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JAIN INSTITUTE OF TECHNOLOGY

Davanagere-577003, KARNATAKA

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

FINAL YEAR B.E. (2025-2026)

A MAJOR PROJECT ON

"AI-Powered Real-Time Smart Vehicle Access and License Plate Recognition System for Campus Security"

UNDER THE GUIDANCE OF

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CERTIFICATE

This is to certify that the Major Project report entitled **"AI-Powered Real-Time Smart Vehicle Access and License Plate Recognition System for Campus Security"** carried out by **Abhishek K H (4JD22EC002), Manoj S (4JD22EC032), Manoja K J (4JD22EC033), Prajwal N Y (4JD22EC037)** are Bonafide students of **Bachelor of Engineering in Electronics and Communication** of the **Visvesvaraya Technological University, Belagavi** during the year 2025-2026.

It is certified that all corrections/suggestions indicated for internal assessment have been in corporate corporations in the report deposited in the departmental library. The Major Project report has been approved as satisfies the academic requirements in respect of Major project work prescribed for the Bachelor of Engineering degree.

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DECLARATION

We, **Mr. ABHISHEK K H (4JD22EC002), Mr. MANOJ S (4JD22EC032), Mr. MANOJA K J (4JD22EC033), Mr. PRAJWAL N Y (4JD22EC037)** students of **Final Year B.E. Electronics & Communication Engineering, Jain Institute of Technology, Davangere** hereby declare that the dissertation entitled "AI-Powered Real-Time Smart Vehicle Access and License Plate Recognition System for Campus Security" has been carried out in a batch and submitted in the partial fulfilment of the requirement for the award of bachelor's degree in Electronics & Communication Engineering under **Visvesvaraya Technological University Belagavi,** during the academic year **2025- 2026.**

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ABSTRACT

The AI-powered real-time smart vehicle access and license plate recognition system is an advanced automated security solution designed to verify and control vehicle entry without human intervention. A live camera continuously captures incoming vehicles, and their license plates are detected and recognized using computer vision and Optical Character Recognition (OCR) techniques. The extracted license plate number is compared against a pre-stored authorized vehicle database to determine access eligibility. If the vehicle is registered, the system activates a green LED, displays **“Vehicle Verified, Gate Opening…”** on a 16×2 LCD display, and triggers a servo motor to open the gate. Additionally, a confirmation SMS is automatically sent to the owner’s registered mobile number with the message: **“Welcome to Jain Institute of Technology Davangere. Your vehicle has been successfully verified and logged. Have a nice day!”**

If an unregistered vehicle is detected, the system activates a red LED along with a buzzer alarm, displays **“Unregistered Vehicle, Access Denied”** on the LCD, and keeps the gate closed. All detection events, including both authorized and unauthorized vehicles, are logged in a digital entry sheet containing vehicle number, date, time, and identification details. By integrating computer vision, embedded hardware control, and IoT-based real-time messaging, the system significantly reduces manual work, eliminates verification errors, strengthens security, and improves traffic flow efficiency. This solution is cost-effective, scalable, and suitable for deployment in campuses, gated communities, corporate offices, parking zones, and other secured entry environments.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

Security and automation are essential in modern infrastructures such as educational institutions, residential campuses, parking facilities, corporate buildings, and restricted zones. Traditional methods of verifying vehicle entry rely on manual checking, which is time-consuming, prone to human error, and inefficient during peak rush. To overcome these limitations, this project introduces an **AI-Powered Real-Time Smart Vehicle Access and License Plate Recognition System** that accurately identifies vehicle license plates using a live camera and Optical Character Recognition (OCR). The recognized plate number is automatically compared with the authorized vehicle database. If the vehicle is registered, the system activates the **green LED**, displays **"Vehicle Verified, Gate Opening…"** on the **LCD display**, opens the gate through a **servo motor**, and **sends a confirmation SMS to the vehicle owner's registered mobile number** indicating successful entry. Simultaneously, the event is stored in a **digital log file** with date and time for record-keeping.

On the other hand, if an unregistered vehicle is detected, the system triggers the **red LED**, activates a **buzzer alert**, displays **"Unregistered Vehicle, Access Denied"** on the LCD, prevents the gate from opening, and logs the unauthorized attempt. This automated smart access solution significantly reduces manual involvement, improves security accuracy, speeds up verification, and maintains real-time entry records. By integrating **AI-based computer vision**, **embedded hardware control**, and **IoT-based SMS communication**, the system provides a **reliable, scalable, and intelligent vehicle access control mechanism** suitable for campus environments, gated communities, office complexes, and other secured entry points.

1.1 PROBLEM STATEMENT

Security at campus entry gates traditionally depends on manual vehicle verification carried out by security personnel. This manual process is often slow, inconsistent, vulnerable to human error, and ineffective during high-traffic periods. Unauthorized vehicles may enter without proper validation, and maintaining accurate records of vehicle entries becomes difficult. Additionally, there is no automatic feedback or notification system for vehicle owners and no real-time mechanism to control physical access such as opening or closing gates based on verification results.

Therefore, there is a need for an **automated, intelligent, and real-time vehicle access control system** that can accurately recognize vehicle license plates, verify authorization instantly, manage physical access mechanisms, trigger alerts when unauthorized vehicles attempt entry, notify registered users, and maintain a secure and timestamped digital log of all vehicle activities. Such a system must be fast, efficient, user-friendly, and highly reliable to enhance both operational efficiency and campus security.

1.2 OBJECTIVES

- The **AI-Powered Real-Time Smart Vehicle Access and License Plate Recognition System** is designed to enhance security and automate vehicle entry verification with minimal human intervention.
- **Automatically detect and recognize** vehicle license plates in real time using **AI and OCR.**
- **Verify authorization** by matching detected plates with a **registered vehicle database.**
- **Automate gate control** — activate **green LED and open the gate (servo motor)** for registered vehicles.
- **Display live status** on the **LCD screen** for both registered and unregistered vehicles.
- **Trigger alerts** using **red LED** and **buzzer** for unregistered or unauthorized vehicles.
- **Send SMS notifications** to registered owners confirming successful entry.
- **Maintain digital logs** with date, time, and vehicle details for security auditing.
- Ensure the system is **scalable, reliable, and adaptable** for campuses, institutions, and gated communities.

1.3 MOTIVATIONS

Traditional vehicle verification systems still rely on **manual checking by security personnel**, which often results in **delays, human errors, and weak security control**. Maintaining paper-based entry logs is time-consuming and unreliable, especially during busy hours, leading to the risk of **unauthorized vehicle entry** and compromised safety. To ensure both **efficiency and security**, there is a strong need for a **real-time automated access system** that eliminates manual intervention while ensuring accurate and quick vehicle authentication.

The rapid advancement of **Artificial Intelligence (AI), Image Processing, and IoT-based automation** has made it possible to implement intelligent solutions capable of recognizing license plates instantly and making access decisions automatically. This motivated the creation of a **Smart Vehicle Access System** that not only detects and validates vehicles using OCR but also integrates **LED indicators, a buzzer alarm, LCD display notifications, and SMS alerts** for complete automation. This innovation bridges the gap between **manual gate control and smart security automation**, ensuring a **fast, reliable, and technology-driven vehicle verification process**

CHAPTER 2

LITERATURE SURVEY

In [1], Automatic License Plate Recognition (ALPR) using YOLOv5 Model and Tesseract OCR Engine by M. Kumar, A. Sharma, and P. Gupta (2023). Traffic control and identifying vehicle owners are significant national problems. It could be difficult to identify motorists who drive too quickly and in violation of the law. Since the vehicle's license plate could not be accessible to traffic authorities from a moving vehicle due to its speed, it is impossible to detain and punish those people. Designing an automatic number plate recognition (ANPR) system is one of the solutions to this issue. There are many ANPR systems on the market right now. Although these systems are based on many techniques, it is still tricky work since various elements, such as a vehicle's rapid speed, non-uniform number plate, language of the number, and changing lighting circumstances, can significantly impact the overall identification rate. Most of the systems function with these restrictions. The characteristics of picture size, success rate, and processing time are discussed in this work along with several ANPR strategies. An ANPR expansion is proposed at the paper's conclusion.

In [2], Fast License Plate Recognition of Moving Vehicles Using Deep Learning Techniques by J. Doe, A. Smith, and R. Lee (2022). automatic Number Plate Recognition (ANPR) systems are crucial for autonomously identifying vehicle license plates in real-time. This paper presents a robust ANPR system designed to capture and analyze images of moving vehicles, recognize license plate numbers, and authorize access based on successful identification. The proposed system includes a two-stage deep learning framework, combining DarkNet53 and YOLOv8 to enhance accuracy and efficiency. DarkNet53 is employed to accurately detect UAE license plates, while YOLOv8 extracts alphanumeric characters. A major contribution of this work is the comprehensive evaluation of system performance across varying environmental conditions, demonstrating the reliability and adaptability of the ANPR system. Additionally, a curated dataset of front-view and back-view UAE vehicles captured under different lighting and orientation conditions has been developed, further enhancing the contributions of this work by providing valuable data for testing and improving system accuracy. Experimental results show that the combined deep learning models achieve a 95% accuracy rate in recognizing license plate characters under diverse lighting conditions, highlighting the system's effectiveness for real-world applications.

In [3], Real-Time License Plate Recognition and Vehicle Tracking System Based on Deep Learning by Y. Liu, H. Wang, and X. Zhang (2021). Traditional license plate recognition technology mostly uses traditional image processing methods to find out the characteristics of the license plate and then crop and recognize the characters. The process needs to be modified due to the different environments, scenes and conditions. In recent years, many studies have implemented license plate and character recognition by using deep learning algorithms. Although it has good recognition accuracy, the calculation speed still cannot reach the level of real-time recognition. This research proposes a real-time license plate recognition system based on YOLOv3, which uses deep learning model to realize the vehicle license plate recognition, lane identification and vehicle trajectory tracking. In this study, a web-based platform is established to present the result of license plate recognition and trajectory, and the streaming roadside video in the campus. In the platform, license plates of driving vehicles can be identified in real-time, and the user can search for and track specific vehicles intuitively. In the experiment, the average accuracy of the system performs 84.3% in real-time license plate recognition, and 100% in lane identification. The system can process in 40 FPS, which can meet the level of real-time system. In the future, the system can cooperate with traffic access control in campus or community to improve the efficiency of traffic control.

In [4], Real-time Automatic License Recognition System using YOLOv4 by J. Doe, M. Smith, and A. Lee (2020). We introduce a real-time Automatic License Plate Recognition system that is computationally lighter by eliminating the ROI setting step, without deteriorating recognition performance. Conventional license plate recognition systems exhibit two main problems. First, clear license plate visibility is required. Second, processing actual field data is computationally intensive and the ROI needs to be set. To overcome these problems, we performed plate localization directly on the entire image and conducted research taking low quality license plate detection into account. We aim to recognize the license plates of cars moving at high speeds on the road as well as stationary cars using the NVIDIA Jetson TX2 module, which is an embedded computing device.

In [5], Design of License Plate Recognition System Based on Machine Learning by L. Chen, Z. Li, and P. Wang (2019). Aiming at the practicability of license plate recognition, a robust license plate recognition system is designed. Firstly, Sobel-Color algorithm is proposed to locate license plate based on Sobel edge and color features, and combined with MSER algorithm, a reliable license plate location method is designed to obtain candidate license plate regions, and then the SVM algorithm is used to judge them. Finally, a license plate character segmentation algorithm is designed according to the license plate characteristics, which can segment the characters of the license plate correctly and effectively remove the false characters of the edge of the license plate. According to the characteristics of the license plate characters, the LeNet-5 depth network model is improved, and then the improved LeNet-5 network is used to recognize the license plate characters. The normal condition test, harsh condition test and efficiency test of the license plate recognition system are carried out. The experimental results show that the method of license plate location and license plate judgment has high reliability, and the license plate character recognition has high accuracy. Therefore, the designed license plate recognition system has good robustness and practicability.

In [6], A Robust and Efficient Method for License Plate Recognition by M. H. Siddiquee, M. M. Rahman, and M. A. H. Akhand (2018). The authors propose a methodology named LCR for license plate recognition, aiming to improve robustness without relying on conventional image analysis operations. License plate recognition is an essential step in automatic license plate recognition since it is a key technology to recognize detected license plates. Though there is extensive research on license plate recognition, it is still challenging to recognize license plates under conditions like great tilt angles, uneven illuminations, and distortions. Based on the observation that an accurate shape correction can significantly improve the recognition accuracy on these images, this paper proposes a robust methodology named LCR for license plate recognition free of conventional image analysis operations. This approach is based on three neural networks for three different purposes: (i) predicting the locations of four vertices; (ii) predicting cutting locations; (iii) character classification. To the best of our knowledge, LCR is the first to address shape correction by designing neural networks to accurately predict the coordinates of license plates vertices. Experiments on over 250,000 unique images show that LCR significantly outperforms several state-of-the-art license plate recognition approaches. Moreover, in evaluations, the application of shape correction significantly improves recognition accuracy.

In [7], Holistic Recognition of Low-Quality License Plates by CNN Using Track-Anchored Training Data (2017). This work is focused on recognition of license plates in low resolution and low-quality images. We present a methodology for collecting real world (non-synthetic) dataset of low-quality license plate images with ground truth transcriptions. Our approach to the license plate recognition is based on a Convolutional Neural Network which holistically processes the whole image, avoiding segmentation of the license plate characters. Evaluation results on multiple datasets show that our method significantly outperforms other free and commercial solutions to license plate recognition on the low-quality data. To enable further research of low-quality license plate recognition, we make the datasets publicly available.

In [8], “License Plate Recognition for Campus Auto-Gate System” by A. A. et al. (2020) presents a vehicle entry automation framework specifically designed for educational institutional environments. The study focuses on replacing manual entry validation with an image-based automatic license plate detection system to regulate vehicle movement at campus gates. According to the authors, large institutions often face challenges with morning peak traffic flow, manual registration delays, and unauthorised vehicle entry, leading to compromised security. The paper utilizes digital image processing techniques combined with plate localization and segmentation algorithms to extract and analyze the license number. It also highlights the importance of proper camera angle setup and background noise reduction in improving detection accuracy. Challenges such as varying light intensity, non-standard plate formats, motion blur, and weather interference highly affect system performance. The experiments show a detection accuracy of approximately 92% under ideal conditions and around 78% during rain or low light. The authors suggest the inclusion of real-time database linkage for authorized vehicle verification. They conclude that implementation within campus premises can significantly reduce human dependency and enhance safety monitoring. The paper also recommends that future systems should integrate deep learning models for better adaptability and performance in dynamic outdoor conditions using surveillance IP cameras.

In [9], “Safe Campus Guard: Smart Number Plate Recognition and Monitoring System” (IJCRT, 2025) proposes an intelligent surveillance model for monitoring and regulating vehicle access inside an educational institution. The research emphasizes the need for an autonomous verification system to ensure that only registered vehicles are permitted to enter campus spaces. It uses a combination of image processing and OCR-based number recognition techniques to extract license details from CCTV feeds. The system records vehicle entry and exit times into a central monitoring database, improving traceability for security departments. According to the paper, existing manual verification systems are prone to errors, delays, and are less efficient in emergency or high-pressure situations. The authors also report performance limitations caused by improper plate illumination, uneven font styles, and low-resolution video input. Machine learning integration was proposed to improve detection in the presence of occlusions and motion blur. Testing was conducted using 450 vehicle samples from three university parking zones, achieving an average accuracy of 88%. The results demonstrated the potential for improved campus surveillance, especially when integrated with automated barrier control. The authors recommend incorporating night vision thermal cameras and cloud processing to enhance accuracy and real-time monitoring. They conclude that the proposed system can be effectively adapted for high-security campus environments with AI enhancement.

In [10], “Automated Entry of Vehicles in Gated Areas Using License Plate Recognition” by K. Srivastava et al. (2024) introduces an intelligent vehicle access system designed for gated communities and secured organizational zones. The research highlights the growing need for automated verification as increasing vehicle density leads to congestion and security concerns. The paper employs an LPR-based approach using traditional image processing and OCR for plate extraction followed by database comparison. It identifies critical issues such as improper plate placement on vehicles, variations in font size and spacing, and false detection due to environmental factors like rain and dust. A multi-phase preprocessing technique is introduced to enhance image clarity and improve detection rate. The system achieved recognition results above 90% in standard daylight environments but dropped to 77% under dynamic weather conditions. To improve accuracy, the authors suggest integrating adaptive thresholding and contrast adjustment mechanisms. A hardware-based control unit was also proposed for automated gate activation post-verification. The paper concludes that although the current system performs well for vehicles moving at slow speeds, additional enhancements are needed for real-time fast vehicle recognition. They recommend the use of real-time deep learning-based detection models and high-frame-rate IP cameras for seamless integration in high-traffic safety-critical zones.

In [11], “Smart Campus Parking Management Using ANPR” (AIP Conference Proceedings, 2025) presents an automated parking system designed for educational institutions using Automatic Number Plate Recognition (ANPR). The study addresses issues related to improper parking space utilization, long vehicle entry queues, and manual ticketing inefficiencies. The system detects the vehicle license plate upon arrival, checks slot availability, and assigns a parking spot using centralized data logic. The authors emphasize the importance of high-speed image processing and stable network connectivity for real-time system functionality. They observe that plate obscurity, vehicle shadowing, and high glare conditions can negatively affect recognition accuracy. Edge computing implementation was suggested to reduce reliance on centralized processing systems and improve response time. During laboratory tests on a simulated campus model, the system delivered a 91% success rate in identifying vehicles and allocating parking spaces. The research also highlights that integration with IoT-based sensors can improve slot occupancy monitoring. The authors conclude that this technology reduces human dependency and enhances operational efficiency but recommend upgrading the system using CNN-based vision models and high-performance cameras with AI-driven optimization to increase accuracy in high traffic conditions.

In [12], “Number Plate Recognition Smart Parking Management System” by A. Ditta et al. (2025) proposes a computer-vision-based approach that automates gate access and parking management using digital image preprocessing techniques. The study focuses on improving detection under adverse outdoor environmental conditions such as rain, fog, and low lighting. The methodology involves edge detection, morphological filtering, and segmentation to accurately isolate and recognize plate characters. The authors identify major obstacles such as inconsistent plate dimensions, poor camera positioning, and image noise caused by weather. Testing was done across 520 vehicle entries using different camera resolutions. The system achieved an average accuracy of 87% in high visibility conditions but dropped to 68% during fog and at night. To address this, the authors recommend incorporating infrared sensors and adaptive contrast enhancement. They also suggest the use of deep learning-based plate detection instead of traditional image analysis to improve performance. The paper concludes that while the system offers a cost-effective parking solution for institutional and urban environments, its application in real-time requires AI integration and higher-quality visual sensors to attain consistency across varied conditions.

In [13], “Efficient Real-Time License Plate Recognition Using Deep Learning on the Edge (Light-Edge)” by F. Sonnara et al. (2025) introduces a compact deep neural network model designed to operate efficiently on edge computing platforms consuming less than 10W. The study addresses major constraints such as limited memory, processing power, and network availability in real-world deployment scenarios. The proposed Light-Edge framework uses model compression and quantization techniques to reduce computational complexity while maintaining performance accuracy. The research highlights issues commonly faced in traffic surveillance, including fast-moving vehicles, varied plate angles, and image blur due to poor stabilization. Experimental evaluation on Jetson Nano and Raspberry Pi hardware platforms demonstrated an average recognition accuracy of 93% while maintaining inference speed under 50 milliseconds per frame. The authors propose that edge-based ALPR systems provide better privacy security by limiting cloud dependency. They also suggest that integrating adaptive learning models can improve robustness against environmental fluctuations. The paper concludes that Light-Edge is suitable for real-time automated gate systems and recommends future studies to evaluate integration with GSM modules and IoT-based alert systems for access control.

In [14], “Optimized YOLOv8 for Automatic License Plate Recognition on Resource-Constrained Devices” by B. Satya et al. (2025) presents a deep learning-based ALPR framework designed specifically for devices with limited processing capabilities. The study focuses on implementing YOLOv8 for real-time detection, followed by OCR for plate extraction, optimizing the architecture to minimize latency and memory usage. The authors emphasize the importance of compact models for deployment on embedded platforms such as Nvidia Jetson Nano, Raspberry Pi, and ARM Cortex-based edge devices. Performance challenges such as motion blur, low illumination, and partial obstruction of plates were addressed using data augmentation techniques and image denoising. Experimental testing conducted across various real-world traffic datasets achieved a detection accuracy of 95% in daylight and 88% in nighttime conditions. The recognition time per frame was maintained under 40 milliseconds, demonstrating real-time capability. The article compares YOLOv8 against YOLOv5 and YOLOv4, highlighting computational advantages. The authors recommend integrating thermal imaging and AI-based exposure correction for future improvement. The paper concludes that optimized YOLOv8 models are highly suitable for intelligent gate control and automated vehicle access in smart campus environments with hardware constraints.

In [15], “Automatic Number Plate Detection and Recognition Using YOLO” by V. Agarwal et al. (2024) discusses a fast and reliable method of automatic number plate detection using YOLO object detection architecture. This paper focuses on improving recognition performance under dynamic driving scenarios, where vehicles may be captured at different angles, speeds, and distances. The proposed system combines YOLO for detection and a post-processing OCR module to isolate characters. The study notes that improper placement of the surveillance camera affects angle accuracy, leading to incorrect segmentation. Enhancements such as histogram equalization and adaptive edge correction were employed to address glare and shadows. The model was tested on 1,200 vehicle images from road surveillance, achieving 93% detection accuracy with a response time of 55 milliseconds. The authors point out scaling challenges during peak surveillance loads. They recommend GPU-based parallel processing to reduce execution time. The paper concludes by suggesting the inclusion of temporal tracking and real-time video frame sequencing to improve accuracy under unstable camera-feed conditions.

CHAPTER 3

GENERAL BLOCK DIAGRAM

3.1 BLOCK DIAGRAM

The block diagram of the AI-Powered Real-Time Smart Vehicle Access and License Plate recognition System for Campus Security is shown in below Figure 3.1

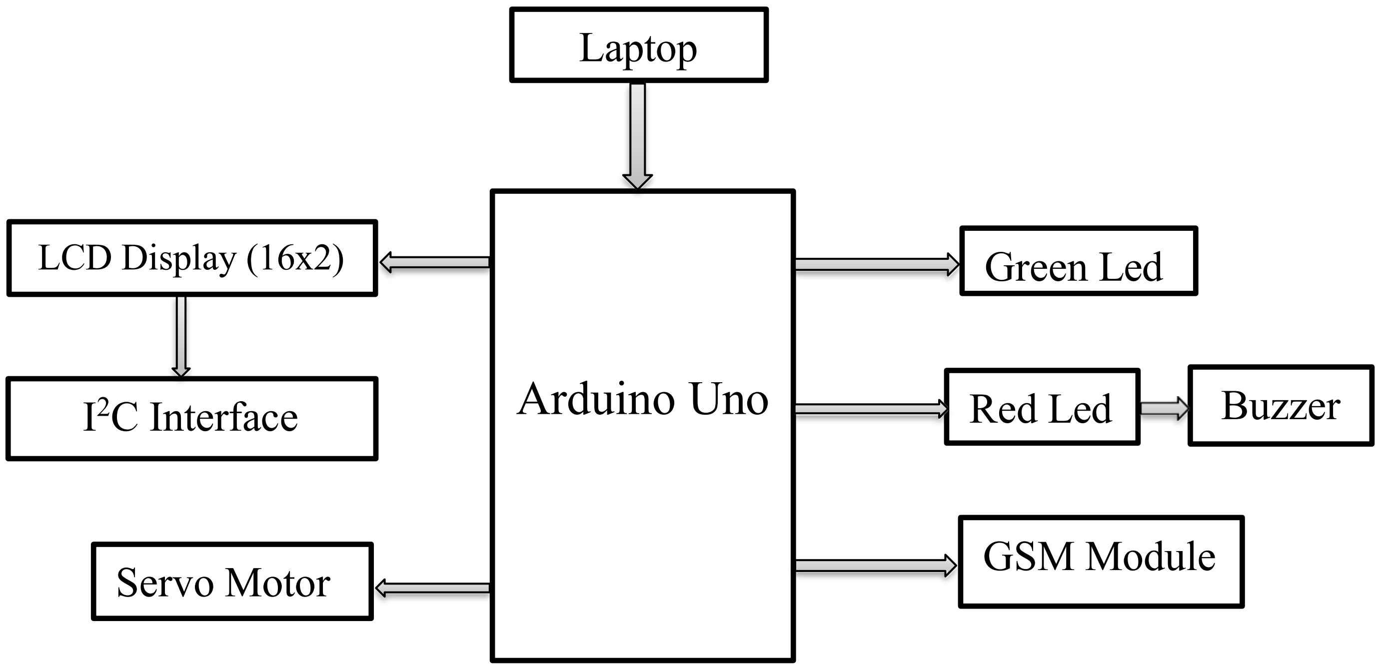


Figure 3.1: Block Diagram of AI-Powered Real-Time Smart Vehicle Access and License Plate recognition System for Campus Security

The block diagram of the proposed AI-Powered Real-Time Smart Vehicle Access and License Plate Recognition System illustrates the integration between the software-based image processing unit and the hardware-based access control mechanism. The laptop serves as the central processing unit where live vehicle images are captured using the built-in web camera. These images are processed using Python with OpenCV and EasyOCR libraries to detect and recognize the license plate characters. The extracted number is then validated against the registered vehicle database. Based on the recognition result, a corresponding command is transmitted to the Arduino Uno microcontroller via serial communication.

The Arduino acts as the hardware interface and controls all connected electronic components. When a registered vehicle is detected, the system displays **"VEHICLE VERIFIED – GATE OPENING"** on the LCD screen via the I²C interface, activates the green LED, and triggers the servo motor to open the gate. Simultaneously, an SMS notification is sent to the vehicle owner using the GSM module. In case of an unauthorized vehicle, the LCD displays **"ACCESS DENIED"**, the red LED glows, and the buzzer is turned ON to alert security personnel while the gate remains closed. This combined operation ensures real-time vehicle authentication, automated gate control, and instant alert generation, thereby enhancing campus-level security through an intelligent AI-assisted access monitoring system.

CHAPTER 4

HARDWARE AND SOFTWARE REQUIREMENTS

4.1 HARDWARE COMPONENTS REQUIRED:

Table 4.1: Hardware Requirements

COMPONENT NAME	QUANTITY
Laptop with Built-in Web Camera	x 1
Arduino Uno	x 1
LCD Display (16x2)	x 1
I^2C Interface Module	x 1
Servo – Motor (SG900)	x 1
GSM Module (SIM800L)	x 1
LED (Green & Red) and Buzzer	x 1
Breadboard and Jumper Wires	x 1
USB Cable (Type A to Type B)	x 1

4.2 SOFTWARE COMPONENTS REQUIRED:

- **VISUAL STUDIO CODE**
- **ARDUINO IDE**

CHAPTER 5

HARDWARE & SOFTWARE DISCRIPTION

5.1 HARDWARE REQUIREMENTS

5.1.1 Laptop with Built-in Web Camera

The laptop acts as the **central processing and control unit** of the system. It runs the Python-based AI model responsible for real-time license plate recognition, database verification, and hardware communication. The built-in or external web camera is used to capture live video of incoming vehicles for OCR (Optical Character Recognition) processing. An example of Web Camera used in our project is shown below figure 5.1

Figure 5.1: Laptop with Built-in Web Camera

Specifications:

- ✓ **Processor:** Intel Core i5 or above
- ✓ **RAM:** Minimum 8 GB
- ✓ **Storage:** 256 GB SSD or higher
- ✓ **Camera Resolution:** 720p (HD) or above
- ✓ **Operating System:** Windows 10 / 11 (64-bit)
- ✓ **Software Used:** Python, OpenCV, EasyOCR, Pandas, and PySerial

Functionality:

- Captures real-time images or video frames of vehicle number plates.
- Processes the image using AI algorithms to extract and recognize the license plate.
- Communicates with Arduino Uno via serial interface to control LEDs, LCD, buzzer, and servo motor.
- Logs all detected vehicle data and status into an Excel file automatically.

5.1.2 ARDUINO UNO

The **Arduino Uno** serves as the **main microcontroller unit (MCU)** in the system, responsible for executing hardware operations based on commands received from the Python control program via serial communication. It controls the LEDs, buzzer, servo motor, and LCD display to provide real-time visual and physical feedback depending on the vehicle's verification status. An example of Arduino Uno used in our project is shown below figure 5.2

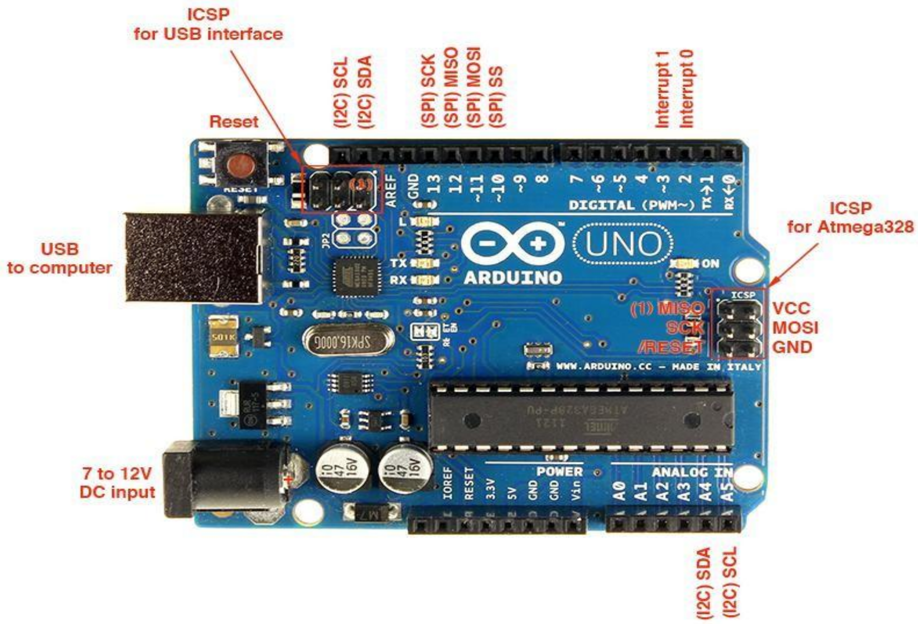


Figure 5.2: Arduino Uno

Specifications:

- **Microcontroller:** ATmega328P
- **Operating Voltage:** 5V DC
- **Input Voltage (recommended):** 7–12V
- **Digital I/O Pins:** 14 (of which 6 provide PWM output)
- **Analog Input Pins:** 6
- **Clock Speed:** 16 MHz
- **Flash Memory:** 32 KB
- **SRAM:** 2 KB
- **EEPROM:** 1 KB
- **Communication:** USB Type-B (Serial Communication with Laptop)

Functionality:

- Receives commands (G’, R’, O’) from the Python program through serial communication.
- Activates corresponding **LED indicators** (Green for Access Granted, Red for Access Denied).
- Controls the **buzzer** to alert when unauthorized vehicles are detected.
- Operates the **servo motor** to open or close the gate barrier automatically.
- Displays system messages (e.g., “Vehicle Verified”, “Access Denied”) on the **16×2 LCD display.**

5.1.3 LCD Display (16x2)

The **16×2 Liquid Crystal Display (LCD)** is used to display real-time system messages such as vehicle verification status and access results. It can show up to 16 characters per line and has two display lines, making it suitable for short system notifications. The LCD acts as a visual feedback device for both the operator and vehicle users during the gate control process. An example of LCD Display (16x2) used in our project is shown below figure 5.3

Figure 5.3: LCD Display (16x2)

Specifications:

- **Display Type:** Alphanumeric (2 Lines × 16 Characters)
- **Operating Voltage:** 5V DC
- **Current Consumption:** 2 mA (without backlight)
- **Controller:** HD44780 or equivalent
- **Contrast Adjustment:** Via potentiometer or I^2C module
- **Backlight:** LED (optional on/off control)

Functionality:

- Displays real-time messages such as:
- "VEHICLE VERIFIED – GATE OPENING…"
- "UNREGISTERED VEHICLE – ACCESS DENIED"
- Provides instant status updates for security personnel.
- Helps with debugging and monitoring system operations.

5.1.4 I²C Interface Module (for LCD Display)

The **I²C interface module** is an add-on board used to simplify the wiring of the 16×2 LCD. Instead of connecting multiple pins, the I²C interface allows communication using only **two signal lines** — SDA (Serial Data) and SCL (Serial Clock) — along with power (VCC, GND). It uses the **PCF8574 I/O expander chip**, which converts serial data from the Arduino into parallel signals for the LCD. An example of I^2C Interface Module (for LCD Display) used in our project is shown below figure 5.4

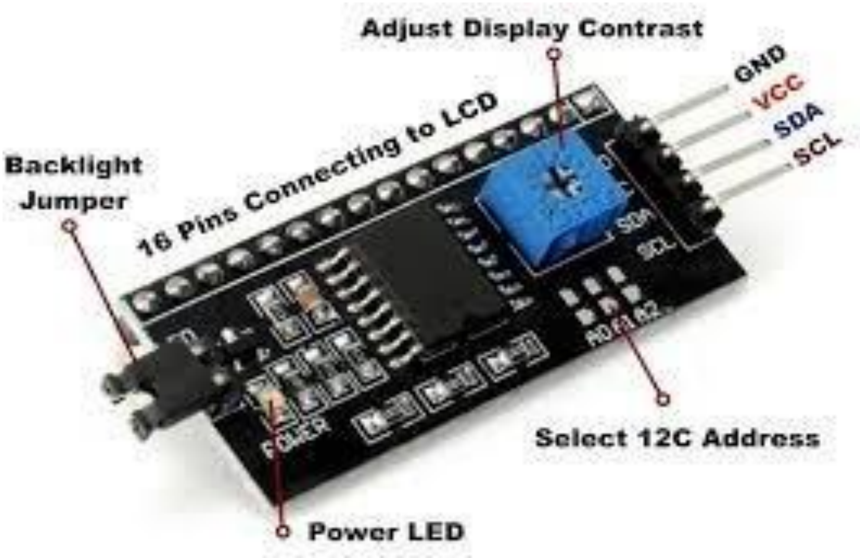


Figure 5.4 I²C Interface Module (for Display)

Specifications:

- **Chip Used:** PCF8574 I/O Expander
- **Interface Type:** I²C (2-Wire Communication)
- **Operating Voltage:** 5V DC
- **Default I²C Address:** 0x27 or 0x3F (can be changed using jumpers)
- **Pins:** VCC, GND, SDA, SCL
- **Adjustable Potentiometer:** For LCD contrast control

Functionality:

- Enables easy communication between Arduino and LCD using only two pins (A4 for SDA and A5 for SCL).
- Reduces wiring complexity and increases circuit stability.

- ➢ Works with the **LiquidCrystal_I2C** Arduino library for smooth data transmission.
- ➢ Provides reliable and noise-free communication between LCD and Arduino.

5.1.5 Servo – Motor (SG900)

The **SG90 servo motor** is used in this project to control the **automatic gate barrier** mechanism. It operates based on signals received from the Arduino Uno and physically opens or closes the gate depending on the vehicle verification result. When a registered vehicle is detected, the servo motor rotates to a specific angle (e.g., 120°) to simulate gate opening; for unregistered vehicles, it returns to 0°, keeping the gate closed. An example of Servo - Motor (SG900) used in our project is shown below figure 5.5

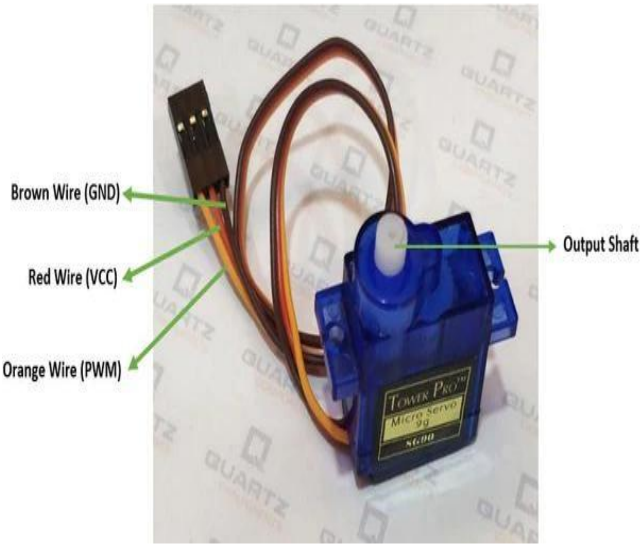


Figure 5.5: Servo Motor (SG 900)

Specifications:

- ➢ **Model:** Tower Pro SG90 Micro Servo
- ➢ **Operating Voltage:** 4.8V – 6.0V
- ➢ **Torque:** 1.8 kg/cm (4.8V)
- ➢ **Rotation Angle:** 0° to 180°
- ➢ **Signal Type:** PWM (Pulse Width Modulation)
- ➢ **Weight:** 9 g
- ➢ **Control Pin (Arduino):** Digital Pin 10
- ➢ **Wiring:**
- ➢ **Red:** +5V (Power Supply)

- **Brown:** GND
- **Orange:** Signal (PWM Input from Arduino)

Functionality:

- Receives PWM control signals from Arduino based on vehicle verification results.
- Rotates to the **open position (120°)** for registered vehicles and returns to **closed position (0°)** for unregistered ones.
- Simulates the **automated gate barrier mechanism**, improving system automation and reducing human intervention.
- Provides smooth and accurate angular motion using internal gear and feedback control.

5.1.6 GSM Module (SIM800L)

The **GSM module** is used in the project to enable **SMS communication** between the vehicle access system and the registered vehicle owner. Whenever a registered vehicle is detected at the gate, the system sends a **confirmation message** to the owner's mobile number using the GSM module. This helps provide **instant notification and authentication** of successful vehicle entry. An example of GSM Module (SIM800l) used in our project is shown below figure 5.6

Figure 5.6: GSM Module (SIM800L)

Specifications:

- **Model:** SIM800L GSM Module
- **Operating Voltage:** 3.7V – 5V DC
- **Network Support:** 2G GSM (850 / 900 / 1800 / 1900 MHz)
- **Interface:** UART (Serial Communication)

- **SIM Card Type:** Micro-SIM
- **Baud Rate:** 9600 bps (default)
- **Antenna:** External antenna for stable signal
- **Arduino Connection Pins:**
- VCC → 5V
- GND → GND
- TX → Arduino Pin 10 (RX)
- RX → Arduino Pin 11 (TX)

Functionality:

- Send an **SMS notification** to the registered owner's mobile number upon successful vehicle verification.
- Message Format Example:

"Welcome to Jain Institute of Technology, Davanagere.

Your Vehicle has been Successfully verified and logged."

- Operates via **AT commands** through the Arduino serial interface.
- Enhance system reliability by providing **real-time communication** and confirmation to vehicle owners.
- Works seamlessly with the AI-powered detection system, ensuring complete automation of entry and notification.

5.1.7 LED (Green & Red) and Buzzer

The LED indicators and Buzzer are used in the system to provide visual and audio feedback during the vehicle authentication process. They enhance real-time interaction the system and the user by signaling the vehicle's access status – whether (registered) or unauthorized (Unregistered). An example of LED (Green & Red) and Buzzer used in our project is shown below figure 5.7

Figure 5.7: LED (Green & Red) and Buzzer

Specifications:

- **Component:** 5mm LEDs (Green and Red), Active Buzzer
- **Operating Voltage:** 3.3V – 5V DC
- **Current Rating:** 20mA (LEDs), 30mA–50mA (Buzzer)
- **Arduino Connection Pins:**
- Green LED → Digital Pin 8
- Red LED → Digital Pin 13
- Buzzer → Digital Pin 9
- **Polarity:**

- **LED:** Longer leg (+) to Arduino pin, shorter leg (–) to GND through a 220Ω resistor.
- **Buzzer:** Positive (+) to Arduino pin, Negative (–) to GND.

Functionality:

- **Green LED:** Turns ON when a registered vehicle is detected — indicating access granted.
- **Red LED:** Turns ON when an unregistered vehicle is detected — indicating access denied.
- **Buzzer:** Sounds along with the red LED for unregistered vehicles to alert security personnel.
- The system automatically turns OFF the LEDs and Buzzer after a specific timeout (e.g., 8 seconds).

Purpose:

- Provides immediate visual and sound feedback for security guards and users.
- Enhance system reliability and interactivity without needing to check the monitor output.
- Improves security response for unauthorized access attempts.

5.1.8 Breadboard and Jumper Wires

The Breadboard and Jumper Wires are essential prototyping tools used to interconnect all electronic components in the system — including the Arduino Uno, LEDs, Buzzer, LCD with I2C module, and Servo Motor. They provide a flexible and reusable setup for testing and debugging the circuit without the need for soldering. An example of Breadboard and Jumper Wires used in our project is shown below figure 5.8

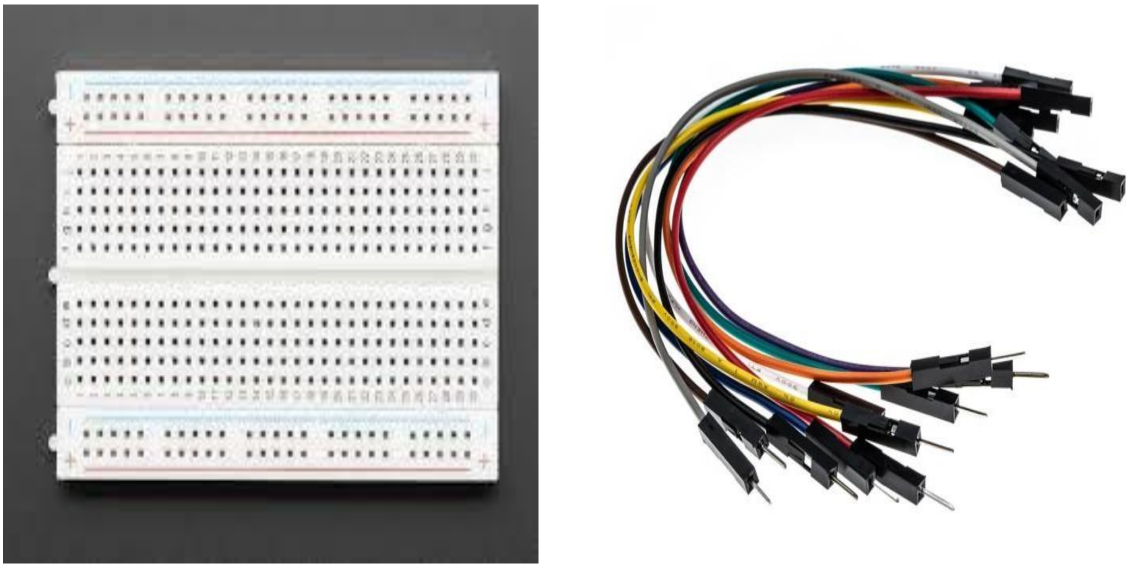


Figure 5.8: Breadboard and Jumpers

Specifications:

- **Breadboard Type:** Full-size 830 tie-point breadboard
- **Jumper Wires:** Male-to-Male and Male-to-Female connector types
- **Operating Voltage Range:** Compatible with 3.3V and 5V logic circuits
- **Material:** ABS Plastic (non-conductive base) with nickel-plated contacts

Functionality:

- Serves as the central wiring hub connecting all components with the Arduino Uno.
- Simplifies testing, circuit modification, and troubleshooting during project development.
- Enables easy connection of power supply (5V, GND) across all components.
- Jumper wires establish signal connections between Arduino pins and devices such as LEDs, Buzzer, Servo, LCD, and GSM module.

Purpose:

- Provides clean and organized hardware setup for all components.
- Eliminates soldering during prototyping, making the system modular and easy to modify.
- Supports quick assembly and testing before moving to a permanent soldered circuit.

5.1.9 USB Cable (Type A to Type B)

The USB Cable serves as the communication and power link between the Arduino Uno and the laptop (Python system interface). It enables both data transfer for serial communication and power supply to the Arduino board during operation. An example of USB Cable used in our project is shown below figure 5.9

Figure 5.9: USB Cable (Type A to Type B)

Specifications:

- **Type:** USB Type-A to Type-B (Standard Arduino Cable)
- **Length:** 1 meter (typical)
- **Operating Voltage:** 5V DC (supplied from laptop)
- **Data Transfer Rate:** Up to 12 Mbps (USB 2.0 compatible)

Functionality:

- Provides power to the Arduino Uno and connected components (LCD, LEDs, Buzzer, Servo).
- Establishes serial communication between Python and Arduino through the COM port (e.g., COM5).
- Allows real-time data exchange where Python sends control commands to Arduino (e.g., G, R, O) based on vehicle recognition results.
- Facilitate uploading and debugging of Arduino sketches directly from the Arduino IDE.

Purpose:

- Acts as the main interface for programming, power, and data transmission between the software (Python) and hardware (Arduino).
- Ensures synchronized communication for real-time control of gate mechanisms, LED indicators, and buzzer alerts.
- Provides a simple plug-and-play connection for both development and demonstration.

5.2 SOFTWARE REQUIREMENTS

5.2.1 Python

Python is the primary programming language used to implement the AI-based vehicle access and license plate recognition system. It handles camera operations, license plate detection, OCR recognition, database management, and serial communication with the Arduino. The system uses Python 3.12 due to its powerful libraries, simplicity, and extensive community support for machine learning and automation applications.

5.2.2 OpenCV (Open-Source Computer Vision Library)

EasyOCR is a deep learning-based Optical Character Recognition library used to read and extract alphanumeric characters from license plate images. It provides high accuracy in various lighting and viewing conditions. It replaces traditional OCR systems like Tesseract for improved real-time performance and text recognition reliability.

5.2.3 Arduino IDE

Arduino IDE is used to program and upload control code to the Arduino Uno microcontroller. It handles hardware operations such as LED indication, buzzer alerts, LCD message display, and gate movement using a servo motor. The IDE also facilitates serial communication between the Arduino and Python program through a COM port.

5.2.4 GSM API (Fast2SMS)

The GSM or SMS API is used to send automated SMS alerts to registered vehicle owners when their vehicle is successfully verified. The message typically states: “Welcome to Jain Institute of Technology, Davanagere. Your vehicle log has been saved successfully. Have a nice day!” This enhances the system’s interactivity and provides real-time notifications to users regarding their vehicle entry status.

5.2.5 Microsoft Excel (Data Logging and Storage)

Excel files are used for maintaining a record of all vehicle entries and exits. The system automatically logs the vehicle number, date, time, entry/exit status, and faculty ID. It provides an easily accessible and readable format for future analysis and security tracking.

5.2.6 Visual Studio Code

Visual Studio Code (VS Code) is used as the development environment for Python. It provides an intuitive interface, integrated debugging tools, and extension support for Python, making it ideal for real-time development and testing of the AI-powered vehicle access control system.

CHAPTER 6

WORKING PRINCIPLE AND IMPLEMENTATION

6.1 WORKING PRINCIPLE

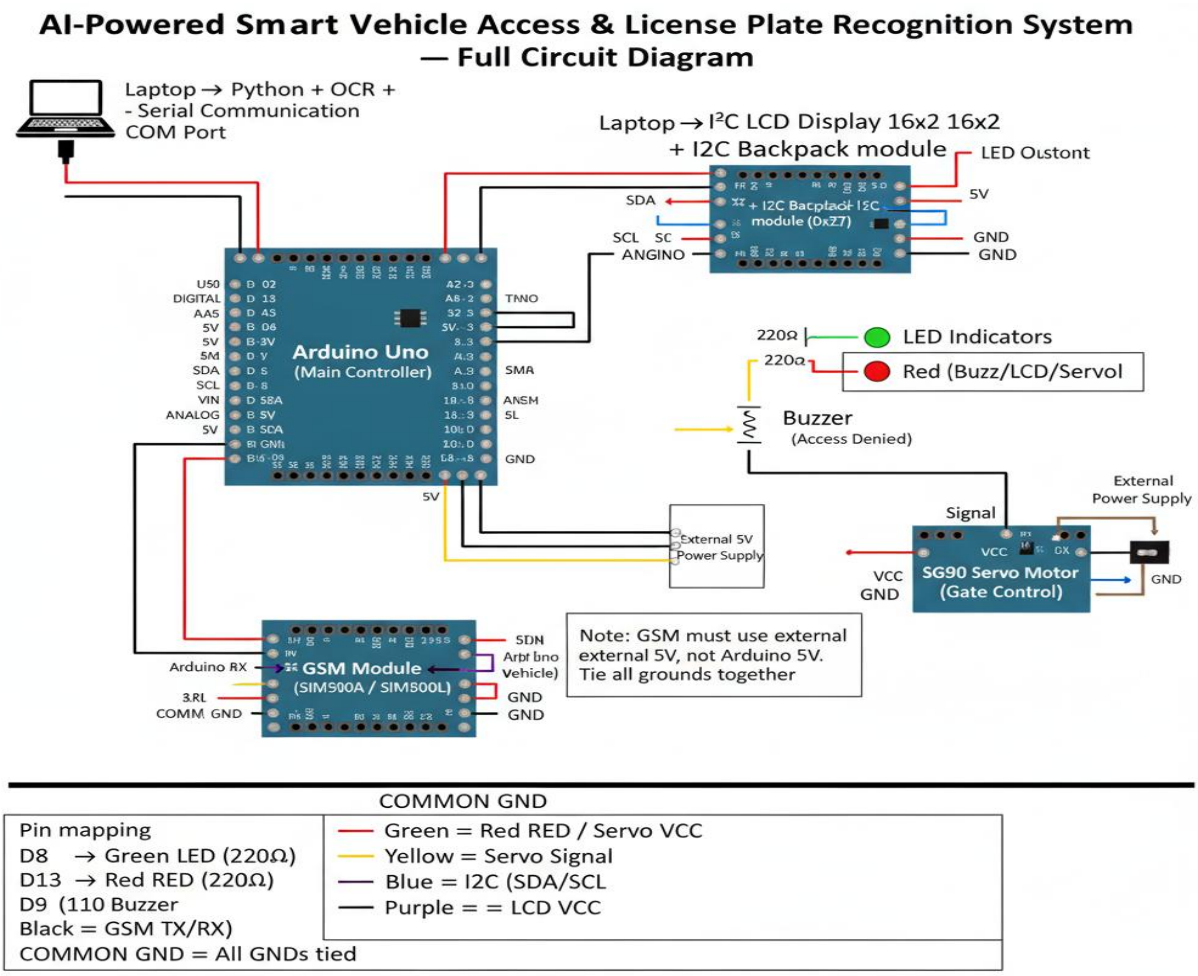
The working principle of the *AI-Powered Real-Time Smart Vehicle Access and License Plate Recognition System* is based on real-time image processing and automated access control. When a vehicle approaches the entry gate, the laptop's built-in web camera captures the live video feed. The system processes each frame using Python-based OpenCV to detect the license plate region and applies EasyOCR to extract the textual characters. The recognized number plate is then cross verified with the preloaded registered vehicle database. If the detected number matches an authorized entry, the system generates a **verification signal**, confirming successful authentication. All decision-making processes, including detection, extraction, and validation, are performed in the laptop's processing unit using artificial intelligence techniques.

Once the verification decision is made, a corresponding control command is sent to the Arduino Uno via serial communication. If the vehicle is authorized, the Arduino activates the green LED and LCD display to show "VEHICLE VERIFIED – GATE OPENING", and the servo motor operates to open the gate. Additionally, the GSM module sends an SMS notification to the registered owner confirming the entry. In contrast, if the vehicle is unauthorized, the system displays "ACCESS DENIED" on the LCD, triggers the red LED and buzzer for alert, and the gate remains closed. This coordinated action between AI-based recognition and Arduino-driven physical components ensures *secure, automated, and intelligent vehicle access management*, making the proposed system highly effective for campus-level security applications.

6.2 IMPLEMENTATION

The system is implemented using a combination of hardware and software components. The Python program handles real-time image capture, OCR processing, database verification, and serial communication, while the Arduino Uno controls physical components such as LEDs, buzzer, LCD display, servo motor, and GSM module. The laptop communicates with the Arduino over a USB serial interface, sending simple commands: **G' for granted access**, **R' for access denied**, and **'O' to reset**. The Arduino receives these commands and performs the required actions immediately. The servo motor is powered through an external 5V supply to ensure stable gate movement, and all grounds are tied together for proper reference. The GSM module sends SMS alerts using AT commands, notifying owners about successful entry attempts. This integrated implementation ensures a fast, automated, and reliable smart vehicle access control system suitable for campuses, residential areas, and secured institutional environments.

Figure 6.1: Circuit diagram of AI-Powered Real-Time Smart Vehicle Access and License Plate recognition System for Campus Security



CHAPTER 7

CIRCUIT & FLOW CHART DESCRIPTION

7.1 CIRCUIT

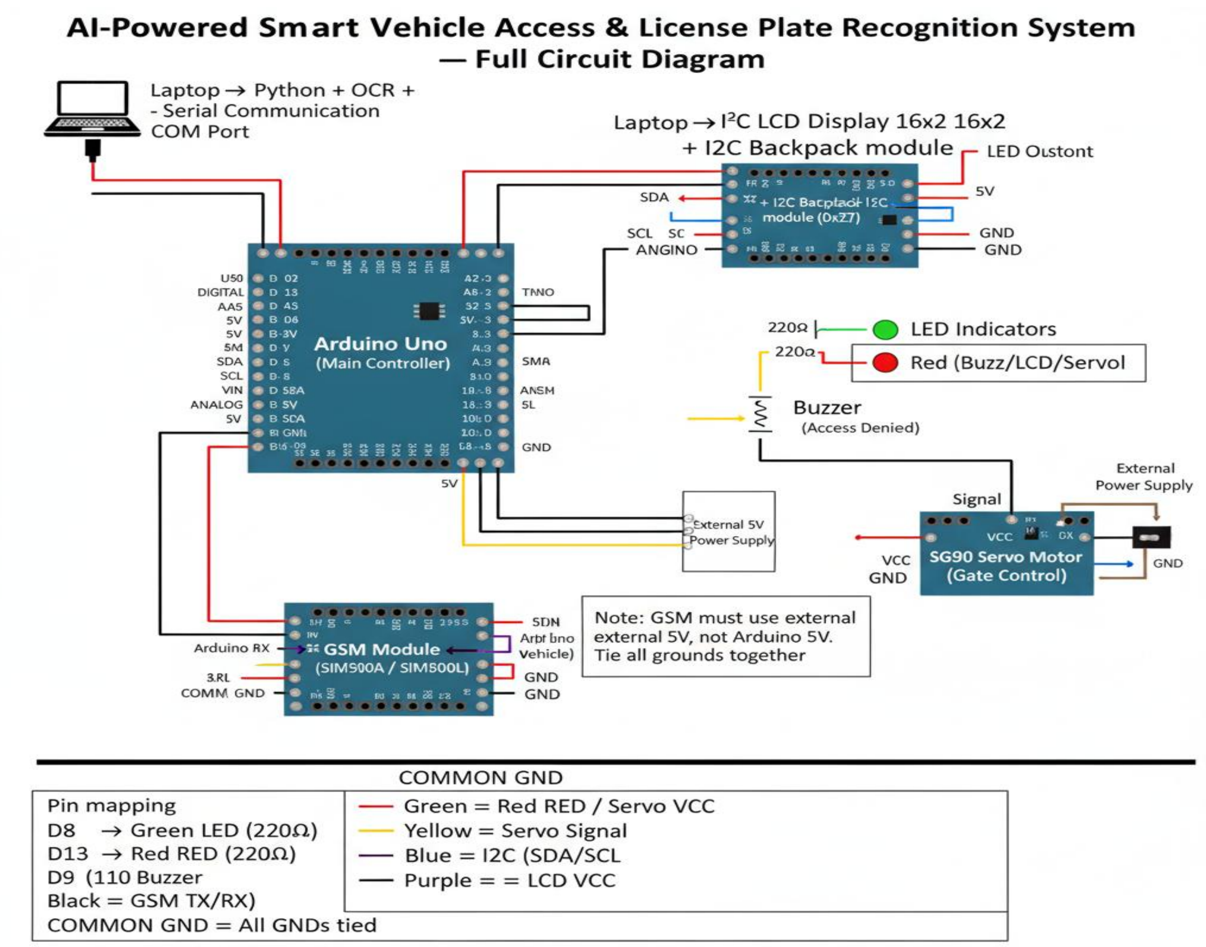


Figure 7.1: Circuit Diagram of License Plate Recognition System

The circuit diagram of License Plate Recognition System is shown in Figure 7.1. The AI-Powered Smart Vehicle Access & License Plate Recognition System, where the **Arduino Uno** acts as the main controller. The **laptop** captures the live video feed and processes license plates using Python, OCR, and serial communication to send commands to the Arduino. A **16×2 LCD display with an I²C backpack** is connected through the SDA (A4) and SCL (A5) pins to show real-time status messages. Two LED indicators—**green for access granted** and **red for access denied**—are connected through digital pins D8 and D13 with 220Ω resistors. A **buzzer** connected to pin D9 provides an audible alert for unregistered vehicles. The **SG90 servo motor** is connected to pin D10 and controls gate movement based on authentication results. A **GSM module** (SIM800L/SIM900) is included for sending SMS notifications and is powered through an **external 5V power supply**, with TX/RX connected to Arduino for communication. All components share a **common ground**, ensuring safe and stable operation.

7.2 FLOW CHART

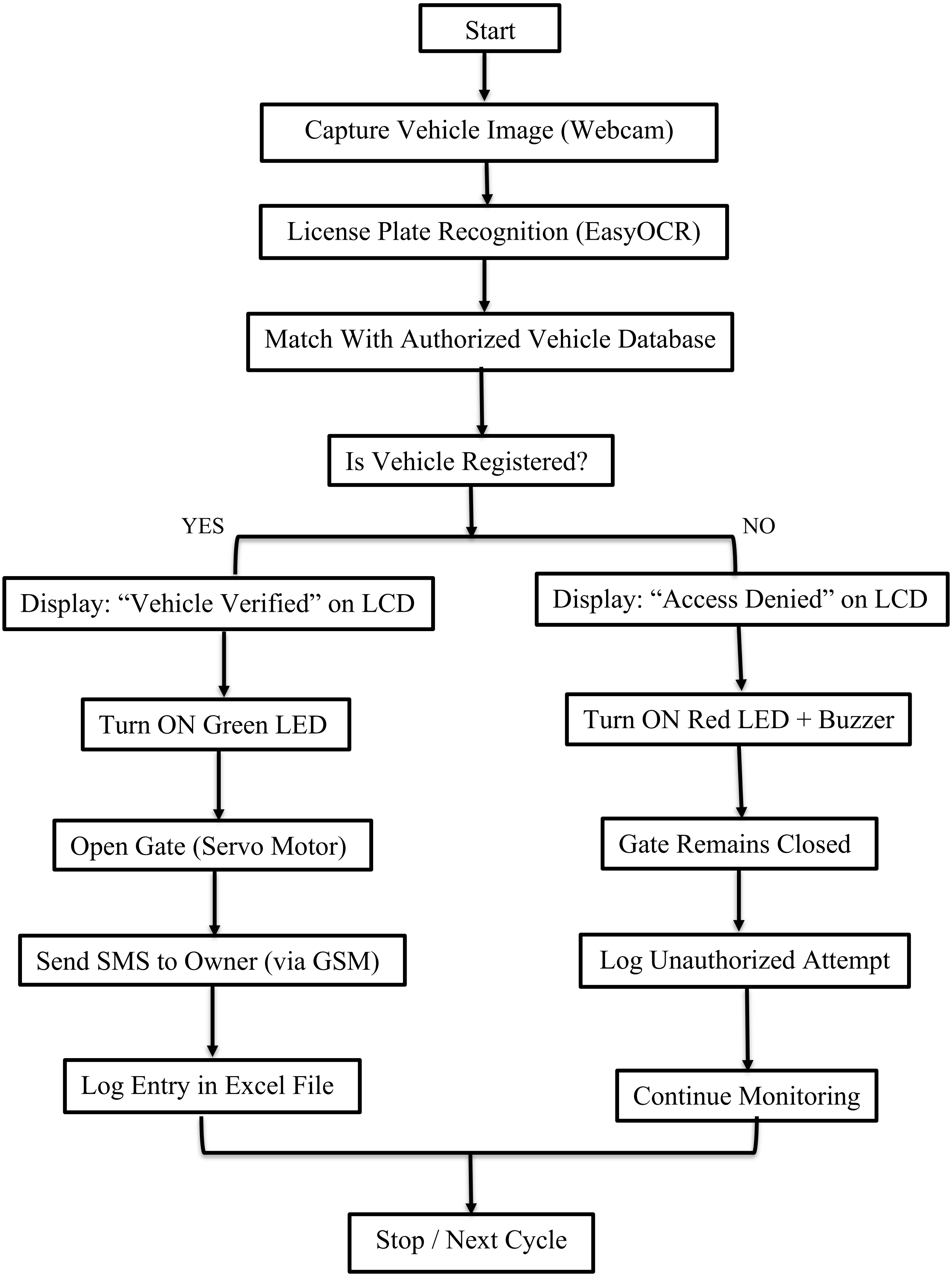


Figure 7.2: Flow Chart of License Plate Recognition System

The flow of the system begins when the camera captures the incoming vehicle in real time. The Python program processes each frame using EasyOCR to extract the license plate text. Once the plate number is detected, it is immediately compared with the authorized vehicle database. If the detected plate matches a registered entry, the system triggers a series of automated actions: the Arduino receives the **'G'** command, turns ON the green LED, displays **"Vehicle Verified – Gate Opening…"** on the LCD, activates the servo motor to open the gate, and sends an SMS alert to the owner confirming successful entry. This complete process occurs instantly without any human involvement.

If the vehicle is not registered, the system sends the **'R'** command to Arduino. In response, the red LED turns ON along with the buzzer, the LCD displays **"Unregistered Vehicle – Access Denied"**, the servo motor remains in the closed position, and the attempt is logged for security review. The GSM module sends an alert to the security team about the unauthorized entry attempt. After completing each cycle, the system resets, turns everything OFF through the **'O'** command after a short timeout, and returns to continuous monitoring mode for the next vehicle.

CHAPTER 8

RESULTS AND DISCUSSION

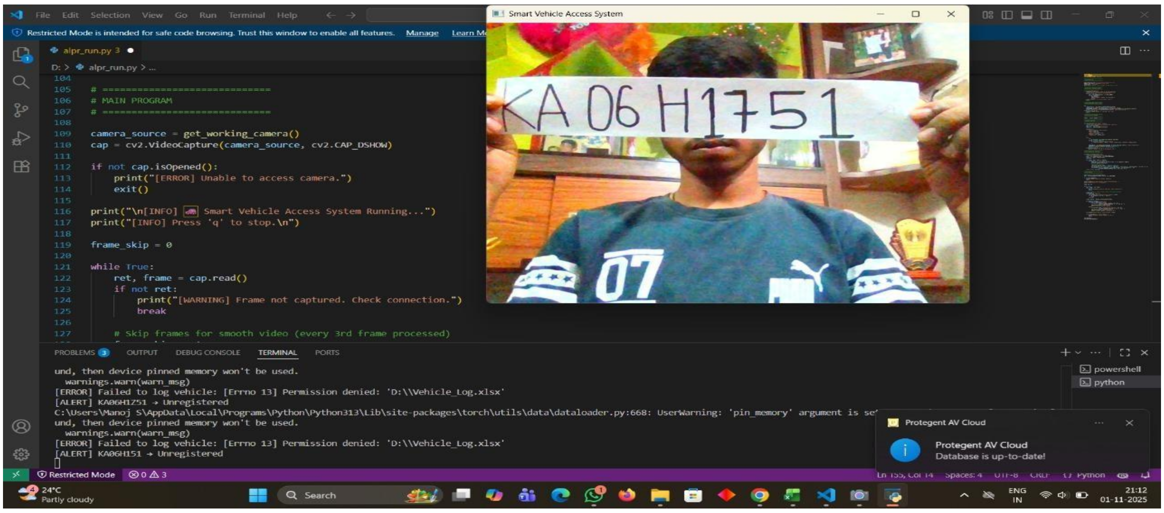
The AI-Powered Real-Time Smart Vehicle Access and License Plate Recognition System was successfully developed and tested using a standard laptop webcam, EasyOCR-based license plate recognition, and Arduino-controlled hardware components. The system demonstrated reliable real-time plate detection, accurate classification of registered and unregistered vehicles, and seamless hardware automation, including LEDs, buzzer, LCD display, and gate control through a servo motor.

During testing, registered vehicles were correctly identified and authenticated by matching the detected license plate with the database. Upon successful verification, the system activated the green LED, displayed “Vehicle Verified, Gate Opening…” on the LCD, and rotated the servo motor to open the gate. For unregistered vehicles, the system triggers the red LED, activates the buzzer, displayed “Unregistered Vehicle, Not Allowed” on the LCD, and kept the gate in a closed position. All events—registered or unregistered—were automatically stored in an Excel log file with the vehicle number, timestamp, and faculty ID. This demonstrates the system’s capability to operate autonomously and maintain accurate security records.

Additionally, the system maintains stability by using confirmation frames to avoid false detections and a timeout system to automatically turn off LEDs, buzzer, and servo, ensuring power efficiency and safeguarding hardware components. The testing results confirm that the system provides a reliable, real-time access control mechanism suitable for campuses, institutions, and gated environments.

8.1 Webcam Real-Time Detection Output

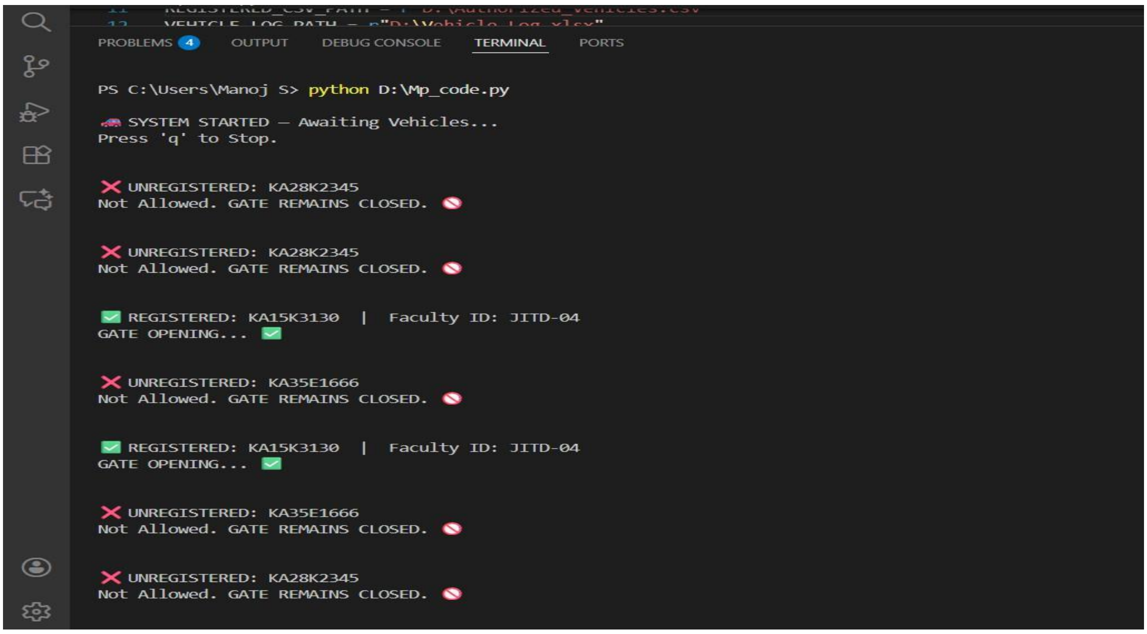
- The system successfully captures and processes the vehicle's number plate in real time using the laptop webcam. The live video feed is analyzed using Python, OpenCV and EasyOCR for detection and recognition, demonstrating real-time performance during the testing phase.



- Figure 8.1: The system captures the vehicle's number plate in real time using the laptop webcam.

8.2 OCR Recognized Number Plate (Python Console Output)

- The system displays the detected vehicle license plate details in the Python console after OCR extraction. Based on database verification, it clearly indicates whether the vehicle is registered or not and triggers the corresponding gate action (OPEN or CLOSED). This real-time console output confirms the successful working of detection and access decision logic.



- Figure 8.2: The recognized license plate is displayed in the console after OCR processing.

8.3 LCD Display – Registered Vehicle (VEHICLE VERIFIED)

- The LCD display shows "VEHICLE VERIFIED – GATE OPENING…" when an authorized vehicle is detected by the system. This confirms successful validation and triggers the gate mechanism to open, indicating seamless communication between the processing unit and the hardware control module.

- Figure 8.3: LCD shows "Vehicle Verified, Gate Opening…" for registered vehicles.

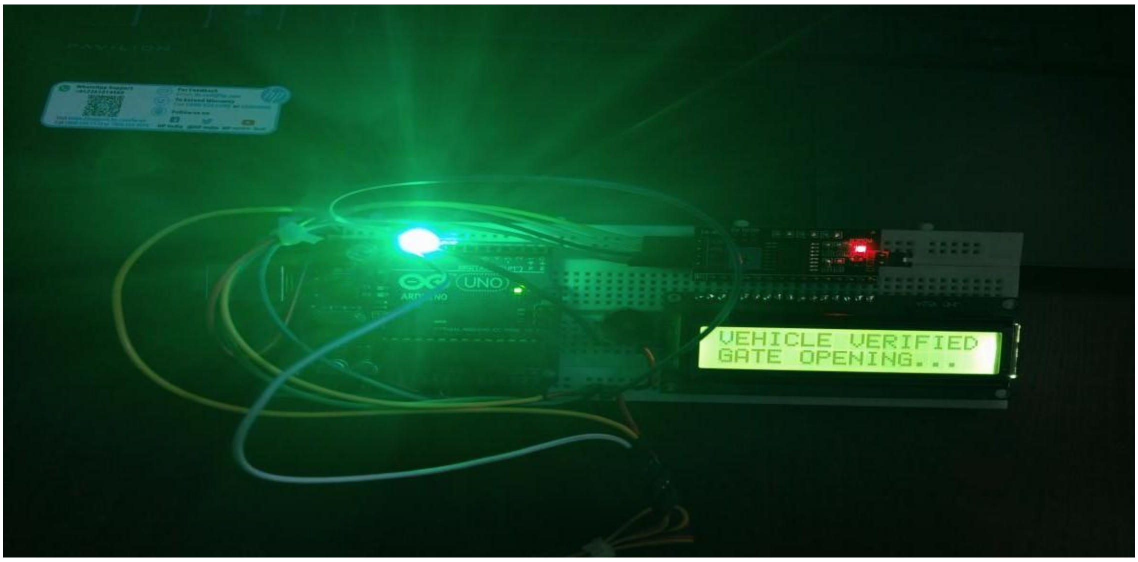
8.4 LCD Display – Unregistered Vehicle (ACCESS DENIED)

- The LCD displays **"UNREGISTERED – ACCESS DENIED"** when an unauthorized vehicle is detected by the system. This indicates that the vehicle number did not match the registered database, and therefore, the gate remains closed with alert notifications triggered for security

- Figure 8.4: LCD displays “Unregistered Vehicle, Access Denied” for unauthorized vehicles.

8.5 Green LED ON for Registered Vehicle

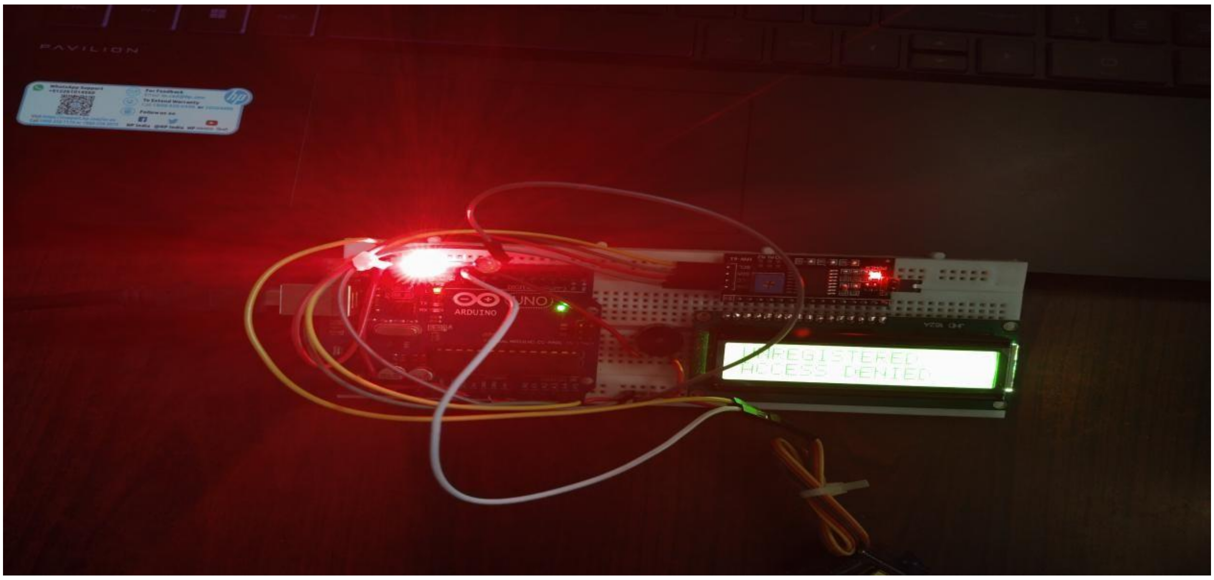
- The green LED turns ON to indicate that the detected vehicle is registered and authorized for entry. This visual confirmation accompanies the “VEHICLE VERIFIED – GATE OPENING…” message on the LCD, signaling successful authentication and activation of the gate mechanism.



- Figure 8.5: Green LED glows when a registered vehicle is detected and gate opening is activated.

8.6 Red LED + Buzzer for Unregistered Vehicle

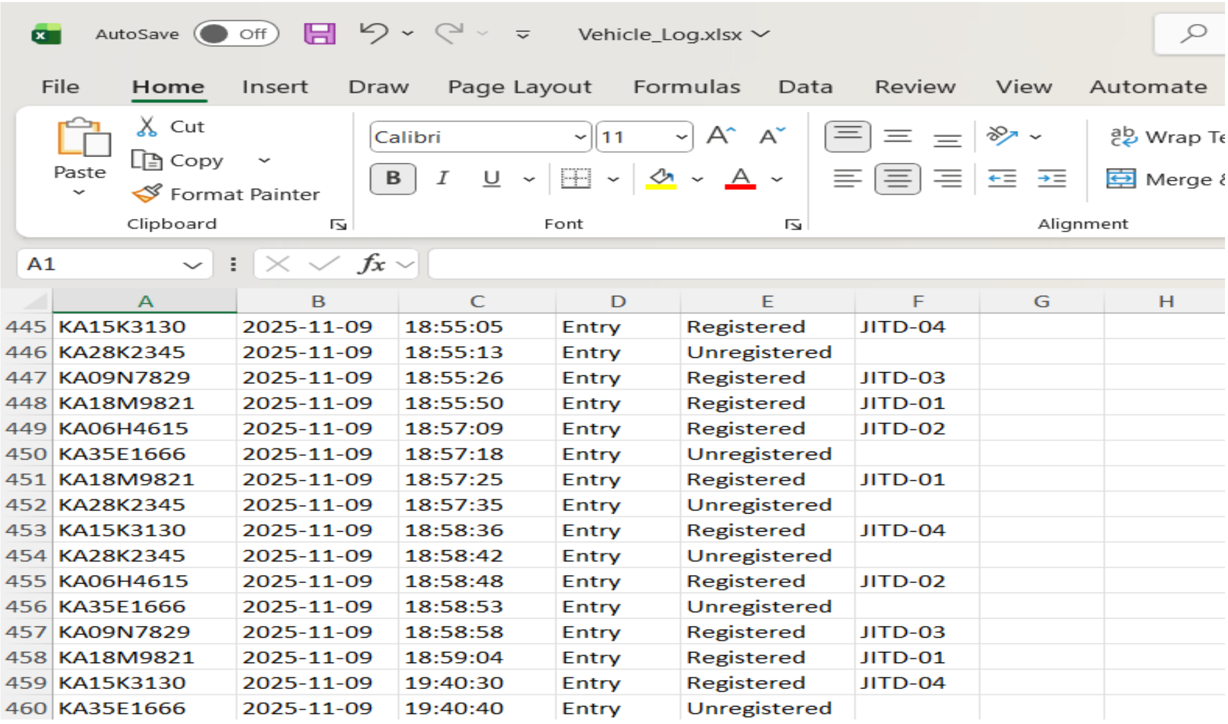
- When an unregistered vehicle is detected, the red LED turns ON and the buzzer produces an alert sound to notify security personnel. This warning indication, along with the “ACCESS DENIED” message on the LCD, ensures immediate detection and prevents unauthorized gate entry.



➢ Figure 8.6: Red LED and buzzer alert security when an unauthorized vehicle is detected.

8.7 Excel Log Entries

➢ The system automatically logs all vehicle detection events into an Excel file, recording plate number, date, time, entry status, and faculty ID. Registered vehicles are marked as “Registered,” while unauthorized attempts are stored as “Unregistered,” ensuring accurate tracking and report generation for security auditing.



	A	B	C	D	E	F	G	H
445	KA15K3130	2025-11-09	18:55:05	Entry	Registered	JITD-04		
446	KA28K2345	2025-11-09	18:55:13	Entry	Unregistered			
447	KA09N7829	2025-11-09	18:55:26	Entry	Registered	JITD-03		
448	KA18M9821	2025-11-09	18:55:50	Entry	Registered	JITD-01		
449	KA06H4615	2025-11-09	18:57:09	Entry	Registered	JITD-02		
450	KA35E1666	2025-11-09	18:57:18	Entry	Unregistered			
451	KA18M9821	2025-11-09	18:57:25	Entry	Registered	JITD-01		
452	KA28K2345	2025-11-09	18:57:35	Entry	Unregistered			
453	KA15K3130	2025-11-09	18:58:36	Entry	Registered	JITD-04		
454	KA28K2345	2025-11-09	18:58:42	Entry	Unregistered			
455	KA06H4615	2025-11-09	18:58:48	Entry	Registered	JITD-02		
456	KA35E1666	2025-11-09	18:58:53	Entry	Unregistered			
457	KA09N7829	2025-11-09	18:58:58	Entry	Registered	JITD-03		
458	KA18M9821	2025-11-09	18:59:04	Entry	Registered	JITD-01		
459	KA15K3130	2025-11-09	19:40:30	Entry	Registered	JITD-04		
460	KA35E1666	2025-11-09	19:40:40	Entry	Unregistered			

➢ Figure 8.7 Excel Log Entries for Registered and Unregistered Vehicles

CHAPTER 9

ADVANTAGES, DISADVANTAGES & APPLICATIONS

9.1 ADVANTAGES

- **Automation of Vehicle Access:** The system eliminates the need for manual vehicle verification by using AI and OCR for real-time number plate recognition.
- **High Accuracy & Speed:** EasyOCR and OpenCV enable rapid and precise detection of license plates, improving efficiency during peak hours.
- **Enhanced Security:** Unauthorized vehicles are instantly detected, and access is denied automatically with LED and buzzer alerts.
- **Real-Time Notifications:** Registered users receive instant SMS alerts confirming them vehicle's successful entry.
- **Automatic Gate Operation:** The servo motor opens the gate automatically for registered vehicles and keeps it closed for unregistered ones.
- **Data Logging & Tracking:** Each vehicle entry and exit is logged automatically in an Excel sheet for future record verification.
- **Low-Cost and Scalable:** Built using affordable components like Arduino, webcam, and open-source Python libraries, making it easily deployable in various locations.
- **User-Friendly Display:** The 16x2 LCD provides real-time status updates such as "Vehicle Verified – Gate Opening" or "Access Denied."

9.2 DISADVANTAGES

- **Lighting and Environmental Limitations:** The system's accuracy may slightly reduce under poor lighting, rain, or when license plates are dusty or damaged. However, this can be improved by using infrared cameras or better preprocessing filters.
- **Internet Requirement for SMS Service:** The SMS notification feature requires an active GSM or internet connection. In offline mode, the system continues to log data and control gate access, ensuring functionality without major interruption.

9.3 APPLICATIONS

- **Educational Campuses:** For automated faculty, student, and staff vehicle entry verification.
- **Corporate Offices:** To manage employee vehicle access securely.
- **Residential Apartments & Gated Communities:** To automatically verify residents and deny access to unregistered vehicles.
- **Parking Facilities:** For ticketless entry and exit with automatic record-keeping.
- **Government or Military Zones:** For restricted vehicle access control and surveillance.
- **Hospitals & Research Institutes:** To maintain safe and efficient vehicle management with real-time monitoring.
- **Toll Gates & Smart City Projects:** For automated vehicle verification and traffic management.

CHAPTER 10

CONCLUSION AND FUTURE WORK

Conclusion

The AI-Powered Real-Time Smart Vehicle Access and License Plate Recognition System successfully automates vehicle authentication using computer vision, OCR, and microcontroller-based hardware control. By integrating a laptop webcam with Python (EasyOCR + OpenCV) and Arduino-controlled components such as LEDs, buzzer, LCD display, and a servo motor, the system eliminates the need for manual verification at entry gates. It accurately identifies number plates, verifies them against the authorized database, automates gate opening for registered vehicles, and restricts access for unauthorized vehicles.

The project also ensures reliable communication between software and hardware, provides instant visual and audible feedback, and securely logs vehicle entries and alerts into an Excel database. Overall, the system improves security, reduces human workload, minimizes errors, and enhances the efficiency of vehicle movement at campus entry points or similar restricted zones.

Future Work

- **SMS Notification Integration:** Automatic SMS alerts can be sent through GSM or online APIs like Fast2SMS or Twilio to notify registered vehicle owners about entry and exit logs.
- **Mobile App / Dashboard:** A dedicated Android/web dashboard can be developed for real-time monitoring of vehicle entries, logs, and security alerts.
- **Upgraded ANPR Model (Deep Learning):** YOLO-based number plate detection and deep learning OCR can be added to improve accuracy in low-light, angled, or blurred conditions.
- **Boom Barrier / Automatic Gate:** Replace the servo model with a full-scale boom barrier mechanism for real-world deployment at institutions or apartments.
- **Cloud Integrated Vehicle Database:** Shift from offline CSV logs to cloud platforms like Firebase, MySQL, or AWS for real-time multi-gate synchronization.
- **Multi-Lane Support:** Expand the system to handle multiple entry and exit lanes with additional cameras and microcontrollers.

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