Hybrid Mobile Smart Parking Application: Intelligent Parking Guidance for Tourists and Locals -Automatic identification and routing the right parking place with the shortest path

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Abstract

The number of tourists visiting the Sultanate of Oman has increased dramatically over the last four years. The usage of Smart Parking Hybrid Mobile Applications will be discussed in this study for both the local and tourists. By using GPS and Geo-fencing, visitors will receive notifications in their mobile applications about parking spaces that are available close to the tourist attractions, shopping malls and centers, etc. By optimizing the distribution of parking spaces, these smart applications enable local governments to make money, which boosts revenue and enhances tourism. This smart parking application will reduce the stress for the locals and tourists while parking vehicles. This problem has been connected to the remarkable rise in the number of cars and other kinds of mobility during the last few decades. Because of this, Oman's public spaces now require minimum payment for parking as of late. These days, it's hard to find unoccupied parking spots in movie theatres and retail center's instead, people must go hunt for spots where the time is delayed. According to the current setup, parking involves intensive labor work to direct cars into the appropriate spaces. Additionally, each location has a green light at the top indicating a free parking space; nevertheless, when customers enter a mall, they should look for a green light from a distance and proceed to the parking area. They were, nevertheless, somewhat unhappy with the inaccurate sensor detection in the interim. A variety of parking management systems using IOT technologies or sensors were also built to determine whether the cars are parked or have left the slots. All these systems required expensive maintenance and equipment, which not everyone could afford. This paper offers, when locals and tourists uses this application to reserve their timely parking availability at a minimal cost, Shortest-path algorithms are integrated into the system to direct users to their assigned parking spaces, minimizing travel time and traffic congestion. Therefore, using this research to provide an easy approach for people to reserve parking spots would help to solve this problem and bring in revenue for the local department.

Keywords: *GPS and Geo-Fencing, Hybrid Mobile application, shortest path routing, Smart parking, IOT*

Introduction

The popular destinations in Oman are far away, tourists are encouraged to use rental cars for sightseeing and travel to the deserts and mountains. There is an increasing requirement for transit as the population expands. It becomes necessary as a result to rely more on parked autos. It might be difficult to find parking for persons who frequently visit metropolitan public places including parks, theatres, malls, and mosques. Even though many systems have been specified in documentation, many locations use manual parking techniques. Only a structured indoor parking structure is provided by most smart city tourism sites. People today consider time and money to be important facets of existence. During the working day, the number of automobiles used increases significantly. In the country's major centres, parking is especially important. To complete tasks and arrive at their destination on time, people drive their automobiles; yet, as is widely known, there are far more cars in urban areas than parking places. Even most of the parking systems that are in use today are manually operated and have certain shortcomings. Also, parking in no parking zones puts drivers at danger of having their vehicles hauled away by tow companies and paying fines. As the smart cities are having different parking zones other than malls, since the parking zones do not have the boundaries, we can adjust the boundaries using GeoFencing. Using GeoFencing, we can adjust the boundaries as we need and we can name it, without any physical boundaries. These boundaries can help us to monitor the parking slots and also we can redirect the vehicles to a specific slot.

Literature Review

To enhance Abu Dhabi's indoor parking management system, Sharaf A. Alkheder, Murad M. Al Rajab, and Khalid Alzoubi [1] created the technical basis for a sophisticated mobile application. Based on the findings, it appears that the suggested mobile application will improve Abu Dhabi's parking system's effectiveness and cut down on the time lost looking for a spot. Tanishq A. Injal et al. [2] used GPS mapping to test an application intended to arrange parking spaces by assigning free parking places. This application aims to reduce the amount of traffic in parking spots. People must go hunt for open parking spaces in large establishments like event halls, shopping malls, movie theatres, and multiplexes. This is a problem. Because of this, parking calls for a lot of labour and personnel to position cars in the appropriate spaces.

Gokul Krishna and colleagues (2017) looked at a weighbridge load sensor and Internet of Things (IoT) smart outdoor parking system [3]. to make it easier for vehicles to be parked in public areas in an orderly, flexible, timely, and safe manner. Praveen and Harini [4] have examined the design of an NB-IoT-based smart automobile parking system. It is managed by software that uses features of a website or application to automate the parking and unparking of cars and sets a limit on the number of vehicles that can be parked in a designated parking lot.

A study by Lei Ye. et al. [5] looked at deep learning and geofencing-based free parking place detection using a camera installed on a vehicle. By examining existing parking spot recognition methods and determining their applicability in specific logistics scenarios, they were able to identify new challenges and potential benefits of logistics yard automation. It presents a new angle on parking spot detection going forward by showcasing the enormous application potential of geo-fencing and the powerful performance of deep learning in object detection.

This study develops a case study for a chain of retail stores in Dhaka, the capital of Bangladesh. Orders from various stores are combined, sorted, and scheduled for Dhaka City's Regions 1 and 2. Navigation and scheduling are done with the "vehicle routing add-on" feature of Google Sheets. The shortest path first algorithm, which was employed in the creation of the Intelligent Route Optimizer android application, is based on the Dijkstra algorithm. The car navigation system's ingenious routing optimizer changed its course based on the shortest path identified on the Google map that M. Azizur Rahman et al. (2021) [6] examined.

Parking Management System via Mobile Application [7] describes a parking management system that addresses parking problems at shopping malls by use of a mobile application. Their system consists of two parts. The hardware consists of specifically engineered sensor units that determine whether a certain parking space is occupied or empty using an infrared transmitter and a phototransistor. A mobile application for the Android operating system was made with the Eclipse IDE. Users could make use of this app after they entered the malls.

The survey's summary was thoroughly studied by Muhammad Khalid et al. [8], including topics ranging from Autonomous Valet Parking (AVP) approaches to Smart Parking (SP). The SP particularly includes high-density parking, smart routing, digitally upgraded parking, and unoccupied slot detecting technologies. Additionally, covered under the AVP are short-range (SAVP) and long-range (LAVP) automated parking systems.

Vankadhara Rajyalakshmi and Kuruva Lakshmanna [9] investigated the detection of car parking places using the Hybrid Deep DenseNet Optimisation approach. Both presenters have talked about the IoT-based concept that makes it possible to optimise the number of parking spaces that can be used. The study uses a Hybrid Deep DenseNet Optimisation (HDDNO) strategy, which combines deep learning and machine learning techniques, to estimate parking spot availability. The National Research Council provides secondary data for the HDDNO-based machine learning model, which promotes environmental safety and smart city development.

Reducing Tourist Stress Through Smart Parking Systems: Smart parking systems have the potential to alleviate stress among tourists by streamlining the process of locating parking spaces. Research by Mehar and Pathak (2020) indicates that tourists often face anxiety and frustration due to the lack of available parking near popular destinations. Implementing intelligent parking solutions that provide real-time availability information can significantly reduce this stress and enhance the overall travel experience [10].

Geo-Fencing Technology for Real-Time Notifications: Geo-fencing technology plays a critical role in notifying tourists about nearby parking spaces through mobile applications. As noted by Chen et al. (2021), integrating geo-fencing into smart parking systems enables the delivery of timely alerts and personalized recommendations, ensuring tourists can quickly find parking spots without unnecessary detours or delays [11].

Revenue Generation and Economic Benefits: Efficient management of parking slots can serve as a sustainable revenue source for local governments and private parking operators. According to Singh and Sharma (2019), the adoption of smart parking systems can optimize occupancy rates and facilitate dynamic pricing, thus maximizing revenue. Moreover, the financial gains from parking infrastructure can support the development of tourism-related facilities [12].

Enhancing Safety in Parking Areas: Tourists are often unfamiliar with the safety risks associated with parking in certain areas. Safe parking solutions, as highlighted by Kumar et al. (2022), can mitigate risks such as theft and vehicle damage. By incorporating surveillance systems and ensuring secure parking zones, smart parking systems address these concerns, improving the perception of safety among visitors [13].

Improving Tourist Satisfaction and Retention: An efficient parking management system not only enhances convenience but also significantly boosts tourist satisfaction. A study by Park and Kim (2020) shows that a seamless parking experience increases the likelihood of tourists revisiting a destination. By minimizing hassles and ensuring a positive experience, smart parking systems can contribute to the long-term growth of the tourism industry [14].

Ibtisam Al Abri. etl la.[15] investigated how political and psychological factors—like Oman's neutrality—affect both attitudinal and behavioral loyalty among domestic and foreign tourists. Psychological factors include things like satisfaction, perceived value, attachment, familiarity, and motivations. The results indicate that foreign visitors show a great deal of loyalty to Oman, with political neutrality being a major factor. Samaa Saif Ali Al-Mahrouqi.etl.la [16] conducted a study on the satisfaction levels of foreign visitors in Oman and highlights the challenges they encounter. The findings provide recommendations for how the travel industry can be enhanced and demonstrate that tourists prefer to visit multiple destinations in Oman. The social, cultural, personal, and economic aspects that influence the preferences for traveling of Omani Generation Z, with a focus on gender disparities. [17] Tumati, R. & Daşkın, M. & Yavuz, E. (2024) found that social media recommendations, security, personal safety, low financial service fees, and the availability of both conventional and Halal foods are important factors influencing destination preferences.

This research investigates by Muhammad.etl.al (2024) [19] various architectures with a primary focus on Vehicle-to-Vehicle (V2V) communication systems. Although it isn't explicitly addressed, vehicle-to-infrastructure (V2I) and vehicle-to-vehicle (V2V) are both essential to intelligent transportation systems (ITSs) in order to improve efficiency and safety. Maryam etl.la [20] studied the developing an algorithm to avoid crashes at intersections is an exclusive use of vehicle-to-vehicle (V2V) communication. It excludes vehicle-to-infrastructure (V2I) communication, which is the transfer of information between automobiles and road infrastructure for the sake of safety and traffic control.

Problem Statement:

Geo-fences are used to monitor parking space movement and identify available spots. Some automakers also allow you to set up geo-fences around your parked car so you may be alerted if it leaves the region. So, one way to get online parking applications is to use Google Maps. Where parking spots can be reserved by people using this programme. Before visiting the malls, customers can reserve parking spots using this app from anywhere, giving them the ability to use a Google Map to locate a close parking spot utilizing geofencing.

The free parking space is indicated by a green light at the top of each place according to the shopping mall's current system. When a person approaches a parking space at a mall, they should see a green light at either 100 or 150 metres. However, in the interim, they were extremely dissatisfied by the incorrect sensor detections, which is a failure. Our research

indicates that by utilizing the application, Geo-Fencing technology will automatically route and identify the shortest path to the appropriate parking spot.

Objectives:

- Develop a predictive routing algorithm leveraging GPS data to accurately forecast available parking spaces.
- Implement geo-fencing technology to establish virtual boundaries for efficient identification and allocation of parking areas.
- Optimize the algorithm to prioritize the shortest path for drivers to reach their designated parking spaces.
- Integrate real-time data feeds to enhance the accuracy of parking predictions and route optimization.

Design a user-friendly interface to provide drivers with real-time information on available parking spaces and suggested optimal routes

Incorporating geofencing technology into parking systems:

Collaboration among diverse parties is essential to tackle citywide parking difficulties. This encompasses not only the operators of geofencing technology—such as municipal authorities, parking facility proprietors, and landowners—but also the drivers seeking open parking spaces. For geofencing to be effective, it must connect smoothly with IoT-enabled software and diverse sensor systems to facilitate efficient communication between parking demand and supply.

Given that a geofence may only yield precise data within an approximate radius of 100-150 meters, establishing a singular geofence for a full city is unfeasible. Each parking facility can establish its own geofence utilizing technologies such as GPS, IoT, image processing, ICT, or RFID, and oversee it through a dashboard. A consolidated smartphone application can be created to compile parking information from many facilities, enabling citizens to access this data when seeking parking.

Users can utilize the mobile application to facilitate machine-to-machine communication with IoT-enabled devices across various parking facilities, obtaining real-time parking data. This interaction may transpire in two manners: the application can establish a temporary geofence surrounding the user's location to detect proximate parking alternatives, or parking lot owners can issue notifications if the user's vehicle enters or nears the facility's geofence.

Upon locating a proximate parking facility or receiving notifications, users can access further information including space availability, pricing, payment options, and navigation via the app. The application enables users to reserve a parking space, prolong their parking duration, pre-pay, or execute digital transactions.

Upon successfully obtaining a parking space, users receive a digital receipt in the form of a security code or QR code for convenient access. LED sensors subsequently navigate the car to the assigned location and steer it towards the exit upon departure. This system automates the management of parking facilities and substantially decreases congestion at entrance points.

Methodology

Optimized Parking Space Detection:

- The suggested approach aims to minimize the duration needed to find an unoccupied parking space through the application of sophisticated technologies and predictive algorithms.
- An exhaustive evaluation of the advantages and drawbacks of existing parking management strategies is performed to pinpoint critical areas for improvement and innovation.

Implementation of Geo-Fencing Technology:

Geo-fencing is utilized to establish virtual perimeters around specified parking zones. This facilitates accurate identification, categorization, and assignment of parking spaces according to designated locations, hence improving the system's overall efficiency.

Predictive Routing Algorithm: **Vehicle-to Vehicle (V2V) and Vehicle-to-infrastructure(V2I) communication-Based Routing algorithm:**

Geo-fencing may significantly enhance smart parking systems by integrating with Vehicle-to-Vehicle (V2V) communication, which makes parking more automated, efficient, and well-organized. Real-time exchange of data between vehicles is made possible by V2V communication, and geofencing assists in organizing when a car enters, leaves, or interacts with specific parking zones. By optimizing routes and speeds, V2V can increase overall traffic safety and efficiency.[18] The wireless exchange of data between cars and road infrastructure is known as vehicle-to-infrastructure (V2I) communication. Additionally, the system may track vacant spots or modify parking arrangements using information from Vehicle-to-Infrastructure (V2I) communication for improving traffic safety [18]

Hybrid Algorithm:

In Hybrid Algorithm we are using both Dijkstra's and A * Algorithm. Both are finding the shortest path with different criteria having their own pros and cons. So, in this application we are recommending Hybrid algorithm which will provide the best shortest path for the user.

This table illustrates the pros and cons of each technique, including how a hybrid approach can reconcile the adaptability of the parking system with its computational efficiency.

Table-1: Comparison of Dijkstra's, A* and Hybrid Algorithms

Component	Dijkstra's Algorithm	A* Algorithm	Hybrid Approach
Goal	Identify the shortest path to all nodes starting from the initial node	Use a heuristic to determine the shortest route to a given vacation spot.	Integrates Dijkstra's preprocessing for effective and dynamic routing

Heuristic Use	No Heuristic	Heuristic helps to search	With help of Dijkstra heuristic driven search, the shortest paths
Optimal path	always yield the optimal path if there is one	find the optimal path if the heuristic is admissible	By utilizing Dijkstra for precomputation, it reaches optimality.
Time Computation	High	Moderate	improves the efficiency of algorithms with specification guiding on real-time searches
Scalability	Better scaling	Poor for complex and static parking systems	Suits for real time updates.
Use Case	finding the nearest available spot	Identifying all possible parking slots from the entrance	Once all cars are routed to their final destination, the remaining single, best path is used.

Procedure for Statistical Reporting:

The following data has been used for statistical metrics performance:

Table 2: Sample data for parking Areas

Parking Area	Total Slots	Occupied Slots	Travel Time (min)	Traffic conditions	User served
P1	50	40	10	Low	100
P2	30	25	15	Medium	80
P3	20	15	12	High	50

Step1: Availability of Slot: The formula used for calculating the occupancy rate is given below, which indicates how much of parking occupancy rate is measured.

$$\text{Occupancy Rate } (\%) = \left(\frac{\text{Number of Occupied Parking Spaces}}{\text{Total Parking Spaces}} \right) \times 100$$

Step2 : Average Travel Time:

The average travel time is being tracked by per area by using the Hybrid algorithm from one point to another to travel with the system. Where, Individual trip for Travel time T_i and observed the total number of trips n. Based on the traffic conditions the travel times will be impacted.

$$\text{Average Travel Time} = \frac{\sum_{i=1}^{n} T_i}{n}$$

It increases by 20 % in peak hours

Step3 : Parking area Rank Recommendations:

By using the scoring function the rank of the parking area is calculated and assigned the scores for each parking area based on the multiple weighted criteria, The scoring function formula is given is :

$$\text{Total Score} = \sum_{i=1}^{n} (\text{Criterion Score}_i \times \text{Weight}_i)$$

The table 3 gives factors which are relevant to calculate the parking areas are defined as

Table 3: Criterion Score

Occupancy Rate	The proximity to the Final Destination	Accessibility	Cost	Security and Safety	Special Features
C_1	C2	C3	C4	C5	C6

To make sure the each scores are normalized within the range of (0-100) scale. The normalized score is defined as

$$\text{Normalized Score}_i = \frac{\text{Value}_i - \text{Min}}{\text{Max} - \text{Min}} \times 100$$

Additionally, the reversed score is also calculated based on the better lower metrics.

$$\text{Reversed Score}_i = 100 - \text{Normalized Score}_i$$

The total score is calculated as per the descending order to sort out the parking area. The highest rank is identified by the highest area.

$$\text{Total Score} = (C_1 \times W_1) + (C_2 \times W_2) + (C_3 \times W_3) + (C_4 \times W_4) + (C_5 \times W_5) + (C_6 \times W_6)$$

Table 4: The Final total score and Rank for parking

Parking Area	Occupancy Rate	Travel time	Traffic Score	User Served	Available slots	Occupancy rate (reversed)	Total Score	Rank
P1	80%	10	100	100	10	60	82.0	1
P2	83.3%	15	50	80	5	0	45.0	2
P3	75%	12	0	50	5	100	19.0	3

Figure 1: Parking Area: Total Score Comparison

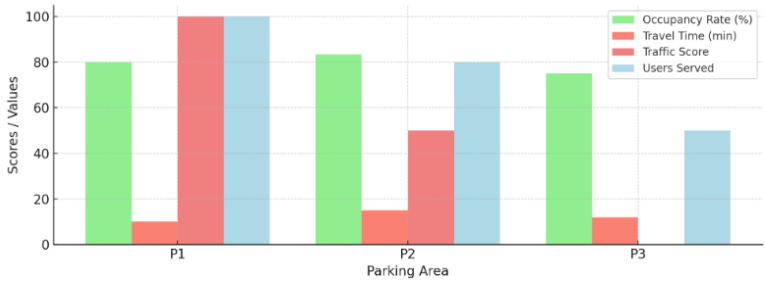

Figure 2: Factors Comparison for Parking Area

The Figure 2 bar graph represents comparison of the total score and Figure 3 Highlighting the individual scores factor comparison. This comparison helps the parking area and its overall rankings as well as the contribution of each factor.

Step 4 : User Activity Report :

User Activity Report is calculated with the above data from the table 1, this can create a meaningful metrics or analyzing the relationship between different parameters such as total occupied slots, users served, travel time and total slots.

a) Occupancy Rate of each parking area occupied:

$$\text{Occupancy Rate} = \frac{\text{Occupied Slots}}{\text{Total Slots}} \times 100$$

b) Occupied slot by the number of users is calculated by User- to Slot Ratio :

$$\text{User-to-Slot Ratio} = \frac{\text{User Served}}{\text{Occupied Slots}}$$

c) Total slot by the number of users by their efficiency:

$$\text{Efficiency} = \frac{\text{User Served}}{\text{Total Slots}}$$

Table 4: User Activity Report

Parking Area	Total Slots	Occupied Slots	Occupancy Rate	User-to-Slot Ratio (users/occupied slot)	Efficiency (users/total slot)
P1	50	40	80%	2.5	2.0
P2	30	25	83.33%	3.2	2.67
P3	20	15	75%	3.33	2.5

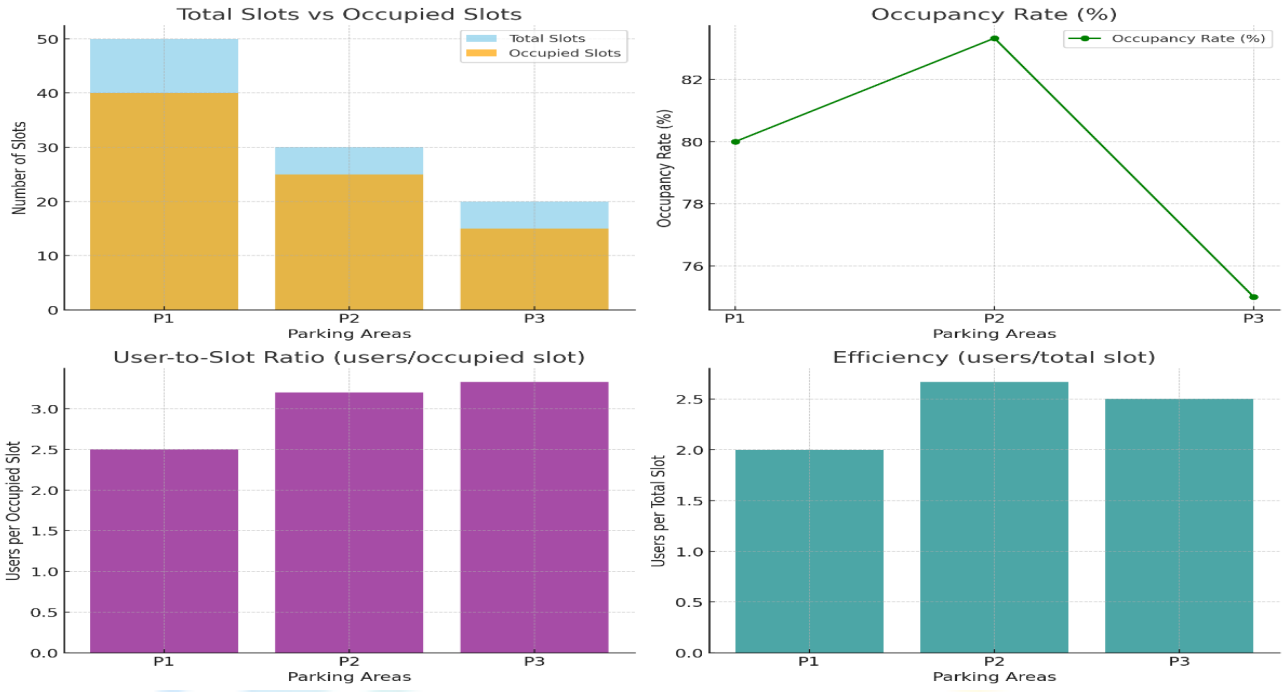

Figure 3: User Activity Report

Monitoring using Sensors and Allocation of Slots:

- Parking spaces within geo-fenced zones are monitored by sensors. Every slot is allocated a distinct identity determined by its position within the geo-fenced perimeter.
- When a car enters the parking lot, sensors identify and document the vehicle's information. The system quantifies the automobiles awaiting entry in the lot and detects available parking spaces.

Real-Time Data Processing and Distribution:

- Sensors perpetually observe and transmit data regarding vacant slots to a central server.
- The predictive system evaluates this data to identify the closest open parking space. The technology offers real-time recommendations to drivers based on the quantity of waiting vehicles and their distance to the slot, facilitating efficient allocation and reducing wait times.

This methodology utilizes modern technology such as geo-fencing, GPS, sensors, and predictive algorithms to develop an intelligent, real-time parking management system that enhances user experience and maximizes resource use.

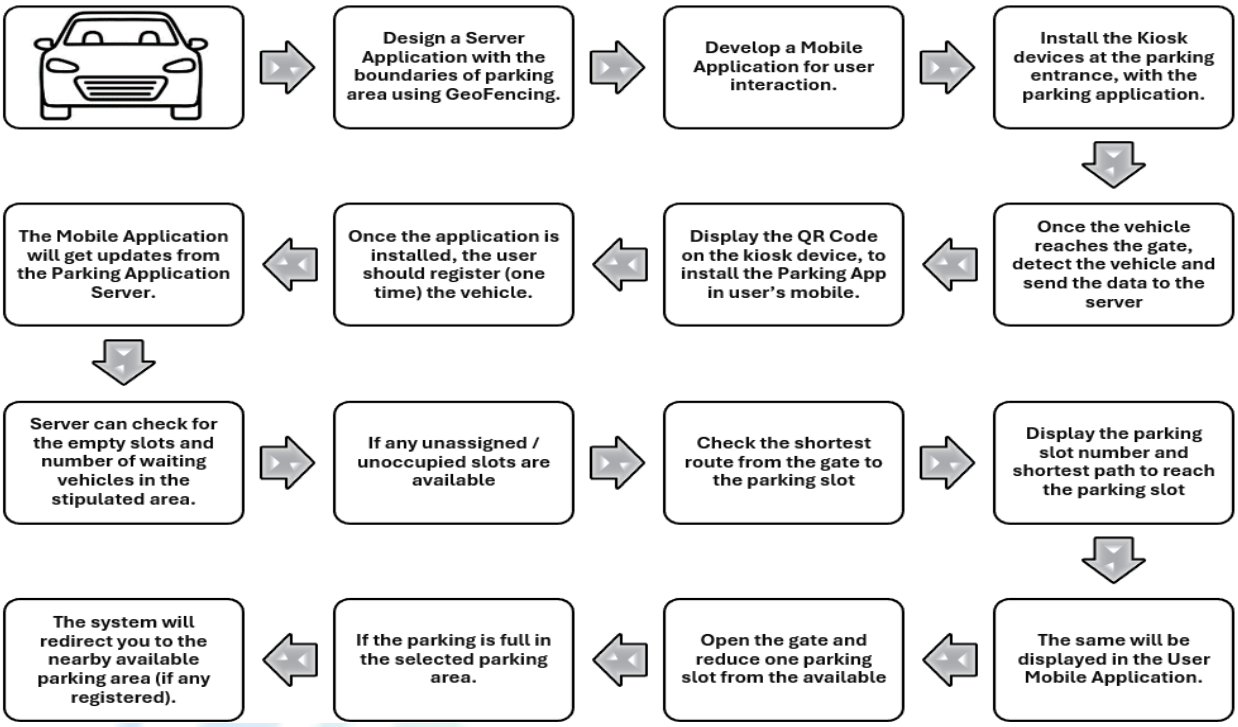

Figure 4: Methodology including steps

Results and Discussion:

Enhanced Parking Efficiency: The deployment of this intelligent parking system is anticipated to markedly improve parking allocation efficiency. The method alleviates aggravation and enhances resource efficiency by decreasing the duration drivers spend locating available parking spaces.

Figure 5: Optimized Parking Slot Routing

Figure 6: Geo-Fenced Parking Zones and Slots

Improved Traffic Flow and Reduced Ecological Footprint: This method enhances urban traffic flow by utilizing technology to reduce congestion, guiding drivers to available parking spaces through optimized routes, and ensuring smoother traffic movement. Additionally, it supports environmental sustainability by minimizing carbon emissions and fuel consumption, achieved by reducing vehicle idling and providing direct routes to parking spots. These benefits contribute to global efforts to combat climate change.

Augmented User Experience: The system emphasizes user comfort by offering efficient and uncomplicated parking experience. This enhanced user experience is expected to elevate customer happiness and cultivate loyalty among frequent users, especially in high-demand regions.

Table 5: Parking System Comparison Data

Category	Existing System	Proposed System
Average Time to Find Parking (minutes)	15	5
Traffic Congestion Impact (Scale 1-10)	8	3
Carbon Emissions (kg per vehicle per day)	5	2
User Satisfaction (Scale 1-10)	6	9
System Maintenance Cost (USD per year)	5000	3000

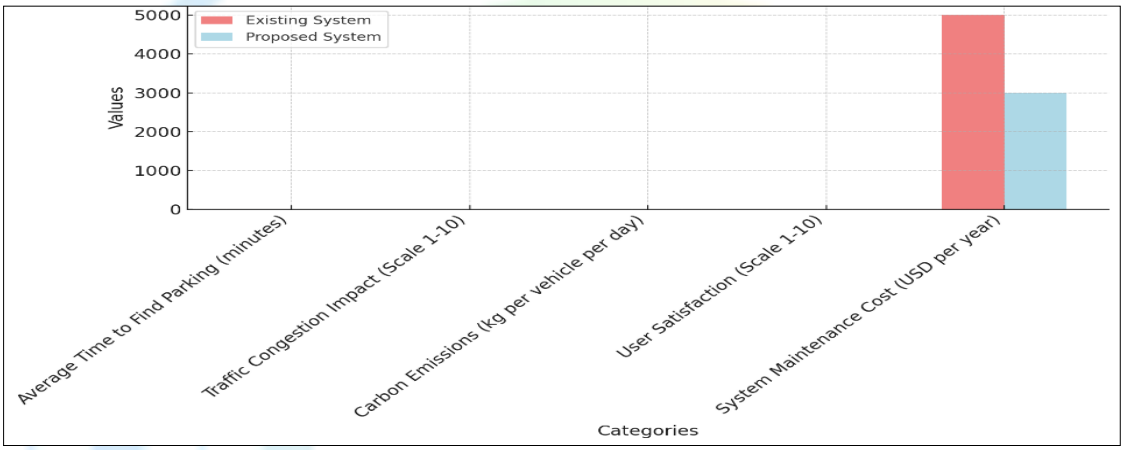

Figure 7: Comparison Of Existing and Proposed Parking Systems

Integration of Geo-Fencing and Its Time-Efficiency Advantages: The technology delineates geo-fenced borders for parking areas, creating logical and manageable zones for the allotment of parking slots. In conjunction with a smartphone application, users may effortlessly identify and secure parking spaces in real time. The optimal route to the accessible parking space is indicated, thus conserving time and effort for users.

Future Scope: In the future, RFID technology and wireless sensors can be integrated into each parking slot to detect vehicles and efficiently redirect them to the nearest available space. This innovation addresses the issue of tourists being unaware of unsafe parking areas by promoting safe parking options, thereby reducing the risks of auto theft or damage. By ensuring secure parking, this system can enhance the overall tourist experience and encourage repeat visits to Oman. Furthermore, we propose integrating this smart parking solution with the Oman Tourism Application to provide added convenience and safety benefits for tourists.

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As a member of esteemed professional organizations, including IEEE and many others, he remains actively engaged in advancing his field. At UTAS, he teaches a variety of courses, including programming, software design, and software testing.