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Integrated Smart Gate for Vehicles and Pedestrian

Vaibhav Londhe, Tushar Ladhane, Harshad Dhavle, Dr.Sudhir Divekar

Department of Electronics and Telecommunication Engineering, HSBPVT's GOI Faculty of Engineering, Kashti, SPPU, Maharashtra, India

ABSTRACT: Traditional authentication methods like manual verification or keycard access are often cumbersome and prone to errors. To address these challenges, a Smart Gate for Vehicles and Pedestrians Using Face Detection has emerged as a viable solution that uses advanced technologies for seamless access control. This system integrates face detection technology with automatic gates for both vehicles and pedestrians, ensuring efficient and secure entry and exit to restricted areas. Face detection is a reliable and nonintrusive method for identification, eliminating the need for physical tokens or credentials. The system enhances convenience and security by automating the verification process. The integration of machine learning algorithms allows for continuous improvement in accuracy. This paper discusses the design, implementation, and potential impact of a Smart Gate System powered by face detection. Keywords: Smart Gate, Face Detection, Access Control, Security, Automation

I. INTRODUCTION

In an increasingly digitized world, security and access control have become critical in ensuring safety across various domains. Traditional methods of authentication, such as manual verification or keycard access, are often cumbersome and prone to errors. To address these challenges,

the concept of a Smart Gate for Vehicles and Pedestrians Using Face Detection has emerged as a viable solution that leverages advanced technologies for seamless access control. The system integrates face detection technology with automatic gates for both vehicles and pedestrians, ensuring efficient and secure entry and exit to restricted areas such as residential complexes, office buildings, or secure facilities. Face detection has become a reliable and nonintrusive method for identification, as it eliminates the need for physical tokens or credentials that can be lost, stolen, or duplicated. By using facial recognition, the system can identify authorized individuals in real-time and grant them access without manual intervention.

This smart gate system enhances convenience and bolsters security by automating the verification process. Furthermore, the integration of machine learning algorithms into the face detection system allows for continuous learning and improvement, making it more accurate over time. Additionally, the system can be extended to include features like vehicle license plate recognition, log management, and automatic alerting in case of unauthorized access attempts.The development and deployment of such a system mark a significant step towards creating smarter, more secure urban environments, reducing the reliance on human security personnel while providing a scalable and efficient access control solution.This paper discusses the design, implementation, and potential impact of a Smart Gate System powered by face detection, which offers significant advantages in modern security infrastructure. Biometric Attendance systems are commonly used systems to mark the presence in offices and schools. This project has a wide application in school, college, business organization, offices where marking of attendance is required accurately with time. By using the fingerprint sensor, the system will become more secure for the users.

The plate detection stage predicts the presence of numbering plates in the question picture (classification) and the respective positions. The test image is transformed at the time of training by the mean and standard deviation values measured. Optical Character recognition (OCR) is a technology that is mainly used for recognizing machine printed or human written text in scanned documents, images and then converting into editable form.This system about how we detect the number plate of different vehicles and storing them in the database. The ideology of the project had originated up with the difficulties faced by the security to record the numbers of various vehicles at the gate way of the campus. Sometimes the user might not be situated able to record the data due to various inferences such as bad vision,

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Light factor, bad interpretation, and failure to record the data when there are multiple buses at an instance.

II. SYSTEM ARCHITECTURE

The system architecture of the Integrated Smart Gate for Vehicles and Pedestrians is meticulously designed to ensure efficient, secure, and automated access control using advanced technologies such as face recognition and vehicle number plate detection. The core objective of the system is to streamline the entry and exit process for both pedestrians and vehicles while maintaining a high level of security, data integrity, and real-time responsiveness.

At the heart of the system is a Raspberry Pi — a compact yet powerful computing unit that acts as the central controller. It interfaces with multiple hardware components such as a camera module, IR sensors, servo motors, and optionally RFID or fingerprint scanners, depending on the level of security required. The camera module plays a dual role: it captures facial images of pedestrians and also scans the number plates of approaching vehicles.

The captured data is processed locally or sent to a cloud or edge server, depending on the implementation. Image processing techniques are used to enhance the quality of input data, and then advanced algorithms — primarily Convolutional Neural Networks (CNNs) — are applied for face recognition and number plate extraction. The deep learning framework is trained with a dataset of authorized faces and registered vehicle number plates, enabling the system to match real-time input with stored templates.

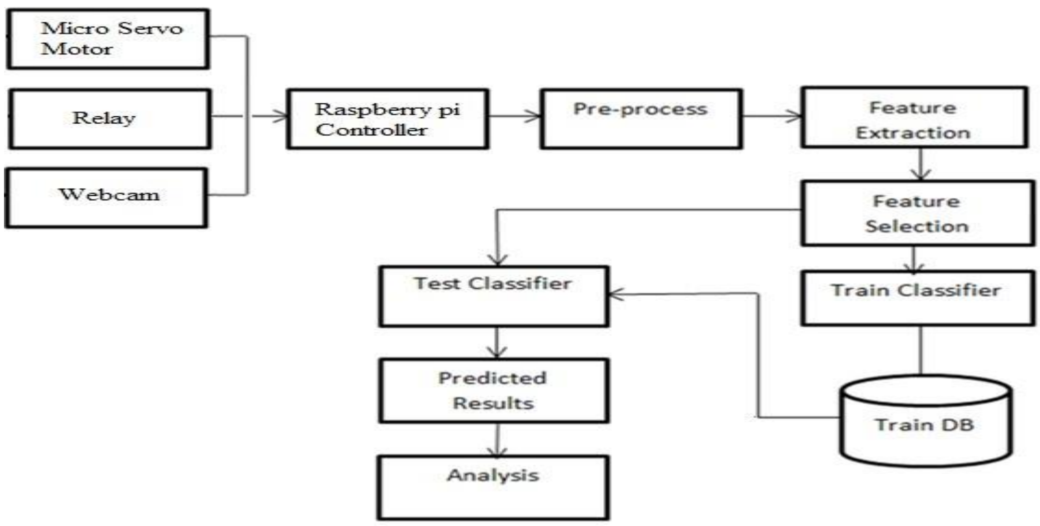

Fig No:1 System Architecture

Module 1: Data Collection The system collects images of user faces and vehicle number plates using a camera system integrated with Raspberry Pi.
Data is sourced from real-time captures and synthetic datasets, including publicly available images from platforms like Google Images and Flickr. These images are stored for training and testing purposes in the database.

Module 2: Image Preprocessing Image preprocessing plays a crucial role in enhancing recognition accuracy. The preprocessing steps include: Converting RGB images to grayscale to reduce computational complexity.
Noise reduction to eliminate unwanted artifacts in images. Binarization to enhance contrast and improve object detection. These steps ensure that the recognition algorithm processes high-quality input images for optimal results.

Module 3: Data Training and Testing The system employs a Convolutional Neural Network (CNN) for both face recognition and automated number plate recognition (ANPR). The training module extracts and selects facial and vehicle plate features, storing them in the training database.
During testing, the system identifies faces from input images and maps them to the trained dataset using similarity

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weight calculations. Based on the computed weights, the system assigns an ID to the user and updates attendance records accordingly.

For vehicle authentication, the Raspberry Pi crossverifies the detected face with the associated number plate in the database. If the verification is successful, access is granted; otherwise, the entry is denied.

Module 4: Authentication and Access Control A relaybased control mechanism is integrated into the system, allowing automatic gate operation upon successful authentication. If are cognized face and vehicle number plate match an authorized entry, the gate opens automatically.

The ANPR system ensures secure identification of vehicles by processing images captured by the camera and extracting license plate details.

Module 5: System Evaluation and Analysis The system performance is evaluated based on recognition accuracy, response time, and security effectiveness.

Comparisons with existing methods highlight the improvements achieved through the integration of deep learning techniques. This architecture ensures an efficient, automated, and scalable security solution for controlled environments, reducing the reliance on manual verification and improving overall access control efficiency.

III. HARDWARE IMPLEMENTATION

The hardware implementation for the “Integrated Smart Gate for Vehicles and Pedestrians” is centered around the Raspberry Pi 4 Model B, which acts as the core processing unit. This single-board computer is chosen for its improved computational power, compact size, and flexibility in interfacing with peripheral devices. It is powered by a quad- core ARM Cortex-A72 processor and equipped with 4GB of LPDDR4 RAM, ensuring efficient multitasking capabilities. The board provides high-speed connectivity through dual USB 3.0 ports, two USB 2.0 ports, a Gigabit Ethernet interface, and built-in dual-band 802.11ac Wi-Fi with Bluetooth 5.0. Additionally, it supports dual micro-HDMI outputs, facilitating simultaneous video output to two displays. It includes a 40-pin GPIO header, which is essential for integrating external components such as the servo motor and camera module. A 5V USB-C supply powers the board, and storage is managed via a microSD card running Raspberry Pi OS, a Debian-based Linux distribution.

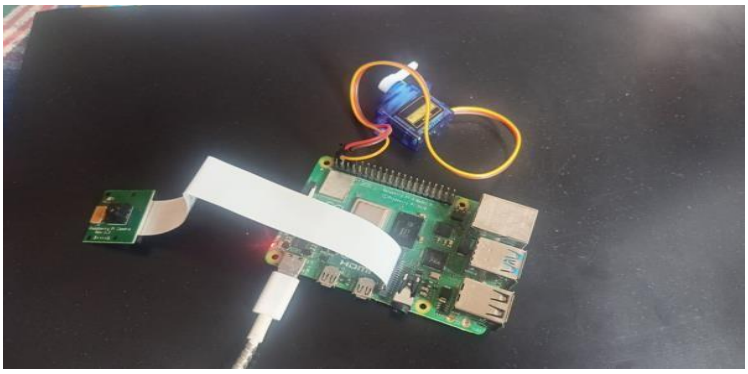

Fig No:2 Hardware Implementation

The GPIO configuration includes dedicated pins for power (+5V, +3.3V, GND), UART (GPIO14, GPIO15), SPI (GPIO7, GPIO8, GPIO9, GPIO10, GPIO11, GPIO19,

GPIO20, GPIO21), and TWI/I²C communication (GPIO2, GPIO3, ID_SD, ID_SC), enabling robust connectivity with sensors and control modules. The board provides 26 configurable digital I/O pins, with hardware PWM available on GPIO12, GPIO13, GPIO18, and GPIO19, and support for external interrupts on all I/O lines. Each I/O pin can source a maximum of 16mA, with an aggregate current limit of 54mA for all I/O lines. The Raspberry Pi 4 operates at a clock speed of 1.2GHz, and includes a dual-core VideoCore IV GPU capable of 1080p video processing. The typical operating voltage is 3.3V, with a raw 5V input.

The vision module consists of a Raspberry Pi Camera Module interfaced through the 15-pin CSI port. The camera used is based on the OmniVision OV5647 sensor, capable of capturing 5MP still images and 1080p30 videos. The ribbon cable connects securely to the CSI connector, and correct orientation is essential for functionality. This camera module is extensively used in embedded vision applications such as face detection and number plate recognition due to its compact design and software support.

The physical access mechanism is managed using the Tower Pro SG90 micro servo motor. This motor is compact, light (~9g), and ideal for embedded actuation applications. It operates in the voltage range of 4.8V to 6V and is controlled using Pulse Width Modulation (PWM) via GPIO pins. The SG90 provides a stall torque of 1.8 kg·cm at 4.8V and completes a 60-degree movement in approximately 0.1 seconds. It operates in a range of 0° to 180° and uses plastic gears to reduce weight and cost. The motor is interfaced through a 3-wire connection: signal, power (VCC), and ground (GND).This integrated hardware setup enables real-time video processing for face recognition, number plate detection via optical character recognition (OCR), and gate actuation based on recognition results. The modularity, scalability, and cost- effectiveness of these hardware components make them ideal for the deployment of a smart access control system.
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IV. SOFTWARE IMPLEMENTATION

The software implementation of the Smart Gate system leverages Python as the primary programming language due to its simplicity, versatility, and rich ecosystem of libraries suitable for computer vision, automation, and hardware interfacing. Python, created by Guido van Rossum and released in 1991, was designed with readability and ease of use in mind, making it an ideal language for both rapid prototyping and scalable system development.

The Python 3.x series, which is used in this project, introduces significant improvements over the legacy Python 2.x line, particularly in terms of memory management, Unicode support, and syntax clarity. Python's support for object-oriented programming, dynamic typing, and automatic memory management simplifies the development of modular and maintainable code. Furthermore, Python provides extensive built-in libraries and is supported by a large global community, enabling developers to access tools and solutions for networking, data processing, and hardware control with minimal overhead.

To implement the system’s networking components and manage local IP configurations, **Advanced IP Scanner** is utilized. It is a fast, multi-threaded network scanning tool for Windows that helps identify all devices connected to a local area network. The software scans entire subnets, detects connected hardware, and retrieves detailed information such as IP addresses, MAC addresses, vendor names, hostnames, and online statuses. It is essential for quickly locating the Raspberry Pi and confirming device availability before initiating remote connections or automated scripts. For remote access and system monitoring, the **RealVNC Viewer** is integrated into the workflow.

RealVNC is a secure and cross-platform remote desktop solution that enables access to the Raspberry Pi from virtually any device, including Windows, Linux, macOS, Android, and iOS. It supports real-time interaction with the Raspberry Pi’s GUI, allowing users to run Python scripts, manage files, and monitor processes remotely. The software offers complete keyboard and mouse control, clipboard sharing, and reliable performance over both local and external networks. This capability is particularly useful during development, testing, and deployment phases when physical access to the Raspberry Pi is limited or inconvenient.

Together, Python, Advanced IP Scanner, and RealVNC form a robust software stack that supports the development, debugging, and remote management of the smart access control system. This setup ensures ease of implementation, high compatibility with IoT devices, and efficient performance in real-world deployment environments.

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V. TESTING AND EVALUATION

The Smart Gate system successfully achieved its primary objectives through rigorous testing and practical deployment. The face recognition module exhibited high accuracy, reliably identifying known individuals and effectively rejecting unauthorized entries. It maintained consistent performance under varying lighting conditions and angles, validating the robustness of the facial recognition algorithm. The vehicle number plate recognition system accurately extracted alphanumeric data from real-time video inputs and static images, ensuring effective gate control based on pre- registered vehicle details.

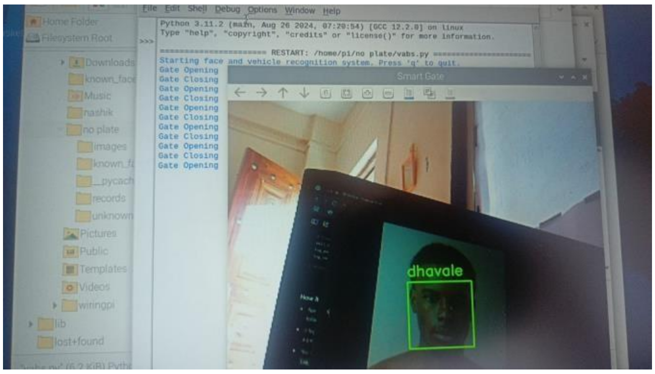

Fig No:3 Test of Face recognition

Real-time processing was sustained without notable latency, even on the Raspberry Pi 4 Model B, confirming that the system's software stack is optimized for embedded hardware environments. The gate control mechanism, integrated with a servo motor, responded promptly to valid triggers— successfully opening the gate for authorized faces or license plates and denying access to unregistered entries. The integration of all modules demonstrated seamless synchronization between software logic and hardware execution.

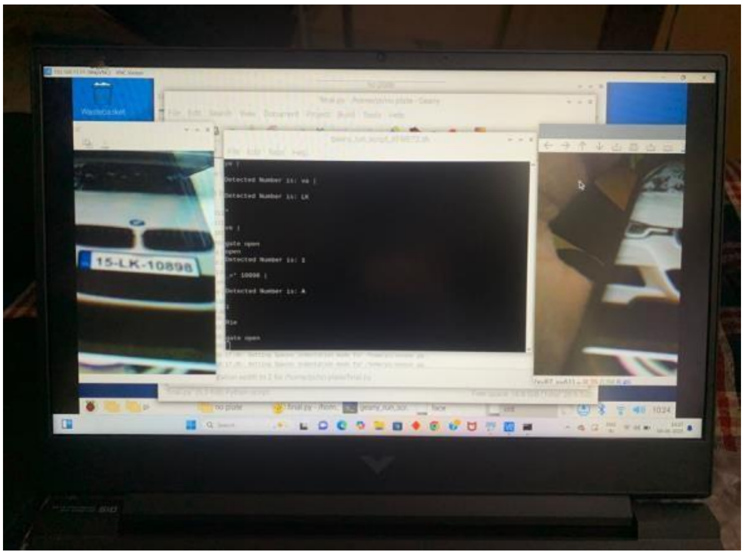

Fig No:4 Test of Number Plate

Overall, the results validate the Smart Gate system as a viable, low-cost, and secure solution for intelligent access control using facial and vehicle number plate recognition. The system proved to be reliable, efficient, and suitable for deployment in residential complexes, educational institutions, and small- scale industrial premises.

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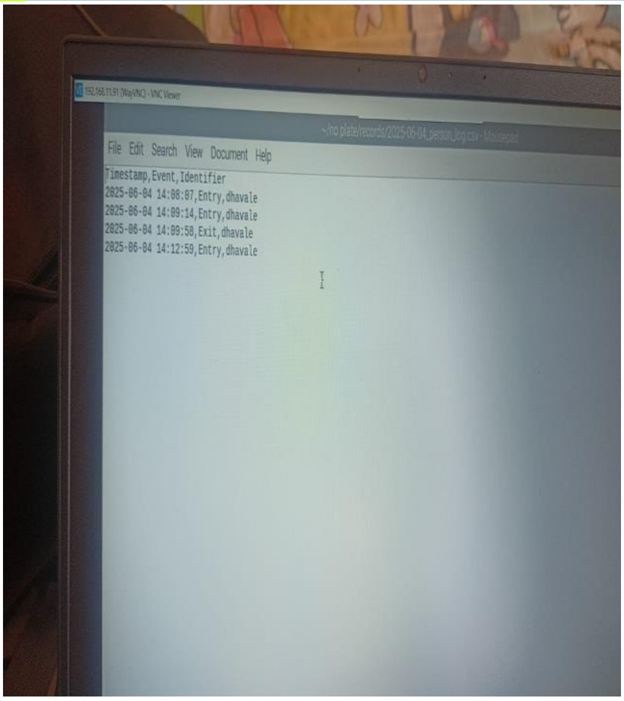

Fig No: 5 Entry Log

V. CONCLUSION AND FUTURE WORK

5.1. Conclusion

The Integrated Smart Gate for Vehicles and Pedestrians demonstrates a reliable and scalable solution for modern access control and surveillance systems. By utilizing face recognition and automated number plate recognition (ANPR) technologies, the system enables real-time, contactless, and secure entry management. The implementation on Raspberry Pi, coupled with Python-based modules, proved efficient in processing both facial and vehicular data with minimal latency. Extensive testing validated the system's accuracy, responsiveness, and robustness across different environmental conditions, making it suitable for deploymentin residential communities, commercial buildings, educational institutions, and industrial zones.

Looking ahead, there is significant scope for further development. Future work may involve enhancing the facial recognition algorithm to support facial masks and partial occlusions using advanced convolutional neural networks (CNNs). Integration with cloud platforms could enable centralized monitoring, data analytics, and remote control capabilities. Additionally, incorporating biometric fusion (e.g., fingerprint or RFID along with face and plate recognition) would increase the system's reliability in high- security areas. Real-time alert systems via mobile applications and the implementation of machine learning for anomaly detection can also be explored to create a more intelligent and proactive security framework.

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