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SMART PARKING AVAILABILITY AND WAITING-TIME PREDICTION WITH AUTOMATIC SLOT REALLOCATION

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Abstract

Finding an available parking space is a common problem in crowded areas. Drivers often waste time and fuel while searching for parking spaces. This paper proposes a smart parking approach that combines the Internet of Things (IoT) and Machine Learning (ML) to improve parking management. IoT sensors are used to identify occupied and available parking slots, while a simple Machine Learning model is proposed to predict parking availability and estimate waiting time. The proposed approach also introduces automatic slot reallocation, in which a reserved parking slot can be released and assigned to another waiting user if the original user does not arrive within the specified time. This approach a ims to improve parking space utilization, reduce unnecessary waiting, and provide a better parking experience. The effectiveness of the proposed approach can be evaluated in future work.

Keywords: *Research; Technology*

II. LITERATURE REVIEW

Smart parking systems help drivers find available parking spaces and improve parking space management. Researchers have explored different technologies, including the Internet of Things (IoT), Machine Learning (ML), sensor-based monitoring, and parking prediction techniques. IoT sensors collect information about occupied and available parking spaces. Machine Learning techniques analyse parking data to predict parking availability and support better parking decisions. Sensor-based parking systems detect whether parking slots are occupied or vacant. The collected information can be displayed on a website or mobile application. However, sensor-based systems mainly pro vide current parking status and may not always estimate future availability or waiting time. Machine Learning -based parking prediction uses historical and current parking data to estimate parking availability. Different algorithms, such as Decision Tree, Random Forest, and other prediction models, have been explored for parking prediction. A Decision Tree is a simple approach that can be considered for predicting parking availability.

However, prediction quality depends on the available data and the method used. Dia, Ahvar, and Lee studied machine -learning and neural-network algorithms for predicting parking segment availability in an AIoT -based smart parking system. Their study compared several algorithms using parking data and evaluated prediction p erformance and execution time. The study highlighted that a Decision Tree can provide a practical balance between prediction performance and computational efficiency. Existing smart parking research has also explored parking guidance and alternative parkin g recommendations. These approaches help drivers identify suitable parking locations when their preferred parking area is unavailable. However, parking management also involves handling reserved slots when users do not arrive within the specified booking period. This research focuses on combining parking availability prediction, waiting -time estimation, and automatic slot reallocation. The proposed approach aims to provide useful parking information and improve the utilization of reserved parking spaces. Its effectiveness would need to be evaluated in future work Recent research has also explored deep learning and advanced prediction techniques for smart parking systems. These methods can analyse complex parking patterns and improve availability prediction, but they may require larger datasets and more computational resources.

A. IoT-Based Parking Monitoring IoT-Based Parking Monitoring identifies parking availability using sensors and parking status information. It uses sensors to detect occupied and vacant parking slots. It collects parking information automatically. It sends parking data to a central system or database. It displays parking availability through a website or dashboard. It helps drivers find available parking spaces easily. However, sensor errors and network problems may affect the accuracy of parking information.

B. Machine Learning-Based Parking Prediction • Machine Learning -based parking prediction uses parking data to estimate parking availability. • It analyses historical and current parking information. • It identifies patterns in parking occupancy. • A Decision Tree model can be used to predict parking availability. • It helps drivers understand whether a parking slot may become available. • It can support better parki ng decisions and reduce unnecessary searching. • However, prediction accuracy depends on the quality and quantity of available data.

C. Smart Parking Reservation and Slot Reallocation • Smart parking reservation and slot reallocation help manage reserved parking spaces efficiently. • Users can reserve parking slots before arriving. • The system records reservation details and booking time. • It checks whether the user arrives within the specified time limit. • If the user does not arrive, the reserved slot can be released according to the system rules.

• The released slot can be assigned to another waiting user after checking its availability. • This approach may improve parking space utilization and reduce unnecessary waiting.

D. Research Gap

Existing studies have explored IoT -based parking monitoring, Machine Learning -based parking availability prediction, and reservation allocation. However, there is scope to study these features together in a simple framework that combines parking availability prediction, waiting -time estimation, and rule -based automatic slot reallocation. The proposed research focuses on this integration to support better

parking management. A detailed comparison with existing studies and future performance evaluation will be required to assess its contribution and effectiveness.

III. PROBLEM STATEMENT

The increasing number of vehicles in crowded areas makes it difficult for drivers to find available parking spaces. Searching for parking takes extra time and fuel and may increase traffic congestion. Existing smart parking systems use IoT sensors to display parking availability, while Machine Learning can help predict future parking conditions. However, drivers may still face difficulties when all parking slots are occupied, as they may not know the ex pected waiting time. In addition, reserved parking slots may remain unused when users fail to arrive within the specified booking period.

Therefore, there is a need for a simple and efficient smart parking approach that provides parking availability information, estimates waiting time, and manages unused reservations. The proposed approach combines the Internet of Things (IoT) and Machine Learning with automatic slot reallocation. It aims to estimate parking availability, provide approximate waiting -time i nformation, and release unused reserved slots for other waiting users according to predefined rules. This approach is intended to improve parking space utilization and reduce unnecessary waiting.

IV. PROPOSED SYSTEM

The proposed system focuses on Smart Parking Using IoT and Machine Learning. The system combines parking availability prediction and waiting -time estimation. It also uses automatic slot reallocation to assign unused reserved parking slots to waiting users.

Core Components:

1. Smart Parking Sensors – Detect vehicle entry and exit to identify available and occupied parking slots.

2. Real-Time Parking Database – Stores parking status, booking details, vehicle arrival times, and slot information.

3. ML-Based Availability Predictor – Analyzes parking data to predict which slots may become available in the near future.

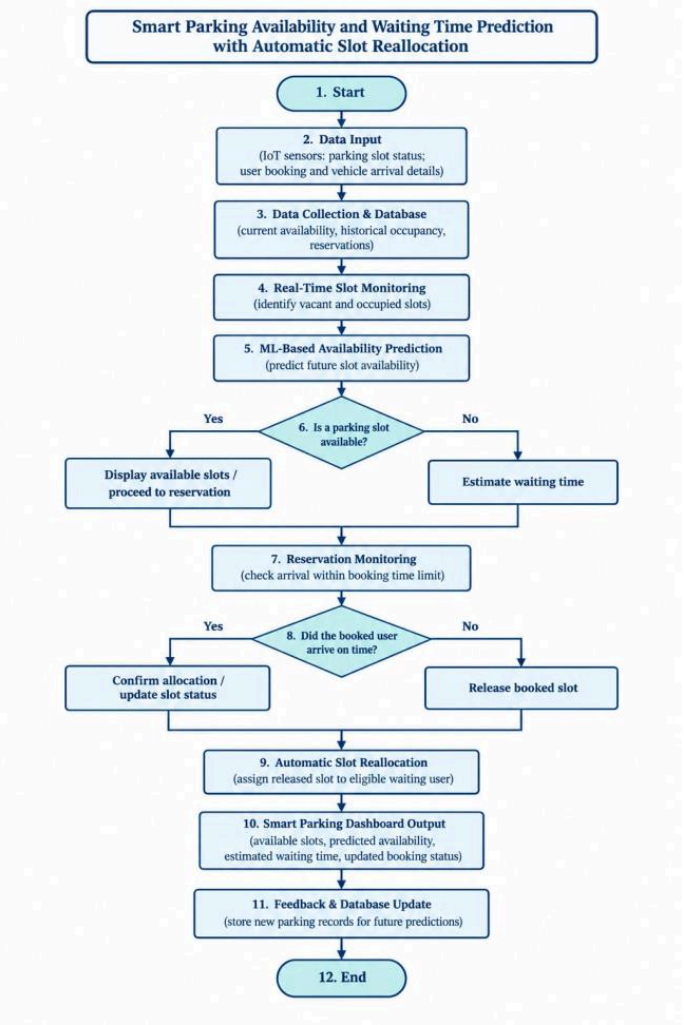
4. Smart Waiting -Time Estimator – Provides an approximate waiting time when all parking slots are occupied.

5. Automatic Reservation Manager – Checks whether a booked vehicle arrives within the permitted time limit and releases the slot if the user does not arrive.

6. Dynamic Slot Reallocation – Assigns released parking slots to eligible users on the waiting list.

7. Smart User Dashboard – Displays current availability, predicted parking status, estimated waiting time, and updated slot assignments.

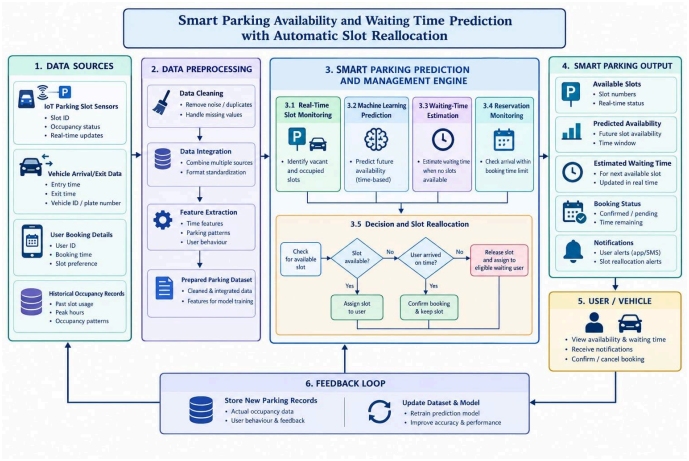
Process Flow: 1. Data Input: IoT sensors collect parking slot status, while users provide booking and vehicle arrival details. 2. Data Collection: The system stores parking availability, historical occupanc y, and reservation details in the database. 3. Real-Time Monitoring: The system identifies vacant and occupied parking slots using sensor data. 4. ML-Based Prediction: The Machine Learning model analyzes parking data to predict future slot availability. 5. Waiting-Time Estimation: If all slots are occupied, the system estimates the user's approximate waiting time. 6. Reservation Monitoring: The system checks whether a user arrives within the specified booking time limit. 7. Automatic Slot Reallocation: If a booked user does not arrive on time, the slot is released and assigned to an eligible waiting user. 8. Smart Parking Output: The dashboard displays available slots, predicted availability, estimated waiting time, and updated booking status. 9. Feedback and Data Update: New parking records are stored to support future predictions and improve parking management.



Working of the Proposed System

The proposed system first collects parking slot information, vehicle details, reservation details, and historical parking data. IoT sensors detect whether parking slots are occupied or available and send the collected information to the system. The data is stored in a database and used for further processing. The Machine Learning module analyzes current and historical parking data to identify parking patterns and predict future parking availability. When all parking slots are occupied, the system estimates the approximate waiting time based on parking occupancy and historical data. This helps users make better decisions before reaching the parking area. The Reservation Management module monitors booked parking slots and checks whether the registered vehicle arrives within the specified time limit. If the user does not arrive within the permitted period, the system releases the unused reservation. The Automatic Slot Reallocation module then assigns the released slot to an eligible user on the waiting list. Finally, the Smart Parking Dashboard displays available and occupied slots, predicted parking availability, estimated waiting time, and updated reservation details. New parking records can also be stored for future analysis and prediction. The proposed system aims to improve parking space utilization, reduce unnecessary waiting, and provide a convenient parking experience.

V ARCHITECTURE DIAGRAM



Architecture Diagram

The proposed Smart Parking System integrates the Internet of Things (IoT) and Machine Learning (ML) to provide intelligent parking management. It monitors parking spaces, predicts future availability, estimates waiting time, and automatically reallocates unused reserved slots to eligible waiting users

1. Data Sources

First, the system collects two main types of information:

• Parking Information – Slot status, vehicle entry and exit, and historical parking records. • Vehicle and Reservation Information – Vehicle details, booking time, arrival status, and waitinglist details.

2. Data Preprocessing

Before making predictions, the collected data is prepared.

• Removes incomplete or incorrect records. • Organizes parking and reservation information. • Checks sensor data to identify possible errors. • Identifies parking occupancy patterns. • Prepares suitable data for the Machine Learning Model. 3. Smart Parking Prediction and Waiting-Time Estimation Module

This is the main part of the proposed system. It uses parking data to predict availability and estimate waiting time.

Parking Availability Prediction:

The Machine Learning model analyzes current and historical parking data to predict future slot availability.

Waiting-Time Estimation:

When all slots are occupied, the system estimates the approximate waiting time using parking occupancy and historical records.

4. Reservation Management

The system checks whether a registered vehicle arrives within the specified booking time limit. If the user does not arrive, the system identifies the expired reservation and releases the slot according to predefined rules.

5. Automatic Slot Reallocation

The released slot is assigned to an eligible user on the waiting list. A pr iority-based allocation method can consider waiting -list order and booking rules to assign slots fairly. This helps reduce unused reservations and improves parking space utilization.

6.Smart Parking Dashboard and Notifications The system displays updated parking information to users. • Current available and occupied slots. • Predicted parking availability. • Estimated waiting time. • Reservation status and updated slot allocation. • Notifications when a slot becomes available or booking details change. 7. User Feedback and Data Update

New parking records, vehicle arrivals, and slot occupancy changes are stored in the database. This information can be used for future analysis and to improve parking predictions.

8. Performance Evaluation and Continuous Improvement The proposed system can be evaluated in future research using prediction accuracy, waiting -time estimation error, parking space utilization, and reduction in unused reservations. These measures can help assess the effectiveness of the proposed approach. The system aims to reduce unnecessary waiting, improve parking space utilization, manage reservations efficiently, and provide a more convenient parking experience.

VI. CONCLUSION

In conclusion, the proposed Smart Parking System provides an intelligent approach to parking management by combining Internet of Things (IoT) and Machine Learning (ML). The system uses IoT sensors to identify available and occupied parking slots, while the Machine Learning model predicts parking availab ility and estimates waiting time. The Automatic Slot Reallocation feature releases unused reserved slots when users fail to arrive within the specified time limit and assigns them to eligible users on the waiting list. Furthermore, the system provides upda ted parking information through a smart dashboard, helping users make better parking decisions. By integrating availability prediction, waiting -time estimation, and automatic reservation management, the proposed approach aims to improve parking space utili zation, reduce unnecessary waiting, and make parking more convenient. Future research can evaluate its prediction performance and overall effectiveness under different parking conditions. Thus, the proposed system offers a practical research approach to smarter, more efficient, and user -friendly parking management.

VII. FUTURE SCOPE

The future scope of the proposed Smart Parking System includes several opportunities to improve parking prediction, efficiency, and user convenience. The system can be extended by u sing advanced Machine Learning techniques to improve parking availability prediction and waiting-time estimation. Integration with mobile applications and GPS can help users locate nearby parking areas and receive real-time parking updates. The system can also incorporate real-time notifications to inform users when a parking slot becomes available. Advanced reservation management can improve automatic slot reallocation by considering booking time limits and waiting-list priorities. Furthermore, integrating payment systems and digital parking passes can make the parking process more convenient. In the future, the system can be expanded to manage multiple parking areas and analyze traffic and parking patterns. Using larger and more diverse parking datasets ma y improve prediction reliability. Thus, these improvements can help develop a more intelligent, reliable, and efficient parking management system.

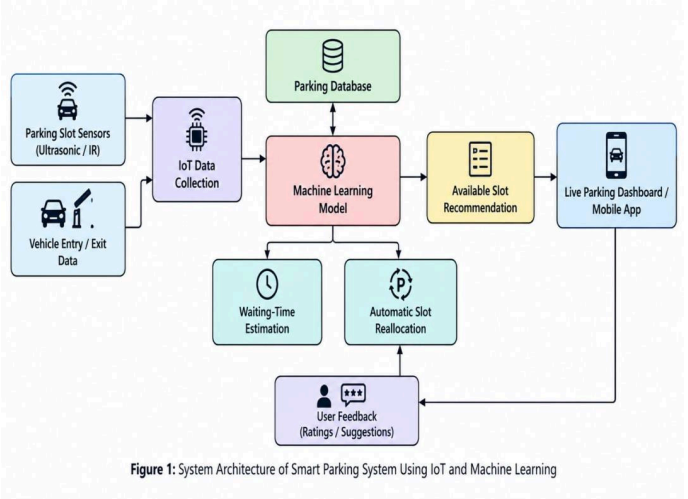


Figure 1: System Architecture of Smart Parking System Using IoT and Machine Learning

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