Control of vehicle platoons and traffic dynamics: catch-up coordination and congestion dissipation

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Abstract

Traffic congestion is a constantly growing problem, with a wide array ofnegative effects on the society, from wasted time and productivity to elevated air pollution and increased number of accidents. Classical traffic control methods have long been successfully employed to alleviate congestion, improving the traffic situation of many cities and highways. However, traffic control is not universally employed, because of the necessity of installing additional equipment and instating new legislation.

The introduction of connected, autonomous vehicles offers new opportunities for sensing and controlling the traffic. The data that most of the vehicles nowadays provide are already widely used to measure the traffic conditions. It is natural to consider how vehicles could also be used as actuators, driving them in a specific way so that they affect the traffic positively. However, many of the currently considered strategies for congestion reduction using autonomous vehicles rely on having a high penetration rate, which is not likely to be the case in the near future. This raises the question: How can we influence the overall traffic by using only a small portion of vehicles that we have direct control over? There are two problems in particular that this thesis considers, congestion wave dissipation and avoidance, and platoon catch-up coordination.

First, we study how to dissipate congestion waves by use of a directly controlled vehicle acting as a moving bottleneck. Traffic data can help predict disturbances and constraints that the vehicle will face, and the individual vehicles can be actuated to improve the overall traffic situation. We extend the classical cell transmission model to include the influence of a moving bottleneck, and then use this model to devise a control strategy for an actuator vehicle. By employing such control, we are able to homogenize the traffic without significantly reducing throughput. Under realistic conditions, it is shown that the average total variation of traffic density can be reduced over 5%, while the total travel time increases only 1%.

Second, we study how to predict and control vehicles catching up in order to form a platoon, while driving in highway traffic. The influences of road grade and background traffic are examined and vehicles attempting to form a platoon are modelled as moving bottlenecks. Using this model, we are able to predict how much the vehicles might be delayed because of congestion and adjust the plan accordingly, calculating the optimal platoon catch-up speeds for the vehicles by minimizing their energy consumption. This leads to a reduction of energy cost of up to 0.5% compared to the case when we ignore the traffic conditions. More importantly, we are able to predict when attemptingto form a platoon will result in no energy savings, with approximately 80% accuracy.