Integrated Adaptive and Coordinated Freeway Traffic Control Using Multi-Agent Reinforcement Learning

Presented by: Kasra Rezaee
Supervised by: Prof. Baher Abdulhaili
University of Toronto
ITS Centre and Testbed
Freeway Traffic Control

5% - 10% drop in freeway throughput

Optimal traffic condition
Traffic Control Using Ramp Metering

• Ramp metering (RM) is the use of a traffic signal(s) employed on a ramp to control the rate at which vehicles enter a freeway

• Improved traffic flow and safety
  • Regulate number of vehicles entering
  • Smoothing out rate of entering vehicle
Ramp Metering Effect
Traffic Responsive RM – Local Algorithms
Traffic Responsive RM - Optimal Control
Current Algorithms' Problems

• Simple Algorithms (ALINEA)
  • Good performance with minimal reliance on network model
  • Hard to coordinate several ramps – lack of equity among users

• Complex Algorithms (Model Predictive Control)
  • Easy to handle coordination
  • Extensive reliance on network model – degraded performance in the presence of uncertainty
Reinforcement Learning (RL)

- Model-free control
- Learning based on experience – trial and error
  - update based on (expected reward – current stored value)
- No supervision required
  - A scalar reward is used

\[ Q(s, a) \]

**Q-Learning**
Result – Average Performance

- 15 simulations performed and the 5 in the middle were averaged:

<table>
<thead>
<tr>
<th>Performance Measures</th>
<th>Control Method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No ramp metering</td>
</tr>
<tr>
<td>$TTT$ ($veh. hr$)</td>
<td>2551</td>
</tr>
<tr>
<td>$TTT$ savings</td>
<td>-</td>
</tr>
<tr>
<td>Mainlinec $TTT$ ($veh. hr$)</td>
<td>2496</td>
</tr>
<tr>
<td>Average on-ramp waiting time ($min$)</td>
<td>&lt; 1</td>
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Multi-agent Reinforcement Learning

Communication
\{\text{states}, \text{Action}, \text{Reward}\}

Control Agent 1

Measurement
Action

Control Agent 2

Measurement
Action

Control Agent 3

Measurement
Action
Coordinated Control of Multiple On-ramps

- The Gardiner expressway test case
Future Directions

- Using Variable Speed Limits to control freeway mainline flow in conjunction with RM.
- Analysing RLRM performance in case of:
  - Spillback from downstream
  - Nonrecurring congestion
  - Over-saturation of network
Acknowledgement

- Loop detector information for simulation network calibration and evaluation