APPROACHES FOR IDENTIFYING AND RECOVERING QUALIFICATION PARAMETERS OF ORGANIZATIONAL AND TECHNICAL SYSTEMS OF MARITIME TRANSPORT

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Abstract

This thesis discusses the importance of controlling seafarers' qualification parameters in the organizational and technical systems of maritime transport in order to prevent possible problems and accidents on ships. To do this, it is proposed to use fuzzy systems for assessing category membership based on several criteria-features, as well as to develop an algorithm for restoring qualification parameters based on a conditional input and an additional parameter. The possibility of creating automated fuzzy classification systems and the use of intelligent systems for managing qualification parameters is also discussed.

Introduction

The problem of constant monitoring of the qualification indicators of the subjects of the organizational and technical systems of maritime transport (OTSMT) is quite acute due to the possible consequences due to the fault of the human factor [1]. Thus, over the past 5 years, accidents in maritime transport due to the fault of the human factor have caused major environmental disasters, disruption of vessel traffic and high economic risks for international maritime companies.

A situation is known when, due to a navigator's error in navigation, a collision of two tankers occurred in 2018 off the coast of China, resulting in an oil spill into the sea. The navigator made a mistake when calculating the distance to another ship and could not avoid a collision [2].

Also, in 2017, a fire and explosion occurred on the Sanchi tanker, carrying liquefied natural gas, which led to the death of the entire crew. The cause of the disaster was a fire on board the ship, caused by non-compliance with technical standards during the operation of the equipment [3].

In addition, in 2019, the tourist vessel "Viking Sky" in Norway had an accident when the vessel began to lose stability due to a severe storm. Despite the experience of the captain and crew, an incorrect assessment of the situation led to the fact that the ship was in a dangerous position and the evacuation of passengers was required [4].

All this indicates the relevance of the study, which is aimed at solving an important technical problem of managing the qualification indicators of the OTWTS both at the macro and micro levels.

Relevance of research

So, for example, if a sailor-navigator, mechanic or electrician has lost the proper level of qualification, serious problems may arise in the workplace, which may lead to dangerous situations on the ship:

- errors in navigation and maneuvering. The navigator is responsible for the safe navigation of the ship, so if he lost the proper level of qualification, this can lead to navigational errors and non-observance of the rules of maneuvering, which can lead to collisions and accidents [5].

- non-compliance with technical standards and rules for the operation of the vessel. The mechanic and electromechanic are responsible for the technical condition of the ship and its equipment, so if they have lost the proper level of qualification, this can lead to improper operation of the equipment, non-compliance with technical standards and rules, which can lead to accidents on the ship [6].

In addition, an incorrect assessment of the situation in emergency situations can lead to an incorrect decision and aggravation of the situation, when time plays a decisive role and can lead to the death of the crew and loss of survivability of maritime transport [7].

In general, the loss of the proper level of skill can lead to serious problems on the ship, which can endanger the safety and lives of the crew and passengers. Therefore, the restoration of the qualifications of seafarers is an important task for ensuring the safety of navigation.

In order to maintain and restore at a sufficient level the qualification parameters of the OTSMT, in general, approaches have been developed, including [8,9]:

1. IMO - model training courses: a seafarer can attend courses to update his skills and knowledge in accordance with new requirements and standards. Courses can be held at maritime training centers or on board a training vessel.

2. Online Courses: Seafarers can also study online using online resources and e-courses. This can be especially useful for seafarers who cannot leave their ships for extended periods.

3. Internship on board: A seafarer may undertake an internship or internship on another ship to improve his skills and knowledge. This can be especially useful for seafarers who want to retrain or gain additional qualifications.

4. Competency assessment: Seafarers can be assessed on their competencies and knowledge to identify their strengths and weaknesses. This can help seafarers develop an individual training plan that will suit their needs.

5. Mentorship: A sailor can find a mentor who will work with him to help him develop his skills and knowledge. Mentoring can be especially helpful for seafarers who want to advance in their profession or move to another position on board.

6. On the job training: A seafarer can be trained on the job, gaining knowledge and skills directly from his colleagues and supervisors. This can be especially useful for seafarers who work on high technology ships where special training is required.

However, there remains an objective problem related to the fact that ships, their equipment and instruments are quite different and require individual getting used to their operation. At the same time, the percentage of accidents in the OTSMT does not decrease, largely due to the emergence of a greater flow of information and new functions of high-tech equipment [10]. There is also a tendency to reduce the crew, which means that the load and functional obligations increase for each individual sailor [11].

All this speaks of the need to develop new automated decision support systems in the OTSMT to monitor the skill level of its subjects in real time.

Presentation of the main material

As is known, one of the important attributes indicating the level of qualification parameters of seafarers is the time of completion of the final operations that make up the trajectory of activity within the framework of the task [12-14].

An important task in the context of the considered problem is still the construction of such an algorithm that would allow finding a solution for restoring (supporting) the qualification parameters of the OTSMT, based on the conditional input (STCW) and an additional parameter that directly affects the recovery time. The choice of the time parameter is not random due to the fact that time is limited and its weight exceeds organizational costs due to the increased intensification of processes in the OTWTS. Such an approach will involve the stages of identification, modeling and management of the qualification parameters of the OTSMT.

However, it should be considered that the restoration of qualifications is possible only in doses, in the conditions of what awaits the navigator on the route of the vessel. So, depending on operations, location, maneuvers and weather conditions, recovery zones are outlined, which are defined by a set of qualifying knowledge fragments (QKF) [15,16]. At the same time, security must be ensured. This condition introduces a restriction on the flow of information that is fed to the input of the subject as a carrier of the qualification parameters of the OTSMT.

As a recovery zone, we will take the QKF area, each element of which represents a separate localized fragment of qualification. Let (I,k) , the recovery problem, with a fixed parameter *k*. Then the definition of the algorithm for solving it is reduced to some arbitrary function of the form $f(k)\cdot poly(I)=q(|I|)$.

In turn, the total set of elements is equal to the set of complexly formalized STCW linguistic data, but in each localized task it is necessary to use such a polynomial algorithm *S* that $S(I,k)\to(I',k')$, for which $|I'|+k'\le q(k)$. That is, there is an additional task in reducing the general task to a smaller task, which is logical.

However, the solution of such a problem entails a number of difficulties, in particular, its formal description with respect to the parameter *k* has the form: $K\to k-k_1,k-k_2,...,k-k_d$.

Then the solution of the problem at the first iteration will be:

$$T(k') \le T(k-k_1) + T(k-k_2) + ... + T(k-k_d),$$

$$T(k) = c\lambda^k, \; c\lambda^k \le c\lambda^{k-k_1}, ..., c\lambda^{k-k_d},$$

where $\lambda^{k_d} - (\lambda^{k_d-k_1} + ... + \lambda^{k_d-k_n}) = 0$.

In doing so, we are dealing with the parameter $k_d \gg 100$, which indicates that the problem is NP hard. And as a result, it involves finding hikes based on probably fuzzy classifications of a large amount of data with their processing using intelligent algorithms. This choice is due to the fact that when processing large amounts of data, fuzzy classification can be useful in cases where the data is heterogeneous and not well defined.

Indeed, the OTSMT classification parameters, due to their linguistic (descriptive) nature, suggest the existence of fuzzy boundaries between categories that may overlap or be in a state of uncertainty. This is quite suitable for the identification problem, where it may be necessary to assess the membership of the QKF based on several criteria. In addition, such an approach, due to dynamically changing QKF relative to recovery zones, can be used to create automated adaptive fuzzy classification systems [17].

Then, in a general form, a formal description of the fuzzy classification of the qualification parameters of the OTSMT is proposed in the form:

$$Rule\,k: IF\ x_1\ is\ A_1, k_1\ AND\ x_2\ is\ A_2, k_2\ AND...$$
$$...AND\ x_n\ is\ A_n, k_n THEN\ y\ is\ B_k,$$

Let there be *N* input parameters - qualification attributes $x_1, x_2, ..., x_n$, as well as *k* fuzzy identification rules (IF-THEN) of the form:

$$Rule\,k: IF\ x_1\ is\ A_1, k_1\ AND\ x_2\ is\ A_2, k_2\ AND...$$
$$...AND\ x_n\ is\ A_n, k_n THEN\ y\ is\ B_k,$$

where $A_1, k_1, A_2, k_2, ..., A_n, k_n$ are the membership functions of the fuzzy sets for each of the input parameters, and $x_1, x_2, ..., x_n, B_k$ is the membership function of the fuzzy set for the output parameter y when the *k*-th rule is fulfilled.

Then the set of fuzzy rules can be defined as: $R = \{Rule\_1, Rule\_2, Rule\_k,\}$, where $Rule\_k$ - *k*-e a fuzzy rule that describes the relationship between input parameters and output parameter under certain conditions.

The generalized formula for determining the membership function of each of the qualifying parameters can be written as follows: $\mu(x) = f(x, p_1, p_2, ..., p_n)$, where *x* - parameter value, $p_1, p_2, ..., p_n$ - membership function parameters, *f* - membership function that determines the degree of membership of the *x* value in the set specified by the parameters $p_1, p_2, ..., p_n$.

For example, the membership function for determining the qualifications of a navigator based on work experience can be given as follows:

$$\mu(Higt) = \min(1, \frac{Exp-10}{10}),\ if\ Exp \ge 10$$
$$\mu(Higt) = 0,\ if\ Exp < 10,$$

where E*xp* is the value of the navigator's work experience, *μ(High)* is the degree of belonging of the *Exp* value to the set of "highly qualified navigators".

To describe fuzzy operations, we introduce a logical conjunction and disjunction: the degree of membership of *x* to set *A* and *y* to set *B* is expressed as: $\mu A(x) \wedge \mu B(y) \wedge ... \wedge \mu W_i(n_i)$, where $\mu A(x)$ is the membership function of *x* to set *A*; $\mu B(y)$ is membership function *y* to the set *B*.

Also $\mu(A \cap B)(x) = \min\{\mu A(x), \mu B(x)\}$, where $\mu A(x)$ and $\mu B(x)$ are membership functions of the element *x* in the sets *A* and *B*, respectively. In our case for fuzzy sets $A_1, A_2, ..., A_n$, the logical "AND" will be expressed as:

$$\mu(A_1 \cap A_2 \cap ... \cap A_n)(x) =$$
$$= \min\{\mu A_1(x), \mu A_2(x), ..., \mu A_n(x)\},$$

where $\mu A_i(x)$ - functions of membership of an element *x* to the set A_i.

The fuzzy logical union (OR) operation for two fuzzy sets *A* and *B*, defined on the same universal set *X*, can be expressed by the formula: $\mu(A \cup B)(x) = \max[\mu A(x), \mu B(x)]$, for all $x \in X$, where $\mu(A \cup B)(x)$ is the membership function of the combined fuzzy set $A \cup B$.

The calculation of the value of the output qualifying parameter based on the obtained membership values and the membership function will be written as: $Y = \frac{y_1 \cdot w_1 + y_2 \cdot w_2 + ... + y_n w_n}{w_1 + w_2 + ... + w_n}$, where *Y* - the value of the output qualifying parameter,

$y_1 ... y_n$ is the membership values of each fuzzy rule,

$w_1 ... w_n$ is the weight coefficients of each fuzzy rule corresponding to its significance determined by the experts.

Further, the application of the defuzzification method will be based on the formula:

$$\hat{y} = \frac{\sum_{i=1}^{n} \mu A_i(x) \cdot y_i}{\sum_{i=1}^{n} \mu A_i(x)},$$

where y_i is clear value of the output parameter,

n_i is number of fuzzy rules.

$\mu A_i(x)$ the membership degree for the i-th fuzzy rule,

x - input value.

To assess the quality of the fuzzy classification algorithm, you can use metrics such as accuracy (accuracy), recall (recall) and F-measure (F_1-score). To do this, we will mark up the data set (ground truth) and compare the classification results of the algorithm with this data set. Formulas for calculating metrics can look like this:

$$\text{Accuracy} = \frac{TP + TN}{TP + FP + TN + FN}, \quad \text{Recall} = \frac{TP}{TP + FN},$$

$$F_1(\text{score}) = \frac{2(\text{precision} \cdot \text{recall})}{\text{precision} + \text{recall}}, \quad \text{Precision} = \frac{TP}{TP + FP},$$

where TP is the number of correctly classified examples of the positive class, FP is the number of incorrectly classified examples of the positive class, TN is the number of correctly classified examples of the negative class, FN is the number of incorrectly classified examples of the negative class.

It should be borne in mind that fuzzy classification can be difficult to implement, since for a formal-logical description of the STCW, it is necessary to process a large amount of data to train the model.

Everything indicated in the thesis narrows the scientific search in favor of the use of fuzzy automated control systems for the qualification parameters of the OTSMT [18]. Which, in turn, involves the development of systems for intelligent decision support under conditions of uncertainty in the management of OTSMT.

Conclusions

Thus, the management of the process of monitoring the qualification parameters of seafarers in the OTCMS is quite important, since their insufficient level can lead to serious problems in the workplace and even to accidents. To assess the qualification parameters of seafarers, the time of completion of final operations is used, and to restore these parameters, it is proposed to use fuzzy systems that allow estimating belonging to categories based on several criteria.

Particular attention is drawn to the development of an algorithm for restoring the qualification parameters of the OTSMT based on a conditional input and an additional parameter that directly affects the recovery time. Also discussed is the possibility of creating automated adaptive fuzzy classification systems to control the qualification parameters of the OTSMT under conditions of uncertainty. In the future, it is planned to develop and use intelligent systems for managing qualification parameters to prevent possible consequences associated with insufficient qualifications of seafarers on vessels.

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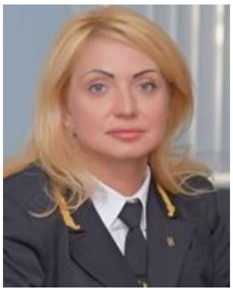

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