Applications to verify and improve the robustness of timetables

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Agenda

1. Introduction
   Who we are and what we do

2. Basics of LUKS®
   Different approaches merged into one tool

3. LUKS-K module
   Conflict detection and timetabling

4. LUKS-S module
   Stochastic simulation of operation

5. OptDis module
   Mathematical optimization of timetables
VIA Consulting & Development GmbH
Key figures

One-stop consulting and software

- Founded in August 2008
- Spin-off from RWTH Aachen University in private ownership
- 28 employees, thereof 15 full-time and 19 with university degree:
  - Civil & traffic engineers
  - Developers
- Customers in eleven countries:
  - Infrastructure Managers
  - Authorities
  - Institutions & Universities
- ~2,35 Mill. Euro turnover (in 2017)
- DIN EN ISO 9001:2008 certified

Consultancy
- Operational infrastructure planning
- Command & control technology
- Operations and timetable concepts

Software
- Development & Sales of standard tools:
  - LUKS
  - OnTime
  - OpenTimeTable (OTT)
- Individual development support & consultancy
General characteristics of LUKS®

Functional modules
- LUKS-K (construction)
- LUKS-S (simulation)
- LUKS-A (queueing theory)
- LUKS-C (concatenation UIC Code 406)

Common data structures for all modules
→ sustainable data management

Master data
- Blocking times
- Running times
- IS data
- ETCS braking model

Import Interfaces
- Infrastructure data
  - railML®
  - LUKS-ISS
  - XML-ISS
  - CSV-lists
- Timetable data
  - railML®
  - XML-KSS
  - LUKS-KSS
  - Viriato

Export Interfaces
- Infrastructure data
  - railML®
  - LUKS-ISS
  - CSV
- Timetable data
  - LUKS-KSS
  - railML®
  - conflict visualizations

database
Infrastructure is modelled as a microscopic graph
Basis of conflict detection: the blocking time model

Physical occupation + clearing time + approach time + switching times + response time = blocking time
Each train move is represented by its blocking-time series

Application of blocking time series
- Exact representation of capacity occupation
- Guarantee of conflict-free timetabling
- Easy determination of actually available buffer times

Realistic model of capacity occupation
- Occupation from an operational POV
- Takes into account all operational aspects
- Easy detection of bottlenecks
LUKS-K: Visual conflict detection and timetable construction
Conflict detection batch mode is available

- Loading of microscopic infrastructure
- Import of daily timetable data
- Microscopic running and blocking time calculation
- Detection and classification of all conflicts
- Visualization and export
Stochastic simulation of railway operations

Operational simulation models the interaction between a centralized traffic management, the trains and the interlocking system

- The conflict-free timetable is disrupted by randomly generated primary delays.
- Delays can occur before a train enters the simulation area or while it is running through the area.
- Each train has its own assumed probability distribution for delays.
- Ensuing conflicts are detected and solved by the traffic management.
- Different primary delays are generated for each simulation run. This model different traffic situations or days.
LUKS simulation is an interaction between two levels

**Operational Field Level**
- Trains run simultaneously
- Dynamic speed profiles
- Simulation based on timetable and decisions from the traffic management
- Disturbances occur randomly, causing primary delays
- Existing reserve times used to reduce delays
- Unsolved conflicts are solved by the interlocking system (first-come-first-served)

**Traffic management Level**
- Incoming position telegrams are turned into a prognosis.
- Conflicts in the near future (e.g. 30 min) are solved
- Wide-area and anticipatory conflict solution
- Considers temporal and other non-functional constraints when solving conflicts
- Models knowledge of traffic managers
Delay evolution and quotients can be analyzed and evaluated in detail.

### Applications to verify and improve the robustness of time tables

- Energy Efficient Timetabling
- 20th February 2018
Bottlenecks are also represented in graphical form.
OptDis – Automatic timetable optimization

Key features
- Global optimization of all trains inside the considered area
- Application of state-of-the-art optimization techniques (MIP)
- Complete integration of leading solvers (Gurobi and CPLEX)
- Highly configurable objective function

OptDis automatically optimizes a roughly planned timetable
- Solves all occupation conflicts (intersection of blocking times)
- Supports all common timetabling approaches
- Respects turnarounds and regular intervals
- Minimization of deviation from roughly planned trajectories
- Maximization of robustness (buffer times and running time reserves)
LUKS: Application to verify the robustness of timetables

LUKS offers several approaches based on a common database
- Microscopic infrastructure graph and train data
- Advanced blocking time calculation

Conflict detection based on blocking times
- Essentially deterministic timetable simulation
- Visualization of all occupation conflicts and buffer times (interactive and batch)

Stochastic simulation of operations
- Models the interaction between a traffic management, trains and interlocking system
- Determines the robustness in case of disturbances
- Train- and infrastructure based

Automatic timetable optimization
- Automatically optimizes a roughly planned timetable
- Maximizes the timetable robustness (buffer times and running time reserves)