Abstract

Nowadays, connected cars are uncommon on our streets, but their percentage is expected to grow uninterruptedly. These devices would provide a lot of data in real-time that can be used for road operators to improve the traffic. This research is focused on one of these applications, which is shockwave damping on freeways. This work evaluates two shockwave detection methods that use probe vehicle data and fixed sensors data and one mitigation algorithm that uses variable speed limits to resolve shockwaves. This paper analyses through microscopic traffic simulation the performance of the selected algorithms and how their parameters affect them in several scenarios. Also, the effect of the penetration rate of probe vehicle data is evaluated. Finally, the best algorithm with the best parameters configuration is applied to a realistic model of the AP7 freeway in Girona (Spain). The obtained results show that the algorithms applied greatly reduce the total travel time in this network.

Keywords: shockwave detection; shockwave damping; probe vehicle data; traffic simulation.

1. Introduction

A shockwave is a traffic phenomenon that happens in high-density roads (non-urban) when a perturbation occurs, like an abrupt change of lane or an accidental breaking of a vehicle. One key difference between shockwaves and regular jams is that although shockwaves can be produced by bottlenecks that reduce the capacity of a road (or because of a jam), they can remain in the road much after this bottleneck has been resolved. Nevertheless, it is remarkable the fact that shockwaves do not require a physical bottleneck to appear. The presence of a shockwave can reduce the maximum flow of a road up to 30% (Hegyi et al. (2008)). Thus, mitigating them the efficiency of freeways would be greatly improved which would provide great benefits from an economical and environmental point of view.

2. Related work and research contribution

The previous step for suppressing shockwaves is to detect them. So, in this paper, we present not only mitigation algorithms but also detection ones that have been proposed in the literature. In most of the older works, authors consider detection algorithms based on fixed sensors (such as magnetometers or induction loops). Nowadays, almost all authors consider that Probe Vehicle Data (PVD) is available. PVD is the data that a connected car sends. This data usually consists of speed and position. The accuracy of algorithms based on PVD depends on the connected car penetration rate.

There are mainly two ways to detect shockwaves. The first one consists of using the data available to estimate the state of the flow (speed, density and flow) and then, search for shockwaves in the regions with lower speeds and higher densities. This is what we do using Adaptive Smoothing Method (ASM) to estimate the state of the flow. This method, presented by Treiber and Helbing (2002), can estimate the speed at any point of the road given measures from fixed
sensors. It was later extended by Van Lint and Hoogendoorn (2010) to merge data from different sources (PVD and fixed sensors, for instance). Other methods directly use the data available to detect the boundaries of a shockwave (head and tail). One example of this is the method presented in Izadpanah et al. (2009), where shockwaves are detected only with PVD data.

Once shockwaves have been detected, there are several algorithms in the literature to damp them. SPECIALIST (Speed Controlling Algorithm using Shockwave Theory) was proposed by Hegyi et al. (2008). It uses variable speed limits (VSL) to mitigate the shockwaves. It was tested on a road by Hegyi and Hoogendoorn (2010) solving 80% of the shockwaves that the algorithm considered as solvable. It was later extended in Hegyi et al. (2013) to consider PVD and video-based monitoring.

The proposal is to implement some of the mentioned literature methods to perform shockwave detection and mitigation in freeways using PVD and fixed sensors and evaluate them through a microscopic traffic simulation. A detection method based on ASM is analyzed and compared with the Izadpanah algorithm based on boundaries detection. This is done in four scenarios with different PVD penetration rates. Besides, the performance using the mitigation proposed in SPECIALIST is also evaluated.

3. Computational Experiments, Results and Discussion

The evaluation of the implemented algorithms is based on a simulation approach because real data is not available. Since connected vehicles must be emulated individually, a microscopic traffic simulation tool (Aimsun) is used. Furthermore, the algorithms interact with the simulator extracting data (emulating PVD and induction loops) and directly modifying the behaviour of the vehicles in the simulation by emulating the effect of a variable speed limit.

The performance of the selected algorithms is tested in four different simulated networks, three dummy networks which consist of a straight freeway of 10 km with 1, 2 or 3 lanes, and one real freeway, the AP7, in the Mediterranean corridor in Spain. To evaluate the selected algorithms, a different partial factorial experimental design is proposed for each method including not only the PVD penetration rate as a design factor but also different algorithm parameters.

Regarding the shockwave detection, the proposed KPI is the delay in the detection, which measures how many seconds elapse between the generation time of the shockwave (generated artificially) and the detection time of the algorithm. With respect to the shockwave mitigation algorithm, the KPI are if the shockwave is mitigated or not, and the improvement it produces on the network measuring the total time spent (TTS).

The fast detection observed with the method based on ASM, which takes approximately 10s, is key to mitigate the shockwave. In opposition, the delay observed in the Izadpanah’s detection is much higher (approx. 20 times larger).

Concerning the penetration rate, the effect is not clear in the ASM method. In contrast, it is observed that a higher penetration rate reduces the detection delay in Izadpanah’s algorithm. Regarding the mitigation algorithm, considerable improvement is not observed in the experiments performed in the three dummy networks, particularly regarding the TTS. However, the improvement of the TTS in the simulated real network (AP7 freeway), for all penetration rates, is around 18%, so this is a very good improvement.

References


