Rerouting and rescheduling the coordinated train management problem via an iterative algorithm

Xiajie Yi[1], Grégory Marlière[2], Paola Pellegrini[2,1], Joaquin Rodriguez[2,1], Raffaele Pesenti[4]

[1] Institut de Recherche Technologique Railenium, F-59300, Famars, France
xiajie.yi@railenium.eu paola.pellegrini@ifsttar.fr

[2] Univ. Gustave Eiffel, IFSTTAR, COSYS, ESTAS, F-59666 Villeneuve d'Ascq, France
joaquin.rodriguez@ifsttar.fr

[3] Dept. of Management, Università Ca' Foscari Venezia, Cannaregio 873, 30121 Venice, Italy
pesenti@unive.it

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1 Introduction

This paper deals with a coordinated train rerouting and rescheduling problem faced by traffic controllers at regional railway control centers. Typically, the railway network is divided into non-overlapping control areas. A control area, for example, a station in this paper, and it can be other combinations of different sections in different definitions accordingly. The problem we consider arises when a perturbation (i.e., an unexpected, degraded operation) occurs and the timetable cannot be operated as planned. To minimize the impact of such a perturbation, i.e., to minimize delay propagation, measures as train rescheduling and rerouting can be applied. This problem is known in the literature as real-time Railway Traffic Management Problem (rtRTMP) [1]. Several approaches have been proposed to deal with it [2]. Nevertheless, only few papers focus on the coordination of traffic management across different control areas.

The objective of this work is to handle the rtRTMP in large infrastructures. To this end, we consider both a macroscopic and a microscopic perspective. This approach allows exploiting the computational efficiency of the former and the precise operational representation of the latter. We propose a coordination framework that includes a microscopic MILP for dispatchers who are in charge of planning train movements with high level of detail, and a macroscopic MILP for an upper level controller, the *coordinator*, who is in charge of ensuring the compatibility of dispatchers' decisions on the overall infrastructure. Specifically, we develop a time-indexed model to solve coordinator's problem and apply RECIFE-MILP [1] to optimize dispatchers' choices. Indeed, any other algorithm can be used for the dispatching problem, provided that it can accept constraints defined by the coordinator.

2 Problem description

In this paper, two control areas are called *adjacent* if a train can move from one to the other without crossing any other control area. The space connecting adjacent control areas is named *coordinator space*. It is composed of *border sections*: points between bordering control areas and lines that join separated ones. Remark that several border sections can connect two adjacent control areas.

The coordinator makes decisions on the locations for trains at the bodering of each control area. Moreover, the coordination problem also consists in choosing precedences between trains using the same border sections, and orders between trains utilizing border sections that connect the same pair of control areas. The sequence of control areas traversed by a train is considered unmodifiable. Decisions on border section movements, and hence on locations, precedences and orders, are transferred to the dispatchers.

The dispatching problem consists in finding the best traffic management strategy compliant with the decisions of the coordinator. The dispatcher is in charge of choosing precedences between trains sharing track portions (track-circuits, block sections, track sections, ... according to the model adopted for the control area dealt with), train timings and train routes within their control areas, provided their consistency with the entrance and exit precedences and locations decided by the coordinator.

In this paper, we assume that all trains start and end their journey in a control area among the ones considered. To coherently assess these timings and hence delays, after all dispatching problems, we solve an overall network microscopic problem by linear programming (*overall LP*) in which both coordinator's and dispatchers' precedences, orders and routes are constraints and only the train timings are to be determined.

3 Iterative algorithm

We propose an iterative algorithm to optimize the collaborative real-time railway management problem.

At each iteration, the coordinator solves the problem of choosing locations, precedences and orders of trains passing from a control area to an adjacent one with the objective of minimizing entrance delay estimates. We do so by solving an integer linear programming formulation based on time-indexed binary variables. The decisons of the coordinator are passed to the dispatchers, who decide internal precedences and routes. It is possible that the decisions made by the coordinator are not feasible when considered from the dispatcher's perspective, as the former lacks information inside control areas. For instance, the coordinator might select a pair of border sections for a train to enter and exit a control area, but it has no guarantee on the existence of a route connecting them. If a feasible solution does not exist in a control area, the dispatcher sends feedback to the coordinator in the form of cuts to be added to the formulation. In this case, a new iteration starts. If feasible solutions exist for all control areas, the set of all routes and precedences there defined constitute a detailed and complete traffic management strategy for the whole network. We then solve the overall LP to compute timings. We use the RECIFE-MILP formulation in which we set all binary variables as defined in the traffic management strategy to be assessed. However, any other approach for train path computations could be applied, as for example any microscopic simulator.

Once we have a solution from the overall LP, we do the following checks. First, we check if the new solutions is the best found one or if it is close enough to it. Second, we check the likely reasons for the observed delay. From this, we deduce a delay-generation cut, which added as a new constraint to the coordination peoblem. In every iteration, we only add one new cut. Each added cut is labelled to avoid repetition.

Through the proposed iterative algorithm, we aim at progressively improving the quality of the overall solution. The whole iterative algorithm is stopped by the elapse of the available computational time, or the lack of new cut.

References

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