# Automated Car Parking System Using Machine Learning Techniques

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**Abstract -** The main aim that we have is to create a completely automated car parking system with minimal human interference. With the rising population in the world, time is of the essence and hence we need to minimize the time taken by trivial activities such as finding a place to park in a busy place and avoid traffic congestion. We have seen in existing systems sometimes accidents can occur in parking situations by cars going at high speed caused by frustrated drivers unable to find a parking space for a long period of time. In our project we propose a smart and automated car parking model that will help the user in booking their parking spaces beforehand and the vehicle will be able to park automatically once in the parking zone .The difference between our project of automated car parking systems is we hope to minimize human interaction as much as possible and make both the vehicle and the parking area fitted with sensors that will help us execute a safe and efficient way of parking. Hence, we aim to provide a completely safe and automated experience that is robust and can be implemented in real time and hopefully be implemented as the general norm for parking systems in the future.

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**Key Words:** Automated parking system, smart parking, machine learning in parking, computer vision, object detection, parking slot detection, image processing, sensor integration, ultrasonic sensors.

## 1.INTRODUCTION

In the 21st century finding a free car parking slot has become a mind-numbing process, especially for people who travel in the morning to work or are following their daily routine, they find it highly difficult and challenging to get a parking slot for their cars. Moreover, the parking slots are never user-friendly and provide no logical data about the availability of the spot unless the user visits it manually.

These kind of problems are faced regularly by every individual because the factor of uncertainty is very high and there are not many possible solutions in existence for solving the issue that may benefit the users by saving their time or keeping their mental state happy and carefree.

In our ever populating cities and districts to find parking space is becoming increasingly difficult as traffic increases. Drivers have to go back and forth desperately looking for parking spaces wasting their valuable time, fuel consumption with increased likelihood of causing accidents. With the help of wireless network technology we propose remote parking monitoring and automated guidance which will help save a lot of time.

In the existing system we can see that some supervision is required for the parking system and it not fully automated. The driver has to make sure that the car is parked in a spot without disturbing the convenience of others. In most cases the main problem is finding the spot and trying to secure the spot for parking which in turn leads to increased stress level for the person driving the car.

Moreover, the relative analysis of the data is structural to the implementation of the parking procedure.

Nowadays, in this busy world it's really hard for a person to find a spot for parking. The current parking system doesn't give the user a specified parking slot inside the area. Parking in general in a long and time consuming process and we hope to provide a solution to alleviate this problem.

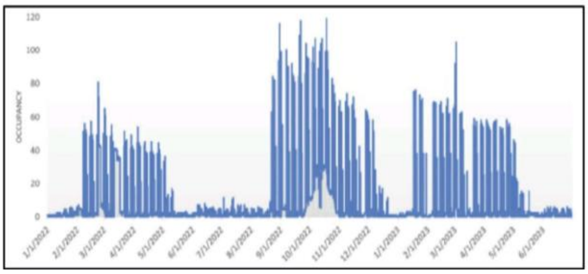
## 2. LITERATURE REVIEW

The complexity of urban environments has escalated the need for sophisticated parking management solutions, and a significant body of research has addressed this urban challenge by focusing on the application of machine learning models. Studies such as those by and have been instrumental in exploring the effectiveness of various machine learning algorithms in the context of urban parking, and the integration of machine learning in urban parking solutions, as highlighted by, reflects a growing trend towards the adoption of data-driven strategies in urban planning. It presents a summary of the literature on this subject.

The consistent effectiveness of random forest and decision trees in predicting parking availability and occupancy is a notable trend in the literature. Works by and others have shown that these models outperform others in terms of accuracy, precision, and F1-score, indicating their reliability for urban parking management systems. Decision trees are noted for their computational efficiency in rapid processing, which is an important attribute for real-time parking management applications, as highlighted in the study by and makes them a practical choice for optimizing urban parking. Comparing the performance of various models suggests that the efficacy of a particular model can be context-specific and influenced by factors such as the type of parking and scale of data. Studies by and indicate variations in model performance based on these parameters and emphasize the need for a tailored approach to model selection and implementation that considers the specific characteristics of the parking environment.

### A. DATA COLLECTION

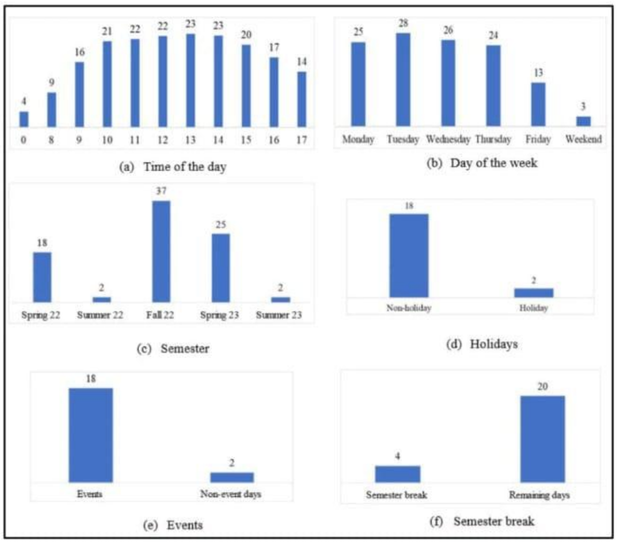
The dataset consisted of 13,104 entries that encompassed the date and hourly occupancy data from January 2022 through June 2023; the hourly occupancy percentages are depicted in below figure . For assessing previous occupancy levels, a retrospective analysis method was utilized, incorporating a range of inputs that provided the model with information on occupancy rates from an hour before predictions were made.




DATA SET

### B. VARIABLE SELECTIONS

Key features such as the day of the week, time of day, and contextual factors like academic semesters, holidays, and special events were chosen for their potential influence on parking occupancy. Figure below illustrates the occupancy variations according to these selected variables. The selected features, including the day of the week, time of day, academic semesters, holidays, and special events, were chosen based on their demonstrated influence on parking occupancy patterns in the specific context of college campus parking. For instance, the day of the week was deemed crucial due to its significant impact on parking demand, with weekdays experiencing higher occupancy levels than weekends, driven by class schedules and staff activity. Similarly, the time of day emerged as a key predictor, reflecting temporal variations in parking demand throughout the day, with notable differences observed between peak commuting hours and off-peak periods. Academic semesters were included to capture seasonal variations in parking patterns, with distinct occupancy levels observed during fall, spring, and summer terms. e.g., occupancy during summer semesters is generally lower than during the fall and spring semesters.




VARIATIONS IN AVERAGE HOURLY OCCUPANCY

### C. DATA PREPROCESSING

This study analyzed hourly occupancy data, both as a continuous and as a categorical variable. The data was classified into three categories (low, medium, and high), based on tercile distributions, with specific thresholds defined for each group to enhance clarity and improve prediction accuracy. The analysis primarily focused on the typical hours of a college's operation, which is from 8 am to 5 pm, and data outside these hours were averaged and aligned with the 0-hour mark. This approach was adopted to fine-tune the analysis by emphasizing the most pertinent timeframes. The data for Saturdays and Sundays were combined and treated as a single ''weekend'' category, simplifying the analysis and acknowledging the different parking patterns that are generally seen on these days.

### D. PREDICTION METHODS

Four models were chosen as contenders for the model that most accurately predicts parking space occupancy at a college campus: random forest, SVM, linear regression, and decision trees. All four possess superior predictive abilities, but the random forest model is particularly distinguished for its robust management of complex variable interrelations and its effectiveness in reducing overfitting, a frequent issue in prediction models. The decision tree model demonstrates straightforwardness and easy interpretability and offers a clear decision-making path based on input features, which makes making it user friendly for non-technical stakeholders and ideal in situations where it's important to understand how the model arrives at decisions. Linear regression is valued for the uncomplicated manner in which it models linear relationships between variables and outcomes, proving effective when the linear model assumption holds true. It is also simple to use and understand, making it suitable for initial analysis or linearly related data. SVM is known for its superior handling of nonlinear relationships and is essential in complex situations like parking occupancy forecasts. Its ability to navigate nonlinearity makes it a viable option for intricate predictor-target relations. Table shown presents a summary of the parameters utilized for each model, along with the values obtained through optimization for each parameter. Python libraries were employed to operationalize these models. To better address the time-sequential characteristics of the dataset, akin to time series data, we implemented k-fold cross validation with k = 10 folds. This method not only maintains the temporal sequence of the data during training but also allows for a more comprehensive assessment across different segments of the dataset. By partitioning the dataset sequentially into 10 folds, we ensure that each validation set consists of data points that immediately follow their corresponding training set, preserving the chronological integrity and avoiding leakage of future information.

| Models | Optimal parameters |
|---|---|
| Random forest | no. of estimators: 100, maximum depth: 15, minimum samples split: 4, minimum samples leaf: 2 |
| Decision tree | maximum depth: 56, minimum samples split = 16, minimum samples leaf = 2, |
| SVM | regularization parameter (c): 1.0, kernel: radial basis function (rbf), tol: 0.1, degree: 3 |
| Linear regression | Default parameters. |

**MODEL PARAMETERS**

### E. EVALUATION METRICS

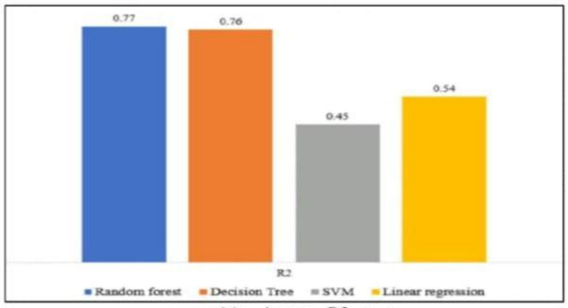
The models' ability to accurately predict parking occupancy was analyzed by performing a regression analysis, using the mean absolute error (MAE), root mean square error (RMSE), and R-squared (R2) as primary metrics. Absolute measures, RMSE and MAE, were compared to identify the model with the lowest average error in predictions; R2 was used to quantify the percentage of variance in the dependent variable that the model explains.

## 3. RESULTS

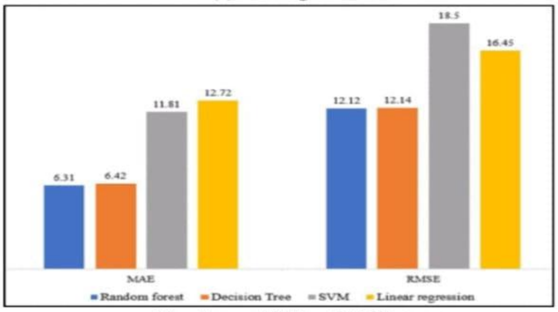
The comparative analysis of the random forest, decision tree, linear regression, and SVR models highlighted each model's specific advantages and limitations in forecasting parking space availability in a college campus garage.

### A. REGRESSION ANALYSIS

An analysis of the machine learning models that used hourly occupancy as a continuous variable revealed the differences in the performance and suitability of each model. Figure below presents the average R2 score, MAE and RMSE across all folds in the cross-validation of the models before pre-processing the hourly occupancy. The random forest model stood out for its excellence in predicting hourly parking occupancy, as it exhibited an MAE of 6.31, an RMSE of 12.12, and an impressive R2 score of 0.77. The decision tree model was closely aligned with the random forest model in performance, with an MAE of 6.42, a similar RMSE, and an R2 score of 0.76. The linear regression model showed a weaker performance with an MAE of 12.72, an RMSE of 16.45, and an R2 score of 0.45. The SVR model displayed an MAE of 11.81, an RMSE of 18.5, and an R2 score of 0.54.



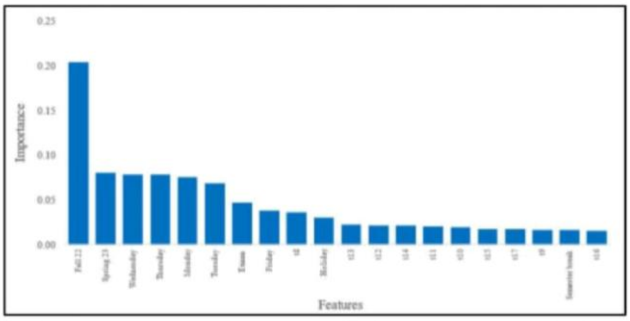

(a) Average R2 score




(b) Average MAE and RMSE scores

**RESULTS OF MODEL**

Figure below depicts the importance of features and shows Wednesday to Friday, was given greater importance in the regression analysis. This suggests that these days are more indicative of high parking usage and may reflect a pattern in which parking demand peaks during the mid-to-late workweek due to increased activities or consistent scheduling patterns. The seasons also exhibited a clear impact on parking usage, with fall emerging as the most influential season, closely followed by spring and winter. This trend could be attributed to the start of the academic year and activities that typically increase parking demand during these times. The significant influence of fall might be due to back-to school periods and new academic sessions, which typically see a surge in campus activity and, consequently, parking demand.




**FEATURES IMPORTANT SCORE DERVIED FROM REGRESSION ANALYSIS**

The time-of-day features, denoted as f1 through f17, show a range of importance scores that reflect the varying parking demands throughout the day. These may correspond to typical daily routines such as morning arrivals, lunchtime exits, and evening departures, which all influence parking space turnover and availability. Holidays and weekends were revealed to be of moderate importance, which indicates their role in the predictability of parking usage and also suggests a more consistent parking pattern on these days compared to regular weekdays.

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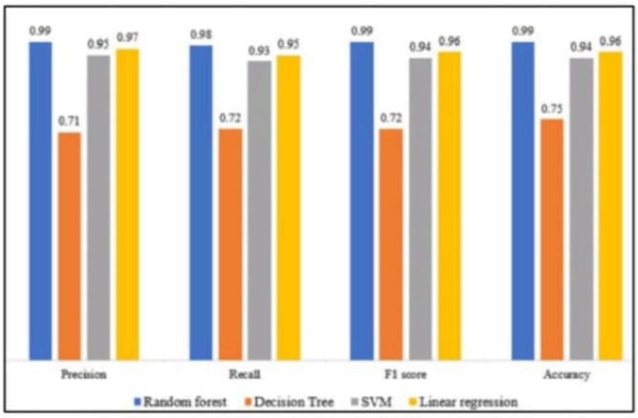
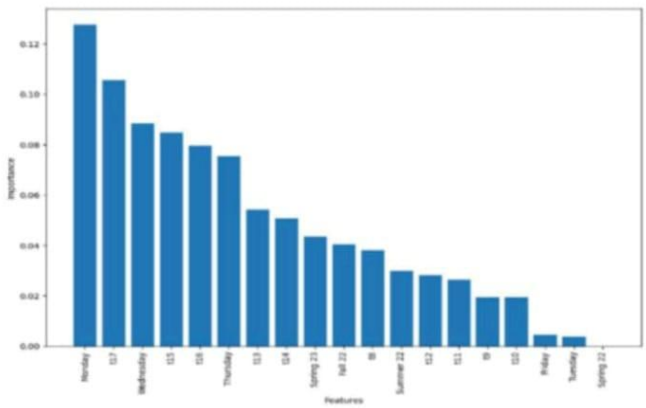
### B. CLASSIFICATION ANALYSIS

The bar chart presented in figure below shows the comparisons of the performances of four machine learning models (random forest, linear regression, SVM, and decision tree), based on four key metrics: precision, recall, F1 score, and accuracy. In terms of Precision, the Random Forest model achieved the highest score with 0.99, followed by Linear Regression at 0.97, SVM at 0.95, and the Decision Tree model at 0.71. For Recall, Random Forest led with 0.98, closely followed by Linear Regression and SVM scoring 0.95 and 0.93 respectively, and the Decision Tree at 0.72. In measuring F1 Score, the Random Forest again topped the chart with a score of 0.99, with Linear Regression and SVM scoring slightly lower at 0.96, and the Decision Tree trailing at 0.72. Finally, in terms of Accuracy, Random Forest excelled with a score of 0.99 followed by linear regression at 0.96, SVM also performed robustly with a score of 0.94, and the Decision Tree showed an accuracy of 0.75.




**RESULTS OF PREDICTION MODELS**

Figure below shows that Monday is the most influential factor in the classification analysis, underscoring the impact of the beginning of the workweek on parking trends. This is closely followed by temporal features labeled f15, f17, and Wednesday, all indicating critical periods within the weekly cycle that shape parking behaviors. Thursday, f13, and the spring season are shown to be of moderate importance, suggesting a tangible but less dominant influence on parking dynamics.



**FEATURES IMPORTANCE SCORES DERIVED FROM CLASSIFICATION ANALYSIS**

The lesser importance attributed to the fall and summer seasons, as well as specific time slots denoted by f8 through f10 and days like Friday, holidays, and Tuesday reveals that these factors have less impact on the classification of parking patterns. This information is indicative of a lower variability in parking behavior or a less acute effect on the differentiation of occupancy levels during these periods.

## 3. CONCLUSIONS

Parking management in urban areas has become increasingly challenging due to the rising number of vehicles and limited number of parking spaces. This study employed a comprehensive analysis of machine learning techniques to predict parking occupancy in an urban setting, based on a dataset of hourly occupancy data collected over a period of 18 months that provided a solid foundation for evaluating the effectiveness of the various models. A comparative analysis was performed of four models (SVM, random forest, decision tree, and linear regression) to assess the performance of each, utilizing metrics such as MAE, RMSE, and R2 for regression analysis, and accuracy, precision, recall, and F1 score for classification analysis. This study not only identifies the most effective models for predicting parking occupancy but also illuminates the various factors that influence parking patterns.
The in-depth evaluation of both regression and classification models revealed the exceptional performance of the random forest model, whose perfect or near-perfect scores in classification metrics and remarkable proficiency in regression analysis unequivocally establishes it as the optimal choice for predicting parking occupancy.

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