Optimization of dispatching decisions

Frédéric Weymann, weymann@via.rwth-aachen.de, Institute of Transport Science, RWTH Aachen

The railway is an open system and therefore very sensitive towards external disturbances which unavoidably lead to delays. One of the main tasks of a dispatcher is to prevent the propagation of such delays. This task can be modelled as an optimization problem. An input instance of this problem consists of the current position of the trains and their projected trajectories and usually contains allocation conflicts. An allocation conflict occurs when two trains compete for the same infrastructure. A valid solution is a new dispatching timetable which provides realistic trajectories for all trains and is free of allocation conflicts.

Several solution methods were developed in the past years, e.g. [3, 5, 7]. However, all these methods either use heuristic solution approaches or simplified models. Most optimization methods use rather abstract models which ignore many real-world constraints. For example, running times are either assumed to be fixed or the effects of changed speed profiles are not modelled correctly. Furthermore, predefined minimal headway times are often used to detect allocation conflicts. However, even small changes to routes or speed profiles can have a large impact on the minimal headway time. As a result, optimal solutions in these abstract model worlds are generally not feasible in the real world and the real costs are much higher than anticipated.

As part of his doctoral thesis project [9], the author has developed the optimal solution method OPTDISPO for this problem using the approach of mixed-integer linear programming. Goal of the thesis was the creation of an evaluation framework for heuristic dispatching methods. The calculation of an optimal solution is one of the key elements of the framework.

OPTDISPO is a three-step method. The first step utilizes a very detailed model of the railway infrastructure and the trains. It is implemented as a module of the LUKS tool developed at the Institute of Transport Science Aachen [6]. LUKS offers a microscopic running and blocking time calculator which is fully compatible to RuT-K, the timetabling tool successfully used by the DB Netz AG since 1998 [8]. It is therefore safe to assume that calculations by LUKS are also valid in the real world. LUKS uses the SPURPLAN graph for modelling railway infrastructure. Under the microscopic SPURPLAN model all elements of railway infrastructure are captured with metre-accuracy and combined into a graph structure [1].

For each train, the module determines all operationally reasonable path alternatives. A path alternative consists of changed interlocking routes, new stops, and deleted stops. For each alternative, microscopic time/distance curves and blocking time stairways are calculated.

Using these data, a mixed-integer linear program (MIP) is created in the second step and solved to optimality by an external MIP solver. The MIP formulation doesn’t use all elements of the SPURPLAN model. Only reference points, stopping places and occupation elements like switches and signals are used. The variables of the MIP determine for each train a simplified time/distance curve. The curve is represented as a sequence of successional routes plus arrival and departure times for all reference points and stopping places along the selected path. All pre-calculated time/distance curves are included in the MIP as possible route combinations and minimum running times between the reference points. The MIP formulation therefore uses realistic minimum running times which depend on the selected routes and the location of the stops, i.e. changes to the speed profile due to rerouting or different stops are considered properly.

Allocation conflicts are detected by deriving blocking time stairways from the trajectories of the trains. A solution is only valid if the stairways of different trains do not overlap. For maximal accuracy, blocking times are calculated during the solution process instead of using pre-calculated values. This is possible because blocking times can be derived from time/distances curves in a linear way. The blocking time stairways calculated in the first step are used to determine the needed linear constraints. Unlike minimum headway times or conflicts graphs [2], this approach can properly deal with modulation (extension of running time) and arbitrary changes to arrival and departure times.

In the last step, the found MIP solution is imported into LUKS and validated by converting it into the microscopic model. An imported solution is considered valid if the simplified time/distance curve is viable in the microscopic model and all microscopic blocking time stairways are disjoint. The validated solution is outputted as the new dispatching timetable.

As OPTDISPO was designed to be one element of an offline evaluation framework, short running times were only a secondary goal. Nevertheless, using LUKS and the MIP-solver Gurobi [4], OPTDISPO is able to determine an optimal scheduling decision for a given situation within short time. For most situations, the computation only takes a few minutes. Future work will focus on improving the performance of the method while preserving the high granularity of the model. By focusing on finding good solutions instead of proving optimality, high-quality solutions can already be obtained in less than two minutes, i.e. fast enough for usage in real-time. This work therefore shows that the computer hardware and the MIP solvers have reached a level which allows a realistic optimization of train dispatching.

References

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