Feedback Control Speed Harmonization Algorithm: Methodology and Preliminary Testing
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Introduction
The rapid growth of both traffic and freight volumes increases the pressure of transportation systems significantly. Recently, most urban transportation systems have experienced congested conditions on a regular basis and provide increasingly unreliable services, such as heavy delay of daily trips, capacity drops, high emissions and fuel consumption, high risk of incidents, etc. Aimed at mitigating traffic congestion, proactive operation strategies, a fully integrated, multimodal, and multi-jurisdictional manner, have been widely implemented on a corridor-wide or region-wide basis. Intelligent transportation system (ITS) is one effective tool to implement proactive operation strategies. ITS can deploy various dynamic actions/strategies based on prevailing and anticipated conditions to prevent, delay, and/or minimize breakdown conditions thereby optimizing the effectiveness, efficiency and safety of the transportation systems.

Research Objectives
• The objective of speed harmonization is to dynamically adjust maximum appropriate vehicle speeds in response to downstream congestion caused by bottlenecks to maximize the discharge flow rates of bottlenecks as well as reducing travel delay, fuel consumption, and emissions. The strategy makes use of the frequently collected and rapidly disseminated multi-source data drawn from connected travelers, roadside sensors, and infrastructure.

Our Work
1. Develop a SH algorithm based on a feedback control system and V2I communications to provide advisory speed limits for connected vehicles to prevent capacity drop at bottlenecks.
2. Investigate the effect of the SH algorithm on improving the discharge flow rates of bottlenecks, reducing delay, fuel consumption, and emissions.

Methodology
Speed harmonization is implemented to improve the discharge flow rates of bottlenecks as well as reduce traffic delay and emissions and fuel consumption. The strategy makes use of the frequently collected and rapidly disseminated multi-source data drawn from connected travelers, roadside sensors, and infrastructure. The objective of speed harmonization is to dynamically adjust maximum appropriate vehicle speeds in response to downstream congestion caused by bottlenecks to maximize the discharge flow rates of bottlenecks as well as reducing travel delay, fuel consumption, and emissions. The strategy makes use of the frequently collected and rapidly disseminated multi-source data drawn from connected travelers, roadside sensors, and infrastructure.

Simulation
Base Scenario (No Control)
Speed Harmonization
Vehicle Trajectories
Speed Profiles
Density Profiles

Table 1: Benefits of the SH algorithm

<table>
<thead>
<tr>
<th>Measurement</th>
<th>No Control</th>
<th>SH algorithm</th>
<th>Diff (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delay (s/veh)</td>
<td>71.24</td>
<td>57.05</td>
<td>-19.92</td>
</tr>
<tr>
<td>Fuel (g/km)</td>
<td>0.125</td>
<td>0.119</td>
<td>-5.24</td>
</tr>
<tr>
<td>HR (g/km)</td>
<td>0.254</td>
<td>0.258</td>
<td>-1.60</td>
</tr>
<tr>
<td>CO (g/km)</td>
<td>6.437</td>
<td>6.736</td>
<td>4.63</td>
</tr>
<tr>
<td>NOx (g/km)</td>
<td>0.297</td>
<td>0.301</td>
<td>-1.98</td>
</tr>
<tr>
<td>CO2 (g/km)</td>
<td>281.2</td>
<td>265.5</td>
<td>-5.59</td>
</tr>
</tbody>
</table>

Conclusion
1. This study develops a dynamic SH algorithm to prevent the generation of capacity drop and to mitigate the existing capacity drop at bottlenecks;
2. The SH algorithm increases the discharge flow rate of bottleneck about 7% and reduces the delay by up to 20%.
3. Applying the algorithm can also reduce fuel consumption and emissions.