Evaluation of Traffic Light Priority for Trucks on Traffic

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Why Priority for Trucks

- Why priority?
  - Slow dynamics and large size
  - Long intersection clearing time
  - Air pollution
Why Priority for Trucks

• Previous Work
  – Bus Priority Signal Control
    • Passive Priority vs Active Priority
  – Adaptive Signal Control Systems
    • LHOVRA
    • OPAC
    • RHODES
  – Model-based Approach Questions
    • Nonlinear and Non-explicit Traffic Flows
    • Difficult Cost Model (Delay, Environmental Emissions, …)
Why Priority for Trucks

• **Objective**
  • Propose a Co-Simulation, Optimization, Control Approach for traffic light priority system for trucks that benefits all vehicles involved

• **Methodology**
  – Take into account the differences between trucks and passenger cars
  – Simulation-based traffic state prediction
  – Multi-agent design for the scalability issue
Signal Priority System Architecture

- Traffic Flow Observer
- Passive Priority Module
  - Simulation-based Optimization
- Baseline Signal Plan
- Active Priority Module
  - Action Decision Process
- Signal Generation
Passive Priority Module

• Simulation Based Optimization

- Why use simulation
  - Nonlinear and non-explicit state predication
  - Easy to compute cost values

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Passive Priority Module

- **Multi-Agent Simulation based Control**
  - **State Predication:**
    \[
    X_{t+1}^i = f^i \left( X_t^i, U_t^i, U_{t-1}^i, W_t \right)
    \]
  - **Optimal Input Decision:**
    \[
    U_t^i = \arg \min_{U_t^i} c^i \left( X_{t:t+p}^i, U_{t:t+p}^i \right)
    \]
  - **Cost Function:**
    \[
    c^i \left( X_{t:t+p}^i, U_{t:t+p}^i \right) = \omega^T P_{t:t+p}^i
    \]
  - **Performance Criteria**
    - Average vehicle delay and stop frequency
    - Environmental Emissions

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Passive Priority Module

• **Optimizer Algorithms:**
  – Gradient-based family algorithms
    • Fast convergence but sensitive to discontinuities
  – Population-based family algorithms
    • Genetic algorithm, Evolutionary programming…
    • Not attracted by local optima but large number of simulations
    • Global minimum cannot be guaranteed
  – Trajectory search family algorithms
    • Simulated annealing, Tabu search, Pattern search…
    • Easy to implement but may be attracted by local optima
Active Priority Module

- Active Priority Scenario

- Priority Request
- Priority Response

- Priority Actions
  - Early Green
  - Green Extension
  - Phase Insertion
Active Priority Module

• Current Vehicle Queue: \( \theta_t = (\theta_1, \theta_2, \ldots, \theta_n) \)

• Action Decision (0 – No, 1 - Yes): \( a_t = \{a_1, a_2, a_3, \ldots, a_r\} \)

• Objective Function (weighted sum of future queues):

\[
R_a(\theta_t, a_t) = \frac{1}{T} \sum_{i} \int_{t}^{t+T} w_i \theta_i(\theta, a, \tau) d\tau
\]

\[
w_i = \frac{N_{icar} + wN_{itruck}}{N_{icar} + N_{itruck}}
\]

- \( n \) – No of directions
- \( r \) – No of approaching trucks that need priority
- \( w \) – Weight of a truck

• Optimal Decision Policy

\[
a_t = \arg \min_{a_t} R_a(\theta, a_t)
\]
Isolated Intersection Results

Average Delay (All)

Average # of Stops (All)

Average Delay (Cars)

Average # of Stops (Cars)

Average Delay (Trucks)

Average # of Stops (Trucks)
Isolated Intersection Results

- **Average Delay (All)**
  - No-Priority
  - Passive
  - Active
  - 20% / 300 / 20% / 500 / 20% / 800

- **Average # of Stops (All)**
  - No-Priority
  - Passive
  - Active
  - 20% / 300 / 20% / 500 / 20% / 800

- **Average Delay (Cars)**
  - No-Priority
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- **Average Delay (Trucks)**
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  - 20% / 300 / 20% / 500 / 20% / 800

- **Average # of Stops (Trucks)**
  - No-Priority
  - Passive
  - Active
  - 20% / 300 / 20% / 500 / 20% / 800

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Networked Intersections

Road Network

VISSIM Network

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## Networked Intersections (3% Truck)

<table>
<thead>
<tr>
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<th>Controller</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Fixed Time</td>
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<tr>
<td>Avg. Delay/Veh (sec)</td>
<td>85.4</td>
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<tr>
<td>Avg. Delay/Car (sec)</td>
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<tr>
<td>Avg. Delay/Truck (sec)</td>
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<td>Avg. Stops/Veh</td>
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<td>Fuel Trucks (g/km)</td>
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<td>Fuel cars (g/km)</td>
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<td>Fuel all veh. (g/km)</td>
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<tr>
<td>CO2 Emis. All (g/km)</td>
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<tr>
<td>NOx Emis. All (g/km)</td>
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## Networked Intersections (20% Truck)

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<td>4.22</td>
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<td>Avg. Stops/Car</td>
<td>4.31</td>
<td>2.68</td>
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<td>Avg. Stops/Truck</td>
<td>3.96</td>
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<td>Fuel Trucks (g/km)</td>
<td>494.4</td>
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<td>Fuel cars (g/km)</td>
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<td>Fuel all veh. (g/km)</td>
<td>179.0</td>
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<td>CO2 Emis. All (g/km)</td>
<td>468.0</td>
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<td>NOx Emis. All (g/km)</td>
<td>1.11</td>
<td>0.88</td>
<td>0.84</td>
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Conclusion

• Contributions:
  – Proposed A truck signal priority system integrating passive and active priority strategies
  – Improved network performance and environmental impacts by evaluation of microscopic simulation

• Future work
  – Study more powerful searching algorithm
Thanks