Modern Approaches and Strategies for Optimal Traffic Control

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An increasing amount of traffic, accompanied by traffic jams and negative environmental impacts, has led, already today, to a high demand for intelligent mobility solutions. At the same time, today's vehicle technology allows to collect an increasing amount of data to improve the vehicles' performance, reliability and safety. Concerning mobility infrastructure, larger and larger datasets can be transmitted faster every year, and new communication technology, such as 5G, is emerging and maturing permanently.

We study approaches to use (real-time) data, communicated between cars and infrastructure, to improve and to optimize traffic flow in the future and, thereby, to support holistic, efficient and sustainable mobility solutions.

To build traffic networks of varying complexity, we consider microscopic traffic models. In these models, single cars and their longitudinal dynamics are modelled via coupled systems of ordinary differential equations (ODEs). Whereas most cars are set up to behave like human drivers, we assume that certain cars have an additional intelligent controller that obtains real-time information from other vehicles. Moreover, these controllers use a model predictive control (MPC) approach and optimal control theory with the overall goal to improve traffic flow for all vehicles in the considered system.

A leading example in this contribution is a virtual version of the prominent ring road experiment [1]. Realistic, human-like driving rapidly generates stop-and-go waves in that experiment. We show that the use of one single, intelligently controlled vehicle as described above, is able to prevent those stop-and-go situations completely. Based on this example, we analyse different optimal control methods and we study different amounts of model-knowledge for the controller as well as varying set-ups of the underlying dynamical system. We present an approach to substitute the MPC controller by a model based on machine learning techniques ("imitation learning") that mimics the MPC controller's behaviour, but requires much less computing times. Last not least, we compare these approaches with model-free *Reinforcement Learning* methods and feedback control based on neural networks.

References

[1] Sugiyama, Y., Fukui, M., Kikuchi, M., Hasebe, K., Nakayama, A., Nishinari, K., Tadaki, S.-i., and Yukawa, S. (2008). Traffic jams without bottlenecks—experimental evidence for the physical mechanism of the formation of a jam. *New Journal of Physics*, 10(3):033001.