

Generalized nets as a tool for modelling of railway networks. Part 3

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Abstract: In this paper, a new (third) example is given that shows that generalized nets can be used as a tool for modelling of railway networks. In the first part of the research, a generalized net model of the railway network in Southern Bulgaria was given, in the second part – a generalized net model of the railway network in Northern Bulgaria was described. Here, we describe a generalized net model the railway networks connecting Bulgaria with its neighbouring counties.

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1 Introduction

In [5], the Generalized Nets (GNs, see [1-3]) were first used as a tool for modelling processes in railways transport, describing the railway network in Southern Bulgaria. In [6], the authors constructed a GN model of the railway network in Northern Bulgaria.

In Section 2, we describe a complete GN-model of the railway networks connecting Bulgaria with its neighbouring countries - Romania, Serbia, North Macedonia¹, Greece and Turkey.

2 A generalized net model

The GN-model contains 8 transitions and 44 places. Its tokens represent separate trains that will move from a train station to the next one or with shunt in a train station (see Fig. 1).

¹There are no railway lines between Bulgaria and North Macedonia

The transitions' input and output places represent the following train stations in Bulgaria: Z_1 – Vidin (l_7), Z_2 – Kalotina (l_{10}), Z_3 – Kulata (l_{13}), Z_4 – Sofia (l_{20}), Z_5 – Ruse (l_{28}), Z_6 – Svilengrad (l_3), Z_7 – Kardam (l_{39}), and Z_8 – Kapitan Andreevo (l_{44}). These places are simultaneously inputs and outputs of the transitions. The rest places represent the activities of the trains related to entering or leaving the respective train station.

Seven places ($l_1, l_2, l_3, l_{21}, l_{22}, l_{35}, l_{36}$) are inputs of the GN. They represent the train stations Kalafat (Romania), Dimitrovgrad (Serbia), Exochi (Greece), Giurgiu (Romania), Ormenion (Grece), Negru Voda (Romania) and Edirne (Turkey), respectively.

Each token, entering a place, obtains as a current characteristic information about the time for realization of the previous activity.

In the places representing the train stations, the token obtains as additional information the train station from where it arrives and the number of passengers that leave the respective train or catch it.

In the present GN-model, we are interested only in the connections between the boundary train stations (Vidin, Kalotina, Kulata, Ruse, Svilengrad and Kardam) and we are not interested in the train stations in the interior of Bulgaria (this will be an object of research in a next paper). In some cases, there are no direct connections between some train stations, more exactly, between Vidin and Kalotina, Vidin and Kulata, Vidin and Svilengrad, Vidin and Kardam, Vidin and Kapitan Andreevo, Kalotina and Kulata, Kalotina and Ruse, Kalotina and Svilengrad, Kalotina and Kardam, Kalotina and Kapitan Andreevo, Kulata and Ruse, Kulata and Svilengrad, Kulata and Kardam, Kulata and Kapitan Andreevo, Ruse and Kardam, Ruse and Kapitan Andreevo, Svilengrad and kardam, Kardam and Kapitan Andreevo. These connections are realized through some other train stations in the interior of Bulgaria.

The GN-transitions are the following.

$$Z_1 = \langle \{l_1, l_7, l_{15}, l_{23}\}, \{l_4, l_5, l_6, l_7\}, \begin{array}{c|cccc} & l_4 & l_5 & l_6 & l_7 \\ \hline l_1 & false & false & false & true \\ l_7 & W_{7,4} & W_{7,5} & W_{7,6} & W_{7,7} \\ l_{15} & false & false & false & true \\ l_{23} & false & false & false & true \end{array} \rangle,$$

where

$W_{7,4}$ = “the train is directed to train station of Kalafat (Romania)”,

$W_{7,5}$ = “the train is directed to train station of Ruse”,

$W_{7,6}$ = “the train is directed to train station of Sofia”,

$W_{7,7}$ = “the train must shunt in train station of Vidin”.

$$Z_2 = \langle \{l_2, l_{10}, l_{14}\}, \{l_8, l_9, l_{10}\}, \begin{array}{c|ccc} & l_8 & l_9 & l_{10} \\ \hline l_2 & false & false & true \\ l_{10} & W_{10,8} & W_{10,9} & W_{10,10} \\ l_{14} & false & false & true \end{array} \rangle,$$

where

$W_{10,8}$ = “the train is directed to train station of Dimitrovgrad (Serbia)”,

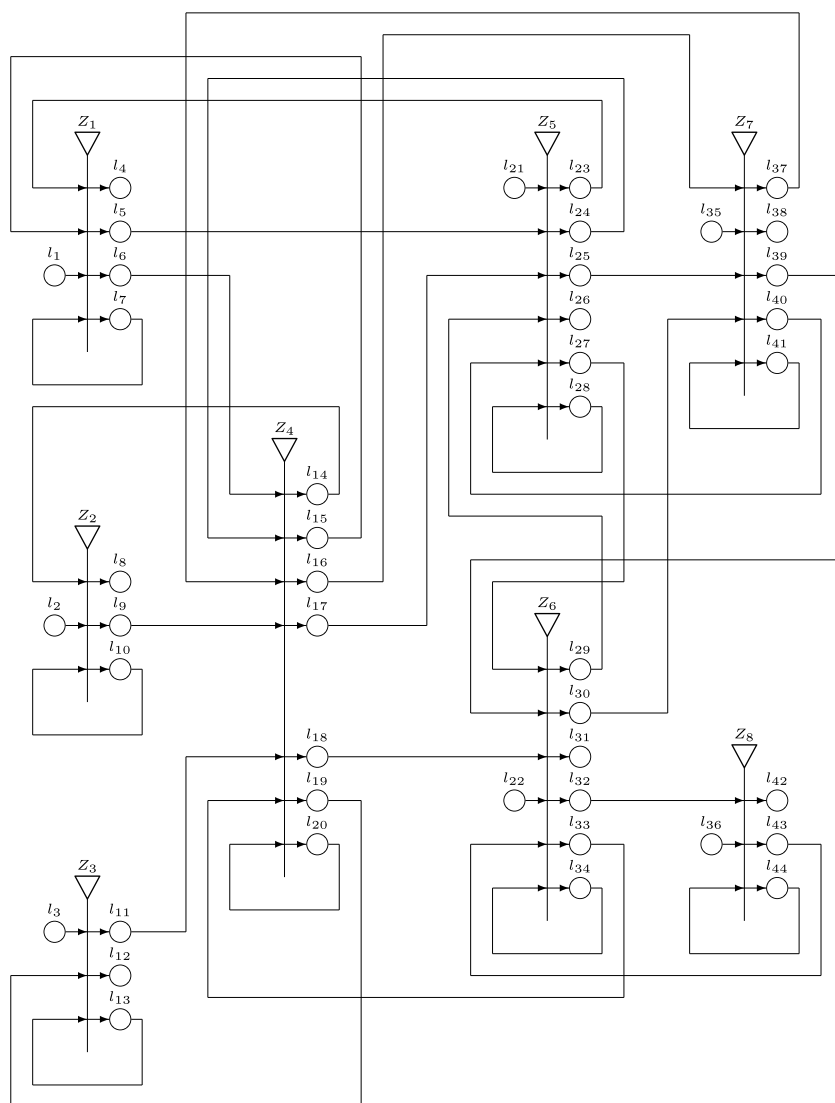


Fig. 1.

$W_{10,9}$ = “the train is directed to train station of Sofia”,

$W_{10,10}$ = “the train must shunt in train station of Kalotina”.

$$Z_3 = \langle \{l_3, l_{13}, l_{19}\}, \{l_{11}, l_{12}, l_{13}\}, \begin{array}{c|ccc} & l_{11} & l_{12} & l_{13} \\ \hline l_3 & false & false & true \\ l_{13} & W_{13,11} & W_{13,12} & W_{13,13} \\ l_{19} & false & false & true \end{array} \rangle,$$

where

$W_{13,11}$ = “the train is directed to train station of Sofia”,
 $W_{13,12}$ = “the train is directed to train station of Exochi (Greece)”,
 $W_{13,13}$ = “the train must shunt in train station of Kulata”.

$$Z_4 = \langle \{l_6, l_9, l_{11}, l_{20}, l_{24}, l_{33}, l_{37}\}, \{l_{14}, l_{15}, l_{16}, l_{17}, l_{18}, l_{19}, l_{20}\},$$

	l_{14}	l_{15}	l_{16}	l_{17}	l_{18}	l_{18}	l_{20}
l_6	<i>false</i>	<i>false</i>	<i>false</i>	<i>false</i>	<i>false</i>	<i>false</i>	<i>true</i>
l_9	<i>false</i>	<i>false</i>	<i>false</i>	<i>false</i>	<i>false</i>	<i>false</i>	<i>true</i>
l_{11}	<i>false</i>	<i>false</i>	<i>false</i>	<i>false</i>	<i>false</i>	<i>false</i>	<i>true</i>
l_{20}	$W_{20,14}$	$W_{20,15}$	$W_{20,16}$	$W_{20,17}$	$W_{20,18}$	$W_{20,19}$	$W_{20,20}$
l_{24}	<i>false</i>	<i>false</i>	<i>false</i>	<i>false</i>	<i>false</i>	<i>false</i>	<i>true</i>
l_{33}	<i>false</i>	<i>false</i>	<i>false</i>	<i>false</i>	<i>false</i>	<i>false</i>	<i>true</i>
l_{37}	<i>false</i>	<i>false</i>	<i>false</i>	<i>false</i>	<i>false</i>	<i>false</i>	<i>true</i>

where

$W_{20,14}$ = “the train is directed to train station Kalotina”,
 $W_{20,15}$ = “the train is directed to train station Vidin”,
 $W_{20,16}$ = “the train is directed to train station Kardam”,
 $W_{20,17}$ = “the train is directed to train station Ruse”,
 $W_{20,18}$ = “the train is directed to train station Svilengrad”,
 $W_{20,19}$ = “the train is directed to train station Kulata”,
 $W_{20,20}$ = “the train must shunt in train station of Sofia”.

$$Z_5 = \langle \{l_5, l_{17}, l_{21}, l_{28}, l_{29}, l_{40}\}, \{l_{23}, l_{24}, l_{25}, l_{26}, l_{27}, l_{28}\},$$

	l_{23}	l_{24}	l_{25}	l_{26}	l_{27}	l_{28}
l_5	<i>false</i>	<i>false</i>	<i>false</i>	<i>false</i>	<i>false</i>	<i>true</i>
l_{17}	<i>false</i>	<i>false</i>	<i>false</i>	<i>false</i>	<i>false</i>	<i>true</i>
l_{21}	<i>false</i>	<i>false</i>	<i>false</i>	<i>false</i>	<i>false</i>	<i>true</i>
l_{28}	$W_{28,23}$	$W_{28,24}$	$W_{28,25}$	$W_{28,26}$	$W_{28,27}$	$W_{28,28}$
l_{29}	<i>false</i>	<i>false</i>	<i>false</i>	<i>false</i>	<i>false</i>	<i>true</i>
l_{40}	<i>false</i>	<i>false</i>	<i>false</i>	<i>false</i>	<i>false</i>	<i>true</i>

where

$W_{28,23}$ = “the train is directed to train station of Vidin”,
 $W_{28,24}$ = “the train is directed to train station of Sofia”,
 $W_{28,25}$ = “the train is directed to train station of Kardam”,
 $W_{28,26}$ = “the train is directed to train station of Giurgiu (Romania)”,
 $W_{28,27}$ = “the train is directed to train station Svilengrad”,
 $W_{28,28}$ = “the train must shunt in train station of Ruse”.

$$Z_6 = \langle \{l_{18}, l_{22}, l_{27}, l_{34}, l_{39}, l_{43}\}, \{l_{29}, l_{30}, l_{31}, l_{32}, l_{33}, l_{34}\},$$

	l_{29}	l_{30}	l_{31}	l_{32}	l_{33}	l_{34}
l_{18}	<i>false</i>	<i>false</i>	<i>false</i>	<i>false</i>	<i>false</i>	<i>true</i>
l_{22}	<i>false</i>	<i>false</i>	<i>false</i>	<i>false</i>	<i>false</i>	<i>true</i>
l_{27}	<i>false</i>	<i>false</i>	<i>false</i>	<i>false</i>	<i>false</i>	<i>true</i>
l_{34}	$W_{34,29}$	$W_{34,30}$	$W_{34,31}$	$W_{34,32}$	$W_{34,33}$	$W_{34,34}$
l_{39}	<i>false</i>	<i>false</i>	<i>false</i>	<i>false</i>	<i>false</i>	<i>true</i>
l_{43}	<i>false</i>	<i>false</i>	<i>false</i>	<i>false</i>	<i>false</i>	<i>true</i>

where

$W_{34,29}$ = “the train is directed to train station of Ruse,

$W_{34,30}$ = “the train is directed to train station of Kardam”,

$W_{34,31}$ = “the train is directed to train station of Ormenion (Grece)”,

$W_{34,32}$ = “the train is directed to train station of Kapitan Andreevo”,

$W_{34,33}$ = “the train is directed to train station of Sofia”,

$W_{34,34}$ = “the train must shunt in train station of Svilengrad”.

$$Z_7 = \langle \{l_{16}, l_{25}, l_{30}, l_{35}, l_{41}\}, \{l_{37}, l_{38}, l_{39}, l_{40}, l_{41}\}, \rangle,$$

	l_{37}	l_{38}	l_{39}	l_{40}	l_{41}
l_{16}	<i>false</i>	<i>false</i>	<i>false</i>	<i>false</i>	<i>true</i>
l_{25}	<i>false</i>	<i>false</i>	<i>false</i>	<i>false</i>	<i>true</i>
l_{30}	<i>false</i>	<i>false</i>	<i>false</i>	<i>false</i>	<i>true</i>
l_{35}	<i>false</i>	<i>false</i>	<i>false</i>	<i>false</i>	<i>true</i>
l_{41}	$W_{41,37}$	$W_{41,38}$	$W_{41,39}$	$W_{41,40}$	$W_{41,41}$

where

$W_{41,37}$ = “the train is directed to train station of Sofia,

$W_{41,38}$ = “the train is directed to train station of Negru Voda (Romania)”,

$W_{41,39}$ = “the train is directed to train station of Svilengrad”,

$W_{41,40}$ = “the train is directed to train station of Ruse”,

$W_{41,41}$ = “the train must shunt in train station of Kardam”.

$$Z_8 = \langle \{l_{32}, l_{36}, l_{44}\}, \{l_{42}, l_{43}, l_{44}\}, \rangle,$$

	l_{42}	l_{43}	l_{44}
l_{32}	<i>false</i>	<i>false</i>	<i>true</i>
l_{36}	<i>false</i>	<i>false</i>	<i>true</i>
l_{44}	$W_{44,42}$	$W_{44,43}$	$W_{44,44}$

where

$W_{44,42}$ = “the train is directed to train station of Edirne(Turkey)”,

$W_{44,43}$ = “the train is directed to train station of Svilengrad”,

$W_{44,44}$ = “the train must shunt in train station of Kapitan Andreevo”.

3 Conclusion

The so constructed GN-model can be used for simulation of different situations that can occur between the trains (e.g., delays, catastrophes, change of the schedule in a neighbouring country, etc.)

In a next research, we shall describe a complete GN-model of the main railway networks in all of Bulgaria, giving the connections between the Northern and Southern Bulgaria, as well as between the neighbouring countries. Our aim is to construct a detailed GN-model of the railway networks in all of Bulgaria, and in this way, we will finalize this study.

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