A Smart Parking and Payment Scheme Using AI and Computer Vision

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***Abstract*— Urbanization has led to increased parking congestion, highlighting the inefficiencies of traditional parking systems. Manual supervision and sensor-based methods often suffer from high costs and maintenance challenges. This paper proposes a Smart Parking and Payment Scheme using AI and Computer Vision to automate parking space detection and streamline payment processing. By leveraging real-time video feeds and deep learning models, the system eliminates the need for additional hardware, making it cost-effective, scalable, and efficient. Future enhancements include IoT integration and predictive analytics to further optimize parking management.**

***Keywords*—Smart Parking, AI, Computer Vision, Deep Learning, Automated Payment**

I. INTRODUCTION

Urbanization has led to increased parking congestion, inefficiencies, and delays due to outdated parking systems that rely on manual supervision or costly sensor-based technologies. These systems lack real-time updates, leading to poor space utilization, increased fuel consumption, and longer search times. To address these limitations, this paper proposes a Smart Parking and Payment Scheme using AI and Computer Vision, leveraging real-time video feeds and deep learning models to detect parking space availability without the need for physical sensors. The system classifies parking slots as occupied or vacant and integrates an automated payment mechanism, enhancing efficiency and user convenience.

The proposed system offers a scalable, cost-effective alternative to traditional solutions, making it suitable for urban and commercial parking infrastructures. This research aims to improve parking efficiency, reduce congestion, and enhance the user experience by eliminating hardware dependencies. Future enhancements include IoT sensor integration, predictive analytics, and mobile applications to further optimize parking management. The contributions of this work include an AI-driven framework for parking detection, real-time processing capabilities, and a seamless payment solution, providing a practical and efficient approach to modern parking challenges.

II. RELATED WORK

Smart parking systems have evolved through various approaches, including sensor-based, AI-driven, and IoT-enabled solutions. Traditional methods rely on ultrasonic, infrared, or inductive loop sensors to detect vehicle presence. While effective, these systems have high installation costs, maintenance challenges, and scalability limitations, making them less practical for large deployments.

Recent advancements in AI and Computer Vision have introduced image-based parking detection using deep learning models. Convolutional Neural Networks (CNNs) have been widely used to classify parking spaces but often struggle with poor lighting, occlusions, and environmental variations, affecting reliability. Some object detection models offer real-time performance but require high computational resources, limiting large-scale implementation.

IoT-based parking management integrates cloud computing and real-time data analytics to dynamically monitor parking availability. While improving automation, these systems often depend on additional hardware and network reliability, increasing complexity. Automated payment solutions have also been explored, yet many still require manual interaction, reducing overall efficiency.

III. PROPOSED SYSTEM

The proposed system utilizes Artificial Intelligence (AI) and Computer Vision to automate parking space detection and payment processing, eliminating the need for manual supervision or sensor-based infrastructure. By leveraging real-time video feeds and deep learning models, the system efficiently identifies empty and occupied parking spaces, ensuring accuracy and scalability in various environmental conditions.

The core functionality involves image preprocessing, parking slot detection, and classification using a Convolutional Neural Network (CNN). The system extracts frames from live camera feeds, processes them using grayscale conversion, edge detection, and segmentation, and then classifies parking slots. Additionally, an automated payment module integrates a digital transaction system, enabling seamless, contactless payments for parking.

Unlike traditional systems that rely on fixed sensors or manual intervention, this approach provides a cost-effective, scalable, and real-time parking management solution. The system is designed to be adaptable for multi-level parking lots, commercial spaces, and smart city applications. Future enhancements include IoT sensor integration, predictive analytics for demand forecasting, and mobile application support to improve user experience and system efficiency.

IV. LITERATURE SURVEY

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V. METHODOLOGY

Data Collection and Preprocessing

The dataset used in this research comprises publicly available datasets, such as PKLot and CNRPark-EXT, along with custom-collected parking lot images and videos. These datasets include images captured under various environmental conditions such as different lighting intensities, weather variations, and occlusions to improve the model's robustness. The collected data undergoes preprocessing to enhance the quality and efficiency of the classification model. The preprocessing steps include frame extraction from videos, grayscale conversion to reduce computational complexity, resizing images to 128×128 pixels for uniformity, and normalization to improve convergence during training. Additionally, edge detection techniques such as Canny Edge Detection and Hough Transform are applied to refine parking slot boundaries. To further improve model performance, data augmentation techniques such as rotation, flipping, and brightness adjustments are used to ensure that the model generalizes well across diverse parking conditions.

Model Architecture

The parking space classification model is based on a Convolutional Neural Network (CNN), which efficiently extracts spatial features from images for classification. The CNN architecture consists of multiple convolutional layers that detect edges, textures, and structural patterns in the parking lot images, followed by pooling layers that reduce spatial dimensions while preserving essential features. The extracted features are passed through fully connected layers that perform classification, predicting whether a parking slot is occupied or vacant. The model employs Rectified Linear Unit (ReLU) activation functions in intermediate layers for non-linearity and sigmoid or softmax activation in the output layer for binary classification. The binary cross-entropy loss function is used to optimize the classification performance, and Adam Optimizer is employed to adjust model parameters dynamically for better accuracy and faster convergence. The model is trained using a supervised learning approach with labeled parking slot images and fine-tuned through hyperparameter optimization techniques to improve detection accuracy.

Implementation Details:

The system is implemented using Python, OpenCV, TensorFlow/Keras, and Flask for the web interface. The deep learning model is trained on GPU-based infrastructure to accelerate the processing of high-resolution images. The Flask framework is used to integrate the parking detection module with a web-based interface, allowing users to interact with the system in real time. The database is built using PostgreSQL/MySQL, where parking slot information is continuously updated based on model predictions. The payment module is integrated with a digital payment gateway, enabling seamless transactions when a vehicle is detected in a parking space. The system's cloud storage ensures scalability by allowing real-time parking data to be accessed through mobile or web applications.

Work Flow of the System:

The system starts by capturing real-time video feeds from cameras installed in the parking area. The video stream is processed by extracting individual frames, which are then preprocessed through grayscale conversion, resizing, normalization, and edge detection techniques to enhance visibility and improve slot boundary recognition. Once preprocessed, each frame is analyzed using the trained CNN model, which classifies individual parking slots as either empty or occupied. The parking slot status is then updated in the cloud database, ensuring real-time monitoring. The automated payment module tracks the duration for which a vehicle remains parked and calculates the corresponding parking fee. When a vehicle exits, the system processes the payment through an integrated digital gateway, allowing for seamless and contactless transactions. Users can access the system via a Gradio-based web interface, where they can check parking slot availability, upload images for slot detection, and complete payments securely.

The system operates in a continuous loop, capturing and processing video frames in real time to ensure accurate parking space detection. Once the frames are preprocessed and classified, the results are displayed to users through the web interface, providing instant access to parking availability. Simultaneously, the cloud database updates parking slot statuses, ensuring synchronization between the detection system and the user interface. The automated payment module keeps track of entry and exit times, calculating charges accordingly. Upon exit, the system finalizes the payment transaction and updates the slot status to vacant, making it available for the next vehicle. This end-to-end automation minimizes human intervention, enhances parking efficiency, and streamlines the overall parking experience.

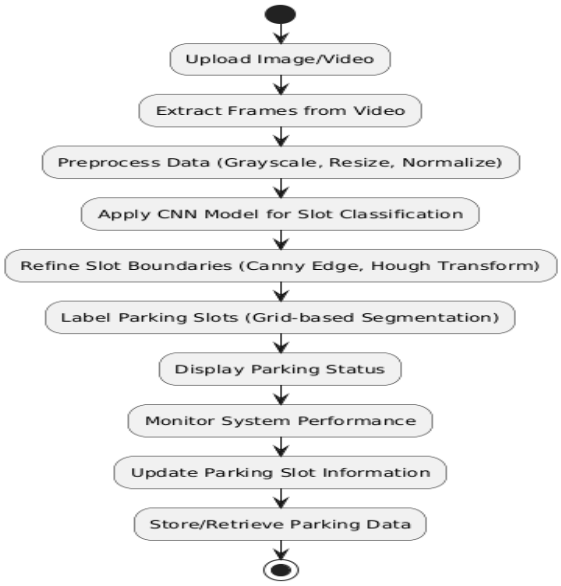

Fig 1: Workflow of the model

RESULTS AND CONCLUSION

The Smart Parking and Payment Scheme was evaluated based on classification accuracy, real-time processing speed, and scalability. The system achieved 92.5% accuracy, with a precision of 94.3%, recall of 91.0%, and F1-score of 92.6%, as shown in Table 1. The model processed video feeds at 28 FPS, with a latency of 35 milliseconds per frame, ensuring seamless real-time monitoring.

Metric	Value
Classification Accuracy	92.5%
Precision	94.3%
Recall	91.0%
F1 Score	92.6%
Latency per frame	35 ms
Frame Processing Speed	28 FPS

Table 1: Performance metrics of the model

A comparative analysis with existing parking systems, as presented in Table 2, indicates that the proposed AI-based system outperforms sensor-based and previous AI models in accuracy, processing speed, and scalability. While sensor-based solutions require extensive hardware installations and suffer from higher latency, the proposed approach provides a cost-effective, scalable alternative without the need for additional infrastructure.

The results confirm that the proposed system effectively automates parking space detection and payment processing while improving efficiency and user experience. The integration of AI and computer vision eliminates manual intervention, reduces congestion, and provides real-time parking availability updates. Future enhancements, such as IoT sensor integration, predictive analytics, and mobile application development, could further improve real-time monitoring and system adaptability for large-scale urban deployments.

Metric	Proposed System	Sensor-Based Systems	Previous AI Models
Accuracy	92.5%	85-90%	90-91%
Frame Processing Speed (FPS)	28 FPS	10-20 FPS	22-24 FPS
Latency	35 ms	500 ms-several sec	45-50 ms
Scalability	High	Low	Moderate
Environmental Adaptability	High	Low	Moderate

Table 2: Comparison with existing systems

The findings confirm that the proposed system enhances parking space detection and payment automation. The integration of AI and computer vision eliminates manual intervention, streamlines parking management, and reduces congestion in urban areas. Future enhancements, such as IoT sensor integration, predictive analytics, and mobile app development, could further optimize real-time monitoring and user experience, making the system more adaptable to large-scale deployments in smart city environments.

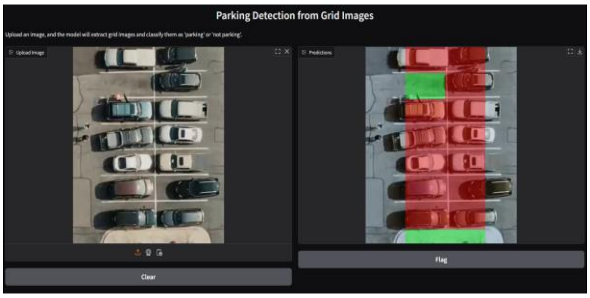

Fig 2(a): Output of the proposed model(Empty slot detection)

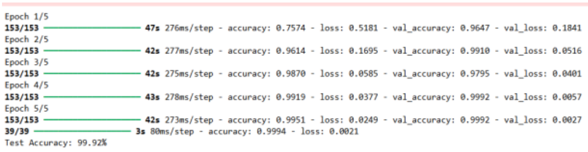

Fig 2(b): Test accuracy of the model

VI. REFERENCES

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