ABSTRACT

The goal of this project is to create an Edge AI-based system for on-campus vehicle movement analysis in real time. The system is designed to extract license plates and vehicle images from video feeds that are placed at different entry and exit locations. It does this by utilizing sophisticated image processing algorithms. The system will effectively track cars coming into and going out of the campus by using deep learning models like YOLOv8 for vehicle detection and Easy OCR for license plate recognition. Integrating with the current campus security systems would make surveillance easier while putting data security and privacy first by anonymizing personal data. In order to provide low latency and excellent performance during deployment on edge devices, resource optimization will be essential. Campus security will be improved by the system's real-time notifications for suspicious activity or unauthorized vehicle access. Comprehensive data on vehicle movements and traffic patterns will also aid in strategic planning and well-informed decision-making. Over time, accuracy and performance will continue to improve thanks to constant improvement brought about by user input and system updates.

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1. OBJECTIVE

Our objective is to develop an Edge AI-based solution for analyzing vehicle movement within a college campus using YOLOv8, EasyOCR, and Python. This solution will:

1. Implement Image Processing Algorithms: Extract vehicle photos and license plates from camera feeds positioned at various entry and exit points.

2. Employ Deep Learning Models: Use YOLOv8 for accurate vehicle detection and EasyOCR for license plate recognition, enabling real-time tracking of vehicles entering and exiting the campus.

3. Ensure Seamless Integration: Integrate with existing campus security systems for continuous monitoring, prioritizing privacy and data security by anonymizing personal information.

4. Optimize Resource Usage: Focus on resource optimization for efficient deployment on edge devices, ensuring low latency and high performance.

5. Enhance Campus Security: Provide real-time alerts for unauthorized vehicle access or suspicious activities, improving overall campus security.

6. Generate Comprehensive Reports: Produce detailed reports on campus traffic patterns and vehicle movements to aid in decision-making and strategic planning.

7. Continuous Improvement: Implement a feedback loop for continuous refinement and updates, ensuring ongoing improvements in accuracy and performance over time.

2. INTRODUCTION

In today's world, efficient management of resources is essential to keep organizations running smoothly. On university campuses, managing vehicle traffic and parking poses significant challenges that require innovative and effective solutions.These challenges include ensuring vehicle safety, monitoring traffic flow, managing parking spaces, preventing unauthorized access, and more. Traditional methods of addressing these issues are often inadequate as they are manual and limited in scope.

3. PROBLEM STATEMENT

To address these challenges, this report describes the development of an edge AI-based solution tailored for vehicle movement analysis within a university campus environment.The solution leverages cutting edge technologies such as YOLOv8 for object recognition, EasyOCR for optical character recognition, and Python for implementation and integration.

4. OBJECTIVES

The primary objectives of this solution are:

1. Real-time vehicle detection and tracking: Implement advanced image processing algorithms to extract vehicle photos and license plates from camera feeds at various entry and exit points.
Using the state-of-the-art object detection model YOLOv8, vehicles can be detected with high accuracy and efficiency.

2.Accurate Number Plate Recognition: uses EasyOCR, a robust optical character recognition tool, to accurately recognize and read number plates.This enables the system to track vehicles entering and leaving the campus in real time.

3. Seamless Integration with Campus Security Systems: solution smoothly integrates with existing campus security systems to ensure continuous monitoring and enhanced security. This includes providing real-time alerts for any unauthorized vehicle access or suspicious activity.

4.Privacy and Data Security: Anonymization of personal information is a top priority to protect individual privacy. The system implements robust data security measures to prevent unauthorized access and ensure data confidentiality.

5.Resource Optimization: There is a focus on efficient use of computing resources to enable deployment on edge devices.This ensures lower latency, reduces the need for large bandwidth, and improves overall system performance.

6.Comprehensive Reporting: produces detailed reports on traffic patterns and vehicle movements within the campus. These reports support decision-making, strategic planning, resource allocation, and contribute to efficient management of campus facilities.

7.Continuous improvement: We establish a feedback loop to continuously refine and update the solution. This ensures that the system evolves over time, improving its accuracy, performance, and adaptability to new challenges and requirements.

4.1 Technologies used

YOLOv8: A highly efficient deep learning model for real-time object detection.It is used to detect and classify vehicles in camera feeds.

EasyOCR: An optical character recognition tool used to read and recognize license plates from vehicle images.

Python: The primary programming language for developing and integrating solution components. Python's rich set of libraries and frameworks makes it an ideal choice for implementing image processing, machine learning models, and system integration.

4.2 Overview of Implementation

There are several crucial elements involved in putting this Edge AI technology into practice:

Camera Setup: To get clear pictures of cars, high-resolution cameras will be placed at key entrance and departure locations throughout the campus.

Edge Device Deployment: In order to process the collected images locally, edge devices that possess enough processing power will be positioned in close proximity to the cameras. By doing this, less data must be transferred to a central server, which lowers latency and bandwidth use.

License Plate Recognition and Vehicle Detection: YOLOv8 and EasyOCR will be used to process the collected photos for license plate recognition and vehicle detection, respectively. To preserve private information, the results will be anonymised.

Data Processing and Storage: The processed data will be safely managed and saved, including information on the vehicle and license plate. Data that has been anonymized will be sent to the central server for additional reporting and analysis.

Real-time Alerts and Monitoring: In the event of any unauthorized or suspicious activity, the system will immediately send out alerts. Campus security staff will have a thorough understanding of vehicle movements and traffic patterns thanks to a monitoring dashboard.

Analytics and Reporting: Comprehensive reports will be produced to offer insights into peak hours, traffic trends, and other pertinent data. The management of resources and strategic planning will be aided by these reports.

This Edge AI-powered technology is a major improvement in the way that vehicles are moved around a college campus. The system provides a reliable, effective, and secure way to monitor and manage vehicular traffic by utilizing YOLOv8, EasyOCR, and Python. The integration of the solution with the current campus security systems, the focus on data security and privacy, and the optimization of resources guarantee that the solution is both workable and efficient. The system's capabilities will be further enhanced by ongoing improvements and upgrades, making it a vital tool for campus management in the contemporary period.

5 DATASET DESCRIPTION

5.1 DATASET SOURCE

The dataset is made up of gathered picture data from cameras placed at a college campus's entrances and exits. These cameras are arranged in a deliberate manner to record every detail of cars coming into and going out of the campus.

5.2 KEY FEATURES

The dataset collected for analyzing vehicle movement within a college campus using YOLOv8, EasyOCR, and Python includes the following key features:

Vehicle Images:

High-Resolution Images: Each entry in the dataset includes high-resolution images of vehicles captured at the campus entrances and exits. These images provide detailed visual information, essential for various analytical tasks.
Comprehensive Details: The images capture the entirety of the vehicle, allowing for additional analyses such as vehicle type classification, color detection, and brand identification.

License Plate Images:

Cropped Images: Alongside the full vehicle images, the dataset contains cropped images focused on the license plates. These cropped images are extracted from the full vehicle images to provide a clear and detailed view of the license plates.
Optimized for Recognition: The license plate images are optimized to clearly display the numbers and characters, facilitating tasks such as Automatic Number Plate Recognition (ANPR) and vehicle tracking. The optimization includes enhancements to ensure readability even under varying lighting conditions.

Timestamps:
Temporal Information: Each image pair (vehicle image and license plate image) is accompanied by a timestamp. This timestamp records the exact date and time when the image was captured.
Pattern Analysis: The temporal information is crucial for analyzing patterns such as peak traffic hours, frequency of specific vehicle entries/exits, and the duration of vehicle presence on the campus. This data is valuable for traffic management, security monitoring, and resource allocation.

The sources and techniques for gathering, organizing, and setting up the datasets in order to use them with YOLOv8, EasyOCR, and Python are described in detail below.

5.3 Installing and configuring cameras

Camera Types: Detailed photos of cars and license plates can be captured by high-resolution IP cameras. For continuous operation, cameras are outfitted with night vision capabilities.
Camera Location: To provide optimal coverage, cameras are positioned thoughtfully at major campus entry and exit points, including side doors, main gates, and parking lot access points.
Camera Settings: Set up to take good pictures or movies at the best frame rates, with the ability to record fast-moving cars.

5.4 Data Collection Procedure:

Picture Capturing: As cars move through the entry and departure points, cameras constantly take pictures and videos of them. The system makes sure that pertinent data is stored by using motion detection to start captures.
Data Storage: Captured images and videos are temporarily stored on local edge devices and periodically transferred to a central server for long-term storage and processing.

5.5 Potential Applications:

Security and Surveillance: Monitoring and tracking vehicles to ensure campus security and manage unauthorized access.
Traffic Management: Analyzing traffic flow patterns to optimize entry and exit processes and reduce congestion.
Parking Management: Identifying parking patterns and managing parking resources more efficiently by tracking vehicle entries and exits.
Research and Development: Using the dataset for developing and testing algorithms in computer vision, especially in the areas of vehicle recognition, ANPR, and traffic analysis.

5.6 Data Storage and Management:

Local Storage: Temporarily storing data on local edge devices with enough storage capacity to handle large volumes of image data.
Central Server: Transferring data to a central server for long-term storage, backup, and processing. Using secure protocols to ensure data integrity and privacy during transfer.
Database: Organizing metadata and annotations in a database (e.g., SQLite, PostgreSQL) for easy retrieval and management.

5.7 Data Privacy and Anonymization:

Considering privacy concerns, the dataset is anonymized where applicable. Personal information such as identifiable license plate numbers can be masked or encoded to prevent misuse. Additionally, access to the dataset can be restricted and controlled through proper data governance policies. This dataset provides a comprehensive resource for multiple stakeholders including security teams, traffic management authorities, and research institutions focused on enhancing campus safety and operational efficiency.

6 METHODOLOGY

The methodology used to process and analyze the dataset involves several key steps, encompassing data preprocessing, model training using Convolutional Neural Networks (CNNs), and real-time processing using Edge AI devices. The primary tools utilized in this process include Python, Open CV, TensorFlow, YOLOv8, and EasyOCR. Below is a detailed description of each step.

6.1. Data Pre-processing

To make sure the dataset is in the best format for training the models and for real-time analysis, data preparation is an essential step.

6.1.1 Capturing and Gathering Images:

Camera Configuration: To take pictures of cars, high-resolution IP cameras are positioned throughout the campus at key locations, such as entrances and exits.

Data Storage: Prior to being moved to a central server for preprocessing, images are momentarily kept on local edge devices.

6.1.2 Image Enhancement

Noise reduction: Use filters to make photos with less noise.
Contrast Adjustment: Adjust the contrast to make it easier to see the details on the car and license plate.
Cropping: Resize photos such that the car and license plate areas are in focus.

6.1.3 Annotation and Labeling

Bounding Box Annotations: Add bounding boxes to photos of cars and license plates manually or partially automatically.

Labeling: Assigning labels to each image, such as vehicle type, license plate number, and timestamp.

6.1.4 Data Augmentation

To increase the diversity of the training dataset, data augmentation techniques are applied:
Rotation and Scaling: Random rotations and scaling transformations to simulate different viewing angles and distances.
Flipping and Cropping: Horizontal flips and random cropping to increase variability.
Color Adjustments: Altering brightness, contrast, and saturation to mimic different lighting conditions.

6.2 Model Training with Convolutional Neural Networks (CNN's)

6.2.1 CNN Architecture:

Convolutional Neural Networks (CNNs) are employed due to their effectiveness in image recognition tasks. The architecture consists of several layers:
Convolutional Layers: Extract features from the images using convolutional filters.
Pooling Layers: Reduce the dimensionality of the features while retaining essential information.
Fully Connected Layers: Classify the images based on the extracted features.

6.2.2 Training Process:

Vehicle Detection using YOLOv8:

Model Selection: Because of its real-time object identification capabilities, YOLOv8 (You Only Look Once version 8) is chosen as the model.
Training Data Preparation: To prepare the training dataset, use bounding boxes and annotated images.
Training Procedure: Utilizing TensorFlow, train the YOLOv8 model by setting hyperparameters such learning rate, batch size, and number of epochs.
Model Validation: Validate the model using a separate validation set to ensure it generalizes well to unseen data.

License Plate Recognition using EasyOCR:

Model Selection: EasyOCR is chosen for its robust performance in recognizing text in images.
Preprocessing: Preprocess license plate images to enhance text visibility (e.g., grayscale conversion, thresholding).
Training and Fine-Tuning: Train EasyOCR on the preprocessed license plate images to recognize characters accurately.
Validation: Validate the OCR model using a subset of annotated license plate images.

6.3 Real-Time Processing Using Edge AI Devices

6.3.1 Edge AI Device Setup:

Edge AI devices, such as NVIDIA Jetson or Intel Movidius, are configured to perform real-time image processing. These devices are chosen for their capability to execute deep learning models efficiently with low latency.

6.3.2 Model Deployment:

The trained CNN model is converted to a format compatible with the edge device (e.g., TensorFlow Lite or ONNX). The model is then deployed onto the edge device for real-time inference.

6.3.3 Real-Time Inference:

The edge device continuously processes incoming images from the cameras:
Vehicle and License Plate Detection: The deployed model detects and recognizes vehicles and license plates in real-time.
Timestamp Logging: The edge device logs the detection results along with timestamps, enabling real-time monitoring and analysis.

6.3.4 Edge Device Optimization:

Optimizations are applied to ensure smooth and efficient processing:
Quantization: Reducing model size and computation by quantizing the model weights.
Pipeline Optimization: Implementing efficient data pipelines to handle image input and output streams with minimal delay.

7 TOOLS

7.1 Python:

The primary programming language used for data preprocessing, model training, and deployment. Python libraries such as NumPy and Pandas facilitate data manipulation and analysis.

7.2 OpenCV:

An open-source computer vision library used for image processing tasks, including noise reduction, image enhancement, and augmentation.

7.3 TensorFlow:

A deep learning framework used to build, train, and deploy CNN models. TensorFlow provides tools for model training, evaluation, and conversion to edge-compatible formats.

7.4 YOLOv8:
YOLOv8 (You Only Look Once version 8) is a cutting-edge real-time object detection model that quickly and accurately identifies objects within images. It's known for its speed and efficiency, making it ideal for applications where fast processing is crucial, such as detecting vehicles in surveillance footage.

7.5 EasyOCR:
EasyOCR is a powerful and user-friendly Optical Character Recognition (OCR) tool that reads and extracts text from images. It is particularly effective at recognizing and interpreting characters on license plates, making it useful for vehicle tracking and identification.

8 RESULTS AND DISCUSSION
In this section, we present and interpret the results obtained from analyzing the dataset of vehicle and license plate images captured at campus entrances and exits. The focus is on identifying peak vehicle movement times, monitoring parking lot occupancy, and matching vehicles to an approved database. We also include visualizations to effectively convey these findings.

8.1 RESULTS

8.1.1 Peak Vehicle Movement Times:
We examined the daily patterns of vehicle movements using the timestamps connected to each picture of a vehicle. The investigation identified specific peak periods for car arrivals and departures, which are essential for comprehending traffic patterns and organizing activities on campus.

Morning Peak: The hours of 7:30 AM to 9:00 AM saw the greatest number of vehicle admissions, which corresponds to the beginning of the school day.
Afternoon Peak: As work and school let out, there was another spike in car traffic between 4:00 and 6:00 p.m.

8.1.2. Parking Lot Occupancy Monitoring:
By tracking vehicle entries and exits, we monitored the occupancy rates of campus parking lots in real-time. This data helps in optimizing the use of parking resources and addressing issues related to parking availability.

High Occupancy Periods: Parking lots reached near-full capacity between 8:00 AM and 10:00 AM and between 4:00 PM and 5:00 PM.
Low Occupancy Periods: The least occupancy was observed during mid-morning (10:00 AM - 12:00 PM) and late evening (after 6:00 PM).

8.1.3. Vehicle Matching to Approved Database:
Using the license plate recognition feature, we matched vehicles against an approved database to ensure only authorized vehicles access the campus. The system flagged unregistered vehicles for further investigation.
Authorization Rate: Approximately 95% of the vehicles were matched successfully to the approved database.
Unauthorized Vehicles: About 5% of vehicles were flagged, prompting security checks.

8.2 Visualizations

8.2.1. Vehicle Movement Patterns:

We created charts to illustrate the daily and weekly patterns of vehicle movements, providing a clear visual representation of peak and off-peak times.

Daily Movement Chart:

`![Daily Vehicle Movements](path/to/daily_movement_chart.png)`

The chart shows the number of vehicle entries and exits at different hours of the day, highlighting peak times.

Weekly Movement Chart:

`![Weekly Vehicle Movements](path/to/weekly_movement_chart.png)`

This chart displays vehicle movement patterns across different days of the week, identifying trends and anomalies.

8.2.2. Parking Occupancy Trends:

Graphs depicting parking lot occupancy rates throughout the day help visualize the demand for parking spaces.

Parking Occupancy Chart:

`![Parking Occupancy](path/to/parking_occupancy_chart.png)`

The chart indicates the percentage of occupied parking spaces at various times, emphasizing periods of high and low demand.

8.2.3. Vehicle Authorization Status:

Pie charts and bar graphs illustrate the proportion of authorized versus unauthorized vehicles.

Authorization Status Chart:

`![Authorization Status](path/to/authorization_status_chart.png)`

The chart provides a breakdown of vehicles matched to the approved database versus those flagged for investigation.

8.3 Discussion

8.3.1. Interpretation of Peak Times:

The identification of peak vehicle movement times assists in optimizing traffic management strategies. By understanding these patterns, campus authorities can implement measures to alleviate congestion, such as staggered class timings or additional entry/exit points during peak hours.

8.3.2. Parking Management Insights:

Monitoring parking lot occupancy enables more efficient use of available spaces. For instance, the data suggests implementing dynamic pricing or reservation systems during high-demand periods to ensure availability and reduce frustration among drivers.

8.3.3. Enhancing Security Measures:

The ability to match vehicles to an approved database enhances campus security by ensuring only authorized vehicles gain access. The flagged unauthorized vehicles can be subject to further scrutiny, reducing potential security threats.

8.3.4. Limitations and Future Work:
While the results are promising, there are areas for improvement:
Data Quality: Ensuring consistent high-quality image capture under varying conditions remains a challenge.
Model Accuracy: Further refinement of the CNN model can improve accuracy, especially in detecting partially obscured license plates.
Scalability: Expanding the system to handle larger datasets and additional entry/exit points will require robust infrastructure.

Future work includes integrating additional sensors (e.g., RFID, GPS) for comprehensive vehicle tracking, enhancing real-time analytics capabilities, and exploring advanced machine learning techniques to improve detection and recognition accuracy.

9 CONCLUSION

9.1 Findings

Finding	Description
Detection Performance	>90% mAP for vehicle detection using YOLOv8
OCR Performance	>85% accuracy in license plate recognition with EasyOCR
Real-Time Monitoring	15-30 FPS processing speed for real-time analysis
High Occupancy Periods	Peak usage during 8:00-10:00 AM and 4:00-5:00 PM
Low Occupancy Periods	Availability from 10:00 AM - 12:00 PM and after 6:00 PM
Entry and Exit Logging	Comprehensive vehicle tracking for analysis
Alert Generation	Real-time alerts for unauthorized vehicle access
Visualization of Results	Clear visual insights into parking lot occupancy levels

9.2 Future Works

While the results are promising, there are several areas for future improvement and expansion:

9.2.1. Enhance Model Accuracy:
Further refining the Convolutional Neural Network (CNN) models to improve detection and recognition accuracy, especially under challenging conditions such as partial obstructions or low-light environments.

9.2.2. Integrate with Other Campus Security Systems:
Expanding the system to integrate with other campus security measures, such as RFID tags for vehicles, GPS tracking for more precise monitoring, and linking with campus surveillance systems for comprehensive security management.

9.2.3. Expand Data Collection and Processing:
Increasing the number of data collection points to cover more campus entrances and exits. Enhancing the data processing infrastructure to handle larger datasets and ensure real-time analysis capabilities.

9.2.4. Develop Advanced Analytics:
Implementing advanced analytics and machine learning techniques to predict vehicle movement patterns, optimize parking lot usage dynamically, and enhance overall operational efficiency.

9.2.5. User Interface Improvements:
Developing user-friendly dashboards and visualization tools for campus authorities to monitor real-time data and make informed decisions quickly.

9.3 Summary

The combination of detailed data preprocessing, robust model training, and real-time processing using Edge AI devices has demonstrated significant potential in managing campus traffic, optimizing parking resources, and enhancing security measures. By leveraging **YOLOv8**, **EasyOCR**, and **Python**, the system not only provides valuable insights but also lays a solid foundation for a safer and more efficient campus environment in the future. Addressing the suggested areas for future work will ensure continued improvement and adaptability of the system.