Dynamic Pricing for Urban Parking Lots

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Problem Statement

The goal is to develop a real-time pricing engine for urban parking lots using live data streams. The pricing should adjust dynamically based on lot occupancy, traffic, queue length, vehicle type, and contextual signals like time of day and special events.

Model 1: Baseline Pricing

Model 1 calculates the price as a linear function of occupancy:

price = base_price × (occupancy / capacity)

This model is straightforward and reflects congestion-based dynamic pricing.

Model 2: Demand-Weighted Dynamic Pricing

Model 2 introduces a multi-variable scoring system based on:

- Occupancy Rate
- Queue Length
- Traffic Condition
- Special Day
- Vehicle Type
- Hour of Day

This demand score is normalized and used to scale price between 0.5× and 2× the base.

Initial Findings & Thought Process

Initially, a simple model (Model 1) was implemented for rapid prototyping. While functional, it lacked granularity. Our hypothesis was that adding behavioral and contextual data (vehicle types, traffic, time, events) would create a more realistic pricing model. Hence, Model 2 was designed to incorporate weighted demand components, simulating real-world pricing logic.

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Implementation Summary

We used Pathway for real-time stream simulation and Bokeh for visual analysis. Both models were implemented in Python with interactive output enabled via Panel. Data was preprocessed using Pathway filters and enriched using Python functions to derive demand scores and price bands.

Key Findings from Visualization

- Model 1 shows smooth linear price curves aligned with occupancy trends.
- Model 2 introduces dynamic shifts, especially during peak hours and high traffic zones.
- Some lots show consistently high prices due to location and congestion.
- Pricing fluctuations are more realistic in Model 2, offering better demand management.

References

- Pathway Docs: https://pathway.com/developer-docs/
- Bokeh Visualization: https://docs.bokeh.org/
- Panel Dashboards: https://panel.holoviz.org/
- Smart Parking: https://ieeexplore.ieee.org/document/7274471
- Dynamic Pricing Concepts: https://arxiv.org/pdf/1707.05413.pdf