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1 Context and contribution

In railway traffic, at peak hours, the infrastructure is extensively exploited for ensuring the trains circulation. It means that many trains travel within short time through critical points. If a disruption occurs, the traffic may be perturbed and, as a result, conflicts may emerge. In a conflict, multiple trains may claim the same track section concurrently. Hence, some trains must be stopped or decelerated for ensuring safety, and delays occur. The emergence of conflicts is particularly critical at junctions, which are locations where multiple lines cross. There are two kinds of delay : primary and secondary delay. The primary delay is the result of unexpected events which disturb the traffic. Due to the interaction between trains, this primary delay may be propagated to other trains causing secondary delay. The primary delay cannot be prevented because we don't have means to avoid unexpected events. However, the secondary delay can be avoided or reduced by suitably managing traffic. Modifying trains route and schedule to limit delay propagation in the network is the focus of the real-time Railway Traffic Management Problem (rtRTMP). It is the problem tackled by dispatchers. They tackle this problem manually, so the result of their choices is generally suboptimal. The use of automatic tools to support dispatchers decision making is crutial to ensure an effective traffic management when disruptions occur. Some optimization algorithms already exist to tackle the rtRTMP. However, they can hardly solve very large instances.

Two models can be used to represent the infrastructure of the rtRTMP : macroscopic and microscopic. In the former, the infrastrure is viewed as a set of nodes (junctions) connected by links and the separation between trains is imposed through the control of generic headway times. In the latter, the infrastructure is viewed as a set of track sections where the train separation is imposed according to the signaling system, as it happens in reality. With the macroscopic model, we can solve very large instances, but with low precision at a local level; hence, the optimization choices may have unexpected effects on traffic when they are actually implemented, due to the specific signaling system. With the microscopic model, these unexpected effects are avoided by considering in the optimization all necessary details. However, solving large instances may become very difficult due to memory or computational time limits. In this work, we consider a state-of-the-art mixed integer linear programming formulation tackling the rtRTMP based on a microscopic model, and we propose a Benders decomposition to increase the size of the instances which can be effectively tackled.

2 Benders decomposition for the rtRTMP

In the rtRTMP litterature, few papers deal with the need of takling very large instances through a decomposition method. Some papers, as [1], propose heuristic approaches to decompose the instances to be solved. Others, as [2], propose classic decomposition approaches as column generation. To the best of our knowledge, only [3] proposes a Benders decomposition approach to solve the rtRTMP. In the paper, the authors combine a macroscopic and a microscopic model to perform a decomposition of the initial problem into two subproblems (master and slave problem). This approach allows dealing with instances representing a big infrastructure but it does not consider the actual details on the microscopic infrastructure characteristics. In this paper, we propose a Benders decomposition approach applied to a model considering all these microscopic characteristics. We use as the model to be decomposed the mixed integer linear programming formulation RECIFE-MILP, proposed by [4].

3 Solution procedure

The definition of the structure of the master and the slave problems is the first task to be performed in Benders decomposition applications. We consider the rtRTMP as the combination of a routing and a scheduling problem. We keep the routing decisions in the master problem, and we delegate the scheduling decisions to the slave one.

The master problem is the real-time train routing problem, it contains the routing variables (binary variables) and one dummy variable representing the contribution of continuous variables to the master problem objective function. Once this master problem is solved, the solution is sent to the dual of the slave problem. This solution is a specific route assignment for each train in the instance. The slave problem is the real-time relaxed train scheduling problem. After sending the solution of the master problem, we solve the dual of the slave one and we add the optimality cut to the master problem to cut off the current solution, if suboptimal. This process is repeated until the algorithm converges to an optimal solution or the maximum computational time imposed by the real-time nature of the problem (3 min) has elapsed.

By applying the described Benders decomposition approach to RECIFE-MILP, we tackle instances representing traffic in the junction of Gonesse, in France. The results are promising.

4 Conclusion and future work

In this work, we addressed the solution of the real-time Railway Traffic Management Problem using a Benders decomposition approach. The decomposition algorithm is applyed to the RECIFE-MILP formulation of the problem. In future work, we will solve other instances to evaluate the effectiveness and the efficiency of our Benders decomposition approach. We plan also to use other decomposition methods, as column generation and Lagrangian decomposition, to compare their performance and to identify the one that is the most suitable for the specific problem tackled.

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