Dynamic Urban Parking Pricing System

(Based on Real-Time Data & Machine Learning Principles)

Objective

To develop a real-time, intelligent pricing engine for urban parking spaces that adjusts parking prices dynamically based on real-time data such as occupancy, traffic congestion, queue length, and special day indicators.

Problem Statement

Static pricing models in urban parking lead to inefficiencies—either over-crowding or underutilization of parking spaces. The need for a responsive and data-driven pricing strategy is crucial for optimal resource utilization.

Solution Overview

This project uses a streaming data pipeline to simulate real-time conditions in urban parking lots and applies machine learning principles and economic logic to compute dynamic prices. Prices change smoothly and logically with respect to demand.

Tools & Technologies Used

- **Programming Language:** Python
- **Libraries:** Pandas, NumPy, Pathway
- **Visualization:** Matplotlib / Bokeh
- **Environment:** Google Colab

System Architecture

- Data streamed from CSV using Pathway in **real-time**
- Applied two pricing models:
    - **Model 1:** Linear Occupancy-based
    - **Model 2:** Demand function with multiple features
- Final output is stored in final_prices.csv

- Prices plotted over time using Matplotlib

Pricing Models Implemented

Model 1 – Baseline Pricing

- Formula:

$$\text{Price}_{t+1} = \text{Price}_t + \alpha \cdot \left(\frac{\text{Occupancy}}{\text{Capacity}} \right)$$

- Simple linear model to establish a baseline.
- Price increases as occupancy approaches capacity.

Model 2 – Demand-Based Pricing

- Formula:

$$\text{Demand} = \alpha \cdot \left(\frac{\text{Occupancy}}{\text{Capacity}} \right) + \beta \cdot \text{QueueLength} - \gamma \cdot \text{Traffic} + \delta \cdot \text{IsSpecialDay} + \varepsilon \cdot \text{VehicleTypeWeight}$$

- Factors considered: Occupancy, Queue, Traffic, Event, Vehicle Type
- Smooth, explainable, bounded pricing range ($5 to $20)

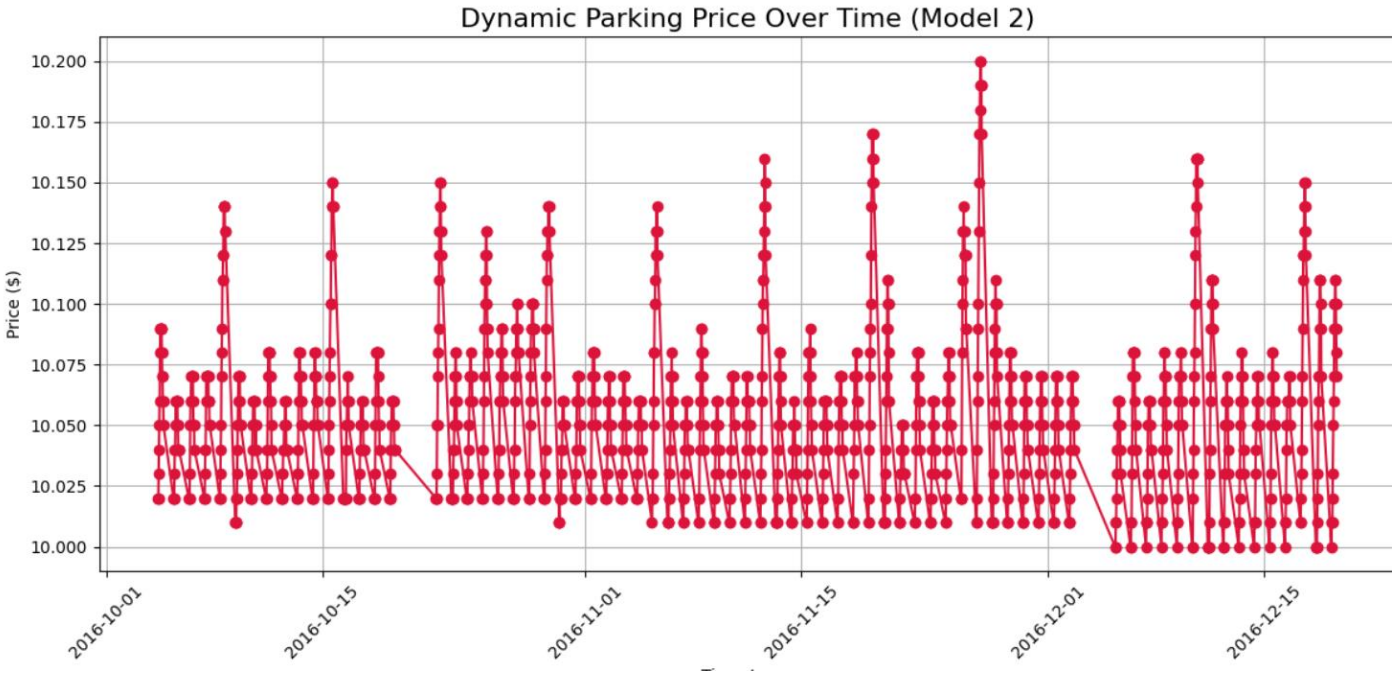
Dataset Description

- Collected data from 14 urban parking locations
- Timeframe: 73 days
- Sampling: 18 time intervals per day (every 30 minutes)
- Fields:
    - Timestamp
    - Occupancy
    - Capacity
    - Queue length
    - Traffic level
    - Special day indicator
    - Vehicle type

Output & Results

- Pricing output successfully written to final_prices.csv
- Graphs plotted for price fluctuations over time
- Observed that prices increased during:
    - High occupancy
    - Special events
    - Longer queues

Visualization



Graph: Dynamic Price Over Time (Model 2)

Project Structure

📦 Parking-Pricing-System

- dataset.csv
- urban_parking_pricing_engine.ipynb
- final_prices.csv
- ProjectReport.pdf
- README.md

Conclusion

This capstone project demonstrates how simple mathematical and economic models, when applied to real-time data, can create efficient and intelligent systems. It shows the practicality of using ML concepts (even without heavy libraries) to solve urban optimization problems.