New Dimensions in Intersection Control with CAVs

Henry Liu
Professor, Civil and Environmental Engineering
Director, Center for Connected Automated Transportation
University of Michigan, Ann Arbor

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Intelligent System: Closed-loop Iterative Evaluation-Optimization

Evaluation

- Delay
- Stops
- Queue length
- Oversaturation

Sensing

- Infrastructure sensors
- Mobile sensors

Optimization

- Splits
- Cycle length
- Offset
- Phase sequence
- Time-of-day plan

Implementation
Current Traffic Signal Systems

- An open loop control system.
- Majority of transportation agencies **DO NOT** monitor or archive traffic signal data.
- Benefit/Cost ratio of signal re-timing is about **40:1**; but usually traffic signal systems will be re-timed every **2 ~ 5 years**.
Key to the Problem

Continuous, Reliable, and Cheap Data
SMART-Signal 1.0: Systematic Monitoring of Arterial Road Traffic Signal

Nowadays many new controllers can provide high resolution data

Event-based high resolution data

TS-1 type cabinet

MnDOT Implementation

Problem Remains

- Many traffic signals in the US are fixed-time
  - NO SENSOR!
- For actuated or adaptive signals, detectors have to be installed and maintained properly
  - Prone to detector errors and failures
Connected Vehicles

Connected vehicles can communicate with other connected vehicles and infrastructure. The wireless communications technology could include:

- 5.9 GHz DSRC
- Cellular networks
- Other wireless technologies such as Wi-Fi, satellite, and HD radio

Source: USDOT
Opportunity and Challenge with CV

• Connected vehicles are used as mobile sensors.
• However, we usually have a very low percentage of connected vehicle data.
• Volume estimation is the key to optimize signal.
Traffic Volume Estimation

Time-Space Diagram Generation

- With arrival profile & volume from upstream int., we can generate vehicle arrival times at the link entrance.
- With arrival times & signal status, we can generate TS-Diagram
SMART-Signal 2.0: Systematic Monitoring of Arterial Road Traffic Signal

- Traffic state estimation
- Optimization
- Signal retiming
- Vehicle trajectory collection and performance evaluation

Iterative learning
Comparison to existing signal control approaches

• Existing signal control approaches
  – Fixed parameter control (pre-timed & vehicle actuated)
  – Real time adaptive control
• Signal control with iterative learning
  – Iteration interval could be monthly/weekly/daily, etc
• Continuous, reliable, and cheap data is the KEY
Didi Data in China

400M+ Users
400+ Cities
14B+ Daily location data
20B+ Daily route planning
20M+ Daily orders

70T vehicle trajectory data daily
济南经十路 (City of Jinan)
济南经十路: Offset optimization

Results of offset optimization: before-after comparison

<table>
<thead>
<tr>
<th></th>
<th>PM peak</th>
<th>AM peak</th>
<th>Off-peak</th>
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<tbody>
<tr>
<td>Mainline traffic delay</td>
<td>-21.87%</td>
<td>+3.53%</td>
<td>-5.85%</td>
</tr>
<tr>
<td>Overall traffic delay</td>
<td>-10.94%</td>
<td>-10.73%</td>
<td>-6.32%</td>
</tr>
<tr>
<td>Queue spillover</td>
<td>-88.2%</td>
<td>-80.1%</td>
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济南纬十二路: Offset, split and cycle length optimization

Before-after comparison

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<th>PM peak</th>
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<tbody>
<tr>
<td>Mainline traffic delay</td>
<td>-13.3%</td>
<td>-27.85%</td>
</tr>
<tr>
<td>Overall traffic delay</td>
<td>+1.07%</td>
<td>-8.98%</td>
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The path toward connected vehicles will ultimately lead to automated vehicles.

**Connected Vehicle**
Communicates with nearby vehicles and infrastructure; Not automated

**Connected Automated Vehicle**
Leverages autonomous automated and connected vehicles

**Autonomous Vehicle**
Operates in isolation from other vehicles using internal sensors

*Source: USDOT*
Towards Next Generation Traffic Control Systems

- Current Practice: Fixed time/actuated/adaptive Signal
- Detector-free signal operation
- Spatial and temporal signal control
- Lane reassignment

Infrastructure Adaptation

Connected and Automated Vehicles

Connected Vehicles

Regular Vehicles

Current Practice - Fixed time/actuated/adaptive Signal

UNIVERSITY OF MICHIGAN
Conclusions

• Continuous and reliable data is the key to closed-loop traffic control systems.

• Vehicle trajectory data will become more available in the future. How to incorporate vehicle trajectory data into traffic signal control system deserves further study.

• Great opportunities exist for traffic control vendors to collaborate with IT companies such as DiDi.
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Contact Information

Henry Liu, Ph.D.
Professor, Department of Civil and Environmental Engineering,
Research Professor, Transportation Research Institute – UMTRI
University of Michigan, Ann Arbor
2320 G.G. Brown, 2350 Hayward Street
Phone: 734-764-4354
Fax: 734-764-4292
Email: henryliu@umich.edu