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# Smart Cars Parking Systems of Big Cities based on the Internet of Things

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**Abstract**

Large areas and cities have a large number of cars, making it uneasy for their drivers to find empty parking, especially during peak hours. With the increasing number of cars and the limited number of roads and parking areas in metropolitan areas, smart parking is necessary to resolve this issue. This project includes an intelligent gate that opens automatically. Multiple sensors installed in the parking lot track the number of vehicles and the availability of empty parking spaces. Information collected is transferred to an online platform. Users can access this information through a smartphone application or computer platform. Thus, the proposed parking system is based on the client-server model, in which the clients are waiting for a service from the servers. Thus, the client can request an empty parking lot, and the server receives the request and analyzes it. The server's installed algorithm utilizes real-time data to determine the available parking area. It then returns the location of the available parking area. The application allows drivers to easily know the number of cars in the parking lot and the locations of empty parking lots, which saves time and increases the efficiency of using the parking lot. Supervisors can use this data to enhance overall parking management by monitoring the current parking status and making informed decisions about its management and maintenance. Therefore, the intelligent parking project effectively improves drivers' experiences and parking management.

**Keywords:** Smart Parking, Internet of Things, Sensors, Smartphones.

## 1 Introduction

Urban areas worldwide are increasingly facing severe parking shortages due to rapid urbanization and the surge in vehicle ownership. In many large cities, the demand for parking spaces far exceeds supply, leading to significant challenges for drivers. Studies show that, on average, drivers spend about 17 hours per year searching for parking, with this figure 1 rising to 107 hours in congested cities like New York, Los Angeles, and San Francisco. This not only causes frustration but also contributes to traffic congestion, air pollution, and wasted fuel. The inefficiency of traditional parking systems is further

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exacerbated during peak hours, where up to 30% of urban traffic is attributed to vehicles circling the block in search of parking. These challenges underscore the urgent need for a smart parking system that can efficiently manage parking resources and alleviate the stress and environmental impact associated with parking in urban areas.

Urbanization is associated with many challenges; this is a result of the migration from rural areas into residential areas (Abdul Rahaim et al., 2023). The reasons behind this migration are the lack of opportunities in rural areas, whereas there are better chances for jobs in urban areas. Consequently, the cities become crowded and filled with cars. The regularization of traffic and parking has become one of the main challenges of our time. It is evident that cities have a lot to offer their residents, especially in terms of education, health, entertainment, and much more. However, crowdedness, jams, and lack of parking are some of the major issues in living in cities, especially big ones. In this scenario, the growing number of cars leads to a parking crisis, particularly when there's a shortage of suitable parking lots due to narrow or closed roads. Urban engineers have planned parking infrastructures according to estimates and historical data, which usually cause wasted space, inefficiencies, and frustrations for drivers. Looking for a parking lot in a crowded city might be a time-wasting and unpleasant experience, leading to increased emissions, congestion, and poor urban standards in cities (Khanal et al., 2017). In this specific domain, where cloud computing, the Internet of Things, and the web can collaborate to provide a solution, technology holds significant potential (Kotenko et al., 2018; Abdulmahdi et al., 2023; Priyanka et al., 2023). The IoT continues to provide services, particularly in health and service applications, as well as when linked with artificial intelligence (Nadu, 2023; Surendar et al., 2024; Alamer et al., 2023; Al-Ja'afari et al., 2020; bAmeer, et al., 2022).

On the other hand, the Smart Parking Project is an innovative solution that aims to alleviate the parking difficulties that city residents are now facing (Shih et al., 2018). The Smart Parking Project primarily relies on the Internet of Things (IoT) as its fundamental technology. It mixes urban planning with cutting-edge technology (Bhatt & Gandhi, 2014; Ud Din et al., 2018; Stephen et al., 2023; Aswathy et al., 2023). Governments are working to enhance their transportation systems and infrastructure, but the slow pace of urban planning exacerbates the problem. Due to the evolutionary increment in industrial facilities all over the world, there has been a large increase in the vehicle count. Experts anticipate a surge in the overall vehicle population from 841 in the past 15 years to over 1.6 billion currently. Consequently, the rarity of availability in empty parking lots becomes clear in different public facilities, like hospitals, schools, universities, shopping centers, and leisure centers (Skarmeta et al., 2015). Governments have enhanced the public transportation and road systems to improve the quality of services (Proença, 2019).

The challenge of finding vacant parking spaces is particularly pronounced in modern cities, where a high number of vehicles vie for limited parking spots, causing concerns about car security. Indoor parking facilities often witness wasted time searching for available spots, leading to traffic congestion. Air pollution from idling cars, whether outdoors or indoors, is another issue. With more people relying on their own vehicles for transportation, cities experience increased congestion, further complicating the quest for available parking. Finding ways to reduce data transmission costs, conserve energy, and deliver real-time information efficiently is an urgent priority (Khattak et al., 2019). Smart car parking systems, powered by IoT technology, are emerging as a solution to address these challenges, as they can capture sensor data for monitoring key points in smart cities. Recent research has explored the potential of IoT in public transportation and urban computing. Several models aim to provide drivers with real-time information about nearby available parking spaces. Recent research in this area explored the impact of IoT technology in transportation and urbanized computing. Some solutions involve collecting and transmitting data to a cloud processing center, which then provides recommendations back to the parking facilities. However, few studies have effectively gathered data on on-street parking. Some research papers propose the development of smart parking systems that directly inform users about available parking spaces nearby, helping them avoid traffic congestion (Guibene et al., 2017; Abdul Rahaim et al., 2023; Hui et al., 2019). An optional feature could show users only free-of-charge parking locations. In the scientific papers and many different academic works that we will discuss in the next section, we witness different articles related to the parking problem all over the world. The utilization of the manual vehicle parking system leads directly or indirectly to situations such as wastage of time and energy looking for empty spaces across the parking surfaces when we require to park our vehicles, which need a suitable amount of fuel.

Large cities and metropolitan areas face significant challenges with parking, especially during peak hours, due to the high number of vehicles and limited parking spaces. As urbanization and car ownership continue to rise, smart parking solutions have become essential to managing these issues efficiently.

This project proposes an intelligent parking system that utilizes advanced technologies to streamline the parking process. The system includes an automated gate that opens when a vehicle approaches, thanks to an integrated RFID (Radio-Frequency Identification) system or license plate recognition technology. The parking lot is equipped with IoT (Internet of Things) sensors, such as ultrasonic or infrared sensors, installed at each parking space to detect the presence of vehicles and monitor the availability of spaces in real-time. Collected data is transmitted to a centralized server using a wireless communication network (e.g., Wi-Fi, Zigbee, or LoRaWAN). This server processes the data using a combination of algorithms, such as machine learning-based predictive algorithms, which analyze traffic patterns and parking occupancy rates to provide optimal parking recommendations. Drivers can access this information through a user-friendly mobile application or a web platform. The application allows them to view available parking spaces in real-time, reserve a spot in advance, and receive navigation guidance to the nearest available space. This reduces the time spent searching for parking and enhances the overall efficiency of parking lot usage. Furthermore, the data collected by the system is invaluable for parking management. Supervisors can monitor parking occupancy, detect irregularities, and optimize space allocation. They can also generate reports on usage patterns, which can inform decisions about maintenance, expansion, or dynamic pricing models.

In this study, we are investigating the application of IOT technology in an auto parking model.

1. Implementing IoT sensors in parking spaces and connecting them to a central network enables real-time monitoring of parking spot availability. This contribution significantly improves the parking experience for drivers, as they can access up-to-the-minute information on vacant parking spaces through mobile apps or digital signage. It helps reduce the time and fuel wasted in circling for available spots, ultimately alleviating traffic congestion and decreasing carbon emissions.
2. Optimizing park space usage through collecting and analyzing data on parking space utilization patterns over time.

This paper arranges the remaining sections as the second section delves into the related work, elucidating its impact on urban mobility, urbanization, parking challenges, the repercussions of inefficient parking, and the corresponding efforts to address this issue effectively. In the third and fourth sections, the design and implementation, along with the text results, are explained, and the final section provides the concluding remarks Section.

The structure of this report is as follows: in the related works section, we elucidate the academic works conducted in this field, in the methodology section, we present the suggested methodology, and finally, we explain the tests and experiments. Finally, we provide concluding remarks along with the primary outcomes derived from this research (Jyothi et al., 2023; Barriga et al., 2019; Bobir et al., 2024; Gheni et al., 2024; Priyanka et al., 2023; Gheni et al., 2024l; Abdul Kareem et al., 2022).

## 2 Related Work

Numerous In this section, we explain the studies regarding the impact on urban mobility. The Smart Parking Project isn't just about parking; it's about reshaping urban mobility. By alleviating one of the key stressors of urban living—finding parking—it indirectly promotes the use of public transportation and sustainable mobility options. The rapid growth of vehicles has rendered urban areas susceptible to congestion, necessitating the proposal of an effective solution to manage this increase. Cloud computing and IOT technology combine to create Vehicular Ad Hoc Networks (VANETs), a technology that mitigates this issue.

There are a large number of applications in smart urban spaces, encompassing smart building automation, healthcare monitoring, and connected transportation (Priyanka et al., 2023). This literature review focuses on a novel framework, VCoT, for integrating VANETs and IoT, with a particular emphasis on LoRaWAN-based vehicular networks in the context of smart cities. For a successful VCoT deployment, it addresses critical research challenges such as data aggregation, security, privacy, data quality, and network coverage.

Furthermore, cities lose substantial revenue when congestion deters people from visiting urban centers for shopping, dining, and entertainment. In (Abdul Rahaim et al., 2023), the authors unveil the outcomes of a collaborative Intel/Nimbus Low Power-Wide Area (LPWA) technology Proof of Concept (PoC) deployment within a smart city context. The PoC initiative places a buoy in Dublin's city center to monitor the River Liffey for eight months. Various sensors, including those for water data (depth, temperature, and velocity), internal data (temperature, humidity, and barometric pressure), GPS data (location and timestamp), and system data (battery voltage), equip the buoy. Additionally, it features a LoRa-based LPWA transceiver and a 3G modem for redundancy. The paper provides insights into the findings regarding range and data consistency, drawing conclusions on the applicability of LPWA technologies in smart cities.

In (Barriga et al., 2019), the authors clarify the role of technology in parking solutions. IoT technology, particularly LoRa networks, offers agricultural benefits because of its long-range, low power usage, and cost-efficiency. This study examines LoRa networks in agriculture, testing communication between a LoRa gateway and multiple ground sensor nodes. The aim is to provide farmers with data from geographically vast or inaccessible areas, benefiting industries like forestry. The research was conducted on a tree farm near Purdue University, Indiana, addressing agricultural IoT in challenging environments. The rapid urbanization and ever-increasing urban population have led to a surge in the number of vehicles on the road, exacerbating the already challenging issue of finding convenient and available parking spaces.

# 3 Proposed System Design

## 3.1 Automated Car Parking Model

The IoT smart vehicle parking system utilizes sensors to locate vacant parking spaces. When a car nears, it transmits a signal to the system, which then use a mobile application to guide the driver to an open parking spot. Sensors monitor the parking place's occupancy status once the car has been parked. The technology can update seat availability in real time. It can provide data analytics to optimize parking usage and efficiently manage operations.

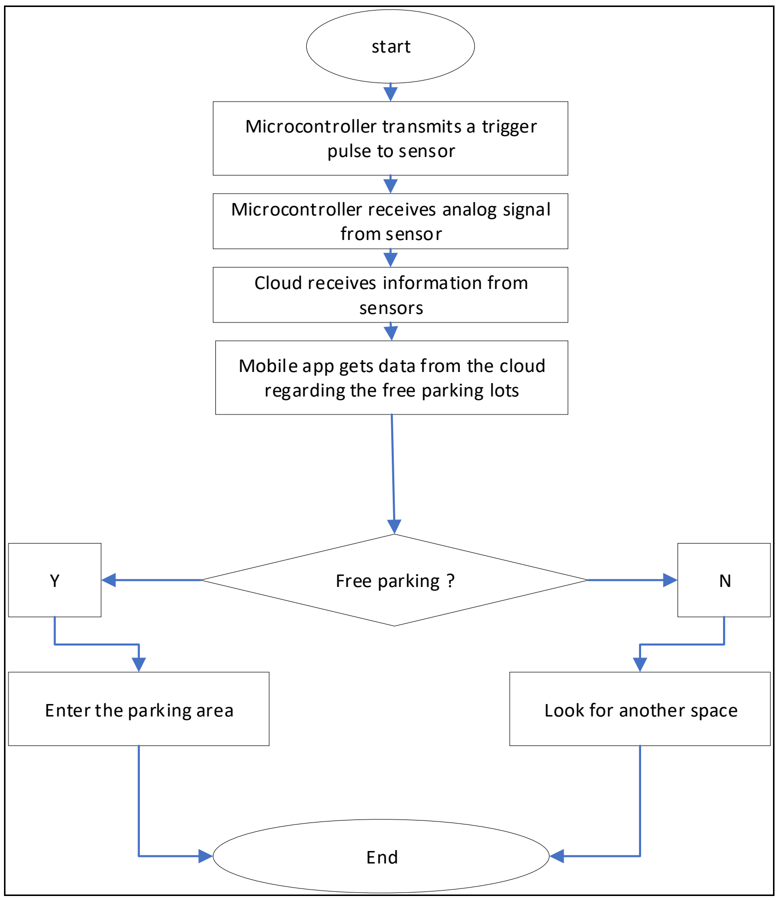


Figure 1: Proposed System Flowchart

## 3.2 System Architecture

In this section, we continue to explain the implementation of the suggested auto parking system. The suggested parking system would interlink each system with the others. The system we propose is an in-ground vehicle detective sensor. The parking sensor in the parking system is equipped with infrared technology. Typically, the sensor uses short-range wireless to communicate with the signal light notifications located on top of each parking lot. The sensor indicates whether the parking lot is full or not. If it is empty, the sensor will emit a signal and change the lights to green. On the other hand, if the parking lot is not complete or has already been reserved, the light will turn red. The parking system includes both mobile and web-based applications. Mobile and web-based applications are where the customer can interact with the parking system. In mobile and web-based applications, customers could conduct different tasks, such as checking the availability of park lots in shopping centers, booking empty park lots, and paying the park fees. Another system is the cloud. The cloud is utilized for databases. Every task in the parking system is recorded. The system also stores the information provided by users. For instance, it records the timing of customer bookings, the duration of car parking, the total cost customers must pay, and the methods of payment. A central control system manages the entire network of IoT sensors, data analytics, and mobile applications. Real-time decisions are made, such as updating parking availability on mobile apps and optimizing parking resources. The SPS implementation utilizes integrated technology, which includes mobile devices, parking monitors, QR scanners, in-ground sensors, and notification signals. The consumers, parking personnel, and shopping mall management will all profit from the SPS deployment. Automobile users can reserve parking spaces online using a smart device and the SPS framework. They may fill out the booking form, establish an account, and log in. Once they produce the digital parking ticket, they can use it to enter the retail center. If a car user forgets to make a reservation, they can still obtain a manual ticket using a ticket machine, either in paper or digital form. The Arduino serves as the system's central nervous system. Each component is overseen and managed. Ultrasonic sensors will be installed in the parking spaces that detect the presence of automobiles within them will have ultrasonic sensors installed in them. There will be one sensor next to the parking lot's main entrance. As soon as the sensors detect a car in front of the entry, the Arduino chip will receive a signal telling it to check if there is an open space in the parking lot. The main entrance will open when the dc servo motor receives a signal from the Arduino chip indicating that one or more slots are vacant. However, the Arduino chip will not detect any empty slots.

Based on the above the main idea of the proposed method in auto parking is to utilize the IOT sensing technology that is connected to an advance camera system such as shown in Figure 2.

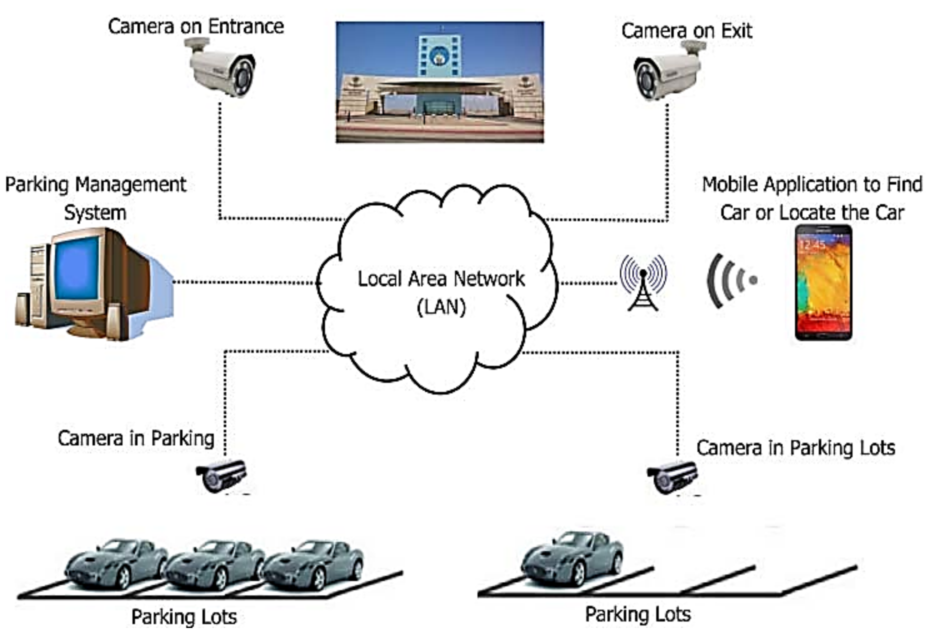


Figure 2: Camera-based Auto Parking System

Permitted vehicles and owner information are registered in the parking lot management system. Information about the parking zone and parking lot is already stored in the system along with other relevant information (e.g., cameras monitor the parking lot and its physical location (X and Y coordinates). The mechanism of making the drivers connected to the LAN is that there is a screen that shows the availability of the parking lot through a screen A screen that displays the number of available parking spaces inside the garage, noticeable to drivers. Parking Space Availability Screen Connected to the IOT-based Camera and Sensing System shown in Figure 3.

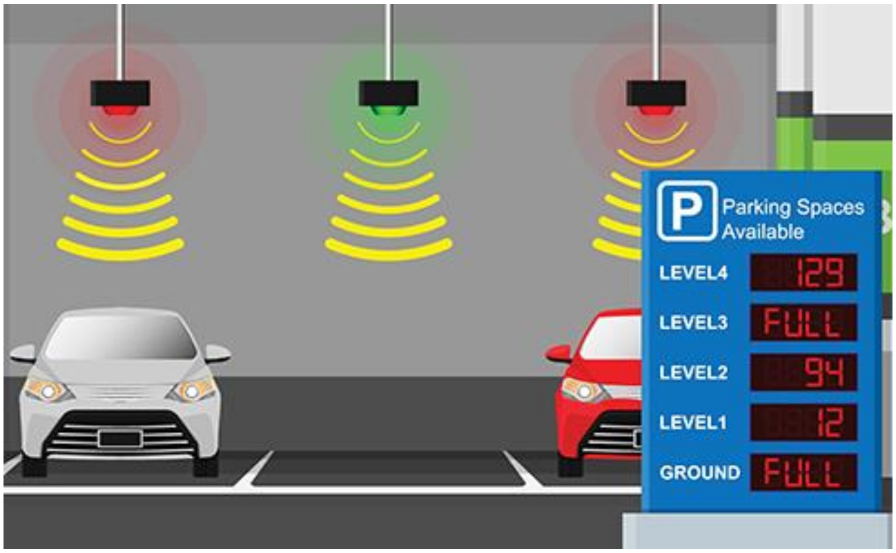


Figure 3: Parking Space Availability Screen Connected to the IOT-based Camera and Sensing System

This integrated setup aims to efficiently meet urban parking needs, offering a comprehensive solution where multiple interconnected garages function as one large unit. Parking lot entrance security systems typically include a set of monitoring and access control measures to improve vehicle safety and security. The system typically includes cameras and sensors that record the car's entry and exit. Barriers, gates, or license plate recognition systems can also be used to regulate vehicle flow via access control measures. Surveillance cameras record activities in the parking lot in real-time. Not only does this help prevent unauthorized access and potential security threats, but it is also a valuable tool for investigating parking lot incidents. Car security systems aim to create a safe and monitored environment for vehicles and their owners.

## 4 Test Results

Clearly illustrates the various parking scenarios in this design. Cameras strategically placed at entry and exit points monitor vehicles, automatically validating permits or reservations for entry. An algorithm dynamically allocates parking spaces, optimizing utilization. The system provides real-time monitoring, alerts for security concerns, and a user-friendly interface with a mobile app for notifications and payment options. With seamless integration of automated payment and data analytics, the smart auto parking system offers a convenient, secure, and efficient parking experience for both operators and users.

In instances where the smart parking lot reaches maximum capacity and cannot accommodate any additional vehicles, a clear message promptly appears on the parking gate's digital screen. This message functions as a real-time indicator, alerting drivers approaching the entrance to the unavailability of parking spaces. This proactive communication mechanism aids in preventing unnecessary traffic congestion within the parking facility, as it restricts access to the lot when it is already at full occupancy. Simultaneously, the electronic portal, which normally opens automatically upon a car's entry into the parking lot, stays closed to underscore the facility's capacity to accommodate no more vehicles. This feature not only improves the parking system's efficiency, but also ensures a seamless and frustration-free experience for both drivers seeking parking and those already in the facility. The inclusion of these automated and informative elements exemplifies the smart parking project's effectiveness and sophistication in optimizing parking management. There are two cases being considered to assess performance.

**Case 1: (45° Parking Spaces)**

In Figure 4 the system works on 45° Parking Spaces that can handle more cars in comparison to the parallelly designed once parking and 30° parking. Thus, it become likely to maximize in the angle of parking. The 45° Parking Space is not hard to make the drivers maneuver as it does not require vehicles to move sharply during the turnaround times shown in Figure 5.

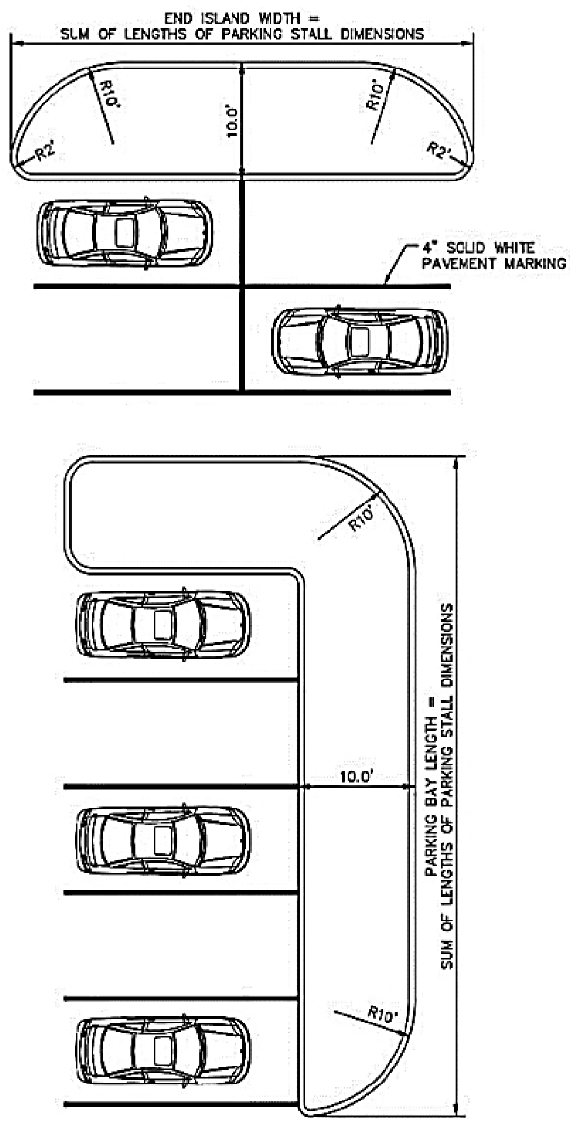


Figure 4: The Simulated Environment of the Parking System

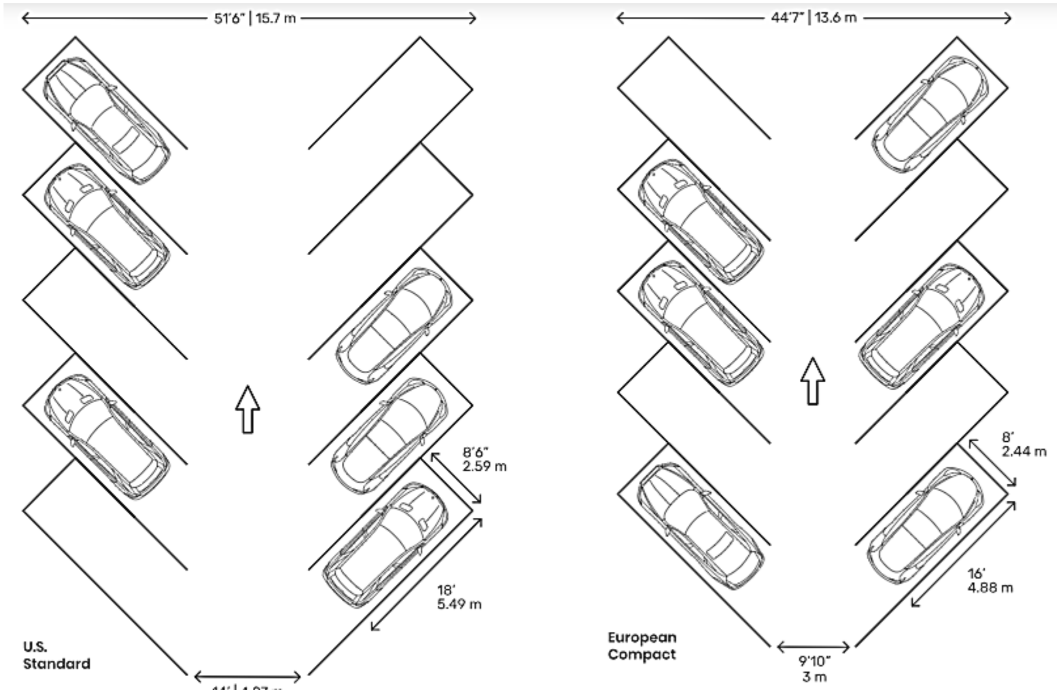


Figure 5: Case 1, Parking in 45 Degrees

**Case 2: (90° Parking Spaces)**

The 90° Parking Space is the perpendicular parking. These spaces are of 90° in the directions of streets. The most concerning point with 90° parking space is that executing it is tricky shown in Figure 6. The client might be risky when collision happens with other car if you don't exercise a lot of caution.

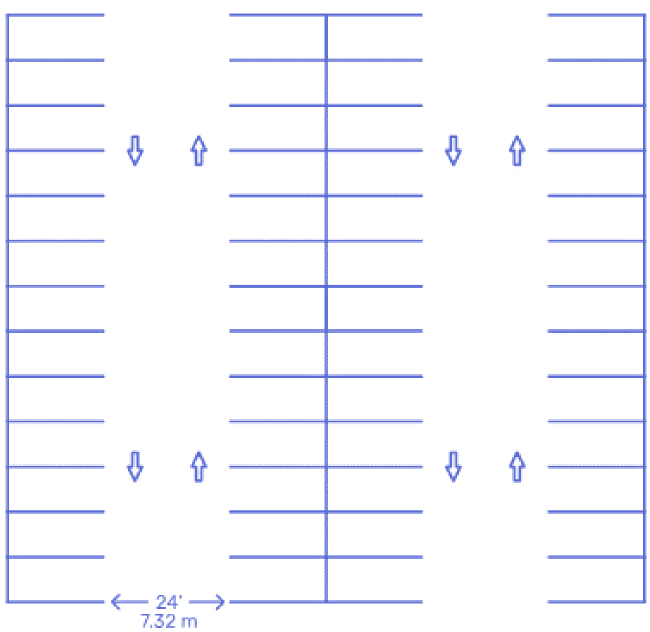


Figure 6: Case 2 Perpendicular Parking

**Case 3: Parallel parking**

A parking Space is a unpaved or paved space for finding the park area in a busy roads, parking lots, or parking garages. cars in a parking space could either be in parallel parking, angled parking, or perpendicular parking. They are marked so that each vehicle fits into the designed marked area. Parking space can either be free or paid for. Case 3, Parking in 90 Degrees shown in Figure 7.

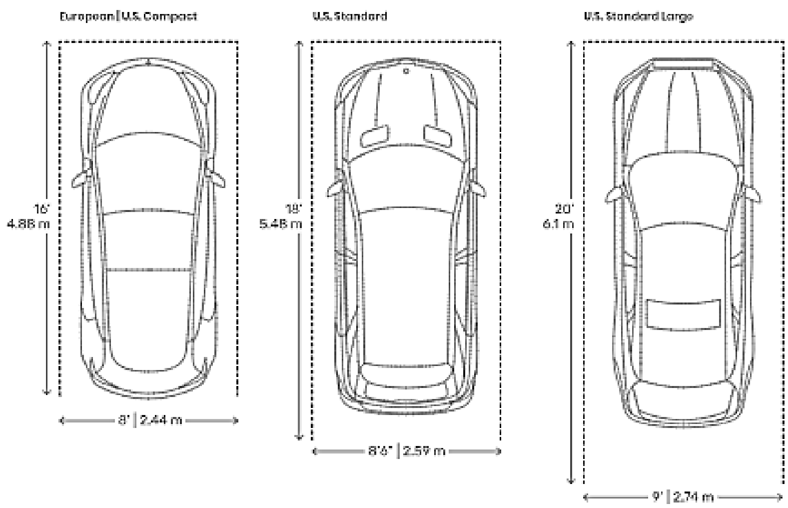


Figure 7: Case 3, Parking in 90 Degrees

The proposed auto parking system is applied on these three kinds of the parking case 1 where the 45-degree parking was test and the case 2 where the 90 degree is used while case 3 represents the parallel parking. Statistical Results of the Entering and Leaving shown in Table 1.

Table 1: Statistical Results of the Entering and Leaving

| Type of Parking | Entering Mean ($\bar{x}$ sec) | Entering std. ($\sigma$ sec) | Entering Sample Size (N) | Entering Range (sec) | Leaving Mean ($\bar{x}$ sec) | Leaving std. ($\sigma$ sec) | Leaving Sample Size (N) | Leaving Range (sec) |
|---|---|---|---|---|---|---|---|---|
| Parallel parking | 4.8 | 2.8 | 41 | 2.2-19.2 | 5.6 | 2.4 | 73 | 2.3-15.2 |
| Angle parking 45° | 4.2 | 1.8 | 144 | 1.9-15.0 | 10.3 | 4.9 | 163 | 3.4-29.8 |
| Angle parking 90° | 4.6 | 1.6 | 143 | 2.1-11.3 | 9.7 | 4.1 | 144 | 4.2-29.8 |

The test results shown above illustrate the statistical results obtained when running the proposed system on the three cases explained above for Entering and Leaving.

# 5 Conclusion

One of the active research areas is auto parking, which involves networking the parking region in an IoT environment. Therefore, the data that is obtained is both real-time and spatiotemporal. This network will send the exact location of an empty room to its clients. This approach will result in significant time savings and a reduction in gas emissions. Such systems are well-suited to urban areas where there is a high traffic density. Auto parking has revolutionized traditional parking. Auto parking allows drivers to park their vehicles for extended periods, particularly during working hours. As a result, the handiness of using the IoT helped societies find solutions to real problems in people's lives, such as congestion and parking issues. In conclusion, the Smart Parking Project is a testament to the power of Internet of Things (IoT) technology in enhancing parking management and utilization. It boasts a smart gate that automatically opens upon a car's entry, along with strategically placed sensors that continuously monitor parking lot occupancy and the availability of free spaces. Not only does this system save time and enhance parking efficiency, but it also provides valuable insights for overall parking management. Supervisors can make informed decisions based on real-time data, ultimately resulting in an improved parking experience for drivers and more effective parking lot management. In essence, the Smart Parking Project is a successful application of IoT, significantly elevating both user convenience and operational efficiency. Future work on the proposed smart parking system should focus on addressing several key challenges to ensure its feasibility and long-term success. One significant concern is the cost of installation and maintenance, particularly in retrofitting existing infrastructure with the necessary sensors, communication networks, and automated gates. Additionally, the system's reliability must be considered, as potential technical failures—such as sensor malfunctions, network connectivity issues, or server downtime—could disrupt service and lead to user dissatisfaction. Exploring cost-effective solutions, developing robust fail-safes, and implementing regular maintenance protocols will be crucial to overcoming these limitations and ensuring the system's sustainable operation.

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