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A Variable Speed Limit Strategy based on Lagrangian Traffic Indicators Resulting from Connected Vehicles : Application of the SPECIALIST Algorithm

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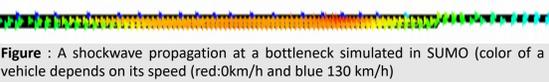
Introduction

Context

Variable Speed Limit (VSL) systems are dynamic traffic control strategies that dictate speed restrictions upstream of a congestion area to **artificially reduce downstream throughput** and dampen congestion waves to **improve traffic conditions**. They have shown their benefits in:

- traffic homogenization for safety purposes
- traffic optimization for efficiency purposes
- traffic smoothing for environmental purposes.

Most of the methods **use loop sensors** to evaluate current traffic conditions i.e., aggregate data as flow or average speed. Thus, the accuracy and efficiency of the VSL control **rely on the number of detectors** on the network, their spacing, and their discrete location.



Positioning

The emergence of Intelligent Transport Systems (ITS) and Connected Vehicles (CV) is promising new traffic control strategies. Thus, information generated from CV can be used to estimate traffic states to deliver control by ensuring direct communication between the Road Side Unit (RSU) and CVs. Such a VSL system could thereby reduce detectors' installation and maintenance costs.

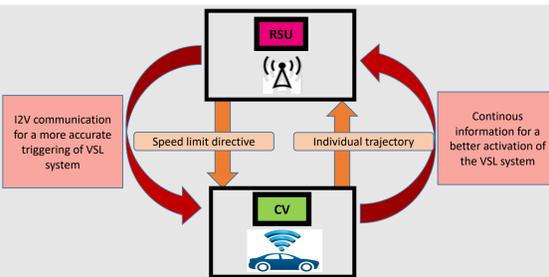


Figure : New VSL system based on CV and I2V communication potentials

Objectives

- To explore the feasibility of implementing a VSL system based on Lagrangian indicators generated by CV
- To assess the performance of such a system

Methodology

Eulerian Approach

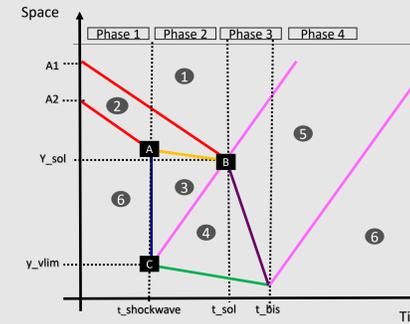


Figure : Implementation of the SPECIALIST algorithm with Eulerian indicators

Lagrangian Approach

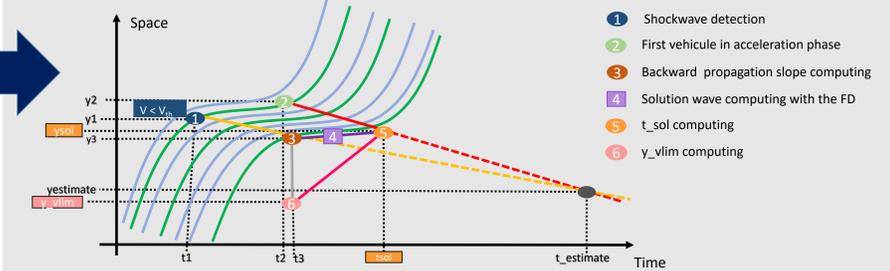


Figure : Implementation of the SPECIALIST algorithm with Lagrangian indicators ie individual CV trajectories

At first, a VSL system based on an Eulerian approach has been reproduced. It comes from the SPECIALIST algorithm [1] based on shockwave theory. It identifies :

- the shockwave detection phase
- the computing phase of the distance and the time of speed limit application computation.

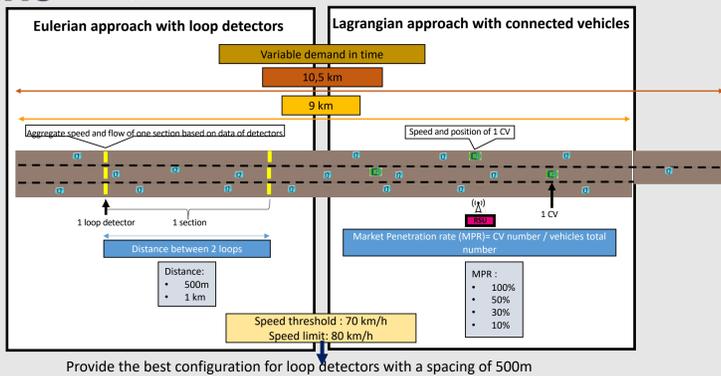
It uses the strong relation with the Fundamental Diagram and Space-Time diagram to compute the solution.

In this approach, the aim is to use individual CV trajectories to evaluate and predict traffic states.

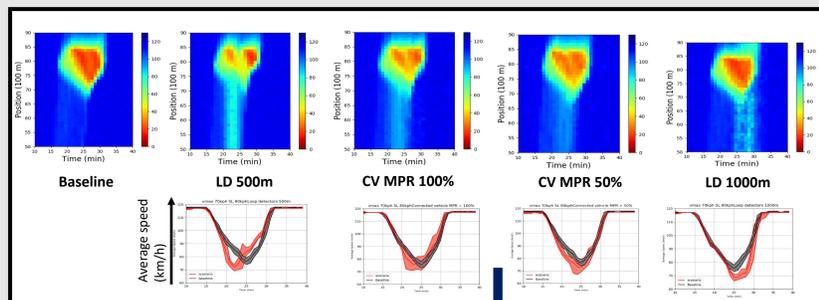
After the detection and computing phases, the RSU directly communicates the speed limit to the CVs.

Results

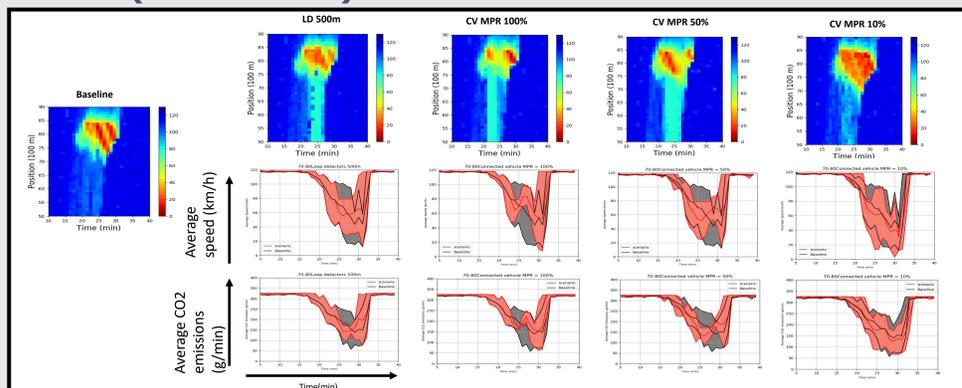
Scenario



Average VSL system performance (10 simulations) – variations between simulations



VSL system performance comparison (1 simulation) – variations between vehicles

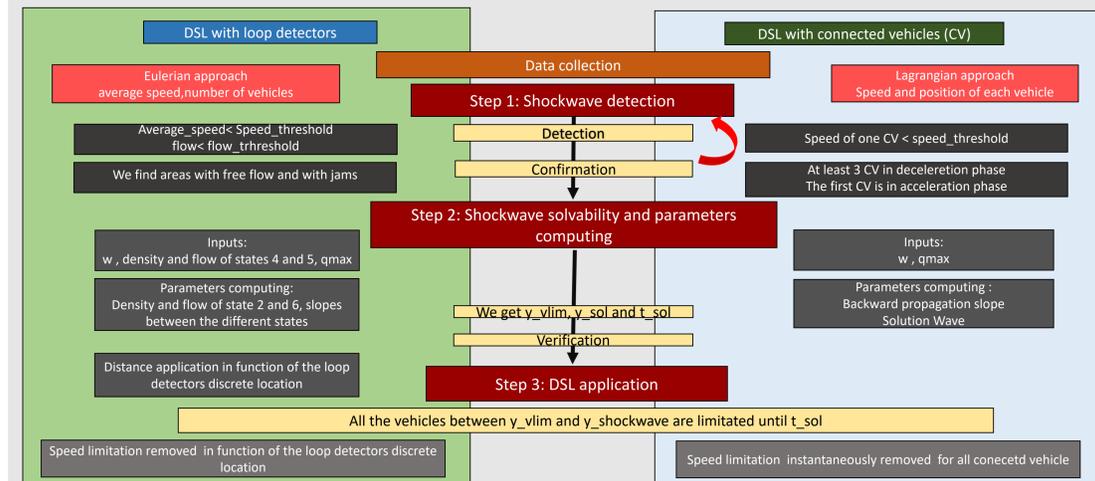


- If the detectors' spacing is larger than 500m (ie 1000 m) the VSL system based on an Eulerian approach is not efficient anymore
- With the best configuration for the two VSL systems (MPR 100% and LD 500m) return to the free flow earlier than without control (VSL system average speed > baseline average speed)

The VSL system based on a Lagrangian approach :

- is efficient to resolve the first shockwave as well as the one based on the Eulerian approach with a MPR >= 50%
- provides a better speed and CO₂ emissions homogenisation than Eulerian approach.

Comparison between the two approaches



Conclusion

- Proposed VSL system based only on Lagrangian indicators resulting from CV;
- Comparable performances between the VSL system based on a Lagrangian approach and the one based on Eulerian indicators resulting from loop detectors;
- Brings out the potential to implement efficient traffic control strategies based on I2V communication.

References

[1] A. Hegyi, S. P. Hoogendoorn, M. Schreuder, H. Stoelhorst, et F. Viti, « SPECIALIST: A dynamic speed limit control algorithm based on shock wave theory », in 2008 11th International IEEE Conference on Intelligent Transportation Systems, Beijing, China, oct. 2008, p. 827-832.
 [2] E. F. Grumert, A. Tapani, et X. Ma, « Characteristics of variable speed limit systems », Eur. Transp. Res. Rev., vol. 10, n° 2, juin 2018, p. 21.