Project Report: Dynamic Pricing for Urban Parking Lots

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1. Introduction

With the rise in urbanization and vehicle ownership, effective management of parking resources has become essential. This project presents a dynamic pricing system for urban parking lots that adjusts prices in real-time based on various factors such as demand, traffic, vehicle type, and competition. Additionally, the system suggests rerouting vehicles to nearby available lots when a lot is full. This solution contributes to better traffic management and optimized revenue generation for parking administrators.

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2. Problem Statement

Fixed-rate pricing models often lead to underutilization or overloading of parking spaces. The aim of this project is to build a dynamic and intelligent pricing system that:

- Adjusts pricing in real-time using multiple features
- Considers spatial competition between parking lots
- Recommends alternative lots for rerouting when a lot is full

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3. Dataset Description

- **Format**: CSV
- **Duration**: 73 days
- **Resolution**: 30-minute intervals
- **Lots**: 14 different locations
- **Key Features**:
- SystemCodeNumber
- Latitude, Longitude
- Capacity, Occupancy
- TrafficConditionNearby (low/medium/high)
- QueueLength, IsSpecialDay, VehicleType (bike/car/truck)

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4. Methodology

4.1 Preprocessing

- Convert categorical features to numerical (e.g., traffic: low=1, high=3)
- Combine date and time into a single datetime column

4.2 Models Implemented

(a) Baseline Model

- Price increases linearly with occupancy rate

- Formula: `price = base_price + alpha * (occupancy / capacity)`

(b) Demand-Based Model

- Considers: occupancy, queue length, traffic, special day, vehicle type
- Normalizes demand and adjusts price accordingly
- Formula: `price = base_price * (1 + λ * normalized_demand)`

(c) Competitive Model

- Computes distances between parking lots using the Haversine formula
- Adjusts price relative to nearby lots within 1km

(d) Rerouting Recommendation

- For full lots, reroute to the nearest available lot with a competitive price

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5. Visualization

- **Bokeh** is used to display time-series graphs comparing Baseline, Demand-Based, and Competitive Prices.
- A mock real-time simulation prints pricing updates at each 30-minute interval.
- Optional: Plotly map visualization to show rerouting arrows between lots.

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6. Results

- Successfully simulated dynamic pricing for all 14 parking lots
- Competitive pricing smoothened prices across nearby lots
- Rerouting logic helped avoid overloading any single lot
- All models run efficiently in a notebook environment

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7. Technologies Used

- Python (Pandas, NumPy, Bokeh, Matplotlib, Plotly)
- Jupyter Notebook / Google Colab

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8. Future Work

- Build a real-time dashboard using Streamlit
- Integrate APIs for live traffic and occupancy data
- Enhance rerouting with user preferences (e.g., walking distance, vehicle size)
- Containerize the app using Docker for scalable deployment

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9. Conclusion

This project demonstrates a robust, data-driven solution for smart parking management. The use of dynamic pricing and rerouting logic ensures both operational efficiency and user satisfaction. With further enhancements, this system can be integrated into real-world parking systems and city planning tools.
