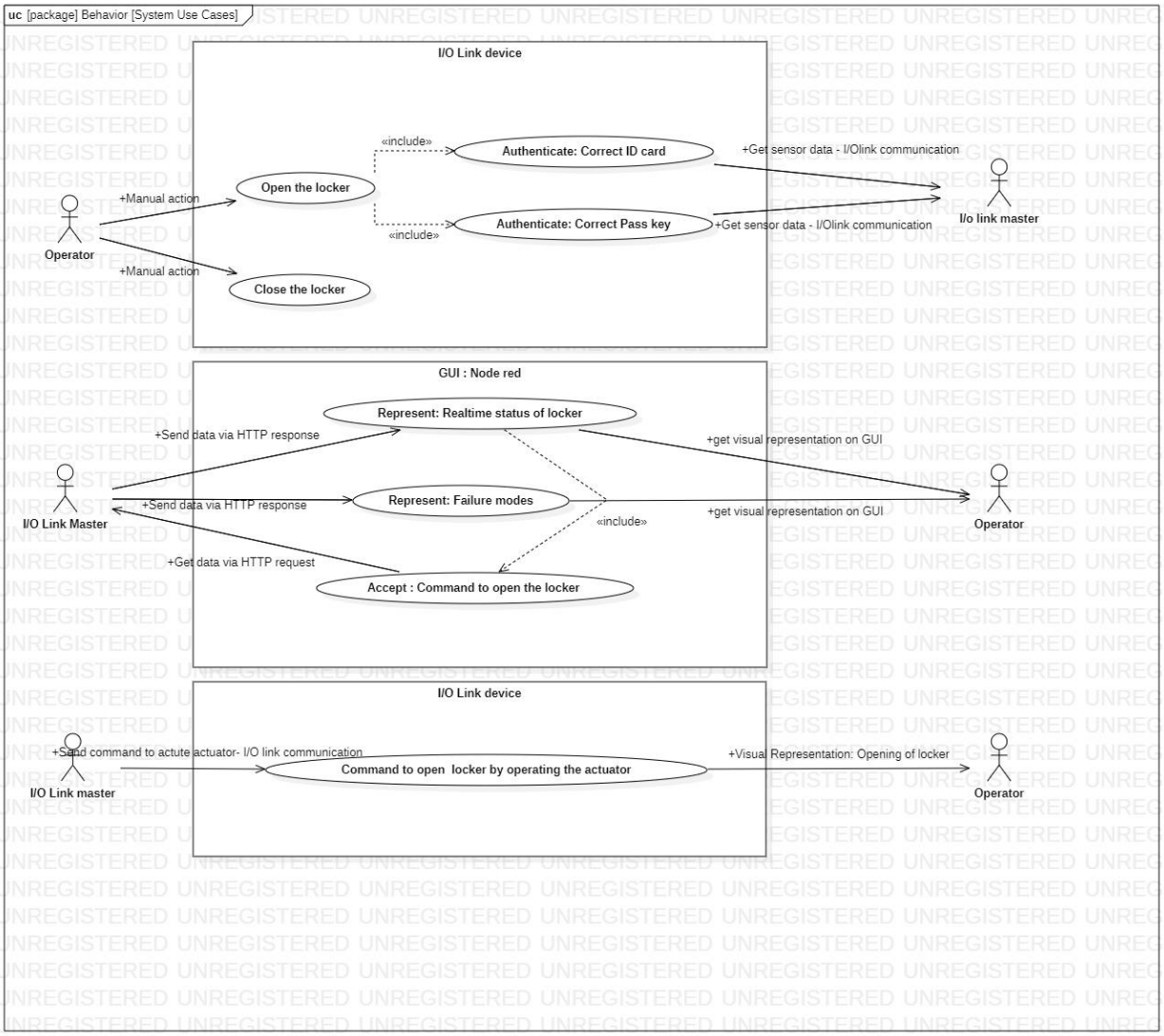

Figure 1: Use case diagram – Elaborates the different use case scenarios and the possible operating states of the system

3.2.2 Block diagram of the System

A parametric block diagram was prepared to understand the basic structure of complete system and the subsystem of the product. A relation was established to understand the constraints of different block elements and corresponding parameters. Following diagram illustrates the parametric block diagram of the product:

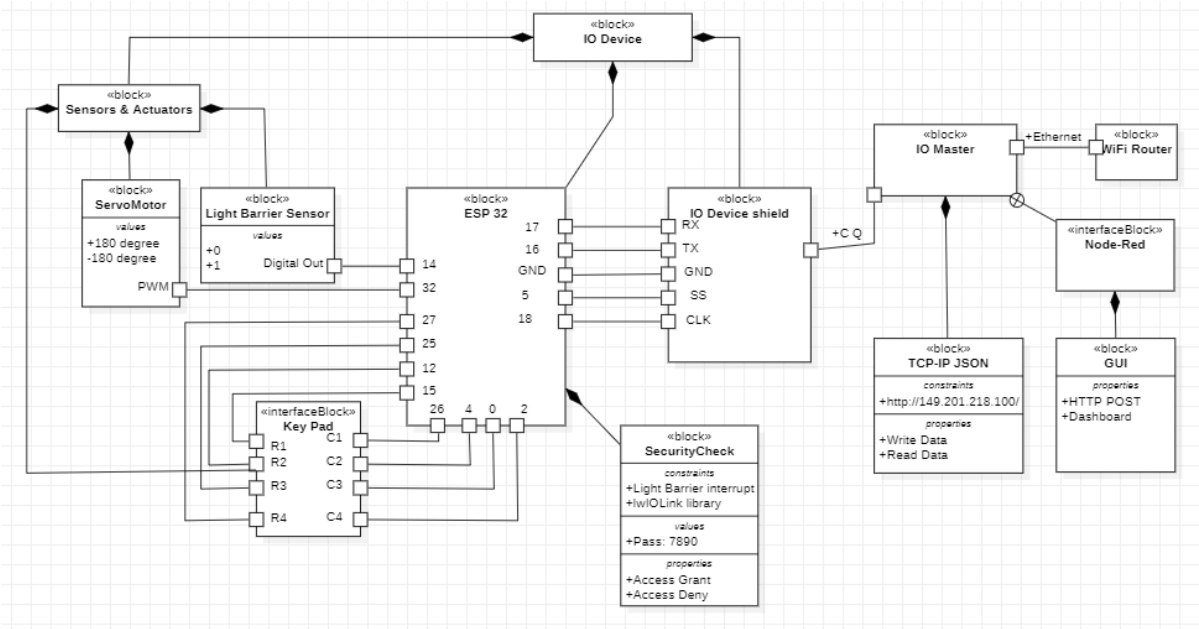

Figure 2: SysML: Block diagram – elaborates the structure of the system

3.2.3 Sequence diagram for communication

A sequence diagram was prepared to understand the basic structure of complete system and to elaborate the communication sequence between different structural components of the system in different mode of operation. Following diagram illustrates the sequence diagram of the product:

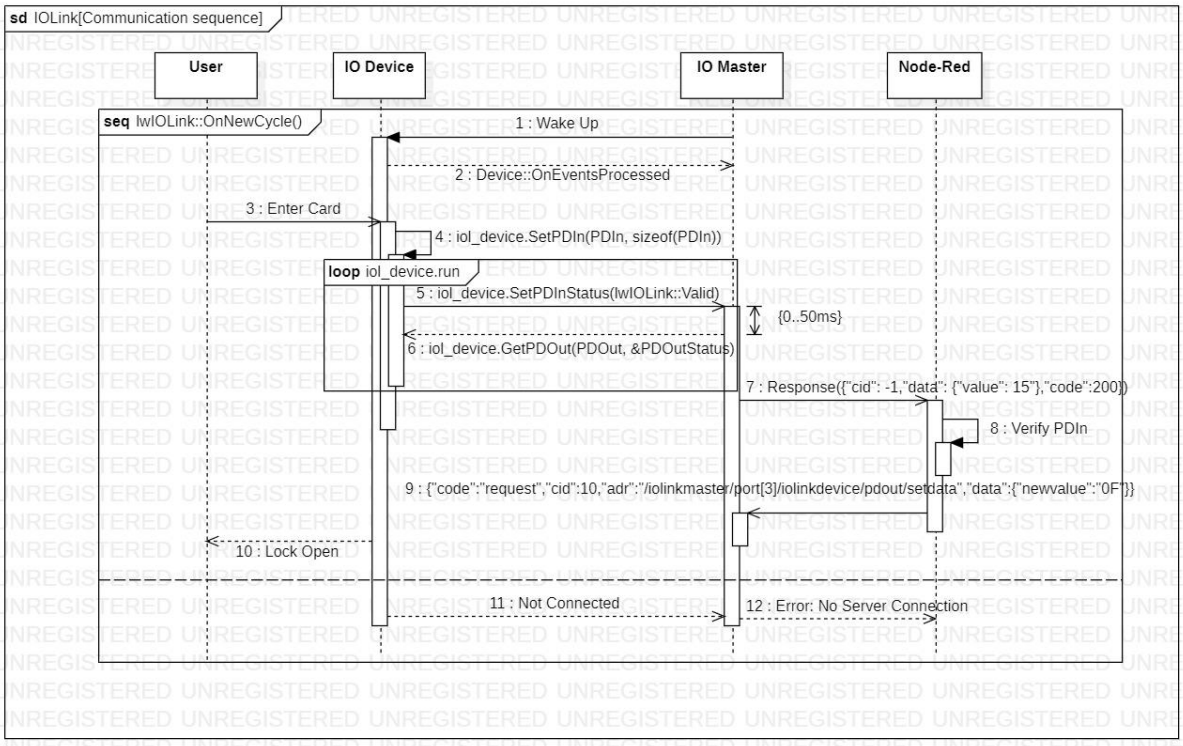

Figure 3: Sequence diagram – elaborates the communication sequence between the subsystems

3.2.4 State diagram for program flows

A state machine diagram was prepared to identify and analyse the different states of the machine. Following figure illustrates the state machine diagram prepared for this project

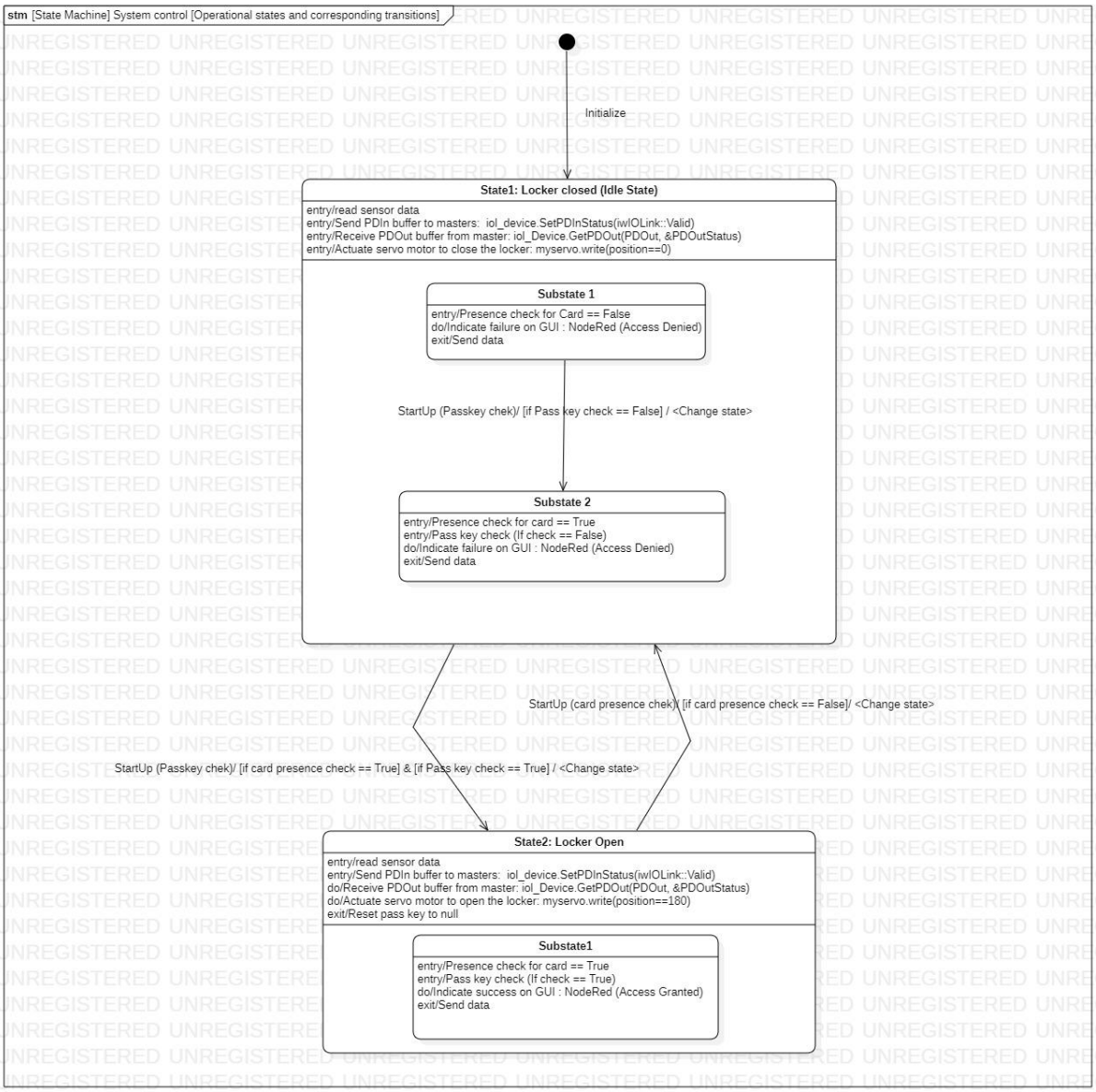

Figure 4: State machine diagram – elaborates the communication sequence between the subsystems

3.2.5 Communication protocols

The scope of this project consists of two communication protocols I/O Link communication protocol and SPI to establish the successful communication between the microcontroller (ESP32), I/O Link shield and I/O link master.

- **SPI communication protocol: (Serial peripheral Interface)**

  This protocol is being used for the communication between the I/O link shield to microcontroller ESP-32. Devices communicating via SPI are in a master-slave relationship. The master is the controlling device (usually a microcontroller), while the slave (usually a sensor, display, or memory chip) takes instruction from the master.

- **I/O link communication protocol:**

  It is a point to point communication protocol used to communicate the cyclic data between I/O link master and I/O link device with cycle time of 50milliseconds. In the scope of this project sensor data is communicated to I/O link master from I/O link device and vice versa

4 Nonfunctional Requirements

4.1 Look and Feel

4.1.1 Style & Appearance Requirement:

- The prototype developed would be made out of recycled cardboard box

4.1.2 Usability & Humanity Requirements:

- The product can be used by any person with a security card.
- The product can be accessed by people who know the password.

4.2 Performance

- **Speed and latency:** The operation cycle time of the product is of 50 milliseconds. The response time depends on the time taken by the user to enter the password
- **Precision and Accuracy:** The product works with maximum accuracy when an authorized user interacts with the system
- **Availability:** The product will be operational 24x7 as long as power supply is maintained
- **Robustness**: In case of unauthorized access to the product locks up
- **Capacity:** Maximum of 16 input characters can be used for password combinations

4.3 Operational and Environmental

- **Physical Environment:** The product shall be installed at the doors of a room or integrated with a steel box
- **Interfacing requirements:** The product can communicate to IO master and other systems via IO Link communication. The data transferred indicates the status of the lock. The data carrier is a 3-conductor connection which transfers data every 50ms

4.4 Maintainability and Support

- **Maintenance requirements:** The product is easily maintainable as the code is open-source. No special maintenance is required for its functioning.
- **Supportability requirements:** Support can be provided by the development team, at request.

4.5 Legal

Personal Information shall be implemented so as to comply with the Data Protection Act

5 Project Issues

5.1 Open Issues

- The card used to interrupt the Sensor is not unique, can be distinctive using RFID
- The system packaging is not defined, but can be implemented in a locker system

5.2 Off-the-Shelf solutions

5.2.1 Ready-made Products:

- Godrej Goldilocks are Ready-made product that can be bought out of the market to provide similar solution as our product

5.2.2 Reusable components:

Libraries Used	Hardware Used
Arduino library	IO Master
Stdint Library	IO Device Shield
lwIOLink Header Library	ESP-32
Keypad Library	KY-010 light barrier module
ESP32Servo Library	Micro-Servo SG90 Motor
	Arduino Keypad

5.3 Risks

- The Light Barrier sensor can be inaccurately interrupted by objects that have small diameter and give inaccurate results
- In order to enter pass code, the Light barrier needs to continuously interrupted
- Due to absence of unique card, unauthorized users could access the Keypad

5.4 User Documentation and Training

5.4.1 User documentation:

Document name	Purpose	People seeing this	Maintenance
Use case diagram	To show different modes and cases demanded by the customer.	user, stakeholders	product maintenance team or product managing team
Parametric diagram	Different values, properties of the parameters in the product and its association with other devices	user, stakeholders	product maintenance team or product managing team
Sequential diagram	to show the sequence of different operations, associations and time taken for the action to complete	user, stake-holders	product maintenance team or product managing team
State machine diagram	to show different stages/features of product which will be triggered with respect to the customer demands and requirements	user, stake-holders	product maintenance team or product managing team

5.4.2 User training:

- Training can be provided, by developers to potential testing engineers and other users
- Training period is of 10 min. and can be easily explained to any user

6 References

• For Sys ML diagrams and documentation:
  - SysML Distilled_ A Brief Guide - Lenny Delligatti.pdf
  - volere-template.pdf
  - 2022 Project Requirements Documentation.pdf
  - NASA Systems Engineering Handbook

• For I/O Link communication protocol:
  - https://io-link.com/share/Downloads/At-a-glance/IO-Link_System_Description_eng_2018.pdf
  - https://io-link.com/de/Download/Download.php

• Technical specification for I/o link master
  -https://www.ifm.com/mounting/80284128UK.pdf