Analysis of the robustness of real-time railway traffic management optimization

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Stations and junctions: network bottlenecks

- Increase of the number of railway services
  \(\rightarrow\) increase of traffic density

- At critical locations, the \textbf{whole infrastructure capacity} is exploited
  \(\rightarrow\) increase of the number of \textbf{possible conflicts} and of their \textbf{impact}

- Train \textbf{interactions} make dispatcher task very hard: they must \textbf{seek an “optimal” solution} within a short time
  \(\rightarrow\) need for a \textbf{real-time decision-support tool}
Routing and scheduling problem

What is the train routing and scheduling which minimizes delay propagation?

We answer to this question with **RECIFE-MILP**:  
- truncated exact algorithm  
- microscopic modeling of the infrastructure  
- route-lock sectional-release interlocking system  
- fixed speed model  
- many/all possible re-routings allowed in the infrastructure  
- open-loop and closed-loop
The model

Objective function

minimization of the total delays suffered by trains at all scheduled stops within the considered infrastructure

Variables

Continuous variables associated to:
- occupation and utilization time
- delay

Binary variables associated to:
- use of routes
- precedence on track-circuit
Perfect vs uncertain information

Deterministic model
As most algorithms proposed in the literature, RECIFE-MILP considers perfect information on traffic conditions.

Uncertain information
In reality, traffic conditions are subject to unpredictable modifications due to:
- train driver behavior
- passenger behavior
- ...

Uncertainty
Perfect vs uncertain information

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**Uncertain information**
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**Research question**
Is an algorithm as RECIFE-MILP effective even despite the strong hypothesis on perfect information?

Or, being uncertainty unavoidable, deterministic optimization is incapable of outperforming a basic strategy as the FCFS?
Assessment proposed

Assessment through simulation

Scenario definition

Predicted traffic condition

RECIFE-MILP

Context
RECIFE-MILP
Uncertainty
Experimental analysis
Conclusions
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Random noise
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Routing and scheduling decisions
Total delay RECIFE-MILP

RECIFE-MILP
Microscopic simulator

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Experimental setup

Instances

30 instances: perturbed traffic between 7 and 8am

Random Noise

The train entrances are shifted by random number in $[-n, n]$

$n \in \{20, 40, 60, 80, 100\}$

RECIFE-MILP

Run of 3 minutes on perturbed instances without noise

Testing different route formation times ($\Rightarrow$ train headway): 15, 25 or 35 seconds
Experimental results

**Total delay for noise factor 0 and 100**

![Box plot showing total delay for noise factor 0 and 100 for different headways and FCFS]

**Mean of total delay FCFS - total delay RECIFE-MILP**

<table>
<thead>
<tr>
<th>noise factor</th>
<th>headway 15</th>
<th>headway 25</th>
<th>headway 35</th>
</tr>
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<tbody>
<tr>
<td>0</td>
<td>124</td>
<td>74</td>
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</tr>
<tr>
<td>100</td>
<td>129</td>
<td>109</td>
<td>133</td>
</tr>
</tbody>
</table>

Bold indicates the best mean difference
Conclusions

We assessed the **effectiveness of RECIFE-MILP** in case of uncertain information

We compared its performance to those of the FCFS through the **Opentrack simulator**

The conclusions of the analysis indicate that:

▶ the improvement of performance allowed by RECIFE-MILP are **quite robust**

▶ in the great majority of the cases, it still **outperforms** the FCFS

▶ this robustness does not improve with the increase of the **minimum headway time** in the optimization
Future works

Produce a wider experimental analysis:

- other sources of uncertainty
- other infrastructures

Compare with robust optimization algorithms

Include the study in a close-loop optimization framework

↓

as in the ON-TIME project: talk 33 at 17:15 in room 615