Abstract

On- and Offline Scheduling of Bidirectional Traffic

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The submitted thesis provides theoretical and practical insights related to bidirectional traffic on a stretch containing bottleneck segments. On a bottleneck segment concurrent traveling of vehicles in opposite direction is not possible. Single tracks in railway planning are an example for such bottlenecks. This thesis is motivated by and considers in particular the ship traffic at the Kiel Canal. It connects the North and Baltic Seas and is operated in both directions. If the dimensions of two opposite ships are two large they are allowed to pass only in designated sidings.

The focus of this work concentrates on two characteristic properties of this ship traffic control. First, it considers the bidirectional component: ships traveling aligned are allowed to enter a segment with little headway while ships in opposite heading must wait for a long time until the segment is empty again. Second, ships register their request only shortly before their arrival, i.e., decisions must be adapted *online*.

To get an understanding of the bidirectional character we develop the compact model of *bidirectional scheduling* which is related to classical scheduling on machines. For the offline setting we identify properties of bidirectional scheduling that increase its complexity compared to classical machine scheduling. Through competitive analysis we obtain insights on the problem's online character. We present upper and lower bounds on the best possible competitive ratio. However, as in many online optimization problems there remain proper gaps between both bounds.

We present a new concept to deal with such gaps and the search for the best possible competitive ratio ρ^*. The developed *competitive-ratio approximation scheme* computes for any given $\varepsilon > 0$ an online algorithm with competitive ratio that exceeds ρ^* by not more than a factor of $(1+\varepsilon)$. Moreover, it determines a value that approximates ρ^* with $(1+\varepsilon)$ precision. The concept is developed for machine scheduling problems and afterward extended to bidirectional scheduling. We furthermore present a *polynomial-time approximation scheme* for the bidirectional offline setting.

The original complex problem of ship traffic control at the Kiel Canal is modeled by a further detailed geometrical description. In addition to its scheduling character we obtain a second component of dynamic routing. We present an approach to blend both components algorithmically. To that end, we embed a sequential (local) method which considers only one ship at a time, in a simultaneous (global) method to optimize the complete fleet. By these ideas we implement eventually a fast heuristic creating solutions whose quality was evaluated by computational experiments on real traffic data and was approved by the experts on site. The heuristic works in a rolling horizon and therefore in an online manner. Therefore, it can be coupled with a program to plan the locking process at the boundaries of the Kiel Canal.