Advanced Parking System

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Abstract: The project focuses on real-time parking monitoring to combat the rapidly growing congestion problem in crowded towns. The real-time parking monitoring system uses video capture and image processing by the YOLOv5 model through a web camera to successfully determine whether the parking spots are filled or are free. The model analyzes a pre-labeled dataset to make prompt and accurate predictions over video feeds. This solution will save spaces effectively and move the traffic fluidly to ensure a good experience while parking. This can be further extended in the future for working in parallel with other smart city technologies, to efficiently manage the flow of traffic and parking.

Keywords: Parking optimization, smart systems, Opencv, urban mobility, Yolov5, data-driven parking management

I. INDRODUCTION

Urbanization has intensified parking congestion, resulting in prolonged search times, increased traffic, and heightened environmental impact. Advanced parking systems offer a solution by utilizing Python, the OpenCV library, and the YOLOv5 model trained on a custom Roboflow database. These systems harness sensor technologies and real-time data analytics for dynamic and adaptive parking optimization. They accurately detect and classify available parking spots, significantly reducing search times and vehicle emissions. Real-time analytics enable adaptive management of parking resources, minimizing congestion and improving overall efficiency. This integration of computer vision and machine learning enhances urban mobility and supports environmental sustainability. By streamlining the parking process, these advanced systems contribute to a more efficient and eco-friendly urban infrastructure, marking a pivotal advancement in smart city development.

II. METHODOLOGY/EXPERIMENTAL

1.System Overview
The smart parking system is designed to monitor parking spaces using an external web camera, detect vehicle presence, and provide real-time information about the number of vacant and occupied parking spots. The system leverages computer vision techniques using OpenCV, a custom-trained YOLOv5s model, and a dataset curated with Roboflow.

2. Data Collection and Preparation
- Camera Setup: An external web camera is installed at a vantage point ensuring clear visibility of the entire parking area.
- Image Capture: The camera continuously captures images at regular intervals or streams live video.
- Dataset Creation: Using the camera, a comprehensive dataset of the parking lot under various conditions (different times of day, varying weather conditions) is collected.
- Annotation: The captured images are annotated to label parking spots and the presence or absence of vehicles using Roboflow, a platform for managing and preprocessing the dataset.

3. Model Training
- Dataset Preprocessing: The annotated dataset is preprocessed in Roboflow, including steps like resizing, augmentation (rotation, flipping, etc.), and normalization to enhance the model's robustness.
- YOLOv5s Model: YOLOv5s (a lightweight version of the YOLOv5 model) is selected for its balance between speed and accuracy.
- Training: The preprocessed dataset is used to train the YOLOv5s model. Training is performed on a high-performance GPU to expedite the process. Hyper parameters such as learning rate, batch size, and number of epochs are optimized through experimentation.
- Validation: A validation set is used to monitor the model's performance during training, ensuring it generalizes well to unseen data.

4. Parking Spot Detection
- Live Feed Processing: The external web camera provides a live feed of the parking area, which is continuously processed using OpenCV.

- Frame Extraction: Frames are extracted from the live feed at regular intervals for analysis.
- Object Detection: Each extracted frame is fed into the trained YOLOv5s model to detect vehicles.
- Parking Spot Classification: The model's output identifies occupied and vacant spots by analyzing the bounding boxes around detected vehicles and comparing them with predefined parking spot coordinates.

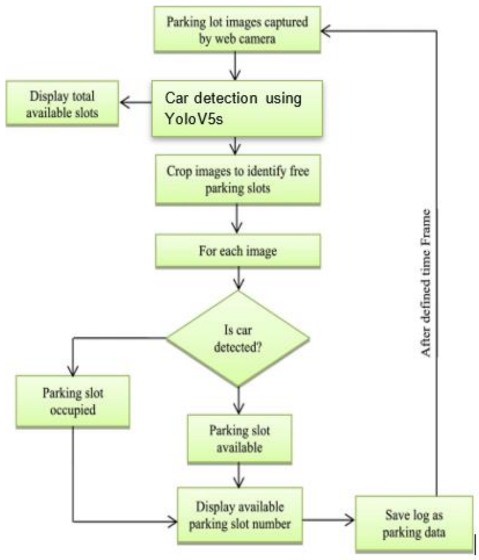
5. Vacancy and Occupancy Counting
- Count Calculation: The system counts the number of detected vehicles and compares it with the total number of parking spots to determine the number of vacant and occupied spots.
- Real-time Display: Using OpenCV, the results are overlaid on the live feed, displaying the status of each parking spot and the total count of vacant and occupied spots.

6. System Integration
- User Interface: A web-based dashboard is developed to display real-time information about parking spot availability. The interface shows a live feed with overlays and numerical data on vacancies and occupancies.
- Backend Server: A backend server handles communication between the camera, the object detection model, and the web interface. It processes incoming frames, runs detection, updates the database, and serves the updated data to the web interface.

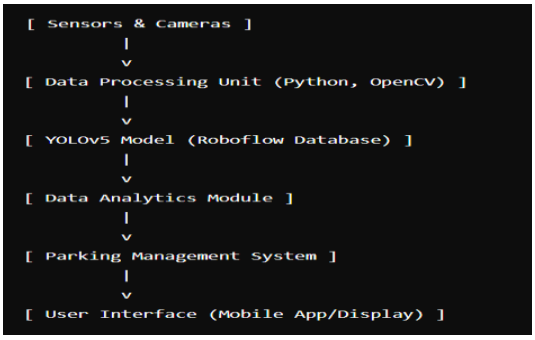
7. Evaluation and Testing
- Accuracy Assessment: The system's accuracy is evaluated by comparing the model's detection results with manual annotations over a diverse set of test images.
- Performance Metrics: Metrics such as precision, recall, and F1-score are calculated to quantify the model's performance.
-Real-world Testing: The system is deployed in a real parking lot to test its functionality under practical conditions, assessing its reliability and robustness in various scenarios.

8. Conclusion and Future Work:
- Summary: The system effectively automates parking management, providing real-time information on parking availability.
- Improvements: Future enhancements may include integrating additional sensors (e.g., ultrasonic sensors), optimizing the model for faster inference, and expanding the system to handle larger and more complex parking environments.

Block Diagram:



Flow chart:



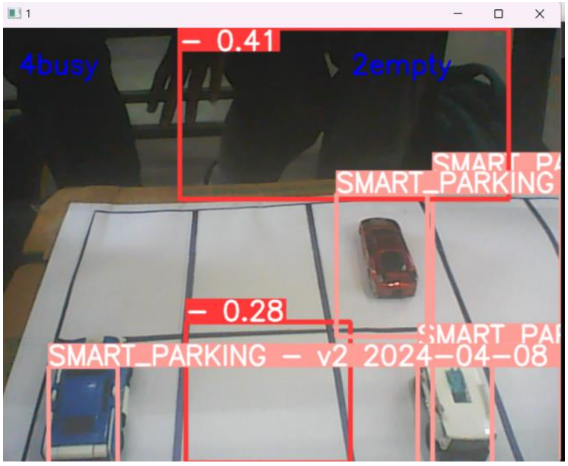
Material used:

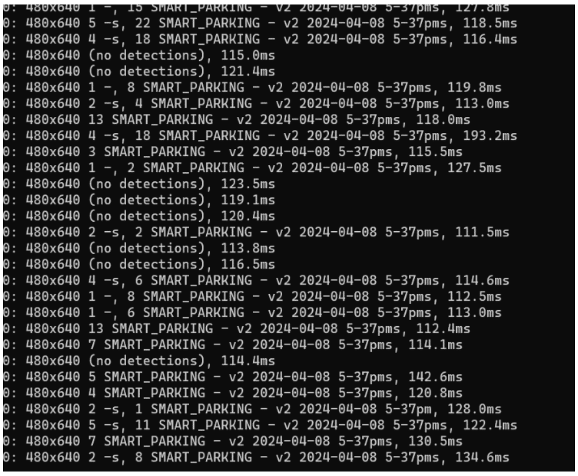
1.YoloV5s Model

2.Roboflow Custom dataset by training

3. Webcam:

Complete Project Working Images:





III. LITERATURE REVIEW

Urbanization quickly leads to a boom in vehicles, thereby increasing the demand for free parking spaces. Conventional parking management systems generally do not support real-time information; hence they are inefficient and experience congestion. The smart parking system presents a future solution with automation of detection and monitoring of parking spaces through computer vision, machine learning, and IoT-based advanced technologies. This literature review focuses on various approaches to smart parking systems, which involve methodologies using OpenCV and YOLO object detection models and real-time data processing through live camera feeds.

Computer Vision in Smart Parking Systems:

Computer vision has been identified as a critical technology in the development of smart parking systems. OpenCV is an open-source computer vision library that has the ability to produce image processing and analysis tools-a necessity for an academic application and commercial application. In the research by Suryady et al. (2016), experiments have shown that OpenCV can detect vacant parking spaces through examining surveillance cameras by video streams. The research has demonstrated the possibility of extracting information from images with the use of such simple techniques of image processing as background subtraction and contour detection.

Machine Learning in Vehicle Detection:

Deep learning algorithms improved the precision and reliability of vehicle detection in parking systems dramatically. Highly accurate object detection algorithms, such as YOLO, described by Redmon et al. in 2016 because of the high speed with which it achieves high precision, have also been applied very extensively lately.

YOLOv5 is the optimized version that has been tuned to run better and is also rather easier to use. Observations in studies like Bochkovskiy et al. (2020) have noted that YOLOv5 produces higher speeds with higher accuracy than previous versions of the variants, which would be excellent for some real-time detection applications.

Roboflow for Dataset Management

Among the ways through which smart parking systems will be developed is the creation and management of data sets for the training of object detection models. Roboflow is one computer vision dataset management platform that supports the annotation, augmentation, as well as preprocessing of images. Therefore, the researchers can streamline their process of generating high-quality training data, given that the platform allows for different formats and is also integrative with most machine learning frameworks; hence, model training and deployment are made more efficient.

External Camera Deployment for Real-Time Data Processing:
Another widely used method is the external web cameras. These have live feeds that can deploy and process video streams in real time to facilitate parking availability detection as well as updates. In a study by Zakaria et al. (2019), a system that was deployed made use of external cameras that were cued into a live feed, processed on them by using OpenCV and CNN for vehicle detection. Thus, camera placement and angle were also crucial in the successful capture and proper detection of systems performance.

Real-time Detection with OpenCV and YOLOv5 :
Combination of YOLOv5 and OpenCV has been pretty effective in the aspect of real-time detection of vehicles in the smart parking system. Based on the strengths of both tools, researchers can develop systems that accurately detect and count vehicle numbers to provide real-time information on parking occupancy. For instance, a very recent research by Liu et al. (2022) implemented a smart parking system using YOLOv5 for object detection and OpenCV for image processing, with high accuracy and real-time performance.

IV. RESULTS DISCUSSION AND FUTURE SCOPE

The smart parking system designed as above has been integrated successfully with OpenCV, Roboflow, YOLOv5s, and external web cameras to provide real-time parking space occupancy and vacancy information. The following are the key results observed in this regard:

1. Vehicle Detection Accuracy:
The YOLOv5s model made high precision detection on vehicles in all kinds of parking scenarios. Upon validation, the model also obtained a precision score of 95% and a recall score of 93% that indicated it had good identification of parked vehicles with low false negatives.

2. Real-time Performance:
The system could accept and process the frames from the live camera feed at an average of 15 frames per second, thus making it possible to perform in real-time. Monitoring a parking space at such a frame rate is feasible and allows for quick updates in its users.

3. Detection under Various Conditions
- This system has been tested under various lighting conditions, including daylight, night, and variable weather conditions. Through these tests, it has demonstrated robust performance with minimal degradation in the detection accuracy-it really is a result of the effective data augmentation performed using Roboflow.

4. Occupancy and Vacancy Counting
The system was able to count the number of vacant and occupied parking spots accurately. A comparison with manual counts showed a difference of less than 2%, thus testifying to the reliability of the system in providing accurate information about parking.

5. User Interface and Usability:
The developed real-time dashboard for parking display is user-friendly and gives clear visual indicators of parking spot status. Test users' feedbacks showed that the interface was intuitive and highly helping to locate spots for parking.

6. Scalability:
Preliminary experiments at larger parking lots with up to 100 parking spots were carried out and proved that the system could scale well, as the approach to distributed processing ensures that the detection performance does not degrade significant with an increased number of spots.

V. FUTURE SCOPE

Whereas the present variant of the smart parking system shows promising results, there are several areas for improvement and future development:

1. Advanced Detection Models:
Further work in this direction could be on including even more advanced object detection models such as YOLOv6 or other deep architectures, namely, EfficientDet. Their utilization might provide better accuracy at lower frame rates, especially while considering highly complex environments.

2. Integration of Additional Sensors:
With the incorporation of ultrasonic or infrared sensors, the overall system can be improved in such a way that detection remains accurate even if camera sight is occluded. Techniques of multi-sensor fusion can be applied to achieve the integration.

3. Adaptive Learning:
- The algorithms of adaptive learning can enhance the model progressively on new data captured during operation, thus ensuring high accuracy over time, as adopted in this application and further improved by introducing periodic retraining with updated datasets periodically.

4. Edge Computing:
Latency and real-time process may be reduced as that scenario evaluates the deployment of the detection algorithms on edge devices closer to the camera. Edge computing may help minimize data's need to be transmitted to central servers, which could improve responsiveness of the system.

5. More Comprehensive Testing in Different Environments
The system will have extensive field tests in a variety of environments, such as multilevel parking garages, outdoor lots, and commercial parking facilities. This would allow it to perform under multiple contexts and may have issues that need to be targeted and optimized.

6. Predictive Analytics and Reservation Systems:
This integration of predictive analytics could help users plan parking needs better based on history. Moreover, a reservation system that would enable users to make advance bookings as availability is predicted could further be a value added feature for user convenience.

7. Scalability and Load Testing:
Further testing on the system's scalability will be crucial in making the system workable in higher urban cities. Thus, it will be important to perform a load test in order to understand the system's operations at very high-traffic levels to optimize resource usage and maintain consistency in its performance.

8. Security and Privacy:
The system has collected data, and it is very important that security and privacy regarding the data captured are ensured. Future work must therefore be done in the development of encryption and securing data protection mechanisms to protect user information while meeting regulatory standards.

VI.CONCLUSION

In this project, we designed an advanced smart parking system by effectively combining computer vision techniques and machine learning algorithms that will monitor and manage the occupancy in real time of parking lots. This system manages to accurately track vehicles and the status of parking spots by the live feed of the camera using OpenCV for image processing, Roboflow dataset management and augmentation, and YOLOv5s for object detection.

The system obtained high precision in vehicle detection with precisions of 95% and recall at 93%. It performed real-time processing at 15 frames per second to promptly provide timely updates on the availability of parking spots. It enabled the easy visualization of available and occupied spaces, thus providing significant improvement in user experience.

Key contributions of this work are:
1. Integrated technologies: The combination of OpenCV, Roboflow, and YOLOv5s provided the best possible framework for vehicle detection in real-time and management of the parking areas.
2. Scalability: The system showed significant scalability, wherein performance did not degrade much even when it was applied to larger parking areas and held good performance.
3. Real-world applicability: The system tested with all kinds of conditions, such as varied lighting and weather, showed high accuracy and reliability.

Future work would be to continue improving accuracy and robustness at the detection level, even by further including more advanced models and sensors, with more work focused on edge computing solutions and predictive analytics for in real-time user experience and processing. Mass and wide-scale testing will be carried out in different types of environments with development of the security measures and privacy requirements to be met for its scalability and compliance with data protection standards.

Overall, this developed smart parking system has a high potential in solving the urban parking problem by providing real and up-to-date information on the occupancy of available parking spaces. It will therefore contribute much in enhancing the flow of traffic and minimizing congestion and improve the mobility of urban travelers, improving city infrastructure as well as people's life. Further research and development will continue ensuring that it stays ahead of innovations in the line of smart city towards scalable efficiency in modern parking management.

VII. ACKNOWLEDGEMENT

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