Dynamic Parking Pricing

Project Report

Introduction

Urban areas frequently experience high vehicle congestion and limited parking availability. This often results in inefficient space usage, long search times for drivers, and increased traffic. To address this, dynamic pricing models can be employed, adjusting parking rates in real-time based on demand, vehicle type, traffic conditions, and other influencing factors. This project explores such dynamic pricing through two models: a baseline linear pricing model and a real-time stream processing model using Pathway. By leveraging parking lot occupancy data and contextual factors, we aim to create a responsive pricing system that better manages demand.

**Objective:**

* To analyse historical parking data and build a baseline dynamic pricing model.
* To implement real-time streaming-based dynamic pricing using Pathway.
* To visualize and compare pricing results across models.

**Tech Stack Used:**

* **Python**: Core data manipulation and modeling
* **Pandas**: Data wrangling and preprocessing
* **Bokeh**: Interactive data visualization
* **Google Colab**: Collaborative and cloud-based notebook environment
* **Pathway**: Real-time stream processing framework

Dataset Description

The dataset contains historical records of parking lot usage across multiple locations. Key columns include:

* SystemCodeNumber: Unique identifier of the parking lot
* Capacity: Total capacity of the lot
* Occupancy: Number of spots occupied
* VehicleType: Type of vehicle (car, bike, cycle, truck)
* TrafficConditionNearby: Traffic level (low, medium, high)
* QueueLength: Number of vehicles waiting
* IsSpecialDay: Indicator for special dates
* LastUpdatedDate & LastUpdatedTime: Timestamp of the record

METHODOLOGY

1. **Data Preprocessing:**
   * Merged date and time columns into a unified Timestamp field.
   * Calculated OccupancyRate as a fraction of total capacity.
   * Normalized demand based on queue length, traffic, vehicle weight, and special days.
2. **Model 1: Baseline Linear Dynamic Pricing:**
   * Formula: Price(t+1) = Price(t) + alpha \* OccupancyRate
   * Price is adjusted iteratively using a linear growth influenced by occupancy.
   * Implemented for each parking lot over time.
3. **Model 2: Real-Time Pricing using Pathway:**
   * Created a streaming pipeline using Pathway.
   * Defined schema for stream input (CSV simulation).
   * Calculated demand score dynamically from incoming events.
   * Wrote output to JSON format in real-time.
4. **Visualization:**
   * Used **Bokeh** to plot pricing over time for selected parking lots.
   * Compared Model 1 vs. Model 2 across timestamps.

**ARCHITECTURE OVERVIEW**

The project architecture consists of the following components:

* **Data Source**: Historical CSV data representing parking lot metrics.
* **Preprocessing Layer**: Cleans and structures the data.
* **Model Layer**:
  + **Model 1** (Offline): Linear pricing logic applied using Pandas.
  + **Model 2** (Real-Time): Pathway-based streaming engine applying dynamic pricing rules.
* **Output & Visualization**: Results written as JSON/CSV and plotted via Bokeh

**CONCLUSIONS**

This project demonstrates how dynamic pricing can be made more responsive and intelligent using real-time data streams. While the baseline model serves as a simple benchmark, Pathway enables scalable and event-driven solutions that better align with real-world variability.

Assumptions Made

Base price of parking is initialized at ₹10.

Only car, bike, cycle, truck considered.

Traffic condition mapped numerically: low=0, medium=1, high=2.

Vehicle weight assumed:

* car=1.0, bike=0.5, cycle=0.3, truck=1.5

Demand is influenced by:

* **OccupancyRate**, **QueueLength**, **TrafficLevel**, **VehicleType**, **IsSpecialDay**