A local feedback controller for mainstream traffic flow control using variable speed limits

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Motorway traffic congestion (Figure 1) is a serious problem of modern societies. The ever increasing traffic demand leads to increasing daily traffic congestion and its undesirable consequences, while several employed control measures to tackle congestion may face limitations. Thus, the efficient, safe, and less polluting transportation of persons and goods on motorways calls for new and innovative control measures that would drastically improve the current traffic conditions.

Variable speed limits (VSL) have become a popular control measure on motorways whereby the main targeted benefit of present VSL installations is enhanced traffic safety. Reductions of 20-30% in the number of accidents on motorways under VSL have indeed been reported. In contrast, there are hardly any consistent and measurable results with respect to the increase of traffic efficiency attributable to VSL.

Several works have studied the use of VSL to increase motorway efficiency (Hegyi, 2004; Chang et al., 2007; Chiang and Juang, 2008; Hegyi et al., 2008; Popov et al., 2008). Most of these works, however, are not deemed sufficiently practicable for ready field implementation, because they use sophisticated methods or require numerous parameters difficult to obtain.

Mainstream traffic flow control (MTFC) (Carlson et al., 2010b) aims at directly influencing the motorway mainstream flow via an appropriate actuator, such as VSL or traffic lights or vehicle-infrastructure integration systems. MTFC holds back traffic in the mainstream few hundred meters upstream of a bottleneck, so as to avoid the detrimental effects of congestion, in particular the capacity drop (Figure 2). Thus, capacity flow is maintained at the bottleneck location in order to maximize efficiency, while a controlled congestion is created further upstream which, however, is shorter in space and time and has also a higher internal speed than in the no-control case.

$q_{in}$ : Mainstream inflow  
$q_{out}$ : Mainstream outflow

$\rightarrow$ Congestion tail moves upstream

$q_{in} < q_{out}$ : $q_{out} < q_{cap}$

Figure 1: A local aspect of motorway congestion
The use of VSL as a MTFC actuator was studied by (Carlson et al., 2010a; Carlson et al., 2010b) by use of a macroscopic second-order traffic flow model that was extended to account for the VSL impact on aggregate traffic flow behaviour based on a related study with real data. The model was cast in an optimal control framework where VSL are control variables that can even be integrated with other control measures. Substantial savings (50% reduction of the average journey times) were demonstrated when applied to a ring-road motorway.

Based on the MTFC concept and VSL studies outlined above, a simple yet efficient local cascade feedback MTFC strategy using VSL as an actuator has been developed (Figure 3). The developed feedback control law takes into account practical restrictions that must be considered for a safe implementation and was applied and tested to a hypothetical motorway stretch using the aforementioned simulation tool. The feedback control law approximates the efficiency of the optimal control approach, while being more suitable for field implementation, as it requires only four easy to design parameters and two real-time measurements.

Along with a real test in the field, future work includes coordination and integration of feedback MTFC, as well as the use of alternative actuators, other than VSL.

References


