Swiss Competence Center for Energy Research
Efficient Technologies and Systems for Mobility

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Towards autonomous driving trains in mixed traffic networks: setups and optimization methods for energy efficient driving and integration into traffic management systems

Automatic Train Operation (ATO) system allows to partially or entirely take over the tasks of train drivers. ATO controls the speed and enables the automation of regular train operation as well as the increase of energy savings. Implementation in Metro systems confirmed its potential. However, there are still many issues to solve before implementing the ATO in mixed traffic networks, mainly because of different characteristics of vehicles and traffic conditions. This project aims at building a mathematical foundation for the implementation of ATO in mixed traffic conditions and aims at integrating research lines on train control and traffic management previously tackled independently, and directly address the practical needs of industry related to the planned implementation of autonomous driving trains.

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Introduction and research objective

ATO systems for mixed traffic lines highly depend on the integration with the larger scope of traffic management. The implementation setup may vary based on the technology available and, in addition, the knowledge of motion parameters is required; these latter are currently not known timely and with sufficient precision. With this project, we propose:

> *"to build mathematical approaches, models and optimization methods to improve ATO functionalities towards its use in mixed traffic networks, and to develop optimal driving strategies according to different signaling systems."*

Real-time schedule fine tuning

In a traffic management system (TMS), the fine-tuning slightly modifies the schedule of one or more running trains, in case a conflict between foreseen trajectories is detected (Fig. 2). Main aim is to make the trains run with all green signals and without unplanned stops [1]. Based on the fine-tuned schedule, optimal time and speed windows at critical points (signals, timetable points, conflict points, etc.) are identified and formulated as information to be sent to the ATO system [2].

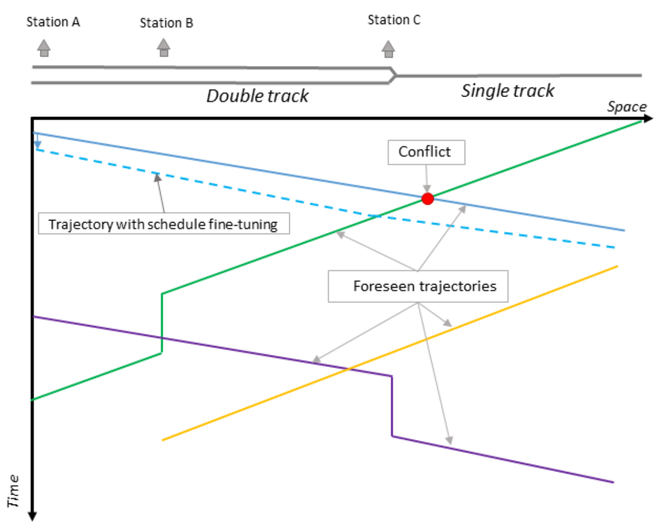

Fig.2 Conflict detection (2 trains crossing on a single track line) and train trajectories (foreseen/after schedule fine tuning)

Research Method

The project will be decomposed into 3 packages:

- Identification and **online calibration of** dynamic vehicle parameters
- **Real-time schedule fine-tuning** in order to avoid conflicts and unnecessary stops
- Identification of **ATO driving strategies** under different signaling systems levels

This latter point will consider the current European standards in rail signaling systems, i.e. ETCS (European Train Control System).

ATO driving strategies vs. ETCS systems

An advanced speed profile optimization algorithm is here developed. It finds the optimal speed profiles according to the ATO driving strategy adopted (e.g. minimum running time, energy saving) and to the real-time schedule. The speed profile optimization must consider the specific signaling system on the track [3]. Here we consider EU standards; from ETCS Level 1 currently adopted in Switzerland (with some national specifications) to the future ETCS Level 3 (see Fig. 3).

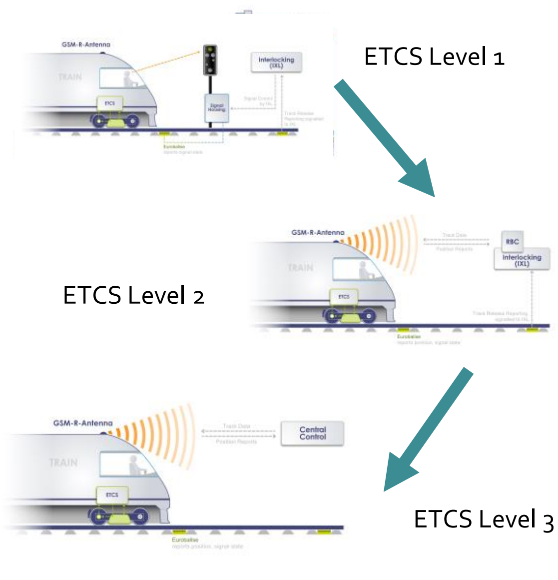

Fig.3 ETCS levels. Source: http://www.Thalesgroup.com/

Online calibration

The Institut für Verkehrsplanung und Transportsysteme (IVT) – ETH Zurich is one the few research institutes which have data of onboard monitoring systems of trains (see Fig. 1). A multivariate time-dynamic calibration method will be developed in order to calibrate dynamic vehicle parameters (i.e. resistances parameters) in real-time. The mathematical calibration approach is developed based on the above mentioned onboard collected data. Data smoothing techniques will be applied to remove errors in data set.

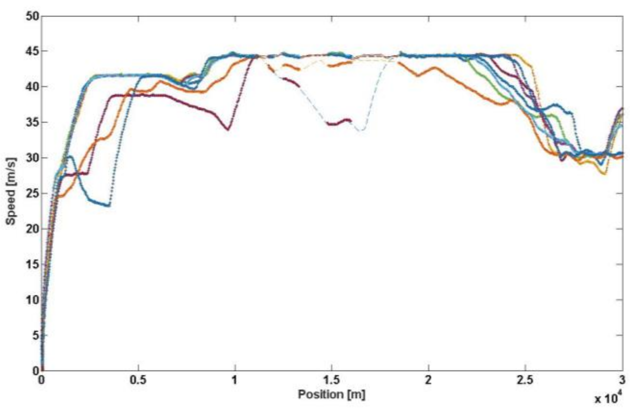

Fig.1 speed profiles of multiple trains on the same track.

Expected results and contributions

Expected results fill the scientific gaps related to the integration of ATO systems with the information given by onboard monitoring systems and with the rail traffic management (i.e. real time scheduling).

Main contribution consist of:

- An online calibration method. Research has shown that real vehicle parameters are quite different from theoretical ones. There is no online calibration method available at the moment.
- New insights into future railway management via shared information between TMS and ATO. Sharing information between the TMS and ATO has significant meanings in improving the real-time traffic management.
- An advanced speed profile optimization algorithm. With the support of the online calibrated parameters, an advanced speed profile optimization algorithm is developed in order to use those parameters and compute optimal speed profiles within short times.

References

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[3] De Martinis V, et al. Feedforward Tactical Optimization for Energy-Efficient Operation of Freight Trains: The Swiss Case. *Transportation Research Record*, 2018, n: 0361198118776508. https://doi.org/10.1177/0361198118776508

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