TECHNISCHE UNIVERSITÄT DRESDEN

PROFESSUR FÜR BETRIEB VON BAHNSYSTEMEN

"Friedrich List" Faculty of Transport and Traffic Sciences
Chair of Railway Operations

Thesis project: Analyzing the Computational Complexity of Railway Traffic Management Problems

Description

Railway Traffic Management (RTM) is critical for ensuring safe and efficient train movements, particularly during unforeseen perturbations and disruptions. RTM problems, such as train rescheduling and rerouting, can be formulated as combinatorial optimization tasks, and are known to be very challenging to solve in short time and/or for larger areas. In practice, the computational effort of solving these problems using state-of-the-art optimization models varies greatly: For some disruption scenarios, high-quality rescheduling solutions can be found within seconds, while others require excessive solver runtimes, even when disruptions are small in space and time. This phenomenon suggests that certain structural features of problem instances strongly influence their computational complexity.

Understanding what makes an RTM instance easy or hard to solve is crucial for improving real-time applications and designing better solution approaches. However, systematic studies identifying and predicting instance complexity are still lacking.

This thesis project aims to investigate which characteristics of RTM problem instances drive the computational complexity of RTM problems and how these can be modeled and predicted.

Assignment

- Review existing literature on Railway Traffic Management and combinatorial optimization, with a special focus on computational complexity
- Analyze simulated instances, and identify and categorize key features (e.g., domain-specific, solver-specific)
- Regression analysis to model CPU time as a function of instance features
- Train econometric and/or Machine Learning-based classification models to distinguish between easy and hard to solve instances
- Evaluate predictive performance and discuss implications for real-time rescheduling and solver strategies
- Write a report/thesis

Background

This thesis project offers the opportunity to gain experience in data science and optimization, while addressing practically relevant challenges in railway traffic management. A solid background in transportation science, Operations Research, or statistics is recommended. Programming skills (e.g., Python/R) and familiarity with Machine Learning tools are advantageous but can also be developed during the project. This topic is suitable for a diploma thesis, MSc thesis, or student research project (Studienarbeit).

References

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Kecman, P., Corman, F., D'Ariano, A., & Goverde, R. M. (2013). Rescheduling models for railway traffic management in large-scale networks. Public Transport, 5, 95-123.

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