Ming Hsieh Department of Electrical Engineering

Combined Variable Speed Limit and Lane Change Control for Highway Traffic

Yihang Zhang, Petros Ioannou

Electrical Engineering/Controls

USC Viterbi School of Engineering

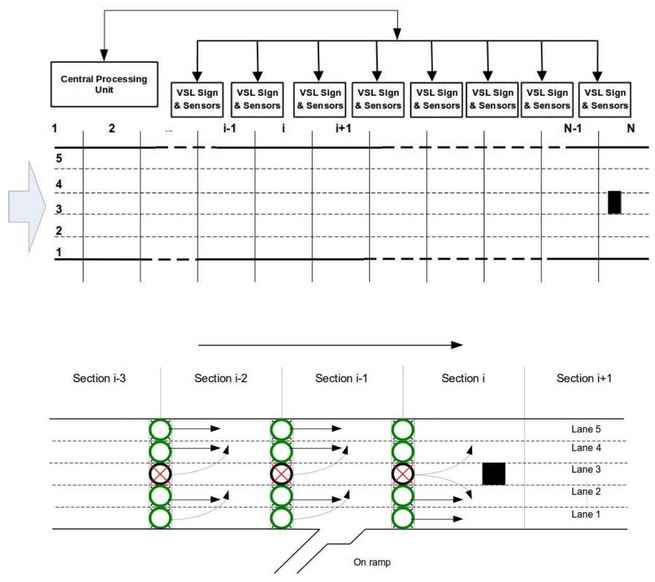
Concepts & Motivations

VSL Control

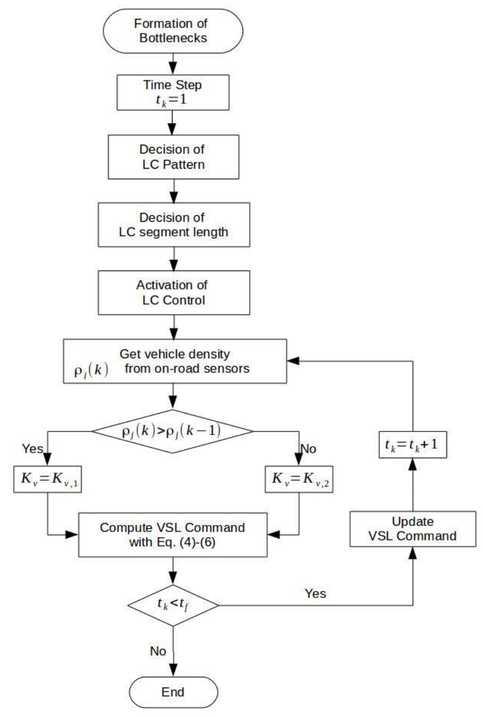
LC Control

- Non-model-based VSL control not able to improve traffic mobility and environmental impact of highway traffic
- Model-based VSL methods are not robust to system disturbance therefore effects are controversial in field experiments
- Combine VSL and LC control to improve traffic safety, mobility, reduce fuel consumption and tailpipe emission.

System Structure



Design Flow Chart



VSL Control Law

- PI control response to vehicle density disturbance

$$\bar{V}_{R,i}(k) = V_{R,i}(k-1) + K_v\left[\sum_{j=i+1}^{N+1}\rho_j(k-1) - \sum_{j=i+1}^{N+1}\rho_j(k)\right]$$

- Constraints on VSL commands
  Variable speed limit may lead to unsafe operations on road if there is no proper constraints.

$$V_{R,i}(k) = \begin{cases} V_{R,i}(k-1) - C_v, & \text{if } \bar{V}_{R,i}(k) \le V_{R,i}(k) - C_v \\ \bar{V}_{R,i}(k), & \text{otherwise} \end{cases}$$

$$V_{\min} \le V_{R,i}(k) \le V_{\max}$$

- Variable Proportional Gain

the proportional gain *Kv* decides how fast the speed limit rises or drops with the variation of downstream density. It should depend on traffic volume and the variation of vehicle density.

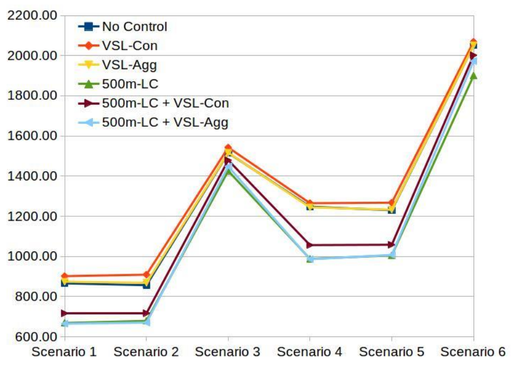
$$K_v = \begin{cases} K_{v,1}, & \text{if density increase} \\ K_{v,2}, & \text{if density decrease} \end{cases}$$

Experiment Design

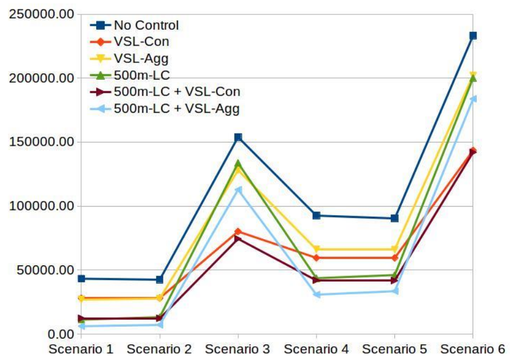
SIMULATION SCENARIOS

Scenario No.	Traffic Demand	Bottleneck Pattern
1	1600 veh/hr/lane	Lane 3 Closed
2		Lane 4 Closed
3		Lane 3&4 Closed
4	1800 veh/hr/lane	Lane 3 Closed
5		Lane 4 Closed
6		Lane 3&4 Closed

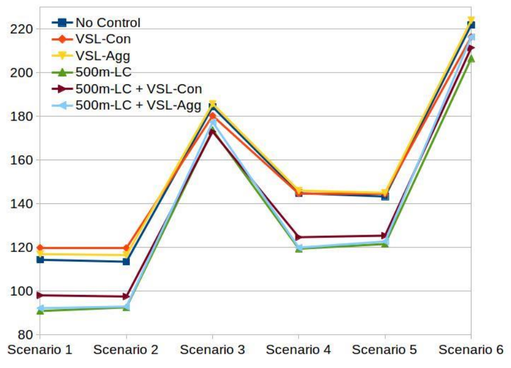
Evaluations



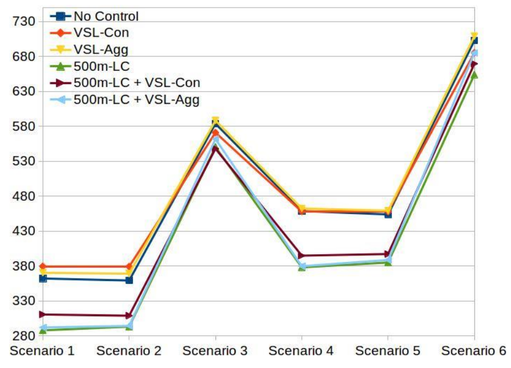
Total Travel Time (hr)



No. of Stops



Average Fuel Consumption (g/km/veh)



Average CO2 Emission (g/km/veh)

DIFFERENT LC SEGMENT LENGTH IN SCENARIO 3

	No Control	500m-LC + VSL-Agg	Improvement	1000m-LC + VSL-Agg	Improvement
Total Travel Time (h)	2051.59	1972.44	-3.9%	1698.49	-17.2%
Average flow rate (veh/hr)	4744.75	4893.90	3.1%	5315.00	12.0%
No. of Stops	233222.40	183804.60	-21.2%	136049.00	-41.7%
No. of lane Change	38169.35	39355.10	3.1%	41408.60	8.5%
Fuel Use (g/km/veh)	221.8456	216.2637	-2.5%	187.8157	-15.3%
CO2 (g/km/veh)	702.797	685.0933	-2.5%	594.9505	-15.3%
Nox (g/km/veh)	0.064	0.0729	13.9%	0.0702	9.7%

Conclusion & Discussion

- LC control provides lane change recommendation in an open loop manner based on bottleneck formation.
- A non-model based reactive PI VSL controller is adopted therefore it is more robust to traffic disturbance and avoids high computation capacity of proactive VSL controllers.
- Necessary constraints and boundaries on VSL command are also introduced into VSL control law to ensure drivers can follow it safely.
- To make VSL controller adaptive to vehicle density variations, variable proportional gain are applied.
- The combined control method can significantly improve traffic mobility and safety, reduce fuel consumption and tailpipe emission, which is better than apply VSL and LC control alone.
- Future study on this topic may focus on developing an algorithm to decide and optimize the controller parameters for digging more potential of this combined VSL and LC control method.

yihangzh@usc.edu

Ming Hsieh Institute
Ming Hsieh Department of Electrical Engineering