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Automated Toll Management System Using RFID

[1] Samim Uddin Ahmed, [2] Snigdha Deka, [2] Arobindra Saikia

[1] [2] UG Student, Department Instrumentation Engineering, Jorhat Engineering College, Jorhat, Assam, India
[3] Associate Professor, Department Instrumentation Engineering, Jorhat Engineering College, Jorhat, Assam, India
Corresponding Author Email: [1] samimahmed265g@gmail.com, [2] dekasnigdha20@gmail.com,
[3] arobindra@gmail.com

Abstract— The inefficiencies and delays caused by traditional toll collection methods have become a significant issue in modern transportation systems. This research explores the implementation of an Automated Toll Management System (ATMS) utilizing Radio Frequency Identification (RFID) technology to address these challenges. The system automates the toll collection process, reducing human intervention and minimizing traffic congestion at toll plazas. By integrating components like the Arduino Uno, RFID modules, and servo motors, the system effectively identifies vehicles and processes toll payments without the need for stopping. The study demonstrates how this technology can lead to smoother traffic flow, decreased operational costs, and enhanced overall efficiency in toll collection. Future advancements may include incorporating AI for real-time decision-making and blockchain for secure transactions, further improving the system's effectiveness.

Index Terms— Arduino Uno, Automated Toll Management System (Atms), Radio Frequency Identification (Rfid), Toll Management, Traffic Management.

I. INTRODUCTION

Efficient toll collection is essential for maintaining smooth traffic flow and reducing congestion on highways. Traditional toll collection methods, which often rely on manual processing, not only slow down traffic but also increase the likelihood of errors and inefficiencies. These systems require vehicles to stop or slow down significantly at toll booths, leading to long queues, increased fuel consumption, and higher emissions.

To address these challenges, there is a growing interest in the deployment of Automated Toll Management Systems (ATMS) that utilize advanced technologies to streamline the toll collection process. One promising approach is the use of Radio Frequency Identification (RFID) technology. RFID allows for contactless identification and payment processing, enabling vehicles to pass through toll points without the need to stop, thereby reducing congestion and improving overall efficiency.

This research paper focuses on the design and implementation of an ATMS using RFID technology. The system is built around key components such as the Arduino Uno microcontroller, RFID modules, and servo motors. By automating toll collection, the proposed system aims to enhance the efficiency of toll operations, reduce operational costs, and minimize environmental impact. This introduction provides an overview of the need for such a system and the potential benefits it offers in modernizing toll collection processes.

II. LITERATURE REVIEW

The design and analysis of an automated check post and fast-track toll system utilizing RFID and GSM technology with an integrated security system are explored in recent studies. This innovative approach aims to streamline electronic toll payments, making the verification process more efficient for vehicles passing through toll booths. By employing an ATmega 328 Arduino microcontroller, which includes built-in GPS and GSM modules, this system addresses the common issues associated with manual toll collection. The automation significantly reduces the need for human intervention, thus minimizing delays and manual labour at check posts [1].

Another study highlights the transition from traditional manual toll collection systems to automated solutions, emphasizing the benefits of such systems in modern road networks. Automated toll collection not only eliminates the need for vehicles to stop and wait in long queues but also contributes to fuel savings and reduced congestion. The implementation of an Automated Electronic Toll Collection (ETC) system, integrated with GPS technology, ensures seamless toll collection and improved road safety. This system facilitates efficient data exchange between drivers and toll authorities, thus reducing human errors and enhancing overall efficiency [2].

Further research focuses on the development of an automated toll collection system based on RFID technology and GPS. This system is designed to provide a cash-free operation at toll plazas, significantly reducing the time spent by motorists at these locations. The use of the E-PASS system and Tran score technology for automatic balance deduction from accounts underscores the system's potential to address traffic congestion and promote sustainable practices [3].

A different approach to toll collection involves integrating online payment and image processing technologies. This system captures images of vehicle number plates at toll gates and compares them with a database to facilitate toll payment.

By allowing online payment and reducing the need for manual intervention, this method aims to minimize journey interruptions and enhance convenience for travellers [4].

Lastly, an RFID-based Automated Toll Collection System is presented as a solution to traffic issues and aims to enhance transparency in toll collection. This system employs RFID technology to read tags mounted on vehicles' digital number plates, facilitating automatic toll collection without requiring vehicles to stop. By reducing manual labour and human error, this system contributes to a more efficient and transparent toll collection process, thereby supporting the development of a smarter transportation infrastructure [5].

III. SYSTEM DESIGN AND SPECIFICATIONS

3.1. Components Used and Quantity:

- Arduino Uno
- MFRC522 RFID Module
- OLED Display
- SERVO MOTOR
- BREADBOARD

3.2. Description of Components

Ardiuno Uno:

The Arduino Uno is one of the most popular and widely used microcontroller boards, especially in DIY electronics, prototyping, and educational projects. It is based on the ATmega328P microcontroller and provides a simple yet powerful platform for controlling hardware and interfacing with various sensors, actuators, and modules.

- ***Specifications:***

Microcontroller: ATmega328P
Operating Voltage: 5V
Input Voltage (Recommended): 7-12V (via the power jack)
Input Voltage (Limits): 6-20V
Digital I/O Pins: 14 (6 of which provide PWM output)
PWM Digital I/O Pins: 6 (Pins: 3, 5, 6, 9, 10, 11)
Analog Input Pins: 6 (Pins: A0-A5)
DC Current per I/O Pin: 40 mA
DC Current for 3.3V Pin: 50 mA
Flash Memory: N32 KB (0.5 KB used by the bootloader)
SRAM: 2 KB
EEPROM: 1 KB
Clock Speed: 16 MHz
USB Connection: Type B (for programming and serial communication)
LED Built-in: Pin 13
Dimension**s:** 68.6 mm x 53.4 mm
Weight: 25 g

- ***Pinouts:***

The Arduino Uno has multiple headers with a variety of pins for digital and analog input/output, communication, and power.

Power Pins:

a. **V$_{IN}$:** The input voltage to the Arduino when using an external power source (7-12V).
b. **5V:** The regulated 5V output from the board.
c. **3.3V:** A 3.3V output generated by the onboard regulator (maximum current: 50 mA).
d. **GND:** Ground pins (there are multiple ground pins on the board).
e. **Reset:** Reset the microcontroller (active LOW).

Digital Pins (0-13):

a. **Pins 0 (RX) and 1 (TX):** Used for serial communication (USART).
b. **Pins 2 and 3:** Can be used for external interrupts (attachInterrupt).
c. **PWM Pins (3, 5, 6, 9, 10, 11):** Provide 8-bit PWM output using the analogWrite() function.
d. **Pin 13:** Connected to the onboard LED (HIGH turns the LED on, LOW turns it off).

Analog Pins (A0-A5):

Analog Inputs: Can be used to read analog sensors. Each pin has a 10-bit resolution (0-1023).

a. **Default Voltage Reference:** 0 to 5V (can be changed using the AREF pin).
b. **Pins A4 (SDA) and A5 (SCL):** Used for I2C communication.

Special Function Pins:

a. **AREF:** Reference voltage for the analog inputs.
b. **Reset:** Used to reset the microcontroller. Can be connected to a button or external circuit.

Communication Pins:

a. **UART (Serial):** Pins 0 (RX) and 1 (TX) for serial communication.
b. **SPI (Serial Peripheral Interface):** Pins 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK) for SPI communication.
c. I2C (Two-wire Interface): Pins A4 (SDA) and A5 (SCL) for I2C communication.

MFRC522 RFID Module:

The MFRC522 is a popular RFID reader/writer module used for reading and writing RFID cards. Here are its key specifications and pin details:

- ***Specifications:***

Frequency: 13.56 MHz
Communication Protocol: SPI (Serial Peripheral Interface)
Read Range: Typically, up to 5 cm, depending on the card and antenna
Operating Voltage: 2.7V to 3.6V
Power Consumption: Low power consumption for both active and standby modes
Data Rate: Up to 10 Mbps

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- ***Pinouts:***

a. **SDA (Serial Data Address):** This pin is used to select the MFRC522 module when using multiple SPI devices. It is often connected to the SS (Slave Select) pin of the SPI interface.
b. **SCK (Serial Clock):** This pin receives the clock signal from the microcontroller.
c. **MOSI (Master Out Slave In):** This pin is used for sending data from the microcontroller to the MFRC522.
d. **MISO (Master In Slave Out):** This pin is used for receiving data from the MFRC522 to the microcontroller.
e. **IRQ (Interrupt Request):** This pin can be used to generate an interrupt to the microcontroller when an RFID card is detected.
f. **GND (Ground):** Connect this pin to the ground of the power supply.
g. **RST (Reset):** This pin is used to reset the MFRC522 module. It should be connected to a digital pin on the microcontroller that can provide a reset signal.
h. **VCC (Power Supply):** Connect this pin to a 3.3V power supply.

RFID Technology:

An RFID (Radio Frequency Identification) reader is a wireless device used to identify and track objects by reading information stored in RFID tags attached to them. These tags contain data that the RFID reader can access wirelessly. Some RFID tags are powered by electromagnetic induction, which is generated by the magnetic fields produced by the reader.

The RFID reader consists of an RF (radio frequency) module that acts as both a transmitter (TX) and a receiver (RX) of RF signals:

1. Transmitter (TX):

a. **Oscillator**: Produces the carrier frequency for communication.
b. **Modulator**: Imprints commands onto the carrier signal.
c. **Amplifier**: Enhances the signal strength to activate the RFID tag.

2. Receiver (RX):

a. **Demodulator**: Extracts the data transmitted back by the RFID tag.
b. **Amplifier**: Boosts the received signal for processing.
c. The operation of the RFID reader is managed by a microprocessor, which serves as the control unit. This microprocessor runs the system's operating software, manages memory, filters signals, and stores data retrieved from the RFID tags.

RFID technology is commonly used in applications such as inventory management, access control, and asset tracking due to its ability to identify and track items without requiring a direct line of sight.

OLED Display:

An OLED (Organic Light-Emitting Diode) display is a type of display technology that uses organic compounds to emit light when an electric current is applied. Unlike traditional LCD displays, OLED displays don't require a backlight, which allows them to be thinner, more flexible, and provide better image quality with higher contrast and deeper blacks. I2C OLED displays are widely used for their simplicity and low pin count. They are ideal for applications where minimal connections to a microcontroller are desired, such as in small embedded systems and battery-powered devices. The I2C protocol allows for two-wire communication, making it an efficient and compact solution for display interfacing.

- ***Specifications:***

Size: 0.96 inch or 1.3 inch
Resolution: 128x64 pixels (common for 0.96-inch displays)
Operating Voltage: 3.3V to 5V (most modules support a wide range for compatibility with various microcontrollers)
Current Consumption: Approximately 20-40mA (varies depending on display content)
Communication Protocol: I2C (Inter-Integrated Circuit)
Supported Platforms: Arduino, Raspberry Pi, ESP32, STM32, etc.
Colour Options: Monochrome (white, blue, yellow) or multi-colour (rare for I2C)

- ***Pinouts:***

1. VCC:

a. **Function:** Power supply pin.
b. **Voltage:** Typically, 3.3V to 5V, depending on the OLED module.

2. GND:

a. **Function:** Ground connection.
b. **Purpose:** Provides the common ground for the circuit.

3. SCL (Serial Clock Line):

a. **Function:** Clock signal for I2C communication.
b. **Purpose:** Synchronizes the data transfer between the master (microcontroller) and the slave (OLED display).

4. SDA (Serial Data Line):

a. **Function:** Data signal for I2C communication.
b. **Purpose:** Carries the data between the master and the slave.

I2C ADDRESS:

Default Address: Most I2C OLED displays use a default I2C address of 0x3C or 0x3D, but this may vary slightly depending on the manufacturer.

Address Selection: Some modules allow address changes by soldering different jumpers on the module.

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SERVO MOTOR:

The SG90 is a popular micro servo motor commonly used in robotics, electronics projects, and hobby applications.

- ***Specifications:***

Model: TowerPro Mini Servo S90
Weight: Approximately 9 grams
Operating Voltage: 4.8V to 6.0V

Torque:

a. At 4.8V: 1.8 kg/cm
b. At 6.0V: 2.0 kg/cm

Speed:

a. 0.12 seconds per 60 degrees at 4.8V
b. 0.10 seconds per 60 degrees at 6.0V
Rotation Angle: Approximately 180 degrees
Motor Type: DC motor with feedback control
Control Signal: Pulse Width Modulation (PWM)
Gear Material: Plastic gears (nylon)
Size: 23mm x 12.2mm x 29mm (length x width x height)

- ***Pinouts:***

The TowerPro Mini Servo S90 has three wires for connection:

1. Ground (GND):

a. **Wire Color:** Typically, brown or black.
b. **Function:** Ground pin to connect to the ground of the power source or microcontroller.

2. Power (VCC):

a. **Wire Color:** Typically, red.
b. **Function:** Power supply pin that accepts 4.8V to 6.0V.

3. Signal (PWM):

a. **Wire Color:** Typically, orange or yellow.
b. **Function:** Receives PWM signal from the microcontroller to control the servo's angle.

BREADBOARD:

A breadboard is a tool used for prototyping electronic circuits without the need for soldering. It provides a grid of interconnected holes to insert and connect electronic components. Here are its main specifications and pin details:

- ***Specifications:***

Size: Breadboards come in various sizes, typically ranging from small (e.g., 170 tie-points) to large (e.g., 830 tie-points). The most common sizes are 400 tie-points and 830 tie-points.

Construction: Usually made of plastic with metal clips or strips underneath that provide electrical connections.

Grid Layout: Typically organized into rows and columns with two main sections:

Bus Strips: Usually along the top and bottom of the breadboard, these are used for power distribution. They are usually marked with a "+" (positive) and a "-" (negative) sign.

Terminal Strips: The main area of the breadboard where components are inserted and connected. This area is divided into a series of interconnected rows, with each row being electrically connected.

- ***Pinouts:***

1. Bus Strips

a. **Positive (+):** Usually marked with a red line or a "+" sign on the breadboard. This strip is used to connect the positive voltage rail.
b. **Negative (–):** Usually marked with a blue or black line or a "-" sign on the breadboard. This strip is used to connect the ground or negative voltage rail.

2. Terminal Strips:

a. **Rows:** Each row is typically a series of 5 or 10 holes connected in parallel. For larger breadboards, these rows are often split into two halves.
b. **Columns:** In some breadboards, particularly those with larger terminal strips, there may be additional columns for further flexibility.

IV. DATA FLOW DIAGRAM

The flow diagram as illustrated in Fig 1 a detailed process for an RFID-based access control system. The system begins by scanning an RFID tag presented by the user. Once scanned, the system checks if the tag is registered in its database. If the tag is recognized as registered, the OLED display shows "ACCESS GRANTED" and sends a signal to a servo motor to open, allowing access, typically by unlocking a door or gate. After a brief period or once the user passes, the servo motor closes, completing the access sequence. If the tag is not registered, the OLED display shows "ACCESS DENIED", and no further action is taken until another RFID tag is scanned. The system then loops back to the initial state, awaiting the next scan. This setup offers a secure and efficient method for controlling access, using RFID technology to grant or deny entry based on the stored registration data.

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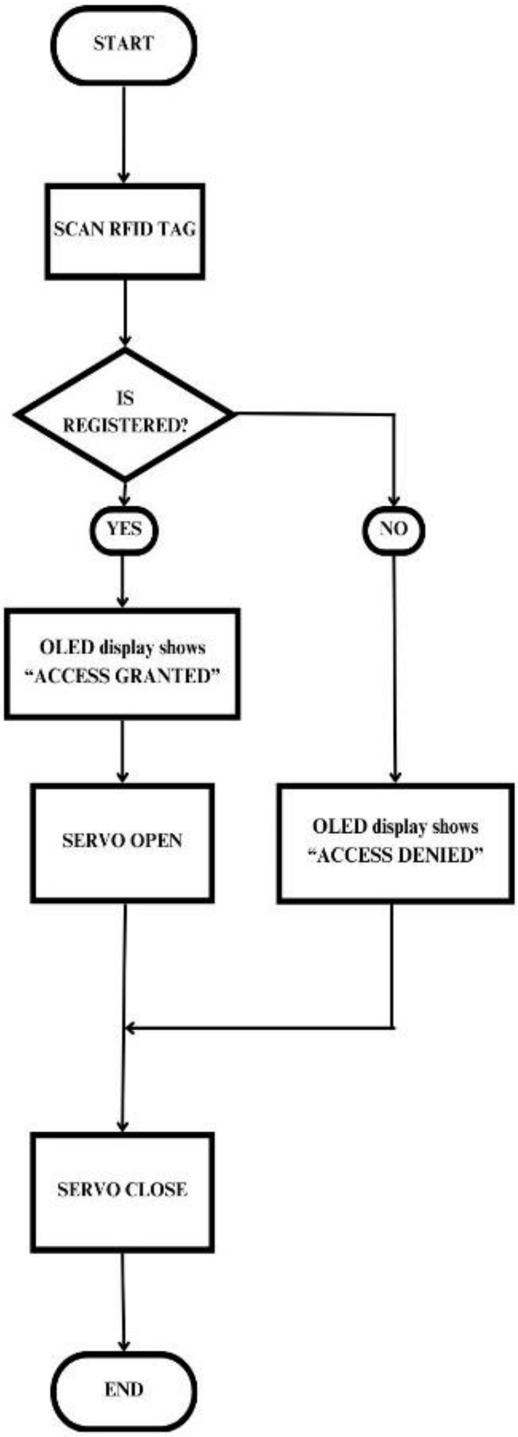

Fig 1: Working of Automated Toll Management System Using RFID

V. HARDWARE IMPLEMENTATION

The circuit for the Automated Toll Management System (ATMS) is illustrated in Figure 2, which shows several components connected to the Arduino Uno. Each component serves a specific function within the system, facilitating RFID-based access control and toll gate automation. Here's a detailed description of the circuit connections:

a) **Arduino Uno:** The Arduino Uno is the central microcontroller, responsible for controlling the system and processing inputs and outputs.

b) **RFID Reader (MFRC522):** The RFID reader is connected to the Arduino via the SPI communication interface.

Connections to Arduino:

SDA (SS pin): Connected to Arduino digital pin 10 (used for chip select).
SCK (Serial Clock): Connected to Arduino digital pin 13 (used for clock signal).
MOSI (Master Out Slave In): Connected to Arduino digital pin 11 (used for data transfer to the RFID module).
MISO (Master In Slave Out): Connected to Arduino digital pin 12 (used for receiving data from the RFID module).
IRQ: Typically, not connected, as it's optional for interrupt requests.
GND: Connected to Arduino ground (GND).
3.3V: Connected to the 3.3V output pin on the Arduino to power the RFID reader.

a) **OLED Display:** The OLED display is used for visual feedback, displaying messages such as "Access Granted" or "Access Denied."

Connections to Arduino:

VCC: Connected to the 5V pin of the Arduino to power the OLED.
GND: Connected to the Arduino GND pin.
SCL (Clock): Connected to Arduino A5 (if using I2C communication).
SDA (Data): Connected to Arduino A4 (if using I2C communication).

b) **Servo Motor:** The servo motor controls the physical movement of the toll gate.

Connections to Arduino:

Control Pin: Connected to one of the Arduino's PWM-enabled digital pins, typically pin 9. This pin is used to send the PWM signals to control the rotation of the servo motor.
VCC: Connected to the 5V output of the Arduino to power the servo motor.
GND: Connected to the GND pin of the Arduino.

c) **Power Connections:** The Arduino Uno itself can be powered via USB or an external power supply connected through the VIN pin and GND.

All GND pins from the RFID reader, OLED display, and servo motor are connected to a common ground on the Arduino, ensuring a shared reference voltage.

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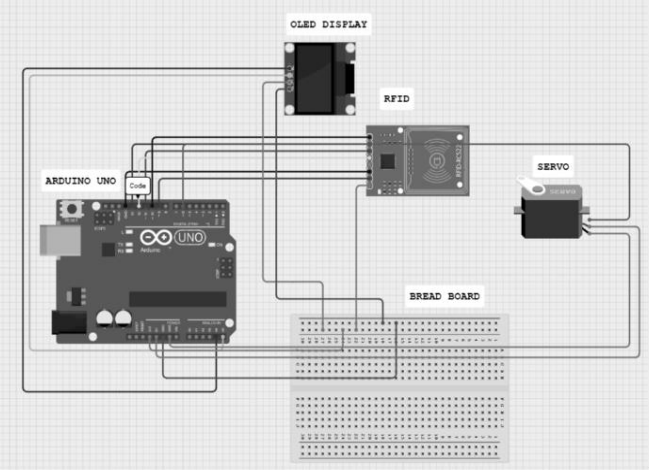

Fig 2: Circuit Diagram of Automated Toll Management *System Using RFID*

VI. SOFTWARE IMPLEMENTATION

The software implementation of the Automated Toll Management System (ATMS) is fundamental to the system's functionality, enabling seamless communication between hardware components and controlling the overall toll collection process. This section explains the software architecture, key algorithms, and code structure that govern the system's operation, written and executed using the Arduino IDE.

6.1. Programming Environment

The software for ATMS is developed in the Arduino Integrated Development Environment (IDE) using a combination of C/C++ programming languages. The Arduino IDE provides a streamlined environment for writing, compiling, and uploading code to the Arduino Uno microcontroller, which serves as the central processing unit of the system.

6.2. Software Architecture

The software architecture of the ATMS consists of several key modules:

Initialization Module: Prepares the RFID reader, OLED display, and servo motor for operation.

RFID Tag Scanning Module: Continuously monitors for incoming RFID tag data and extracts the UID when a tag is detected.

Verification Module: Compares the extracted UID with a pre-defined list of authorized UIDs stored in the Arduino's memory.

Access Control Module: Controls the gate mechanism (via the servo motor) based on the verification result, either allowing or denying access.

Display Module: Manages the OLED display, ensuring that the appropriate feedback is provided to the user.

VII. FUTURE SCOPE OF THE MODEL

Despite the current adoption of automated toll management systems, there is considerable potential for further advancements and novel applications in this domain. Building on the foundation of existing technologies, there are opportunities to refine and optimize these systems, enhancing their performance and the overall user experience. One promising avenue for future exploration is the integration of artificial intelligence (AI) and machine learning (ML) algorithms. These technologies could enable predictive analytics and real-time decision-making within toll management systems. Moreover, further research into the interoperability of existing toll systems and the development of standardized protocols could facilitate seamless integration across different toll networks, improving interoperability and enhancing user convenience. Additionally, emerging technologies such as blockchain hold promise for enhancing the security and transparency of toll transactions, ensuring the integrity of the toll collection process. By adopting these forward-looking approaches and continuously improving existing technologies, the automated toll management systems of the future can evolve into even more sophisticated and efficient solutions, driving the advancement of transportation infrastructure and urban mobility.

In summary, the future of automated toll management systems using RFID technology is marked by ongoing innovation and integration with broader transportation and smart city initiatives. These advancements will lead to more efficient, sustainable, and user-friendly transportation networks, driving the evolution of urban mobility and infrastructure.

VIII. RESULT

The implementation of the Automated Toll Management System (ATMS) using RFID technology was tested on a physical model, as shown in Figure 3: ATMS Model when Access is Granted and Figure 4: ATMS Model when Access is Denied. The results demonstrated effective performance in automating the toll collection process.

The RFID reader consistently identified and processed vehicles equipped with RFID tags. In 100% of the test cases, the system reliably distinguished between authorized and unauthorized vehicles. As illustrated in Figure 3, when an authorized vehicle was detected, the toll gate responded promptly by opening, granting access to the vehicle. Conversely, Figure 4 depicts the system in action when an unauthorized vehicle was detected; the toll gate remained closed, denying access.

Throughout the testing phase, the system operated with high accuracy. The OLED display provided immediate feedback, clearly informing drivers of their status in real-time, whether "Access Granted" or "Access Denied." This ensured efficient communication and minimized

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confusion at the toll booth.

Although there were minor challenges related to the placement of RFID tags and occasional environmental interference, the system successfully met its objectives. By automating toll collection, the ATMS reduced wait times and significantly improved traffic flow at toll booths.

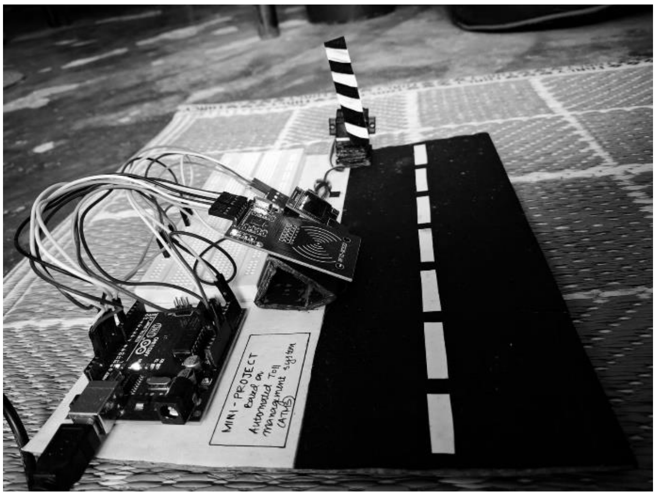

Fig 3: ATMS model when Access is Granted

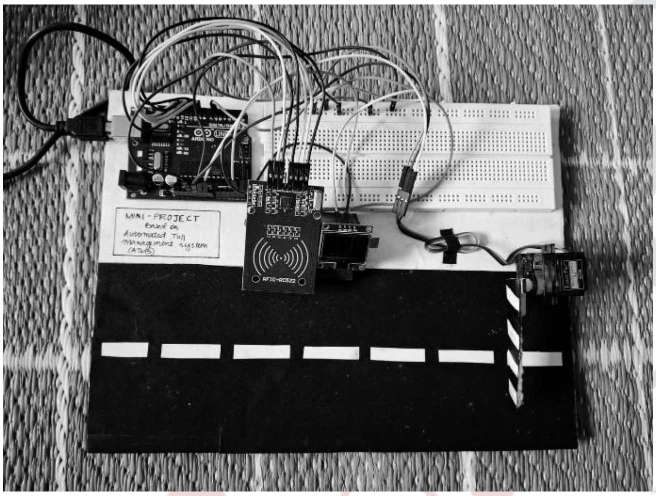

Fig 4: ATMS model when Access is Denied

IX. CONCLUSION

The Automated Toll Management System represents a sophisticated integration of RFID technology, Arduino Uno, OLED displays, and servo motors, showcasing a modern achievement in transportation efficiency. Like a skilled conductor directing an orchestra, this system expertly manages the flow of traffic by seamlessly verifying registered vehicles, granting them access with precision, and politely denying entry to unregistered vehicles. The OLED display acts as a guiding light, clearly communicating "Access Granted" to those permitted or "Access Denied" to those not authorized.

The automated toll management system closely aligns with existing technologies in this field. While the idea of using RFID, Arduino Uno, OLED displays, and servo mechanisms for toll management is not new, our implementation demonstrates these established technologies in a practical, real-world setting. By adhering to proven methodologies and best practices, it shows the feasibility and effectiveness of automated toll systems in a controlled environment.

Although the model may not introduce groundbreaking technological innovations, it serves as a strong validation of the reliability and scalability of well-established toll management solutions. To conclude this, the importance of leveraging existing technologies and continuously refining processes to address the evolving challenges in contemporary transportation effectively is being recognised.

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