optimising railways

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# Microscopic Conflict Visualisation and Resolution Using Co-Pilot Support

## The internship - "An open Setup"

sma.software has introduced the label #openviriato to identify collaborative projects based on our Viriato software between industry and academia. As we explained previously, with this type of collaboration we want to contribute to accelerating urgently needed digitalisation efforts in the capacity management role of railway Infrastructure Managers (IMs).

Within the scope of an internship with Luca Bataillard, a student of computer science at EPF Lausanne, three different aspects of this collaboration concept could be implemented simultaneously.

The first is the collaboration with the EPFL as a representative of the academic world and through the topical context of the Microscopy on Demand (MoD) concept the second, in the further development of the integration of a third-party software from our industrial partner VIA-Con.

Finally, the third aspect of our strategy was aligned with the later part of the internship through the inclusion of the Viriato Algorithm Platform. This is aimed, among other things towards the accelerated development of optimisation and automation algorithms for capacity management.

Now to the first part of Luca's internship: The implementation of the MoD concept and its introduction and testing in practice has been a focus of SMA's R&D activities now for several years. These have culminated in the deployment within a pioneering project for the creation of a national railway concept, which was carried out by SMA's consultancy team in 2020 and 2021.

## Software Engineering - "Let's get visual"

In an example of the cooperation between the two business areas of SMA, the findings about desirable improvements to the software from this project flowed directly and quickly from the users to the development team. This led to a further development programme that focused on three specific features within MoD's topology visualisation tool, Topoviewer.

During the productive use of the first version of the Topoviewer it had become apparent that the geographical area considered was not sufficient for the users' purposes when planning trains in detail. Furthermore, the wish was expressed to be able to graphically represent all routes and microscopic conflicts in a track graph.

Finally, the possibility to visualise the track occupancy over time was considered important.

SMA's software production process has a strong focus on quality and reliability. While this is a desirable goal, it tends to make such developments rather expensive, especially where the outcomes are less clear at the beginning of the project. To mitigate this dilemma, a few years ago we started to implement a lightweight, more research-oriented, development process that focuses on technical and architectural feasibility for these types of projects.

The method of choice for this is the creation of software prototypes. The crucial point is how the migration step from this process into the product development process is performed.

Within the first part of this internship, the creation of a new Topoviewer prototype which implements the features described above was the focus. This was a strongly software-engineering oriented task.

Fortunately, all the goals of the work were fully achieved, so that the prototype is already in use at SMA internally, and the migration step into the production process has been started.

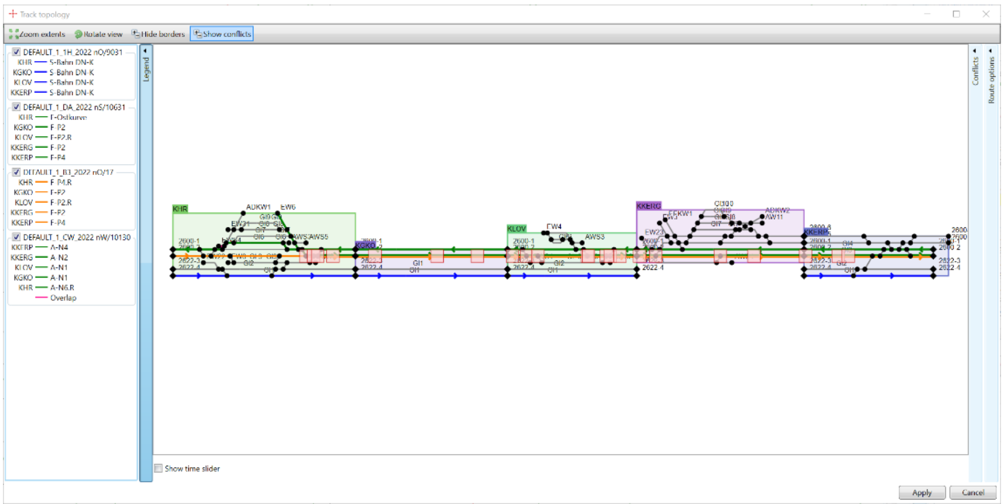


Figure 1 The Topoviewer-UI displaying routes and microscopic conflicts in a track graph of multiple nodes

## Research - "You'll never plan alone"

The second part of the internship should perhaps be considered more research than development.

It investigated whether a microscopic conflict resolution approach using a MILP-based heuristic with an MoD service is useful. SMA decided on a decision support approach in the form of an assistant working on a local area, since a network-wide fully automated conflict resolution is not realistic in the near future due to the difficulty of the problem. By choosing this approach, the requirements for short response times can already be met. Through developing an assistant, the user's expectations of the desired solution type and quality can also be better considered.

The following methods for conflict resolution were examined within the framework of the study: Extending stop durations and running times – in both cases using corresponding time reserves to solve headway conflicts. The rerouting of trains to solve through-traffic conflicts and the swapping of train sequences at conflict locations to increase capacity utilisation were not implemented due to the limited duration of the internship.

A linear program ("LP") was developed as a mathematical model that can quickly calculate how headway conflicts on both the lines and in stations can be avoided by extending only the stopping times without changing the sequence of trains. The occupancy times provided by the MoD service were sufficient as input data for this algorithm because a lengthening of the stopping time only requires a temporal shift of the occupancy times by the same amount.

However, even this very limited proof-of-concept has generated great interest among users which justifies a future in-depth investigation of the concept's feasibility. The local conflict resolution already saves the timetable planner a lot of tedious detail work. In follow-up projects, with regard to running time reserve extensions, it needs to be clarified how big the capacity loss through a simple linear approximation is and whether a more exact approximation using piecewise linear functions is required. We will continue to investigate to what extent the inclusion of changing tracks and the swapping of the sequence of trains as measures for conflict resolution can be implemented locally in such a way that the solvability of the problem is maintained in an acceptable time.

Congratulations on this very successful internship to Luca and the supervisors of the internship work!

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## A Peek under the Hood

Extending running time reserves can be considered as equivalent to reducing the speed of the planned trains on a part of their run. In practice, the trains have to decelerate and accelerate and therefore the added reserves are not distributed evenly along the train run. Consequently, there is not a linear relationship between the added running time reserve and the occupation time of a given block section, as is the case for extended stop times, but instead it depends on the location of each block section. However, this can be modelled linearly if a loss of capacity is accepted and the added running-time reserve is constrained by a bound.

To compute the effect of an increased running-time reserve we call the MoD Service twice. In the first call we assume that the train is running at Vmax on the considered part, and for the second call with the largest allowed reserve time. From these results we can derive a block section specific factor for the increase of the running-time reserve. Block sections towards the end of the affected section tend to have a factor nearer to 100%, whereas at the beginning it is closer to 0%.

These percentages are used as input parameters to the linear program ("LP") and the solution of this gives the factor by which we have to increase the running-time reserve on the considered part of a train run in order to resolve headway conflicts.

Ideally, these percentage values should be delivered by the MoD services directly instead of having to calculate by two calls to the MoD service interface, in order to keep the number of calls to the service small and to allow for performance improvements in the calculation of the service itself, e.g. by reusing intermediate results of the block occupation calculation when doing multiple similar calculations. This would also allow more accurate calculation results in comparison to the pragmatic setup when the MoD services is used as a black box.

If a linear approximation in this setting turns out to not be sufficiently accurate, a MILP could be formulated to model multiple train speed levels though binary decision variables along a train's run. This MILP increases the solution time of the conflict resolution method, and if train sequence swaps and track changes were to be included then the corresponding problem becomes NP-hard, implying that the conflict resolution problem can only be solved for limited geographical areas and time horizons, and cannot be expected to be solved network-wide in a reasonable time. Therefore, in the future a good trade-off between problem size and required computation time needs to be found. However, the limiting the geographical area and the considered time horizon so that a useful result can be found in an acceptable time is more an art than science and this requires a deep understanding of the problem domain and the mathematics behind it.