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The ON-TIME real-time railway traffic management framework: A proof-of-concept using a scalable standardised data communication architecture

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ABSTRACT

Automatic real-time control of traffic perturbations has recently become a central issue for many European railway infrastructure managers. The aim is to make use of mathematical algorithms to maintain the required service availability during unplanned disturbances to operations. In the literature many tools for real-time traffic control are proposed, but their effects on traffic have never been studied neither in real life nor in fully realistic simulation environments. We can mention only a few pilot tests and a unique installation in the Lötschberg Base tunnel in Switzerland, which uses a replanning framework that is generally applicable but does not consider a standard data communication format. Standardisation of railway data is instead one of the main requirements of the European Railway Traffic Management System (ERTMS) to enable traffic interoperability across different countries along the Trans-European Transport Network (TEN-T). Following this direction, this paper introduces one of the outputs of the European project ON-TIME: a framework for the automatic real-time management of railway traffic, designed for being standard and interoperable across different European railways. We make use of a web-based Service-Oriented Architecture to ensure scalability and flexibility of application. A standard railML interface is used for the input/output data of the modules, allowing immediate applicability of the framework to any network having a railML representation. A proof-of-concept is provided where the framework is tested in a closed-loop with the simulation environment HERMES for perturbed traffic scenarios on different networks in the UK, the Netherlands and Sweden. Tests are performed for two different replanning

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algorithms (ROMA and RECIFE) used for the automatic detection and optimised resolution of train conflicts. The two algorithms are compared on the test case in Sweden. Results show that the design of the proposed framework is effective in managing traffic perturbations and is extendible to real-life systems.

1. Introduction

The recent growth in the demand for railway transportation has resulted in a high traffic density and heavily used networks, which are sometimes working in saturated conditions. In this context, perturbations to traffic (e.g., extensions of running and/or dwell times) can lead to track conflicts, i.e., situations where two or more trains request the same track portion in overlapped time periods. Track conflicts force trains to slow down or even stop at unplanned locations, thereby deviating train services from the original plan.

Slight perturbations can typically be absorbed by time allowances in the timetable, but larger ones need to be specifically managed by replanning trains in real-time. Real-time replanning means adjusting the space–time trajectory of trains based on the current traffic information, with the aim of mitigating the impact of perturbations as much as possible. Basically trains can be replanned with control measures such as: changing the passage order at a given station or junction (reordering), modifying the arrival/departure times at a station (retiming), or even detouring the trains over a different route (rerouting). The set of control measures that is planned to be taken in a given time period ahead is called the Real Time Traffic Plan (RTTP). A RTTP therefore contains the list of passage orders, arrival/departure times and/or routes that are planned to be respected by trains in the near future. In other words, the RTTP is the microscopic train path plan resulting when control measures are taken.

So far, the control measures contained in the RTTP are decided by human dispatchers on the basis of their own experience and/or rules-of-thumb. Nevertheless, it is very difficult for a human being to understand the effects of his/her decisions on traffic, especially in the case of large networks or heavily congested areas. This can sometimes result in control measures that may be not effective or even counterproductive. To this end, advanced decision support systems have been proposed to automatically compute a set of control measures (i.e., a RTTP) that optimises given traffic performance indicators (e.g., minimises the total delay, maximises the punctuality) while ensuring conflict-efficient train operations. Conflict-efficient means that we aim to remove all track conflicts, but we cannot guarantee that trains will run without any conflicts even once these measures are put into operation. Some trains could indeed still encounter restricted signal aspects during real operations if this is inevitable or if imposing a train to slow down in a critical location is efficient for the system as a whole according to the traffic performance indicators considered. Train operations are optimised by a Conflict Detection and Resolution module (CDR), which consists of a mathematical model for both detecting and tackling track conflicts. Briefly, the Conflict Detection element considers current traffic information to predict future traffic conditions and detect potential track conflicts. The Conflict Resolution tackles the detected conflicts by identifying a set of control measures that optimises a given objective function and allows conflict-efficient train operations. A Train Path Envelope Computation module (TPEC) may be executed between the computation of the RTTP by the CDR and its implementation, to identify energy efficient train speed profiles compatible with the RTTP itself.

Although several CDR models are proposed in the literature (Barbara' de Oliveira et al., 2012; D'Ariano and Pranzo, 2008; Pellegrini et al., 2014; Törnquist, 2014) nothing more than pilot tests can be mentioned (Mannino and Mascis, 2009; Mazzarello and Ottaviani, 2007; Montigel, 2009). Automatic replanning tools have not been seriously implemented into practice yet, mostly because infrastructure managers are wary of implementing systems whose impacts on traffic are blurry and not well known. In addition, it is not clear yet how these systems can interface with real traffic, whether a standard communication interface can be defined and if these tools work for any traffic condition.

A concrete reply to these issues is provided by the European FP7 funded project ON-TIME (ON-TIME, 2014). A relevant part of this project focussed on designing, developing and testing an integrated framework for the automatic real-time management of railway traffic perturbations. This paper describes the main outcomes of this research explaining the different modules of the framework and their interactions. The focus is on the integration of different modules for railway traffic management together in a single framework, and in understanding how this framework performs in simulated operations. A proof-of-concept is given that shows how traffic perturbations can be optimally and automatically managed by mathematical algorithms connected to operations through standard software interfaces.

The main contribution of this paper stays in the development of a framework that meets the requirements of the European Union on interoperable cross-border railway traffic management. The outcomes of this work could therefore contribute to set the basis for the European Traffic Management Layer. This objective has been reached by means of the following:

- A software framework has been developed that integrates algorithms for traffic state monitoring, prediction, track and connection conflict detection and resolution, automatic route setting, and a driver advisory system.