COLOURED PETRI NET MODEL OF TRAIN HANDLING IN MARSHALLING YARD

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Summary:
Paper presents a model of train marshalling yard in the form of timed hierarchical coloured Petri net. The model focuses on typical technological activities by train servicing and resource handling. After brief description of the Petri net model, paper evaluates advantages and shortcomings of such an approach in modelling. As the most significant benefit of using this formalism, we can consider presence of tools for analysis of the model's state space. Thanks to it, we can know the system's behaviour closer.

1. Introduction

Aim of this paper is to present a Petri net model of railway marshalling yard including typical technology of train servicing and resource handling. Motivation for its construction consists in verifying facilities of Petri nets formalism for modelling and analysis of the system. The model should later serve as an environment for experimenting with algorithms for resource management.

The created demonstration yard is based on experience with real marshalling yards. Its parameters are fictitious. Technological processes have been defined according to technological rules used by Slovak railways. Values of parameters of the modelled yard are of minor importance and can be tuned according to user needs.

For implementation of the model, timed hierarchical coloured Petri nets and the Design/CPN tool have been chosen.

After a short introduction to Petri nets, the marshalling yard and its technology of trains handling will be introduced. After that, design process of the coloured Petri net is briefly described and finally, evaluation of the approach discussed.

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2. Sample Marshalling Yard

Sample marshalling yard (Figure 1) chosen for this purpose contains one hump and three yards: arrival (with 8 tracks), sorting (24) and departure yards (6). For humping, there is one track available.

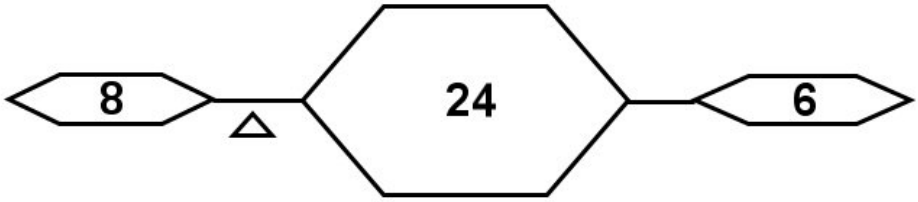

Figure 1 Scheme of modelled yard

There are two engines operating in the yard: one for humping of train that have arrived and one for shunting of train between sorting and departure yards. Train locomotives arrive with incoming trains and leave with outgoing trains. In between they stay in a fictitious locomotive depot.

Personnel in the yard are divided into 2 groups. First group looks after technological processes of incoming trains on arrival yard tracks. One shift consists of 6 examiners, 6 transiteurs, 2 couplers and 4 shunters. Second group is assigned to technology of outgoing trains on sorting and departure yards tracks. It consists of 6 examiners, 4 transiteurs and 3 couplers.

Other yard workers operating in real marshalling yards are not mentioned here, since they are not relevant for the model. That is because the model focuses on management of resources that are usually assigned to and released from technological processes on individual trains during their work time. The model does not include resources which are not bounded with operation of trains.

Technological processes are defined by flowcharts. There is one technology flowchart for incoming trains and one for outgoing trains. More details to their construction as well as to the whole Petri net model can be found in and .

The modelled marshalling yard handles some 920 wagons coming in 36 trains per day. They are humped to 24 relations.

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3. Modelling with Petri Nets

Petri net is a formalism used for modelling and analysis of systems with concurrent processes. It has graphical notation, precise mathematical language and analysis methods for specifying the system behaviour.

Basic construction elements of Petri net are places, transitions, arcs and tokens. Places and transitions are two types of nodes in the net. Arcs are directed edges that link places with transitions and vice versa, while no pair of nodes of the same type can be connected. Tokens are elements that move in the created network between places through arcs and transitions.

Principal difference between places (rounded nodes in Figure 2) and transitions (black square nodes) lies in their relation to tokens (black dots). Places can hold tokens for a period of time. Number of tokens and their distribution in places represent state of the net. Transitions take tokens from input places (i.e. place from which there is a directed arc to the transition) and provide tokens to output places (i.e. place to which there is a directed arc from the transition). This process is called firing – it performs an action in the net, changing its state. In this way, it is also possible to change overall number of tokens in the net.

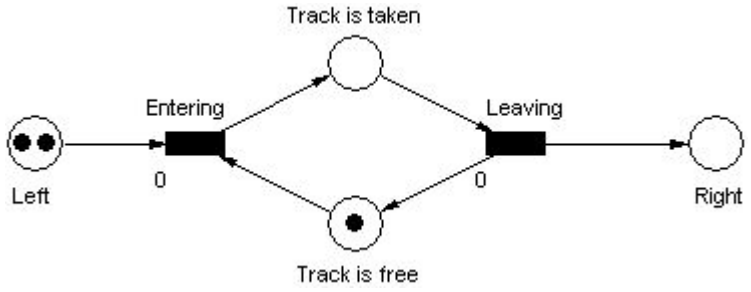

Figure 2 Petri net model of a line section with two trains on the left-hand side.

The introduced Petri net belongs to basic type called place/transition nets. More details to the topic can be found in .

The introduced concept has been developed to different, usually more complicated formalisms by enhancing attributes of the four basic elements of Petri net.

Modification used for discussed model is timed hierarchical coloured Petri net . Time property enables user to depict time relations in the system. Hierarchy allows defining actions more

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precisely by subnets while keeping the simple overview of the whole Petri net in primary page. Finally colour of tokens brings a significant flexibility for modelling of larger and more complex systems. Further details on Petri nets and their classification can be found in .

Modelling tool that was used for building of the model is called Design/CPN . It is a tool package supporting editing, simulating and analysing of coloured Petri nets (CPN).

4. **Coloured Petri Net Model of Marshalling Yard**

CPN model of the outlined marshalling yard is hierarchically organised, where three subnets represent transitions in the principal net (see Figure 3). One is for generating of incoming trains, another one for technology process of incoming trains and the final one for technology process of outgoing trains. A deeper insight in how the Petri net is built can be found in and .

Created Petri net model counts 72 transitions and 137 places.

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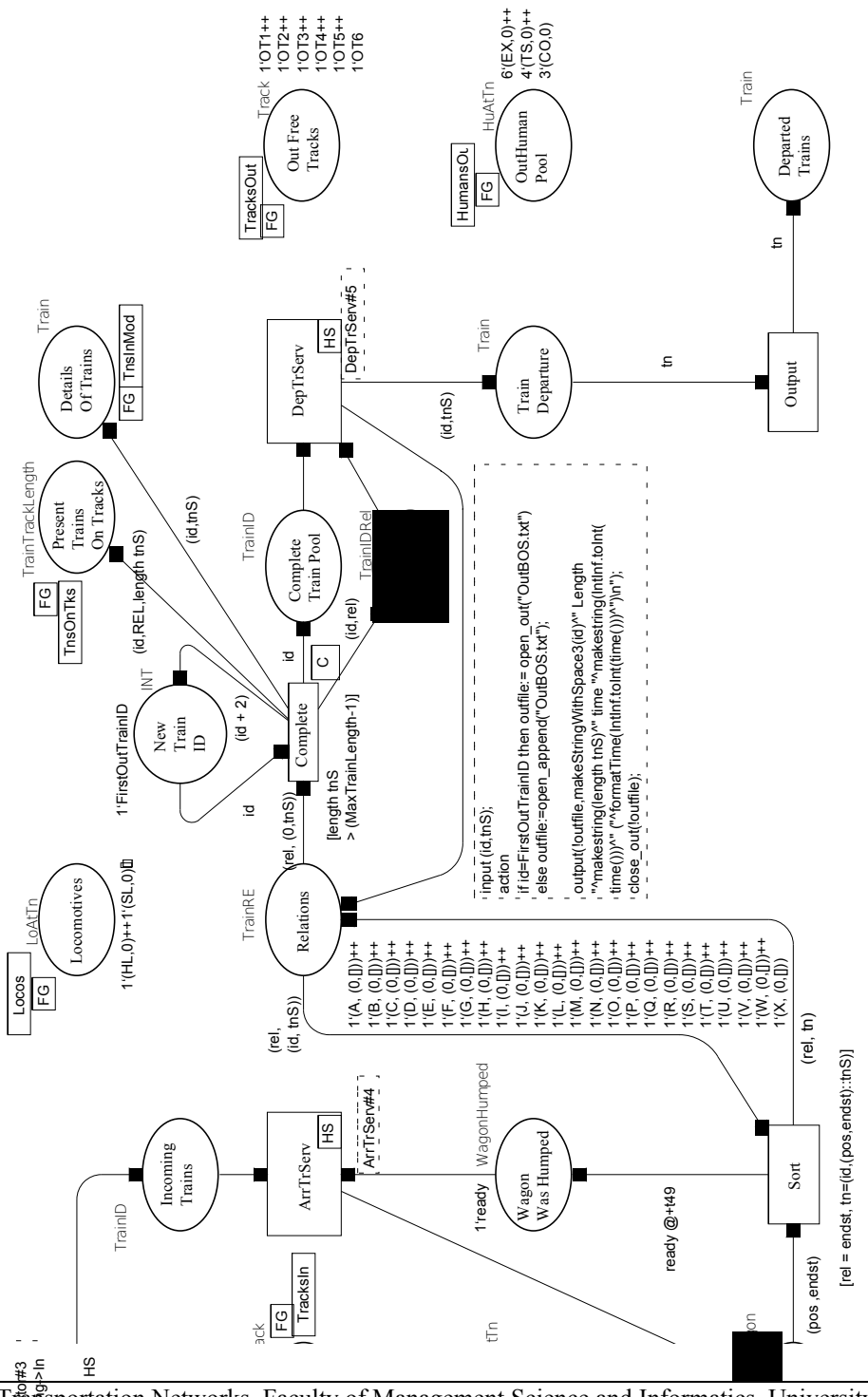

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Figure 3 Principal page of Petri net model.

5. Advantages and Shortcomings of This Approach

Modelling of marshalling yard technology using hierarchical timed coloured Petri nets brings benefits as well as shortcomings. Among benefits one can count construction of the model, existing tools for Petri nets and support for analysis of model's state space.

Construction elements of Petri net are simple and in small number. Relations among them are expressed in graphical way, what may help in understanding the model.

For coloured Petri nets with time and hierarchy, there are additional benefits. Hierarchical approach allows designer to divide a Petri net into a group of smaller subnets. Thus he can capture complex systems in understandable way. Colours help in representing sample system with simpler Petri net than it would be by basic Place/Transition net formalism (where tokens are just identical black dots). Together with colours, it is possible to add simple code expressions that are bound to basic construction elements: transitions and arcs. Time property simplifies modelling of time-bounded systems. In total, all three attributes add flexibility and make modelling power of the formalism significantly higher.

Another advantage of this approach is availability of tools for design, simulation and analysis of models. Generally, there is a wide range of tools for Petri nets available. For the specific formalism used in this case, there is Design/CPN (as it was mentioned) and its replacement CPN Tools. Both software packages provide tools for design, simulation and analysis of the model. This fact can save time for development of models.

Perhaps the most important advantage of the Petri net formalism is the possibility of analysis of model's state space. It can help in understanding its behaviour. It can reveal potential dangerous states, e.g. deadlocks, sequences of states between current state and desirable state or attributes of some system details. Construction of state space is possible thanks to simplicity of construction elements and rules for building of models.

Among shortcomings, one must mention size and complexity of Petri net for complex systems. Even if the modelled marshalling yard has been rather simple, its Petri net model has over 70 transitions and almost twice as many places. Solution here may be to focus on some part of the model which can be developed separately. In the end, the part can be included in the whole system, thanks to hierarchy feature.

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Another problem that one could bring up may be size of model's state space for analysis. It depends on the actual modelled system. In some cases the state space can be small and compact, in other cases too large to be calculated in reasonable time (or infinite). However, this is not a problem brought by the Petri net formalism. It is a general feature of modelled system, despite of used modelling tool.

Petri net formalism, on the contrary, provides tools for analysis of the state space and also some ways for making the state space smaller. It is realised via occurrence graphs with equivalence classes and symmetries. More on this topic can be learnt in and .

6. Conclusion

In this paper, I described briefly a Petri net model for simple marshalling yard and its technology and I evaluated usability of the chosen approach. In the end, I can summarize that the used timed coloured Petri net with hierarchy proved to be able to model such a system. With more details, the model gets more complex, however simple construction elements, hierarchy, colours and time allow keeping it in understandable form. There are also ways how to simplify the model.

When evaluating use of the formalism, I'd put as the most important advantage the existence of support for state space analysis. It can help in understanding the system better. Simple construction elements with enhancements of time, hierarchy and colours form a simple approach to modelling with yet high modelling power. However, complex systems may get complicated Petri net models, so designers are forced to find ways of simplifying of their models.

The created model will be further used for analysis of the system and for experiments with management of resources. Results of the analysis will be published in near future.

The future work also includes moving from Design/CPN tool to CPN Tools , since the latter one offers already almost the same functionality as the former one.

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