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Smart Parking Waiting Prediction and Simulation Using XGBoost and SimPy

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Abstract: This paper presents a data-driven smart parking simulation and prediction model using the "smart parking dataset.csv" dataset. The study focuses on four key features: parking duration, available slots, cars in queue, and time of day. An XGBoost clas-sifier was trained to predict whether a driver will wait (is waiting), achieving perfect evaluation metrics. Additionally, a discrete-event simulation using SimPy was imple- mented to model real-time parking flow and compute historical waiting rates. The results demonstrate the effectiveness of machine learning combined with simulation techniques for smart parking management.

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I. INTRODUCTION

Smart parking systems aim to reduce congestion, driver waiting time, and inefficient use of parking spaces [2]. This study focuses on analyzing real parking data and building a predictive model to estimate waiting behavior. The paper integrates machine learning and simulation to understand both prediction accuracy and real-environment behavior [3].

II. BACKGROUND

Machine learning models, specifically ensemble models such as XGBoost, have been widely used to classify complex patterns in transportation systems [1, 5]. Simulation environments like SimPy allow dynamic modeling of parking facilities, including car arrivals, capacity handling, and service time [4]. Combining both techniques offers a comprehensive overview of smart parking systems [3].

III. EXPERIMENT DISCUSSION

The experiment consisted of two major parts:

A machine learning model trained using XGBoost.

A parking simulation environment built with SimPy to replicate real-world parking events.

The dataset contained six columns: arrival time, parking duration, available slots, cars in queue, is waiting, and time of day. Four features were selected as predictors: parking duration, available slots, cars in queue, and time of day.

➢ *Machine Learning Model*

Data preprocessing included normalization using StandardScaler and handling class imbal- ance with SMOTE. After training, the model produced perfect results.

➢ *Simulation Environment*

A SimPy-based parking lot simulation was executed using parameters extracted from the dataset, including:

- Parking capacity: 9 spots
- Average parking duration: 66.3 minutes
- Arrival rate: 0.2 cars per minute

The simulation generated car arrival events, parking operations, and departure events across 200 simulation minutes.

IV. FINDINGS/RESULTS ANALYSIS

➢ *Machine Learning Results*

The XGBoost classifier achieved perfect performance metrics. Table 1 summarizes the eval- uation scores.

➢ *Simulation Results*

The simulation successfully modeled car arrival and parking behavior. Based on the dataset, the historical waiting rate was computed to be 4.3%. Table 2 summarizes the extracted simulation parameters.

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Table 1 XGBoost Classification Results

Metric	Score
Accuracy	1.0000
Precision	1.0000
Recall	1.0000
F1 Score	1.0000
Confusion Matrix	[[195, 0], [0, 5]]

Table 2 Simulation-Based Findings

Parameter	Value
Parking Capacity	9
Average Parking Duration	66.3 minutes
Arrival Rate	0.2 cars/min
Historical Waiting Rate	4.3%

V. CONCLUSION

This study presented an integrated machine learning and simulation approach for predicting and analyzing waiting behavior in smart parking environments. The XGBoost classifier successfully predicted waiting outcomes with perfect accuracy, while the SimPy simulation provided realistic modeling of parking dynamics and historical waiting behavior. These results confirm that combining ML prediction with simulation can enhance smart parking decision-making and improve real-time parking management.

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