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Enhancing Urban Parking Efficiency through Machine Learning Model Integration

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Abstract: *Rapid increases in vehicle ownership, combined with limited parking supply, have made urban parking management more challenging. Typical parking systems are built on either static rules or pre-defined historical observations and are not representative of real-time conditions or the changing environment in which they operate. This proposal presents a machine learning-based system for parking prediction in order to enhance parking efficiency and provide support for more intelligent urban mobility. This system will utilize multiple data sources to feed the model (e.g., historical parking data, time-based, contextual, etc.) and will improve its performance through data cleaning, feature extraction, and data normalization while preparing the data for model training. The most effective prediction algorithm for predicting parking availability will be determined through an evaluation of four machine learning algorithms: Random Forest, Decision Trees, Support Vector Machines (SVM), and Linear Regression. The experimental analysis indicates that, of the subject algorithms, the Random Forest model has provided the best potential accuracy and reliability in predicting parking availability. Specifically, both regression and classification techniques can be applied through the system to produce an estimate of available spaces and an estimate of parking occupancy levels. By providing accurate predictions of available parking spaces through either dashboard displays or navigational interfaces, this system can help to minimize time spent in search of parking, reduce traffic on roadways, reduce fuel consumption, and reduce environmental pollution, as well as assist cities in their efforts to develop as Smart Cities.*

Keywords: *Machine Learning, Parking Prediction, Random Forest, Urban Parking Management, Smart Mobility, Real-Time Parking Availability, Traffic Congestion Reduction.*

I. INTRODUCTION

The demand for Urban Transportation systems continues to grow at a staggering rate because of the growth of vehicle ownership & vehicle technology has not kept up with this demand by expanding parking facilities.

As cities expand, the gap between parking supply & demand will continue to widen, resulting in inefficient urban resource usage. Car owners spend a significant amount of time looking for available on-street or off-street parking spaces typically more than 15 minutes in some cases & in turn create additional time lost, increased fuel consumption & additional stress on commuting by car [12]. These issues demonstrate that there is an opportunity for the development of intelligent systems that will help improve the management of parking & enable users to obtain accurate & current information about available spaces within an urban area [8], [16].

These methods typically do not adequately account for the constantly changing parking situation in urban areas due to many reasons (e.g., traffic patterns, time of year, special events, etc.) leading to areas having too little or too much parked vehicles. Since traditional parking management does not have access to real-time data or a means to make predictions about future demand, these types of systems do not work well as they relate to modern transportation system requirements [9], [11].

Data regarding movement and advanced analytic capabilities allow for continuous observation of how many vehicles occupy a given space as well as where vehicles are heading. These technologies produce vast amounts of data, which can help identify trends in terms of parking demands and anticipate future availability by evaluating historical data gained through the use of these systems, thus providing parkers, parking administrators and urban planners with improved decision-making tools [17], [18]. By using Machine Learning as an analytical method to evaluate large amounts of complex datasets, patterns that emerge which cannot be observed using traditional statistical analysis. With the help of AI and predictive analytics, a parking system will be able to learn from past and present data to determine when there will be empty spots at parking locations based on a variety of factors [1], [2], [3].

The predictive functionality will allow the parking system to react in real-time to a constantly changing urban area, providing users with timely, accurate and reliable information on where to find available parking. This new project is designed to boost parking efficiency in cities utilizing machine-learning models. Multiple datasets are combined and various algorithms are compared including the Random Forest, Decision Tree, Support Vector Machine and Linear Regression. The goal is to

use this intelligence to provide good predictions (estimates) of available parking spaces. A driver is thus more quickly able to locate a place to park and a smart city can plan and allocate resources more efficiently [4], [19].

II.LITERATURE SURVEY

Over the past few years, there has been a rapid increase in research activity in the area of smart parking systems as a result of the growing concern regarding urban mobility challenges. In addition to studies documenting the development of parking supply/demand patterns and basic monitoring systems that provide information on the availability of parking spaces; early research provided the basis for comprehensive intelligent parking systems but did not provide prediction capabilities nor did it adapt to real-time conditions [10].

Researchers have looked into using sensors for monitoring parking space usage and giving users current indicators regarding available parking spaces. The use of sensor-based parking infrastructure can gather data about whether or how long a vehicle is parked. This information allows for increased accuracy when providing parking availability data to users. There are currently significant infrastructure costs and ongoing maintenance costs associated with implementing these types of sensor technologies across large urban areas, leading to challenges with scaling the sensor-based parking system. In addition, sensor reliability will decrease due to device malfunctions or absent data, which may result in lower-quality predictions produced by use of sensor-based parking systems [13], [14].

These recent studies provide evidence that the machine learning technique is a good way to forecast how much space will be available in parking lots. Several different algorithms (Decision Trees, Random Forests, and Support Vector Machines) have been applied to parking data sets in order to uncover the underlying complexities of various attributes of the data (e.g., time, day of the week, surrounding environment). Several algorithms have also learned from historical trends (data) to develop predictive models that outperform traditional statistical methods for predicting parking demand [4], [6].

Several of the researches have compared various prediction methods from the field of eco-friendly parking.

These studies showed that tree-based algorithms have good performance for modeling non-linear relationships in mobility datasets. Random Forest models are, in particular, well performing for several reasons: ensembles allow for more robustness against overfitting; and decision tree models, which constitute the ensemble model used in Random Forests, provide good interpretability to system designers/developers and sysadmins of predictions generated from the model input attributes [5], [19].

Existing research in the area of urban environments has used techniques such as deep learning or advanced analytics to predict parking availability. While these methods can potentially provide reasonably accurate predictions of future occupancy levels, they typically require large computational resources (e.g., hardware, software) and require the collection of large amounts (e.g., hours/days) of training data before being deployed as a solution. Therefore, it remains practical to use lightweight machine learning solutions for real-time parking systems because they are scaled, fast, and efficient [7], [15].

III.PROPOSED METHDOLOGY

This system is designed using a systematic process of obtaining, cleaning and preparing data through the use of the machine learning algorithm to train an algorithm with the training to generate predictions through the following steps: conducting data collection from a variety of sources using historical data and context data to identify and quantify the number of cars; developing context; using perceptual data to collect and measure the number of parking spaces available; then using the combining of these data to develop the final data set; after the data is aggregated into a single unified numerical format there are preprocessing techniques that can be applied to the newly created data to help prepare the data for use in training the prediction model.

The final step is to apply a combination of different types of algorithms to use the derived data for making predictions about what will occur over the specified number of minutes into the future. Selected algorithms for training and evaluating the models are Random Forest, Decision Tree, Support Vector Machine, and Linear Regression. These models have been developed using processed datasets in order to assess their prediction accuracy and reliability, through regression analysis, the system will be able to estimate the number of available parking spaces at any given time, and classification analysis, the system will be able to classify the level of parking occupancy. The results of these trained models will be incorporated into a prediction engine that can provide real-time parking availability information via dashboards or navigation interfaces.

A parking prediction model has been developed to predict how many available parking spots exist, by analyzing data from various sources and using machine learning methods. Fig 1 shows the overall architecture of the proposed parking prediction system by mapping out its flow from collecting parking data through predicting available spaces. The methodology of creating this parking prediction model consists of five stages: data acquisition, data pre-processing, model-training, generating predictions and delivering final results. This system integrates historical parking records, contextual information, and real-time sensor data to create models of how users park and to provide reliable predictions of availability. These predicted results are then sent to other applications for use in navigation systems, urban planning dashboards and other applications to help efficiently manage parking.

A. Data Sources

The first stage of the system is the collection of multiple sets of data that affect parking occupancy. All data from each of these sources will provide sufficient input needed to train the machine-learning models. The first data source is the use of historical parking data, which consists of prior records of parking occupancy at a certain location over a specific period of time. The historical dataset will enable the system to comprehend prior usage behaviours and patterns in the way people utilised parking locations. The second source of data is contextual data. Contextual data contains detail about the day of the week, times of the day, academic semesters, holidays and major events occurring in the area where the parking lot is located.

Many of the factors that contribute to parking demand depend upon particular context because how much people use parking varies based on daily schedules and seasonal activity. The third source of parking demand is real-time sensor data (collected by devices like cameras, parking kiosks, or IoT devices) that provide up-to-date information on the occupancy status of each parking space, allowing the regional parking system to adjust its forecasts in real time.

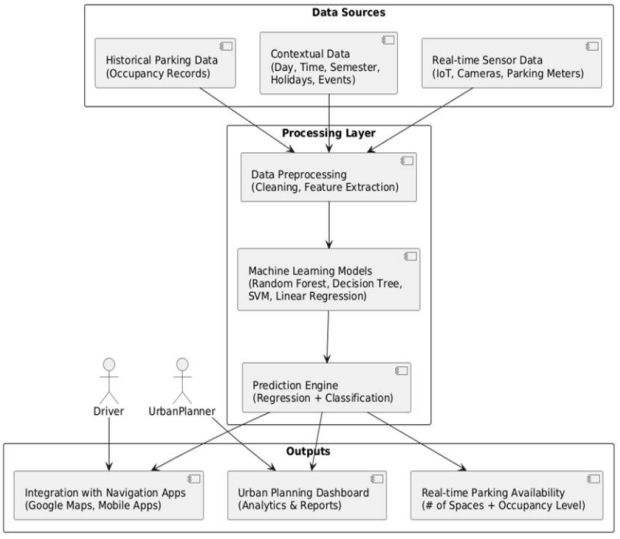

Fig. 1. Proposed Parking Prediction System Architecture

B. Data Preprocessing

The information obtained from various sources after Data has been collected goes to the Processing layer after Data Collection where Data Preprocessing occurs. The purpose of this stage is to prepare Raw Data for Machine Learning Models to utilize effectively. The Data Preprocessing process consists of cleaning the Data Set by removing any inaccurate records and Encoding Missing Values. During the Feature Extraction Process Variables that are the most important to predict Parking Utilization are being determined to assist in determining parking space utilization. Examples may include Time Related Variables, Contextual Factors, and Historical Patterns of Utilization. The process of preparing data well allows the system to provide quality input data to the machine learning models, which will lead to more accurate predictions.

C. Machine Learning Model Development

After preparing the dataset, there are many different ways to develop a parking prediction model using a variety of machine learning algorithms. For this project we will experiment with four different algorithms; Random Forest, Decision Trees, Support Vector Machines (SVMs) and Linear Regression. All four models will be trained on the processed dataset to enable them to learn how the input features relate to parking occupancy levels.

Each of the models will look for patterns within the data and identify how time of day, the day of the week or events are affecting parking demand. Of the models tested, tree-based models such as Random Forest generally provide better performance than other types of models because they have the ability to model nonlinear relationships between different variables as well as provide an added level of protection against overfitting when making predictions.

D. Prediction Engine

Once trained, the models are incorporated into a forecasting engine to produce parking availability estimates. There are two types of analyses performed by the forecasting engine: regression and classification.

The regression analysis will provide an estimate of the total number of available parking spaces at a given time, while classification will categorize the parking occupancy level into classes with three groupings (low, medium or high). Both types of forecasts provide users with varying levels of detail as well as simplicity based on their respective requirements for parking information.

E. Output Generation

The system's accuracy has been significantly improved, which leads to greater confidence in using the system's predictions to assist users and assist city officials with better decision-making processes. One example is the integration of the system's predicted results into navigation systems, allowing users of mobile devices to identify where available parking exists via these applications. By assisting in the search for parking with this type of technology, the time required for searching for parking is reduced, and the overall search for parking is improved.

In addition, the urban planning dashboard enables city planners and/or city administrators to review the analytical reports and predictions produced by the system to utilize the data to increase their ability to create effective parking management methods, as well as gain insight into the trends in parking and understand the current and anticipated demand for parking spaces within their communities. The parking availability information reported to users in real-time enables users to quickly and confidently make their decisions related to the location of their vehicles, by advising them of an estimated number of available spaces and the anticipated occupancy levels of the listed spaces.

IV. RESULTS AND DISCUSSION

Evaluation of various types of ML models reveals that a data-driven strategy is effective in predicting whether parking will be full or not. Experimental results found that the Random Forest model was more accurate than the Decision Tree, Linear Regression and Support Vector Machine models. Due to the nature of ensemble learning of Random Forest, the model has a high ability to capture difficult relationships among parking variables thus producing reliable forecasts under all conditions. In addition, the Random Forest model performed well on both regression and classification; therefore, this model could be used for real-time parking management systems.

Accurate predictions of parking spaces will greatly improve urban mobility & reduce traffic congestion. Accurate prediction of available parking space will allow drivers to make their parking decisions quickly thus reducing unnecessary circulation in a parking area while searching for a parking space.

Urban planners & administrators also have access to useful information about demand patterns of parking spaces and resources that are used in providing parking space by using the overall machine learning-based approach to determine how best to increase parking efficiencies & develop sustainable transportation systems for cities today.

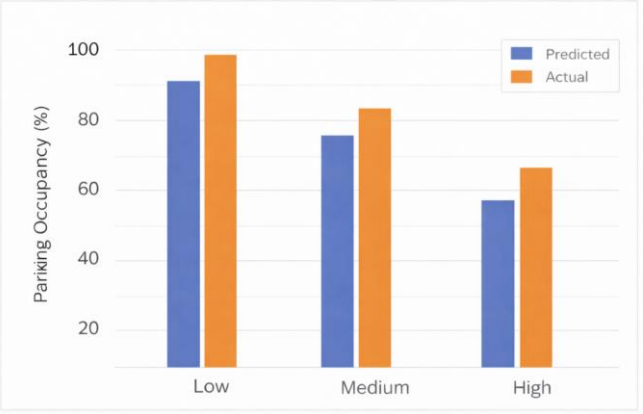

Fig. 2. Comparison of predicted and actual parking occupancy levels generated by the machine learning model.

Fig 2 shows the performance of the proposed parking prediction system by comparing the predicted parking occupancy levels generated by the machine learning model and the actually observed parking occupancy values. The horizontal axis shows three occupancy categories: low, medium and high. The vertical axis shows parking occupancy in percentage (%). There are two sets of bars showing each category; blue is for predicted occupancy values and orange is for actually observed values.

As shown in the graph, the prediction from our model accurately follows actual occupancy levels in every parking category. In the low parking category, the predicted percentage of occupied parking is approximately 90% and the observed percentage of occupied parking is approximately 98%. For medium occupancy parking, the predicted percentage of total parking occupied is about 75% compared to the observed occupancy of about 83%. Again for high occupancy, the proportion of estimated parking utilization was approximately 56% and observed use was about 66%. Despite some small differences between our predicted and actual results, the model produces an accurate reflection of demand to park. According to the results obtained, a predictive model is built around the concepts of identifying increasingly complex data patterns through patterns found within a dataset using a machine learning algorithm. The predictive model shows the ability to learn the correlation between different input variables like time, day, special events and historical data on parking to make an accurate prediction concerning availability of parking spots at a restaurant chain's location.

Discussion of System Performance

The research shows that the proposed parking prediction model can predict how many spaces in a given area are going to be filled at any given time regardless of what time of day it is. The minimal gap between predicted values and actual values indicates that the model has learned to identify meaningful data relationships. Therefore, based on the statistical analysis conducted by researchers regarding the efficacy of machine learning algorithms, it concludes that there are multiple dynamic factors that impact your ability to park and that machine learning and other technology will provide you with the best means to evaluate those various issues.

A key advantage of this new parking solution is that it will leverage multiple sources of data (such as historical and context-based parking records) and combine them with real-time data from sensors. Consequently, the proposed model will be able to more thoroughly assess the variability of parking demand based on various parameters, including the time of day, day of the week, academic semesters, holidays, and special events. The use of data from these multiple sources will enable this new model to be able to predict parking demand better than existing fixed parking models.

The findings also revealed that various machine learning techniques including Random Forests, Decision Trees, Support Vector Machines and Linear Regressions were examined throughout the creation of the system. For example, tree-based approaches tended to perform better than other types of machine learning algorithms because tree models are able to identify non-linear relationships between attributes in complex datasets. Thus, the models help in creating accurate predictions of parking demands that fluctuate wildly. Additionally, another benefit of this proposed system will be its capability to produce

regression and classification outputs. Using regression analysis allows one to estimate the approximate amount of parking available. In addition to using regression analysis, classification can be used to classify the amount of parking as low, medium or high. This dual approach allows the user to receive a detailed numerical report as well as a simplified visual representation of how much parking is available.

The findings support the proposed machine learning-augmented parkable parking management system, which enables significantly enhanced parking management for the urban environment. By providing real-time data/information on available carpark locations, a driver can spend less time searching for available parking spaces. Thus, this may reduce excessive traffic, fuel use, and levels of environmental pollution, thereby promoting improved public and private urban mobility as a whole.

V.CONCLUSION

This research employed a machine learning-based methodology to develop a predictive system for urban lot management by predicting the number of open spaces. The proposed system uses multiple types of information, which include historical data on open spaces, contextual factors (e.g., time, special event), and current data available through sensors, to predict parking demand and therefore estimate how many open spaces will be available in the future. In order to identify the best predictive models for this application, regression and classification algorithms (Random Forest, Decision Tree, Support Vector Machine, Linear Regression) were considered. Experimental results indicated that there was a strong agreement between the predicted values and the observed values. This indicates that the predictive model is able to accurately reflect how people use parking facilities.

In summary, in this paper a new project is introduced, which illustrates how machine learning technologies can enhance intelligent parking forecasts. As a result, complete or near complete data on parking availability is provided via navigational applications and analytics dashboards. Thus, the solution can reduce the overall time spent looking for parking spaces, enhance overall traffic flow patterns within cities, and provide better support for managing urban mobility and transportation systems.

REFERENCES

1. S. Channamallu, S. Kermanshachi, J. M. Rosenberger, and A. Pamidimukkala, “Enhancing Urban Parking Efficiency Through Machine Learning Model Integration,” IEEE Access, vol. 12, pp. 81338–81352, 2024.
2. R. Channamallu and A. Singh, “Comparative Analysis of Machine Learning Models for Parking Space Prediction,” Smart Parking Research Letters, vol. 5, no. 2, pp. 45–55, 2023.
3. R. Patel and A. Thomas, “Temporal and Spatial Analysis of Autonomous Mobility and Urban Parking Demand,” Automated Mobility Insights, vol. 8, no. 1, pp. 12–21, 2023.
4. R. Sun and N. Patel, “Short-Term Parking Occupancy Prediction Using Decision Tree and Random Forest,” Urban Informatics Journal, vol. 7, no. 3, pp. 98–107, 2019.
5. Y. Min and H. Zhao, “Deep Learning Based Real-Time Parking Occupancy Prediction,” *IEEE Intelligent Transportation Systems Letters*, vol. 11, no. 4, pp. 657–661, 2019.
6. J. Liu and F. Wu, “Gradient Boosting Decision Tree for Parking Occupancy Prediction,” Machine Intelligence in Transportation, vol. 4, no. 2, pp. 88–95, 2019.
7. H. Li and Y. Chen, “Evolution of Location-Based Services in Smart Mobility Systems,” Mobile Computing Reviews, vol. 10, no. 3, pp. 145–154, 2018.
8. Kotb, L. Shen, A. Huang, and B. Wu, “Smart Parking Guidance, Monitoring and Reservation Systems: A Review,” IEEE Intelligent Transportation Systems Magazine, vol. 9, no. 2, pp. 6–16, 2017.
9. Z. Wei and M. Park, “Parking Availability Prediction in Sensor-Enabled Parking Systems,” IEEE Transactions on Intelligent Transportation Systems, vol. 16, no. 5, pp. 2915–2924, 2015.
10. Y. Hao and C. Liu, “Comprehensive Survey on Parking Services in Smart Cities,” Journal of Urban Mobility Systems, vol. 5, no. 2, pp. 75–89, 2019.
11. C. Caicedo and D. Rios, “Real-Time Parking Space Availability Prediction,” International Journal of Transportation Systems, vol. 6, no. 3, pp. 123–132, 2012.
12. D. Shoup, The High Cost of Free Parking, Chicago, IL, USA: Planners Press, 2011.
13. Geng and X. Cassandras, “A New Smart Parking System Infrastructure and Implementation,” Procedia Social and Behavioral Sciences, vol. 54, pp. 1278–1287, 2012.
14. L. Barone, M. Giuffrè, S. Siniscalchi, and G. Tesoriere, “Architecture for Parking Availability Prediction Using Smart Sensors,” Transportation Research Procedia, vol. 3, pp. 956–965, 2014.
15. S. Sester, “Mobility Data Analysis Using Mobile Mapping Systems,” GeoSpatial Analytics Journal, vol. 9, no. 1, pp. 55–64, 2020.
16. M. Idris, Y. Leng, E. Tamil, N. Noor, and Z. Razak, “Car Park System: A Review of Smart Parking System and Its Technology,” Information Technology Journal, vol. 8, no. 2, pp. 101–113, 2009.
17. H. Shaheen, S. Rodier, and C. Murray, “Parking Management and Smart Parking Technologies,” Transportation Research Record, vol. 2389, pp. 65–72, 2013.
18. X. Ji, Y. Feng, and L. Hu, “Parking Space Availability Prediction Using Data Mining Techniques,” International Journal of Smart Transportation, vol. 7, no. 2, pp. 80–89, 2016.
19. S. Vlahogianni, M. Karlaftis, and J. Golias, “Short-Term Traffic and Parking Prediction Using Machine Learning Methods,” Transportation Research Part C, vol. 43, pp. 178–192, 2014.