Real-time adaptive signal control for urban road networks

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Traffic Congestion Increases Fuel Consumption and Decreases Air Quality

- Costs $121 Billion per year in lost time and fuel consumption
- Results in 56 Billion pounds of CO$_2$ in emissions
- 40% of time spent on surface streets in urban areas is spent idling

Smarter Traffic Signals Can Help

- Traffic signal control improvements generally provide the biggest payoff for reducing congestion on surface streets
- Although not yet in wide use, *adaptive traffic control systems* are generally believed to hold most promise for improvement
Adaptive Traffic Signal Control for Urban Road Networks
Stephen F. Smith, Gregory J. Barlow, Xiao-Feng Xie, Zachary B. Rubinstein
www.surtrac.net

**Goal:** Real-time optimization of traffic flows for urban (grid) road networks

**Technical Approach:**
- Decentralized control
- Coordinated action

**Research Progress**
- 2010-11: Development of core approach; Simulation of performance on downtown Pittsburgh network
- 2011-12: East Liberty pilot deployment
- 2013-14: Expansion of pilot test site

**Benefits**
- True real-time response
- Multiple dominant flows
- Scalable, incremental deployment
- Multi-modal optimization
1. Current traffic conditions are extracted from sensor data streams.

2. System computes phase schedule that optimizes flow at intersection and sends commands to the controller when it is time to change phases.

3. Schedule is communicated to downstream neighbors to indicate what is coming.

4. **Rolling Horizon:** Scheduling cycle is repeated every few seconds.
Penn Circle Pilot Study

Test Site
- Developing area of Pittsburgh with changing traffic patterns and volumes
- Mixed commercial, retail and residential land use
- 9 recently upgraded intersections with camera detection

Partners
- The Heinz Endowments
- City of Pittsburgh
- East Liberty Development Corp.
- Traficon Traffic Video Detection
- Traffic Control Products
Initial Deployment

- Camera
- Controller
- Video Processing Boards
- Network connection to fiber optic cable
- Surtrac Processor

Carnegie Mellon
SURTRAC in Action
East Liberty Pilot Test Results

- **Performance comparison to current coordinated-actuated timing plans**
  - Series of before and after drive-through runs over 12 routes at 4 different periods of the day
  - GPS tracking of travel times and number of stops
  - Traffic volume data used to combine data from different routes

- **Summary Results:**

<table>
<thead>
<tr>
<th>% Improvement</th>
<th>Travel Time</th>
<th>Speed</th>
<th># of Stops</th>
<th>Wait Time</th>
<th>Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM rush</td>
<td>30.11%</td>
<td>33.78%</td>
<td>29.14%</td>
<td>47.78%</td>
<td>23.83%</td>
</tr>
<tr>
<td>Mid Day</td>
<td>32.83%</td>
<td>48.55%</td>
<td>52.58%</td>
<td>49.82%</td>
<td>29.00%</td>
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<tr>
<td>PM rush</td>
<td>22.65%</td>
<td>27.45%</td>
<td>8.89%</td>
<td>35.60%</td>
<td>18.41%</td>
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<tr>
<td>Evening</td>
<td>17.52%</td>
<td>27.81%</td>
<td>34.97%</td>
<td>27.56%</td>
<td>14.01%</td>
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<tr>
<td>Overall</td>
<td>25.79%</td>
<td>34.02%</td>
<td>31.34%</td>
<td>40.64%</td>
<td>21.48%</td>
</tr>
</tbody>
</table>
CO, NOx and VOC Emissions

• Per Day
  – Number of vehicles: 29,940
  – Fuel savings: 247 gallons
  – Reduction in toxic emissions (CO, NOx, VOC): 24.67 kg
  – Reduction in CO\(^2\) emissions: 2.2 metric tons

• Per year
  – Fuel savings: 64,580 gallons
  – Toxic emissions: 6.44 m. tons
  – CO\(^2\) emissions: 577.8 m. tons
Bakery Square Expansion

- Operational since Nov. 2013
- Nine additional intersections
  - Moving east along Penn Ave. around Bakery Square to Fifth Ave.
- Same evaluation methodology
- Summary Results:

<table>
<thead>
<tr>
<th>% Improvement</th>
<th>Travel Time</th>
<th>Delay</th>
<th># of Stops</th>
<th>Wait Time</th>
<th>Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM rush</td>
<td>17.02%</td>
<td>26.31%</td>
<td>33.81%</td>
<td>32.76%</td>
<td>16.21%</td>
</tr>
<tr>
<td>Mid Day</td>
<td>21.35%</td>
<td>34.04%</td>
<td>37.23%</td>
<td>38.09%</td>
<td>17.62%</td>
</tr>
<tr>
<td>PM rush</td>
<td>28.61%</td>
<td>39.35%</td>
<td>44.87%</td>
<td>46.40%</td>
<td>24.77%</td>
</tr>
<tr>
<td>Overall</td>
<td>24.10%</td>
<td>35.41%</td>
<td>40.42%</td>
<td>41.59%</td>
<td>20.69%</td>
</tr>
</tbody>
</table>
2014-15 Expansion Plans

2014-15:
• 23 Intersections
• Hillman, Heinz, RK Mellon, UMPC

Fall 2014:
• 6 intersections
• Heinz, RK Mellon

Fall 2014:
• 2 Intersections
• URA

• Scalability test of 49 intersections in early 2015
Current Research Directions

• Multi-modal traffic flow optimization
  – Real-time detection and response to buses and pedestrians

• Optimization for environmental impact

• Monitoring and shaping traffic flows
  – Communication with vehicles and integration with route choice
  – Real-time incident detection and congestion mitigation

• Real-time use of traffic data
  – Self-monitoring traffic networks