

Jozef BALÁK *, Peter NAGY **

SIMULATION MODEL OF RAILWAY SIGNALLING

SIMULAČNÝ MODEL ŽELEZNIČNÝCH ZABEZPEČOVACÍCH SYSTÉMOV

Abstract

This paper deals with a possibility of a modeling of a block system. A created modeling tool contains a graphic editor of a track section configuration and a graphic editor of control algorithms, which serves on a writing of behavior algorithms of exterior devices of the block system. In order to the modeling of the block system was possible general models of basic exterior devices and a programming language for the writing of control algorithms to a source code form had to be created. It describes a work with different parts of the modeling tool and their possibilities on a selected example of an automatic block. The paper also describes an ability of to simulate a modeled block system activity and an ability to simulate the movement of the train in track section.

Abstrakt

Tento príspevok sa zaoberá možnosťou modelovania traťového zabezpečovacieho zariadenia. Vytvorený modelovací nástroj obsahuje grafický editor konfigurácie medzistaničného úseku a grafický editor riadiacich algoritmov, ktorý slúži na zápis algoritmov definujúcich požadované správanie sa vonkajších prvkov traťového zabezpečovacieho zariadenia. Aby bolo možné modelovať traťové zabezpečovacie zariadenie, bolo nutné vytvoriť všeobecné modely základných vonkajších prvkov a programovací jazyk pre zápis algoritmov do podoby zdrojového kódu. Na zvolenom príklade automatického bloku opisuje prácu s jednotlivými časťami modelovacieho nástroja a ich možnosti. Článok taktiež opisuje schopnosť simulovať funkčné správanie sa modelovaného traťového zabezpečovacieho zariadenia a schopnosť simulovať jazdu vlaku v medzistaničnom priestore.

Keywords

model, simulation, block system, ladder diagram, track, exterior devices of block system

1 INTRODUCTION

A railway traffic is controlled by a railway signalling. The railway traffic is unique in it that a failure of safety functions realized by railway signalling is connected to a high risk of a damage of a railway infrastructure, railway track vehicles, an environment or human life hazard. For this reason, it is required that railway signalling used to direct railway traffic disposes with a high level of technical safety and a high level of functional safety [1].

A creating of a system model is advantageous for an analysis of system behavior or a system synthesis. The model is a set of symbols, relationships between them a rules which reflect a structure of a real object in a simplified form. A structure of model and the structure of the modeled object are

* Ing., Department of Control and Information Systems, Faculty of Electrical Engineering, University of Žilina, Univerzitná 8215/1, 010 26 Žilina, Slovak Republic, tel. (+421) 41 513 3321, e-mail jozef.balak@fel.uniza.sk

** Ing. PhD., Department of Control and Information Systems, Faculty of Electrical Engineering, University of Žilina, Univerzitná 8215/1, 010 26 Žilina, Slovak Republic, tel. (+421) 41 513 3357, e-mail peter.nagy@fel.uniza.sk

identical which means that a behavior of the model is the same as a behavior of the modeled real object [2].

It is appropriate, if during a development is created the model which describes a functional behavior of a developing system. The model is a result of an analysis of functional requirements and it aims to ensure that a functional requirements specification is complete, unambiguous, easily controlled and testable. Conversely, when safety properties of an existing are evaluated it is advisable to have the model which describes selected properties of the original. An investigation of the system behavior under various ambient conditions may be replaced by an investigation of the model behavior under same ambient conditions. Then we works with the model. Is has benefits such as lower costs, less time-consuming, higher safety (if a functionality of the system fails, then the system or its ambient are not damaged) and the others [2].

The railway traffic is usually controlled by several types of railway signaling systems. The block system is one of them. Its role is to safety manage a movement of trains in track section. It has to ensure [1]:

- protection of following movements;
- protection of opposing movements.

For automatic block system is typical that transport staff is not present in track section. A train detection in a block section have to be controlled by technical means such as track circuits and axle counters. Several types of block systems exist such as [1]:

- automatic block system with the one-block signalling – it is typical for the automatic block system with the one-block signalling operated by ŽSR (Železnice Slovenskej republiky) that the track section is divides at most to two block sections, the signal of the track section have two aspects (*Proceed* aspect, *Stop* aspect) and *Exception* aspect, *Stop* aspect is displayed on the signal in basic state, *Stop* aspect has absolute importance, an independent harbinger signal is placed before block section signal on a braking distance;
- automatic block system with the two-block signalling – it is typical for the automatic block system with the two-block signalling operated by ŽSR that the signal of the track section have three aspects, signals are located on the braking distance from themselves, each signal of the track section is also the harbinger for a next signal, *Stop* aspect has permissive meaning.

2 MODELLING TOOL

The modelling tool with name *Virtual model of block system* has been created to the modelling of a functional behavior of the block system and modelling of the movement of the train in track section. The created SW tool is based on .NET Framework, specifically, it is WPF (*Windows Presentation Foundation*). It follows that a program kernel is written in C# and user interface in XAML. A design patten MVVM (Model-View-ViewModel) has been implemented during a creation of the SW tool. The created modelling tool contains three base parts:

- an editor of a track section configuration,
- an editor of control algorithms,
- a simulator of the movement of the train and a simulator of the functional behavior of the block system.

2.1 Editor of track section configuration

The graphic editor of track section configuration is placed on the tab *trať* (Fig. 1). It defines, what exterior devices will place in a model of the track section and how this devices will be

deployed. A scheme of track section and simplified schemes of two station which delimit the track section occupy a majority part of the tab.

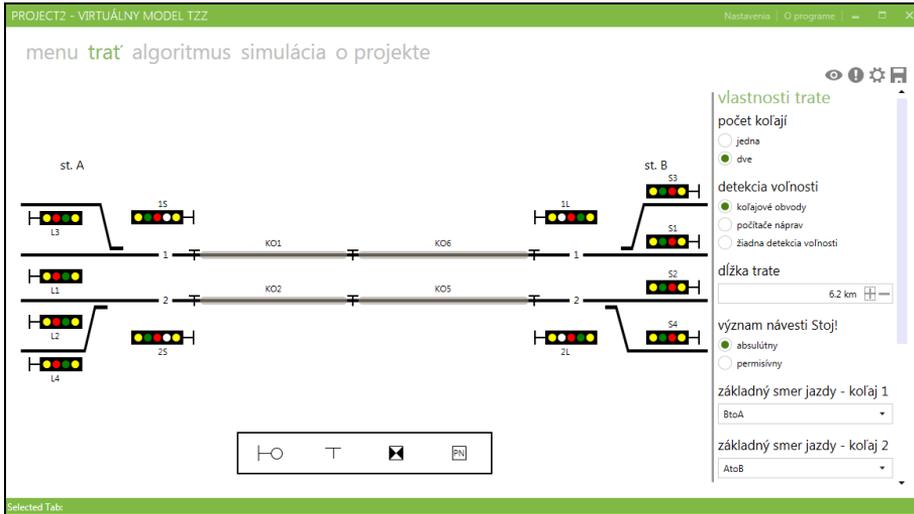


Fig. 1 The graphic editor of the track section configuration

A properties panel is located in a right side of the tab. It can shows and edits track properties which are opened by a gear ikon placed above the properties panel. It can be edited in the track properties:

- a count of tracks – the station schemes are adapted to the tracks count. When a double-track line is changed to a single-track line exterior devices assigned to second track line are not visible in the editor of control algorithms. But the editor of the track section configuration remembers them. Therefore, this devices are restored when the single-track line is changed to the double-track line.
- a method of a train detection in block sections – a combination of different ways of the train detection is possible;
- a track length – when the track length is changed exterior devices positions are suitably adjusted;
- a meaning of a signal *Stop!*;
- a basic direction of travel for each track rail.

A list of selected exterior devices which can be manually inserted to the track section scheme is in a lower part of the tab. The list contains:

- a signal – universal, a specific type can be defined in signal properties,
- a block joint,
- a counting point,
- an axle counter.

The track section can also contains a track circuit (serial or parallel). This component cannot be manually inserted. It is automatically inserted between each two neighbors block joints.

A new exterior member is inserted by *Drag&Drop* method. The exterior member can have two states:

- free – the member is not assigned to the track; it is placed anywhere in the editor of track section configuration and it is invisible for the editor of control algorithms;
- fixed – the member is assigned to the track; its location is limited to a restricted area and it is visible for the editor of control algorithms.

Each exterior devices contain several editable properties which are also showed in the proprieties panel. The properties of exterior member can be showed by command from a context menu of exterior member.

The initial state at start of a simulation can be defined at some exterior devices. The track circuit can be unoccupied or occupied in basic state. The axle counter can have basic counter value set to zero (a watched section is free) or other number (the watched section is occupied). It can be defined for each lamp what light mode will be initialized at start of the simulation (turn off, lights, slow impulse lights, fast impulse lights).

2.2 Editor of control algorithms

A tab *algorithmus* contains second basic part of the modelling tool – the graphic editor of control algorithms (Fig. 2). This tab contains tools for a writing of behavior control algorithms of exterior devices by a graphic programming language based on ladder logic which is named as the ladder diagram. It is used on programming of programmable logic controllers (PLC) in practice [4].

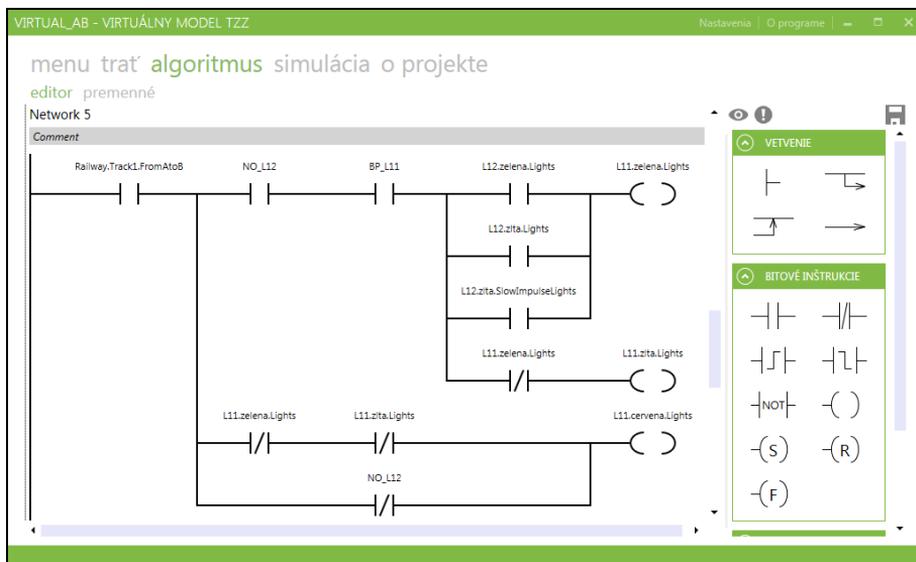


Fig. 2 The graphic editor of control algorithms

An instruction panel of the ladder diagram is placed in a right side of this tab. It contains instructions which can be used in ladder diagram. It contains instructions of network branch, bit instructions, mathematical instructions, timers, comparators and instructions for a manipulation with variable content. Properties of exterior devices, properties of track lines, properties of stations, local variable defined and initialized in tab *premenné* or constants.

An inserting of a new instruction to a network consists from two steps. In first step, an existing instruction have to be highlight. In second step, a new instruction from the instruction panel is selected by double-click. The instruction is inserted the right of the existing instruction. An intelligent help speeds up a definition of instruction parameters. It suggests a list of suitable items after a writing

several letters. A new network can be inserted at the end of a network list or between existing networks.

The network 5 in Fig. 2 shows a logical function for a control of a lighting of signal lamps on the ladder diagram. Instructions can be combined series, in parallel or series-parallel in one network. Several outputs can be controlled in one network, too.

A resultant ladder diagram containing all required commands serves as a source code for a virtual control system.

2.3 Simulator of movement of train and simulator of functional behavior of the block system

The simulator of the movement of the train and the simulator of functional behavior of the block system are placed on tab *simulácia* (Fig. 3). This part of the modelling tool contains a compiler, the virtual control system and the simulator of the movement of the train.

The compiler controls whether all parameters of the exterior devices placed in the track section and all parameters of the instructions of the created ladder diagram have specified correct values. If no error was found during a control, then the compiler translates the track section configuration to a suitable form for the simulator of the movement of the train and the ladder diagram to the source code for the simulator of the functional behavior of the block system. The compiler running background of modelling tool. Only errors found during first part of compilation are graphic showed in panel in a left side of the tab.

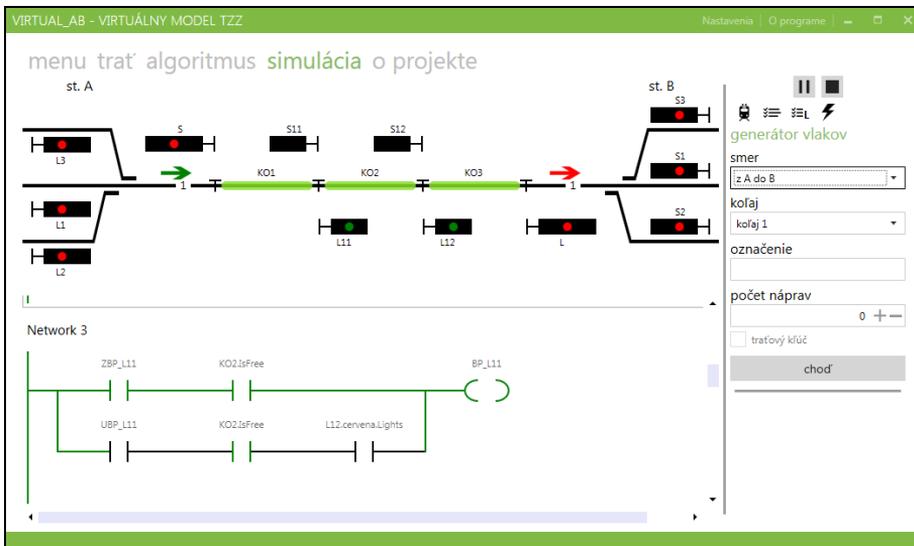


Fig. 3 The simulator of the movement of the train

The virtual control system (VCS) is graphic showed in this tab by ladder diagram situated the bottom of the tab. VCS represents a programmable automat which centralized controls the exterior devices of the block system in according to the source code. An actual state and functional behavior of the exterior devices are displayed in the track section scheme at the top of the tab. VCS simulates an activity of the block system by the performing of source code and the controlling of the exterior devices.

VCS performs the source code by a cyclic control of the networks. This cycle is named as a scanning cycle. The networks are cyclic controlled to end of the simulation. The networks are controlled from top to bottom. The instructions in the network are performed from left to right. If

network contains in parallel connected instructions, then a topmost instruction is performed the first and a lowermost instruction is performed as the last.

The simulator of the movement of the train is the final component of this part of modeling tool. It is process which runs parallel and independently with respect to VRC. A new train is generated from a control panel in right side of the tab. It is possible to set a direction and a track line of the movement of the train, a train identification and number of axles of a train. All generated rains are showed in a list of trains in bottom of the control panel. Characteristic properties are showed at each train. The movement of each train can be individually controlled. The train can be stopped, started up again or canceled. The movement of the train is controlled by relevant signals and at the same time train influence on devices for the train detection in the block section.

3 AN EXAMPLE OF MODELLING TOOL

Let a single-track line have a length 3 km and a track speed 120 kmh⁻¹ and it is controlled by a simple automatic block system with the two-block signalling for which it is valid:

- *Proceed* aspect may be displayed on a signal, if a block section for this signal is unoccupied and on next signal is *Stop* aspect,
- if *Proceed* aspect is displayed on a signal, the keeping of this aspect is conditional only with a block section,
- if a filament bulbs is blown, then less proceed aspect is displayed on the signal,
- *Proceed* aspect is displayed on track section signals for defined direction of the movement of a train and the others track section signals are lightless.

Fig. 4 shows a track section configuration for the defined single-track line. It contains three block sections with length 1 km and two signals for each direction of the movement of the train.

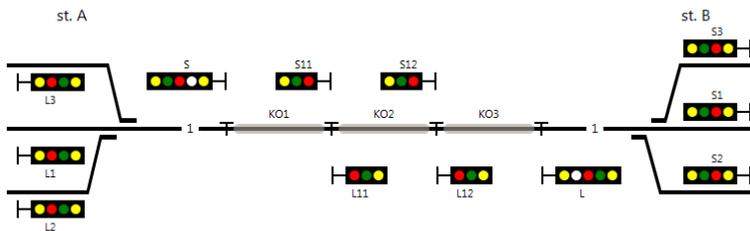


Fig. 4 the track section configuration

Fig. 5 shows a principled algorithms for control of the functional behavior of the signal L11. Fig. 6 shows condition for proceed aspect on the signal L11. Fig. 7 show functional behavior of exterior devices for the defined direction of the movement of the train. This behavior is controlled by the source code generated from the ladder diagram.

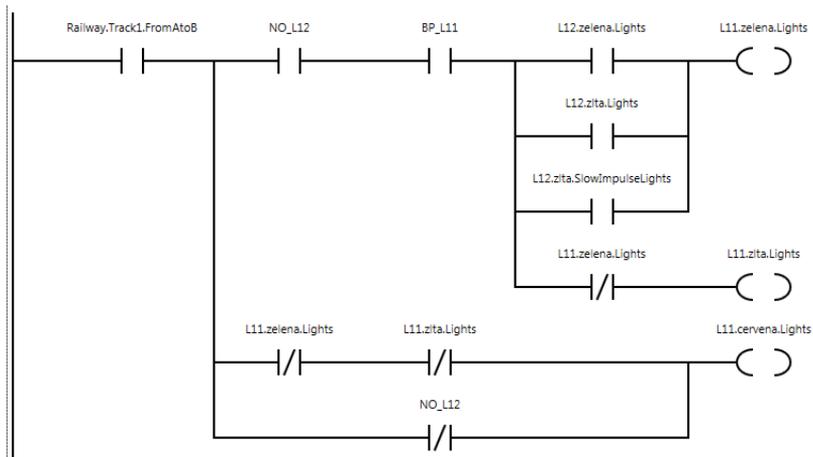


Fig. 5 The network for control of signal L11

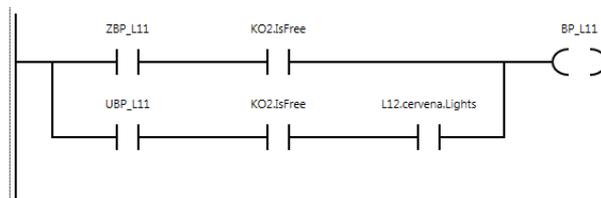


Fig. 6 The condition for proceed aspect on the signal L11

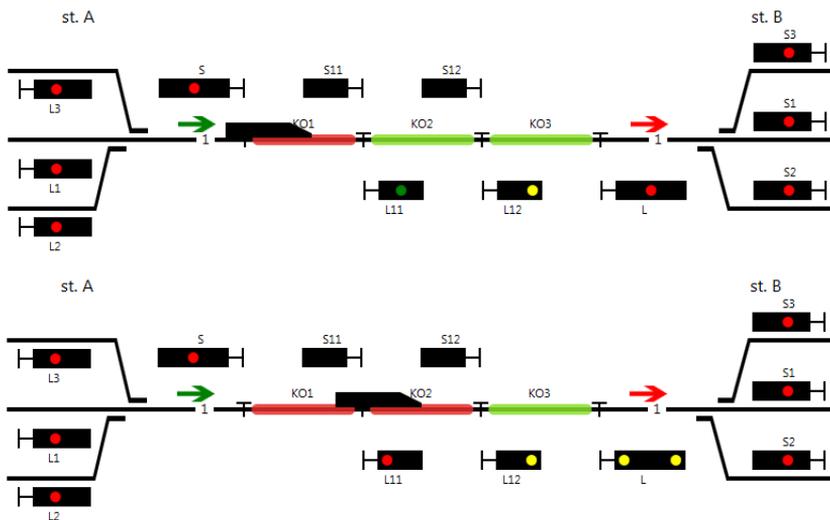


Fig. 7 The functional behavior of the exterior devices

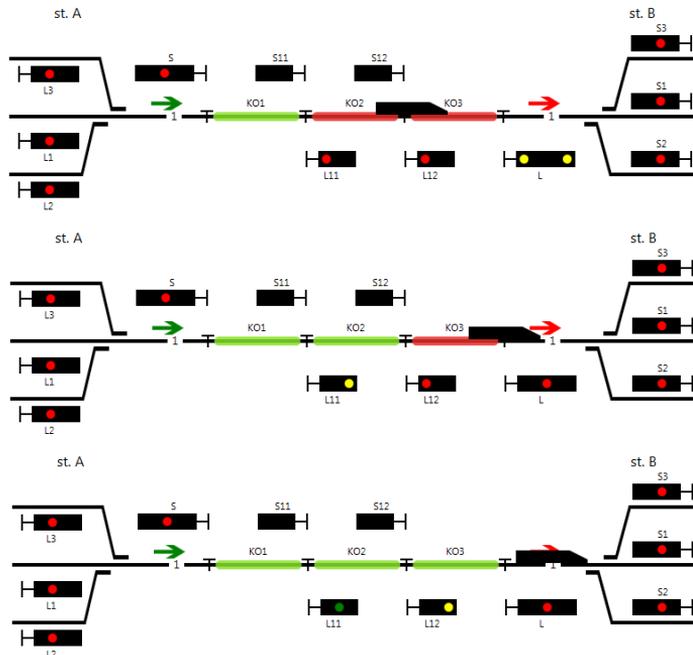


Fig. 8 The functional behavior of the exterior devices

5 CONCLUSIONS

In this paper we focused to a possibility of the modelling of the block system, the simulation of its functional behavior and the simulation of the movement of the train in the track section by the modelling tool *Virtual model of block system*. The modelling tool allows not only to confirm the functional behavior of existing block systems at various track configurations, but also to model and simulate new control algorithms and new versions of block systems. The modelling tool can be used at an analysis or a synthesis of the railway signalings.

In further development, a current version of modelling tool has a potential for an expansion. It can be expanded with new exterior devices, an ability of a modelling of interlocking systems or an ability of a modelling of level crossing systems.

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