A Project Report

On

Automated Vehicle Verification at Toll Plaza

By

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2024

CERTIFICATE

This is to certify that the project report titled 'Automated Vehicle Verification at Toll Plaza' has been carried out by Neel Patel and Meet Padaliya under the guidance of Dr. Amit Singh. The report is submitted in partial fulfillment of the requirements for the award of the degree of IOT Lab Project in the Department of Computer Science and Engineering at PDEU. This work is original and has not been submitted elsewhere for the award of any degree.

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ACKNOWLEDGEMENT

We would like to express our heartfelt gratitude to our supervisor, Dr. Amit Singh, for their invaluable guidance, support, and encouragement throughout the project. Their expertise was instrumental in overcoming challenges and refining our approach to achieving the project objectives.

We also extend our thanks to the faculty and staff of the Computer Science and Engineering, PDEU, for providing us with the necessary resources. Special thanks to our classmates for their constructive feedback and motivation during the course of this work.

ABSTRACT

The project, 'Automated Vehicle Verification at Toll Plaza' aims to revolutionize the traditional toll collection process by addressing its inefficiencies and limitations. Traditional toll collection methods, such as cash payments or manual verification, are often time-consuming, error-prone, and contribute to traffic congestion, causing inconvenience for commuters and higher operational costs for toll operators. To overcome these challenges, this project introduces an automated system that leverages cutting-edge technologies to enhance the efficiency, accuracy, and convenience of toll collection.

The proposed system utilizes vehicle number plate recognition technology to identify vehicles as they approach the toll plaza. Once a vehicle’s number plate is detected, it is automatically verified against a pre-existing database. Based on the verification, the toll amount is deducted seamlessly from a linked account associated with the vehicle. Additionally, the system sends a real-time notification to the vehicle owner via WhatsApp, providing transaction details such as the toll amount deducted, the remaining balance, and the time of the transaction. This ensures transparency and keeps vehicle owners informed.

The hardware implementation includes a Raspberry Pi as the core processing unit, a camera module to capture images of number plates, servo motors for controlling the toll barrier, and LEDs for status indication. The software components include OpenCV for image processing and number plate detection, Pytesseract for optical character recognition (OCR), and the Twilio API for WhatsApp notifications. These technologies work in unison to create a robust, automated toll verification and collection system.

This report details the objectives, methodology, implementation process, and results of the project. It highlights the potential of this system to streamline toll operations, reduce human intervention, and improve overall efficiency at toll plazas. By automating key processes, the system minimizes delays, enhances security, and sets a foundation for future advancements in toll infrastructure management.

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LIST OF SYMBOLS, ABBREVIATIONS AND NOMENCLATURE

API: Application Programming Interface

OCR: Optical Character Recognition

LED: Light Emitting Diode

GPIO: General Purpose Input Output

Chapter 1: INTRODUCTION

Toll plazas are essential components of transportation infrastructure, serving as key points for collecting revenue to maintain and develop roads and highways. They play a crucial role in ensuring that infrastructure costs are distributed fairly among vehicle owners who utilize these facilities. However, traditional toll collection methods have significant limitations. Systems that rely on manual verification of vehicles or cash transactions are not only labour-intensive but also prone to inefficiencies and errors. These issues result in prolonged wait times for commuters, leading to traffic congestion at toll booths. Furthermore, such outdated methods can contribute to inaccuracies in revenue collection and increase the operational costs associated with managing toll plazas.

To address these challenges, the *'Automated Vehicle Verification at Toll Plaza'* project introduces a modern, technology-driven solution. This innovative system leverages advanced vehicle number plate recognition technology to automatically detect vehicles as they approach the toll plaza. Instead of relying on human operators or manual input, the system processes the number plate, verifies it against a pre-existing database, and ensures seamless toll deduction from the vehicle owner’s linked account.

In addition to automating the toll collection process, the system incorporates real-time communication technologies to keep vehicle owners informed. Upon successful transaction, a notification is sent via WhatsApp, providing details such as the amount deducted and the current balance. This not only enhances transparency but also adds convenience for vehicle owners, ensuring they are updated about their payments immediately. By automating these key functions, the project eliminates delays, reduces the need for human intervention, and significantly improves the efficiency and accuracy of toll operations.

Chapter 2: OBJECTIVES

Automate Vehicle Verification:

One of the primary objectives of this project is to eliminate the need for manual verification at toll plazas by implementing a fully automated vehicle recognition system. The system employs advanced computer vision techniques to detect and recognize vehicle number plates accurately. By utilizing technologies such as OpenCV and trained classifiers, the system captures real-time images of approaching vehicles and processes them to identify the registration number. This automated approach ensures higher accuracy and consistency compared to manual methods, reducing human error and enabling faster verification. Additionally, automation streamlines the flow of traffic at toll plazas, minimizing delays and improving the overall user experience.

Efficient Toll Collection:

To enhance the toll collection process, the project integrates a system that automatically links detected vehicle number plates to pre-registered accounts associated with their owners. This ensures that toll amounts are deducted seamlessly and accurately from the owner's digital wallet or linked payment system. The automated deduction mechanism eliminates the need for cash transactions or physical toll passes, reducing the time spent at toll booths and improving transaction efficiency.

Real-Time Notifications:

Transparency and user awareness are integral parts of the project. The system is designed to provide immediate feedback to vehicle owners by sending real-time notifications through WhatsApp. After every successful transaction, the system sends a message detailing the toll amount deducted, the vehicle's registration number, and the updated account balance. In cases where the account balance is insufficient, the system notifies the owner with a low-balance alert, prompting them to top up their account. This feature not only keeps users informed but also builds trust in the system by ensuring clear and instant communication about every transaction.

Chapter 3: IMPLEMENTATION

The system for *'Automated Vehicle Verification at Toll Plaza'* is designed using a carefully selected combination of hardware and software tools, each contributing to the seamless operation and functionality of the project. Below is an expanded explanation of the components and their roles:

Hardware Components:

Raspberry Pi:
Acting as the central processing unit, the Raspberry Pi is responsible for orchestrating all operations of the system. It processes data from the camera module, runs the image recognition algorithms, and communicates with other hardware components like LEDs and servo motors. Its compact size, low power consumption, and versatility make it ideal for this application.

Camera Module:
A high-resolution camera module is used to capture images of the vehicles approaching the toll booth. The camera ensures that the number plates are clearly visible and the captured images are of sufficient quality for the image processing algorithms to work effectively. Proper placement and angle of the camera are crucial for accurate detection.

Servo Motors:
Servo motors control the movement of the toll barrier. Upon successful verification of a vehicle's number plate and confirmation of toll payment, the servo motor lifts the barrier, allowing the vehicle to pass. After a short delay, the motor resets the barrier to its original position. This automation eliminates the need for manual operation.

LEDs:
LEDs are used as visual indicators to display the status of the verification process. For example, a green LED lights up when a vehicle is authorized to pass, while a red LED indicates an issue such as insufficient balance or unregistered vehicles. These indicators provide real-time feedback to drivers.

Supporting Components:
Components like breadboards, jumper wires, and resistors are used to connect and stabilize the hardware setup. These components ensure reliable communication between the Raspberry Pi and other hardware elements.

Software Tools:

OpenCV (Open Source Computer Vision Library):
OpenCV is a powerful library used for image processing and analysis. It is employed in this project for detecting and isolating the vehicle's number plate from the captured images. Techniques such as edge detection, contour finding, and Haar Cascade classifiers enable the system to identify the plate region effectively.

Pytesseract (Python-tesseract):
Pytesseract is an Optical Character Recognition (OCR) tool that extracts text from images. After detecting the number plate, Pytesseract processes the plate image to convert the characters into machine-readable text. Preprocessing techniques like noise reduction, thresholding, and contrast enhancement are applied to improve the accuracy of the OCR output.

Twilio API:
The Twilio API is integrated into the system for sending real-time WhatsApp notifications to vehicle owners. Notifications include details about the transaction, such as the toll amount deducted, the vehicle's registration number, and the updated wallet balance. In cases where the balance is insufficient, alerts are sent to prompt users for account top-up.

RPi.GPIO (Raspberry Pi GPIO Library):
RPi.GPIO is a Python library that allows control over the General Purpose Input/Output (GPIO) pins of the Raspberry Pi. In this project, it is used to interact with hardware components like LEDs and the servo motor. For instance, the GPIO pins control the rotation of the servo motor to lift or lower the barrier and toggle the LEDs based on the verification result.

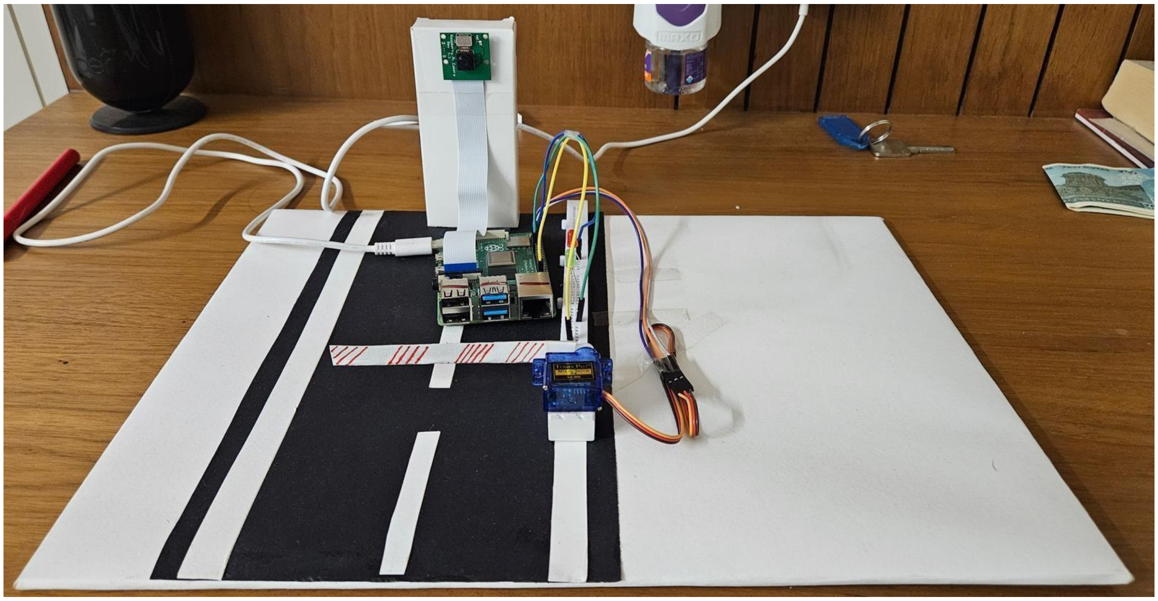


Fig 1. Hardware Setup

Procedure:

Image Capture: The camera module captures an image of the vehicle as it approaches the toll plaza. The captured image is saved temporarily for processing.

License Plate Detection: The saved image is loaded, and the number plate is detected using a Haar Cascade Classifier from the OpenCV library. The image is converted to grayscale and processed to identify the number plate region accurately.

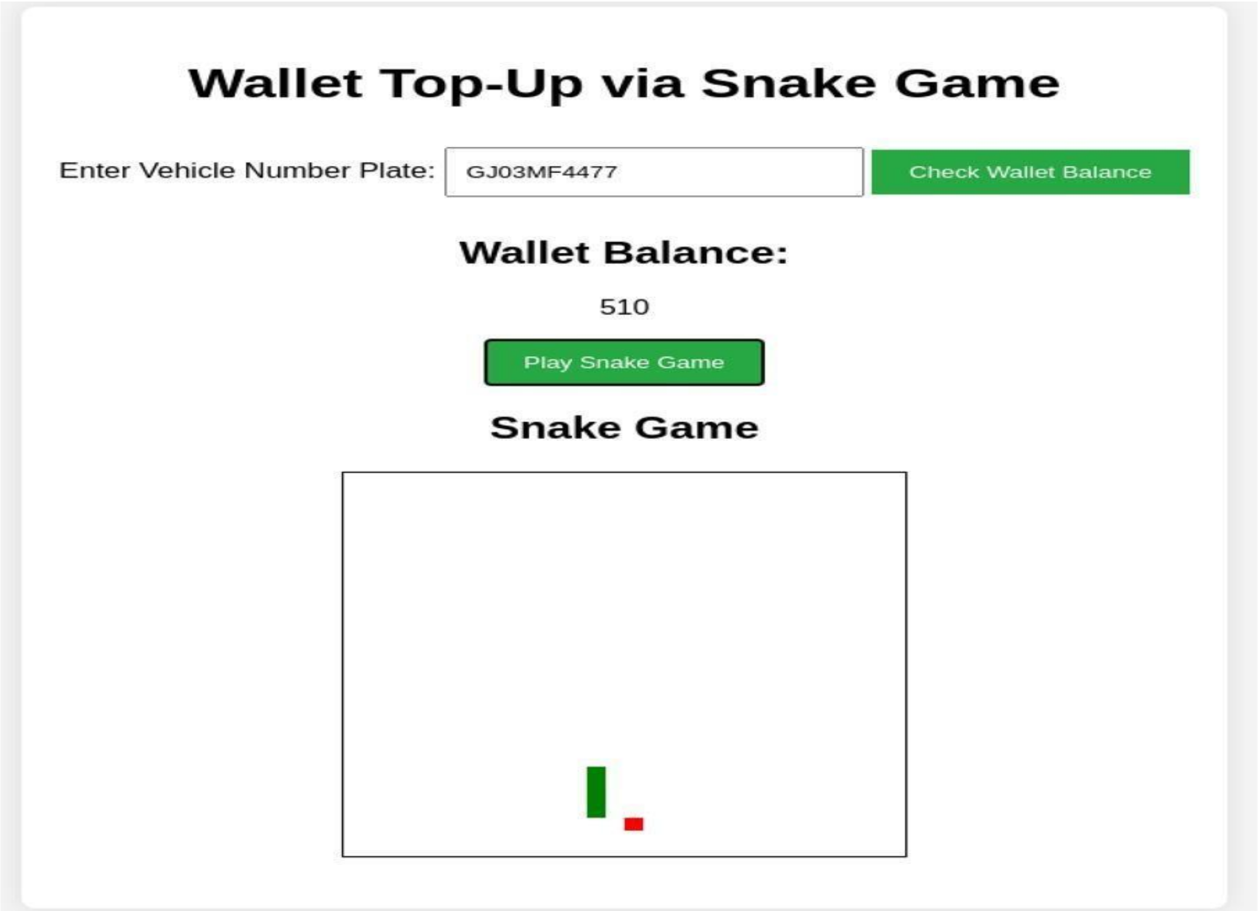
Text Extraction from Number Plate: The detected number plate is extracted and converted to text using Pytesseract. Pre- processing techniques like noise reduction and thresholding are applied to improve OCR accuracy. The extracted text is cleaned and formatted for further processing.

Database Verification: The extracted number plate text is compared with a pre-existing database stored in a JSON file. The database contains information about registered vehicles, including wallet balance and the owner's phone number. A fuzzy matching technique is used to handle minor discrepancies in the OCR output, ensuring reliable identification.

Wallet Balance Check and Toll Deduction: If the vehicle's number plate matches an entry in the database, the system checks the wallet balance. If the balance is sufficient, the toll amount is deducted, and the updated balance is saved back to the database. If the balance is insufficient or the vehicle is unregistered, appropriate actions are taken.

Controlling LEDs and Servo Motor: The LEDs are controlled based on the verification result. The green LED lights up if the vehicle is authorized, and the red LED lights up otherwise. The servo motor rotates to lift the barrier if the vehicle is allowed to pass. The motor returns the barrier to the closed position after a short delay.

WhatsApp Notification: Using the Twilio API, the system sends a real-time WhatsApp message to the vehicle owner. The message includes details about the transaction, such as the number plate, toll amount deducted, and remaining balance. In case of insufficient funds, a notification is sent alerting the owner of the low balance.



Wallet Top-Up via Snake Game

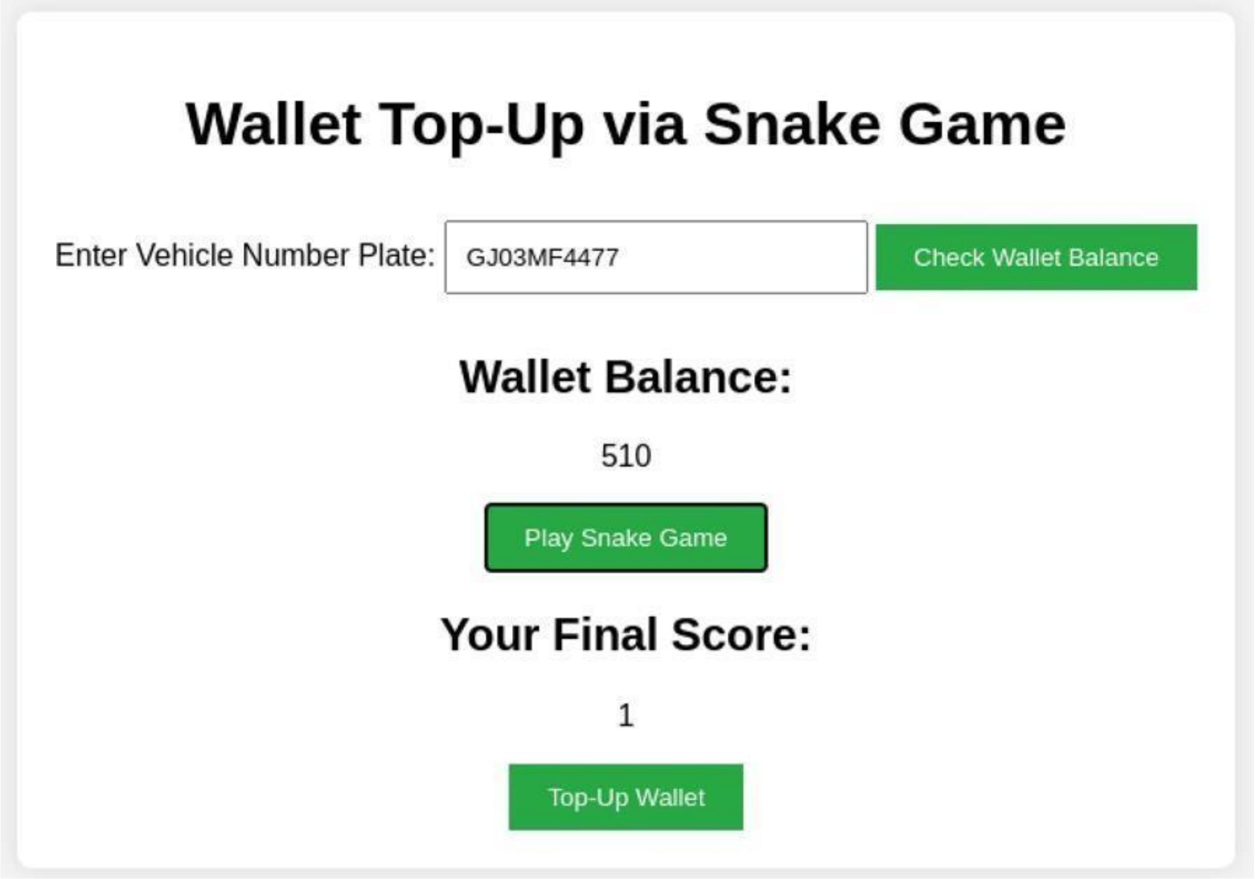
Enter Vehicle Number Plate: GJ03MF4477

Wallet Balance:

510

Snake Game

Fig 2. Wallet Topup



Wallet Top-Up via Snake Game

Enter Vehicle Number Plate: GJ03MF4477

Wallet Balance:

510

Your Final Score:

1

Fig 3. Final wallet balance

The Snake Game serves as an engaging and gamified method for topping up the toll wallet in the Automated Vehicle Verification at Toll Plaza system. Implemented using Python and the Pygame library, the game allows users to control a snake that grows as it consumes food, with the player's score determining the wallet top-up amount. For example, a predefined conversion rate (e.g., 1 point = ₹1) translates the player's score into a corresponding monetary credit to their wallet. At the end of the game, the system calculates the top-up amount based on the score and updates the wallet in real-time, with a confirmation sent via WhatsApp. This interactive approach not only makes the top-up process enjoyable but also encourages user participation and engagement.

Chapter 4: RESULTS AND DISCUSSION

The system was rigorously tested under a variety of conditions to assess its performance, reliability, and effectiveness in real-world scenarios. The testing focused on three key aspects: the detection and processing of vehicle number plates, the accuracy of toll deductions, and the transparency achieved through real-time notifications. Additionally, the testing highlighted certain limitations that provide insights into areas for future improvement.

1. Successful Detection of Vehicle Number Plates:

The system demonstrated a high success rate in detecting vehicle number plates under normal conditions. The camera module, paired with OpenCV, efficiently captured and processed images of approaching vehicles. The detection algorithm reliably isolated the number plate from the image, even in cases where plates were not perfectly centered. This ensured that the subsequent steps, such as text extraction using Pytesseract, could proceed smoothly.

However, the system's performance was influenced by external factors such as:

Lighting Conditions: Bright daylight provided optimal conditions for image capture, resulting in higher detection accuracy. Conversely, low-light scenarios or nighttime operation required additional lighting to maintain performance.

Angle and Distance: The camera placement was optimized to ensure that the number plate was within the field of view and aligned correctly, avoiding skewed or blurry captures.

These results confirm the robustness of the detection system under most controlled conditions, providing confidence in its deployment at toll plazas.

2. Accurate Toll Deductions in Real-Time:

Once the vehicle number plate was successfully detected and recognized, the system accurately verified the extracted number against a pre-registered database. The system was able to identify registered vehicles and deduct the appropriate toll amount from their linked accounts. Update the wallet balance in real time and record the transaction in the system database.

This automation eliminated delays associated with manual toll collection methods, streamlining the process and reducing the time vehicles spent at the toll booth. Real-time deductions also ensured that all transactions were recorded accurately without discrepancies, contributing to the financial integrity of the system.

3. Notifications Sent to Vehicle Owners:

Transparency is a critical feature of the project, and the system successfully sent real-time WhatsApp notifications to vehicle owners. Notifications included details of the toll transaction, such as the amount deducted, the vehicle’s number plate, and the updated wallet balance and alerts for low balances, prompting users to recharge their accounts for uninterrupted service.

This feature not only kept vehicle owners informed but also increased trust in the system by providing immediate and clear communication. The use of the Twilio API ensured reliability and swift delivery of messages.

4. Limitations Identified:

Despite its successes, the system faced challenges that affected performance under certain conditions:

OCR Accuracy: The Pytesseract-based OCR struggled with plates that were dirty, damaged, or had complex fonts. Such issues occasionally led to errors in text recognition, requiring manual intervention or additional preprocessing steps to correct the output.

Poor Lighting Conditions: Insufficient lighting during nighttime operations or in tunnels reduced image clarity, affecting the detection and recognition process. External light sources, such as infrared or LED illumination, were tested as potential solutions.

Plate Variations: Variations in plate designs, including reflective coatings, unusual fonts, and non-standard sizes, posed additional challenges for accurate detection and text extraction.

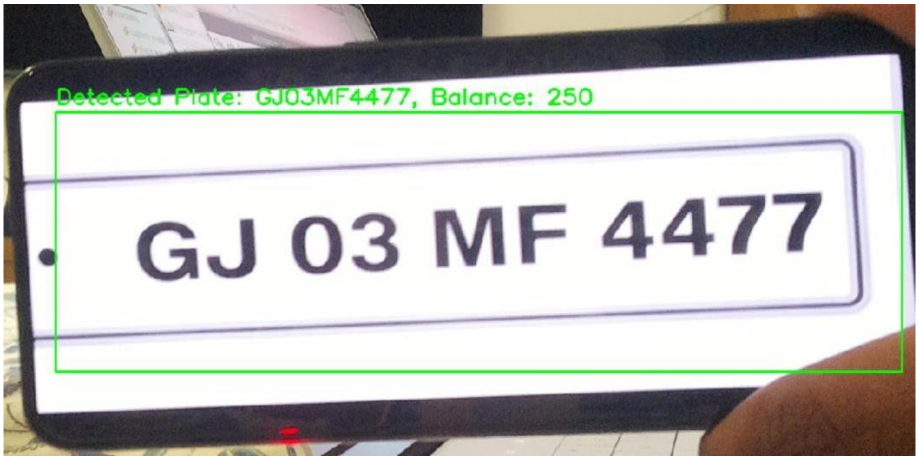


Fig 4. Registered Number Plate-1

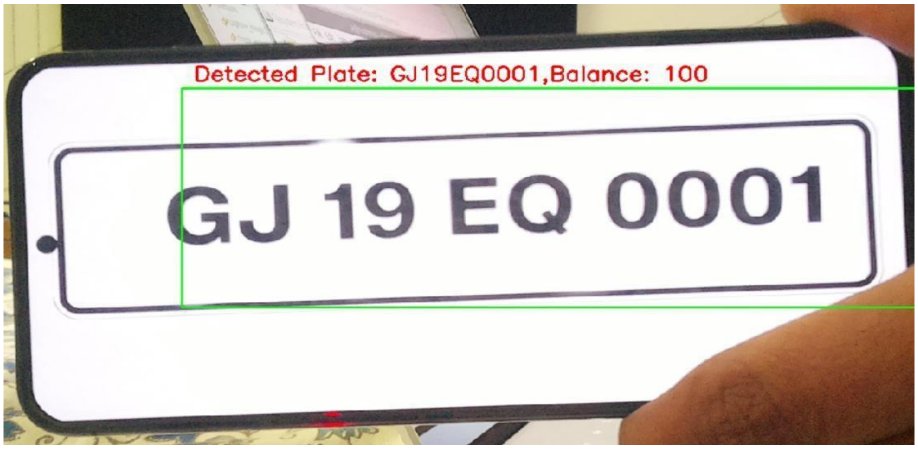


Fig 5. Registered Number Plate-2

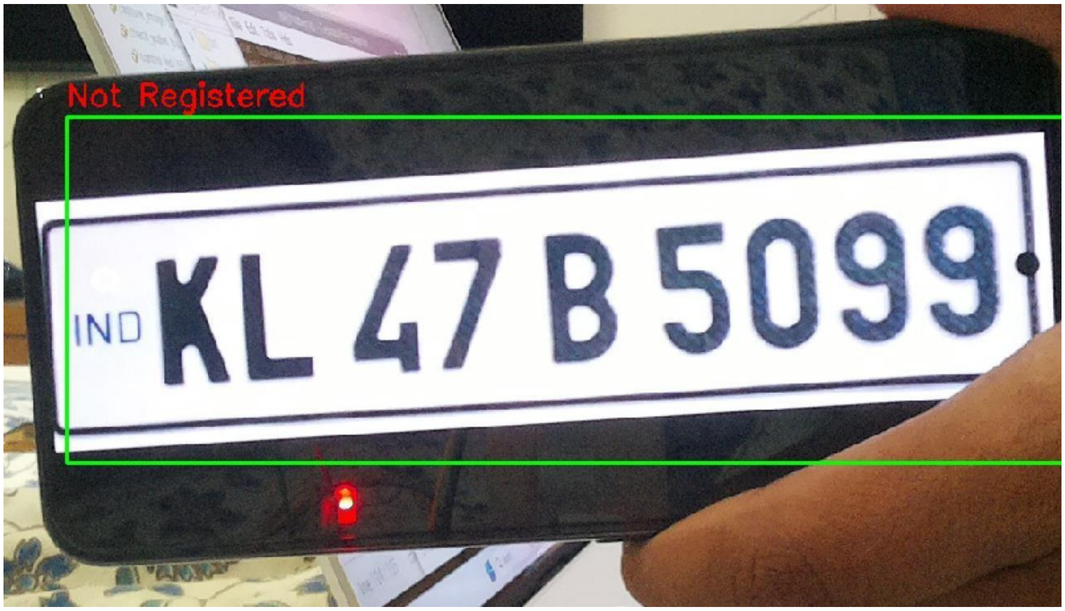
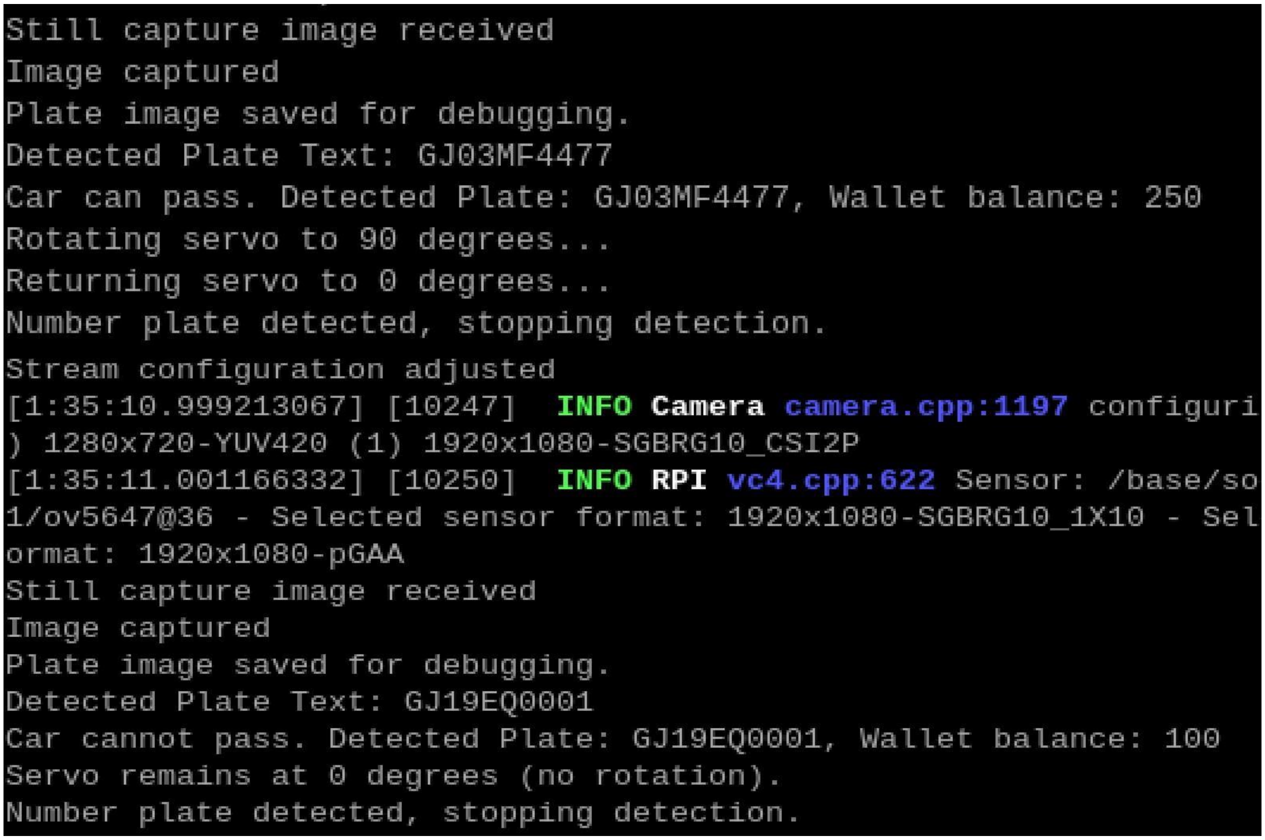
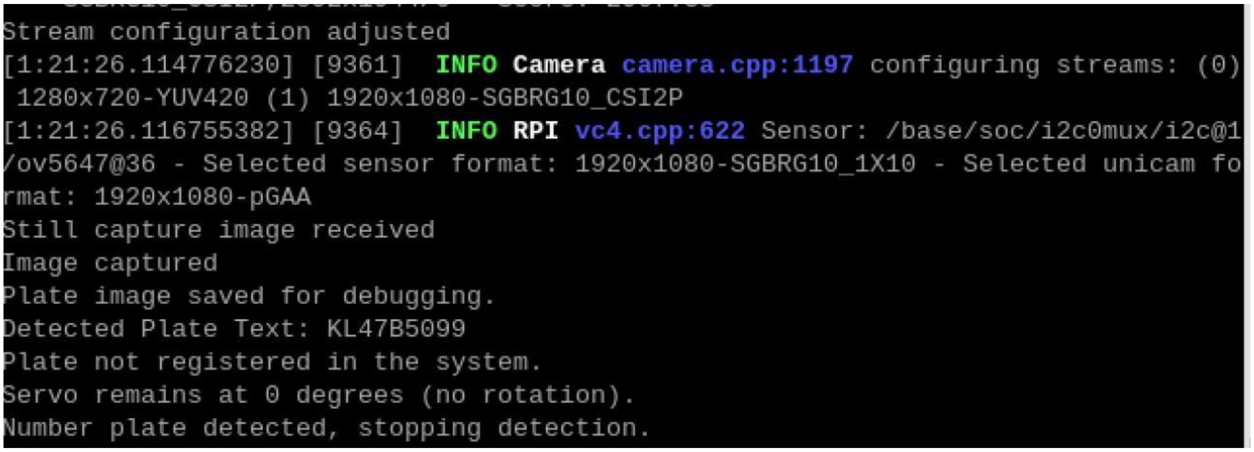


Fig 6. Unregistered Number Plate-1



```
Still capture image received
Image captured
Plate image saved for debugging.
Detected Plate Text: GJ03MF4477
Car can pass. Detected Plate: GJ03MF4477, Wallet balance: 250
Rotating servo to 90 degrees...
Returning servo to 0 degrees...
Number plate detected, stopping detection.
Stream configuration adjusted
[1:35:10.999213067] [10247]  INFO Camera camera.cpp:1197 configuri
) 1280x720-YUV420 (1) 1920x1080-SGBRG10_CSI2P
[1:35:11.001166332] [10250]  INFO RPI vc4.cpp:622 Sensor: /base/so
1/ov5647@36 - Selected sensor format: 1920x1080-SGBRG10_1X10 - Sel
ormat: 1920x1080-pGAA
Still capture image received
Image captured
Plate image saved for debugging.
Detected Plate Text: GJ19EQ0001
Car cannot pass. Detected Plate: GJ19EQ0001, Wallet balance: 100
Servo remains at 0 degrees (no rotation).
Number plate detected, stopping detection.
```



```
Stream configuration adjusted
[1:21:26.114776230] [9361]  INFO Camera camera.cpp:1197 configuring streams: (0)
 1280x720-YUV420 (1) 1920x1080-SGBRG10_CSI2P
[1:21:26.116755382] [9364]  INFO RPI vc4.cpp:622 Sensor: /base/soc/i2c0mux/i2c@1
/ov5647@36 - Selected sensor format: 1920x1080-SGBRG10_1X10 - Selected unicam fo
rmat: 1920x1080-pGAA
Still capture image received
Image captured
Plate image saved for debugging.
Detected Plate Text: KL47B5099
Plate not registered in the system.
Servo remains at 0 degrees (no rotation).
Number plate detected, stopping detection.
```

Fig 7. Terminal Output

Chapter 5: CONCLUSION AND FUTURE WORK

The ″Automated Verification at Toll Plaza″ project successfully demonstrates how automation can streamline toll collection processes by integrating computer vision and real-time communication technologies. By using a Raspberry Pi to capture and process vehicle number plates, the system ensures accurate verification, seamless toll deductions, and instant notifications to vehicle owners via WhatsApp. This approach eliminates the need for manual verification and cash transactions, significantly reducing traffic congestion and operational delays at toll plazas. Despite encountering challenges such as variations in image quality and OCR inaccuracies, the project has proven to be a reliable and scalable solution for modernizing toll infrastructure, enhancing both efficiency and user experience.

To further improve the system in future, several enhancements can be pursued:

Improved OCR Accuracy: Implementing advanced machine learning algorithms to handle diverse plate designs, poor lighting conditions, and dirty or damaged plates.

Integration with National Databases: Linking the system with government databases to verify vehicle registration and streamline the identification process.

Mobile Application Development: Developing a user-friendly mobile app for vehicle owners to manage their accounts, view transaction history, and top up wallets conveniently.

Scalability: Optimizing the system to handle higher traffic volumes and simultaneous transactions for deployment in larger toll networks.

Advanced Analytics: Introducing data analytics capabilities to generate insights on traffic patterns and toll collection efficiency, aiding in infrastructure planning and management.

Multi-Language Notifications: Expanding real-time notifications to support multiple languages for better accessibility across diverse user demographics.

APPENDIX

DECLARATION

I hereby declare that the project report entitled “Automated Verification at Toll Plaza” is the result of my own work and has been written by me. This report has not utilized any language model or natural language processing artificial intelligence tools for the creation or generation of content, including the literature survey.

The use of any such artificial intelligence-based tools was strictly confined to the polishing of content, spellchecking, and grammar correction after the initial draft of the report was completed. No part of this report has been directly sourced from the output of such tools for the final submission.

This declaration is to affirm that the work presented in this report is genuinely conducted by me and to the best of my knowledge, it is original.

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List of Tools Used for the Report with Purpose:

For example,

- **ChatGPT: Polishing the text.**
- **Grammarly: Correcting the grammar.**

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