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SmartFuelGuard-AI-Assisted Vehicle Verification and Fraud Detection System for Fuel Stations

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Abstract: ***SmartFuelGuard is an intelligent AI-assisted vehicle verification and fraud detection system designed for petrol fuel stations. The system automates vehicle authentication using camera-based Automatic Number Plate Recognition (ANPR) integrated with Optical Character Recognition (OCR). Extracted vehicle numbers are validated against a backend database to check Registration Certificate (RC), insurance validity, Pollution Under Control (PUC) status, and blacklist records. A rule-based decision engine determines whether to allow or block fuel dispensing. Real-time alerts and logs are generated for monitoring. The system is developed using Flutter for frontend, FastAPI for backend, and SQLite for data management. SmartFuelGuard enhances fuel station security, reduces fraud, and improves operational efficiency through real-time automated verification.***

Keywords: SmartFuelGuard, OCR, ANPR, Fraud Detection, Fuel Station Automation

1. Introduction

With the rapid increase in vehicle usage, fuel stations face significant challenges in verifying vehicle authenticity and preventing unauthorized fuel dispensing. Traditional manual verification methods rely heavily on human operators, making the process slow, error-prone, and inefficient. These methods are also incapable of effectively detecting fraudulent activities such as the use of expired documents, fake registrations, or blacklisted vehicles.

The lack of an automated verification system can lead to serious issues including fuel theft, financial losses, and reduced operational efficiency. Moreover, manual processes do not provide proper logging or monitoring capabilities, making it difficult to track suspicious activities and maintain accountability.

Recent advancements in artificial intelligence and computer vision have enabled the development of intelligent systems capable of automating such verification tasks. Technologies like Automatic Number Plate Recognition (ANPR) and Optical Character Recognition (OCR) have been widely used in traffic monitoring, surveillance systems, and smart city applications. These technologies provide an opportunity to enhance fuel station operations through automation and real-time validation.

SmartFuelGuard is proposed as an AI-assisted vehicle verification and fraud detection system that automates the process of validating vehicle credentials before fuel dispensing. The system uses camera-based ANPR combined with OCR techniques to extract vehicle number plates from images. The extracted information is then verified against a backend database to check critical parameters such as Registration Certificate (RC), insurance validity, Pollution Under Control (PUC) status, and blacklist records.

Based on this verification, a rule-based decision engine determines whether the vehicle should be allowed or blocked from refueling. In addition, the system generates real-time alerts for suspicious cases and maintains logs for monitoring and analysis. This ensures improved transparency, accountability, and security in fuel station operations.

The system is implemented using Flutter for the frontend, providing a user-friendly interface, and FastAPI for the backend, enabling efficient data processing and communication. SQLite is used for lightweight and efficient data storage. By integrating AI-based recognition with backend validation, Smart- FuelGuard offers a scalable and reliable solution for modern fuel management systems.

Overall, the proposed system aims to reduce human intervention, improve accuracy, enhance security, and enable real- time decision-making, making it a valuable component in smart transportation and smart city infrastructures.

2. Related Works

Recent advancements in artificial intelligence and computer vision have significantly contributed to the development of automated security and verification systems. Optical Character Recognition (OCR) and Automatic Number Plate Recognition (ANPR) technologies are widely used in applications such as traffic monitoring, toll collection, and surveillance systems for vehicle identification.

Sharma et al. (2025) demonstrated the effectiveness of OCR-based systems in accurately recognizing vehicle number plates under controlled conditions. Their work highlighted the importance of image preprocessing techniques such as grayscale conversion and thresholding to improve recognition accuracy. Similarly, Kumar et al. (2024) proposed an AI-based fraud detection system that utilizes rule-based validation to identify anomalies and unauthorized activities in real-time systems.

Singh et al. (2024) developed an ANPR system using deep learning models for vehicle detection and number plate

extraction. Their system achieved high accuracy but required significant computational resources and lacked integration with real-time decision-making systems. Patel et al. (2023) introduced a smart monitoring system that combines OCR with cloud-based storage for vehicle tracking; however, the system primarily focused on data storage rather than automated action or decision control.

In another study, Verma et al. (2023) explored the use of machine learning algorithms for detecting fraudulent activities in transportation systems. Their approach improved detection accuracy but did not provide a direct mechanism for controlling physical processes such as fuel dispensing. Rao and Nair (2022) proposed a centralized monitoring system for smart city applications, emphasizing real-time data col- lection and analysis, but without integrating vehicle verification with operational control.

Although these systems provide valuable contributions in areas such as number plate recognition, fraud detection, and monitoring, most of them focus on individual functionalities. They lack a unified framework that integrates vehicle identification, document verification, decision-making, and real- time operational control.

SmartFuelGuard addresses these limitations by integrating OCR-based number plate recognition with backend validation of vehicle documents such as RC, insurance, and PUC. In addition, the system incorporates a rule-based decision engine that directly controls fuel authorization by generating ALLOW or BLOCK outcomes. The inclusion of real-time alerts, logging mechanisms, and role-based access control further distinguishes SmartFuelGuard from existing systems, making it a comprehensive and practical solution for fuel station automation.

3. Outlined Method

Designing the SmartFuelGuard system involves a structured methodology focused on automating vehicle verification and enhancing security at fuel stations. The system integrates artificial intelligence techniques, computer vision, and web/mobile technologies to provide a reliable and real-time fuel authorization solution.

3.1 Requirement Analysis

The requirement analysis phase focuses on identifying the limitations of traditional fuel station operations. Manual verification of vehicle documents is time-consuming, prone to human error, and ineffective in detecting fraudulent or black- listed vehicles. Additionally, there is a lack of real-time monitoring and centralized control in existing systems.

To overcome these challenges, the system defines key functional requirements such as automatic number plate detection, OCR-based text extraction, vehicle document verification (RC, insurance, PUC), blacklist detection, alert generation, and centralized logging. Non-functional requirements include system reliability, real-time performance, scalability, accuracy of OCR, and user-friendly interface design.

a) System Design

The system architecture is designed as a modular structure where components interact through a backend server and database. The major modules of the system include:

- **User Module:** Handles login and role-based access for admin, petrol pump owner, and operator.
- **Scanning Module:** Captures vehicle number plate images using a camera interface.
- **OCR Module:** Uses AI-based Optical Character Recognition to extract vehicle numbers from images.
- **Verification Module:** Validates extracted vehicle num- bers against database records including RC, insurance, and PUC.
- **Decision Engine:** Applies rule-based logic to determine ALLOW or BLOCK status.
- **Alert and Logging Module:** Generates alerts for violations and stores logs for monitoring and analysis.
- **Admin Module:** Manages users, monitors system activity, and views analytics.

All modules are interconnected and communicate with a centralized database that stores vehicle records, logs, and user data.

b) Development

The development of the system is carried out using mod- ern technologies to ensure efficiency and scalability. The backend is implemented using FastAPI, which handles API requests, business logic, and database communication efficiently. The frontend application is developed using Flutter, providing a responsive and user-friendly interface for opera- tors and administrators. SQLite is used as the database for lightweight and efficient data storage.

Artificial intelligence techniques such as OCR (using Easy-OCR) and image preprocessing (using OpenCV) are used for number plate detection and extraction. Techniques such as grayscale conversion and thresholding improve image quality for better recognition accuracy. Additionally, fuzzy matching algorithms are used to handle OCR errors and improve reliability.

c) Integration & Testing

After development, all modules are integrated into a unified system to ensure smooth communication and functionality. Integration testing is performed to verify that all components such as scanning, OCR, verification, and decision-making work together without errors.

Functional testing is conducted to validate key features including number plate detection, document verification, deci- sion generation, and alert system. Performance testing ensures that the system provides real-time responses with min- imal delay. Usability testing evaluates the ease of use for operators and administrators.

These testing processes help in identifying and resolving issues, ensuring that the SmartFuelGuard system is reliable, accurate, efficient, and suitable for real-world deployment in fuel stations.

4. Evaluation & Optimization

Evaluation and optimization involve analysing the performance of all modules within the SmartFuelGuard system. This includes measuring the accuracy of number plate detection, evaluating OCR performance, analysing document verification reliability, and validating the correctness of decision- making (ALLOW/BLOCK).

The system performance is assessed based on OCR accuracy, response time, decision accuracy, and system reliability. The OCR module is evaluated based on its ability to correctly extract vehicle numbers under different lighting and image conditions. The verification module is tested to ensure accurate validation of RC, insurance, PUC, and blacklist records.

Optimization techniques are applied to enhance overall system performance. These include improving OCR accuracy through image preprocessing techniques such as grayscale conversion and thresholding, optimizing database queries for faster verification, and reducing API response time. Additional improvements such as efficient image handling, caching mechanisms, and user interface optimization are implemented to ensure smooth system operation.

4.1 Machine Learning Approach

The SmartFuelGuard system applies artificial intelligence and computer vision techniques to automate vehicle verification and fraud detection. One of the core components of the system is the OCR module, which uses machine learning-based text recognition models to extract vehicle numbers from captured images.

The system processes image input captured from the camera. Image preprocessing techniques such as noise reduction, grayscale conversion, and thresholding are applied to enhance image quality. The processed image is then passed to the OCR engine (EasyOCR), which extracts the vehicle number.

To improve accuracy, fuzzy matching algorithms are used to correct minor OCR errors and match extracted text with database records. The extracted vehicle number is then validated against stored data, including RC validity, insurance status, PUC, and blacklist information.

The decision engine uses rule-based logic to determine whether the vehicle is authorized for fuel dispensing. Based on the verification results, the system generates an ALLOW or BLOCK decision. In case of violations, alerts are triggered and logs are stored for monitoring.

By integrating OCR, image processing, and decision logic, SmartFuelGuard provides an efficient and automated solution for real-time vehicle verification at fuel stations.

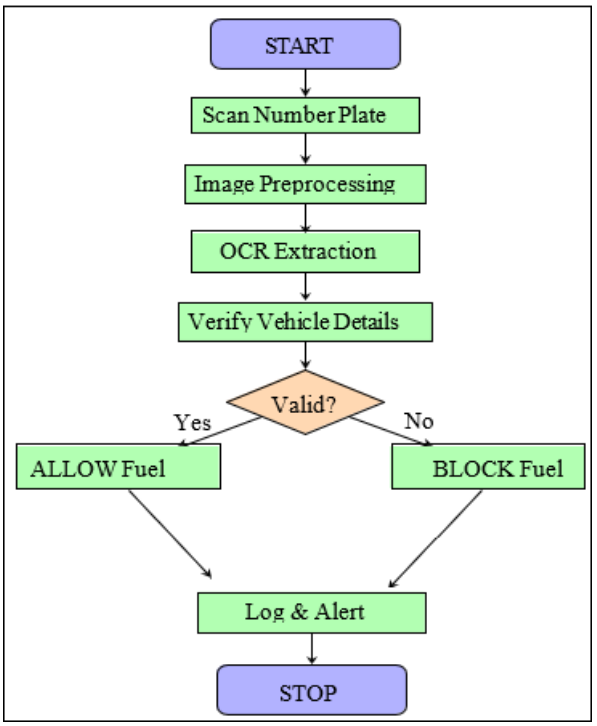

Figure 1: Flowchart of SmartFuelGuard System

4.2 Dataset Description

The SmartFuelGuard system utilizes a dataset consisting of vehicle-related records and captured image data. This includes vehicle numbers, Registration Certificate (RC) details, insurance status, Pollution Under Control (PUC) records, and blacklist information stored in the database.

Image data captured from the camera is processed using OCR techniques to extract vehicle numbers. The extracted data is compared with stored records to perform verification. The dataset is structured to ensure quick retrieval and efficient validation during real-time operations.

Different types of data are handled within the system. Image data is used for number plate detection, textual data is used for vehicle record verification, and system logs are maintained for monitoring and analysis. The system ensures proper organization and storage of this data to maintain consistency and improve performance.

The dataset can be updated dynamically as new vehicles are added or existing records are modified. Efficient data management techniques are implemented to ensure data integrity, security, and fast retrieval, enabling reliable and scalable system performance.

5. Result & Discussion

5.1 System Performance

The SmartFuelGuard system demonstrates effective performance in automating vehicle verification and fraud detection at fuel stations. The system successfully detects vehicle number plates using camera input and extracts the vehicle number using OCR techniques.

The OCR module accurately identifies vehicle numbers

under proper lighting and image conditions. Image preprocessing techniques such as grayscale conversion and thresholding improve recognition accuracy. The extracted vehicle number is then verified against the database, ensuring correct validation of RC, insurance, PUC, and blacklist records.

The decision engine efficiently determines whether a vehicle should be allowed or blocked from refueling. Real-time alerts are generated for invalid or blacklisted vehicles, improving system security and monitoring.

The overall system performance is enhanced by the integration of FastAPI, Flutter, and SQLite technologies, which ensure fast processing, efficient data handling, and smooth user interaction. The centralized database allows quick verification and reliable storage of vehicle records and logs.

5.2 Test Cases and Outcomes

The system was tested under various scenarios to evaluate its functionality and reliability. Multiple test cases were conducted for different modules of the system.

The number plate detection and OCR module successfully extracted vehicle numbers from captured images. Minor inaccuracies occurred in cases of low image quality or unclear plates, which were minimized using preprocessing techniques and fuzzy matching.

The verification module correctly validated vehicle details such as RC, insurance, PUC, and blacklist status. The decision engine generated accurate ALLOW or BLOCK results based on predefined rules.

The alert system was tested to ensure that notifications are triggered for invalid or suspicious vehicles. The logging module successfully recorded all transactions for monitoring and analysis.

These test results indicate that the SmartFuelGuard system performs reliably and provides accurate outputs under different operating conditions.

5.3 Comparative Analysis with Existing Systems

A comparison between SmartFuelGuard and traditional fuel station operations highlights significant improvements in efficiency, accuracy, and security. Conventional systems rely on manual verification, which is time-consuming and prone to human error. These methods are also ineffective in detecting fraudulent or blacklisted vehicles.

In contrast, SmartFuelGuard automates vehicle verification using OCR and backend validation, reducing manual effort and improving accuracy. The system provides real-time decision- making, ensuring that only authorized vehicles are allowed to refuel.

Unlike traditional systems, SmartFuelGuard integrates multiple functionalities such as number plate recognition, document verification, decision-making, alert generation, and logging within a single platform. This integration enhances operational efficiency and simplifies monitoring.

Additionally, the system provides better tracking and transparency through centralized data management. All vehicle records and logs are stored and can be accessed easily, enabling better control and analysis of fuel station operations.

Overall, SmartFuelGuard transforms traditional fuel station processes into a smart, automated, and secure system.

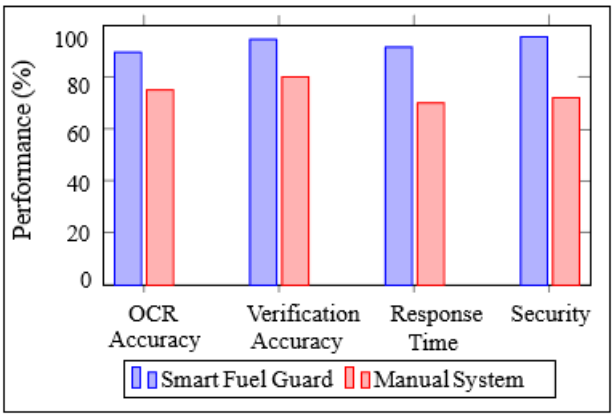

Figure 2: Performance Comparison of SmartFuelGuard and Manual System

6. Conclusion

SmartFuelGuard presents an effective and intelligent solution for enhancing security and efficiency in fuel station operations by automating vehicle verification and fraud detection processes. The system successfully integrates artificial intelligence and computer vision techniques to detect and recognize vehicle number plates using OCR, followed by real-time validation of vehicle documents such as Registration Certificate (RC), insurance, Pollution Under Control (PUC), and blacklist records.

By eliminating manual verification, the system reduces human errors, minimizes fraudulent activities, and improves operational efficiency. The rule-based decision engine ensures accurate and instant ALLOW or BLOCK decisions, while the alert and logging mechanisms provide improved monitoring and accountability.

The system demonstrates reliable performance across different modules including number plate detection, OCR extrac- tion, backend verification, and decision-making. The use of technologies such as FastAPI, Flutter, EasyOCR, OpenCV, and SQLite ensures efficient data processing, fast response time, and a user-friendly interface.

Overall, SmartFuelGuard highlights the potential of integrating artificial intelligence with real-time verification systems to enhance security in fuel stations. The proposed system represents a significant step towards smart fuel management and can be further extended to support large-scale deployment, cloud integration, and smart city infrastructure.

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