Signalized intersection control in a connected and autonomous vehicle environment

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Traditional approaches of traffic signal control

• Fixed-time
  • Not very flexible
  • Unique plan needed for every demand pattern

• Actuated
  • Flexible within a pre-defined range to capture minor variations
  • Relies on information from fixed sensors

• Adaptive
  • Robust to larger variations in travel demand patterns
  • Relies on (aggregated) information from fixed sensors
Connected vehicles offer richer source of information that can be used to inform traffic signal timings…

- Vehicles can provide actual locations and speeds to signal controller

- Information may be transmitted across multiple signals for coordinated control

http://www.dot.state.fl.us/trafficoperations/ITS/Projects_Deploy/CV/Connected_Vehicles.shtm
…and information can be provided back to the vehicles to help further improve operations

• Speed guidance can be provided to human-driven or autonomous vehicles to keep traffic running smoothly (minimize stops)

http://fortune.com/2016/12/06/audi-traffic-lights-vegas/
Challenges

• Most existing approaches:
  – Assume 100% CAV penetration
  – Either:
    • Very flexible but do not adhere to traditional signal phasing options (e.g., signal free methods) and are not appropriate when non-CAVs present
    • Adhere to traditional signal phasing options but are not very flexible
  – Assume full compliance with speed guidance
  – Does not account for multimodal traffic
Goal

- Develop a CAV-based signal control algorithm that:
  - Works under <100% CAV penetration
  - Leverages CV information to identify non-CVs
  - Adopts traditional phasing options with flexible phasing sequences
  - Provides speed guidance to both human-driven and autonomous vehicles
  - Can consider multimodal traffic
CV information used to understand where CVs are located…

- At regular intervals (e.g., every 10 sec) CVs communicate to signal:
  - Location
  - Speed

Legend:
- CAV
- Non-CAV

Zone of Interest

Vehicles on the road
...and to identify presence of some other non-CVs

Legend:
- **CAV**
- **Non-CAV**

Zone of Interest

**Vehicles on the road**

**Input to the algorithm**
Naturally occurring vehicle platoons are identified

- Platoons are vehicles assumed to travel through the intersection together based on:
  - Headway
  - Spacing
Naturally occurring vehicle platoons are identified

- **Dark blue:** autonomous
- **Light blue:** connected but not autonomous
- **Yellow:** conventional
- **Rectangle:** No platoon
- **Oval:** Platoon
The sequence platoons are allowed to discharge then determines the signal phasing and timing plan.
Optimal sequence can be determined by enumerating all options…
...intelligently enumerating a subset of options...
...or by using advanced heuristics like genetic algorithms to find the optimal sequence
The CV-based control reduces queues and delays at the intersection

| Fixed-time control | Flexible CAV algorithm |
Algorithm can also leverage various vehicle types/technologies to further improve operations

1. All vehicles

2. Connected vehicles

3. (Human-driven) Non-connected vehicles
Speed guidance can be provided to help vehicles arrive to intersection only when they can discharge.
Simulation accounts for human drivers willingness and ability to adhere to provided speed guidance.
Provision of speed guidance reduces number of stopping maneuvers performed.
Analysis of trajectories verifies that speed guidance to human vehicles performs slightly worse than to AVs.
When AVs are present, intersection operates even more efficiently...

- Fixed-time control
- Algorithm with AVs
Results suggest both vehicular delay and number of stops can be reduced using CV-based control...

- 0% AVs
...and the benefits only improve as vehicles become autonomous

- 20% AVs
Current work focuses on adding multimodal traffic, such as pedestrians...
Thank you!

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