NEURAL NETWORK CONTROL OF MARSHALLING PROCESSES

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ABSTRACT

On the basis of selected factors that determine quality of operational control over technological processes, it is proposed to create an automatic control system of marshalling yard operation with elements of artificial intelligence. Proposed mathematical apparatus could include typical methods, characteristic of artificial neural networks (ANN) and complex simulation models. The basic requirements for ANN models are formulated, designed to solve the problems of current forecasting at marshalling yard, as well as criteria and principles that should be taken into account in the design of neural networks.

Keywords: railway, freight transportation, marshalling yard, control, intelligent technologies, artificial neural networks.

Background. *In recent years, a considerable number of studies on intellectualization of technological processes in rail transport, including the automation of operational control have been carried out [1, 3, 4, 9].*

If we keep in mind the quality of operational control at marshalling yard, it is determined primarily by choosing the right or best (optimal) solution, its timeliness and the degree of implementation.

Any erroneous, delayed or poorly sound decision in the control system leads to underutilization of carrying capacity and processing ability of stations, deterioration of rolling stock use. Therefore, in conditions of intensive work [10,14], the operational control of transportation process requires a particularly fast and accurate information on location and conditions of rolling stock fleet, situation with locomotives and crews, loading and unloading of cars to ensure timely adjustment measures.

Objective. *The objective of the author is to consider application of neural networks in control of operations at marshalling yards.*

Methods. *The author uses general scientific and engineering methods, statistical analysis, comparative analysis, simulation, as well as specific methods of optimization, situation and heuristic programming, fuzzy logics, artificial neural networks.*

Results. *The main purpose of operational control system in considered case is to increase profit by reducing overhead costs. The cost reduction method serves to minimize deviation of actual values of transportation process parameters from defined in operational plan. That is, the objective function in this case is minimization of such deviations.*

To find the minimum value of the sum of deviations per unit measurement value of the operating parameter a set of amounts should be considered calculated for all versions of the model, evaluating the work of train-forming station. Each option becomes the result of the use of a certain combination of adjustment measures, each of which is a planned event.

The objective function [6, 8] or optimality criterion for selection of a variant of control solution is found by the formula

$$C = \min_{i \in M^{CO}} \left\{ \sum_{\kappa=1}^{K^{IND}} \Delta X_k C_k \right\}, \quad (1)$$

where C means operational costs of the station arising due to deviation of actual indicators values from planned;

M^{co} is a set of considered control options;

i is a number of a current plan version;

K^{IND} is a number of indicators in performance of operational control functions;

k is a number of the current indicator;

ΔX_k is deviation of values of k-th indicator;

C_k is cost of indicator measurement unit.

Methods for solving the objective function (1) are optimization methods. At the same time complexity of the solutions requires the use of elements of situation-heuristic programming and fuzzy logic and artificial neural networks.

One of priority directions of research in this domain has been aimed at increasing efficiency of the processes of formation, dissolution of trains at marshalling yards through creation of new systems of forecasting, operational control and continuous monitoring of operational stops and technical condition of equipment at the station. This, in our opinion, provides for the following priorities:

- *development of integrated information control systems at the marshalling yard;*
- *creation of new ACS with elements of artificial intelligence;*
- *improving reliability of information in real time about dislocation and availability of mobile units;*
- *automatic entry into ACS of information about rearrangement of cars on tracks;*
- *equipment of AWS of station and shunting dispatchers with additional information board on which in a comfortable and ergonomically optimal format information is provided for planning and control of marshalling operation at the station.*

The intensity of dissolution of trains at marshalling yards is more dependent on efficiency of mechanization and automation of the sorting process, main elements of which comprise hump retarders, automation systems of hump operations, as well as continuously developing information control complexes, train formation planning systems [10]. The ultimate goal of automation of operational control of sorting processes is to create automated control system of marshalling yard with elements of artificial intelligence.

The analysis of use of existing ACS showed that in practice dispatching staff of a station use a set of 2–4 programs while total number of available programs is at least twenty. Systems are not used to full extent, not only because of fault of the operative staff, but also because of development and significant ergonomic deficiencies. Obviously there is also inconvenience of constant transition from one system to another, which in turn creates an additional psycho-physical burden for the persons taking control decisions. Research and practical solution of the problem of better use of information systems, avoiding duplication and operation of some of them in isolation from each other, could be integration of the latter on the basis of a unified information platform of intelligent system of station operation control [11].

In the process of designing such a system it is proposed to use a method of constructing intelligent models of the situation or scenario forecasting based on technological knowledge of dispatching personnel. According to the chosen method appropriate forecasting modeling algorithms are based on inductive learning, which is a unique identification of a formalized study of the situation. Such situations, for example, should include [7, 13]:

– Acceptance of the train;

– Dissolution of the approaching train;

– Formation of single-group train or two- group train while cumulating each group on a separate track;

– Formation of a multi-group train while cumulating cars of all groups on one track;

– Formation of single-group and multi-group trains before sending them to non-public tracks;

– Semi-handling of transit trains;

– Transit trains passage without handling by changing locomotive and / or locomotive crew;

– Departure of train of its formation;

– Rearrangement of angular gears;

– Passage on station of various mobile units to ensure implementation of economic and other necessary technological operations;

– Ensuring implementation of private technological process of any kind in terms of its exclusion from the work of station complex.

The formalization of these processes is realized on the basis of associative search algorithms. In this case, situation is characterized by the vector of system state parameters values, for each cycle of analysis can be related to a specific area in the parameter space via adaptive clustering algorithm. Application of identification models is only possible in conjunction with simulation modeling of marshalling yard operation. Simulation model should meet a number of requirements:

1. Repeatability. Simulation model should serve for an unlimited number of experiments with different parameters.

2. Accuracy. Simulation allows to describe the structure of the system and its processes in a natural way, without resorting to the use of formulas and strict mathematical relationships.

3. Visibility. A simulation model has capabilities for imaging the process of work of facilities during certain time, schematic assignment of the structure and return of results in graphical form.

4. Universality. Simulation helps to solve problems from different areas of railway activity. In each case, the model simulates, reproduces a real process and allows for a wide range of experiments, without affecting real objects.

The basis of considered modeling process is laid by a digital model of arrangement of tracks (DMAT) of the marshalling yard [4], where decision-making logics of operating personnel, referring to operational work, is reproduced in detail, and solutions are displayed directly in the schematic plan of the station. In fact, it is a process of modeling functions of station operator in their entirety.

Within the study it is proposed to design a complex of simulation models and programs that provide the user interface to the model, which are able to carry out a detailed analysis of the dynamics of the operation of all subsystems of the marshalling yard. In particular, these applications are designed to verify the actual possibilities (taking into account operational changes of the situation) of application of the system recommendations.

Ample opportunities of designed system are conditioned by virtually unlimited computing possibilities of existing computers, including personal (PC).

Particular attention is paid to integrated design of workstations of officials involved in technological processes at every level of control [14]. The WS implement all the fuctionality, that staff needs (analytics, automated work plans and operational tasks; interactive system of plan adjustment, monitoring of their implementation, performance evaluation, results of simulation, planning; output data of external systems related to objects of area of competence of the official) in a single ideology of user interface. In this subsystem, the main link between a decision maker and a computer is executed by machines advisers, the use of which will allow, while maintaining for control procedures experience and intuition of operators, to include additional benefits of machine resources.

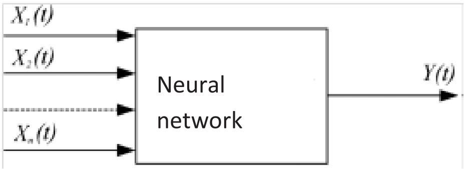
Technical solutions of separate subsystems of the control complex are introduced at a number of marshalling yards in Russia. An example is CSAC SP, in which neural network technologies are implemented.

In principle, a neural network or an artificial neural network (ANN) is a big parallel distributed processor. Among many outstanding qualities of the neural network the most important thing is an ability to induction learning of absolutes based on numerical data. By successive calculation of linear combinations and nonlinear transformations an approximation of arbitrary multidimensional function with an appropriate choice of network parameters is achieved. The device allows to assess the impact of qualitative and quantitative factors in their dynamics [15].

It seems also promising to apply neural network apparatus to predict the time of arrival of trains at a marshalling yard, basing on estimated deviations from the standard timetable. Implementation of factor neural network forecasting is carried out by means of the model (Pic. 1), wherein $Y(t)$ and $X(t)$ are output (predicted) and input (criterial) parameters.

In particular, it is possible to use ANN for solving the task of current prediction of stochastic sequence $x(k)$ according to its prehistory $x(k-1)$, $x(k-2)$. The problem is reduced to finding the estimates $\hat{x}(k) = F(x(k-1), x(k-2),\dots, x(k-p))$ in real time nad at a pace with receiving of data. In the linear case, this problem can be well researched and successfully be solved using adaptive forecasting autoregressive models. However, to construct nonlinear projections the most appropriate way is the use of ANN, for example, as shown in Pic. 2.

When considering the use of neural networks as a forecasting tool (for example, in order to predict size of movement in the area, the number of freight trains arriving at the marshalling yard with their main characteristics: weight, length, number of uncouplings in the train, the number of closing groups, etc.) it is necessary to take into note the following:



Pic. 1. Model of an artificial neural network.

1. It should be noted that the construction of neural networks requires a significant investment of time and effort to obtain a satisfactory model, so that unnecessarily high accuracy of the training set can result in instability of the results at the test stage – in this case, there is a need for «re-education» of the network.

2. The process of solving tasks by a neural network is a «non-transparent» to the user, that may cause distrust of its predictive ability.

3. Predictive ability of the network reduces significantly, if facts (data) received at the input, have significant differences from the examples, on which the network was trained. This drawback is evident in solving the economic forecasting tasks.

4. There are no theoretically sound rules of design and effective learning of neural networks. This leads, in particular, to the loss of ability to generalize domain data in overfitting conditions (overtraining).

At the stage of ANN design it is important to consider:

1. There is a need to get a certain number of observation results for creation of an acceptable model. This can be quite a large number of data, and they are not always available for ANN designer. For example, when predicting seasonal goods production history of previous seasons will be not enough, if it is necessary also to change a product's style, sales policy, etc.

2. In the training of neural networks «traps» can occur associated with getting into the local minima. Deterministic learning algorithm cannot detect global extremum or leave a local minimum. One of the methods, which allows to bypass traps, experts believe, is expansion of dimension of the space of scales by increasing a number of neurons in hidden layers. Some possible solutions to this problem can be found with stochastic methods of training.

3. The sigmoid nature of neuron's transfer function is a reason that, if in the process of learning a few weighting factors become too large, the neuron reaches the horizontal portion of the function in the saturation region. The changes of other weights, even quite large, almost do not affect the output value of the neuron, and hence the value of the objective function.

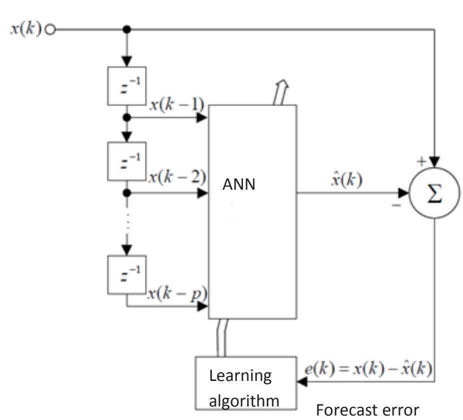
4. A bad choice of a range of input variables is rather elementary, but often causes mistakes. If X_i – is a binary variable with values 0 and 1, then in about half of cases it will be zero: $X_i = 0$. Since X is included in the expression for modification of weight as a multiplier, the effect is the same as that at saturation: modification of the respective weights will be blocked. The proper range for input variables must be symmetrical – for example, from +1 to –1 [16, 17].

Probabilistic and statistical techniques, used now as initial statistical data, have point values at the model input. In some cases, for various reasons, information on the size of movement and influencing factors could be inadequate, have a fuzzy character. Such cases make it difficult to use traditional methods of assessment and forecasting in view of the emergence of uncontrolled random errors in forecasting results in case of incorrect input data.

The most promising for operational and short-term forecasting of size of train movement under uncertainty are interval methods in which boundaries of the projected value are present, i. e. boundaries of confidence interval constructed for the test parameter in the considered prediction step. In particular, such methods include interval regression.

The system under consideration includes two basic blocks, which are responsible for prediction of the plan of train approach. They are blocks of long-distance train arrival and «random local background». The result of operation of the system is transmitted to the input of the neural network, which provides conclusion based on train position on the last haul and reaction of workers of road control center.

Moments associated with the operation of depot complex and delivery of faultless locomotives for trains, are fixed in the block «TPS forecast system for the station». In the first phase the unit will have a probabilistic nature, giving the average number of locomotives and the planned time of their readiness for the exit in the selected period taking into account the distribution of failures of locomotives subject to delivery. At the second stage forecast for delivery of locomotives is made on the basis of the train approach plan issued by the system.



Pic. 2. Chart of neural network forecasting.

Given the influence of the TPS factor, a forecast of arrival-departure times of trains at the selected station will be made regardless of whether neural networks or their combinations with other means of modeling environment are used.

Next is reading or calculation of the current situation at the station (number of trains, tracks occupancy, idle times, deviation from train departure points), as a result the difference between actual and expected position should enter the system in order to adjust forecast calculation. Till its accuracy enters the zone predetermined by the user, the adjustment is being made. Forecast, which is satisfactory in its accuracy, is taken as a planned target for the next period.

Conclusions. *Analysis of functioning of the automated control systems at the marshalling yard showed that in real conditions operational dispatch staff does not apply all available systems, some of them are overlapping. The necessity of transition to a new information level of operation of marshalling yards, as well as comprehensive development of automated control of their operation with elements of artificial intelligence are determined. In the suggested system one of the key roles is played by the forecast unit which is to be built on the basis of neural network models which are logically interconnected.*

There is reason to believe that widespread introduction of innovative methods of organizing transportation process based on neural network technologies will increase the performance of sorting systems, level of safety and failure-free operation of station processes, and ultimately will result in accrued competitiveness of rail transport.

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