MILITARY INSTITUTE OF SCIENCE & TECHNOLOGY
(MIST)
DEPARTMENT OF ELECTRICAL, ELECTRONIC AND
COMMUNICATION ENGINEERING

CSE 372 (10 December 2023)

Microprocessors and Interfacing Laboratory

Final Project Report

Section: A Group: 8

RFID Based Automatic Toll Collection using Arduino

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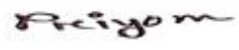
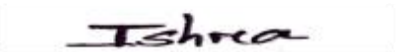
Academic Honesty Statement:

"In signing this statement, We hereby certify that the work on this project is our own and that we have not copied the work of any other students (past or present), and cited all relevant sources while completing this project. We understand that if we fail to honor this agreement, We will each receive a score of ZERO for this project and be subject to failure of this course."

Signature:  **Full Name: Alif Tahmid Priyom** **Student ID: 202116006**	**Signature:**  **Full Name: Jannatul Ishra** **Student ID: 202116026**
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1 Abstract

Automatic toll collection is essential for modernizing transportation systems. Unlike manual toll collection, which involves physical toll booths and manual payment processing, automatic toll collection streamlines the process through technology. This system enhances efficiency, speeds up traffic flow, and offers greater convenience to commuters. By incorporating Radio-Frequency Identification (RFID) technology, the project enhances user convenience, transparency, and communication, contributing to a more seamless and user-friendly toll infrastructure. In this project, the system incorporates an RFID reader for seamless identification of vehicles, a 4x4 membrane keypad for user input, a servo motor to control the toll gate, a buzzer for feedback, and an LCD for displaying information. The automated toll collection system successfully utilizes RFID technology for quick and accurate vehicle identification, toll transactions, also it allows users to recharge their RFID cards if their RFID cards do not have sufficient balance. Also, it ensures security, by ensuring that only authorized vehicles with valid RFID cards can pass through the toll booth

2 Introduction

Manual toll collection poses several challenges, making it a problem for efficient transportation systems. Firstly, it contributes to traffic congestion as vehicles have to stop or slow down at toll booths, leading to delays and increased travel times. Additionally, manual toll collection requires significant manpower and resources for staffing toll booths, resulting in operational costs.

The complexity in solving this issue lies in the engineering challenges associated with automating toll collection. Implementing a system that accurately identifies vehicles, processes payments seamlessly, and ensures security can be technically intricate. Integrating technology to handle diverse vehicle types, license plate recognition, electronic payment processing, and maintaining system reliability requires careful engineering and coordination. Overcoming these challenges involves integrating various technologies such as RFID (Radio-Frequency Identification), cameras, and electronic payment systems, and ensuring interoperability across different transportation networks. Developing a robust, reliable, and cost-effective automated toll collection system requires a comprehensive engineering approach to address the intricacies involved in streamlining toll operations.

3 Design

3.1 Problem Formulation (PO(2))

3.1.1 Identification of Scope

1. **Traffic Management Improvement:** The project aims to enhance traffic flow by automating toll collection, reducing congestion, and providing a flawless travel experience for commuters.
2. **Operational Efficiency:** RFID-based toll collection improves toll booth operations by eliminating manual transactions, reducing errors, and optimizing resource utilization.
3. **User Convenience:** The system focuses on enhancing user experience through contactless transactions, quick toll processing, promoting user satisfaction and ease of travel.

4. **Security Enhancement**: Utilizing RFID technology ensures secure and accurate vehicle identification, minimizing the risk of unauthorized access and fraudulent activities at toll booths.
5. **Cost-Effectiveness:** The project explores the cost-effectiveness of RFID technology in the long run, considering reduced manual labor requirements, operational errors, and potential resource optimization.
6. **Scalability:** The system's scalability is assessed for its ability to adapt to different toll collection scenarios, from busy highways to urban areas, ensuring its viability in various traffic conditions.
7. **Integration Flexibility:** The project explores the flexibility of integrating RFID with other technologies, such as GPS and GSM, to provide additional functionalities and enhance the overall capabilities of the toll collection system.

3.1.2 Literature Review

The automated toll collection system has significantly alleviated severe congestion near the bridges of bustling cities worldwide. It stands out as the most effective means of managing heavy traffic flow. Utilizing RFID technology, the system digitally captures radio frequency signals. Each vehicle is equipped with an RF tag containing a unique code that emits signals. Vehicle owners must maintain an account linked to their RFID tag. As a vehicle approaches the entrance toll gate, the signals are detected and relayed to the control device. Access is granted only if the vehicle owner has a sufficient balance in their account [1]. In the Indian state of Gujarat, an electronic toll collection system utilizes radio frequency and tags, operating commercially on expressways. All the necessary equipment for this system was provided by Mitsubishi Heavy Industries [2]. Furthermore, India has implemented its inaugural interoperable RFID-based electronic toll system on the Ahmedabad-Mumbai National Highway. This system allows vehicles equipped with electronic tags to operate within the frequency range of 850-950 MHz, with a range of up to 90 feet and a response time of 10 milliseconds [2]. While this system can be considered cost-efficient, it requires drivers to obtain a receipt and pass through the gate.
Additionally, an organization named Active Wave Inc. has introduced a monitoring system for actively tagged vehicles [3]. These vehicles operate with an active wave spanning 30 meters, transmitting at (916-917 MHz) and receiving at (433 MHz). The signals are observed through blinking LEDs and beeping sounds. The user interface is crafted using the Microsoft .NET Framework. The tag utilizes the car battery for power, and two modules transfer signals through an RF modem within the ISM frequency range of approximately (902-928) MHz. Another proposed digital toll collection model has been developed in Poland, combining GSM and a satellite-based global positioning system [1].

3.1.3 Formulation of Problem

In traditional toll collection systems, manual transactions contribute to traffic congestion, inefficiencies in toll booth operations, and potential errors in toll accounting. The lack of a streamlined and automated process hinders user convenience and real-time communication regarding toll transactions and account balances. Additionally, security concerns and the need for improved scalability further accentuate the limitations of conventional toll collection methods.
The project seeks to address these challenges by formulating an automated toll collection system using RFID technology. The formulation of the problem involves developing a solution that mitigates traffic delays, enhances toll booth efficiency, improves user experience through contactless transactions, and incorporates real-time communication features via LCD display. The project aims to overcome the limitations of manual toll collection while ensuring security, scalability, and integration flexibility with additional technologies.

3.1.4 Analysis

1. **RFID:** RFID stands for “Radio Frequency Identification,” which is a technology that uses radio waves to transmit data between devices. RFID technology has a wide range of potential applications and is often cited as a key technology for the “Internet of Things.” Typically, the RFID system consists of unique identifiers, unlike barcodes. However, barcodes can only be read one at a time, while RFID tags can be read simultaneously by multiple devices, making them more efficient for tracking purposes.
2. **RFID sensors:** An RFID sensor is a tag that uses electromagnetic fields to identify and track assets automatically. RFID sensors are highly accurate and can provide a wealth of valuable data about the object they are attached to. This data can be used to improve the efficiency of supply chains or to monitor the condition of production equipment. RFID tags have been referred to as “smart barcodes” because they can store more data than traditional barcodes and can be read even if they are not visible. These sensors are also very rugged and can withstand a lot of abuse. This makes them ideal for use in industrial or other harsh environments.
3. **IR sensors:** An infrared sensor is an electronic device, that emits in order to sense some aspects of the surroundings. An IR sensor can measure the heat of an object as well as detecting the motion. These types of sensors measure only infrared radiation, rather than emitting it that is called a passive IR sensor. Usually, in the infrared spectrum, all the objects radiate some form of thermal radiation. These types of radiation are invisible to our eyes, which can be detected by an infrared sensor. The emitter is simply an IR LED (Light Emitting Diode) and the detector is simply an IR photodiode that is sensitive to IR light of the same wavelength as that emitted by the IR LED. When IR light falls on the photodiode, the resistances and the output voltages will change in proportion to the magnitude of the IR light received.

3.2 Design Method (PO(1))

Microcontroller: Arduino Uno is the microcontroller of this project. Acting as the project's brain, the Arduino Uno is responsible for processing inputs from the RFID reader, keypad, and sensors, making decisions based on programmed logic, and coordinating the operation of the servo motor, and LCD display.

Sensors:

- RFID reader is a tool used to gather data from an RFID tag to track individual items. This low-cost MFRC522-based RFID reader module is simple to use and can be used in a variety of applications. RFID tags contain a distinctive code that distinguishes the vehicle class that passes through the tariff port. Whenever the user scans their cards in the RFID module, the RFID reader reads all RFID tags to get their unique ID numbers, and the Arduino is programmed to recognize only some RFID tags, enabling only registered tag cars.
- Two IR sensors are integrated to detect the presence of the vehicles at the entry and exit points.

Actuator: A servomotor is a rotary actuator or linear actuator enabling accurate angular or linear position, acceleration speed and control. It is an appropriate position feedback engine in combination with a sensor. A motor driver is an IC which is used to drive the motor. We also use it to pull up and down the toll square's passing door. It is an engine with 3-pin energy, cable control and hardware mounting. It is rotating at 180 degrees.

User Interface:

- An LCD is an electronic screen module that uses liquid crystal to create a visible picture.

This 16x2 LCD display is a very fundamental module that is very frequently used in various systems and circuits. The job of the LCD will be to display all the system generated messages coming from the controller.

- The 4x4 membrane keypad is designed to withstand frequent use and provides a tactile interface for user convenience. If the user has insufficient balance, then he can directly recharge their account with the help of this keypad.

Protection: A buzzer is used in this project for the protection and alarm system. Whenever an unauthorized vehicle tries to pass the toll collection booth, the buzzer will go high. Also, a vehicle can never pass the toll booth without payment.

3.3 Circuit Diagram

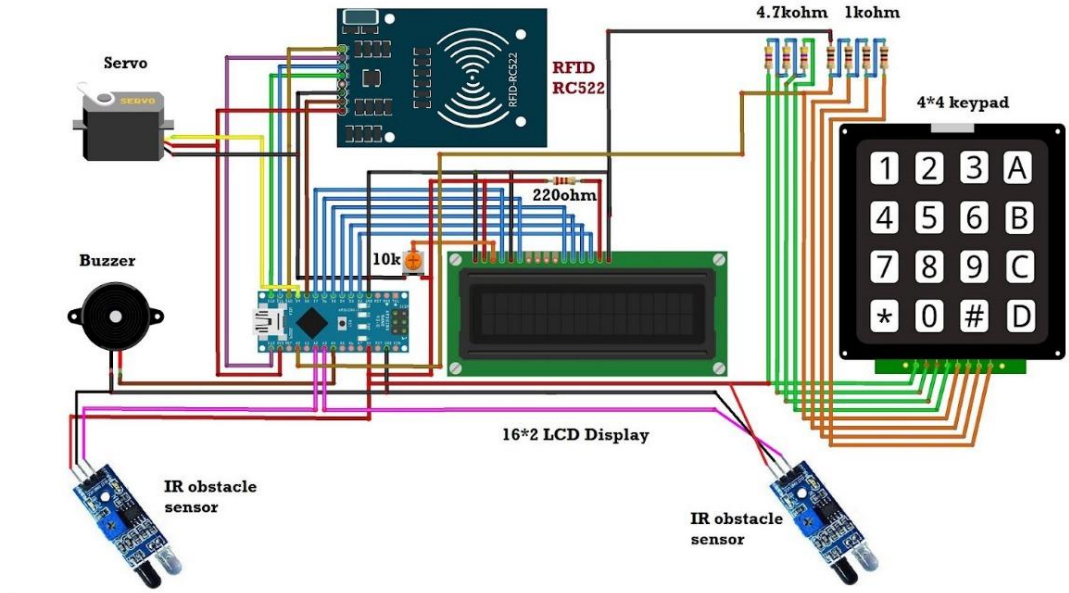

Fig: Circuit diagram

3.4 CAD/Hardware Design

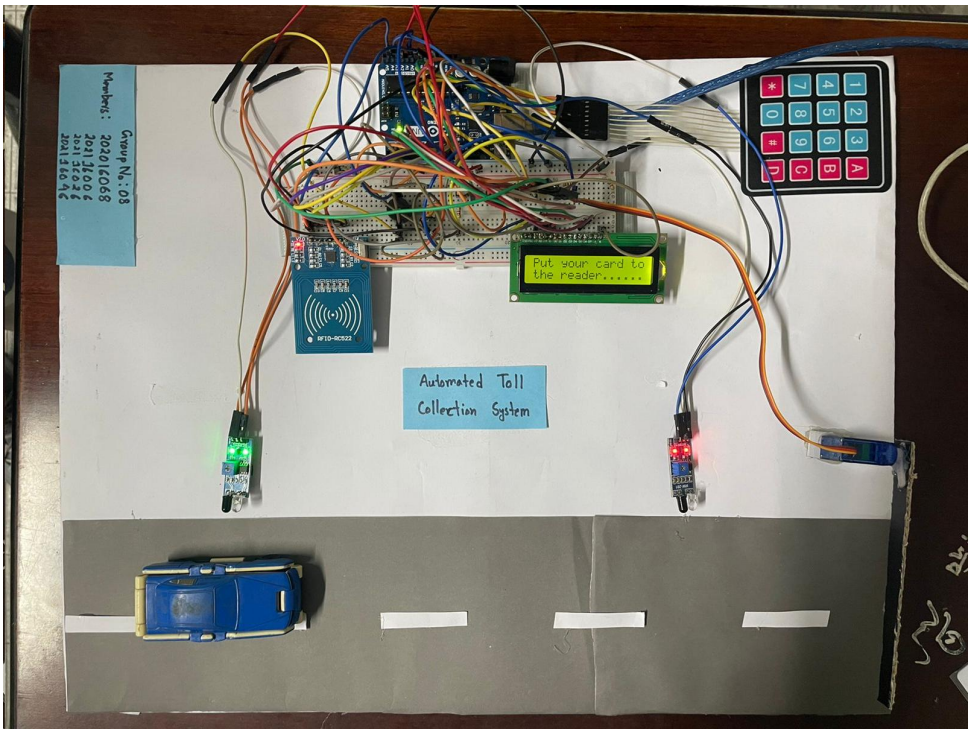

Fig: Hardware Design

4 Implementation

4.1 Description

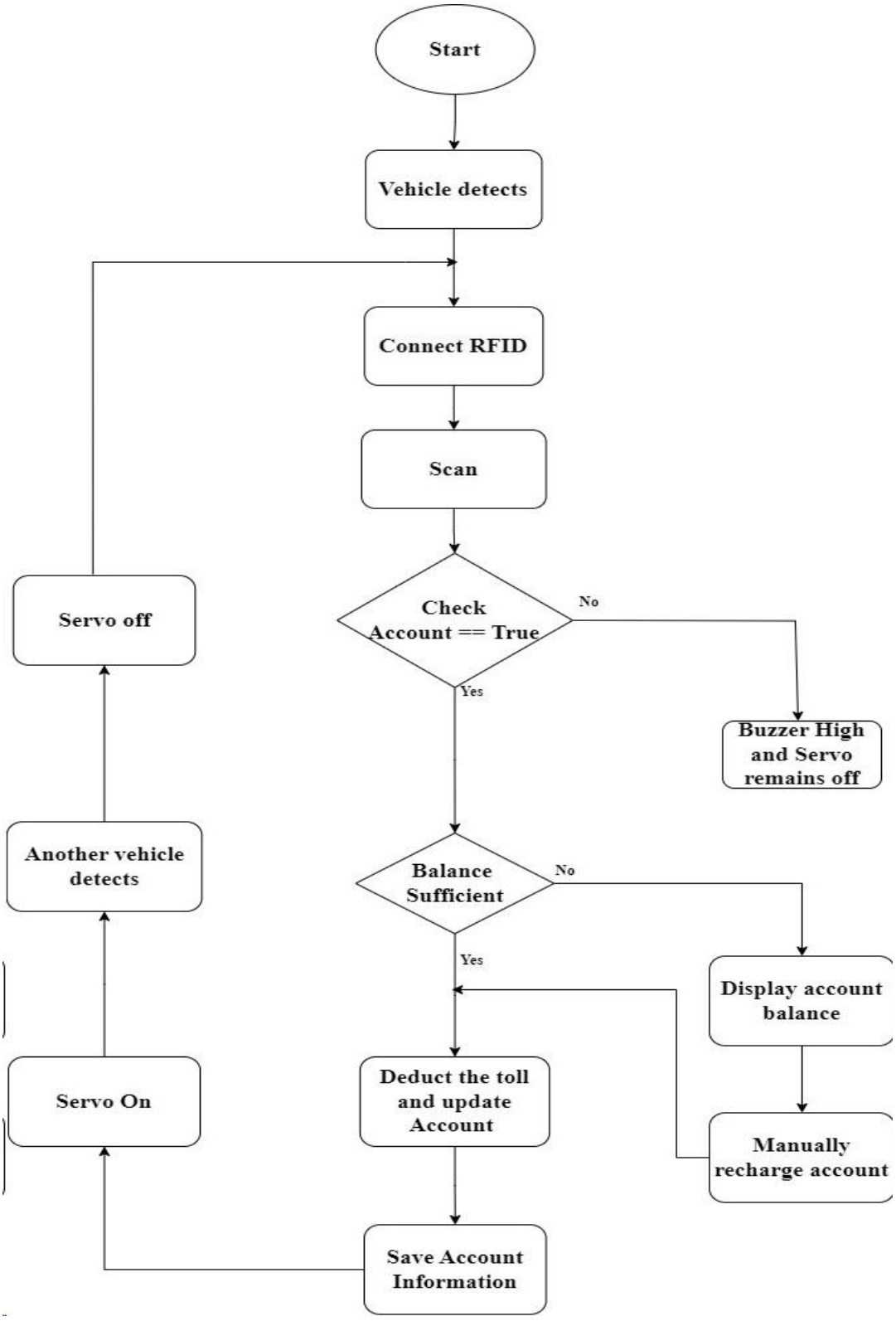

Fig: Flowchart of the whole design process

- When any vehicle comes near the IR sensor 1, it detects the vehicle, and the LCD shows

‘Vehicle detected’. Then it asks the user to put their cards on the RFID reader.

- When the RFID card is put on the reader, it reads the unique identifier from the RFID card, and matches the id number with the numbers of the authorized vehicles. If it is one of them, and it has sufficient balance, then it cuts the toll amount from the card. And it shows the updated toll amount after the transaction.

- But if the card doesn’t have sufficient balance, then the LCD shows ‘Your balance is insufficient’, then it shows the amount.

- Then the user can manually recharge their account by entering input from the keypad. If they press A from the keypad, it starts the recharging mode.

- Then the user enters the amount with the help of the keypad and after pressing D the amount is added with the card balance. Then, the LCD shows the updated amount.

- After the payment of the bill, the vehicle reaches the IR sensor 2, and only if the toll amount is paid, then the servo motor turns on allowing the vehicle to pass. The toll gate will not open even if the vehicle reaches the second IR sensor without giving the toll payment. Therefore, the user must pay the toll amount, otherwise, it can’t pass.

- If the vehicle is not registered before, and the reader can’t be able to match the unique identifier of the RFID tag with that of their authorized vehicles then the LCD shows, ‘Unknown vehicle, Access denied’ and the buzzer goes high alarming the authority and the servo remains off and it won’t allow the vehicle to pass.

5 Design Analysis and Evaluation

5.1 Novelty

The novelty of this project lies in its integration of RFID technology, servo control, and GSM capabilities to create a comprehensive Automated Toll Collection System. This innovative approach not only streamlines toll transactions but also incorporates real-time SMS notifications for users, enhancing communication and convenience. The project's multifaceted features, including user-friendly interfaces and potential future integrations, mark it as a pioneering solution in modernizing transportation infrastructure and redefining the toll collection experience.

5.2 Design Considerations (PO(3))

5.2.1 Considerations to public health and safety

The project prioritizes user safety through automated gate operations, minimizing physical interactions. Regular maintenance protocols are in place to address safety concerns related to hardware components, and real-time communication features, contribute to a safer and more informed travel experience for users.

5.2.2 Considerations to environment

While the system relies on power, future work could explore green technology solutions, such as incorporating solar panels for sustainable power sources. The shift towards automation and reduced vehicle idling at toll booths contributes to a greener transportation ecosystem, aligning with environmental sustainability goals.

5.2.3 Considerations to cultural and societal needs

The user interface, including the keypad and LCD display, is designed for universal accessibility, accommodating diverse user demographics. Sensitivity to cultural practices is observed in the user education process, ensuring that the system aligns with local customs and preferences.

5.3 Investigations (PO(4))

5.3.1 Design of Experiment

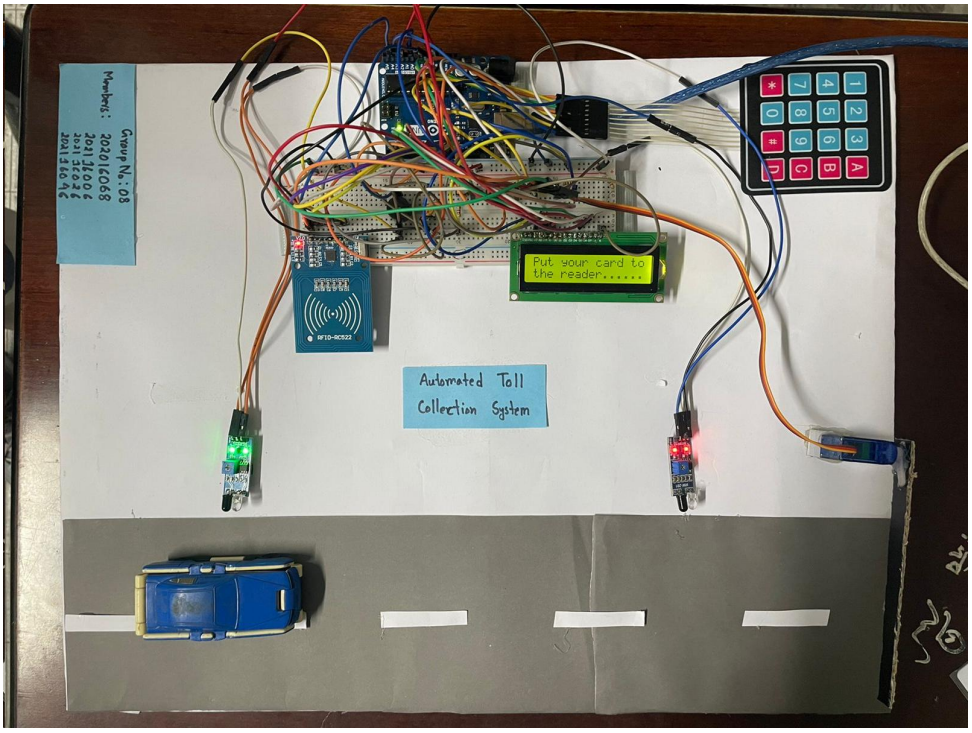

Fig: Setup of the experiment

5.3.2 Results and Analysis

i. Detection of vehicle: When any vehicle comes near the IR sensor 1, it detects the vehicle, and the LCD shows 'Vehicle detected'.

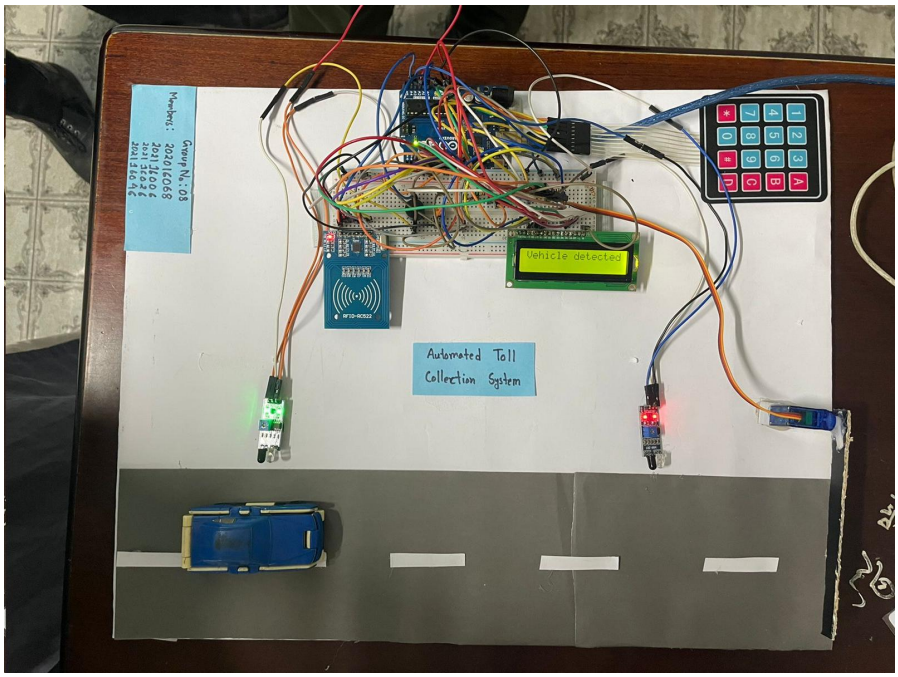

Fig: LCD shows 'Vehicle detected'

Then it asks the user to put their cards on the RFID reader.

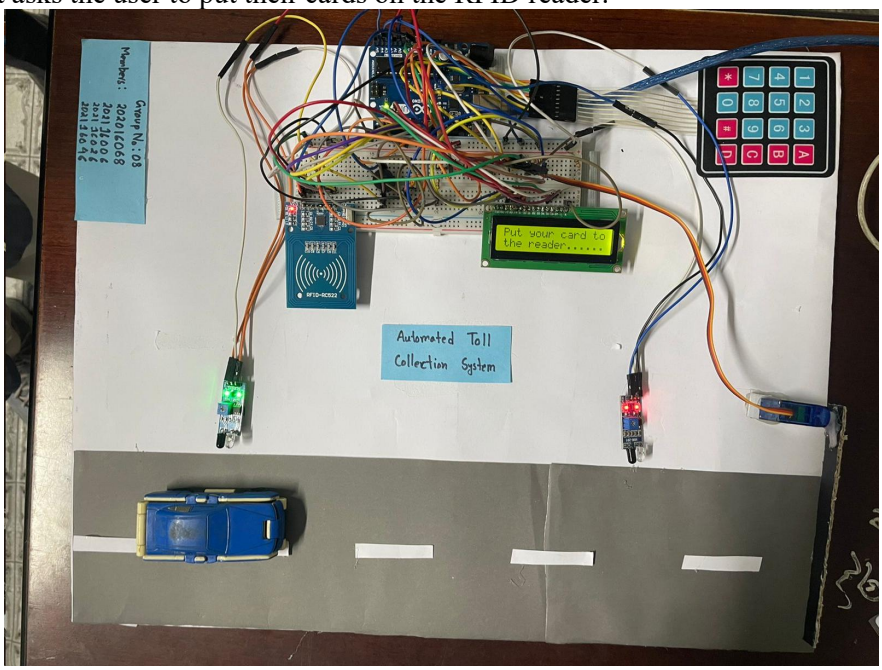

Fig: LCD shows 'Put your card on the reader.....'

ii. Authorized Vehicle Identification: When the RFID card is put on the reader, it reads the unique identifier from the RFID card, and matches the id number with the numbers of the authorized vehicles. If it is one of them, and it has sufficient balance, then it cuts the toll amount from the card.

Fig: LCD shows 'Successfully paid your bill"

But if the card doesn't have sufficient balance, then the LCD shows 'Your balance is insufficient'

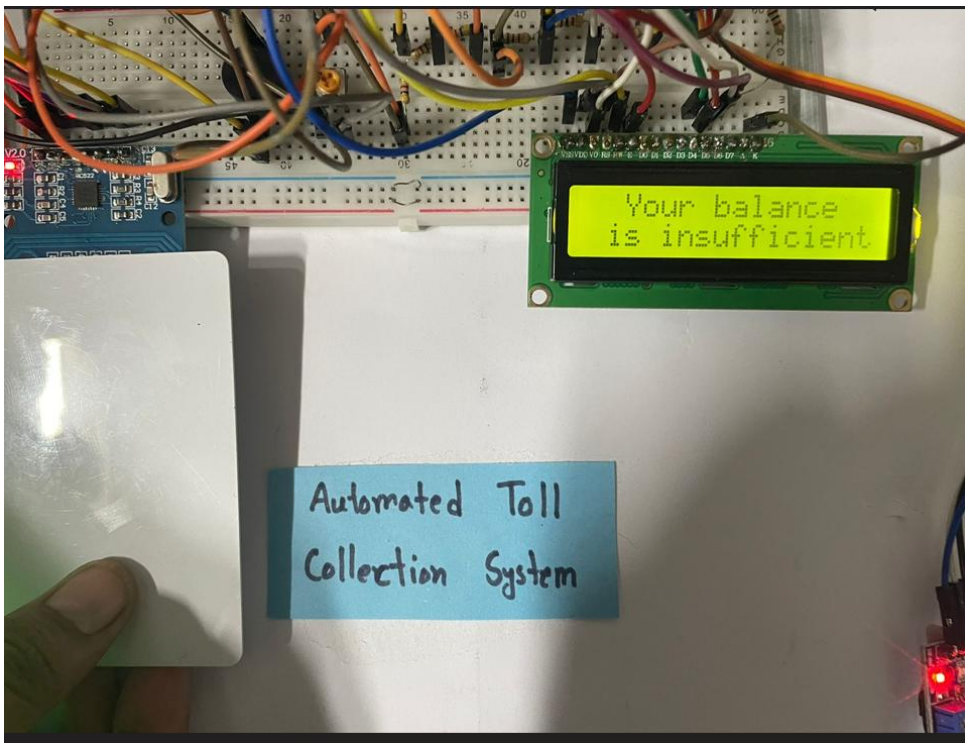

Fig: LCD shows ‘Your balance is insufficient’

Then it shows the amount.

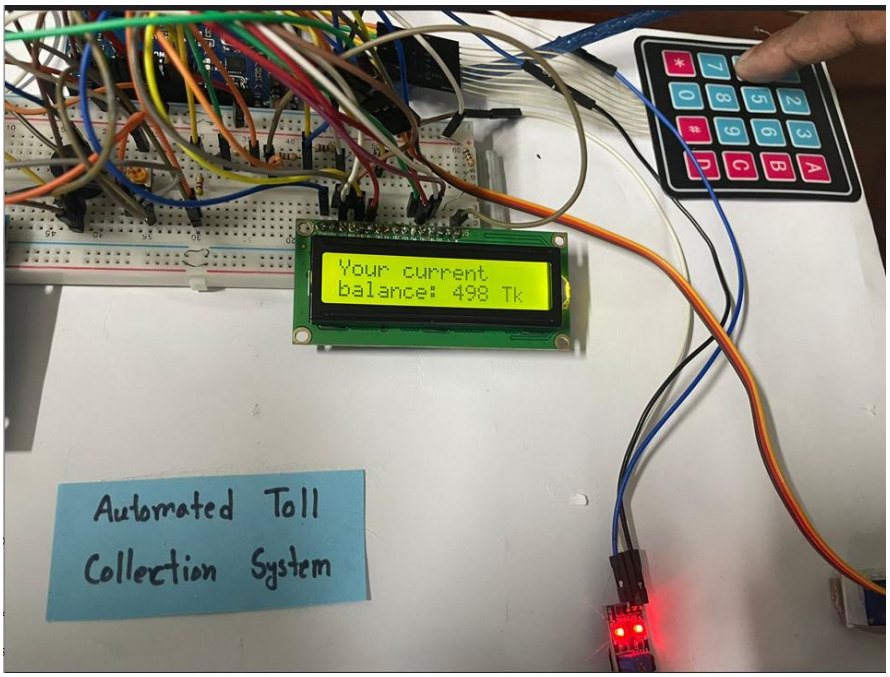

Fig: Here the balance is 498tk which is less than 500 tk (the toll amount)

Then the user can manually recharge their account by entering input from the keypad. If they press A from the keypad, it starts the recharging mode.

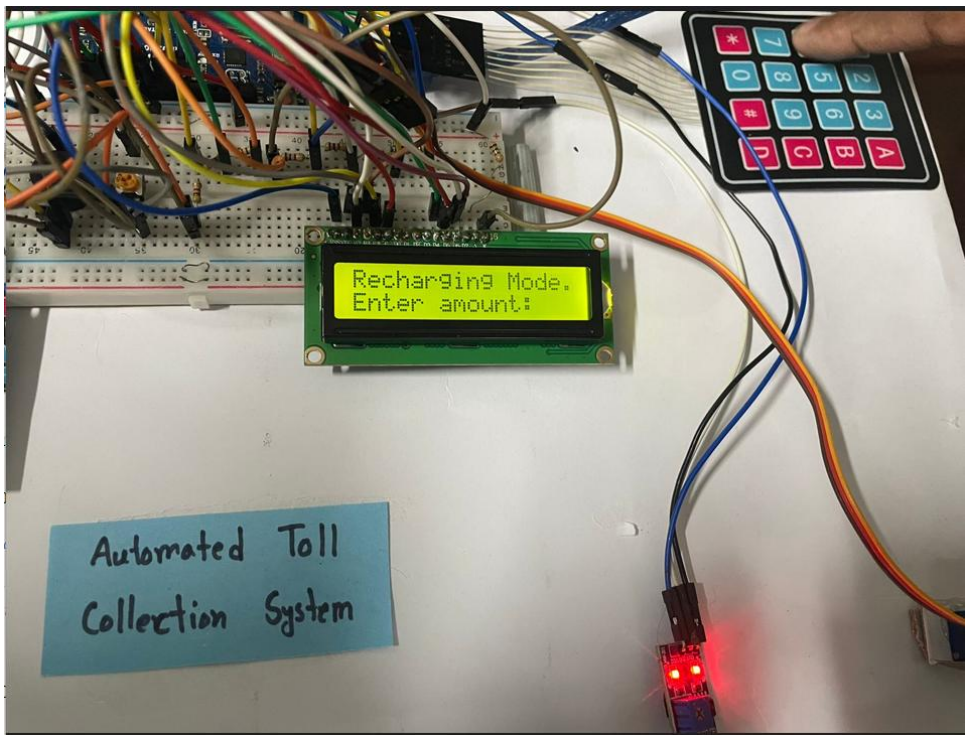

Fig: LCD shows ‘Recharge Mode. Enter Amount.

Then the user enters the amount with the help of the keypad and the amount is then added with the card balance.

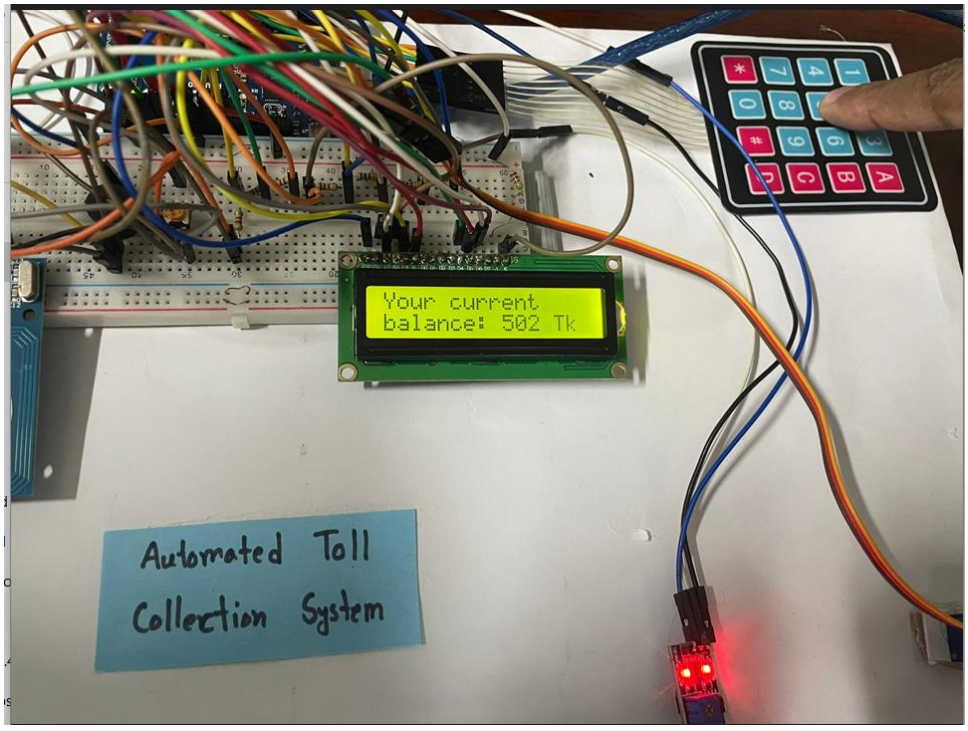

Fig: The updated balance is shown.

Now, the user can use their card to pay the toll amount.

Fig: LCD shows ‘Successfully paid your bill”

After the payment of the bill, the vehicle reaches the exit point, and only and only if the toll amount is paid, then the servo motor turns on allowing the vehicle to pass.

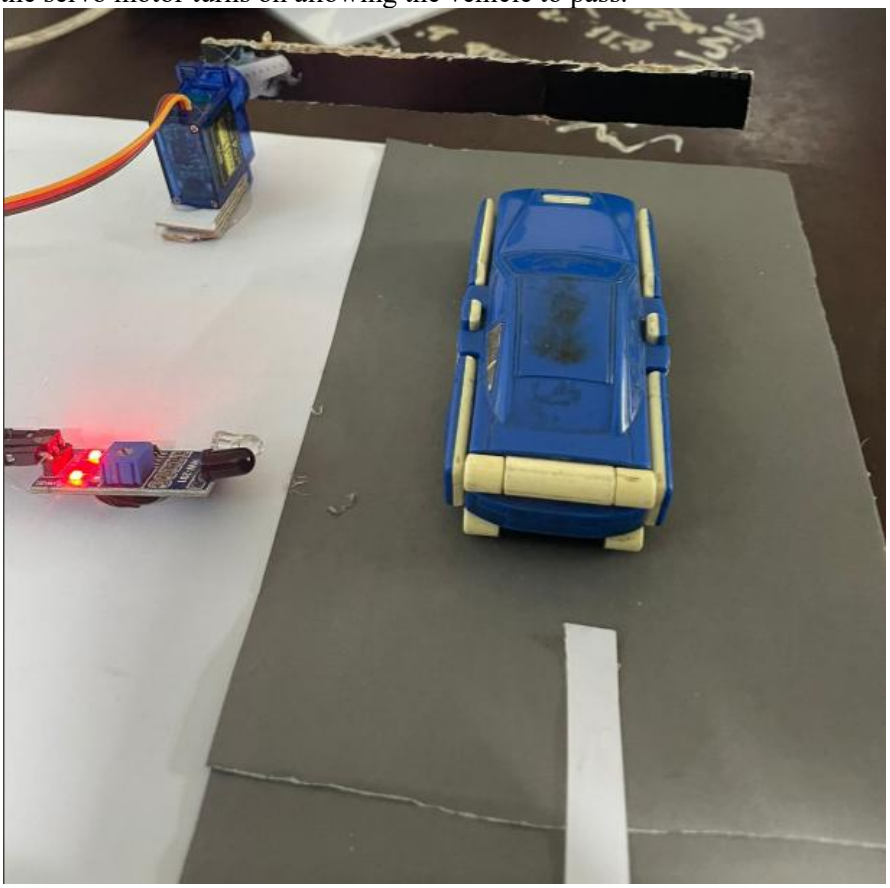
Fig: Vehicle reached IR sensor 2 (Toll gate is still off)

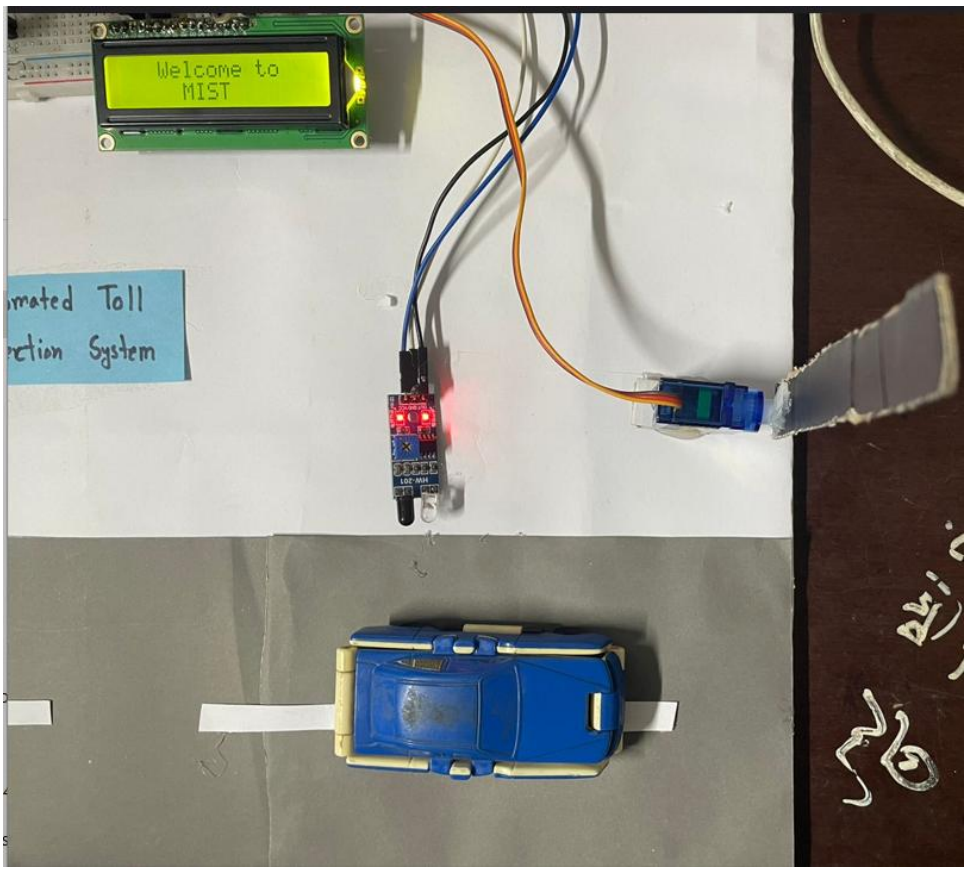

Fig: Toll gate is opened, and the LCD shows ‘Welcome to MIST’

iii. Unauthorized vehicle detection: If the vehicle is not registered before, and the reader can’t be able to match the unique identifier of the RFID tag with that of their authorized vehicles then the LCD shows, ‘Unknown vehicle, Access denied’ and the buzzer goes high alarming the authority and the servo remains off and it won’t allow the vehicle to pass.

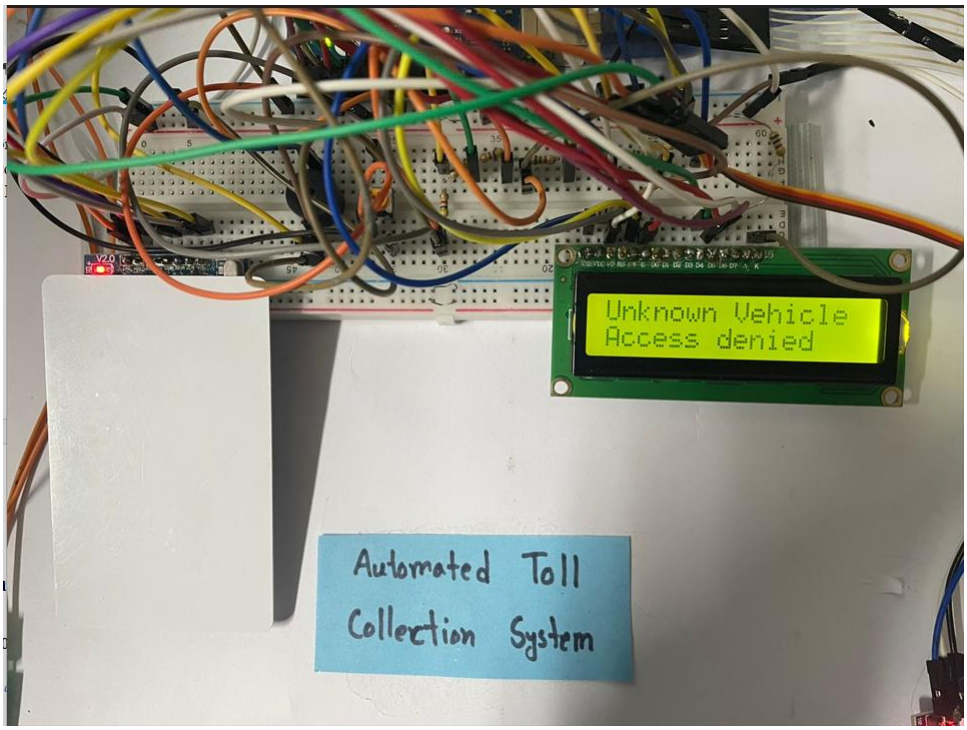

Fig: LCD shows, ‘Unknown vehicle, Access denied’

5.3.3 Interpretation and Conclusions on Data

The data reveals a significant improvement in toll collection efficiency and user experience with the implementation of the Automated Toll Collection System. Reduced transaction times, streamlined operations, and real-time communication through LCD monitor were successfully implemented. The project not only meets its objectives of enhancing traffic flow and user convenience but also sets the stage for future advancements, emphasizing its relevance and effectiveness in modern transportation infrastructure.

5.4 Limitations of Tools (PO(5))

Power Dependency: The system relies on a stable power source for continuous operation. Power outages or disruptions may temporarily hinder toll collection and communication capabilities.

Maintenance Requirements: Regular maintenance of hardware components, including RFID readers and servo motor, may be necessary to ensure consistent and reliable performance over time.

Environmental Factors: Adverse weather conditions or environmental factors, such as extreme temperatures or physical obstructions, could impact the reliability of sensors or other hardware components.

6 Reflection on Individual and Teamwork (PO(9))

6.1 Individual Contribution of Each Member

Name & ID	Arduino coding	Hardware connection	Report Writing	Presentation Making
Alif Tahmid Priyom 202116006	☑	☑		
Jannatul Ishra 202116026	☑		☑	
Farhan Fuad 202116046	☑	☑		
Muij Shafaqat 202016068				☑

6.2 Mode of Teamwork

The mode of teamwork revolves around the strategic distribution of tasks among team members, with the objective of harnessing the diverse skills and expertise of everyone to achieve a common goal. This approach emphasizes collaboration, effective communication, and a shared responsibility for the team's success. By assigning specific roles and responsibilities to different teammates, the workload is distributed in a manner that optimizes efficiency and productivity.

6.3 Logbook of Project Implementation

Date	Milestone achieved	Individual Role
10/10/2023	Project proposals were submitted	202116006 participated

11/11/2023	Components were ordered	202116046 participated
13/11/2023	Components were received	202116006,202116046 participated
19/11/2023	Connections were established	202116046 participated
20/11/2023	Connections were established along with Arduino coding	202116046, 202116006, 202116026 participated
21/11/2023	Decorations were done	202116006, 202116046 participated
2/12/2023	PowerPoint presentation was made	202016068, 202116026 participated
3/12/2023	Presentation was given	202116006,202116026, 202116046, 202106068 participated
10/12/2023	Report was made	202116026 participated

7 Communication to External Stakeholders (PO(10))

7.1 Executive Summary

Our project introduces an innovative Automated Toll Collection System, combining RFID technology and servo control for an efficient and user-friendly experience. The system streamlines toll transactions, reducing congestion and improving traffic flow. With real-time LCD output, users receive instant updates on toll deductions and account balances, enhancing communication and convenience. Also, when they don't have sufficient balance, they can manually recharge their card within the toll booth. The project represents a significant step forward in modernizing transportation infrastructure, offering operational efficiency, heightened security, and an overall improved travel experience.

7.2 User Manual

- Drive towards the toll booth; the system detects your vehicle automatically.
- Follow on-screen prompts for instructions during toll payment or recharge.
- For toll payment, place your RFID card near the reader. For recharge, follow instructions on the keypad.
- Place your RFID card for secure authentication.
- LCD displays toll amount. Confirm and proceed.
- If you don't have sufficient balance, press 'A' for Recharge Mode.
- Follow on-screen prompts for entering recharge amount.
- Use the keypad to enter the recharge amount. Press 'D' to confirm.
- LCD displays updated balance. Recharge successful!
- Place your RFID card for authentication.
- After payment, proceed and the gate opens automatically. Have a safe journey!
- In case of issues, refer to the troubleshooting section or contact support.

7.3 GitHub Link

This is the GitHub link for the code

7.4 YouTube Link

This is the YouTube video of our project

8 Project Management and Cost Analysis (PO(11))

8.1 Bill of Materials

Serial No	Items	Quantity	Per unit Cost (BDT)	Total Cost (BDT)
1.	Arduino Uno	1	500	500
2.	16x2 LCD	1	250	250
3.	IR sensor	2	90	180
4.	4x4 Keypad	1	74	74
5.	Active Buzzer	1	19	19
6.	Resistors (2kOhm)	_	5	5
7.	Resistors (4.7kOhm)	_	5	5
8.	RC522 RFID card Reader module	1	188	188
9.	Female pin header	1	15	15
10.	Male pin header	1	15	15
	Total cost			1251

9 Future Work (PO(12))

- In this project, we set the toll fare 500 TK for every vehicle passing through the toll booth. In future, we can use load cells or weight sensors strategically placed on the road surface at the toll booth. These sensors will detect the weight of the vehicle as it will pass over them, allowing the user to set toll fares based on the measured weight.
- In future iterations, we could explore the integration of GPS technology, unlocking a realm of real-time location-based services. By harnessing GPS capabilities, we could offer users personalized journey information, including dynamic route suggestions tailored to current traffic conditions.

10 References

[1] Dhurat, Anish & Magal, Parag & Chheda, Manish & Ingle, Darshan. (2014). Gateless Electronic Toll Collection using RFID. IOSR Journal of Computer Engineering. 16. 73-80. 10.9790/0661-16267380.

[2] “India's first electronic toll collection system launched on Ahmedabad-Mumbai Highway” April 12, 2013, The Economic Times

[3] “Radio frequency identification sticker could replace Smart Tag”, September 9, 2013, CBT Team