Abstract

The use of regenerative braking is a key factor to reduce the energy consumption of a metro line. In the case where no device can store the energy produced during braking, only the metros that are accelerating at the same time can benefit from it. Maximizing the power transfers between accelerating and braking metros thus provides a simple strategy to benefit from regenerative energy without any other hardware device. In this thesis, we use a mathematical timetable model to classify various metro energy optimization rescheduling problems studied in the literature and prove their NP-hardness by polynomial reductions of SAT. We then focus on the problem of minimizing the global energy consumption of a metro timetable by modifying the dwell times in stations. We present a greedy heuristic algorithm which aims at locally synchronizing braking metros along the timetable with accelerating metros in their time neighbourhood, using a non-linear approximation of energy transfers. On a benchmark of six small size timetables, we show that our greedy heuristics performs better than CPLEX using a MILP formulation of the problem, even when it is able to prove the optimality of a linear approximation of the objective function. We also show that it runs ten times faster than a state-of-the-art evolutionary algorithm, called the covariance matrix adaptation evolution strategy (CMA-ES), using the same non-linear objective function on these small size instances. On real data leading to 10000 decision variables on which both MILP and CMA-ES do not provide solutions, the dedicated algorithm of our thesis computes solutions with a reduction of energy consumption ranging from 5% to 9%.

Keywords: Regenerative braking, MILP, Timetable optimization, Energy optimization, Mass rapid transit, Operations research, Heuristics.