MODELING THE BEHAVIOR OF NAVIGATOR TO IMPROVE SAFETY OF MARITIME TRANSPORT OPERATION

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Introduction. Autonomous vessels controlled by navigators by means of satellite and coastal communication systems are gradually being put into operation. However, switching to fully autonomous navigation is impossible due to the lack of mathematical and logical-algorithmic models of vessel control in critical situations. An effective replacement of the operator-navigator with an artificial control system is reuired, which will be able to perform navigation tasks with sufficient efficiency.

For this replacement, research is needed to analyze the navigator behavior in order to obtain an effective and universal model of vessel control in difficult situations. Thus, the task is to conduct a number of experiments to create a unified series of vessel control models. It should also be taken into account that trends in the development of water transport infrastructure are intensively transformed into specialized centers for managing complex logistics and traffic control systems for sea vessels [1].

This introduces additional requirements both to navigators' qualifications and ability to adequately perceive navigational situations, promptly and efficiently navigate vessels, and make effective management decisions [2]. In these conditions, it is especially important that in a number of studies aimed at analyzing marine accidents, there is a clear pattern from the navigation situation initially identified by the navigator [3]. In real conditions, the identified situation is usually associated with the previous experience of the navigator and directly affects the planning of one's own actions when performing navigation tasks and vessel controls [4].

The relevance of research. The problem of constructing models of navigator behavior in complex and multi-stage navigation situations is considered. In the course of modeling, systems for extracting knowledge about the trajectory of the navigator's actions are considered.

The approaches are considered allowing to determine the probabilities of complex critical situations and approaches to automated prevention of non-agressive consequences.

Research results. In order to confirm the identified patterns, an automated predictive model was built based on data mining technology, which made it possible to identify the likelihood of critical situations. The model was based on a database of navigation parameters in four locations, which allowed building a decision tree and determining the predicted effectiveness at its nodes. With regard to the processed data, based on typical navigation operations, it became possible to create a class of unified critical situations with a similar decision-making structure [5-9].

Based on the presented descriptions, we implement a simulation of the prediction of the probability of a critical situation according to the criterion "Effectiveness of task performance by the navigator". Based on the CART algorithm and data mining module.

As a result of modeling, a tree was built in an automated way in which the main nodes of situation transformation were identified with respect to the parameters of the factors influencing the navigator's actions [10-13] (Fig. 1). To build a decision-making system based on the data obtained, this is sufficient and does not require more complex data identification models.

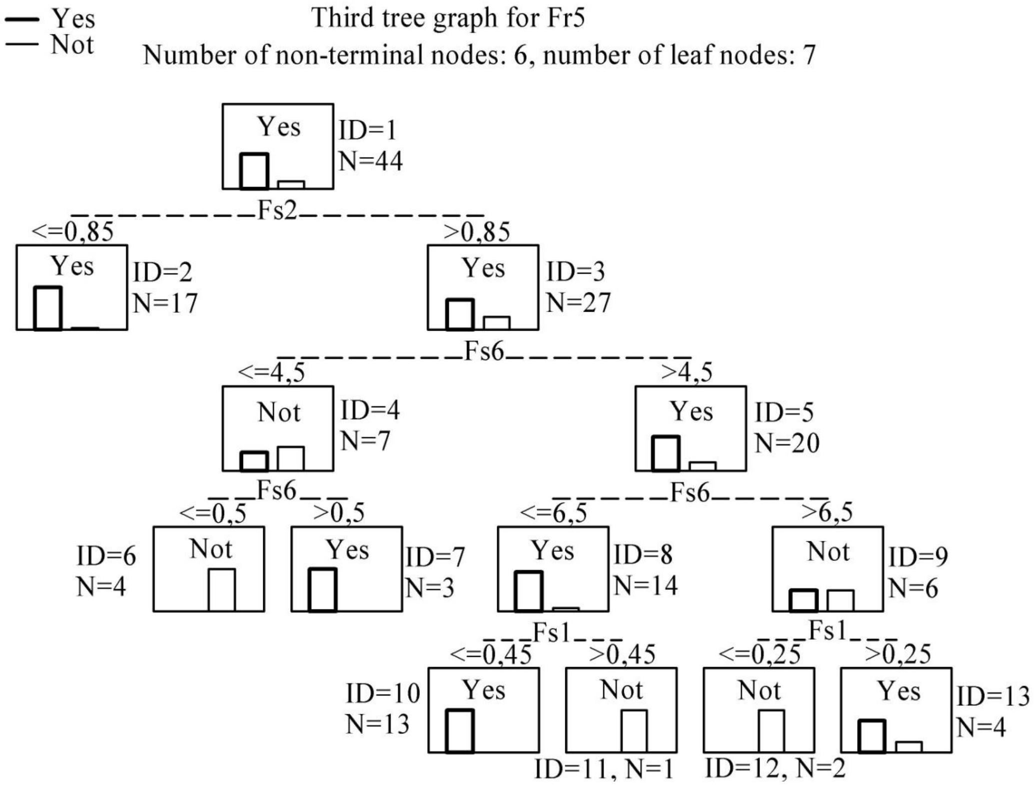

Figure 1. Prediction tree of the situation under the influence of the navigator "human factor" on the ergatic vessel control system

When considering the obtained prediction results, the following dependences of the tree formation were determined, Table 1.

Table 1.

Formation of simulation tree

Development of navigation situation in relation to Fs*i* factors
The situation is based on the factor Fs2 "Determination of similarity completeness (flow rate, date and time of day, vessel type)". Moreover, in situations where the similarity exceeds 85 % ID=3, the probability of a successful outcome is lower than in those where the similarity is lower. This is due to the fact that in situations without a clear similarity ID=2, the navigator is more focused on the task, the area of attention and focus on elementary actions is increased
The situation goes to the node of the factor Fs6 "Complexity by the *p*-adicity of the stage (ECDIS, ARPA, AIS, GPS interfaces)" [15-18]. There is also a similar trend, indicating that if the complexity of the stage exceeds 4.5 units out of 9 maximum (50 %) ID=5, then the navigator is more aware of the navigation task being performed, which increases the chances of success, in contrast to the reverse ID=4.
In the case of low Fs6 (less than 50 %) ID=4, the situation depends on the factor Fs9 "Synchronization with the team. Coincidence of actions with the navigational watch". This factor can ensure safety if the synchronization is high and other members of the watch perform the task at a high qualification level ID=7. Otherwise, the situation will inevitably develop into critical ID=6, with an emergency outcome for the ergatic system and the vessel as a whole. In the case of ID=6, it

Development of navigation situation in relation to Fs*i* factors
is necessary to resort to extreme emergency measures, switch to automatic vessel control using specialized control modules [19-20].
As can be seen in Fig. 3, the situation develops towards complication with respect to Fs6 ID=5 and this leads to a continuous stressful situation regarding the next stage of vessel movement in the location.
Consider an option for this situation when the level of *p*-adicity of the stage increases significantly. It is clearly seen that if the navigator is not helped at Fs6> 6.5 ID=9, then the probabilities of a safe outcome and an accident become equal. This development of events cannot satisfy either the vessel captain or the owner company
When the complexity level decreases, Fs6>6.5 ID=8, the probability of a successful outcome of the situation is much higher.
In each of the cases 3.1 and 3.2, the situation becomes dependent on the factor Fs1 "Superposition of situations. Vessel position relative to the ECDIS waypoint" with different parameters.
In this case, the factor Fs1 ID=13 can stabilize the situation if the recognition of the area exceeds 25 %. But the probability is not so high as not to resort to hints for the navigator. If the situation recognition is low ID=12, then it is necessary to switch to automatic vessel control [21-23].
In the case of ID=11, with a high coincidence of the situation, the effect of "distraction" is also observed, affecting the concentration of attention and focus on the situation, while a negative result is very likely, which requires preventive measures, namely, strengthening the watch or replacing the navigator. At the same time, a moderate similarity will stimulate the readiness of the navigator for the qualified performance of the task in ID=10

Conclusions. The uniqueness of the developed generalized model of the identification process and the influence of the navigator "human factor" on the ergatic vessel control system lies in analyzing the subject's influence on navigation safety. The proposed logical-formal approaches to extracting data with a complex structure made it possible to synthesize external influences, navigator's perception of the situation, prediction of the probabilities of disasters and the final performance of the task [24].

In this case, the key parameters of the factors were the temporal indicators of atomic reactions, psychophysiological state, the complexity of situation perception, criterion of distinguishability of situations in relation to the navigator's experience. The presented feature of the model made it possible to synthesize data in the form of factors that determine the situation and factors affecting the occurrence of risk, as well as correlate them with the results of modeling on the navigation simulator. Data synthesis directed the research towards the use of data mining automated simulation tools.

The feasibility of the developed predictive model of probable critical situations by data mining means made it possible to obtain a full range of probabilities of ~~o~~critical situations in relation to the processed data array. Probabilistic trees constructed in an automated way made it possible, on the one hand, to determine the most significant factors relative to the selected set of typical situations, and on the other hand, to generate the response of the navigation safety control system at each node of the tree.

This allowed determining the dynamics of navigation situations and identifying the most dangerous branches of the model, depending on the parameter ranges of the influencing factors.

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