Optimal Management of Railway Perturbations by Means of an Integrated Support System for Real-Time Traffic Control

High level aim:
improve ‘capacity’ on European railway networks

Innovations:

- **Standardised** definitions, methods and processes
- Improved methods for **timetable** construction
- **Real time** traffic algorithms
- Improved decision support for **major perturbations**
- **Centrally guided** train operation
- Standardised **ICT architecture**
19 partners:

4 case-studies:
- A part of the Dutch network
- A part of the ECML in the UK
- The Iron-Ore line in Sweden and Norway
- The Bologna central station in Italy
Real time traffic algorithms

• Real-time perturbation management in case of small delays

• Control measures:
  • re-order trains
  • re-route trains
  • re-time trains
  • cancel or add non-commercial stops (operational stops)

• No interaction with RU necessary

• Aiming at automatic decisions
Closed-loop optimization

Conflict Detection and Resolution (CDR): Real-time scheduling and routing optimization

Traffic State Prediction (TSP)

Traffic Management System (TMS)

Train Path Envelope Computation (TPEC)

Traffic State Prediction (TSP)

Automatic Execution Function (AEF)

{future traffic state} → {Real Time Traffic Plan (RTTP)} → {Train Path Envelopes} → {Enriched RTTP}

{current traffic state} → {Real Time Traffic Plan (RTTP)} → {routes, train orders} → {train speed profiles}
Real-time traffic plan (RTTP)

- Describes microscopically how the traffic shall be executed:
  - Routing: which **routes** will the trains take
  - Scheduling: in which **order** will trains pass over sections

**Train view**

<table>
<thead>
<tr>
<th>Train 1001</th>
<th>Route</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>O-A</td>
<td>TC1</td>
<td></td>
</tr>
<tr>
<td>A-C</td>
<td>TC2</td>
<td></td>
</tr>
<tr>
<td>C-D</td>
<td>TC4</td>
<td></td>
</tr>
<tr>
<td>D-E</td>
<td>TC5</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Train 801</th>
<th>Route</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>O-A</td>
<td>TC1</td>
<td></td>
</tr>
<tr>
<td>A-B</td>
<td>TC2</td>
<td></td>
</tr>
<tr>
<td>C-D</td>
<td>TC4</td>
<td></td>
</tr>
<tr>
<td>B-D</td>
<td>TC5</td>
<td></td>
</tr>
<tr>
<td>D-E</td>
<td>TC6</td>
<td></td>
</tr>
</tbody>
</table>

**Infrastructure view**

```
TC1  1001  801
TC2  1001  801
TC3  801   1001
TC4  1001  801
TC5  801   1001
TC6  801   1001
```
Common data and communication models based on open standards:

- Data model: RailML
- Data exchanges: RabbitMQ
The architecture: in detail

- Open Source Architecture
- Traffic State Prediction
- Route Setting
- Traffic Management System (TMS)
- Conflict Detection and Resolution (CDR)
- RTTP
- Traffic State
Benchmarking

- **RECIFE** (IFSTTAR)
  - Mixed-integer linear programming
  - Minimization of **total delay**
  - Proved optimality for scheduling and routing
  - **Track Detection Section** representation

- **ROMA** (TUDelft)
  - Alternative graphs
  - Minimization of **maximum delay**
  - Proved optimality for scheduling, as good as possible solution for routing
  - **Block-section** representation
Case-study

- **Iron Ore Line** (Sweden & Norway)
  - single track line 475 km long
  - 32 stations/meeting points between 500 and 750 m long
  - intensively used by mixed traffic (Iron Ore trains 750 m long)
  - about 40 trains per day
Train path diagrams
Perturbation scenarios

HMI showing the train path diagram and the network layout
Case-study

• **Dutch network** (Netherlands)
  • mostly double track lines
  • short four-track section
  • few single-track branches
  • 5 main stations
  • about 80 trains during two morning-peak-hours
Demonstration

Recife Closed-loop Integration Dutch Network
Key Performance Indicators

KPI defined by IM’s
Computed by an independent MATLAB module

- Punctuality: total delay at selected stations
- Resilience:
  - Maximum deviation
  - Delay area
  - Time to recover

Total train deviations w.r.t. baseline simulation throughout the scenario horizon
Conclusions

• A modular automatic real-time traffic management of small perturbations is feasible

• Modules, tools and experience are available for further steps of test and integration with real rail system

• Future research will aim to include the interaction of the human dispatcher