Constraint programming based iterative heuristic for scheduling trains and maintenance tasks
RAS problem solving competition

Seriu Carpov Loïc Cudennec François Galea

CEA, LIST,

Point Courrier 172, 91191 Gif-sur-Yvette Cedex, France.

{sergiu.carpov, loic.cudennec, francois.galea}@cea.fr

Mots-clés : *railway network, timetable, schedule, maintenance task.*

1 Introduction

Periodically the INFORMS Railway Applications Section (RAS) organizes a problem solving competition. 2016 RAS problem solving competition [1] was to timetable trains and schedule maintenance tasks on a complex railway network. Hereafter we describe the solution of our team, which was chosen amongst the finalists.

2 Problem description

Given a railway network description the goal of the competition was to schedule a set of trains and maintenance tasks on this network. The objective was to minimize the total travel time of all trains. A railway network topology includes nodes, links connecting nodes, cells grouping several links, blocks consisting of several cells (giving the authorized ways to traverse the network) and stations. Refer to illustration 1 for a railway network toy example. Each train has origin and destination nodes, a set of stations to service and starting time window constraint. A maintenance task is described by a duration, a set of cells to maintain and a time window to perform the maintenance. Amongst other constraints of the problem are link minimum running time, minimum dwelling time in stations, speed reduction after and during maintenance tasks, occupancy of links, cells and blocks.

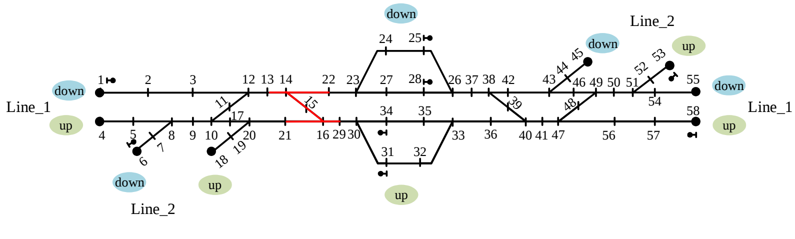

FIG. 1 – A railway network toy example.

3 Global lower bound

We introduce a *railway network graph* $G = (N, L, W)$ where N is the set of railway nodes, L is the set of links together with block traversal links [1] and $W = \{c_t : t \in T\}$ is a set of link minimum running time functions $c_t : L \to \mathbb{N}$ for each train. Function $c_t(l)$ includes station dwelling time and has infinite value for station main tracks where the train should stop [2].

A path in graph G is a valid railway network traversal route with respect to link minimum running time, train required stops, minimum dwelling time and block traversal constraints. Namely, the length of graph G paths are lower bounds to actual train travel times. A straightforward global lower bound for this problem is computed by summing up origin-destination path lengths for all trains. Roughly speaking the global lower bound gives total travel time for a solution not considering train collision and maintenance tasks

4 Iterative heuristic

A simple heuristic we propose consists in decomposing the problem in two : firstly the trains are routed through the railway network and afterwards a constraint programming (CP) model is used for timetabling trains on found routes and scheduling maintenance tasks. In the first step for each train a traversal path is found in the railway network graph. The CP model of the second step uses interval variables (IV) for train traversal of links and blocks (spans over respective link IVs), and also an IV for each maintenance task. The constraints we introduce ensure minimum duration of link traversal and of maintenance tasks, the respect of link traversal order for each train (according to first step paths), starting time windows for trains and maintenance tasks, no overlap between trains using same links and same blocks. The objective is to minimize the sum of link IV durations.

We introduce a second heuristic which solves the CP model iteratively. The iterative heuristic starts from a starting solution found using the simple heuristic. Afterwards it solves a reduced CP model in which the timetables for a set of trains are fixed. This step is repeated many times.

We have performed experimentations using 3 problem instances provided by the competition organizers. Both heuristics were executed with a time limit of 2 hours. The iterative heuristic performs better than the simple one. The distance to the optimal value of the solutions obtained using the iterative heuristic is under 3%. The proposed global lower bound was used to compute optimality distances.

5 Conclusions et perspectives

In this work we have proposed two heuristics for the train timetabling and maintenance tasks scheduling problem proposed by the organizers of the RAS competition. Solutions found by these heuristics respect complex problem constraints and are under 3% distance from the optimal value. In perspective we envisage to enhance the heuristics and to propose a better global lower bound.

Références

[1] `https://www.informs.org/Community/RAS/Problem-Solving-Competition/2016-RAS-Problem-Solving-Competition`

1. A block traversal link is an artificial link which corresponds to the traversal of a block.
2. Trains cannot stop on station main track.