Integrated IoT-Based Vehicle Access Control System with Number Plate Recognition and Facial Authentication

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***Abstract*— In this paper, we present a compact IoT project developed for the purpose of number plate detection, reading, and face recognition for authorization. Leveraging computer vision and Machine Learning techniques, the system utilizes a pre-trained Haar Cascade classifier for face detection and a Local Binary Pattern Histograms (LBPH) face recognizer for facial identification. The underlying model is trained using a labeled dataset and associates detected faces with corresponding individuals through a mapping stored in a structured CSV file. The access control system also incorporates number plate detection through image processing techniques, enhancing security measures. The proposed system operates in real-time, continuously capturing video feed from a camera, and dynamically updating access permissions based on recognized faces and vehicle number plates. The system's modular design allows for scalability and adaptability to various access control scenarios. Experimental results demonstrate the effectiveness of the approach in accurately identifying individuals and vehicles, showcasing its potential for practical implementation in security-sensitive environments.**

Keywords*: *IoT, Machine Learning, Deep Learning Models, Home Security

I. INTRODUCTION

In the modern world, the proliferation of Internet of Things (IoT) technologies is revolutionizing daily life, introducing heightened automation, security, and convenience. This project introduces a cutting-edge solution for vehicle access control, seamlessly uniting number plate detection, reading, and facial recognition.

Access control is fundamental for safeguarding restricted areas, parking facilities, and private spaces. Traditional methods often entail manual inputs or proximity cards, which can be cumbersome and prone to security vulnerabilities. In response, our project leverages IoT, deep learning, and computer vision to create an intelligent access control system.

The code leverages computer vision with OpenCV and a Haar cascade classifier for real-time face detection from a webcam feed. Image processing techniques, including grayscale conversion and face region extraction, are applied to the captured frames. Later, we employed OpenCV's LBPH algorithm to train a face recognition model. Once the model is trained, it is all set up for face recognition. Further, number plate recognition is done using contour detection, masking, and OCR to extract text from the isolated number plate region.

This project, combining IoT, deep learning, and computer vision, presents a sophisticated and integrated approach to vehicle access control. Through precise number plate recognition and facial authentication, it offers a compelling solution for security-conscious environments, potentially setting new standards in access control and surveillance systems. Subsequent sections will delve into technical details and implementations, paving the way for successful deployment and further advancements in the field.

II. SYSTEM OVERVIEW

Data Processing

Data processing code manages user information, captures facial images, and stores them in a structured manner for later use in training a facial recognition model. The user's ID and name are recorded in a CSV file, and the captured images are stored in directories corresponding to each user's ID.

The code for Number plate detection captures a frame from a webcam, saves it as 'image.jpeg', resizes it, applies grayscale and bilateral filtering, detects edges using Canny, identifies contours, isolates the number plate, performs OCR using Tesseract, saves results in 'data.csv'.

Hardware Components

The hardware components employed in this project are selected to achieve an optimal balance between performance, power consumption, and cost-effectiveness, making them well-suited for deployment in various real-world scenarios.

- Camera Module/ Webcam
- ESP8266

Software Requirements

- Feature extraction algorithm
- Operating System
- Libraries and Frameworks
- OpenCV for image processing
- pytesseract for Optical Character Recognition (OCR)
- Other required Python libraries for IoT and system integration

Machine learning

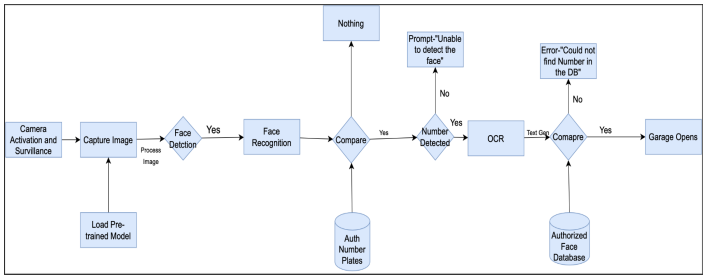
ML is at the core of the integrated IoT-based vehicle access control system presented in this research. This technology facilitates number plate detection, reading, and facial recognition, greatly enhancing security and automation. The system leverages several machine learning components:

1. Optical Character Recognition (OCR): Detected number plates undergo OCR using the pytesseract library. This involves preprocessing to enhance text quality, extracting alphanumeric characters from the image, and verifying the extracted text against an authorized list, enhancing system security.
2. Facial Recognition: In the provided code snippet, the Local Binary Pattern Histogram (LBPH) algorithm serves as a crucial component in a face recognition system. This robust technique characterizes local patterns within an image and enhances accuracy and reliability. The code initializes the LBPH face recognizer, loads a pre-trained model from a file, and seamlessly integrates it with a Haar cascade classifier for face detection in real-time. In the face recognition loop, LBPH predicts user IDs and trust levels based on facial features, associating them with corresponding names from an 'id-names.csv' file. The code provides visual feedback by drawing rectangles around detected faces and displaying recognized names. This continuous recognition process operates in real-time until the user decides to exit. Overall, LBPH's role in modeling local facial patterns significantly contributes to the system's success in accurately associating detected faces with known user identities. Security measures, such as anti-spoofing techniques, are implemented to prevent unauthorized access.

These machine learning components collectively create a robust and automated vehicle access control system, offering heightened security and convenience. The system is adaptable to various applications, from residential access control to parking management. Further details on model training, data collection, and system integration will be explored in subsequent sections, providing a comprehensive insight into the machine learning aspects of the project.

Design

The system design seamlessly integrates IoT, deep learning, and computer vision technologies. Initial user identification is facilitated by face recognition, employing a pre-trained LBPH (Local Binary Pattern Histogram) model. The system relies on the OpenCV library for computer vision tasks, utilizing the Haar cascade classifier for face detection. Concurrently, a comprehensive user database stored in a Pandas DataFrame is referenced for associating user IDs with corresponding names. Real-time recognition is achieved through machine learning techniques, as the LBPH model predicts labels and trust levels for detected facial regions. The integration also includes a mechanism for number plate detection, enhancing security measures. The system's robustness is demonstrated through the utilization of advanced image processing, contour analysis, and feature extraction methodologies. The research investigates the intricacies of these technologies, delving into the collaborative synergy between machine learning libraries, computer vision algorithms, and database management for an efficient and secure access control paradigm.



III. IMPLEMENTATION

We Initialize a Haar cascade classifier for face detection, LBPH (Local Binary Pattern Histogram) face recognizer, and a webcam capture. The LBPH face recognizer is trained with a pre-trained model ('TrainedLBPH.yml'). The threshold is set to 500 for face recognition confidence.

Then we capture video frames from the webcam, convert them to grayscale, and detect faces in each frame using the Haar cascade classifier.

For each detected face, it extracts the face region, resizes it, and uses the LBPH recognizer to predict the person's label. If a match is found in the 'id_names' DataFrame, it draws a rectangle around the face and displays the name.

The recognized name is printed, and the frame is displayed for 10 seconds. If a name is found, the loop breaks, otherwise it keeps running until the face is detected. Shifting gears to Number Plate Recognition, our approach involves a sophisticated interplay of contour detection, masking techniques, and OCR (pytesseract). But it doesn't stop there – we've bolstered security by implementing text verification against an authorized list, adding an extra layer of protection. Now, the magic happens when both the face and number plate recognition modules seamlessly integrate. Picture this: when our system detects both the face and number plate, a visual cue in the form of an LED blinking on the ESP8266 signifies a successful recognition event. It's not just about detection; it's about integration and enhanced security measures working hand in hand for a robust outcome.

IV. OUTCOMES

The final project outcome presents an integrated IoT-based vehicle access control system that offers advanced security and convenience for applications in residential areas, parking facilities, and more. It includes effective number plate detection and reading, leveraging computer vision techniques for accurate identification. Additionally, the system incorporates deep learning-based facial recognition for identity verification, enhancing security by granting access to authorized individuals.

Future work entails refining number plate recognition, optimizing machine learning models, and improving scalability. Mobile app integration, data analysis, and enhanced security measures are planned. A user management portal and potential open-source contributions aim to enhance user-friendliness and community collaboration. Energy-efficient components and user feedback-driven enhancements complete the vision for a comprehensive and adaptable access control solution.

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