Coping with Real-World Challenges in Real-Time Urban Traffic Control

Xiao-Feng Xie, S. Smith, G. Barlow, Ting-Wei Chen
The Robotics Institute, Carnegie Mellon University, Pittsburgh, Pennsylvania

Challenges
- Uncertainty and disturbances can significantly degrade the accuracy of real-time flow predictions
- Optimization of vehicle flows requires active attention to bus and pedestrian flows

Our Work
- Investigate real-world challenges in the context of SURTRAC, a live, urban adaptive signal system testbed
- Propose strategies for strengthening SURTRAC to better deal with real-world uncertainties and multi-modal traffic demands
- Evaluate the effectiveness and impacts of these strategies using both simulations and analysis based on field data

SURTRAC (Scalable Urban TRAFFIC Control) System

Schedule-Driven Intersection Control
- Treat each intersection as a single machine scheduling problem
- Use aggregate representation of traffic flows (as sequences of queues and platoons) to identify input jobs
- Use schedule to decide whether to extend or switch phase

Neighborhood Coordination Mechanisms
- Communicate schedules to downstream neighbors to give visibility of future input jobs
- Layer mechanisms for coping with mis-coordinated situations (e.g., spillover) to account for fact that schedules might change

The East Liberty Adaptive Signal Testbed

Network Characteristics
- Grid-like character in contrast to arterials settings
- Tightly coupled intersections impose a challenge for coordination in decentralized control
- A range of uncertainties and disruptions

System Performance and Robustness
- Pilot tests: 26% lower travel time, 41% lower wait time
- Inherent robustness for handling significant changes in traffic flow patterns over time
  - e.g., flow changes caused by the closing of the Highland Avenue bridge between Mar 4-Oct 23, 2013

Percentage increase in vehicle counts at B after the bridge closing

Schedule: Weekday

<table>
<thead>
<tr>
<th>Day</th>
<th>Before</th>
<th>Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mon</td>
<td>23.0%</td>
<td>23.0%</td>
</tr>
<tr>
<td>Tue</td>
<td>4.0%</td>
<td>11.0%</td>
</tr>
<tr>
<td>Wed</td>
<td>10.0%</td>
<td>17.0%</td>
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<tr>
<td>Thu</td>
<td>12.6%</td>
<td>21.0%</td>
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<tr>
<td>Fri</td>
<td>22.6%</td>
<td>32.6%</td>
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<tr>
<td>Sat</td>
<td>28.0%</td>
<td>40.0%</td>
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<tr>
<td>Sun</td>
<td>18.0%</td>
<td>21.8%</td>
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</tbody>
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Acknowledgements

The Heinz Endowments
Howard Heinz Endowment • Vera J. Heinz Endowment
Hillman Foundation

Strengthening Strategies

1. Queue Management
- Problem: Handle various forms of sensing uncertainty (e.g., detection errors, hidden flows from/to mid-block side streets)
- Approach: (1) Define states using detection information; (2) Adjust arrival counts dynamically based on arrival/departure ratio
- Result: Restore the performance to near optimal

2. Disruption Management
- Problem: The flow on a road might be temporarily blocked during the green period (e.g., caused by bus stops, or spillback)
- Approach: Treat disruption as a job delay in scheduling problem
- Result: (1) Optimize the efficiency for both vehicle and bus flows; (2) No need to define a number of heuristic decision rules

3. Minor Flow Management
- Problem: How to service minor flows more intelligently
- Approach: Hybrid control; major flows by the local scheduler, minor flows by an actuated mode with history-based prediction
- Result: Balance system adaptivity and robustness; keep efficiency for major flows; and ensure stability from minor flows

4. Pedestrian Flow Management
- Problem: Pedestrians are often ignored in vehicle-centric systems
- Approach: Vehicle-pedestrian mixed coordination protocol
- Result: Reduce pedestrian wait time and ensure coordination