«Academic research and railways: lessons learnt»

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Ambra Toletti, ETH Zurich

Zurich, 28 March 2018
Agenda

→ Overview on formal collaboration ETH Zurich – SBB on timetabling and operations topics

→ Focus on current PhD thesis of Ambra Toletti

→ Lesson learnt from the collaboration and future challenges
18 years of formal collaboration between ETH Zurich and SBB: PhD theses

Institute of Operations Research
Prof. Hans-Jakob Lüthi

Dan Burkolter → Thomas Herrmann
2000-2005: Dan Burkolter and Thomas Herrmann

- Capacity of Railways in Station Areas using Petri Nets, 2005
- Stability of Timetables and Train Routings through Station Regions, 2005
18 years of formal collaboration between ETH Zurich and SBB: PhD theses

Institute of Operations Research
Prof. Hans-Jakob Lüthi, Dr. Marco Laumanns

Dan Burkolter
Gabrio Caimi
Thomas Herrmann

Institute for Transport Planning and Systems
Prof. Ulrich Weidmann

Marco Lüthi
2004-2009: Marco Lüthi and Gabrio Caimi

- Improving the efficiency of heavily used railway networks through integrated real-time rescheduling, 2009

- Algorithmic decision support for train scheduling in a large and highly utilised railway network, 2009
18 years of formal collaboration between ETH Zurich and SBB: PhD theses

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Martin Fuchsberger

Institute for Transport Planning and Systems
Prof. Ulrich Weidmann

Marco Lüthi
Steffen Schranil
2009-2013: Martin Fuchsberger and Steffen Schranil

- Algorithms for railway traffic management in complex central station areas, 2012

- Prognose der Dauer von Störungen des Bahnbetriebs, 2013
18 years of formal collaboration between ETH Zurich and SBB: PhD theses

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Dan Burkolter
Gabrio Caimi
Thomas Herrmann

Martin Fuchsberger
Sabrina Herrigel

Institute for Transport Planning and Systems
Prof. Ulrich Weidmann

Marco Lüthi
Steffen Schranil
2012-2015: Sabrina Herrigel

→ Algorithmic decision support for the construction of periodic railway timetables, 2015
18 years of formal collaboration between ETH Zurich and SBB: PhD theses

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- Dan Burkolter
- Gabrio Caimi
- Martin Fuchsberger
- Sabrina Herrigel

Institute for Transport Planning and Systems
Prof. Ulrich Weidmann

- Thomas Herrmann
- Marco Lüthi
- Steffen Schranil
- Ambra Toletti
2014-2018: Ambra Toletti
Current research at IVT in collaboration with SBB

Automated railway traffic rescheduling and customer information
Research question

How can algorithmic real-time rescheduling procedures support the resolution of small disturbances in railway operations in condensation zones and inbound lines, in order to make traffic management automatable and, as a consequence, improve consistency and timeliness of passengers information?
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Research question

Small disturbances are more frequent than larger ones

[Steffen Schranil, PhD at ETH Zurich, IVT, Transport Systems group]
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Network decomposition in condensation and compensation zones and rescheduling algorithms for condensation zones

[Martin Fuchsberger, PhD at ETH Zurich, IFOR]

[Gabrio Caimi, PhD at ETH Zurich, IFOR]
How can algorithmic real-time rescheduling procedures support the resolution of small disturbances in railway operations in condensation zones and inbound lines, in order to make traffic management automatable and, as a consequence, improve consistency and timeliness of passengers information?
Methodology

- Real world railway operations
- Functional requirements of traffic management
- Mathematical model of railway traffic rescheduling
- Algorithmic solution
- New adapted schedule
Methodology

Real world railway operations

Functional requirements of traffic management

Resource conflict graph model for local railway traffic rescheduling

Lagrangian relaxation for problem partitioning and coordination

Column generation based heuristic for local railway traffic rescheduling

Negotiation based heuristic for coordination

New adapted schedule
Methodology

Simulator of railway operations

Functional requirements of traffic management

Resource conflict graph model for local railway traffic rescheduling
Lagrangian relaxation for problem partitioning and coordination

Column generation based heuristic for local railway traffic rescheduling
Negotiation based heuristic for coordination

New adapted schedule
Experimental setup

Infrastructure (track-circuits granularity)

Official Timetable 2017, 06:45-08:00

Delay distributions (operations data SBB)

Rolling stock

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[Pixabay.com]
Experimental results

The new adapted schedules built according to the resource conflict graph model are feasible.

Simulator of railway operations

The column generation heuristic decreases the computational time of the resource conflict graph model w.r.t. commercial solver.

Resource conflict graph model for local railway traffic rescheduling

Lagrangian relaxation for problem partitioning and coordination

Column generation based heuristic for local railway traffic rescheduling

Negotiation based heuristic for coordination

New adapted schedule
Experimental results

Consistency at portals is not implicitly achieved using the yearly timetable as common reference

The coordination approach improves consistency of decisions at portals between local rescheduling models

Resource conflict graph model for local railway traffic rescheduling
Lagrangian relaxation for problem partitioning and coordination

Column generation based heuristic for local railway traffic rescheduling
Negotiation based heuristic for coordination

New adapted schedule
Discussion

Insights into the final results of this thesis:
- algorithms can be used to support railway traffic rescheduling;
- the integration of these algorithms into the current traffic support systems is possible;
- as a consequence, passenger information can be improved.

Lessons learnt from collaboration with SBB
- the form of the collaboration evolved during the project;
- at the beginning, support by SBB enabled dive into the topic;
- (direct) access to relevant information has highly contributed to the quality of the thesis.
Lesson learnt from the past collaboration

From the industrial point of view:

3 key factors for a successful collaboration with academy

1. Good and useful results of the PhD → Close collaboration during the PhD thesis, possibility for students to discuss with specialists and have access to data.

2. Have a plan for a stepwise practical implementation → Keep going in the topic, integrate the results and have internal resources and organization for the «translation in practice».

3. Make use of the know-how accumulated by the student during the PhD → Hire the person, if possible!
Future collaboration

Institute of Operations Research
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- Dan Burkolter
- Gabrio Caimi
- Martin Fuchsberger
- Sabrina Herrigel

Institute for Transport Planning and Systems
Prof. Ulrich Weidmann

- Thomas Herrmann
- Marco Lüthi
- Steffen Schranil
- Ambra Toletti

Prof. Francesco Corman
Challenge for the future
SmartRail 4.0: Key Components.

Traffic Management System («TMS»)

All business processes only on the «IT Layer» – basic and expensive «safety» systems only as «slim gatekeepers»

Planning (long- and short-term)

Commercial Schedule

Future

Soon

Now

Control:

Very precise control of train movements and infrastructure (in „seconds and meters“)

Very small and very performant pure «ETCS geometric interlocking»

Connectivity (high bandwidth)

Precise and automatic localisation (GLAT)

Track occupations by train, persons, Buildings sites, obstacles,

• Only points and barriers.
• Trackside assets reduced by up to 70%.

Automatic train operation (ATO)
SmartRail 4.0: Research Topics.

- Occupational psychology / changing job profiles
- Using simulation for whole-system optimization.
- Capacity effects:
  - How to increase capacity?
  - How to use capacity?

- Dynamic systems and control loops
- Maintaining a safe (SIL-4) image of track topology.
- Vehicle architecture for interoperability, upgradability (modularization)
- Options for precise, highly available, provably safe, economically viable localisation.

- Automated Planning and Dispatching
- Communication bus: achieving safety and reliability over given networks.
- Procedures and techniques to ensure and prove RAMS-characteristics (CENELEC processes).
- Analysing, protecting and ensuring for IT-Security.
Questions?