Smart Parking

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Smart parking is an artificial intelligence-based solution to solve the challenges of inefficient utilization of parking slots, wasting time, congestion producing high CO_2 emission levels, inflexible payment methods, and protecting parked vehicles from theft and vandalism. Nothing is worse than parking congestion caused by drivers looking for open spaces. This is common in large parking lots, underground garages, and multi-story car parks, where visibility is limited and signage can be confusing or difficult to read, so drivers have no idea where available parking spaces are.

smart parking | Internet of Things (IoT) | Artificial Intelligence (AI)

1. Introduction and Motivation

Searching for suitable car parking in modern cities is considered a challenge in terms of wasted time and power consumption [1]. In the modern era, car licenses are daily growing at a very high rate, which means the number of vehicles has expanded, which leads to severe traffic conjunctions, and onerousness to find suitable car parking. In modern cities, car parking slots remain as they are, while the number of vehicles is expanding. Hence, modern cities are suffering from car parking shortages. According to [1], in the USA, over 70 billion dollars are wasted every year searching for parking, which is equal to 3.6 billion hours of time and 1.7 billion gallons of fuel. According to [2], one hour of congestion could emission enhancement fluxes of air pollutants and carbon dioxide by 14.3~30.4%.

According to [3][4], the main reason for traffic conjunction in big cities is the car parking problem. Finding a suitable parking space is a challenge in big cities. Therefore, governments should implement laws to address this issue [5]. The developed systems [6][7] have proved the significance of using intelligent parking modes in modern cities. Although modern cities have applied different intelligent solutions for solving car parking issues, the problem still does exist [8].

There are two types of parking spaces: those reserved for specific individuals and free parking spaces available to everyone. Parking spaces reserved for specific individuals may be unoccupied if the person is on leave or absent from work. The problem becomes apparent when the number of employees in an organization is greater than the number of parking spaces allocated to the organization. On the other hand, when the number of visitors exceeds the available parking spaces, visitors may park incorrectly, causing traffic congestion.

The daily parking problems can be summarized as (1) shortage of designated parking slots for certain buildings, which is not enough for employees and visitors. (2) traffic congestion caused by visitors searching for parking slots.

(3) Incorrect parking where drivers park vehicles in a spot that is not designated for them. This could happen in a variety of settings, such as in a parking lot where each spot is assigned to a specific individual or in a public street where there are specific regulations about where and how long one can park. Hence, the optimal solution that could deal with the above challenges should: (1) provide dynamic parking slot distributions to address the shortage of parking slots. (2) provide a mechanism for pre-booking by specifying a specific parking slot at a specific time to address the problem of incorrect parking. (3) provide a mechanism to make sure that the car is parked in its correct parking slot, this solution is to address the issue of incorrect parking. In addition, the optimal solution should keep records of traffic patterns in the parking. These steps would formulate a control and monitoring mechanism for a smart parking system. To ensure the success of this mechanism, it must operate in real time.

2. The Significance of Smart Parking

The significance of smart parking, both from a theoretical research perspective and from an applied commercial perspective, is reflected in the large volume of research work in this field. Thus, only recent works have been considered, and the analysis of related works is limited to a timeframe of five years, from 2018 to 2023.

The related works have been analyzed for extracting strengths and weaknesses aiming for highlighting the research gap and providing beneficial directions for researchers interested in this subject. As an exclusion criterion, all works related to smart and electric vehicles have been neglected. These works should consider power consumption and recharging, which are outside the scope of this research. In addition, works with repeated ideas have been excluded.

The work presented in [9] involves a development of a system based on employing an Artificial Neural Network (ANN) for selecting a suitable parking slot in a real-time environment. The system analyzed employees' behavior and accordingly suggested a suitable parking slot time and location. This solution lacks a real time control system. The work in [10] developed a system based on drone-based surveillance to find suitable parking slots. This work has a high cost of implementation. The work presented in [11] proposed intelligent parking system by using Arduino sensors. This system is working by connecting chips with the Ethernet W5100 network and then transmits the collected information to the server. This system does not keep records of the movement of cars within the parking lot. The work presented in [12] have developed an intelligent system to find free parking slots. This system is developed based on a detector that consists of three parts: the STM32 microcontroller, the geomagnetic sensor, and the NB wireless module. The geomagnetic sensor collects the intensity of the magnetic field around, and then the magnetic field intensity is sent to the microcontroller. The microcontroller determines whether the parking space is free or not. This solution only includes a service for finding free parking slots. In [13], authors improved Radio Frequency Identification (RFID) by using a low-profile vertical polarized antenna to enhance intelligent parking based on (RFID). This solution is just to assist in finding free parking slots. The work presented in [14] includes the development of an intelligent method based on genetic algorithms for optimizing the selection process for selecting free public parking. The lack of a tracking mechanism could be a significant limitation of this proposal. The work presented in [15] have developed an intelligent parking system based on ultra-wideband (UWB) position and navigation technology. This system is suffering limitations due to the limitation of UWB.

In [16], authors developed an intelligent method for assisting drivers by predicting suitable paths and parking slots. This method has been developed by using the Internet of Things (IoT), and genetic algorithms. It was enhanced by using Artificial Neural Network (ANN). The work presented in [17] have developed a simulation of the shared parking operation that considers the uncertainties with four parameters which are users, arrival, and departure time. The presented work in [18] involves the employment of a canny edge detection method and a USB camera to define the available parking slots. The work in [19] is used wireless vehicle detectors and magnetic sensors to define the availability of parking spaces. The four aforementioned works lack tracking and controlling mechanisms.

The work presented in [20] employed a Raspberry Pi 4 B+ (RPi) computer, Pi camera module, GPS sensor, ultrasonic sensors, and Blynk App to develop an intelligent parking system. This solution is successfully finding the available parking slots over the Internet. The work in [21] has developed an intelligent system that allows users to pre-reservation free parking slots and then update the parking status after detecting a car's plate by using the OCR algorithm. The work in [22] has developed an intelligent mobile application that can suggest free parking slots around the target location. The suggestions are generated based on the user's preferences.

In [23], authors have developed a parking management system based on ARM and ZigBee wireless sensor networks to define free parking slots. The deep learning model has been used as a car's plate recognition system, where the system controls the entrance and exits of the parking. The work in [24] has developed an intelligent model to recognize the free parking slots based on AI vision and the MobileNet classification model. This system can recognize occupied parking slots and the vehicle's type. The work in [25] has developed an intelligent parking system by integrating related technologies such as ZigBee, geomagnetic sensors, and RNN to detect the status of parking spaces.

The work presented in [26] includes the development of an intelligent model that utilizes a Convolutional Neural Network–Long Short-Term Memory (CNN-LSTM) architecture, along with comprehensive 360-degree panoramic images, ultrasonic and sensor distance measurements. The model is designed to assist drivers in accurately parking their cars, thereby reducing congestion in open parking spaces. In [27], authors have developed an automatic parking lot occupancy detection model. This model utilizes an around-view monitor (AVM) image sequence with a 360-degree bird's-eye view camera, as well as ultrasonic sensors, to accurately determine the presence of adjacent vehicles.

The optimal solution should provide (1) dynamic parking slot distribution, (2) a mechanism for pre-booking a parking slot, and (3) a mechanism to ensure that the car is parked in the correct slot. (4) inquire about the location of any car at any time. The first two represent control of the parking system, while the third, and fourth pertain to monitoring. Based on the discussion and analysis of related works, it is evident that there is a critical need for a real-time system that provides both control and monitoring subsystems. Therefore, researchers will use the features of optimal solution as benchmark to compare the proposed smart parking with the related works. **Table 1** shows this comparative summary.

Table 1. Comparative summary between related works and the proposed system.

The Work	Dynamic Distribution	Pre-Booking	Ensure the Correct Slot	Inquire about the Location of Any Car at Any Time
[9]	X	√	X	X
[10]	X	√	X	X
[11]	X	X	√	X
[12]	X	√	√	X
[13]	X	√	X	X
[14]	X	√	√	X
[15]	X	X	√	X
[16]	X	√	√	X
[17]	X	√	X	√
[18]	X	√	√	X
[19]	X	√	√	X
[20]	X	√	X	X
[21]	X	√	√	X
[22]	X	√	√	X
[23]	X	√	√	X
[24]	X	X	√	X
[25]	X	X	√	X
[26]	X	√	X	X
[27]	X	√	X	X
The proposed system	√	√	√	√

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