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Calibration of disturbance parameters in railway operational simulation based on reinforcement learning

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ABSTRACT

In railway operations, delays are used as one of most important factors to quantify and evaluate the quality of the railway services. However, data about stochastic disturbances and the causes of the delays are hard to be collected and measured. The efforts to manually estimate these disturbances are also considerably high. In this paper, a method for the automatic calibration of disturbance parameters, which are used to generate stochastic disturbances in simulation tools, is developed with the support of the reinforcement learning technique. Simulation and application results show that the efforts for calibrating parameters can be significantly reduced with ensured consistency between simulation models and the actual railway operations.

1. Introduction

In railway operations, delays are used to quantify and describe the level of punctuality and the required quality of railway services. For example, the percentage of trains (train-type dependent) that is not allowed to exceed a given threshold of delays is specified in (DB Netz AG, 2008) as a guideline for railway operators in Germany.

Delays are determined by comparing the scheduled and the actual arrival/departure/passing time at certain measurement points. In timetable scheduling, a measurement point is used as a reference point of the infrastructure along a train path. It can be a stop at a station with published arrival/departure/passing times for passengers and operators, or a control point used only by operators. During railway operations, the actual arrival/departure/passing times of a train at a measurement point can be measured. Hence, the delays can be determined by comparing the scheduled timetable and the measured real-time data in the form of deviations related to a defined scale. Delays are categorized as primary delays (including original delays and initial delays) and consecutive delays (Hansen and Pachl, 2014). The measured delays can be the mixture of both primary delays and consecutive delay.

Many methods were developed and put into practice to record and analyze delays of railway traffic automatically. In Daamen et al. (2008) and Goverde et al. (2008), a tool for automatic identification of route conflicts was utilized to analyze consequences of route conflicts and consecutive delays. The data sources are train describer log files with infrastructure and

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train description messages based on Dutch train describer system TNV. The algorithm was further developed for the new train describer system TROTS (Kecman and Goverde, 2012).

To evaluate and improve the stability and robustness of the railway operations, not only the delays but also the causes of the delays should be analyzed. Delays are caused by various technical, human, and natural events, e.g. technical failures, stochastic driving styles or variations of passenger boarding/alighting time. In this paper, the causes of delays are modeled as stochastic disturbances in the form of the additional time extensions. Unlike traffic disruptions, which require special dispatching measures such as rerouting, cancellations of trains and/or replacement of crews, the delays caused by disturbances may fade out without intervention by dispatchers due to scheduled recovery time in the timetable.

The difference between disturbances and delays should be distinguished. Same as delays, disturbances are represented by units of time (in the form of time extension). However, a disturbance may not always lead to delays. Here, delays are only referred to as the measured deviations between the scheduled and the actual arrival/departure/passing time at certain measurement points. Depending on the operational situation and the concrete timetable, a disturbance may directly lead to delays, or be recovered through the scheduled recovery time. In the latter case, there is no delay observed at the measurement point, although disturbances took place before the train arrives at that measurement point. The difference between delays and disturbances also indicates the difficulties to obtain the information of disturbances. Delays can be measured through comparison of actual and scheduled arrival/departure/passing time, but disturbances are hard to be measured or be calculated directly. Stochastic disturbances need to be further analyzed and calibrated based on the observed delays.

Disturbances are the sources of delays. Primary delays and the induced consecutive delays are resulted from disturbances. Disturbances are modeled by a set of disturbance parameters based on its statistical distribution. The model of the delays and disturbances will be presented in Chapter 2.

With the knowledge of the disturbances, the delays of a timetable can be determined through operational simulation, even the timetable has just been planned and not been put in use yet. Operational simulation is a widely used method to examine the robustness and the quality for infrastructure layouts and/or operating programs. Through operational simulation, train runs are simulated with randomly generated stochastic disturbances. The quality of railway service will be investigated through observing the resulting delays caused by the introduced stochastic disturbances. The idea behind operational simulation is to predict system behaviors in the future based on the knowledge learned from the past. For a specific application of operational simulation, the quality of simulation depends on the availability of real data. If real data of the disturbances is not available, the empirical or assumed statistical distribution of disturbances can be utilized instead. The application of operational simulation with disturbances and delays is shown in Fig. 1. During an operational simulation, multiple sets of randomly generated disturbances are introduced into the operational simulation, which consists of several rounds of single simulations. For each round of single simulation, a certain set of randomly generated disturbances will be applied. The impacts of the disturbances will be analyzed in the form of delays. Based on the calculated delays and the level of punctuality, the quality of the railway services, the deficiencies, and the possible improvements can be derived. Supported by simulation tools, the approach of operational simulation is widely used to support timetable scheduling, dispatching, and capacity research.

Limited by the high complexity of the stochastic processes in railway operations, it is impossible to directly collect all of the detailed disturbances information. The efforts to manually estimate the disturbances are also considerably high; they can reach up to 50% of the whole amount of work for calibrating the disturbance parameters in applications of railway operational simulation (Martin and Schmidt, 2010).

In order to generate the “correct” disturbances for operational simulation, it is necessary to “speculate” the value from the known delays through reverse engineering. More generally, it is a precondition for a simulation tool to adjust the parameters to ensure the plausibility and usability. The parameters should be adjusted so that the results of simulation can reach the expected values. This process is called calibration.

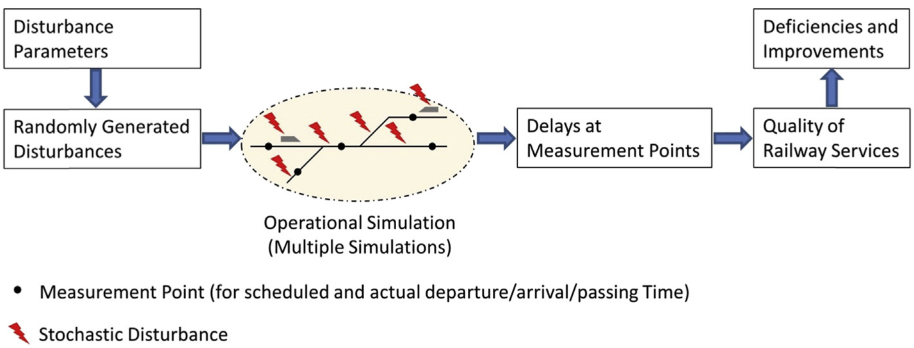

Fig. 1. Disturbances and delays in operational simulation.