

Guiding to available parking spots with AR device

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Abstract. Parking congestion has become a pressing issue in urban areas, leading to increased traffic congestion and environmental pollution. This paper presents a comprehensive study on intelligent parking systems aimed at addressing these challenges. The study targets urban drivers, transport authorities and citizens who are affected by parking difficulties and traffic congestion. Intelligent Parking System is a technology-driven solution that aims to optimise parking space utilisation and reduce traffic congestion. It efficiently guides drivers to available parking spaces through real-time data collection and analysis. The study was conducted in Unity3D environment over a period of 2 weeks and covered the phases of system design, development, testing and implementation. The main motivation for this research was to mitigate the negative effects of parking congestion. Intelligent parking systems have the potential to increase traffic efficiency, reduce air pollution and improve the overall quality of life in cities. Server and Unity models were used in the study. Real-time sensors collect parking occupancy data, which is processed to provide real-time parking availability information to drivers via the server. In conclusion, this paper presents an intelligent parking system that can solve the challenges of parking congestion. By utilising server technology and data-driven insights, the project aims to improve the way cities manage parking and contribute to more sustainable urban mobility.

Keywords: Cloud Sever, Parking space management, Wireless transmission, Navigation.

1. Introduction

The growing number of cars on the road has resulted in an increased demand for parking spaces, necessitating the development of innovative solutions. Smart cities, powered by the Internet of Things (IoT), present opportunities to address issues such as traffic congestion, vehicle leaving office problems, and street safety concerns. Various parking organization systems have been devised, utilizing smartphones, wireless algorithms, and mobile applications. The IoT concept involves the interconnection of diverse devices, vehicles, and structures embedded with hardware to gather and exchange information via a network. By incorporating sensors in parking areas, users can access real-time information about available parking spaces through a AR(Augmented Reality)device, leading

to enhanced efficiency and cost reduction. The intelligent parking system comprises three stages. The first stage involves the interaction between Arduino devices, sensors installed in the parking area, and the user. The second stage incorporates a cloud service acting as an intermediary between the user and the parking area. The third stage revolves around the user experience, where notifications regarding parking space availability are delivered through an AR device. Sensors are placed in each parking area to detect the number of parking spaces, available parking spaces, and reserved parking spaces. Communication between the AR device and the sensors is facilitated via a wireless transmission.

2. Related Work

In this section, some related works of smart parking are presented. The Kudai parking lot [4], which encompasses 2500 parking spaces, was selected for the simulation and implementation of the intelligent parking system. The hardware components employed in the experiment consist of ultrasonic and geomagnetic sensors, RFID (radio frequency identification devices) card reader modules, S50 RFID cards, LoRa (Long Range) radio modules, rechargeable lithium-ion batteries, photovoltaic panels, LED (light-emitting diode) lights, Raspberry Pi 3, and an HP workstation.

In the experiment, the LoRa communication modules are utilized to transmit sensor data to the Raspberry Pi, which serves as a fog node. The Raspberry Pi then processes the data locally and forwards it to the backend server for further analysis. The backend server estimates the availability of parking spaces based on historical data, allowing or restricting parking reservations accordingly.

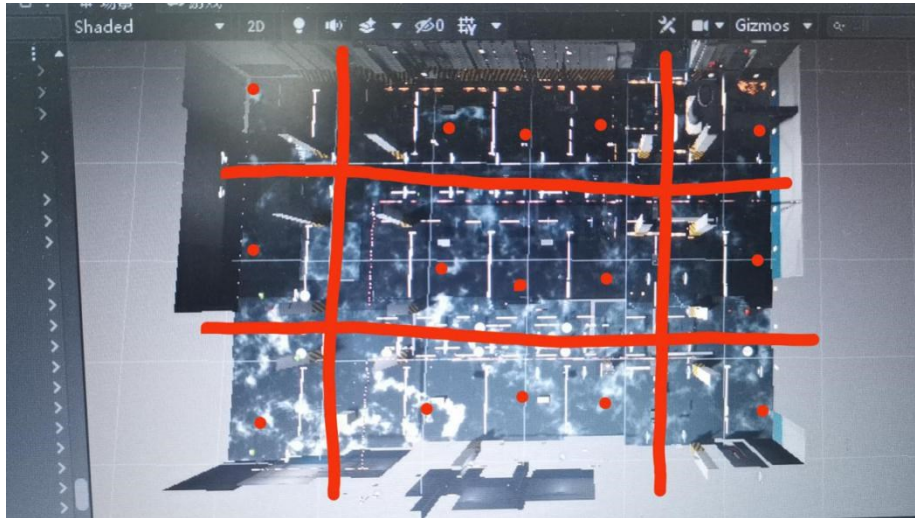


Figure 1. Parking lot sample map

To evaluate the performance of the proposed parking system compared to traditional methods, simulation assessment is conducted using the SUMO (Simulation of Urban Mobility) simulator. Key performance metrics, such as arrival time, search time, and parking revenue, are evaluated. The results demonstrate that the proposed system surpasses traditional methods in terms of arrival time and search time. Additionally, the inclusion of a dynamic pricing algorithm enhances the revenue generated from long-term parking plans.

3. Background

In order to accurately represent real life scenarios, the parking space specifications for the model were derived from the “Code for the Design of Garage Building”. The specifications take into account the minimum clear distance required between vehicles and between vehicles, walls, columns, and guardrails. The calculations for the underground garage parking area are based on a 35-square meter allocation per parking space. Therefore, in a 10,000 square meter garage, it can accommodate 285 parking spaces. For the outdoor parking lot, each parking space is calculated using a 25-square meter allocation, resulting in

a capacity of 400 parking spaces in a 10,000 square meter area. Non-motor vehicles, such as bicycles, have different parking requirements and areas. In most cases, the calculations are based on a double row arrangement, with each parking space occupying 1.74 square meters per vehicle. Alternatively, it can be estimated at 1.8 square meters per vehicle. Access areas are also included in the calculations. For instance, in a 10,000 square meter area, the non-motor vehicle parking can accommodate approximately 5,747 vehicles using the 1.74 square meter calculation. The length and width of each vehicle can be calculated based on 0.6 meters by 2.0 meters. The width typically ranges from 2.6 to 3.0 meters, while the length is commonly set at 5.3 meters to ensure sufficient space for adjacent cars to park and open doors. This planning size also adequately meets the length requirements of standard cars in the market.

Parking spaces can be monitored using sensors to determine their occupancy status [1]. One type of sensor, the laser sensor, utilizes a laser beam to scan the parking area and detect the reflection of the laser beam to determine the occupancy. The process is as follows: The laser sensor emits a narrow, focused laser beam, typically red, which is then focused by the transmitter to create a tiny point of light. This laser beam is then directed towards the parking area, where it can be reflected, scattered, or absorbed by the surface. When the laser beam shines on an empty parking space, it will usually be reflected back to the sensor. The receiver of the laser sensor receives the reflected laser beam and converts it into an electrical signal, commonly done using a photodiode. The laser sensor analyzes this received light signal to determine the status of the parking space. If the intensity of the reflected laser beam surpasses a pre-determined threshold, it indicates that the space is occupied by a vehicle. Conversely, if the intensity falls below the threshold, the space is considered available. By interpreting the received signal, the laser sensor can accurately determine the occupied or vacant status of the parking space. The laser sensor exhibits characteristics such as high precision, quick response, and the ability to detect remotely, making it suitable for accurately locating parking status in various scenarios. Furthermore, due to the narrow and focused nature of the laser beam, the sensor can provide accurate measurements in tight spaces or complex environments.

The parking lot radar sensor utilizes radar technology to determine the position and distance of vehicles [2]. The operating principle is as follows: Firstly, the parking lot radar sensor emits radar waves, typically electromagnetic waves at radio frequencies such as microwaves or millimeter waves. These radar waves are directed towards vehicles within the parking lot. Upon contact with a vehicle, a portion of the radar wave is reflected back from the surface of the vehicle. The receiver of the parking lot radar sensor captures the reflected radar waves and converts them into electrical signals. Receivers typically employ antennas and radar receiving modules for wave signal reception. By measuring the time delay between transmission and reflection of the radar wave, as well as considering the speed of the wave (approximating the speed of light), the sensor can calculate the distance between the vehicle and the sensor. Effective coverage of the entire parking lot can be achieved by installing multiple radar sensors. By analyzing the time delay and distance of the waves received by different sensors, the sensor can accurately determine the position and direction of the vehicle. The parking lot radar sensor offers high-ranging accuracy and broad coverage, making it well-suited for large parking lots and scenarios where real-time and precise vehicle location is essential. It provides accurate distance and direction information, aiding owners in locating parking spaces faster. Additionally, it offers valuable data to parking lot management systems for intelligent parking space management and navigation purposes.

4. Solution Design

Upon entering the parking lot through the entrance, a sensor located at the entrance identifies the license plate number of the vehicle. This information is then transmitted to the server, which in turn provides a unique vehicle number. Simultaneously, the server relays the number of available parking spaces in the current parking lot to an Augmented Reality (AR) device worn by the driver. To determine the most efficient path to an available parking space, the server employs the A* algorithm. Each corner of the road within the parking lot is equipped with a marker to facilitate vehicle navigation and positioning. These markers are responsible for guiding the vehicle to the nearest vacant parking space using the shortest path. The allocation and management of parking spaces are handled by each individual marker.

A prompt from the marker indicates the presence of a free parking space that can be reached. As the vehicle proceeds into the parking lot, arrow information is displayed on the AR device, guiding the driver along the designated route. The server continuously calculates and updates the route, providing arrow guidance for each marker the vehicle passes. The AR device indicates the availability of parking spaces through the display of red and green color markers, wherein red signifies occupied spaces and green indicates vacant ones. Once the driver reaches the last marker, there will be a selection of free parking spaces nearby from which to choose.

In the design of an efficient parking system, it is important to consider several key components. Firstly, the installation of physical markers at strategic locations within the parking lot is essential. These markers should have unique identifiers and utilize technologies like RFID tags for easy identification and communication with vehicles. Additionally, equipping the markers with wireless transmitters, such as Bluetooth or Wi-Fi(wireless fidelity), enables seamless transmission of information to vehicles. It is crucial to establish a robust communication protocol to ensure accurate positioning and reliable navigation. Advanced localization systems can be implemented to precisely determine a vehicle's position relative to the markers.

The directional symbols in augmented reality (AR) products play a vital role in guiding vehicles towards available parking spaces by providing clear visual cues. To enhance visibility, markers should be easily distinguishable and well-lit, accommodating both daytime and nighttime scenarios. Integrating sensors into the markers allows for the detection of vehicle presence and enables the server to be updated about parking space occupancy. The use of computer algorithms can facilitate marker recognition and classification of different types of vehicles.

Establishing a feedback loop between the markers and the server is crucial as real-time bidirectional communication ensures the exchange of updated information. The markers should periodically receive data regarding parking space availability, enabling them to adjust their guidance accordingly. Regular monitoring of marker status is necessary to ensure proper functioning and prompt resolution of technical issues.

To maintain uninterrupted navigation, redundancy measures should be implemented. Multiple markers positioned in close proximity provide alternative guidance in case of marker failure or obstruction. Adaptive routing instructions can be developed to dynamically guide vehicles around temporary obstacles. Additional technologies, such as GPS(Global Position System) or indoor positioning systems, can complement marker-based navigation.

By considering these design aspects, an integrated parking system can effectively guide vehicles within the parking lot, facilitating efficient navigation towards available parking spaces. The incorporation of advanced technologies, along with robust communication between markers and the server, contributes to a seamless and reliable parking experience for drivers.

5. Discussion

5.1. Evaluation (Limitation & Next Steps)

1) **Blockchain:** The integration of blockchain technology introduces a transformative avenue for the smart parking system. By implementing smart contracts on the blockchain, the payment process between drivers and the parking system can be automated and streamlined. These smart contracts possess the inherent capability to accurately calculate parking fees by factoring in variables like the duration of stay and predefined rates. With the driver's digital wallet seamlessly linked to the smart contract, an environment of instantaneous and secure payment can be established, effectively eliminating the need for traditional intermediaries. The immutable and transparent nature of blockchain enhances trust and reduces disputes, further enhancing the overall efficiency and reliability of the parking system.

2) **Machine Learning:** The incorporation of machine learning (ML) algorithms stands to revolutionize license plate recognition systems within the smart parking ecosystem. Through rigorous training on extensive datasets containing diverse license plate images, these ML models can elevate the

precision and speed of license plate identification and extraction. By mastering the ability to navigate challenging conditions such as varying lighting, angles, and vehicle types, the ML-powered recognition system can significantly reduce false positives and negatives, optimizing the accuracy of parking management. This enhancement translates into quicker entry and exit processes for drivers, ultimately contributing to smoother traffic flow and improved user satisfaction.

3) **Microservices Architecture:** The adoption of a microservices architecture represents a logical progression towards the refinement and expansion of smart parking systems. Embracing this architecture allows for the modularization of the system into discrete microservices, each catering to specific functional modules. For instance, components such as license plate recognition, payment processing, and parking space updates can be treated as distinct microservices. This segregation facilitates more efficient development, easier maintenance, and scalability. Development teams can focus on individual microservices, promoting collaborative development practices and enabling rapid innovation. Furthermore, this architecture enhances system flexibility, as updates or changes to one module do not necessitate extensive alterations to the entire system. As the smart parking system grows in complexity and usage, the microservices architecture can provide a foundation for seamless evolution and adaptation.

5.2. *limitation*

Due to limited knowledge, we have only created one example in the form of an animation by using Unity.

- 1) Environmental factors, such as extreme temperatures, dust, or high humidity, can have an impact on the accuracy and performance of the system. These conditions have the potential to disrupt the functioning of cameras, sensors, or AR devices, leading to temporary interruptions or inaccuracies in the system.
- 2) The collection and storage of personal data, such as license plate numbers and vehicle information, raise privacy concerns. It is crucial to find a balance between efficient parking management and safeguarding individuals' privacy rights. This requires careful consideration and adherence to relevant regulations to ensure the proper handling and protection of personal data.
- 3) The implementation of a comprehensive smart parking system can involve significant upfront costs. These costs may include the acquisition and installation of hardware, software development, and ongoing maintenance. This financial aspect can limit the adoption of the system, particularly for smaller parking operators or municipalities with constrained budgets.
- 4) The infrastructure utilized for the smart parking system, including cameras, sensors, and markers, is vulnerable to acts of vandalism or intentional damage. These malicious actions have the potential to disrupt the functionality of the system and necessitate frequent monitoring and maintenance to ensure its proper operation.
- 5) Navigation pathfinding methods need to be optimized. In our project solution, each sensor is listed from the perspective of the mark at each intersection, and sorted in the order from near to far from the mark. However, this method will require a large amount of engineering work in real situations, and a simpler and more accurate method may be needed to realize the navigation function.

6. Conclusion

Intelligent parking systems, leveraging the capabilities of the Internet of Things (IoT), present a promising solution to the parking challenges confronted by urban areas. By integrating sensor technology, wireless algorithms, and AR device, these systems offer real-time information regarding the availability of parking spaces. This not only reduces the time spent searching for parking spots but also minimizes fuel consumption and enhances the overall convenience for car users. The paper introduces a sample design that explores the incorporation of sensor technology in practical parking scenarios, followed by the implementation and operation of an actual system. Such advancements in parking management enable optimization and contribute to a more efficient and sustainable urban mobility.

References

- [1] S. Lee, D. Yoon and A. Ghosh, "Intelligent parking lot application using wireless sensor networks," 2008 International Symposium on Collaborative Technologies and Systems, Irvine, CA, USA, 2008, pp. 48-57, doi: 10.1109/CTS.2008.4543911.
- [2] Paidi, V., Fleyeh, H., Håkansson, J. and Nyberg, R.G. (2018), Smart parking sensors, technologies and applications for open parking lots: a review. *IET Intell. Transp. Syst.*, 12: 735-741.
- [3] A. Zajam and S. Dholay, "Detecting Efficient Parking Space Using Smart Parking," 2018 9th International Conference on Computing, Communication and Networking Technologies (ICCCNT), Bengaluru, India, 2018, pp. 1-7, doi: 10.1109/ICCCNT.2018.8493964.
- [4] Balfaqih, M.; Jabbar, W.; Khayyat, M.; Hassan, R. Design and Development of Smart Parking System Based on Fog Computing and Internet of Things. *Electronics* 2021, 10, 3184.
- [5] Copy Nathan Chandler "Is There a Scientific Strategy for Finding a Good Parking Spot?" 30September2019.HowStuffWorks.com.<<https://auto.howstuffworks.com/car-driving-safety/accidents-hazardous-conditions/strategy-good-parking-spot.htm>> 18 August 2023
- [6] A. Zajam and S. Dholay, "Detecting Efficient Parking Space Using Smart Parking," 2018 9th International Conference on Computing, Communication and Networking Technologies (ICCCNT), Bengaluru, India, 2018, pp. 1-7, doi: 10.1109/ICCCNT.2018.8493964.
- [7] Jemmali, M., Melhim, L.K.B., Alharbi, M.T. et al. Smart-parking management algorithms in smart city. *Sci Rep* 12, 6533 (2022). <https://doi.org/10.1038/s41598-022-10076-4>.
- [8] Bandyopadhyay, A.; Misra, S.; Nath, D.; Sarkar, V. Automatic Smart Parking One-Sided Free Slot Booking Using Internet of Things (IoT). In *Advances in Medical Physics and Healthcare Engineering*; Springer: Singapore, 2021; pp. 463–472.
- [9] Sotres, P.; de la Torre, C.L.; Sánchez, L.; Jeong, S.M.; Kim, J. Smart city services over a global interoperable internet-of-things system: The smart parking case. In *Proceedings of the 2018 Global Internet of Things Summit (GloTS)*, Bilbao, Spain, 4–7 June 2018; pp. 1–6.
- [10] Charles, S.W. The Design and Implementation of a Smart-Parking System for Helsinki Area. Master's Dissertation, Aalto University, Espoo, Finland, 2010.
- [11] Shi, J.; Jin, L.; Li, J.; Fang, Z. A smart parking system based on NB-IoT and third-party payment platform. In *Proceedings of the 2017 17th International Symposium on Communications and Information Technologies (ISCIT)*, Cairns, Australia, 25–27 September 2017; pp. 1–5.
- [12] Angelov, K.K. Development and Implementation of a Demonstration Model of Smart Parking with LoRa-Based Communication Module. In *Proceedings of the 2020 XI National Conference with International Participation (ELECTRONICA)*, Sofia, Bulgaria, 23–24 July 2020; pp. 1–4.