Dynamic Pricing for Urban Parking Lots

1. Objective

The aim of this project is to implement a dynamic pricing system for urban parking lots using streaming data. The model adjusts prices based on real-time occupancy, traffic level, queue length, special days, and vehicle types. The approach is built using the Pathway streaming framework and visualized with Bokeh and Panel.

2. Dataset & Streaming

The dataset includes timestamped records for each parking lot with columns: Occupancy, Capacity, QueueLength, TrafficLevel, IsSpecialDay, and VehicleTypeWeight. Streaming is simulated using Pathway's replay_csv to replay data at 1000 rows per second.

3. Demand Function

A custom UDF computes the demand-based price as:

price = 10 * (1 + lambda * norm_demand)

Where norm_demand = (demand + 5) / 10 and:

demand = alpha * (Occupancy / Capacity) + beta * QueueLength - gamma * TrafficLevel + delta * IsSpecialDay + epsilon * VehicleTypeWeight

The price is clipped between 5 and 20 to ensure fairness and control.

4. Assumptions

- Occupancy rate and queue length increase pricing.
- Traffic congestion reduces pricing.
- Holidays and events drive price increases.
- Prices are capped to maintain customer trust.
- Each lot is priced independently (no inter-lot dynamics considered).

5. Pipeline & Aggregation

Streaming data is windowed into 15-minute intervals per parking lot using tumbling windows. Mean values are calculated per window and used to determine pricing in real time.

6. Visualizations

Bokeh-based plots display real-time prices for each lot in a grid layout using Panel. Each plot includes a time series of price updates, clearly showing the impact of demand changes.

7. Conclusion

This solution demonstrates how dynamic, data-driven pricing can be implemented in urban infrastructure using real-time analytics. The model is extendable to include competition, predictive forecasting, and reinforcement learning strategies.