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Application of fuzzy neural network technologies in management of transport and logistics processes in Arctic

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Abstract. The method of modeling the transport and logistics process using fuzzy neural network technologies has been considered. The analysis of the implemented fuzzy neural network model of the information management system of transnational multimodal transportation of the process showed the expediency of applying this method to the management of transport and logistics processes in the Arctic and Subarctic conditions. The modular architecture of this model can be expanded by incorporating additional modules, since the working conditions in the Arctic and the subarctic themselves will present more and more realistic tasks. The architecture allows increasing the information management system, without affecting the system or the method itself. The model has a wide range of application possibilities, including: analysis of the situation and behavior of interacting elements; dynamic monitoring and diagnostics of management processes; simulation of real events and processes; prediction and prevention of critical situations.

1. Introduction

Management of transport and logistics processes in the Arctic and subarctic region requires the use of new intelligent information technologies, since transport logistics in polar conditions depends on many difficult circumstances. There are such factors as: organization of safe navigation in ice conditions, complex hydrometeorological as well as navigational and hydrographic conditions, vulnerability of the unique natural environment and, as a consequence, the necessity and the challenges of its protection, and a weak port infrastructure [1, 2]. The complexity of planning and arranging cargo delivery requires process automation, including operational analysis along with information processes and its timely provision, ice monitoring, electronic document management, and a convenient calculation system.

2. Analysis of the management process

The complexity of planning and arranging cargo delivery in special Arctic conditions can be resolved by modeling with the use of artificial intelligence technologies, such as fuzzy neural networks and a genetic algorithm.

This approach was implemented and tested on transnational multimodal cargo transportation [3].

The point of this method is that planning, organization, management and control of cargo delivery requires an effective information system. Thanks to the information that allows one to make predictions, accompanies and completes this process, it is possible to organize sea transportation and other types of transportation in the transport management system, especially in conditions of uncertainty.

The effectiveness of the information system directly depends on the quality of processing a huge amount of data, which includes the description of business processes, information flows and their parameters, takes internal and external environment into account, and then issues factor analysis - options for possible management decisions. Organization of safe navigation, organization of search and rescue operations, assistance in eliminating the consequences of pollution from ships with hazardous and noxious substances, sewage or garbage, analysis of economic planning and decision-making in terms of risks and uncertainties, as well as incomplete and unclear initial information, monitoring the hydrometeorological, ice and navigation situations in a real dynamic mode, etc. [4]. These tasks belong to poorly formalized problems, and they can not be solved with classic deterministic methods. A powerful intellectual tool is needed for this processing [5].

The required tool is an imitation model of the information management system of the transport and logistics process, developed on the base of artificial intelligence systems, namely neural networks and the mathematical tool of fuzzy inference.

According to the traditional control scheme for the object shown in Figure 1, the control process is affected by n values of inputs xz_i, which can be estimated at any time (observable parameters) and r values xn_j, which either can not be estimated at all, or it is too expensive (unobservable parameters) [3].
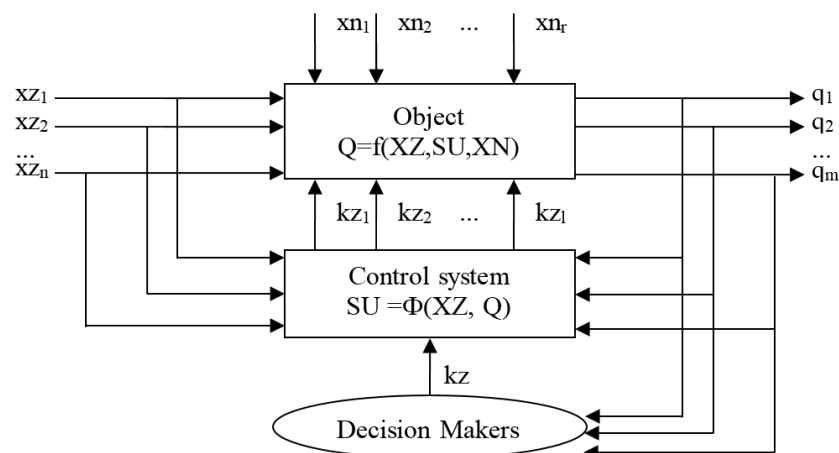

Figure 1. Traditional object management scheme

The dimension of the input vector is (n + r) and m is the output vector - q_i. Between input vector <XZ, XN> and Q output, there is some connection Q = f (XZ, XN). It is important to determine the value of Q for any XZ and XN and with the help of special control actions SU that affect the Q values. In addition, it is possible to make changes to the control process using correction vector KZ. Thus, the first requirement is the set of preferred values of vector Q, which are the objects of the object's operation, and the second requirement is the definition of mapping Q (.), which describes the operation of the control object. So, it is necessary to know the description of the object and the purpose of its functioning.

The objective function of object management can be maximizing or minimizing any values of vector Q, maintaining them in certain prescribed limits, preventing some combinations of these values, prohibiting the appearance of certain time sequences of the value of vector Q, and so on.

The uncertainty of the cargo transportation process is expressed in the fact that all the regularities that exist in it are unknown, especially if the object of management is a poorly defined or semi-structured system. It is also necessary to consider inaccurate knowledge that belongs to the subjective

category and cannot be defined as completely true or false, while the certainty of some is expressed by an intermediate measure.

The construction of the simulation model will give management the opportunity to properly assess existing strengths and weaknesses, find sources of potential, visualize and secure the options for management decisions in conditions of uncertainty.

3. An algorithm for managing the transport and logistics process

First of all, the factors assessing and influencing the transportation process and their interrelation were determined. A fuzzy neural network model of the information management system of the transport and logistics process was developed, based on the knowledge of the expert group, taking fuzzy factors into account. The model consists of six modules, each of which implements one block of a fuzzy neural network. The seventh module of the model is the accumulation of all previous modules, the input data of which are the outputs of the modules from the 1st to the 6th (Figure 2) [3].

The main eight transportation routes were identified. In each route, a number of factors are sorted by importance or priority. The number of factors can be supplemented in the process of model modernization, without affecting the system or the method itself.
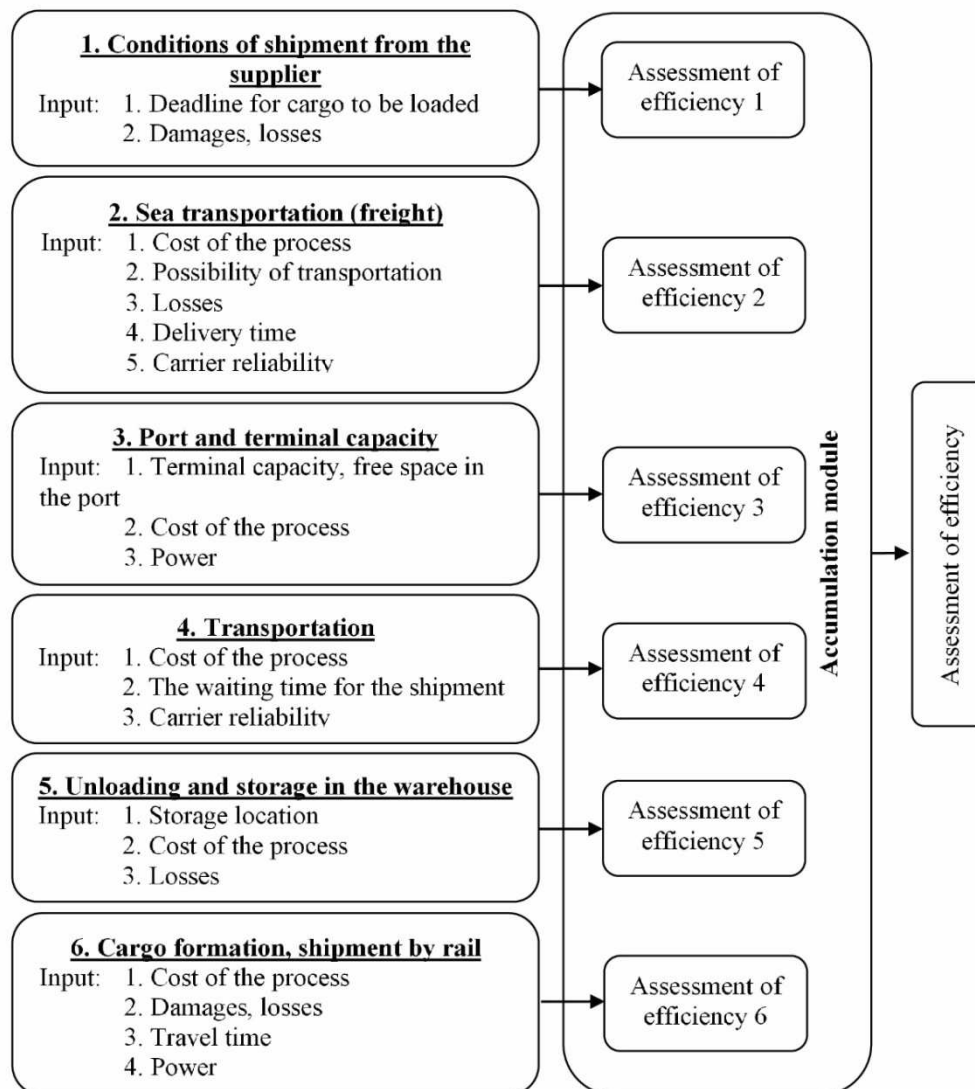

Figure 2. Model of information management system of transport and logistics process

Mathematical description:

$ypr = F (yk)$ or

$ypr = F (O (xj), M (xj), P (xj), A (xj), S (xj), Z (xj))$, where ypr is the assessment of transportation efficiency;

"Conditions of shipment from the supplier": $y1 = O (xj)$, where $j = 1, 2$;

"Sea transportation (freight)": $y2 = M (xj)$, where $j = 3, 4, 5, 6, 7$;

"Port and terminal capacity": $y3 = P (xj)$, where $j = 8, 9, 10$;

"Road transport": $y4 = A (xj)$, where $j = 11, 12, 13$;

"Unloading and storage in a warehouse": $y5 = S (xj)$,где $j=14, 15, 16, 17$;

"Cargo formation, shipment by rail": $y6 = Z (xj)$, where $j = 18, 19, 20, 21$,

where xj are input variables of each fuzzy neural network module, which are various factors - these are the qualitative characteristics of a separate block process; yk is the output of each of these six modules – assessment of efficiency of the k-th block process, where $k = 1, 2 ... 6$ is the corresponding module number.

Each of the input / output linguistic variables corresponds to the following five terms: bad; below average; average; OK; Excellent (or operation is missing), each of which is given from 0 to 1

For example, the term "Bad" will have a membership value different from 0 in the values of the universe from 0 to about 2, and so on.

Considering that within the fuzzy zone of each term, the law of variation of each variable is clearly nonlinear, the form of the membership functions was chosen by the Gaussian form. The total of input variables is 168: twenty-one variables in each of the eight transportation schemes.

4. Implementation of the model

The software implementation was carried out in the Fuzzy Logic Toolbox of the MATLAB system in the form of an adaptive system of neuro-fuzzy inference using the Sugeno method.

Figure 3 shows a fuzzy neural network model of the transport and logistics process control system [3]. For the training of a fuzzy neural network, samples were generated, while the interrelation and the importance of factors relative to each other in each block process were taken into account. The network was trained by the method of back propagation of error.

The calculated absolute and relative modeling errors showed that the results of training and testing of the fuzzy neural network are comparable with the corresponding expert estimates.

The acquired training experience of the developed neural network should be taken into consideration when teaching the intellectual model of the management of transport and logistics processes in the Arctic and subarctic regions. For example, the training of a hybrid network must be done in stages, taking several samples into account in one step, gradually increasing the data array to avoid error growth on the test set.

The factor analysis carried out on the constructed model using real data from a transport and logistics company's practical activities revealed a high degree of sensitivity to the change in the values of the factors. The model adequately reacts to the change in the factors and is ready for application in the working mode, which was also confirmed by experts in the field of transport and logistics processes.

The constructed model provides multiple options for guiding solutions in conditions of uncertainty. The problem of finding the most effective solution is multicriteria, multifactor and belongs to problems of discrete optimization. It can be solved either by a full search of possible solutions, or by means of a genetic algorithm.
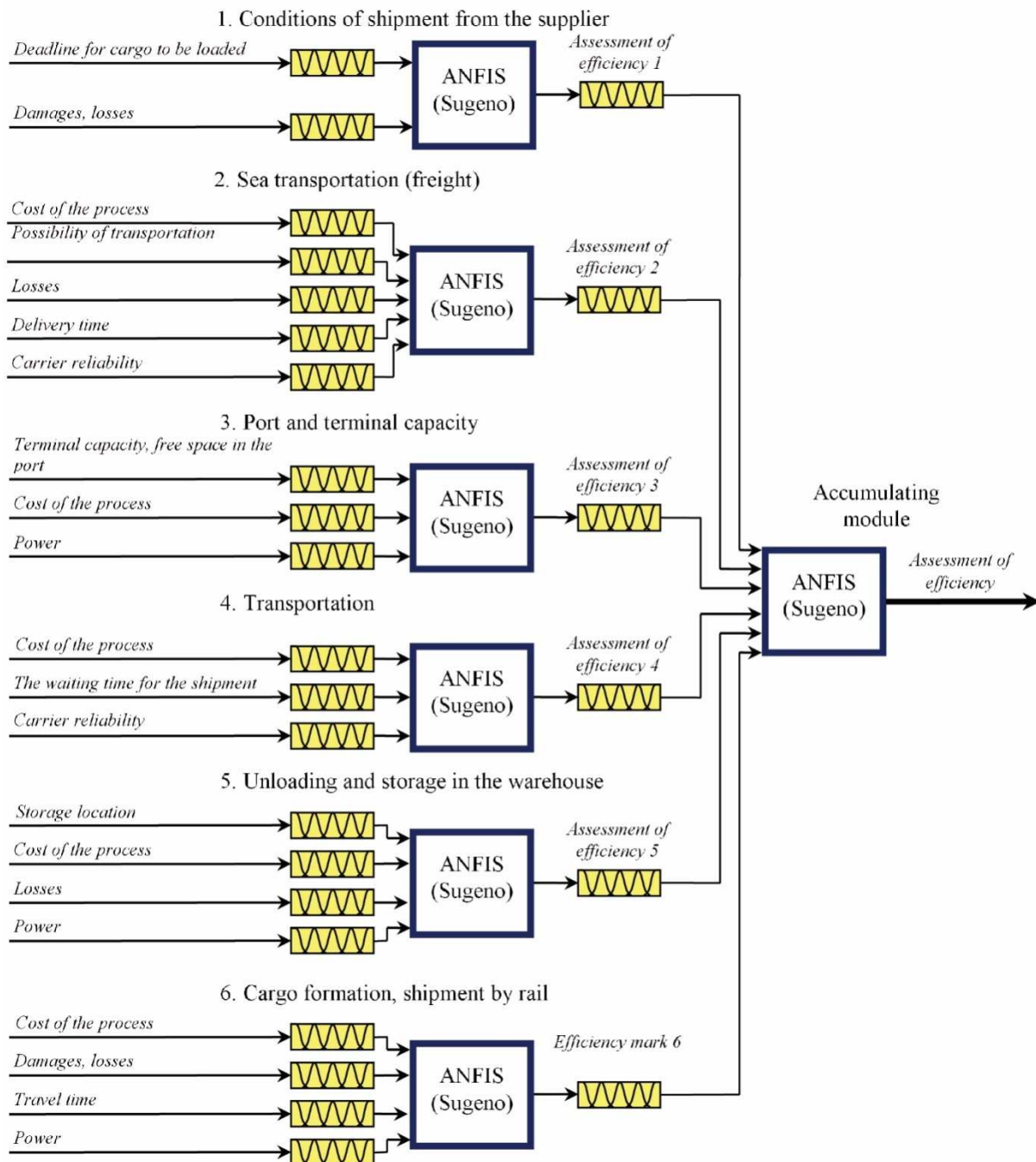
Figure 3. Fuzzy neural network model of information management system of transport and logistics process

Since the problem is poorly formalized and there is a need to get a result for decision-making in real time, it is advisable to apply the evolutionary method - a genetic algorithm based on the processes of crossing, crossover, mutation and natural selection, since the evolutionary modeling feature is invariance to the dimension of the problem due to high solution speed as a result of the algorithm parallelism, where each object of the population can be processed independently of each other. Also, it allows one to solve problems where the solution structure is unknown [6].

5. Conclusion

The examined method of fuzzy neural network modeling will allow one to consider the peculiarities of the transport and logistics process as a complex management object, especially in the Arctic and subarctic conditions, taking into account not only quantitative but also qualitative assessments, unclearly defined and non-formalized criteria and connections between them.

The modular architecture of this model can be expanded by incorporating additional modules, since the conditions of work in the Arctic and the subarctic themselves will present more and more realistic tasks. Architecture will increase the information management system, without affecting the system or the method itself.

The model has a wide range of application possibilities, including: analysis of the situation and behavior of interacting elements; dynamic monitoring and diagnostics of management processes; simulation of real events and processes; prediction and prevention of critical situations, etc.

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