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Automatic generation of train path envelopes for Automatic Train Operation

Kemal Keskin, Ziyulong Wang, Rob M.P. Goverde

Department of Transport and Planning, Delft University of Technology, Delft, The Netherlands; k.keskin@tudelft.nl

Efficient railway operations are essential to accommodate growing traffic demand and to sustain high levels of system performance on heavily utilized corridors. Conventional train scheduling methodologies often face challenges in preventing train path conflicts arising from deviations in planned trajectories or operational uncertainties. To address this, we developed a framework to automatically generate conflict-free Train Path Envelopes (TPEs) for successive scheduled trains from a real-time traffic plan in a designated railway corridor. Specifically, the TPE is defined as a sequence of time targets or windows at key network locations (known as timing points) and serves as train trajectory constraints in generating conflict-free train trajectories aligned with the real-time traffic plan. The computational framework processes infrastructure and timetable data autonomously, identifies potential track occupation conflicts using blocking time theory across three typical train driving strategies and resolves them through the automated determination of intermediate timing points and dynamic adjustment of departure tolerances. Buffer times are incorporated into the blocking time bounds to tolerate train trajectory tracking errors.Lastly, the framework computes the earliest and latest feasible trajectories for each train. From this the TPEs are derived as a list of timing points with their time windows or targets. This framework not only optimizes track utilization by ensuring conflict-free train operations but also promotes energy efficiency by defining flexible and robust time-distance boundaries for train movements. The efficacy of the proposed framework has been validated through integration with FRISO (Flexible Rail Infrastructure Simulation of Operations), a microscopic simulation tool with discrete, dynamic, stochastic and deterministic properties. This development marks a first step towards a better link between railway traffic management and automatic train operation and is a cornerstone in Europe's Rail FP1-MOTIONAL project.