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by Consulting & Analytics Club, IIT Guwahati

Final Capstone Report: Dynamic Real-Time Parking Price Optimizer

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Introduction

This capstone project presents two pricing models that dynamically adjust parking prices in real-time using streaming data. Implemented using **Pathway** and visualized with **Bokeh**, these models use **from-scratch logic** leveraging only Pandas, NumPy, and Pathway.

Model Summaries

Model 1: Baseline Linear Pricing

- **Objective:** Simple linear increase in price with occupancy.
- **Formula:**
  $\text{Price} = 10 + \alpha \cdot \left(\frac{\text{Occupancy}}{\text{Capacity}}\right)$
- **Features Used:** Occupancy, Capacity
- **Base Price:** $10
- **Alpha (scaling factor):** 0.5
- **Purpose:** Reference model for comparison

Model 2: Demand-Based Pricing

- **Objective:** Responsive pricing based on real-time demand factors
- **Features Used:**
  - Occupancy rate
  - Queue length
  - Traffic condition
  - Special event indicator
  - Vehicle type
- **Formula:**

  demand_score = 0.5 * occupancy_rate + 0.3 * (queue_length / 10) + 0.2 * traffic_score + 0.4 * is_special_day + 0.1 * vehicle_weight

  price = 10 * (1 + clamp(demand_score, 0, 1))

Demand Function Explained

• Model 1:

- Demand is indirectly measured via occupancy ratio.
- As capacity fills, prices increase linearly.

• Model 2:

- Combines occupancy, traffic, and behavioral context.
- Queue length and special events add pressure.
- Vehicle type adjusts impact (bike < car < truck).
- Traffic levels mapped to numerical scores.
- Result is a demand score → scaled to affect price.

Assumptions

- **Base price:** Always starts at $10.
- **Vehicle types:** Only three types assumed (car, bike, truck).
- **Traffic levels:** Discretized to low, medium, high.
- **Queue lengths:** Normalized by max length (10 assumed).
- **Demand score:** Clamped between 0 and 1 to avoid erratic pricing.

Visual Justification (Bokeh)

Model 1 Visuals:

- Time vs Price Line Plot
- Daily Pricing Trends (per lot)
- Boxplots comparing competitor prices during peak hours
- Hourly Avg Bar Plot across all lots

Model 2 Visuals:

- Hourly Heatmap by Lot
- Top 5 Lot Pricing Trends
- Scatter Plot (Occupancy vs Price), colored by Hour

Architecture & Workflow

Real-Time Simulation:

- Used Pathway's replay_csv() for stream simulation
- Input rate set to 1000 rows/sec

Processing:

- Timestamps converted to datetime
- Feature engineering via Pandas
- Pricing logic applied using Pathway stream ops

Output:

- Streaming data converted to Pandas via `pw.debug.table_to_pandas()`
- Visualizations plotted using Bokeh

Tools Used

- **Google Colab**
- **Python (NumPy, Pandas)**
- **Pathway** (stream processing)
- **Bokeh** (visualization)

Conclusion

- **Model 1** serves as a simple, interpretable benchmark.
- **Model 2** adds realistic pricing logic based on demand.
- **Pathway** enables near real-time responsiveness.
- **Bokeh** helps visualize and justify the pricing strategy.

This project showcases practical applications of data streaming and pricing logic — without the need for black-box ML models.