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# A routing filter for the real-time railway traffic management problem based on ant colony optimization

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**Abstract**

The growth in transport demand of the last years is a trend expected to continue in the coming years. In railways, the difficulties in building new infrastructures due to high costs or physical obstacles have translated into the need to utilize the already existing infrastructures at their full capacity. During the daily operations disturbances may happen, creating overlapping requests for the same tracks at the same time by multiple trains. Traffic controllers are thus required to solve these problems, taking decisions on how to answer the overlapping requests. This may lead to the creation of consecutive delays on the network, which in turn may create new conflicting requests and so on, impoverishing the quality of the service offered. In order to minimize the propagation of consecutive delays, thus recovering the quality of the service, real-time traffic adjustments are necessary. A stream of research focuses on the real-time railway traffic management problem. In this problem both routing and scheduling decisions are considered simultaneously. The problem dimension and the computational time required to find a solution of acceptable quality are strongly affected by the characteristics of the rail network and traffic flows, and in particular by the number of routing combinations that can be assigned to the trains. This paper presents a new filtering method for the selection of a set of possible routings for each train, whose maximum dimension is a parameter to be set, in order to facilitate the computation of a good solution for the subsequent train routing and scheduling problem. We call this the routing selection problem. It represents a first step in the solution process of the real-time railway traffic management problem. We model this problem using a N-partite graph in which each partition represents the set of alternative routings for a train. To solve the routing selection problem we use ant colony optimization, a meta-heuristic based on ant colonies' behaviour. Each ant builds a solution by assigning one routing to each train based on heuristic information and pheromone trails. The heuristic information is a greedy measure of the effect of a particular assignment on the overall solution quality. The pheromone trail represents the shared knowledge on the quality of the previously built solutions which include the assignment itself. A pool of good quality solutions are generated and the corresponding combination of routings is released as input to the real-time railway traffic management solver.



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## 1. Introduction

Nowadays, due to the increasing traffic demand in transports in general and railways in particular, railway companies face the challenge of expanding their offer and appropriately address this growth. Infrastructures are thus often used at their full capacity. To maintain a satisfactory quality of service and reduce passengers' inconvenience (Ginkel and Schöbel (2007)), an efficient management of traffic situations that may affect the normal course of daily operations is required. Dispatchers manage at the best of their capacity railway traffic, intervening in case of unexpected events to minimize the disturbances they may provoke. However, it is not easy to immediately judge the effects a particular decision may have. In some cases, new delays may be caused, creating new problems for the traffic such as concurrent conflicting requests of the same tracks by multiple trains. Therefore, the delays may propagate in the network. Still, few decision support tools are available to help controllers evaluate the effectiveness of their decisions.

We call real-time Railway Traffic Management Problem (rtRTMP) the detection and resolution of conflicting requests in disturbed operations. The problem is well studied in the literature and different characteristics and approaches can be found. Two different granularities are mainly used to model the infrastructures: macroscopic, where resources model groups of block sections (Dessouky et al. (2006), Kecman et al. (2013), Törnquist and Persson (2007)) or microscopic, where each resource represents a single block section (D'Ariano et al. (2014))) or a single track circuit (Caimi et al. (2012), Corman et al. (2009a), Pellegrini et al. (2014), Rodriguez (2007)). In Lamorgese and Mannino (2015) where the problem is tackled with a decomposition algorithm, both granularities are considered: a microscopic model is used for stations while a macroscopic one for the overall network. A number of objective functions are used in the problem. While an agreement on the most important does not exist, most of the objective functions in the literature deal with delay minimization. We call *primary delays* the delays caused by unexpected events in the network and *secondary delays* the additional delays due to primary delay propagation. In this problem, to recover feasibility, both routing and scheduling decisions may be taken. In both cases these decisions may cause secondary delays due to increasing travel times: for routing decisions, when an alternative routing requires a higher travel time compared to the previously planned one; for scheduling decisions, when two trains require the same resource at the same time and one has to wait for the other to complete its operations before beginning its own.

The high number of routing possibilities significantly affects the complexity of the problem. In order to limit it, different approaches have been considered. A line of research does not take into consideration re-routing possibilities, leaving to each train its planned routing and studying scheduling decisions optimization (Corman et al. (2014), D'Ariano et al. (2007), Liu and Kozan (2009), Törnquist Krasemann (2012)). In other cases, a certain number of alternative routing is selected based on a-priori (Caimi et al. (2011)) or random decisions (Pellegrini et al. (2015)). Furthermore, iterative methods have been considered where a scheduling solution is found for a combination of routings which varies throughout the iterations of the algorithm (Corman et al. (2009b), Lusby et al. (2013)), or where decomposition is used to simultaneously solve the routing and scheduling problem (Meng and Zhou (2014)). To the best of our knowledge, no formal methods to select suitable subsets of the available routings have been studied in the literature.

We call Routing Selection Problem (RSP) the problem of choosing a number of promising routings for each train. It is a sub-problem of the rtRTMP. Indeed, considering only the so selected routings reduces the number of variables of the overall problem, simplifying the search of a solution. Thus, the RSP represents the first step in the solution process of the rtRTMP and its performance shall be evaluated based on how the selected routings improve the rtRTMP optimization process. From now on we consider the rtRTMP as microscopically modelled on a track circuit level, using as objective function the minimization of the total secondary delays at end stations, including all possible rerouting decisions.

In this paper, we develop a filter for tackling the RSP. It uses an algorithm based on Ant Colony Optimization (ACO), a meta-heuristic inspired by the foraging behaviour of ant colonies (Dorigo and Stützle (2004)). Originally successfully applied to the traveling salesman problem, in railways it has been used in the rolling stock problem (Tsuji et al. (2012)), the timetabling problem (Huang (2006)) and the re-scheduling problem (Fan et al. (2012)).

Section 2 presents a model formalization of the RSP. In Section 3, the meta-heuristic used and its specific characteristics are detailed, while Section 4 shows the evaluation of the filter performance on a practical French case study. Section 5 reports the paper conclusions and outlines future research directions.