Smart Parking Systems: A Review of Sensor-Based and Image Processing Approaches

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***Abstract*—Now, parking systems are considered very important in campus areas since they provide a necessary service to users. Usually, managing these parking lots involves hiring outside help for some technology and services. The system initially used old methods where guards were at the entrance gate, writing down when vehicles came in and out. A better method added cameras to the system to take pictures of cars coming in and out while also helping with tickets. Even though both technologies are used a lot, there are some problems that need to be fixed. First, keeping records well requires several workers. Also, it is hard to find criminal activities when stolen cars look similar, like having the same color, because the data from the pictures is not clear. In order to solve this problem well, a modern parking system was developed with advanced image processing methods to enhance the accuracy and efficiency of vehicle identification. The high-tech computer vision system makes use of the top algorithms like OCR and SURF for reading the license plates of various vehicles correctly. With the integration of these complex algorithms, the system captures and stores both the unique identifying characteristics of every vehicle and its corresponding number plate without any modifications or omissions.**

I. INTRODUCTION

Rapid urbanization and an increased number of motorized vehicles have created challenges in managing parking facilities, especially in metropolitan areas. Daily commuting, shopping, and work travel are increasing the need for parking spaces. Thus, it becomes essential to create better parking management systems. In the regular parking system, people use manual ticketing and security staff to keep watch, which creates problems like delays, crowding, and safety issues. With the growth of cities, the old systems are not good enough to handle the complicated flow of traffic and parking needs today.

A. Issues with Conventional Parking Systems

Manual monitoring of large parking facilities is not effective when there are several entry and exit points. Some of the common issues include:

- Theft and Ticket Swapping: Vehicles are exposed to theft and ticket swapping, and unauthorized parking.
- Inefficient Space Utilization: Traditional systems do not provide real-time information about available spaces.
- Traffic Congestion: Searching for parking spaces contributes to congestion and increased fuel consumption.
- Human Error: The manual ticketing and record-keeping may lead to discrepancies and errors.

B. Smart Parking: Sensors and Image Processing Integration

Smart parking solutions employ sensor technology and image processing integrated with Artificial Intelligence that automatically identifies vehicles, distributes the available parking space, and also monitors security. Modern parking systems can effectively implement OCR to allow for automated license plate recognition. OCR algorithms will process images of plates by extracting the text data into identification and security purposes. Also, Speeded-Up Robust Features (SURF) and other ways to find features help in recognizing objects beyond just spotting license plates. This is important for telling apart cars that look alike, even if they have the same color and model. Using video processing, OCR, and AI-powered analytics together makes parking systems more accurate, cutting down on mistakes and boosting security.

C. Artificial Intelligence and Machine Learning in Parking Systems

The technologies behind computer vision, sensors, and deep learning algorithms make real-time monitoring and surveillance feasible in parking systems. AI-based approaches improve predictions for vehicle entry and exit in parking stations, but factors like lighting, camera installations, and ambient noise are bound to downgrade the accuracy of such predictions. Advanced image processing techniques, calibration techniques, and background noise cancellation need to be executed for system reliability.

Modern parking solutions provide the ability to track vehicles in real-time, print tickets automatically, and ensure more security with modern technology. Smart parking systems also enhance the operational efficiency and promote environmental sustainability through reduced idling and fuel consumption.

II. LITERATURE REVIEW

A. The Increasing Population and Its Impact on Demand for Parking

With such growth of urban populations, the number of vehicles on roads has increased. The result is a serious concern relating to the lack of parking facilities and traffic congestion that interferes with the smooth movement of vehicles. As reported, studies have revealed that around 30% of traffic congestion in urban cities is caused by the movement of the vehicle in search of free parking spaces [1]. In solving this concern, researchers have thus looked into sensor-driven and image-processing methods that help improve parking management.

B. Role of Image Processing in Vehicle Identification

In the modern parking management system, image processing plays a very important role. The most common technique used in ALPR is Optical Character Recognition, which involves the following steps:

- Pre-processing: It enhances the quality of the image, removes noise, and segments the image into individual parts. Plate Detection: Finds the region that has the license plate. Feature Extraction: Recognizes characters and unique vehicle features.
- Text Extraction: Converts image-based plate data into readable text.
- However, the performance of OCR depends on lighting changes, obstacles, and distortions in images. In order to improve the accuracy of recognition, several techniques have been implemented, including color adjustments and edge detection [2]. Furthermore, deep learning models, including CNNs, have been included in OCR systems to improve accuracy in real-world conditions.

C. Sensor-Based Smart Parking Systems

Another crucial method that modern parking systems employ is through the use of sensors to identify if parking spots are occupied. Sensors are classified into:

- Ultrasonic Sensors: Identify the existence of a vehicle through sound waves.
- Infrared Sensors: Identify heat signals from vehicles.
- Magnetic Sensors: Identify metal objects by measuring the variation in the magnetic field.
- IoT-Enabled Smart Sensors: Report in real-time whether parking spots are occupied or not to cloud-based parking systems.

  Sensor-based systems are inexpensive, and installation does not pose as a problem. Such systems also ensure real-time information. The disadvantage is though that sensor-based systems often experience environmental interference along with faults themselves in the sensor [3].

D. Artificial Intelligence to Secure Parking Through Object Detection

The presence of illegal vehicles and fraud activities makes security a need in parking systems. The artificial intelligence-based object detection models used for surveillance enhance the ability of YOLO (You Only Look Once) and Faster R-CNN to detect stolen vehicles, people accessing unauthorized parking, and the prevention of fraud tickets by comparison of license plates in real-time.

Artificial intelligence-based security systems offer superior detection accuracy as compared to traditional surveillance methods and are, therefore, suitable for large-scale parking management [4].

E. Cloud Computing and Storage of Smart Parking Data

Intelligent parking systems generate large amounts of data, including information like arrival and departure times of vehicles, license plate numbers, and the status of parking space occupancy. Traditional local storage methods are not adequate for processing such large amounts of data. Researchers have proposed cloud computing-based frameworks for the management of parking data [5]. Cloud-based solutions offer several advantages:

- Scalability: The ability to process large amounts of data.
- Remote Access: Enables real-time monitoring and control from any location in the world.
- Data Security: Uses encrypted storage mechanisms to avoid data breaches.

However, cloud-based parking management systems should have robust cybersecurity measures to avoid hacking and data manipulation risks.

F. Image Processing-Based Empty Space Detection

The efficient management of parking spaces is contingent upon the precise identification of unoccupied areas. Although sensor-driven parking solutions are prevalent, they can experience inaccuracies stemming from sensor malfunctions or errors. An alternative method involves the utilization of image processing techniques for detecting vacant spaces, which encompasses the following approaches:

- RGB to HSV Conversion: This technique improves image contrast, facilitating better detection.
- Thresholding Techniques: This method discerns vacant areas by evaluating variations in color.
- Binary Segmentation: This process transforms images into grayscale, thereby simplifying subsequent analysis.

Recent studies have shown that deep learning-based image processing increases the efficiency of detection by 15% as compared to the traditional sensor-based method [6].

G. Future Development and Challenges in Smart Parking Systems

Even though there is a development in AI, sensor technology, and image processing, there are still some challenges in smart parking systems:

- High Implementation Costs: Advanced surveillance, AI models, and OCR technologies require a lot of investment.
- Environmental Impact: Detection accuracy may be affected by poor lighting conditions and weather variations.
- Cybersecurity Risks: Cloud-based parking management systems must employ strong encryption that prevents data breaches.
- Scalability Issues: There is a challenge for smart parking solutions to scale and expand with more vehicles.

III. RESEARCH MODEL

A smart parking system combines various technological elements, such as cloud computing, OCR, image processing, and real-time monitoring, in order to make parking management efficient, secure, and user-friendly.

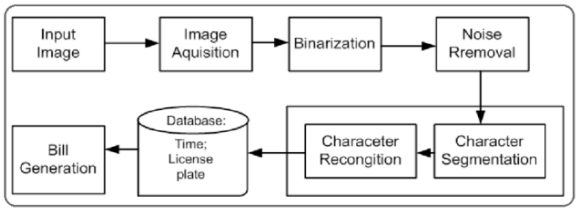

Figure 1.1 illustrates the overall architecture of a smart parking system.

A. Transportation and System Components

The intelligent parking system has been developed to cater for a wide section of users ranging from pedestrians, tourists, and visitors to museums and shoppers in malls. It is equipped with an advanced infrastructure that optimizes the allocation of parking spaces while reducing traffic congestion and enhancing user experience.

B. Inclusion of Monitoring Cameras

In the intelligent parking infrastructure, cameras are systematically mounted in different sites around the parking to enable monitoring, vehicle identification, and automated license plate recognition. The cameras could be either hardwired or wireless to gather real-time information. Installation of this system is easy and feasible in different types of environments and includes both public and private car parks.

C. Optical Character Recognition's Role in License Plate Detection

This system has an OCR algorithm as the primary part of it. The central role this OCR algorithm plays in automatic vehicle identification makes it very important in identifying license plate numbers of vehicles and converting them into textual data, which is directly stored in the database. This improves security through automatic verification and access control.

D. Cloud-Based Server Management and Monitoring

The entire parking system is connected to the cloud computing infrastructure to manage data and monitor it from a remote location. The server deals with:

- Real-time processing of data received from the vehicles.
- Storage and retrieval of parking-related information.
- Security monitoring to prevent unauthorized vehicles from entering the facility.
- Optimization of the utilization of parking space using historical and real-time data about the occupancy.

IV. IMPLEMENTATION AND TESTING

This implementation and testing phase will be a vital part of the proposed intelligent parking system for making sure the reliability and efficiency of the system. In this phase, it is important to test the performance of the OCR algorithm for license plate detection of vehicles and SURF algorithm for vehicle features.

Figure 1.1 depicts the overall structure of the intelligent parking system, which consists of several surveillance cameras installed strategically across the parking lot. The cameras are easy to install and can be used in both wired and wireless configurations. The security structure of the intelligent parking system is not limited to the main entrance but covers several parking areas. It reads and logs the vehicle license plate numbers through the OCR algorithm and stores the extracted data in a central database for further processing.

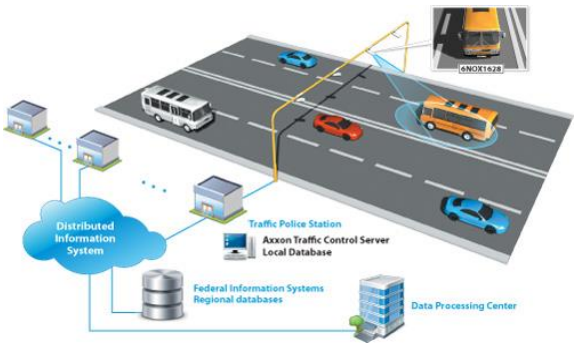

Figure 1.2 License Plate Detection System

The system will employ OCR techniques and advanced methods in image processing in identifying license plates. Camera installations in the parking area collect data input. The system checks the captured information on the license plate against already registered vehicle information. When the system finds a match, it will give visual indication, either through marking or tagging, of successful registration.

For the improvement of the accuracy in license plate recognition, further experiments were conducted in larger parking areas as shown in Figure 1.3.

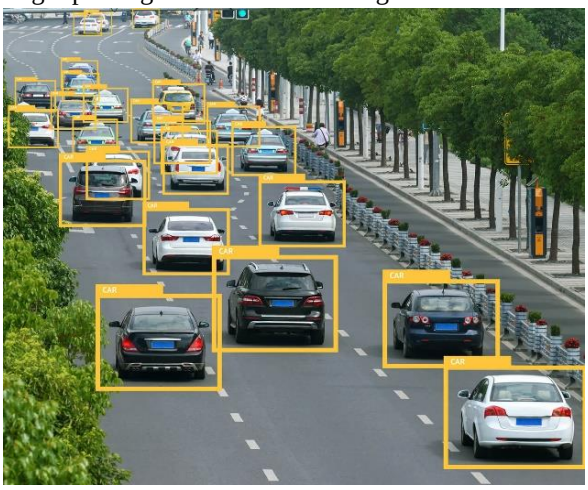

Figure 1.3 Implementation of the OCR Algorithm in a motorized vehicle area

The experimental results indicated high resolution cameras having a higher magnification capability that would improve the OCR performance. In this configuration, the license plate of the vehicle is detected and marked by a yellow bounding box, indicating it has successfully been recognized and registered in the database at the time of entry.

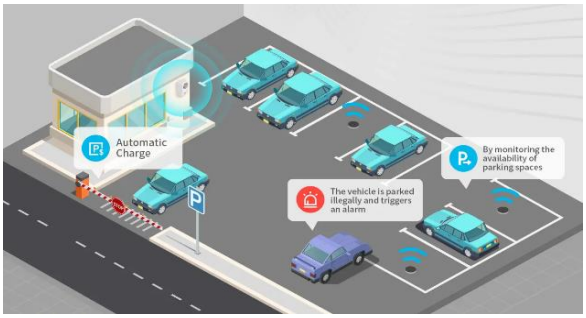

Figure 1.4 parking system in the car area

Figure 1.4 shows the operational capabilities of the parking system in cases where there are several vehicles of the same make and model. Conventional vehicle recognition systems often fail to differentiate between identical vehicles, thus leading to potential security breaches. There have been cases of criminal activities such as license plate switching, where a criminal replaces a vehicle's license plate with one that matches the model and type of the vehicle they wish to steal. The conventional system cannot identify such fraudulent practices, whereas the proposed system improves security by using advanced feature recognition algorithms.

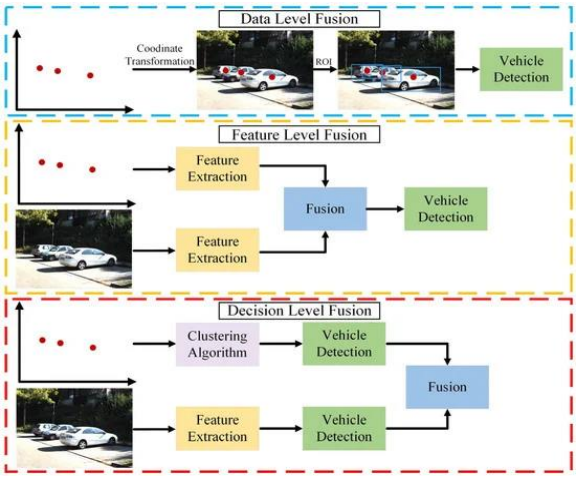

Figure 1.5 Feature-Based Vehicle Identification Using the SURF Algorithm.

Figure 1.5 shows the implementation of a feature identification system that uses the SURF algorithm. Cars that are the same make, model, and color pose a significant challenge for traditional identification methods. However, the SURF algorithm makes provision for the extraction of unique features of vehicles based on the structural details studied in various views including front, side, and top views. The thorough analysis ensures that the system can distinguish the most similar vehicles. The extracted unique feature information is then stored in a safe database for future checking and verification.

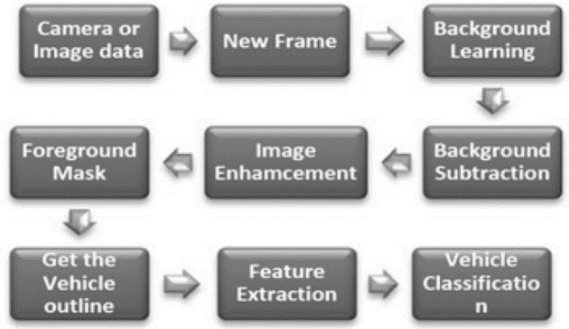

Figure 1.6, OCR with SURF Algorithm

In Figure 1.6, OCR is applied along with the SURF algorithm to capture and analyse the unique features of each vehicle for the system to keep track of parked vehicles. The data obtained in this process will not allow possible errors in vehicle identification, thereby reducing confusion and enhancing security in general. The accuracy of this method is around 80%.

The system continuously analyzes every vehicle in real-time using the SURF algorithm. Traditional parking security systems are unable to distinguish between similar models of vehicles; however, the proposed intelligent parking system uses machine learning-based pattern recognition to enhance security features. In the experiment, a green bounding box has been used to focus on a car that the algorithm correctly detected; thus, validating its ability to identify and distinguish cars based on their different structural features.

V. CONCLUSION

From empirical evaluation, the proposed intelligent parking system shows the security vulnerabilities with conventional methods applied in the use of manual issuance of parking tickets and photographic records of vehicles as they enter the parking lot. The above could be improved using advanced image processing techniques that recognize the structural design, shape, and color variations of different types of vehicles.

The OCR algorithm successfully recovers and authenticates data relating to the vehicle license plates, and the SURF algorithm improves the recognition of major features in vehicles, therefore offering a more

reliable and efficient management system for parking. It provides accuracy at an approximate figure of 80%, and hence, this can be a substitute to some traditional techniques of verification for vehicles. This smart parking system also supports advanced security measures and can seamlessly integrate into other existing smart parking infrastructures with minor changes only.

The proposed framework could be further expanded to the Internet of Things with real-time processing, remote monitoring, and integration of cloud computing. Further research on deep learning algorithms would improve the system's efficiency further. The developed solution would prove robust and intelligent for parking management. Innovation in the development process would also support better urban mobility and safety inside the automated parking spaces.

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