An-Najah National University

Faculty of Engineering and Information Technology Computer Engineering Department

Graduation project II

Smart Secure Student Depot : Intelligent Package Storage and Retrieval

Done by:

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Presented in partial fulfillment of the requirements for a Bachelor's degree in Computer Engineering.

Acknowledgment

In the name of Allah, the Most Gracious, the Most Merciful.

We begin by offering our gratitude to Allah for His continuous guidance and blessings, which illuminated our path as we completed our graduation project. His unwavering support was the foundation upon which we achieved this significant milestone in our academic journey.

We extend our sincere appreciation to our esteemed supervisor, Dr. Abdallah Rashed, whose unwavering encouragement and support played a pivotal role in shaping the success of our project. His expert guidance and mentorship empowered us to navigate challenges and achieve our goals.

Our heartfelt thanks go to the distinguished faculty members, Drs., and Laboratory supervisors from the Computer Engineering department, as well as other Engineering departments in addition to the university carpentry. Their invaluable insights, feedback, and assistance were integral to overcoming obstacles and bringing our project to fruition.

We reserve a special place of gratitude for our families and friends, whose constant motivation, unwavering support, and understanding fueled our determination throughout this journey.

Disclaimer Statement

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Project abstract

in light of the frequent incidents involving defacement, loss, or theft of books and belongings exchanged among students using conventional lockers. In this project we propose the development of an advanced student locker system. This intelligent and secure system aims to facilitate the safe and efficient exchange of items, obviating the necessity for students to spend time searching for their belongings within the locker room.

Key aspects that will covered in this project include the development of a student secretariat storage machine operating in storage and retrieval modes using. Sensors are employed for monitoring system status and ensure the security of the system.

The system employs a robot equipped with RFID reader to allow authorized students to access the safe deposit box using a unique PIN or RFID card. When a student places their box on the robot arm, it automatically assigns the box to appropriate storage cell within the locker. Additionally, the robot has the capability to deliver the box to the student upon request. To facilitate the automated dispensing process, a website or application will integrated into the system.

While similar applications may exist, our project aims to enhance convenience for students, reduce security risks associated with package storage, and facilitate the exchange of books, slides, and other items through a student-friendly locker system.

Chapter 1:
1 Introduction

1.1 Statement of the problem:

Using regular lockers for student storage comes with several disadvantages. These traditional lockers often rely on physical locks and keys, making them susceptible to security breaches when keys are lost, stolen, or duplicated. This compromises

the safety of students' belongings. Additionally, the need to carry and keep track of a physical key can lead to inconvenience, and forgetting or misplacing the key might result in difficulty accessing stored items. Schools also face the challenge of managing a large number of keys, which can be time-consuming and costly in terms of key replacement and maintenance. Moreover, these lockers may suffer from wear and tear over time, requiring repairs that disrupt normal usage and require additional resources. Lastly, the fixed-size nature of regular lockers might limit their ability to accommodate items of various shapes and sizes effectively, leading to inefficient utilization of storage space.

1.2 Objectives

The Smart Secure Student Depot project introduces a smart package storage and retrieval system. This innovative solution aims to enhance the process of storing and retrieving student parcels. By incorporating smart technology, the project seeks to simplify parcel handling, making it more efficient and safer. It consists of several parts, the most important of which is the fork that will pick up the items from the gate and is moved by stepper motors supported by rods to facilitate moving the fork on three axes and placing the parcel inside the box, and the other part is the presence of an IR sensor inside the box to ensure that it is free from any parcel. This approach optimizes space utilization and facilitates precise movement. System security features include student card and password access, which reduces reliance on traditional keys and locks. Administrators can remotely manage access to the safe, ensuring controlled and convenient use. This innovative project is compatible with technological advances, which enhances the security and efficiency in storing and retrieving packages within educational institutions.

1.3 Scope of work

The scope of this project includes the design, development and implementation of a smart locker that can store and return student items. The locker will have two modes - storage and retrieval - and it will include a screen for selecting the stored category, whether it is from the student himself or from people related to the student, and choosing the type of operation required to be stored or returned. The cabinet will also include sensors such as infrared to monitor the contents of the shelves and check if they are full or empty. Finally, an administrator application will be developed to allow the administrator to monitor the machine and receive notifications if any faults occur. It will include testing and maintenance to ensure that the machine is operating reliably and efficiently.

1.4 Significance of the work:

The "Smart Secure Student Depot: Intelligent Package Storage and Retrieval" project is highly significant as it modernizes and improves package management, particularly for students. By implementing automation and advanced security measures, the project enhances the efficiency and safety of storing and retrieving packages. The inclusion of a smart fork with stepper motors streamlines the process, saving time and effort. Student card and password access enhance security compared to traditional locks, while remote

administrative control offers convenience and swift adjustments .Dynamic allocation further maximizes storage efficiency.

1.5 Organization of the report:

In this report, we illustrate the idea in its full details. Going through the report you can first see the constraints we faced during our work including equipment, tools we used and earlier course work. Then, you can read about similar systems to get a background about the topic being discussed and what special features we have done upon other systems. After that, the methodology of our work is extensively explained. Next chapter states our results and a discussion to interpret and compare the results. Ending it up with the conclusion of the whole work and what is our vision for the future to improve our work.

Chapter 2:

Constraints, Standards/ Codes and Earlier course work

2.1 Constraints:

The biggest difficulty in the project was dealing with the mechanical part because as computer students we did not install mechanical parts with this complexity, in addition to not being available in the shops, and where we needed a design that could bear the weight on it and at the same time be able to move on its rails freely on the three axes Without the disadvantage of weight and because of the high rail prices we had to change the design to a wooden one to suit the movement.

While developing our project and designing the cabinet to fit the mechanical part, we encountered several limitations that posed challenges to our work. One of the main drawbacks was the limited time frame during the summer semester. It was building a machine with many electronic components, understanding and using those components, creating connections, learning to program the Arduino to control the hardware, and integrating everything into the system a great challenge amidst our other academic commitments.

2.2 Standards/Codes

To implement our project, we incorporated several external libraries that proved essential for various functionalities. These libraries greatly facilitated the integration of specific features into our system. The following is the inclusion of these libraries in a consistent pattern:

```
#include <Keypad.h>

#include <Wire.h>

#include <LiquidCrystal_I2C.h>

#include <SPI.h>

#include <MFRC522.h>
```

The Keypad library enabled us to effectively use matrix-style keypads with the Arduino, allowing for seamless interaction and input from users. The LiquidCrystal_I2C library provided a reimplementation of the standard Arduino LCD library, enabling us to control

I2C displays using functions closely resembling those found in the LiquidCrystal library. This facilitated the integration of LCD display functionality into our system.

Furthermore, we utilized the MFRC522 library to enable our system to read and write various types of Radio-Frequency Identification (RFID) cards. This library facilitated communication with an RC522-based RFID reader through the Serial Peripheral Interface (SPI) interface, enhancing the capability of our project to interact with RFID technology effectively.

The Wire.h library is crucial for I2C communication, allowing devices to communicate with each other using the I2C protocol. In our project, this library likely facilitates communication between our Arduino and devices connected via I2C, such as the LiquidCrystal_I2C display.

The inclusion of these libraries was essential to the successful implementation of our project, as they streamlined the integration of specific functionalities and contributed to the overall functionality and efficiency of our system.

2.3 Earlier course work:

In the process of developing our project, we leveraged the knowledge gained from various courses within our Computer Engineering program. Notably, the "Microcontroller" course provided us with a fundamental grasp of PIC Microcontrollers and how to program hardware components. This knowledge was instrumental in navigating the complexities of the Arduino Mega components in our project. Similarly, our "Electronic Circuits" course equipped us with essential skills for working with electrical circuits and establishing vital connections. This foundation in circuitry, gained from diverse circuit applications and wiring techniques, greatly influenced the electronic design and implementation of our project . Our educational journey in Computer Engineering encompassed a range of courses such as digital design, microprocessors, electrical circuits, electronic circuits, and microcontrollers. These courses collectively formed the bedrock upon which our project was constructed. Complementing our formal education, we engaged in supplementary online courses that honed our proficiency in Arduino utilization and code composition. This holistic educational background empowered us to successfully conceive, develop, and execute our system.

Chapter 3:

Literature review

Traditional lockers have long been a staple in educational settings, providing students with a simple storage solution through physical keys or combinations. Although cost effective and familiar, these safes have drawbacks such as security holes, the inconvenience of lost keys, and maintenance issues that can arise from worn out locks.

In response, the advent of smart safes, also known as electronic or electrical safes, has revolutionized safety systems. These advanced solutions provide a range of benefits. Most notably, it enhances security through personal access methods such as RFID cards. This enhanced security reduces unauthorized access and theft, promoting a more secure environment for student property.

Moreover, smart wardrobes prioritize convenience. And by using access mechanisms such as RFID cards, they eliminate the need for physical keys, making the locker easy for students to use. Administrative tasks are also simplified with remote management capabilities. Administrators can supervise access to the vault, monitor usage, and receive alerts in real time, boosting efficiency.

The choice between traditional and smart safes is influenced by factors such as budget, security concerns, and technology integration. Although cost effective and familiar, traditional safes lack modern features. In contrast, smart lockers provide safe, convenient and smart technological solutions. Educational institutions around the world are increasingly adopting these innovative systems, in line with the trend towards more secure, efficient and easy-to-use storage solutions.

Therefore, the idea of our project was a way to facilitate the process of storing students' belongings by providing a place in the school or university where their belongings are delivered and then stored automatically.

The greatest importance in our project lies in providing a safe environment to preserve students' properties and facilitate their remote management.

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Chapter 4:

Methodology

The essence of our concept becomes clear when reviewing the previous discussion, highlighting the fundamental advantages that this project holds over traditional approaches.

In this endeavor, we have seamlessly combined software and hardware to control a sophisticated device. This device works in two main modes:

- Storage of student property
- Return of student property

Let's dig deeper into the integrated components used in our innovative project.

4.1 Hardware:

The following list contains the hardware components that have been used in our project:

❖ *Arduino Mega 2560:*

The pivotal cornerstone of our project's hardware configuration is the Arduino Mega 2560 microcontroller board. This powerful microcontroller serves as the brain behind the smart locker system. It embodies an extensive array of input/output pins, facilitating the seamless communication between the software and hardware aspects of our project. Its robust processing capabilities empower efficient execution of commands, ensuring swift and accurate responses during both packet placement and retrieval phases.

The Arduino Mega 2560 is a microcontroller board built around the ATmega2560 chip. It offers an extensive range of features, including 54 digital input/output pins (with 15 capable of PWM output), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. This board provides all the necessary components to support the microcontroller's functions. To begin, one can connect it to a computer using a USB cable or power it using an AC-to-DC adapter or battery. The Mega 2560 is compatible with numerous shields designed for previous Arduino boards such as the Uno, Duemilanove, and Diecimila. Serving as an advancement over its predecessor, the Mega 2560 is an updated iteration of the Arduino Mega. (Arduino, Arduino - Introduction, 2023)

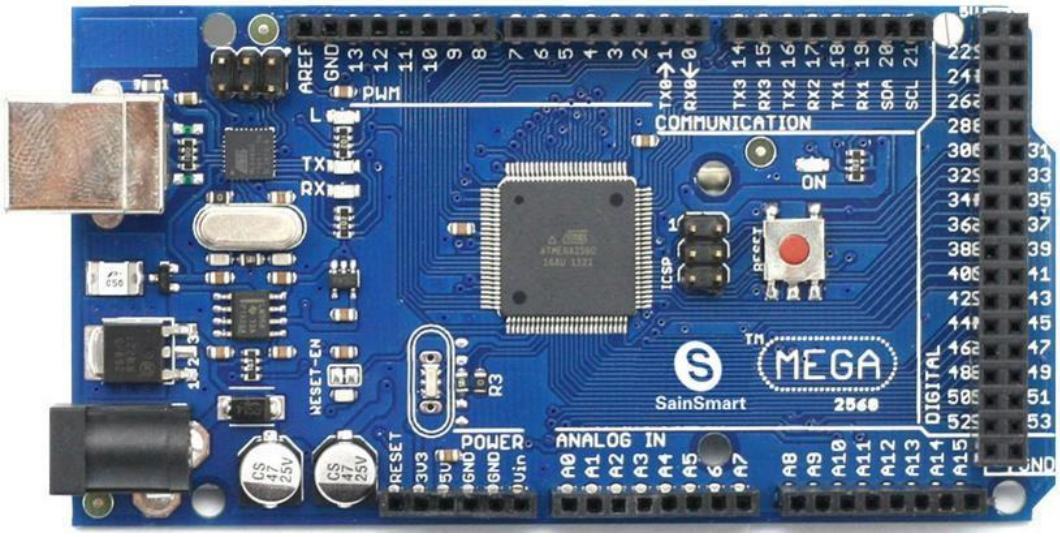


Figure 1: ***(Arduino mega)***

❖ *Infrared Sensor (IR sensor):*

The Infrared (IR) sensor is a pivotal electronic component designed to sense and measure infrared radiation within its immediate surroundings. It operates within a specific spectral sensitivity range in the infrared wavelength spectrum, spanning from 780 nanometers to 50 micrometers.

- 780 nm ... 50 µm

In our project, we have deliberately selected this sensor to discern whether the students' storage compartments are vacant or occupied by their belongings. To achieve this, we have incorporated a total of five IR sensors—one for each storage box. These sensors are meticulously connected to designated pins on the Arduino Mega, namely pins 36, 38,

40, 42, and 44.

To provide a visual representation of this configuration, the following circuit diagram serves as an illustrative example, showcasing the interconnection of the IR sensors with the Arduino Mega microcontroller:

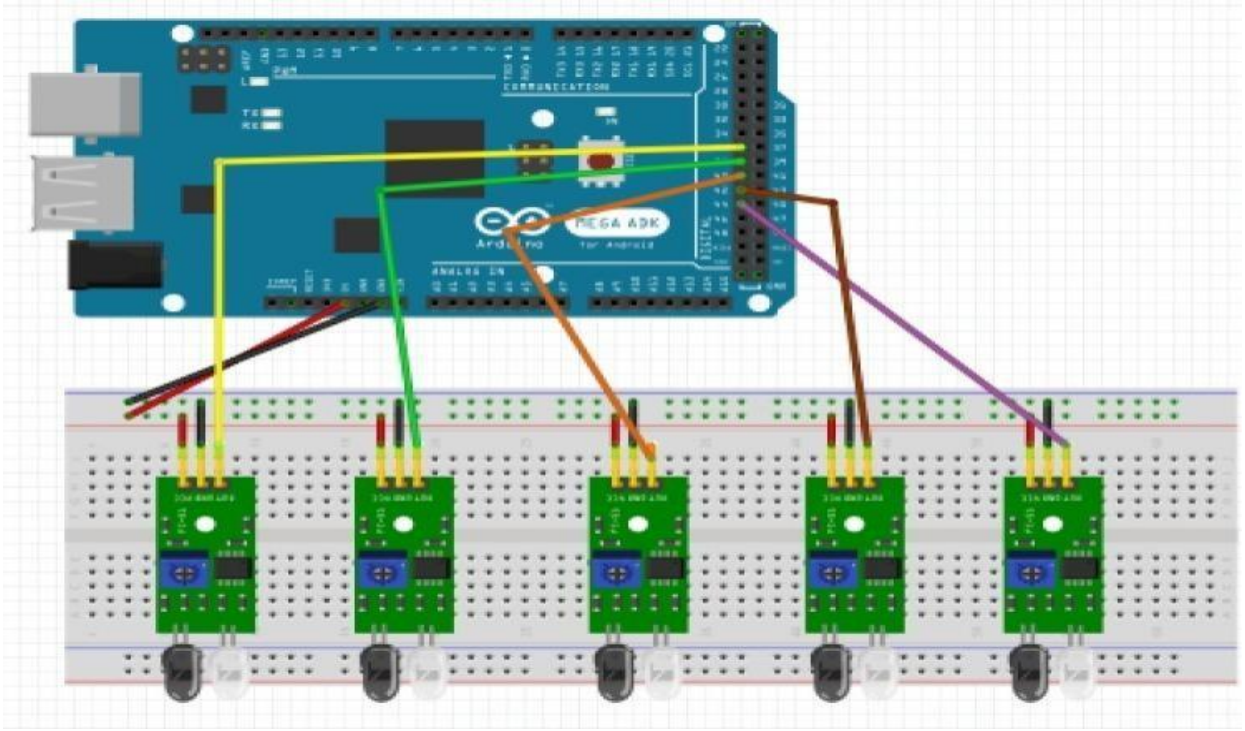


Figure 2: ***(IR-sensor Interfacing with Arduino)***

❖ *Stepper motors:*

A stepper motor is an electromechanical apparatus that converts electrical energy into mechanical motion. These motors function by moving in discrete steps, hence the name "stepper." The mechanism behind their operation involves a toothed wheel and electromagnets.

1. Here's how our stepper motors operate:

Stepper motors utilize a toothed wheel (cogged wheel) along with a set of electromagnets.

When a HIGH electrical pulse is sent to the motor, it energizes a specific coil, attracting the teeth on the cogged wheel nearest to it.

This attraction causes the motor to move forward by a single step, resulting in controlled and precise motion.

2. Several factors influence the motor's behavior:
- Pulse Sequence: The order in which pulses are sent determines the rotational direction of the motor.
- Pulse Frequency: The rate at which pulses are sent dictates the motor's speed.
- Number of Pulses: The total count of pulses defines the extent of the motor's rotation.

3. Rationale for Choosing Stepper Motors in Our Project:

We have opted for stepper motors in our project due to their ability to provide meticulous speed control, precise positioning, and dependable movement repeatability – all of which align with the requirements of our project.

4. Within our setup, we have incorporated four stepper motors:
- One motor for the x-axis movement.
- One motor for the y-axis movement.
- Two motors for the z-axis movement.

(The decision to employ two motors for the z-axis arises from the need to support the weight of the structure effectively, ensuring smoother movement).

This comprehensive utilization of stepper motors empowers our project to achieve the desired levels of accuracy, control, and seamless motion across various axes.

Figure 3: (stepper motor)

❖ *A4988 driver:*

The A4988 stepper motor driver stands as a dedicated, self-contained solution chosen to efficiently control multiple stepper motors in our project. Its adoption stems from the need to streamline control and avoid overburdening a single Arduino Mega with extensive processing demands, making it the ideal fit for our endeavor.

Notably, the A4988 driver facilitates both speed regulation and directional control of bipolar stepper motors, leveraging just two pins. With the inclusion of MS1, MS2, and MS3 pins, we can select from various microstepping modes, with our choice being the Full Step mode for optimal performance.

5. Microstepping Options:
   - Full Step (Selected): MS1: Low, MS2: Low, MS3: Low
   - Half Step: MS1: High, MS2: Low, MS3: Low
   - Quarter Step: MS1: Low, MS2: High, MS3: Low
   - Eighth Step: MS1: High, MS2: High, MS3: Low
   - Sixteenth Step: MS1: High, MS2: High, MS3: High
   -
6. The crux of this driver's functionality lies in its "STEP" and "DIR" inputs:

- "STEP" input orchestrates microsteps. Each HIGH pulse advances the motor by a number of microsteps defined by microstep pins. The frequency of these pulses dictates motor speed.

- "DIR" input governs rotation direction. Setting it HIGH induces clockwise rotation, while a LOW signal initiates counterclockwise motion.

Connection of stepper motors to the A4988 driver and subsequently to the Arduino involves a structured setup. By harnessing the power of multiple A4988 drivers, our project gains precision and synchronized control over multiple stepper motors across various axes. (HowToMechatronics, n.d.)

Figure 4*: (A4988 driver)*

We connect stepper with driver and Arduino like this:

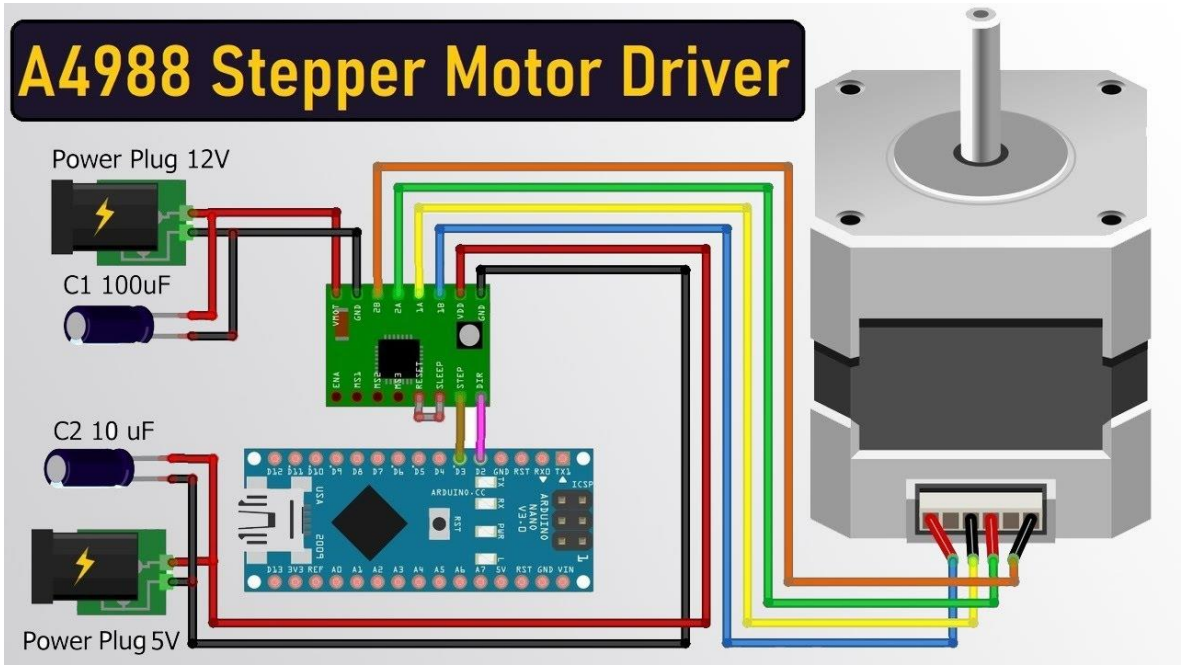


Figure 5*: (stepper motor with driver)*

❖ *LCD Display (20x4) with I2C Interface:*

To visually present information, we've incorporated a 20x4 LCD display into our project. Notably, we've opted for the I2C version of the display due to its streamlined connectivity, requiring only four wires to link to the Arduino. This I2C-enabled version offers simplicity and ease of integration, making it particularly appealing for Arduino-based projects.
The I2C interface allows efficient communication between the LCD display and the Arduino, minimizing the complexity of connections. Here's an overview of how the 20x4 LCD display is interfaced with the Arduino using the I2C protocol:

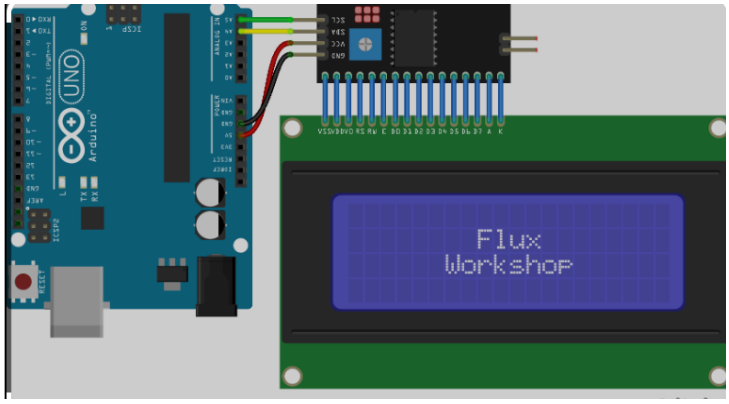


Figure 6: ***(LCD Display (20x4) with I2C Interface and Arduino)***

4x4 Matrix Keypad:

The 4x4 matrix keypad is a valuable input component frequently utilized for acquiring user input in various projects. Comprising a total of 16 keys, this keypad effectively provides 16 distinct input values. Its configuration entails the use of 8 GPIO (General Purpose Input/Output) pins on a microcontroller to enable its functionality.

By employing this keypad, our project gains the capability to gather user inputs in a straightforward manner, enhancing its interactivity and usability. This versatile input device contributes to a seamless user experience by facilitating the entry of specific values or commands.

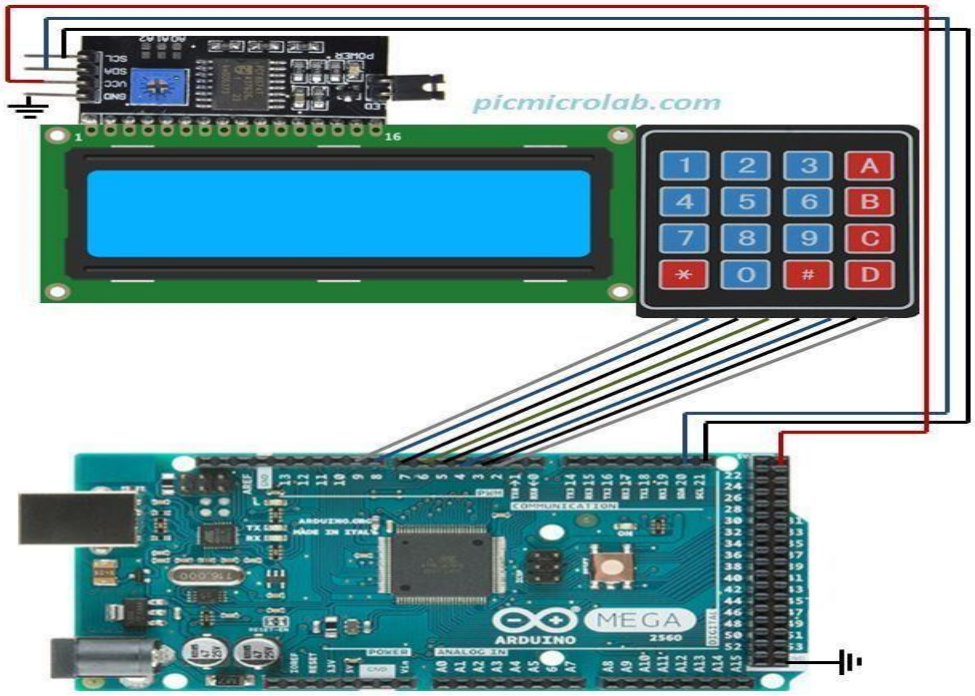


Figure 7:*(LCD a n d k e y p a d with Arduino mega)*

❖ *RFID (Radio Frequency Identification):*

RFID is a technology that uses electromagnetic fields to exchange data over a short distance. This technology is valuable in identifying individuals, facilitating transactions, and many other applications. In the context of our project, we use RFID technology to enable students to verify their identity, and to ensure safe and accurate access to their assigned spaces.

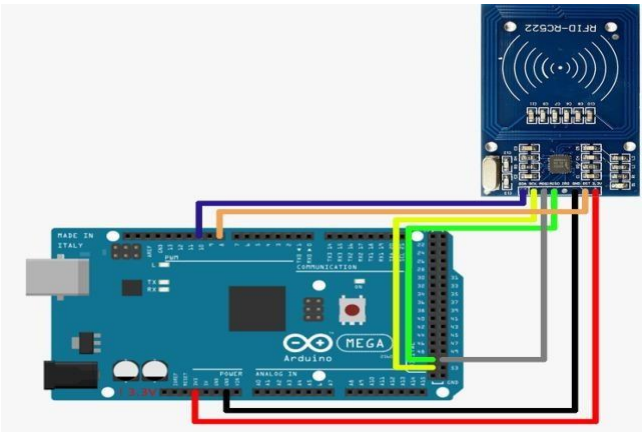


Figure 8: *(Arduino mega with RFID)*

❖ *Limit switches:*

Limit switches are essential components in machines like CNC systems and 3D printers. They detect when an axis reaches its physical limits (minimum or maximum) during movement. When a limit switch is triggered, it sends a signal to the control system to stop the machine's motion along that axis, preventing overtravel and potential damage. These switches are also used to define the machine's home position, ensuring accurate and consistent operation. Overall, limit switches contribute to safety, accuracy, and the proper functioning of the machine.

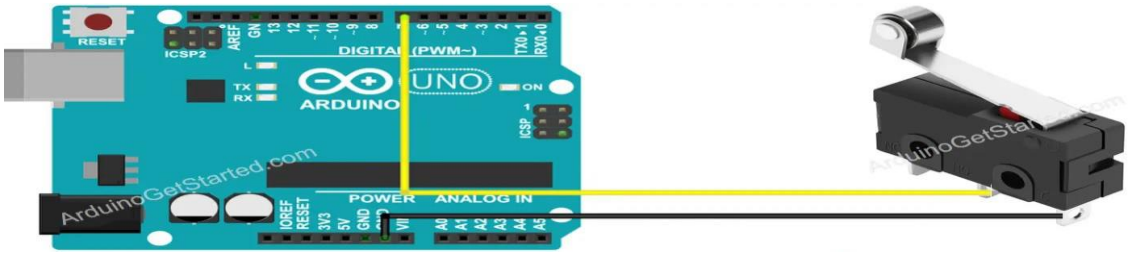


Figure 9: *(limit switch)*

❖ *Esp 32:*

We use this controller in our project for one task, which is send message to user when its parcel is received. (Arduino, Serial Communication Between an ESP8266 and Arduino Mega2560, n.d.)

Figure 10*:(ESP32)*

❖ *Coin Acceptor:*

In our automated storage and return system, we've integrated a coin acceptor to enhance user-friendliness and flexibility. This allows non-student users to participate in the process of storing or returning items belonging to students. When a non-student user engages with the system, they insert a coin into the coin acceptor for validation. Upon successful validation, they input their student number and mobile number. The system verifies this information against its database for authenticity. If validated, the motor control activates to manage item movement. Throughout the process, clear instructions and updates are displayed on the user interface. This integration of the coin acceptor and user data creates an adaptable, user-friendly system for a wider range of users. (Miliohm, n.d.)

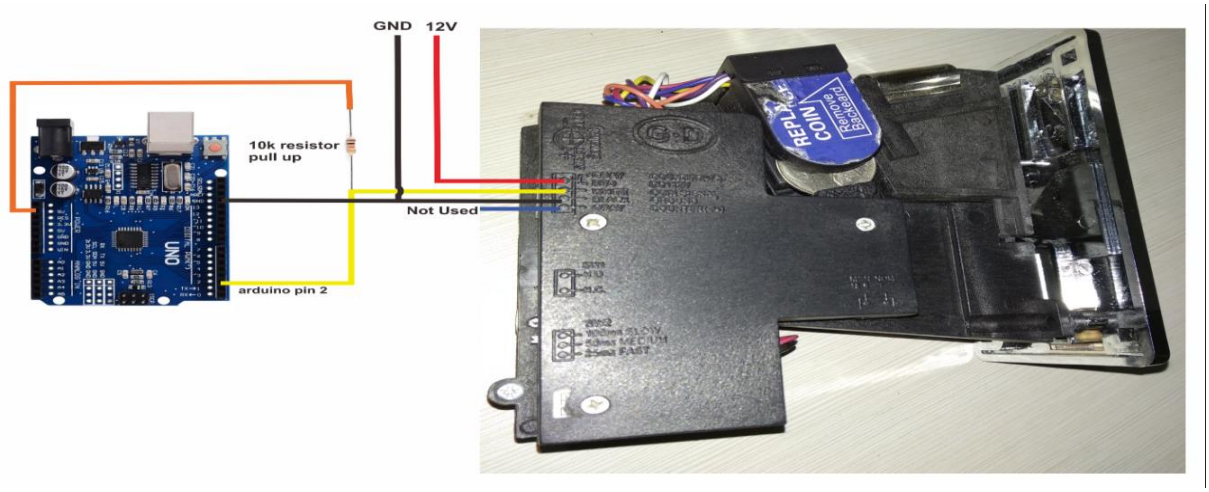


Figure 11: *(Coin Acceptor with Arduino)*

❖ *Servo Motor:*

A servo motor is utilized in our system to automate the opening and closing of a cabinet door. The motor keeps the door open when the cabinet is available for use, closes it during storage or return processes, and automatically reopens the door when the operation is completed and the relevant components are in position. This integration optimizes user interactions, ensuring ease of access and security for the cabinet's contents. (EngineersGarage, n.d.)

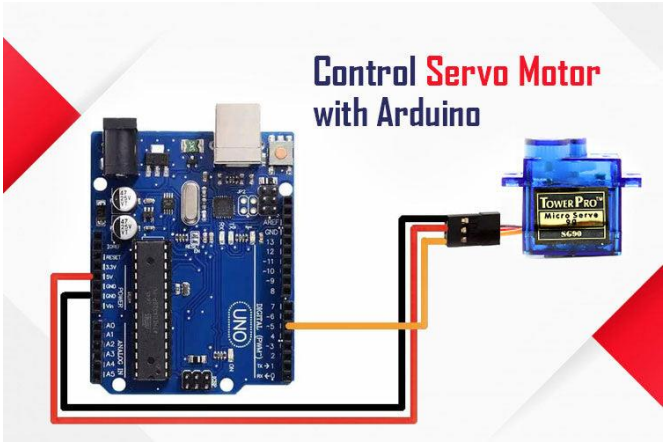


Figure 12: *(Servo motor with Arduino)*

❖ *copper core cables(8 Core):*

The copper core cables(8 Core) we used in our project was very useful to use because we needed longer cables to suit with our machine and also to ensure optimal performance and reliability.

Figure 13: ***(Copper core Cable (8 CORE))***

❖ ***Arduino wires :***

We used three types of Arduino wires which are:

male to male.
male to female.
female to female.

Figure 14:(***1. Male to Male*****)**

Figure 15: ***(2. female to female)***

Figure 16: (3. female to Male)

4.2 Mechanical Parts:

Material selection:

- STRUCTURER

-Aluminum

Advantages: This lightweight and stiff material offers excellent compatibility with mechanisms like rollers due to its built-in rails.

Disadvantages: However, its higher cost of approximately $35 per meter and challenges in forming the structure led us to explore other alternatives.

-Wood

Advantages: Cost effective and readily available, wood's formability allows for direct shaping during construction.

Disadvantages: It requires additional mechanisms such as smooth rails or linear rails to ensure smooth movement.

- AXES MECHANISM

- linear rail

Advantages: Provides very smooth movement, no bends, and easy attachment to the frame.

Disadvantages: Considered expensive (400nis per meter) , add additional weight to thestructure, so we use smooth rod.

-Smooth rod

Advantages: Relatively cheaper option with reasonably smooth movement.

Disadvantages: Not perfectly straight (may have some bends), can be somewhat challenging to attach to the frame.

- AXIS PART

-Aluminum:

Advantages: Lightweight and stiff, providing stability.

Disadvantages: Difficult to shape without CNC machining, adds weight compared to plastic.

-plastic

Advantages: Easy to 3D print, cost-effective, and can be strong enough for some applications.

Disadvantages: Requires precise settings during printing, might not be as sturdy as aluminum.

In **Z-Axis** we use smooth rod to support screw rod:

Figure 17: (smooth rod)

And we use screw rod ,the motors use it to move easily.

***Figure 18** :(screw rod)*

In **Y-Axis** we use GT2 Belt.

Figure 19: *(GT2 belt)*

In **X-Axis** we use spur gear , slider and fork.

Figure 20 *:(spur gear)*

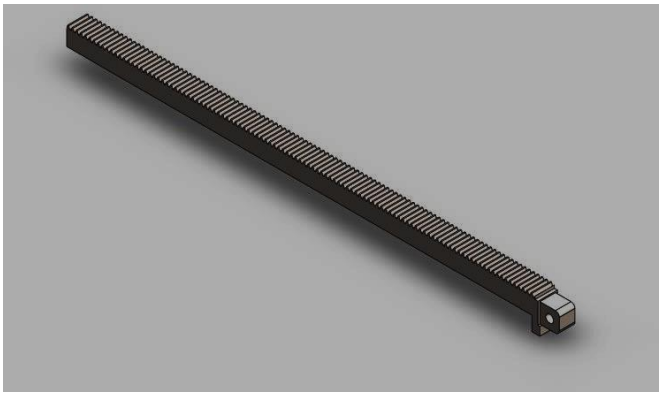


Figure 21 : *(slider)*

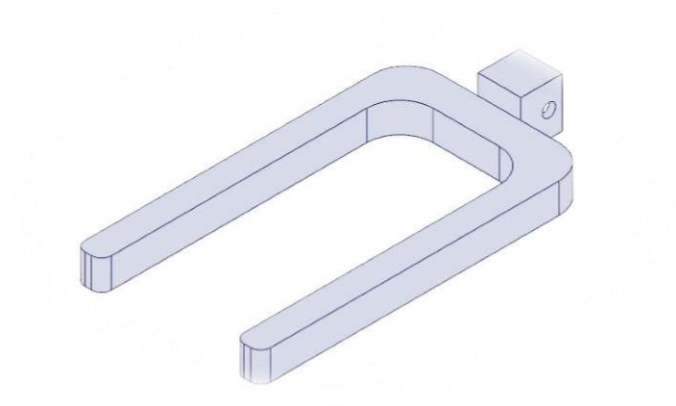


***Figure 22** :(Fork)*

STRUCTURE:

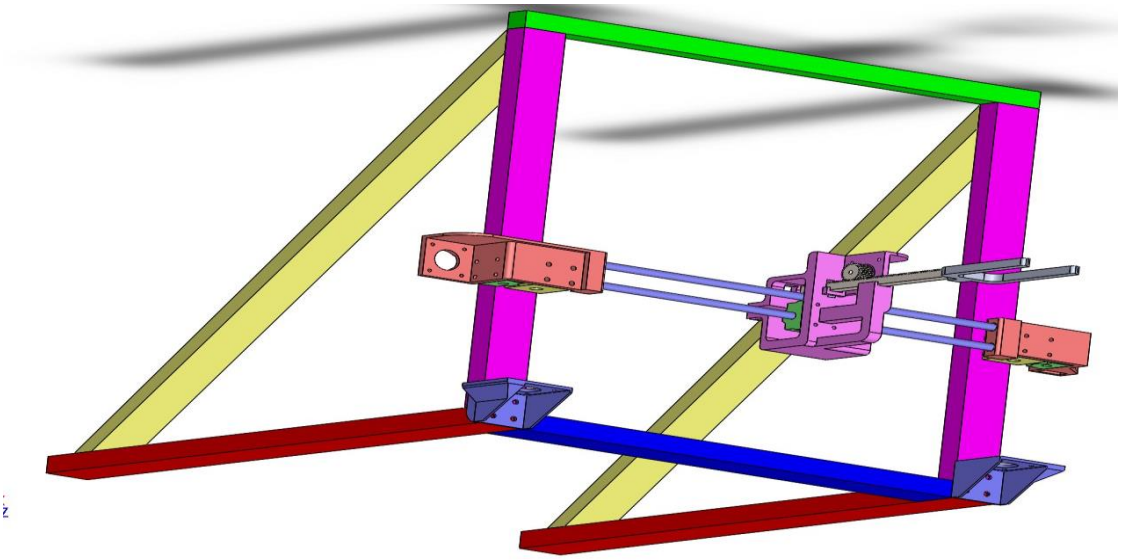


Figure 23 *:(structure for the project)*

4.3 Programs:

- We used **Arduino IDEs** for programming the microcontrollers and all used hardware.
- **Fritzing** to design the circuits.

Figure 24: (Arduino IDEs)

Figure 25 :(Fritzing)

4.4 Block Diagram:

The figure below shows the outline with an overview of the project parts. In our project we use Arduino Mega 12V supply for motors. First, the user must choose whether he is a student or a non-student.

• If it is a student, he must verify his identity using the RFID card, then enter the pass number, then choose either storage or Retrieve, then the CNC starts working and moves to the correct place.

• If he is not a student, he must enter a coin into the accepted currencies, then enter the recipient student number, then choose Store, and then the machine will work.

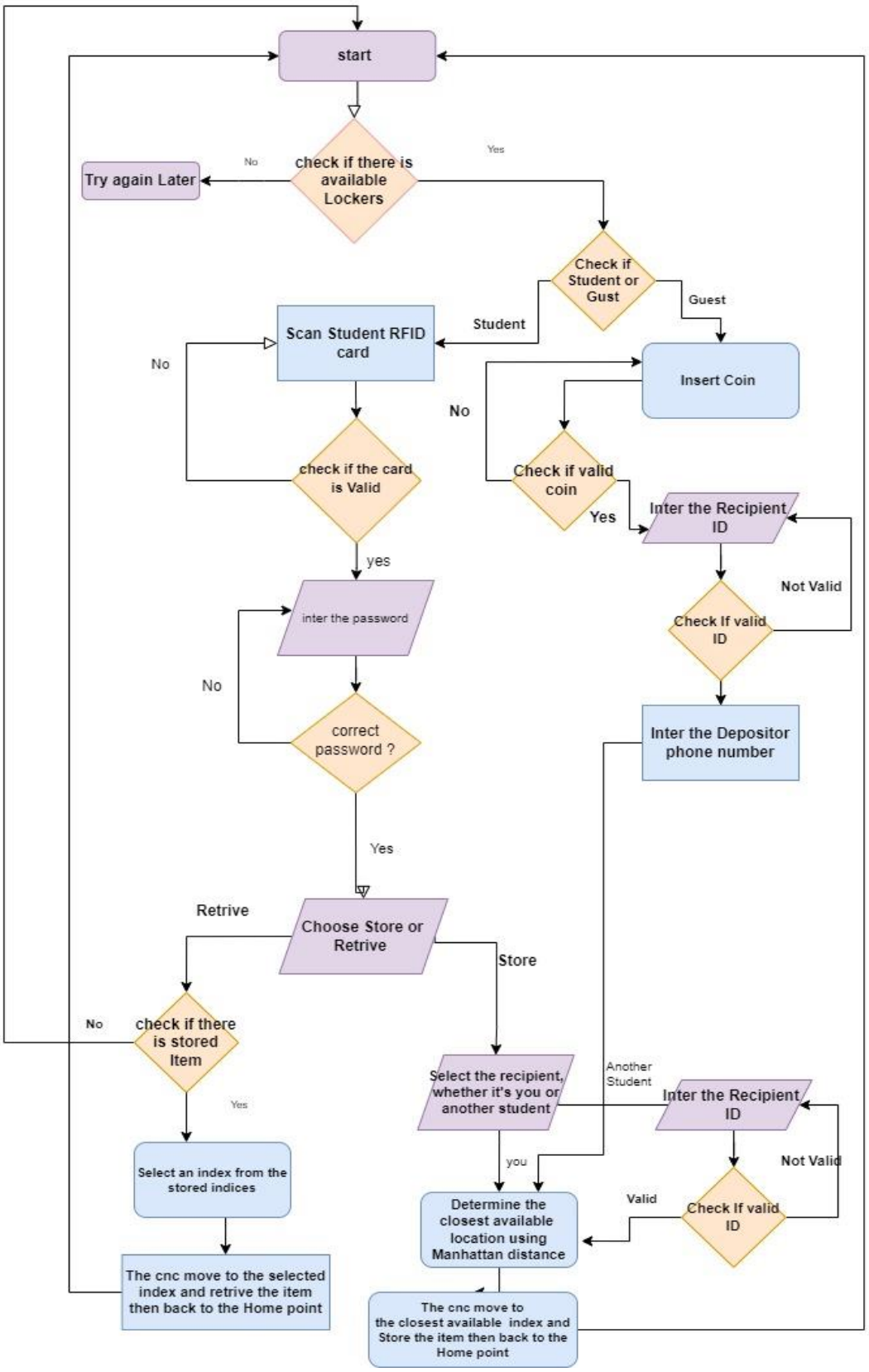


Figure 26: *(Block Diagram)*

4.5 Circuit Connection:

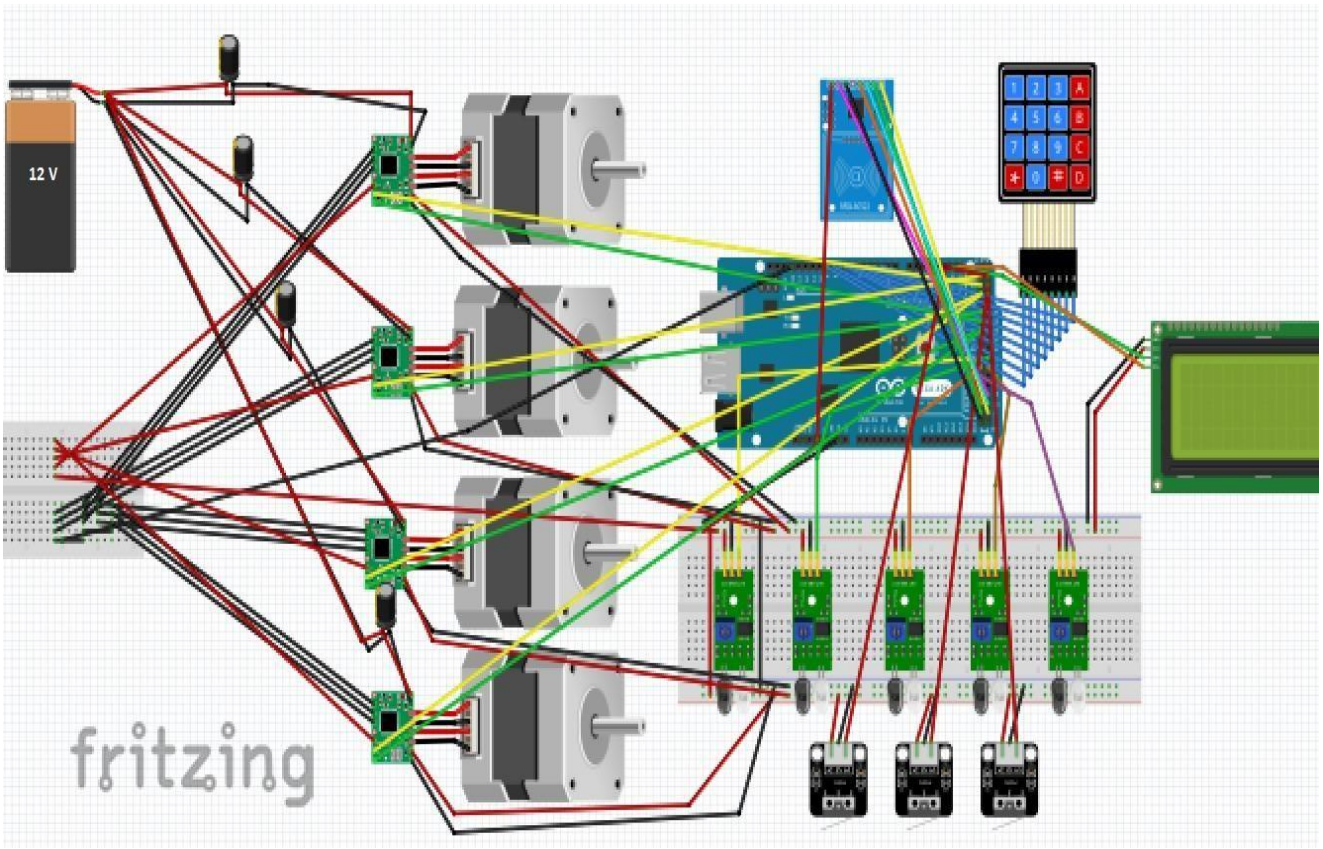
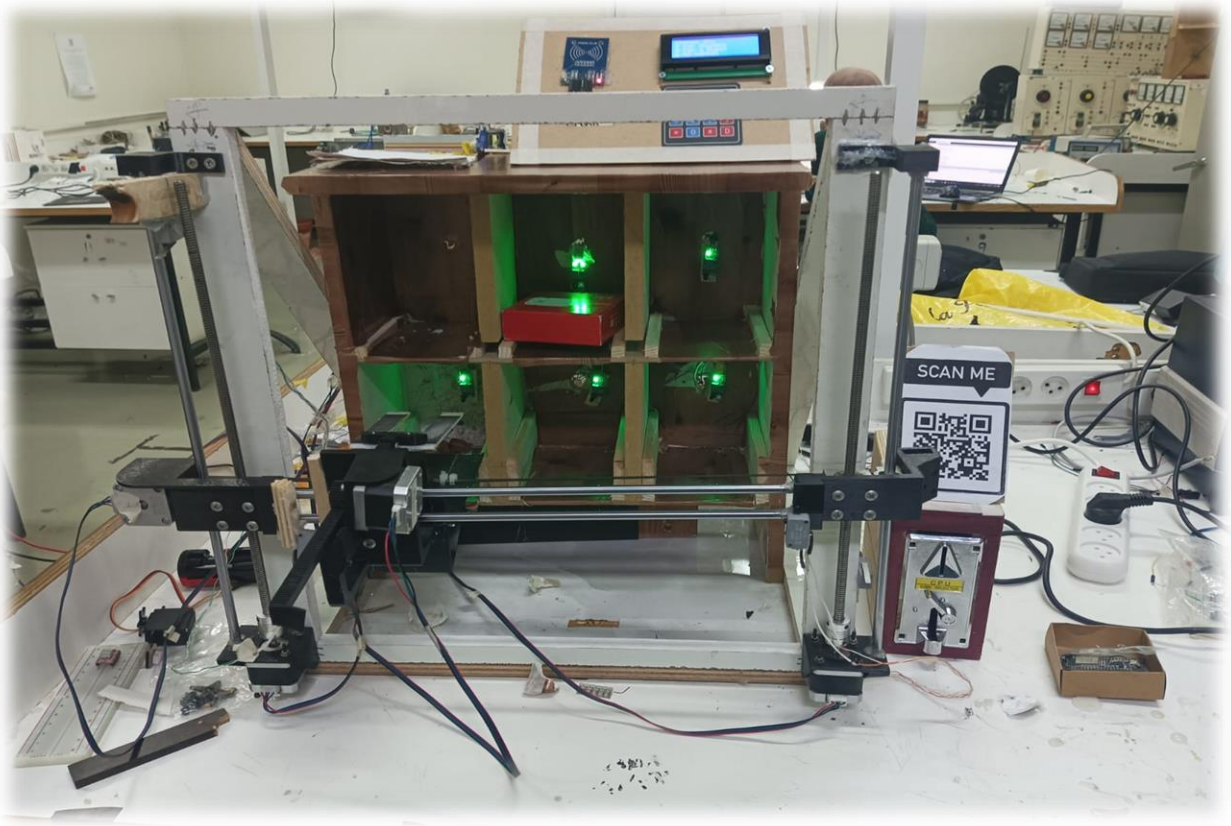


***Figure 27** :(circuit connection)*

4.6 Overall Design:



28 *Figure 28 :(overall design)*

Chapter 5:

5.1 Software Implementation:

Chapter 5 focuses on the critical software implementation of our Smart Secure Student Depot system: a smart package storage and retrieval system. These functions serve different roles, including user interaction, data processing, and mechanical control.

Each function plays a specific role in facilitating packet storage and retrieval with an emphasis on ease of use and security. It serves as a step-by-step guide to understanding the programming foundation of our Smart Secure Student Depot.

```
1. void reset(){…}.
2. void xyz_value( int selectedIndex){…}.
3. bool isAvailabil(int index){…}.
4. void coinInterrupt() {…}.
5. void setup() {…}.
6. void loop() {…}.
7. Void homing(){…}.
8. void storeItem(int selectedIndex){…}.
9. int findNearestAvailableSlot(){…}.
10.int showStoredItem (){…}.
11.void moveRight(int y){…}.
12.void moveLeft(int y){…}.
13.void moveBackWord(){…}.
14.void moveForWord(){…}.
15.void goDown(int z ){…}.
16.void goUp(int z ){…}.
17.void retrieveItem(int selectedIndex){…}.
18.int showMainMenu() {…}.
19.String readRFID(){…}.
```

5.2 Mobile application :

In the mobile application, we have three interfaces, one for the administrator, another for the student, and another for registering in the application. The administrator can monitor empty and full shelves, and the student user can go to a page that scans and then go to a page where the student chooses to store his belongings or return them as desired. (Hackster.io., n.d.)

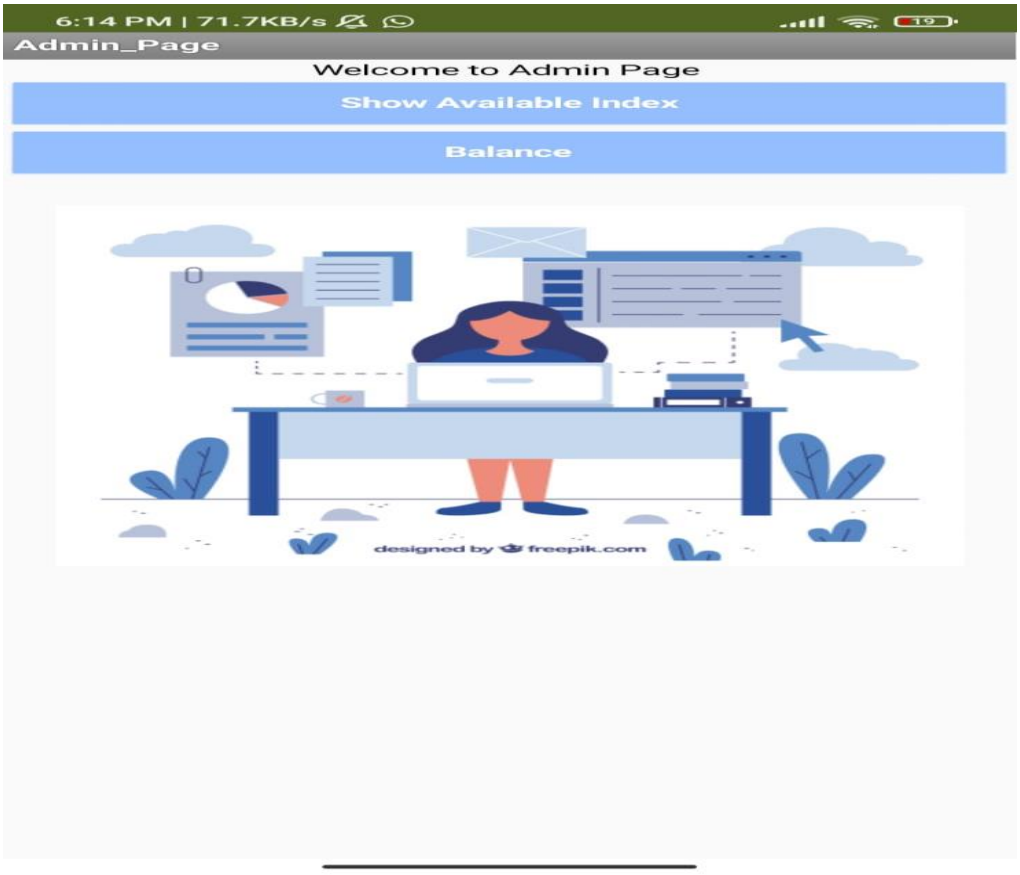


Figure 29: (admin page)

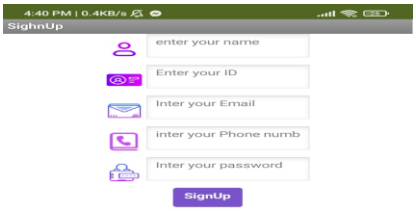


Figure 30: (signup page)

Figure 31:(login page)

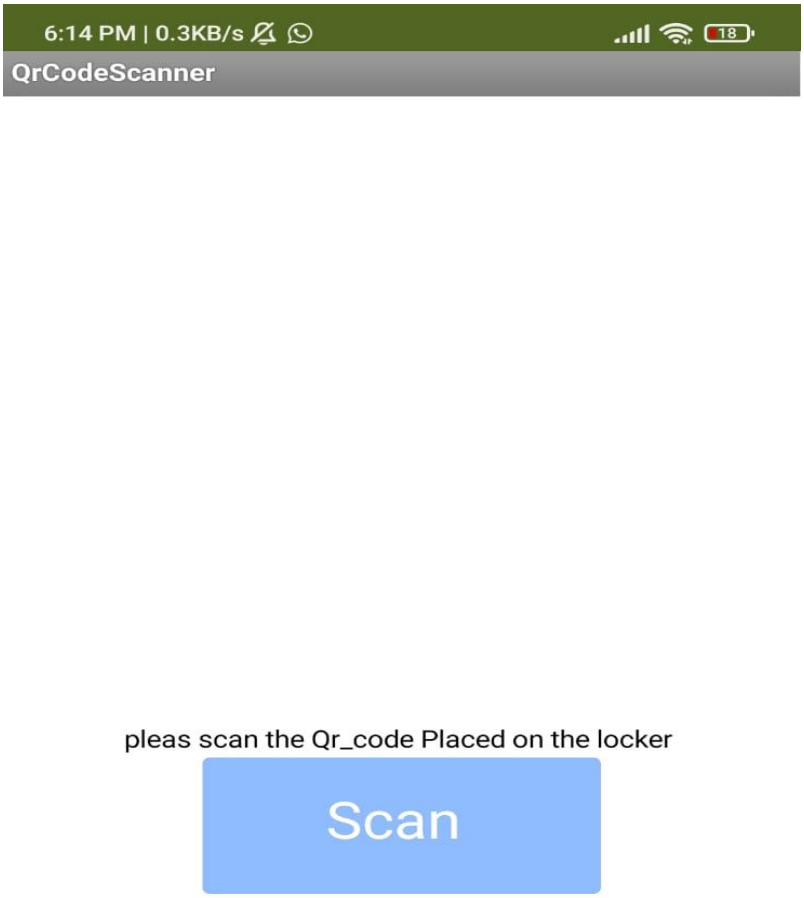


Figure 32 : *(scan page)*

Chapter 6:

Results and Discussion

The journey of working on this project has been both challenging and rewarding. We started this business with no prior knowledge of Arduino, but through determination and perseverance, we succeeded in developing a fully functioning Smart Secure Student Depot that includes all the features we initially planned.

The development process was an important learning experience. Building this machine from the ground up not only allowed us to achieve our project goals, but also provided us with invaluable hands-on experience with the Arduino. We encountered and overcame many obstacles, and this process provided us with a strong foundation in Arduino programming and hardware integration.

Chapter 7:

Conclusion

In conclusion, building our own Smart Secure Student Depot : Intelligent Package Storage and Retrieval machine has been a transformative experience, providing us with a wealth of knowledge and experience. We have gained a deep understanding of the hardware components, including the Arduino Mega, stepper motors, limit switches, and A4988 drivers. We also explored different communication methods such as I2C, input devices such as keyboards, RFID, IR sensors, and ESP32, and became skilled in handling mechanical components such as screws, smooth bars, belts, spur gears, sliders, and forks. This hands-on journey not only allowed us to successfully create a complex automation system, but also provided us with valuable skills and insights for future technological endeavors

Chapter 8:

Future Work

We've developed the Smart Secure Student Depot, a cutting-edge package storage and retrieval system that's highly adaptable for future enhancements. Notable features include:

- Enhanced Surveillance System: Integrated cameras linked to the mobile app for real-time monitoring and heightened security.
- Size-Based Storage: Customizable storage spaces to accommodate packages of various dimensions.
- Intelligent Package Routing: Automated transport to a designated location if recipients are unable to collect their packages within a specific timeframe.

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