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IDENTIFICATION OF "HUMAN ERROR" NEGATIVE MANIFESTATION IN MARITIME TRANSPORT

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ABSTRACT

Context. There is a problem of identifying the subjective entropy of the navigator as an indication of negative human error in maritime transport. The aim of the study is to develop the data system to identify the negative manifestations of the human error for ensuring safety in maritime transport.

Objective. The objective of the work is to design the data system consisting of two levels. Levels are targeted at detection of primary factors and secondary factors of subjective entropy of the navigator increase.

Method. Within the scope of this work, the phases of the navigator's activity are determined, in which negative manifestations of the human error arise. This most often occurs during emergency situations. It is determined that the navigator's loss of focus leads to inadequate actions in relevant situations. Stressful situations are the second reason that affects self-control level. The factors' expanses influencing the navigator's subjective entropy increase as well as the vector affecting the subjective entropy at the first level of the formal system are determined. The arrangement of sets of factors was carried out. The arrangement result represents the formal system's first level description. Multi-objective optimization problem is vital for optimal solutions identification. The patterning's target is error evaluation on finding a vector, which is an essential stage. The lower limit of the system identification level is determined. The formal description of actions at the second level of the system is carried out and vector is specified at this level. The dependences of second-level vectors' impacts on navigator subjective entropy increase are specified with maximum accuracy. Time input estimation for system actuation allows us to determine three operating modes of the system. The input data for operating modes specification is indicated. The matrix-based framework algorithm of navigator's behavior during emergency situations is given.

Results. Formal approaches were confirmed by simulation patterning using the navigation simulator NTPRO 5000. The data obtained allowed to build an algorithm in navigator's shaping of in various situations.

Conclusions. The proposed formal approaches, patterns and algorithms will provide a basis for navigator's behavior analysis during emergency situations. The search of the best practice of human error data mining based on real data and simulator training data can be the direction for future research. This will allow to determine the mathematical expectation of navigator's behavior in emergency situations, as well as when performing operations with a low coefficient of experience.

KEYWORDS: human error, behavior pattern, subjective entropy, emergency situations.

ABBREVIATIONS

NTPRO 5000 – navigation simulator "Navi-Trainer Professional 5000".

NOMENCLATURE

δ is a nonnegative number function;

π is the result provided by the system when choosing the level vectors;

ξ is the system result after the second level;

φ_s is a continuous function of system status;

M is a Euclidean factors expanse affecting the navigator's subjective entropy increase manifested at the first level;

J is a Euclidean factors expanse affecting the navigator's subjective entropy increase manifested at the second level;

W is a navigator's personal factors set;

$\dot{W}$ is an acceptable limit of factors at the first and second levels;

E is a parallelepiped display expanse;

$\dot{M}$ is an acceptable limit of factors at the first level, which are displayed in the second level;

Y is a Euclidean subjective entropy manifestations expanse;

$\hat{y}$ is the vector required at the first level;

$F(m, y)$ is a identification criterion;

$\dot{Y}(\cdot)$ is the set of $\boldsymbol{y}$ vector values by factor analysis;

$\dot{M}_a$ is a sufficient factors set for vector identification;

H is a Euclidean vectors expanse $\mathbf{z}$;

z is the control impact vector on subjective entropy level decrease

c is an actuation system time input

S is a system status index

A is an individual navigator's reactions, dependent on work experience;

B is a navigator's focus;

C is a navigator's optimism;

d is a modes I and II constant (invariable).

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INTRODUCTION

One of significant reasons for emergencies to occur in maritime transport is the human error. Statistics provides evidence of maritime accidents reason in 75–96% of cases to be human errors [1, 4]. Most often this occurs when ships collide, as well as when servicing the tankers.

One of reasons for the human error negative manifestations is poor safety culture management in maritime transport. High-level indicators of emergencies causes are also low level of competence of marine officers [5].

From practical experience it was noted that due to simultaneous manifestation of distracting information factors, the individual's focus is lost when taking decisions (navigators) while ship handling. This is the serious problem for the safety management and requires thorough analysis and solution.

1 PROBLEM STATEMENT

The study is aimed to create identification information system and to prevent navigator's human error negative manifestations. In relation to sector-specific issues, the information system is proposed to be divided into two levels: detection of primary factors and detection of secondary factors of navigator's subjective entropy increase. There is a dependency: the more information resources are consumed by the system at the first level, the more accurate the formal description at the second level is. This will make it possible to perform the functions of navigator's subjective entropy elimination in emergency situations more effectively. The system should be designed so that the balance of information resources could be changed at the time of navigator's individual behavior pattern identification.

At the first level, the system forms approximate values of the subjective entropy level, depending on navigator's behavior. The second level depends on the time indices of navigator's steady negative manifestations.

Therefore, it is essential to complete following tasks:

1. To identify M and J factor feature spaces, which affect navigator's subjective entropy increase. The requirement to determine M and J space edges is that their Cartesian product will represent individual set of navigator's factors W.

2. To find an individually-oriented vector of navigator's subjective entropy increase $\hat{y}$ by identification criterion $F(m,y)$ utilizing minimization function on m parameters.

3. In order to increase modeling accuracy, it is necessary to determine lower limits of critical factors individual set identification that affect the subjective entropy $\hat{y}$, by nonnegative number function implementation $\delta(m)$.

4. To determine control action vectors space to subjective entropy level z reduction by implementing $\boldsymbol{\Phi}(m, y, j, z)$ function as the final characteristics of formal system performance after the second level.

5. To specify most likely system actuation modes in emergency situations at first and second levels, depending on factors manifestations from y and from m.

6. To design the information system scheme for human error negative manifestation identification in maritime transport.

7. To confirm experimentally the hypothesis of sudden factors negative influence on subjective entropy increase and, therefore, navigator's management decisions leading to devastating consequences.

8. To design algorithm of navigator's behavior pattern creation in various situations to prevent human error negative impact in maritime transport.

Thus, the highlighted tasks implementation will create an information system for identification and prevention of human error negative manifestations in maritime transport.

2 LITERATURE REVIEW

One of indicators of focus loss while ship operation is subjective entropy level increase [6].

Our study is targeted at navigator's operational stages during emergency situations, in which negative manifestations of the human error [2] and [3] occur. This leads to navigator's inadequate actions when focus loss occurs. [7]. Factor identification process is an objective problem for safety system management in maritime transport and this occurs in conditions of uncertainty.

From practical experience [8] it is noted that stressful situations have a direct impact on self-control level and increases navigator's negative subjective behavior. Stress reasons can be tensions between crew [2, 13] and [3] that happens quite often.

The study purpose is to build an information system for identifying human error negative effects to ensure safety in maritime transport.

3 MATERIALS AND METHODS

Let M and J be the Euclidean factors expanses that affect the navigator's subjective entropy increase shown at the first and second levels of formal system [11], respectively. Let's take that the system can determine their level. For each navigator there is a psychological barrier to work in conditions of factors actuation from M and J expanses, as well as an individual set of factors such that, $W = M \times J$, $\dot{W} \subset w$, $\dot{W}$ – a set of acceptable limit of factors $w = (m, j) \in W$ at the first and second levels.

The system task is to find an individual-oriented vector of navigator's subjective entropy increase.

We assume that:

$$\dot{M} = \left\{ m \in M : \exists\, j \in J \text{ such that } w = (m, j) \in \dot{W} \right\},$$

$$J(m) = \left\{ w \in W : (m, j) \in \dot{W} \right\} \left(m \in \dot{M} \right),$$

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$M \, u \, J(m), \left(m \in \overset{\bullet}{M} \right)$ – acceptable limits of factors sets at the first and second levels.

Sets arrangement of $\overset{\bullet}{M}$ and $J(m)$ is true when $M = J = E$, $\overset{\bullet}{M}$ – is a parallelepiped in E, and $J(m) = \left\{ j \in E : (m + j) \in \overset{\bullet}{M} \right\}$.

Let Y be the Euclidean manifestations expanse of subjective entropy, is subject to system analysis. $\hat{y}$ – the vector required at the first level out of Y, which is identified by a number of features from factors m, $\overset{\bullet}{Y}(m)$ is the set of vector values y in the analysis by factors m, $F(m, y)$ – the identification criterion.

Formal description of the first level will be:

$$F(m, y) \to \min y \in \overset{\bullet}{Y}(m).$$

This patterning approach represents the task of multicriteria optimization [9, 12].

Then the point-set mapping $\overset{\bullet}{Y}(m)$ for F *(m, y)* assumes that the $\overset{\bullet}{Y}(\cdot) = \left\{ \tilde{m} \in \overset{\bullet}{M} : \overset{\bullet}{Y}(\tilde{m}) \neq \varnothing \right\}$ and set of optimal problem solutions is not empty (1):

$$\overset{\bullet}{Y}(m) = Arg \min \left\{ F(m, y) : y \in \overset{\bullet}{Y}(m) \right\} \neq \varnothing . \quad (1)$$

It should be assumed that in cases where the set $\overset{\bullet}{Y}(m)$ consists of a single point $y(m)$ for any $m \in dom \overset{\bullet}{Y}(\cdot)$, then the operator $y(\cdot) : dom \overset{\bullet}{Y} \to Y$ providing with an approximate vector value $\hat{y}$ will be called the navigator's subjective entropy identification operator.

We will assume that the closed set of subjective entropy manifestations will be fully analyzed by the system for the main navigator's functions when handling a ship: $\overset{\bullet}{M}_a \subset dom \overset{\bullet}{Y}(\cdot)$ for precise vector identification $\hat{y}$, if $\overset{\bullet}{Y}_0(m) = \{\hat{y}\} \forall m \in \overset{\bullet}{M}_a$.

Error evaluation in finding a vector is an important step in the patterning $\hat{y}$, for this purpose we introduce a nonnegative number function $\delta(m)$ defined on a set $dom \overset{\bullet}{Y}(\cdot)$ such that (2):

$$\sup \left\{ \| y - \hat{y} \| : y \in \overset{\bullet}{Y}_0(m) \right\} \leq \delta(m). \quad (2)$$

While $\delta(m) = 0$ for $m \in \overset{\bullet}{M}_a$ and $\delta(m) > 0$ and for $m \in dom \overset{\bullet}{Y}(\cdot) \setminus \overset{\bullet}{M}_a$, where $\overset{\bullet}{M}_a$ – a sufficient sets of factors for the vector identification.

This will allow us to determine the lower limit of the system ability at the time of individual set of critical factors identification affecting subjective entropy.

To describe the second level, we denote: H is the Euclidean z vectors expanse controlling impacts on subjective entropy level decrease, that are planned together with vector $\hat{y}$.

Let $Z(y, j) \subset Z$ and the number function is $\mathbf{\Phi}(m, y, j, z)$ – acceptable limit of human factors set and criterion for choosing the vector z, $\mathbf{\Phi}(m, y, j, z)$ is the final characteristic of the system after the second level.

The introduction of Φ dependence on both y and m is caused by the need to determine the time balance of the system operation at the first and second levels.

The aim of controlling impacts of the system is to determine influence vectors on navigator's subjective entropy increase most accurately.

It is possible to obtain after the second level, considering the time input of system actuation $c_1(m)$ and $c_2(j)$ regarding factors m and j, such that,

$$\mathbf{\Phi}(m, y, j, z) = -[\pi(y, z) - c_1(m) - c_2(j)],$$

where $\pi(y, z)$ is the result provided by the system when selecting vector z of controlling impacts with the original vector y data.

The second level model is (3):

$$\mathbf{\Phi}(m, y, j, z) \to \min, \; j \in J(m), \; z \in Z(y, j). \quad (3)$$

The effectiveness at the second level is based on the value of $\delta(m)$ – error evaluation function of vector $\hat{y}$ location after the first level. The system task at the second level after dominant factors selection $m \in \overset{\bullet}{M}$ at the first level, and looks like:

$$\mathbf{\Phi}(m, \hat{y}, j, z) \to \min, \; j \in J(m), \; z \in Z(\hat{y}, j).$$

For any $m \in \overset{\bullet}{M}$ function $\xi(m)$ defined on the set $\overset{\bullet}{M}$, we will call the system result after the second level.

$$\min \left\{ \mathbf{\Phi}(m, \hat{y}, j, z) : j \in J(m), z \in Z(\hat{y}, j) \right\} \leq \xi(m).$$

The set Z *(y, j)* is set by a finite number of dependencies on y, j:

$$Z(y, j) = \left\{ z \in Z : \varphi_s(y, j, z) \leq 0 (s \in S), \varphi_s(y, j, z) = 0 (s \in S'') \right\},$$

(here $\varphi_s, S \in S = S' \cup S''$, continuous functions in $(Y \times J \times Z)$.

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The system result after the second level can be considered for three most likely modes.

Mode I. The functions $\varphi_s(s \in S = S' \cup S'')$ do not depend on vectors *y*, therefore, in the second level task only the objective function of **Φ** depends on vectors *y*, there is a constant of navigator's individual reactions, dependent on work experience – A [10,14]. Moreover, A>0 for any $m \in \dot{M}, j \in J(m), y(m) \in \dot{Y}_0(m), z \in Z(j)$, so that the inequality follows (4):

$$\mathbf{\Phi}(m, y, j, z) \le \mathbf{\Phi}(m, y(m), j, z) + A\|y(m) - y\|. \quad (4)$$

Mode II. The indexing set $S'' = \varnothing$, but there are constants $A > 0, A_s > 0(s \in S)$ such that for any $m \in \dot{M}, y \in \dot{Y}, y(m) \in \dot{Y}_0(m), z \in Z$ inequality is true (4), as well as the inequality:

$$\varphi_s(y, j, z) \le \varphi_s(y(m), j, z) + A_s\|y(m) - y\|(s \in S'),$$

and the set *Z* (*y*, *j*) is the closure of an open set in *Z* $\{z \in Z : \varphi_s(y, j, z) < 0(s \in S')\}$.

Mode III. There are constants $A > 0, B > 0$ $A_s > 0(s \in S = S' \cup S''), C > 0$ (where B and C are individual indicators of human error manifestations that prevent subjective entropy increase – focus and optimism) such that for any:

$$m \in \dot{M}, y \in \dot{Y}, y(m) \in \dot{Y}_0(m), \|y(m) - y\| \le \delta(m),$$

$$z \in Z(y(m), j), \hat{z} \in Z(y, j),$$

$$\varphi_s(y, j, z) \le \varphi_s(y(m), j, z) + A_s\|y(m) - y\|(s \in S),$$

$$\mathbf{\Phi}(m, y, j, \hat{z}) \le \mathbf{\Phi}(m, y(m), j, z) + A\|y - y(m)\| + B\|\hat{z} - z\|.$$

in this way,

$$\mathrm{dist}(\mathrm{z}, \mathrm{Z}(\hat{\mathrm{y}}, \mathrm{j})) \le C\left\{\sum_{s \in S'} \varphi_s^+(\hat{y}, j, z) + \sum_{s \in S''} |\varphi_s(\hat{y}, j, z)|\right\},$$

$$\mathrm{dist}(\mathrm{z}, \mathrm{Z}(\hat{\mathrm{y}}, \mathrm{j})) = \min\left[\left\{\|z - \tilde{z}\| : \tilde{z} \in Z(\hat{y}, j), \varphi_s^+ = \max(\varphi_s, 0)\right\}\right].$$

The task of system result optimization will be (5):

$$\xi(m) \to \min,\ m \in \dot{M}. \quad (5)$$

Then, if

$$m_* \in Arg\min\left\{\xi(m) : m \in \dot{M}\right\},\ y_* \in \dot{Y}_0(m_*),$$

and a pair

$$\{j_*, z_*\} \in Arg\min\{\mathbf{\Phi}(m_*, y_*, j, z) : j \in J(m_*), z \in Z(y_*, j)\}$$

then (m_*, y_*, j, z) we take as the system result.

This solution optimizes the result obtained after the second level, considering the error $\delta(m)$ in vector y identification at the first level.

In each of modes I, II, III, the task (5) is equivalent to the task of minimizing a function $\varphi(m, y, j, z)$ on a certain set under conditions of extreme restriction $y \in \dot{Y}(m)$ to connect *m* and *y*.

We put $d = A$ in mode I, II, and in mode III we assume that $d = A + BC\left(\sum_{s \in S} A_s\right)$

wherein $\varphi(m, y, j, z) = d\delta(m) + \mathbf{\Phi}(m, y, j, z)$.

Then for modes I-III, $\min\left\{\xi(m) : m \in \dot{M}\right\} =$

$$\min\left\{\varphi(m, y, j, z) : m \in \dot{M}, y \in \dot{Y}_0(m), j \in J(m), z \in Z(j)\right\},$$

$$\min\left\{\varphi(m, y, j, z) : m \in \dot{M}, y \in \dot{Y}_0(m), j \in J(m), z \in Z(m, y, j)\right\},$$

$$\min\left\{\varphi(m, y, j, z) : m \in \dot{M}, y \in \dot{Y}_0(m), j \in J(m), z \in Z(y, j)\right\}.$$

System operating modes regulation is carried out individually for each navigator during the training using the Navi-Trainer Professional 5000 (NTPRO 5000) navigational simulator. The experiments are held at Kherson State Maritime Academy (Ukraine). The first individual signs of subjective entropy manifestation are determined at the stage of training cadets and depend on the set of influence factors.

The system is adjusted to locations and tasks carried out during the ship operation in real conditions, based on navigators' dispositions. Data allows us to regulate and improve the system.

The final stage is the design of navigator's behavior when emergency occurs.

The NTPRO 5000 system identifies 55 indicators, which are generalized into two groups of factors, m_i and y_i, where $i \in (1.55)$. Each navigator takes individual approaches when makes decisions in ship operation. Consequently, the interdependence of these 55 factors will characterize navigator's behavior in various situations. The general system operation scheme looks like (Fig. 1).

This process is cyclical and data-bank is designed for each navigator. Data processing allows the system to identify the most vulnerable categories of factors leading to emergency situations. The function of backward recurrence makes it possible to make corrective influence on navigator's retraining or improvement of his individual psycho-emotional characteristics.

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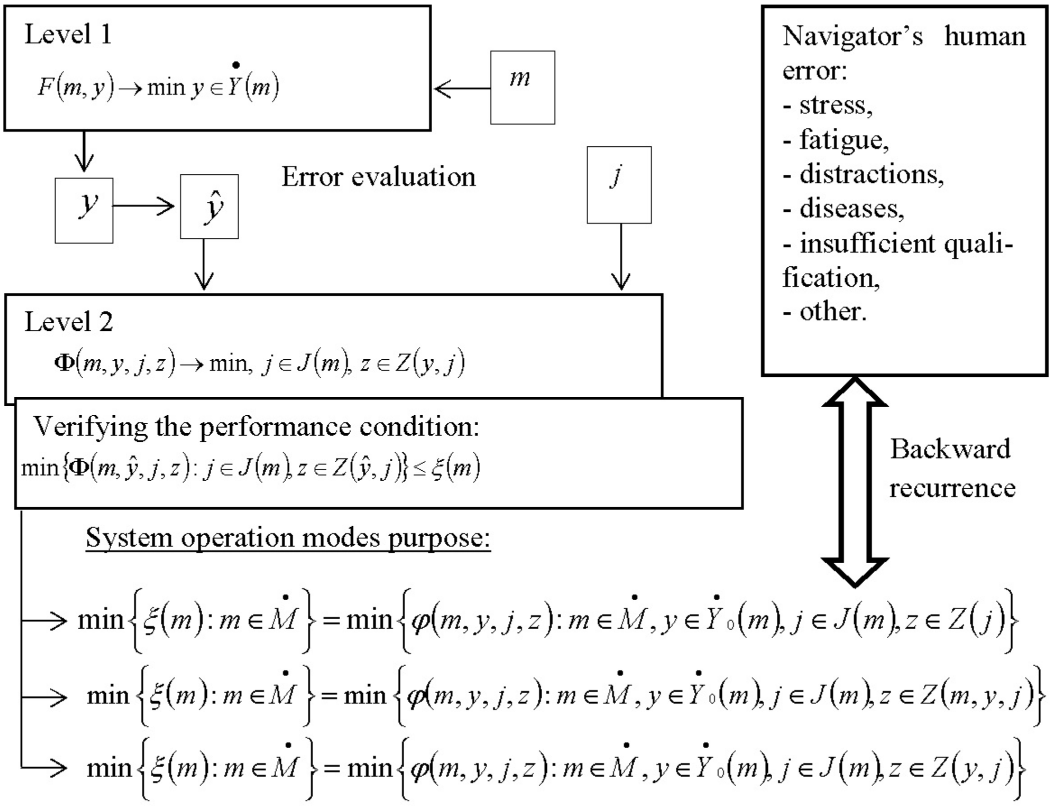

Figure 1 – Information system operation scheme for human error negative manifestations identification for safety in maritime transport

4 EXPERIMENTS

We will carry out human error negative manifestation simulation patterning while operating a ship.

We will carry out the experiment using the Navi-Trainer Professional 5000 navigational simulator (NTPRO 5000) at Kherson State Maritime Academy (Ukraine). The experiment purpose is to determine subjective entropy areas of influence while operating a ship.

Prior to exercise commencement, cadets made course plotting to pass "Bosfor", with initial parameters:

– board time is set at 12:00:00;
– wind, 13 knots (direction 0 degrees);
– wave height, 1.3 m;
– current, 0 knots.

Chronology of events during the experiment (Fig. 2):

1. **12:00:19**; Ship movement start.
2. **12:09:39**; Start of overtaking ship #1 (Bulk carrier 21); complexity – low (Fig. 2a).
3. **12:16:40**; Finish of overtaking ship #1 (Bulk carrier 21); complexity – low.
4. **12:22:00**; Start of passing procedure with the vessel No. 2 (Coast guard boat 1); sudden event (Fig. 2b).
5. **12:24:20**; Finish of passing procedure with the vessel 2 (Coast guard boat 1); sudden event.
6. **12:24:20**; Wind 10 knots (direction 0 degrees); reduced from 13 knots.
7. **12:24:20**; The current is 0.3 knots (direction 0 degrees); increased from 0 knots.
8. **12:29:40**; Start of passing procedure with the vessel No. 3 (Passenger ferry 2); sudden event.
9. **12:30:09**; Suddenly snow started; the intensity 70% (Figure 2, *c*).
10. **12:30:11–12:30:26**; During the passing procedure, the maneuver is to bypass from the right side; (right to the side 6°–16°).
11. **12:30:28**; Short shift left on board 4 °(Fig. 2 d).
12. **12:30:30**; Quick setting right 50 ° (Fig. 2 e).
13. **12:30:31**; Quick left-sideways 44 °(Fig. 2 f).
14. **12:30:36**; Engine stop.
15. **12:30:43**; Turn on reverse; power 30%.
16. **12:30:49**; Turn on reverse; power 40%.
17. **12:30:52**; Collision with vessel number 3 (Passenger ferry 2); sudden event (Fig. 2 g).
18. **12:30:53**; Reverse actuation; sudden event.
19. **12:31:18**; The wave height is 1.5 m.
20. **12:36:00**; Overtaking ship No. 4 (Container ship 22); complexity – low.
21. **12:37:19**; Reducing visibility; from 10 miles to 4 miles.
22. **12:38:00**; The wave height is 1.6 m.
23. **12:41:50**; Detecting an obstacle; drifting container "40 foot".

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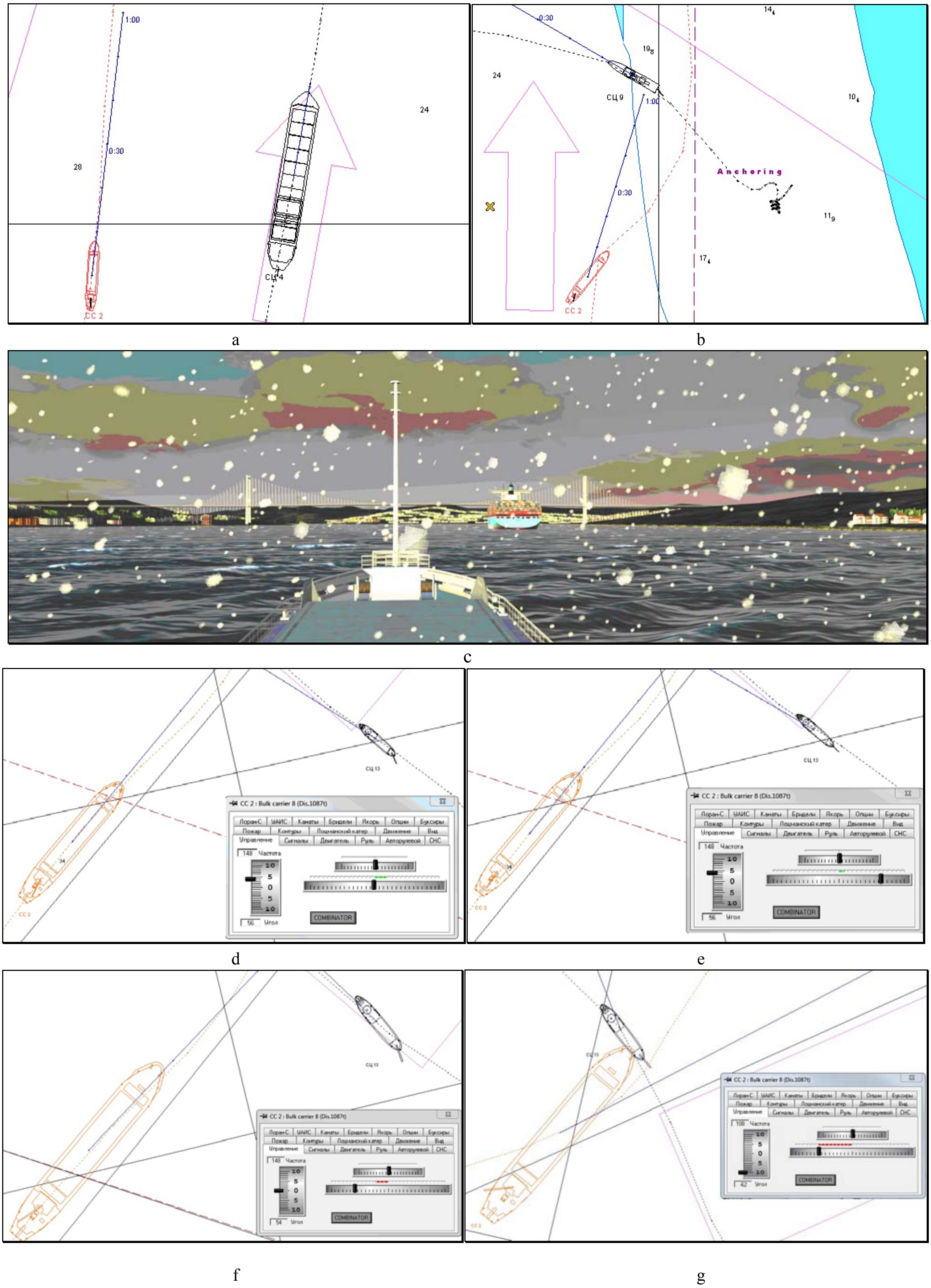

Figure 2 – Chronology of events during the experiment

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24. **12:42:28**; Current 0.6 knots (direction 0 degrees); increased from 0.3 knots.

25. **12:43:06**; Passing with an obstacle; drifting container "40 foot".

26. **12:48:34**; The start of passing procedure with the vessel No. 4 (Passenger ferry 1). The passing procedure was predetermined as well as maneuver speed and course; sudden event.

27. **12:50:30**; Finish of passing procedure from vessel No. 4 (Passenger ferry 1); sudden event.

28. The rest of the time has no significant events

The experiment shows significant navigator's focus loss after first two maneuvers with low complexity. When adding random factors "Sudden snow", navigator's readiness to perform adequate maneuvers while passing procedure with vessel No. 3 was decreased.

5 RESULTS

To determine the degree of mutual dependence of the factors $F(m_i, y_i)$, the Spearman correlation coefficient was chosen [15]. This coefficient represents the measure of the linear relationship between random variables. It becomes possible to create a behavioral matrix P_k of a certain navigator in a particular situation k, where $k \in (1, \infty)$.

There is an opportunity based on dependencies between factors to build navigator's behavior pattern in various situations. That's important to mention that the trainee's experience does not always reflect his experience in unusual situations for him. Navigator's in certain situations does not guarantee a high level of competency in the whole range of possible events, especially during emergency situations.

$$P_k = \begin{bmatrix} F_k(m_1, y_i) & F_k(m_2, y_i) & F_k(m_3, y_i) & \ldots & F_k(m_i, y_i) \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ F_k(m_1, y_3) & F_k(m_2, y_3) & F_k(m_3, y_3) & \ldots & F_k(m_i, y_3) \\ F_k(m_1, y_2) & F_k(m_2, y_2) & F_k(m_3, y_2) & \ldots & F_k(m_i, y_2) \\ F_k(m_1, y_1) & F_k(m_2, y_1) & F_k(m_3, y_1) & \ldots & F_k(m_i, y_1) \end{bmatrix}.$$

Because the matrix displays the data of one situation only, it becomes necessary to select the corresponding behavioral matrices for unusual cases. To do this, it is essential to determine the set of matrices P_k of the dependencies of the indicators that are specific to a particular navigator. This model displays knowledge of navigator's behavior in particular situations, which corresponds to the specific matrix P_k (Fig. 3).

Since the model is a 3D matrix, it can be stored and processed as a database object. The algorithm of this model formation is shown in Fig. 4.

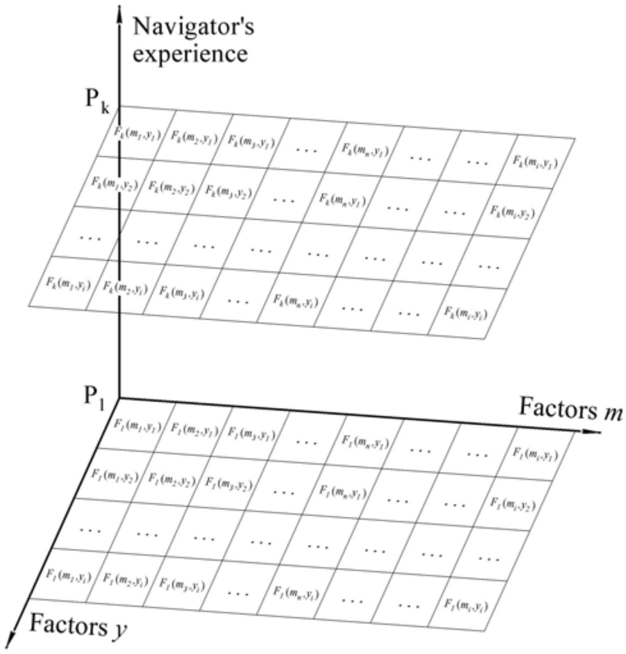

Figure 3 – Skipper's behavior model in a specific situation

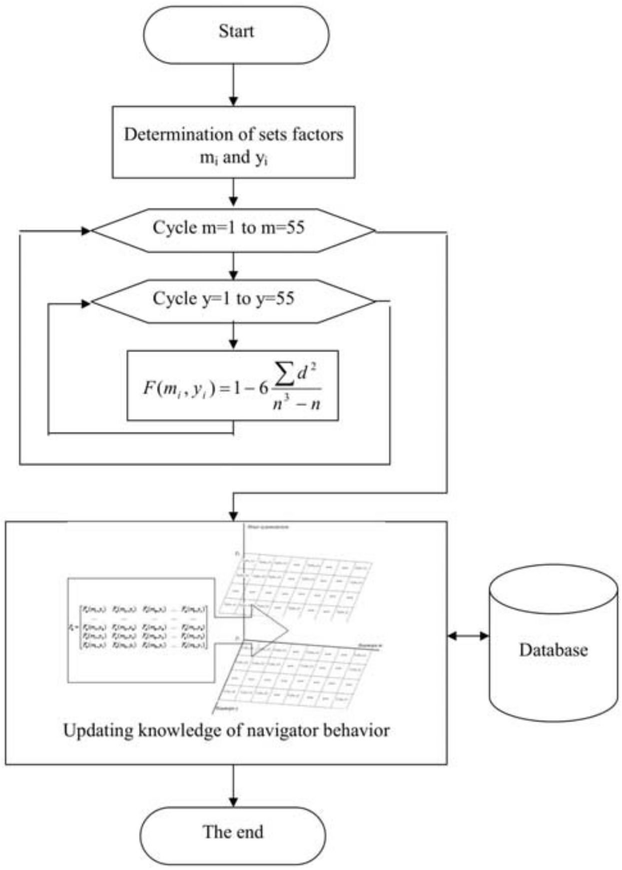

Figure 4 – The algorithm of navigator's behavior pattern formation in different situations

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6 DISCUSSION

The experiments conducted have confirmed the feasibility of the study. The highlighted approaches are based on the analytical experience of emergency situations investigations, both during simulator practice, and in real conditions. The designed models, methods and algorithms for subjective entropy identification as the reason of human error negative manifestation were implemented into training program of NTPRO 5000 simulator at Kherson State Maritime Academy (Ukraine). Besides, the studies' results were talked through at the 10th International Scientific and Practical Conference "Modern Information and Innovation Technologies in Transport" MINTT-2018 [16].

The implementation of highlighted solutions will make it possible to minimize human error negative manifestation in maritime transport. The technology will also assist in tracing Marine Officers competency level.

The information system knowledge base increases continuously, which, eventually, will lead to real time result obtaining rate reduction. In the long term, further studies of evolutionary system development to prevent emergency situations in maritime transport are intended for the purpose of both system actuation rate and forecast time step increase.

CONCLUSIONS

The result of the simulation is the determination of three operating modes of the system, which depend on the level of preparedness of the navigator. For the most experienced navigators, the control of the system is carried out at the second level. Identification of factors of emergency situations is carried out in mode I. For mid-level navigators, the forms of control that monitor the most complex functions during ship operation in the regime of III will be characteristic. Finally, for the least experienced navigators, the system is to be monitored at both the first and second levels, identifying all the influencing factors in Mode II.

The construction of the system based on the proposed formal approaches will significantly improve safety in ship operation in conditions of human error negative manifestations.

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ІДЕНТИФІКАЦІЯ НЕГАТИВНОГО ПРОЯВУ ЛЮДСЬКОГО ФАКТОРА НА МОРСЬКОМУ ТРАНСПОРТІ

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АНОТАЦІЯ

Актуальність. Існує проблема ідентифікації суб'єктивної ентропії судноводія як показника негативного людського фактора на морському транспорті. Метою дослідження є побудова інформаційної системи ідентифікації негативних проявів людського фактора для забезпечення безпеки на морському транспорті.

Завдання. Метою роботи є проектування інформаційної системи що складається з двох рівнів, виявлення первинних факторів і виявлення вторинних факторів підвищення суб'єктивної ентропії судноводія.

Метод. В рамках дослідження визначено фази діяльності судноводія, в яких виникають негативні прояви людського фактора, а саме під час позаштатних ситуацій. Визначено, що втрата концентрації уваги призводить до неадекватних ситуації дій з боку судноводія. Крім того, другою причиною можуть служити стресові ситуації, що впливають на рівень самоконтролю. Визначено простір факторів, що впливають на підвищення суб'єктивної ентропії судноводія у вигляді вектора що проявляються на першому рівні формальної системи. Проведена компоновка множин факторів, в результаті чого отримано формальний опис першого рівня системи. Завдання зводиться до багатокритеріальної оптимізації з метою знаходження множин оптимальних рішень. Важливим етапом в ході моделювання є оцінка похибки при знаходженні вектора і визначення нижньої грані можливості системи. Виконано формальний опис дій другого рівня системи і визначення векторів. Визначено Отримано максимально достовірне визначення векторів впливу на підвищення суб'єктивної ентропії судноводія на етапі другого рівня з урахуванням тимчасових витрат спрацьовування системи, що дозволяє визначити три режими роботи. Позначено вхідні дані для визначення режимів роботи системи у вигляді матриць поведінки судноводія під час позаштатних ситуацій.

Результати. Формальні підходи були підтверджені імітаційний моделюванням із застосуванням навігаційного тренажера NTPRO 5000 і стали основою для побудови алгоритму формування моделі поведінки судноводія в різних ситуаціях.

Висновки. Запропоновані формальні підходи, моделі та алгоритми дозволять створити підставу для аналізу поведінки судноводіїв під час позаштатних ситуацій. Перспективами подальших досліджень може бути знаходження найбільш оптимальних методів інтелектуального аналізу людського фактора на основі реальних даних і даних тренажерної підготовки. Це дозволить визначати математичне очікування поведінки судноводіїв в нестандартних ситуаціях, а також при виконанні операцій з невисоким коефіцієнтом досвіду.

КЛЮЧОВІ СЛОВА: людський фактор, модель поведінки, суб'єктивна ентропія, позаштатні ситуації.

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ИДЕНТИФИКАЦИЯ НЕГАТИВНОГО ПРОЯВЛЕНИЯ ЧЕЛОВЕЧЕСКОГО ФАКТОРА НА МОРСКОМ ТРАНСПОРТЕ

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АННОТАЦИЯ

Актуальность. Существует проблема идентификации субъективной энтропии судоводителя как показателя негативного человеческого фактора на морском транспорте. Целью исследования является построение информационной системы идентификации негативных проявлений человеческого фактора для обеспечения безопасности на морском транспорте.

Задачи Целью работы является проектирование информационной системы состоящей из двух уровней для обнаружения первичных факторов и обнаружение вторичных факторов повышения субъективной энтропии судоводителя.

Метод. В рамках исследования определены фазы деятельности судоводителя, в которых возникают негативные проявления человеческого фактора – во время внештатных ситуаций. Определено, что потеря концентрации внимания приводит к неадекватным ситуации действиям со стороны судоводителя. Кроме того, вторичной причиной могут служить стрессовые ситуации, влияющие на уровень самоконтроля. Определены пространства факторов влияющих на повышение субъективной энтропии судоводителя в виде вектора проявляемых на первом уровне формальной системы. Проведена компоновка множеств факторов, в результате чего получено формальное описание первого уровня системы. Задача сводится к многокритериальной оптимизации для нахождения множеств оптимальных решений. Важным этапом в ходе моделирования является оценка погрешности при нахождении вектора и определение нижней границы возможности системы. Выполнено формальное описание действий второго уровня системы и определение вектора. Максимально достоверное определение векторов влияния на повышение субъективной энтропии судоводителя, получаемое после второго

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уровня с учетом временных затрат срабатывания системы, позволяет определить три режима ее работы. Обозначены входные данные для определения режимов работы системы в виде матриц поведения судоводителя во время внештатных ситуаций.

Результаты. Формальные подходы были подтверждены имитационный моделированием с применением навигационного тренажера NTPRO 5000 и стали основой для построения алгоритма формирования модели поведения судоводителя в различных ситуациях.

Выводы. Предложенные формальные подходы, модели и алгоритмы позволят создать основание для анализа поведения судоводителей во время внештатных ситуаций. Перспективами дальнейших исследований может быть нахождение наиболее оптимальных методов интеллектуального анализа человеческого фактора на основе реальных данных и данных тренажерной подготовки. Это позволит определять математическое ожидания поведения судоводителей в нестандартных ситуациях, а также при выполнении операций с невысоким коэффициентом опыта.

КЛЮЧЕВЫЕ СЛОВА: человеческий фактор, модель поведения, субъективная энтропия, внештатные ситуации.

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