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Development of Neural-Network Based Control Algorithm for Train Adaptive and Smooth Braking System

A. Potapovs*, M. Gorobetz, A. Levchenkov*****

**Institute of Industrial Electronics and Electrical Engineering, Riga Technical University, 1, Kalku Street, LV-1658, Riga, Latvia, Andrejs.Potapovs@rtu.lv*
***Institute of Industrial Electronics and Electrical Engineering, Riga Technical University, 1, Kalku Street, LV-1658, Riga, Latvia, mihails.gorobecs@rtu.lv*
****Institute of Industrial Electronics and Electrical Engineering, Riga Technical University, 1, Kalku Street, LV-1658, Riga, Latvia, anatolijs.levcenkovs@rtu.lv*

Abstract

This paper provides a new insight into the smooth and precise adaptive railway transport braking system design. The first phase of the development is described and includes a development of a necessary mathematical and computer model. Components of new adaptive braking system and their interactions are defined. Mathematical model contains equations that describe the movement of the train and the pneumatics braking system of the train, as well as offering new features of the developed system, which will adaptively adjust the service brake modes and will perform real-time system diagnostics without any human interaction. The computer model and simulation results are described in this position paper.
KEYWORDS: *adaptive control systems, intelligent control, railway transport embedded devices, modelling.*

1. Introduction

Nowadays the industry of railway transport is developing new solutions for increasing a capacity and speed of the railway. These actions are followed by various problems that connected with railway transport movement safety, which has to be at least at the same or higher level than before [1].

Authors are solving the safety problem and propose to develop new smooth and precise adaptive braking system of the rolling stock. This new system is aimed to reduce various deficiencies of existing railway safety systems. The purpose of the system is an automatic braking of the rolling stock using service braking and previously developed safety functions [2], which allow to stop the train before another railway vehicle, before a level-crossing where a road vehicle is stuck or before the signal with restrictive aspect. Usage of emergency braking has negative effect and not recommended if regular service braking might be performed. Therefore, the new proposed system is based on authors' previously developed railway safety systems and may increase safety level of the train and the railway system as a whole.

After real field test experiments [3] authors concluded that efficiency of the previously developed railway safety system is not sufficient, because the system does not adapt to various working environment conditions and may work imprecise if the rolling stock contains various wagons.

Therefore, the research and development of new smooth and precise adaptive train braking system, which is now patented [4], is going on. This process contains some development stages and the first one is described in this paper.

2. Purpose and Tasks

The main problem of classical approach for smooth target braking calculation is a necessity to receive data about various parameters of the train and railway infrastructure such as length of train, mass of train, braking coefficients, condition of braking system, slopes and curves of the track etc.

The purpose of this paper is to analyse a possibility to apply the adaptive control algorithms in the management of a train braking system, with the purpose to accomplish a smooth and precise (according to a stop point) braking, and also build a prototype of a smaller embedded device which would perform automatic train stopping before the red light.

Adaptive algorithms provides new approach, when the braking control system is self-adjusting to current conditions of the braking and performs the process adaptively without additional sensors and data.

The evolution stages of the proposed system are connected with the development of the mathematical model and the computer model of train movement and work of the pneumatics braking system un development of mathematical and computer model of smooth and precise braking control are described in literature [5].

Main objectives of this paper:

1. Development of the adaptive control algorithm using neural networks, for the new braking control system, based on the developed mathematical un computer models;
2. Simulation of self-organization of the adaptive braking control system using developed algorithms.

3. Proposed Structure of Braking System of Rolling Stock

Objects of braking system of rolling stock are: steel rails - S, locomotive - L; wagon - V; steel wheels - R; brake pads - K; brake cylinder - BC, stopping transmission levers - PS; air splitter - G; stock air tank - KR; main reservoir - GR; air pipe with fittings - GV; compressor – LK; brake control devices - BV; release valve - AV, automatic mode - AR.

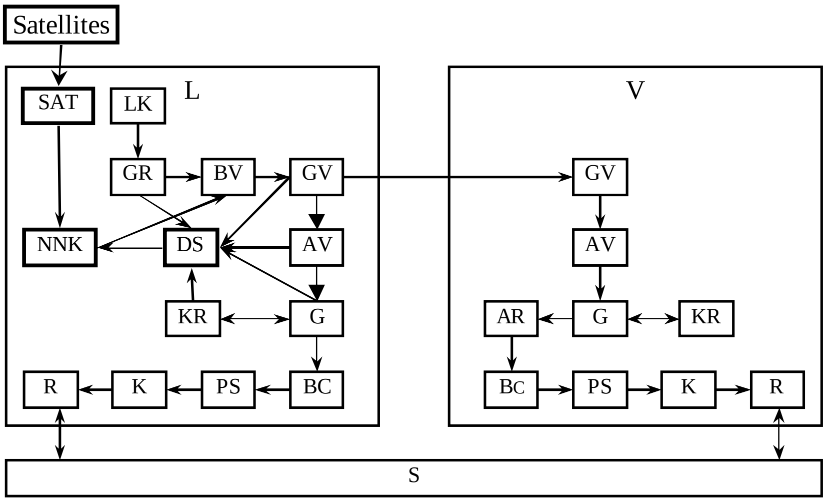

Fig. 1. Structure of proposed braking system with diagnotics devices

Fig.1. presents structure of existing braking system improved with new devices for diagnostics of braking system:

- NNK – Neural-network based adaptive braking controller;
- DS – Sensors, that measures current state of the braking system and train motion;
- SAT – receiver of satellite navigation signals.

4. Main working principle of the smooth and precise adaptive braking system of the rolling stock

The working principle of the proposed system is based on the software for programmable logic controller (PLC) with implemented adaptive control algorithm using neural network training. The goal is to perform a precise train braking and stop at the target point using service mode, but not emergency braking. The braking process consists of two braking steps. The first step is performed from time moment t_2 till t_3, the second one – from t_5 till t_7 shown in Fig. 2.

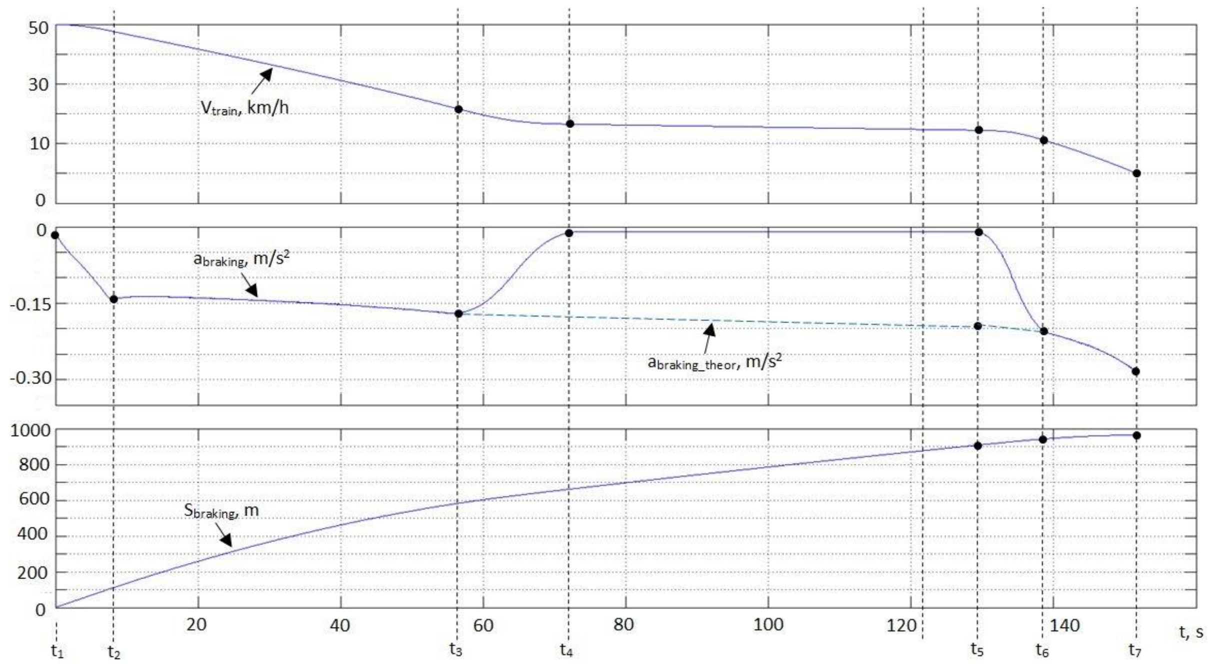

Fig. 2. Graphics of train motion parameters by performing two step braking in time

During self-learning the control program gets data, which provides direct and indirect characteristics of current status and condition of the braking system and its efficiency. This data should be in accordance to external conditions, state of the braking system and selected mode. More detailed description of the system and its elements may be found in a paper [5].

5. Usage of Neural Networks for proposed smooth and precise adaptive braking system of the rolling stock

The hypothesis is provided, that neural networks may be used for self-training of the control system during the braking process. The self-learning is performed as during the regulation of braking system work by driver and during the automatical train braking while performing the first braking step.

It is worth to mention that interest of using artificial neural network has been grown in last few years. The application of them is a research subject in fields much far from control systems such as philosophy, psychology, physiology

Artificial Neural networks may change their behavior in dependence on the external environment. There are different configurations of neural networks exist, but the organization of neurons in layers copies the structure of the human brain. Therefore, multi-layer structure is selected for the solution of the task. It has more advantages than signle-layer networks and have efficient algorithms for training.

As the braking process is continuous the previous input and output values make sense and the feedback is needed, because it ensures the neural network with the memory, similar to the short-time memory of the human being.

After some experiments, authors have chosen the Elman network [6], as a one type of recurrent networks, where feedback is implemented not from the output of the network, but from the hidden layer neurons. It allows taking in account prehistory of the observed processes and storing the information for the correct and precise control strategy. These networks may be used in the control systems of the moving objects, because the main particularity is the storing of the sequences.

On the base of the Elman network the RAAM (Recurrent auto-associative memory) network is built. RAAM - is a double Elman network with the structure 2N-N-2N, which is usually used for compressing and encoding of the information. The input of this network is a bit signal containing 2N bits. Usually, the network has size 20-10-20, where the first 10 bits are named "left" and the last 10 bits are "right".

In the beginning the left matrix gets zero bit vector (0000000000), but the right matrix gets the code of the symbol or the sentence (for example, 0010000000="A"). Then the same is fed to the output matrix elements. Using the back-propagation method the network is trained. After that 10 bits from the hidden layer are input to the left matrix, but the right matrix gets the next symbol.

In case of the smooth and precise control braking, inputs of the neural network are (figure 3):

- Train speed (V, km/h);
- Train moving distance (S, m);
- Train braking acceleration (a_{br}, m/s^2);
- Braking main line air pressure (P_{br_m}, MPa);
- Driver cotrol valve position (P, n);
- Slope of the track profile (i, ‰);
- External temperature (t, °C).

Outputs of neural network are control signals according to five braking modes.

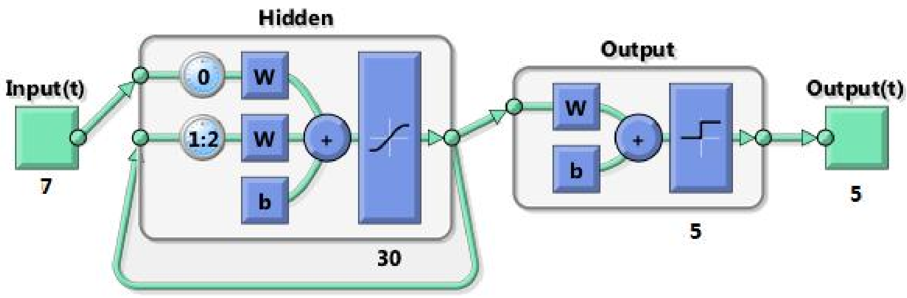

Fig. 3. Elman network structure with recurrent layer is selected as adaptation mechanism for automatic train braking system

6. Simulation results after training

After the training of the selected neural network, following simulation results are obtained. In figure 4 the upper line shows the value of the neural network output, but lower line is a real signal, which is generated by the computer model.

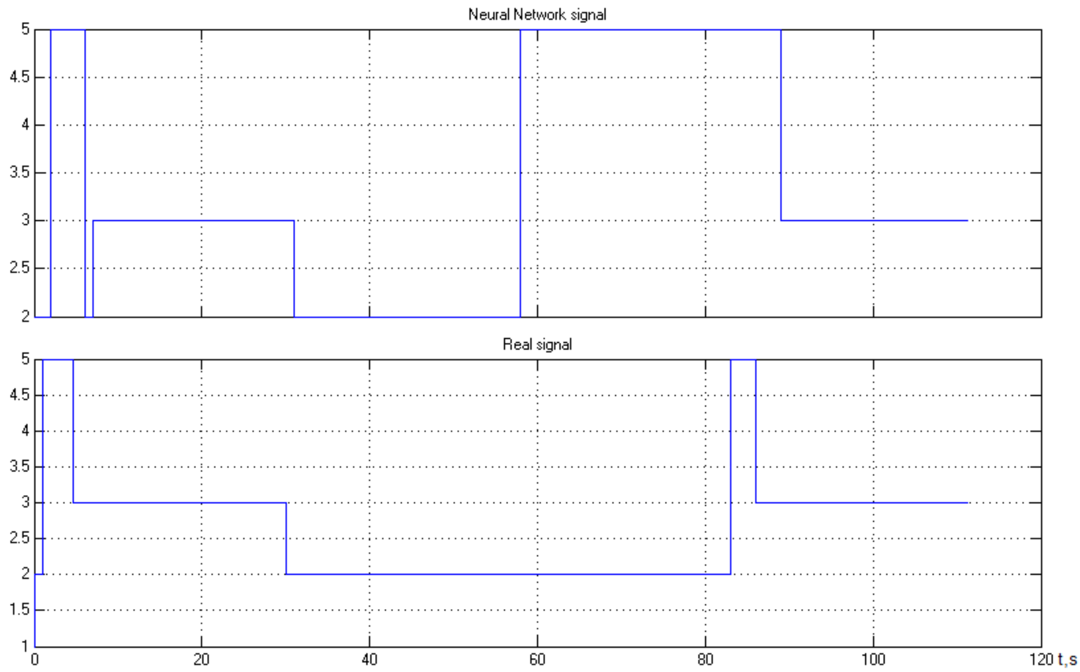

Fig. 4. Modeling results

7. Analysis of the results and evaluation

The operation effectiveness of the prototype device at the moment the following results are achieved may be evaluated as following:

- The neural network is trainable for control of the train motion and of the smooth and precise braking process, using parameters of the computer model;
- The integration of neural network into the model of the smooth and precise braking system computer model has been performed successfully;
- The tendency of neural network to learn and repeat the control signal is obvious, bur at this stage the results of training has a performance error.

8. Conclusions

The proposed neural network is workable in general, but needs further improvement. The tuning and adjustment of the training data set, data frequency and number of neurons is needed to get better results. Also efficiency of the neural network may be increased using additional elements for precision of the neural network input signal in accordance to exploitation conditions of the braking system of the rolling stock.

For the improvement of the effectiveness of the algorithm operation it is necessary to complete an analysis of application of another adaptive algorithm that is the task of further authors' publications.

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