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17–19 May 2018, Zadar, Croatia

Road and Rail Infrastructure V

Stjepan Lakušić – EDITOR

Organizer
University of Zagreb
Faculty of Civil Engineering
Department of Transportation

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EDITOR
Stjepan Lakušić
Department of Transportation
Faculty of Civil Engineering
University of Zagreb
Zagreb, Croatia

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APPLICATION OF KRONECKER ALGEBRA FOR RAILWAY LINE ZAGREB – RIJEKA

Andreas Schöbel[1], Hans Blieberger[2], Christian Schöbel[1]
[1] OpenTrack Railway Technology GmbH, Austria
[2] Vienna Univ. of Technology, Institute of Comp. Engineering, Automation Systems Group, Austria

Abstract

Within the Shift2Rail-Project "GoSafeRail" so called Kronecker Algebra is applied on the railway line from Zagreb to Rijeka for traffic flow optimisation. Kronecker Algebra consists out of Kronecker Product and Kronecker Sum to describe concurrency of tasks as well es their interleavings. The railway line from Zagreb to Rijeka has been successfully modelled by software tool called OpenTrack. In this project data from OpenTrack model is converted into input for Kronecker Algebra to manage rail capacity in an efficient manner. To model the infrastructure so called IVT format is used to export an itinerary covering the main track. The entire line from Zagreb to Rijeka is modelled by 250 edges. The timetable is exported in OpenTrack text format and used to create train run files for the 225 daily running trains. Train dynamics are also considered by tractive effort diagram and braking force diagram.

Keywords: Railway Operation, Kronecker Algebra, Rail Traffic Flow

1 Introduction

Rail infrastructure managers are responsible for safety measures and planning within the infrastructure network. Although the railway transport mode is considered one of the safest modes of transport there is a number of infrastructure failures that have happened in recent years. Unfortunately, the number is expected to rise in the future, mainly due to ageing railway network and stronger climate changes. Consequently, the objective of the Shift2Rail project Global SAFEty Management Framework for RAIL Operations (Go SAFE Rail project) is development of an evolutionary Decision Support Tool with the main goal of offering safer, reliable and efficient rail infrastructure [1]. Application of microscopic simulation of railway operations based upon a physical and mathematical model of the railway system is the state of the art in railway traffic operations. Normally, such tools output indicators for the operational performance, like for example, delays or energy consumption. Up to now, optimization was typically predefined by the user of the tool, introduced into the simulation and 'tested' for its applicability during the simulation. This led to missed opportunities for finding an optimal solution, which led to the simulation programs not being able to solve dispatching questions or handle headway conflicts. Simulation tools have, however, one shortcoming; namely, the inability to optimize train ran automatically. To close this gap within railway operations with increased traffic, algorithms which consider all train runs at the same time have been developed and applied. Using Kronecker algebra, microscopic simulation tool will both improve traffic flow and assess the impact of maintenance and renewal proposals, as part of support for decision making of the infrastructure manager. The algorithm for calculating the optimal driving strategy and optimizing the overall railway system is based on the PhD-thesis "Energy-efficient Optimization of Railway Operation. An Algorithm Based on Kronecker Algebra" by

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Volcic [2]. Moreover, with OpenTrack micro-simulation modelling tool, traffic model will be developed that will use multi-criteria optimization algorithms to address complex requirements, for both passenger and freight transport. Using Kronecker algebra [3] which showed good results in dealing with optimization scenarios in railway traffic flow, especially avoidance of bottlenecks and conflicts, simulation of actual network performance on the line between Zagreb and Rijeka in Croatia will be performed. The input data used for the traffic flow optimization tool is defined by two components: first, the current characteristics of the rail system will be supplied, the set of infrastructure, rolling stock and timetable characteristics, which represent the base for future calculations. Secondly, infrastructure manager's identification and assessment of restricted availability of infrastructure assets. Those two components will be merged using simulation tool OpenTrack [4] for the visualization of all existing data, and further processed into the concrete syntax for the input files needed by the optimization tool.

2 Transformation of an OpenTrack Project into Kronecker Algebra

Starting from an OpenTrack model of a railway line two files are generated and exported by existing filters. Based upon an itinerary covering the main track from first to last station of an OpenTrack model a text file in IVT format is generated. The structure of an ivt file is always the same and contains the information listed in table 1. The four speed limits have their origin in the Swiss regulation for track speed limits for passenger, cargo (two braking settings) and tilting trains. This file in IVT format is used to create the so called tracks.csv file for Kronecker Algebra. The content of tracks.csv is described in table 2. Here, the macroscopic structure of a railway line is defined. In addition, there is a micro tracks file to describe the microscopic structure including gradients and speed limits. This input is required for the calculation of running times later on. The timetable is exported as a text file in OpenTrack format (table 3). Based upon this information about the timetable of all trains running in a project for each train a text file trainID.csv is generated as input for Kronecker (table 4). Additionally, train movements are calculated in accordance with their tractive-effort and braking characteristics.

Table 1 Structure of IVT format

Position	Content	Unit
1	Position	Meter
2	Vertex Name Up	None
3	Vertex Name Down	None
4	Vertex km Up	km
5	Vertex km Down	km
6	Speed Up 1	km/h
7	Speed Up 2	km/h
8	Speed Up 3	km/h
9	Speed Up 4	km/h
10	Speed Down 1	km/h
11	Speed Down 2	km/h
12	Speed Down 3	km/h
13	Speed Down 4	km/h
14	Gradient	‰
15	Radius	Meter
16	Tunnel Type	None
17	Signal Up	None
18	Signal Down	None
19	Station Name	None

Table 2 Structure of tracks.csv for Kronecker Algebra

Position	Content	Unit
1	Edge ID	None
2	Initial Condition for Semaphore	Number
3	Maximum Semaphore	Number
4	Start	Meter
5	End	Meter
6	Sight Position for Start	Meter
7	Release Position for End	Meter
8	Sight Position for End	Meter
9	Release Position for Start	Meter

Table 3 OpenTrack Timetable Format

Position	Content	Unit / Format
1	Course ID	None
2	IntervalCourseID	None
3	TimeToIntervalReference	Seconds
4	StationIndex	None
5	StationSign	None
6	TrackName	None
7	ArrTimeDayOffset	None
8	ArrTime	HH:MM:SS
9	DepTimeDayOffset	None
10	DepTime	HH:MM:SS
11	UseDepTime	None
12	Dwell	Seconds
13	StopAtStation	None
14	MeanDelay	Seconds
15	Distribution	None
16	DeltaMass	Tons

Table 4 Structure of trainID.csv for Kronecker Algebra

Position	Content	Unit / Format
1	Start Node ID	None
2	End Node ID	None
3	Direction	1 UP; 2 DOWN
4	Arrival Day	DD
5	Arrival Month	MM
6	Arrival Year	YYYY
7	Arrival Hour	HH
8	Arrival Minute	MM
9	Arrival Second	SS
10	Departure Day	DD
11	Departure Month	MM
12	Departure Year	YYYY
13	Departure Hour	HH
14	Departure Minute	MM
15	Departure Second	SS
16	Stopping Point	Meter
17	Timeinteger	HHMM
18	Virtual Stop	No “0” Yes “1”
19	Kronecker operation	Blocking “p” Releasing “v”

3 Use Case of Zagreb – Rijeka Line

The original infrastructure topology of Zagreb – Rijeka Line has been divided on 10 documents in OpenTrack. As an example for this type of documents the infrastructure topology between Fuzine and Meja is shown in figure 1. After compression of the entire railway line from Zagreb to Rijeka only 250 edges have to be considered for the Kronecker Algebra in the tracks.csv file. This compression can be visualized by reimporting this compressed tracks.csv file in OpenTrack (figure 2). Additionally, figure 3 shows all passenger trains running on Zagreb – Rijeka line which are used for testing the performance of Kronecker Algebra in an early stage.

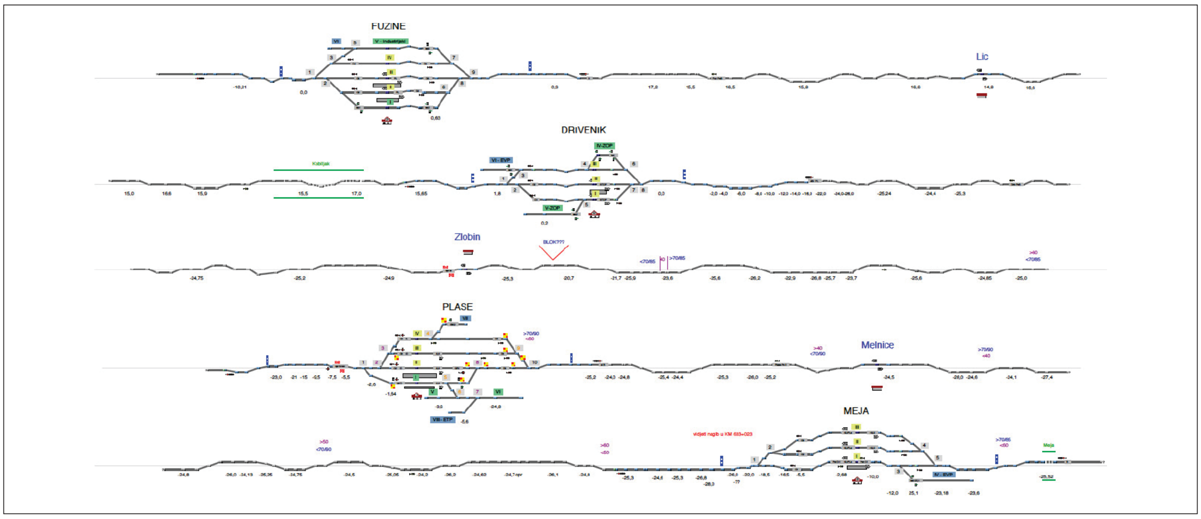

Figure 1 Infrastructure Topology between Fuzine and Meja

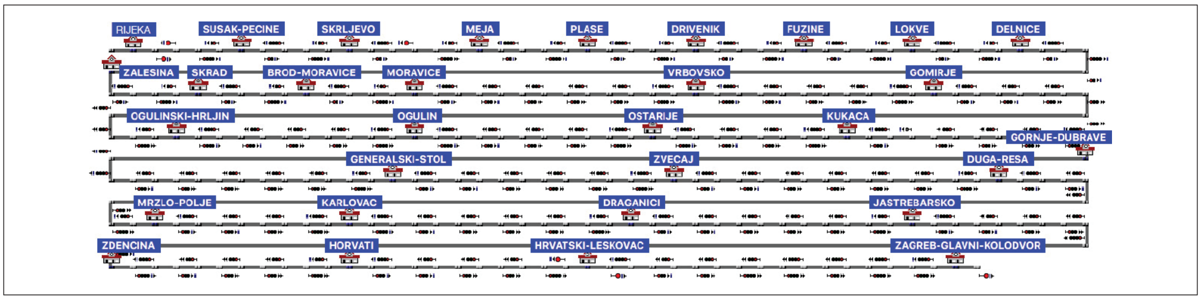

Figure 2 Reimported tracks.csv in OpenTrack covering Zagreb – Rijeka

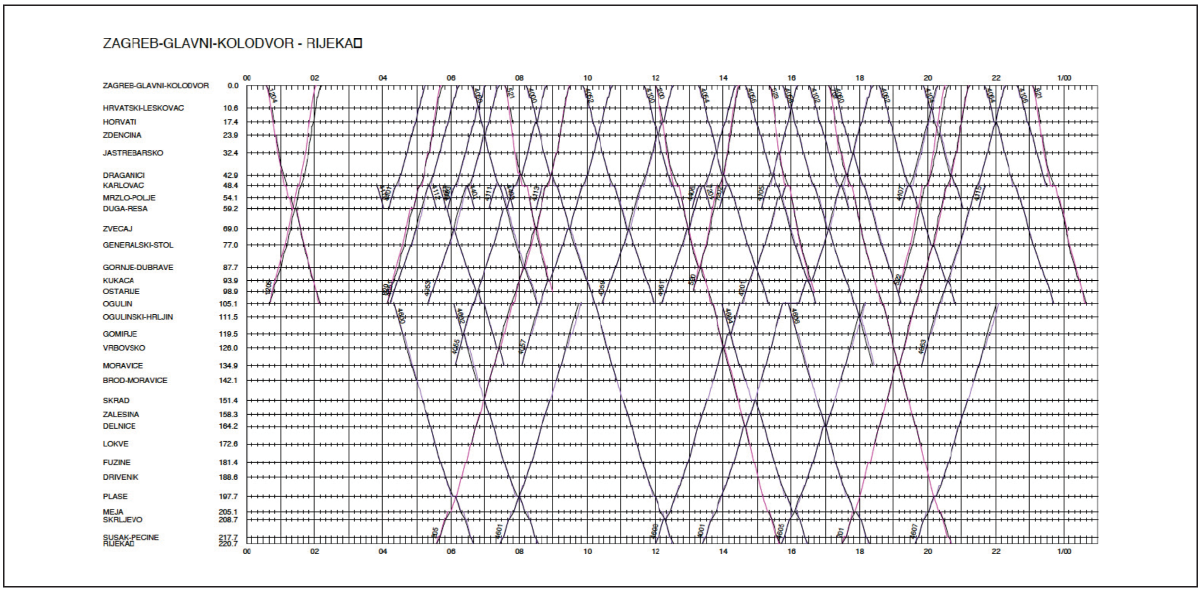

Figure 3 Train Diagram for all Passenger Trains on Zagreb – Rijeka

4 Conclusions

In conclusion, development of rail traffic flow optimization tool enables infrastructure managers to plan their decisions in a more efficient manner. Optimal solutions will ensure high level of efficient use of, very often scarce, resources and optimal process flow. Kronecker Algebra enables one to set clear priorities based on reliable date and ensure punctuality, and even more important, energy consumption for traction.

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