Data-Driven Robust Taxi Dispatch Approaches

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- Goal: Develop a system level control framework, to incorporate data information with real-time control decisions, balance vacant taxis with minimum total idle driving distance, and consider model uncertainties

Problem: Real-time GPS information provides transportation network knowledge; non-cooperative taxi service, or a greedy algorithm are not efficient

Objectives: System level optimal performance:
- Balanced supply/demand ratio
- Minimal idle cruising distance
- Utilize data information with model uncertainties

Our Contributions:
First to design a receding horizon control (RHC) framework for large-scale taxi dispatch
- Both current and anticipated future costs
- Multi-objective: balance supply with minimum idle mileage

Uncertain demand model: robust dispatch formulations
- Data-driven modeling of demand uncertainties
- Theorem: robust optimization form to equivalent convex form

- Build the uncertainty set \( \mathcal{U}_\varepsilon \) given \( \varepsilon \) from the data set *
  1. The robust constraint is computationally tractable.
  2. The set \( \mathcal{U}_\varepsilon \) implies a probabilistic guarantee for \( \mathbb{P}^* \) at level \( \varepsilon \).

Theorem 1: Polytope uncertainty equivalent convex form

\[
\Delta := \{ A_1 r^1 + \ldots + A_r r^r \leq b, r^k \geq 0 \}
\]

\[
\min_{X^k,\alpha \geq 0} \sum_{k=1}^r \left( \sum_{j=1}^r X^k_j W_{ij} + X^k_j \alpha J \right) + b^T \lambda
\]

subject to \( A^T x \lambda - \beta \left( \sum_{k=1}^r X^k_j \alpha J \right) \geq 0 \)

\[
\text{constraints of (2), } k = 1, \ldots, r
\]

Theorem 2: SOC uncertainty set equivalent convex form

\[
\Delta = \{ (\tilde{x} + y + C^T w : 3y, w \in \mathbb{R}^r \text{ s.t. } \| y \|_2 \leq \gamma, \| w \|_2 \leq \lambda \}
\]

\[
\min_{X^k,\alpha} \sum_{k=1}^r \left( \sum_{j=1}^r X^k_j W_{ij} + \alpha J \right) + b^T \lambda
\]

subject to \( \gamma^T x + \Gamma^T \| y \|_2 \leq \lambda, \| y \|_2 \leq \lambda \),

\[
\alpha(x) \leq \epsilon,
\]

\[
\text{constraints of (2), } k = 1, \ldots, r
\]

Trade-off between probabilistic guarantee level and the average cost of robust solutions

Consider demand uncertainties:
The average demand supply ratio error is reduced by 31.7% with robust dispatch solutions

Consider demand uncertainties:
The average total idle mileage is reduced by 10.13% with robust solutions