A Constraint-Based Interactive Train Rescheduling Tool

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Abstract. In this paper, we formulate train rescheduling as constraint satisfaction problem and describe a constraint propagation approach to tackle it. Algorithms for timetable verifications and train rescheduling are designed under a coherent framework. We define two optimality criteria that correspond to minimizing passenger delay and the number of station visit modifications respectively for rescheduling. Two heuristics are then proposed to speed up and direct the search towards the optimal solutions. The feasibility of our proposed algorithms and heuristics are confirmed with experimentation using real-life data.

Keywords: Rescheduling, Constraint Propagation, Variable and Value Ordering

1 Introduction

The PRaCoSy (People's Republic of China Railway Computing System) project [10] is undertaken by the International Institute for Software Technology, United Nations University (UNU/IIST). The aim of the project is to develop skills in software engineering for automation in the Chinese Railways. A specific goal of the project is the automation of the preparation and updating of the running map\(^1\), for dispatching trains along the 600 kilometer long railway line between Zhengzhou and Wuhan in the People's Republic of China. The Zhengzhou to Wuhan section has been chosen as a case study because it is along the busy Beijing-Guangzhou line, the arterial north-south railway in China. The rate of running trains, both goods and passengers, of this section is high and present management procedures are not adequate with the dramatic development of domestic economy.

A running map [9] contains information regarding the topology of the railway, train number and classification, arrival and departure time of trains at each station, arrival and departure paths, etc. A computerized running map tool should read in stations and lines definition from a descriptor file, allow segments (subsets of all stations) and time intervals to be defined, allow train timetable to

\(^1\) A running map is a method of monitoring the movement of trains and rescheduling their arrivals and departures to satisfy operational constraints.
be read, and finally display graphically the projection of the timetable against a given segment and a given interval. A sample running map is shown in figure 6. Train dispatchers, users of the tool, have to modify the timetable when trains in some sections cannot run according to the map, possibly due to accidents and/or train delays. The modification to the map should be performed in such a way that certain scheduling rules (laid down by the local railway bureau) are not violated. Therefore, a computer running map tool should check users' modifications against possible violation of scheduling rules, and warn users of such violations. In addition, the tool should also assist the user in repairing, either automatically or semi-automatically, an infeasible timetable so that the least train service disruption is made. We call this process rescheduling. Scheduling and rescheduling are different in two aspects. First, while scheduling creates a timetable from scratch, rescheduling assumes a feasible timetable and user modifications, which may introduce inconsistencies to the timetable, as input. Second, optimality criteria used in scheduling, such as minimum operating cost, are usually defined in the absolute sense. In rescheduling, however, the quality of the output is measured with respect to the original timetable.

The PRaCoSy project has resulted in a running map tool capable of train timetable verification [7]. Our task at hand is to enhance the PRaCoSy tool to perform automatic rescheduling, which can be considered as constraint resatisfaction. A major problem with the PRaCoSy implementation is that constraints are used only passively to test possible violation of scheduling rules. In view of this limitation, we decided to re-create the running map tool from scratch using a constraint programming approach. In this paper, we give algorithms for timetable verification and train rescheduling used in our tool, and show that constraint programming allows us to perform constraint checking and solving (or propagation) in a coherent framework. We study two notions of optimality for the rescheduled timetable with respect to the original timetable. These notions provide a measure of the quality of the rescheduling operation. We also present two heuristics that direct and speed up the search towards optimal rescheduled timetables.

The rest of the paper is organized as follows. Section 2 defines basic terminology and discusses related work. Section 3 explains the timetable verification algorithm. In section 4, we show how to formulate train rescheduling as a constraint satisfaction problem and give an associated algorithm. We also discuss two heuristics that help to direct and speed up the search towards optimal solutions. In section 5, we describe our prototype implementation and sample runs of the tool. We summarize our contribution and shed light on future work in section 6.

2 Preliminaries

In the following, we provide informal definitions of necessary terminology according to [9] to facilitate subsequent discussions. Names not defined should be self-explanatory or clear from the context. Interested readers can refer to [9] for