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Development of efficiency module of organization of Arctic sea cargo transportation with application of neural network technologies

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Abstract. The analysis of software intended for organizing and managing the processes of sea cargo transportation has been carried out. The shortcomings of information resources are presented, for the organization of work in the Arctic and Subarctic regions of the Far East: the lack of decision support systems, the lack of factor analysis to calculate the time and cost of delivery. The architecture of the module for calculating the effectiveness of the organization of sea cargo transportation has been developed. The simulation process has been considered, which is based on the neural network. The main classification factors with their weighting coefficients have been identified. The architecture of the neural network has been developed to calculate the efficiency of the organization of sea cargo transportation in Arctic conditions. The architecture of the intellectual system of organization of sea cargo transportation has been developed, taking into account the difficult navigation conditions in the Arctic. Its implementation will allow one to provide the management of the shipping company with predictive analytics; to support decision-making; to calculate the most efficient delivery route; to provide on demand online transportation forecast, to minimize the shipping cost, delays in transit, and risks to cargo safety.

1. Introduction

In the Arctic and Subarctic zone of the Russian Far East, there are prospective transport corridors, including transit ones, which, provided an efficiently built management system and timely infrastructure modernization, will soon be a key link in ensuring a stable and geopolitically independent development of the country [1].

Ensuring the cargo delivery in the polar environment depends on many difficult circumstances: severe climate conditions; presence of ice, danger of marine environment pollution, which could seriously damage the ecological balance; lack of a developed infrastructure overseeing the processes of sea cargo transportation [2].

Thus, the main goals of the intellectualization of the organization of cargo transportation by sea are: to increase the efficiency of the logistics infrastructure and the quality of the ports, as well as the cargo transportation system [3].



2. Analysis of existing software and information resources

Information sources of companies in this field have been considered and the following software tools have been selected: Cabotage; Sea Voyage; MultiMix; Packer3d; Magaya Cargo; CargoWiz. The analysis of existing software tools and information resources in the field of organization of sea cargo transportation showed the lack of: a decision support system; a cargo monitoring system in real time; an algorithm for calculating the effective use of icebreakers; an algorithm for calculating the most efficient way of goods and passengers delivery; multilanguage user interface.

The analysis also showed the need to develop a fundamentally new intellectual system for the organization of sea cargo transportations in the Arctic and the Subarctic zone as a whole.

3. The architecture of the module for calculating the efficiency of organization of sea cargo transportation

It is necessary to develop the module architecture which will allow one to calculate the efficiency of sea cargo transportation in the Arctic, depending on the type of cargo, the type of vessel, the navigation and ice conditions, etc. [4]. Ways of calculating the cargo delivery efficiency can be very different, since it is necessary to take into account the system of discounts for stable carrier companies, discounts for large volumes of transportation, or accounting for the return path in empty carriage, or ensuring the loading of the vessel in cyclic navigation, etc.

Based on the analysis and needs of the shipping company, a semantic network has been proposed in a general form, which represents the information model of the domain (Figure 1) [2].

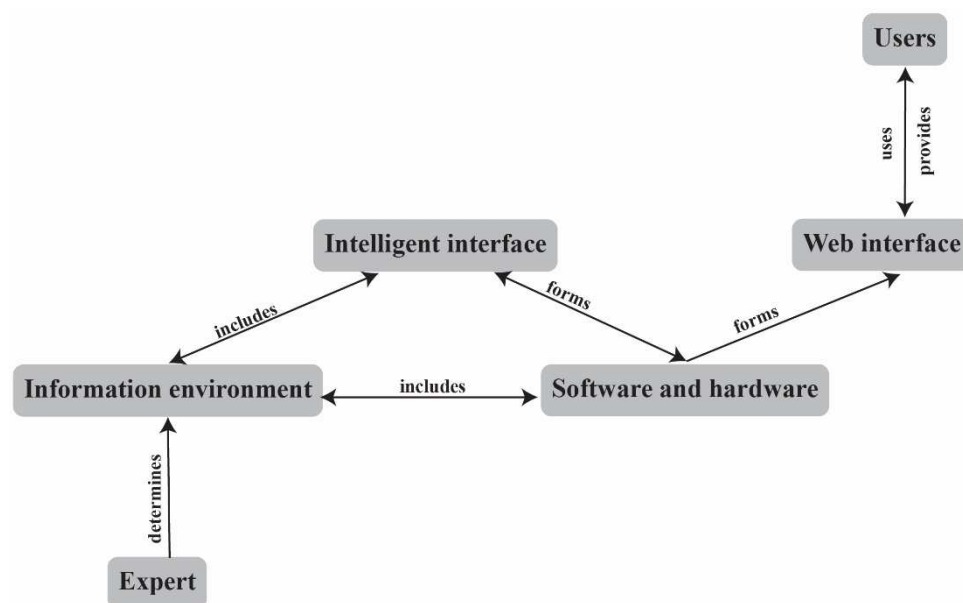


Figure 1. A semantic network for the organization of sea cargo transportation on the base of an intelligent system

Also, the architecture of an intelligent system for the organization of sea cargo transportation has been developed (Figure 2) [2].

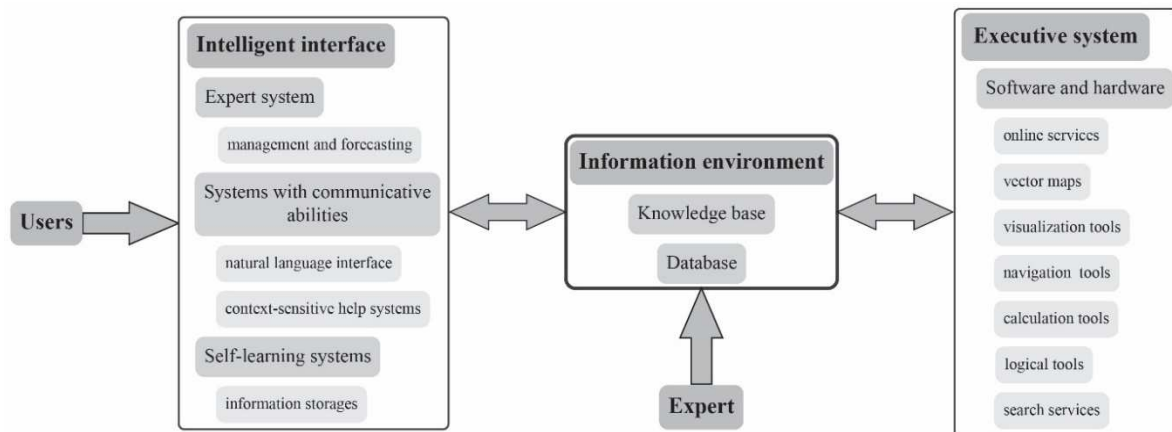


Figure 2. The architecture of an intelligent system for the organization of sea cargo transportation

The architecture of the module for calculating the effectiveness of the organization of sea cargo transportation has been developed, which is presented in Figure 3 [2].

The proposed architecture of the module for calculating the effectiveness of the organization of sea cargo transportation will allow to calculate the efficiency of sea cargo transportation in the Arctic and Subarctic regions, depending on the type of cargo, the type of vessel, the specifics of cargo transshipment, seasonality, traffic density and other factors [2].

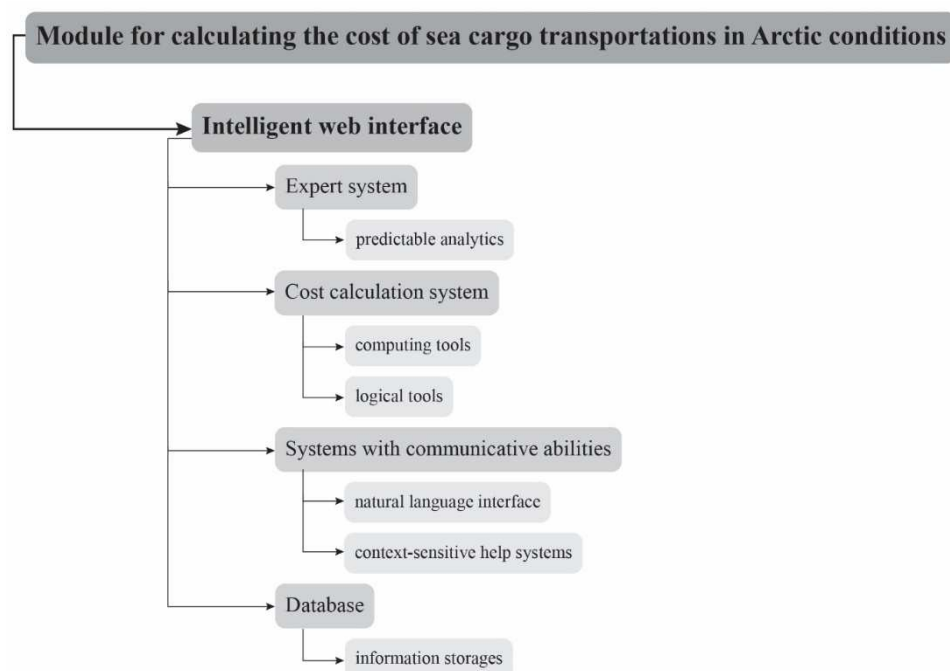


Figure 3. The architecture of the intelligent information system module for calculating the effectiveness of the organization of sea cargo transportation in Arctic conditions

When developing intelligent control systems, two basic principles are taken into account: situational management, i.e. management based on the analysis of internal and external situations or events, and the use of modern information technologies for knowledge processing [5]. So, intellectual technology - a neural network trained on a limited set of training samples summarizes the accumulated information and develops the necessary reaction applicable to the new data, thus ensuring the

generation of the appropriate control action in real time. When solving problems of managing complex dynamic transport and logistics processes with a large number of parameters with complex interrelations, the neural network can act as a tracking system that adapts to the changing conditions of the external complex polar environment. The neural network's ability to process information in parallel allows one to speed up significantly the information processing.

Neural networks can self-adjust and learn, change their behavior depending on the state of their environment. A trained network can be resistant to some deviations in input data, which allows it to correctly recognize an image containing various interference and distortions.

To construct a simulation model based on a neural network, real data are required to compile training samples.

Figure 4 shows the general scheme for carrying out simulation experiments using an intelligent system.

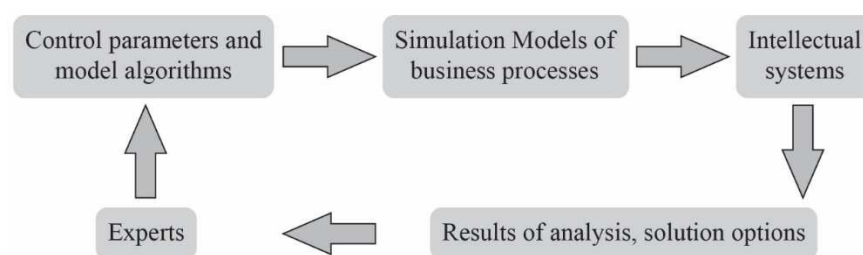


Figure 4. Scheme of simulation experiments

The input of intelligent systems receives the results of simulation experiments that perform analysis and offer a selection of several solutions. Further, experts can choose a more rational solution or reconfigure the parameters, guided by the results of the intellectual analysis, and continue the experiment.

4. Determination of the main classification factors and their weighting coefficients

For the module for calculating the efficiency of the organization of sea cargo transportation in Arctic conditions, the main purpose of which is minimizing the cost of delivery, it is necessary to identify the main classification factors with their weighting coefficients. Tables 1-5 show the main necessary part of the factors with coefficients, which in the future, if successfully implemented, can be supplemented without the risk of increasing the time of solving the problem.

Table 1. Vessel [V]

| Description | Classification features |
|------------------|--|
| Class | Ice1 - Ice3; Arc4 -Arc9; Icebreaker 1- Icebreaker 9 |
| Type of vessel | cargo-dry cargo; freight – bulk; cargo-and-passenger; special transport ship |
| Speed | 6-12 knots |
| Lifting capacity | 8000 tons - 12000 tons |

Table 2. Cargo [C]

| Description | Classification features |
|---|--|
| According to the form | piece; bulk; liquid |
| According to the physical and chemical properties | gyroscopic; poisonous; flammable; explosive; caking; regelating; fritting; smell absorbing; dust-forming |
| Tonnage | 1000 tons - 10,000 tons |

Table 3. Navigation [N]

| Description | Classification features |
|--------------|---|
| Season | Winter – Spring; Spring – Summer; Summer - Autumn |
| Age of ice | New ice |
| | Nilash, Ice rind<10cm |
| | Young ice 10-30 cm |
| | Grey ice 10-15 cm |
| | Grey/white ice 15-30 cm |
| | First-year ice 30-200 cm |
| | Thin first-year ice/white ice first stage 30-70 cm |
| | Thin first-year ice/white ice second stage 50-70 cm |
| | Medium first year ice 70-120 cm |
| | Thick first year ice > 120 cm |
| | Second-year ice 180-280 cm |
| | Multi-year ice > 300 cm |
| Thickness | 0-5 points |
| Ice cohesion | 0-10 points |
| Form of ice | Pancake ice - 0 |
| | Brash ice < 2 m |
| | Ice cake 2 - 20 m |
| | Small floe 20-100 m |
| | Medium floe 100 - 500 m |
| | Big floe 500 m -2 km |
| | Vast floe 2 - 10 km |
| | Gient floe > 10 km |
| | Fast ice, bergy bit or floeberg |
| | Iceberg |

Table 4. Tariff [T]

| Description | Classification features |
|----------------|-----------------------------------|
| Ice channeling | Σ channeling + icebreaker |
| Cargo | Σ cost of cargo |
| Vessel | Σ cost of operation + fuel |
| Route | Σ number of ports |

Table 5. Route [R]

| Description | Classification features |
|-----------------|--------------------------|
| Number of ports | 0-10 |
| Range | 100-10000 nautical miles |

5. Development of a neural network for the calculation of the effectiveness of the organization of sea cargo transportation in Arctic conditions

Based on the number of factors listed above (Vessel [V], Cargo [C], Navigation [N], Tariff [T], Route [R]), a multilayer perceptron was chosen to construct the functional scheme of the neural network, since it is a feedforward neural network, the input signal is transmitted directly from layer to layer.

An approximate (initial) scheme of the neural network for calculating the efficiency of organization of sea cargo transportation in Arctic conditions is shown in Figure 5. The presented scheme of a multilayer perceptron consists of: input nodes that form the input layer; layer of computational

neurons; output layer [6]. The input layer is formed from a variety of factors listed above, for example, the input signal "V" - "Vessel" is formed from a set of attributes (classification characteristics) - \tilde{V} . The output is the value of the objective function - the minimum cost of organization of sea cargo transportations in Arctic conditions with different input parameters.

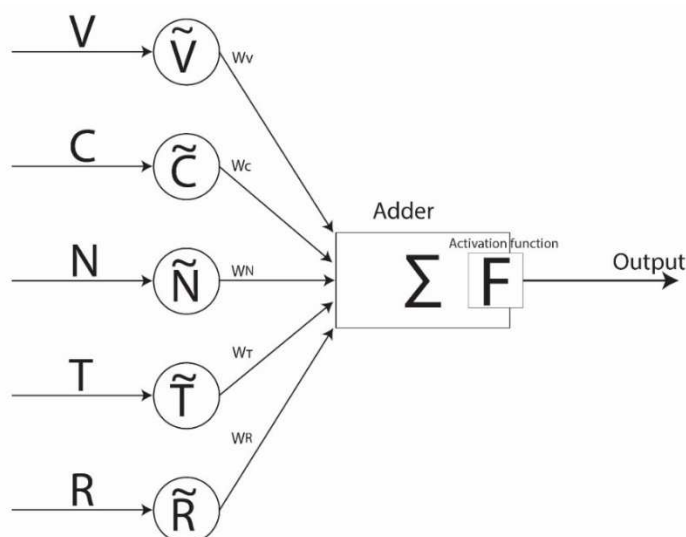


Figure 5. A scheme of a multilayer perceptron for calculating the efficiency of organization of sea cargo transportation in Arctic conditions

6. Conclusion

This intelligent system of organization and management of sea cargo transportation in Arctic conditions will allow one, first of all, to provide the management of the shipping company with the predictive analytics in order to make timely decisions for further development and to attract customers.

The analysis of the effectiveness of the examined transport scheme is one of the key modules of the intellectual system for ensuring the organization of sea cargo transportation in Arctic conditions.

The implementation of an intelligent system for the organization of sea cargo transportation is assumed through a web interface, which provides the ability to analyze the work with the system in real time.

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