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A RCG rescheduling model for energy savings in mixed rail traffic

The objectives and constraints considered in freight train rescheduling are different from those related to passenger trains. For example, there is generally more flexibility in freight train scheduling regarding routes and departure/arrival times. On the other hand, freight trains have frequent unplanned stops for overtaking and acceleration phases use significant amounts of energy, especially for long freight trains. Therefore, energy consumption can be reduced by choosing energy efficient paths (less traffic, less gradient) and driving with energy optimal speed profiles, in order to improve both route regularity (i.e., to avoid unplanned stops and minimize acceleration phases) and energy efficiency of train operation. The proposed rescheduling approach has been tested using the test track of the Railway Operations Lab located in the facilities of the Institute for Transport Planning and Systems (IVT) at ETH Zurich.

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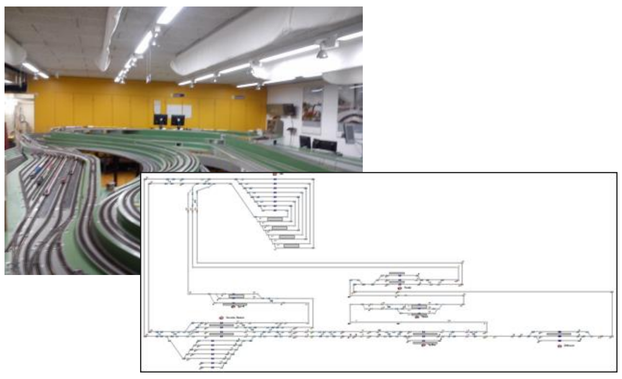
Introduction & Motivation

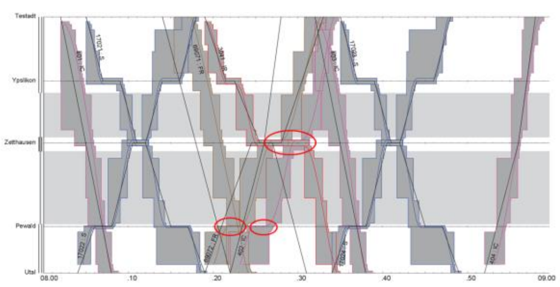
Railways want to reduce energy consumption and efficiently use infrastructure in order to reduce operation costs and fulfill the transport demand, towards a more efficient and sustainable transport system. Therefore, identifying approaches for increasing energy efficiency and optimizing traffic management have become very important during the last decades. In addition, increasing automation in the dispatching process is a key aspect for increasing capacity on existing railway networks, improving timetable robustness and optimizing energy consumption. From these assumptions, a rescheduling model, based on Resource Conflicts Graph (see [1], [2] and [3]), has been specified to generate multi-objective solutions.

Case study

The tests have been conducted on the simulation model of the physical EBL (see [4] for more details).

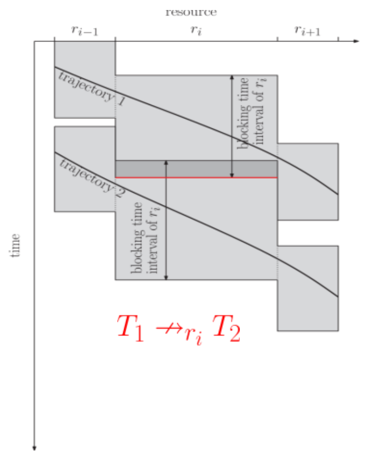


The initial scenario consists of a conflict generated by a delay of a freight train, with consequent knock-on delays.



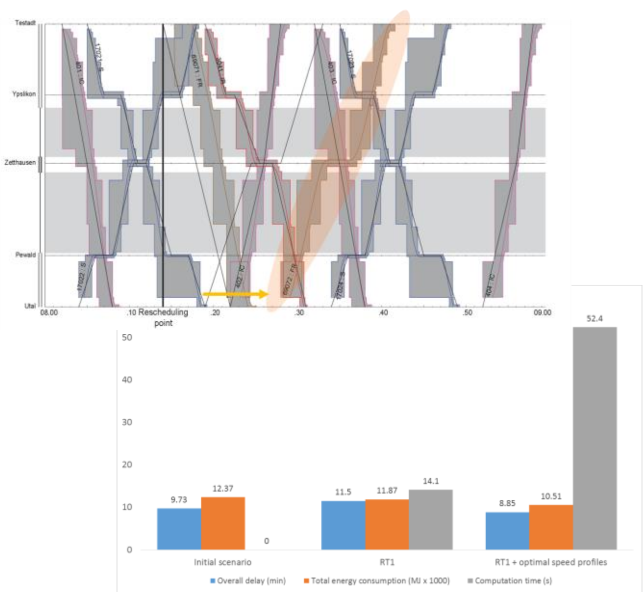
Model description

The RCG (Resource Conflicts Graph) model is based on the concept of "end conflicting". This enables the routine to quickly check, on the basis of time priorities, all the trains trajectories in conflict with an already existing trajectory on a given resource (e.g., a track section). End conflicting also prevents from counting multiple times the same conflict.



Results from operating scenarios

"RT1" is simple rescheduling scenario
"RT1 + optimal speed profiles" considers also a set of alternative trajectories built from energy optimal speed profiles. Speed profiles have been generated according to [5].



Multi objective function formulation

x_T = decision variable to include a trajectory {0,1}

$$\min \; f(x) = w_1 f_1(x) + w_2 f_2(x) + w_3 f_3(x)$$

Subject to :

$$\sum_{T\in T_z} x_T \le 1 \quad \forall z \in Z$$

i.e. only 1 trajectory per train

$$\sum_{T' \in \bigcup_{z\in Z} T_z \,|\, T \not\to_r T'} x_T \le 1 \quad \forall T \in \bigcup_{z\in Z} T_z, \forall r$$

i.e. when 2 or more trajectories are in conflict, only one can be chosen

Targets

f_1 is the overall arrival delay at station

$$f_1(x) = \sum_{z\in Z, s\in S_z} W_{z,s} \sum_{T\in T_z} x_T (t_{T,s} - \hat{t}_{s,z})$$

f_2 is the number of runs cancelled

$$f_2(x) = \sum_{z\in Z} W_{z,c} \left(1 - \sum_{T\in T_z} x_T\right)$$

f_3 is the overall energy consumption

$$f_3(x) = \sum_{z\in Z} \sum_{T\in T_z} E_T x_T$$

Conclusion and further developments

The proposed model was tested in a numerical experiment at the ETH Railway Operations Laboratory. In case of alternative trajectories (RT1+optimal speed profiles), the rescheduling process is completed within few seconds and the solution reduces both delay (9%) and energy (15%). From first results, it has been found that the computation time grew quite fast with an increase of the number of variables. Thus, future works should address the issues on the selection of the trajectory set and focus on heuristics to be used within the rescheduling procedure. Moreover, model calibration on a real test case is needed.

The research results suggest also considering an integrated approach as a further model development by including speed profile optimization and rescheduling in a comprehensive environment.

References

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