COMPLEX ANALYSIS OF ECDIS-DATA TO INCREASE THE SAFETY OF MARINE TRANSPORT OPERATION

Nosov P.S., Zinchenko S.M., Mamenko P.P., Mateichuk V.M., Moiseenko V.S., Kyrychenko K.V.
Kherson State Maritime Academy
(Kherson, Ukraine)

Introduction. In the practice of managing navigation processes using navigation systems, the initial stage is to draw up a transition plan for a given route [1,2]. As a rule, the planned route is divided into a number of stages that require additional information from the navigator, as a subject of the ergatic maritime transport system, which allows performing the task with the highest efficiency and safety [3-5].

In this context, the navigator is the decision-maker in the full range of navigation situations along the route. In this case, the most important factor for effective decision-making by the navigator is completeness, quality and intensity of incoming navigation information from ECDIS systems and sensors. International maritime and information technology organizations, within their legislative powers, have determined the conditions and requirements for the operation of navigation information systems [6-9]. However, for a more effective increase in maritime safety, it is necessary to take into account more parameters that determine the behavior of the navigator [10-11].

The relevance of research. This paper proposes an approach to data analysis of navigation information systems based on ECDIS for the structured and meaningful formation of the information model of the navigator. The solution of an urgent technical problem to improve the safety of sea transportation in the context of in-depth analysis is considered. The processes of converting ECDIS data into method data represent a big problem for ensuring navigation safety. These methodological data can indicate the perception of the navigational situation by the watch. The more accurately the identification process is performed, the more effectively the safety of navigation is ensured.

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 [12]. 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 ergatic vessel control system [13].

Research results. To achieve the aim, the following objectives were set: to propose a diagram of the ergatic vessel control system, which will allow determining means of monitoring and identifying the situation by the navigator in the process of vessel navigation [14-18]. A diagram of the ergatic vessel control system was developed. Within the framework of the proposed diagram of the ergatic vessel control system, approaches to data extraction based on the results of analyzing navigation processes in critical situations were determined [19-23]. Connections between the structural elements of the diagram in the form of logical and algorithmic dependencies were determined (Fig. 1).

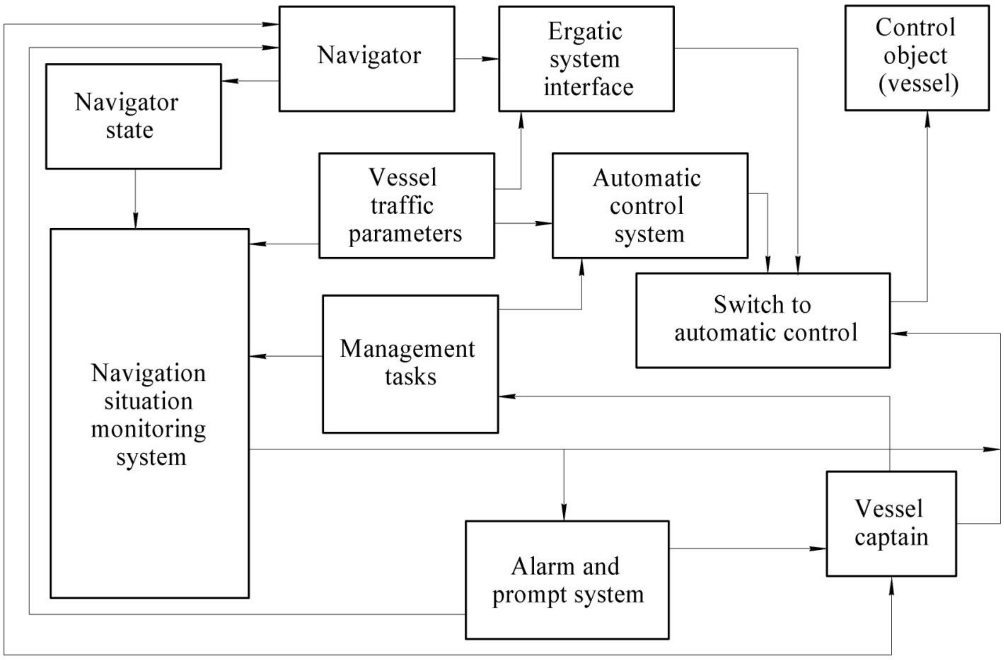

Figure 1. Diagram of the ergatic vessel control system

Table 1.

Group of factors that identify the situation for the navigator

No.	Factor	Factor determination process	Parameters
Fs1	Danger of vessel movement	Vessel speed (relative to maximum) near hazardous objects (ECDIS data)	0…1 max
Fs2	Determination of similarity completeness	Similarity in flow rate, date and time of day, vessel type	0…1
Fs3	Risk of indistinguishable situations	Determination of significant differences between two similar situations by external weather factors	>10 %
Fs4	Analysis of “emotional outburst”	Coincidence of emotional outburst near the vessel’s waypoint	0.2…0.5 nm
Fs5	Analysis of navigator’s heart rate/saturation	Determination of maximum pulse extremes and minimum blood saturation extremes	>135 bpm 96 %<
Fs6	Analysis of the complexity of the p-adicity situation of the stage	Determination of transitions to the ECDIS, ARPA, AIS, GPS interfaces, operating with many information factors and signals	p=3…n
Fs7	Analysis of the impact on the ergatic system	Degree of danger of current operating modes for objects of the ergatic system	0…1
Fs8	Behavior analysis based on the experience of actions	Coincidence of the chains of current navigators’ actions with respect to established experienced reactions	>85 %
Fs9	Synchronization with the team	Coincidence of the chains of current actions of the navigational watch relative to experienced reactions	>70 %

The formal description of the links allowed determining the range of the concepts of complex formalization of navigators' actions. This approach made it possible to algorithmize the means of monitoring and identifying the situation in the process of vessel control.

According to the proposed model, we define a group of factors that identify the situation for the navigator (Table 1) and factors influencing the occurrence of risk (Table 2).

Table 2.

Factors influencing the occurrence of risk in the current situation

No.	Factor	Factor determination process	Parameters
Fr1	Determining the situation complexity	Sharply increasing *p*-adicity of the stage	p_{i+m}, (m>2)
Fr2	Temporal parameters	Similarity of time ranges of operations performed by navigators	0…1
Fr3	Determinant of the emergence of an "unrecognizable situation", continuous emotional outburst	Determination of high heart rate and oxygen saturation, exceeding the average values for the whole team	>30 %
Fr4	Comparison of time indicators of stress	Determination of long-term deviations of heart rate and saturation	>1.4 Δt
Fr5	Criteria for the effectiveness of task performance by the navigator	Using data mining technology to build task performance trees based on influencing factors	successful/unsuccessful

Thus, it becomes possible to simulate the generalized control life cycle, in particular, the process of vessel movement in ergatic systems, using the example of four locations: the Hong Kong Strait, the Singapore Strait, the East River (New York), and the Bosphorus Strait.

Conclusions. The peculiarity of the developed diagram of the ergatic vessel control system for critical situations is that the "Navigation situation monitoring system" module has been introduced, which makes it possible to identify critical situations by indirect features. The diagram provides for the differentiation of control actions in critical situations by means of modules: alarm system, automatic control system and switching to automatic control. Information links between the diagram modules made it possible to determine the most significant factors affecting the navigation safety control processes.

Automated analysis of experimental data from the Navi Trainer 5000 navigation simulator made it possible to determine the physical parameters of vessel movement and correlate them with the probability of critical situations. As a result, a module for emergency switching of vessel control to the automatic maneuvering mode was developed to prevent accidents. Using the maneuvering characteristics of the vessel at a given speed, the position of the rudder blade and vessel's circulation capabilities made it possible to determine the boundary point on the trajectory when switching to automatic control mode. At the moment of extreme danger, the mode of the full reverse of vessel movement is provided.

REFERENCES

1. Andersson, P., Ivehammar, P. (2016). Cost Benefit Analysis of Dynamic Route Planning at Sea. Transportation Research Procedia. 14. 193 – 202. DOI:10.1016/j.trpro.2016.05.055.
2. Benyon, D. (2005). Navigating Information Space. Encyclopedia of Human Computer Interaction. DOI:10.4018/978-1-59140-562-7.ch053.
3. Chen, L., Xu, X., Zhang, P., Zhang, X. (2018). Analysis on Port and Maritime Transport System Researches. Journal of Advanced Transportation. 2018. 1-20. DOI:10.1155/2018/6471625.
4. Косенко Ю.І., Носов П.С. Механізми ідентифікації та трансформації «знань» суб'єкта критичної інфраструктури // Інформаційні технології в освіті, науці та виробництві. Збірник наукових праць [Текст]. — Вип. 3(4) – Одеса: Наука і техніка 2013, С. 99 – 104.
5. Shevchenko, R., Cherniavskyi, V., Zinchenko, S., Palchynska, M., Bondarevich, S., Nosov, P. & Popovych, I. (2020). Research of psychophysiological features of response to stress situations by future sailors. Revista Inclusiones. Vol.7, Numero Especial, pp.566-579. http://ekhsuir.kspu.edu/handle/123456789/12273.
6. Shevchenko, R., Popovych, I. Spytska, I., Nosov, P., Zinchenko, S., Mateychuk V. & Blynova O. (2020). Comparative analysis of emotional personality traits of the students of maritime science majors caused by long-term staying at sea. Revista Inclusiones. Vol.7, num. Especial, P. 538 – 554. http://www.archivosrevistainclusiones.com/gallery/45%20VOL%207%20NUM%20ESPECIAL%20EUROASIA.pdf.
7. Popovych, I.S., Cherniavskyi, V.V., Dudchenko, S.V., Zinchenko, S.M., Nosov, P.S., Yevdokimova, O.O., Burak, O.O. & Mateichuk, V.M. (2020). Experimental Research of Effective “The Ship’s Captain and the Pilot” Interaction Formation by Means of Training Technologies. Revista Espascios, Vol.41(11), pp.30. http://www.revistaespacios.com/a20v41n11/20411130.html.
8. Nosov, P., Zinchenko, S., Ben, A., Prokopchuk, Yu., Mamenko, P., Popovych, I., Moiseienko, V. & Kruglyj, D. (2021). Navigation safety control system development through navigator action prediction by data mining means. Eastern-European Journal of Enterprise Technologies. Information and controlling system, Vol. 2, No. 9 (110). DOI: 10.15587/1729-4061.2021.229237.
9. Nosov, P., Zinchenko, S., Popovych, I., Safonov, M., Palamarchuk, I. & Blakh, V. (2020). Decision support during the vessel control at the time of negative manifestation of human factor. CEUR Workshop Proceedings, Vol. 2608, P. 12 – 26. http://ceur-ws.org/Vol-2608/paper2.pdf.
10. Nosov, P., Ben, A., Zinchenko, S., Popovych, I., Mateichuk, V., & Nosova, H. (2020). Formal approaches to identify cadet fatigue factors by means of marine navigation simulators. CEUR Workshop Proceedings, Vol. 2732, pp. 823-838. http://ceur-ws.org/Vol-2732/20200823.pdf.

11. Nosov, P.S., Cherniavskyi, V.V. , Zinchenko, S.M., Popovych, I.S., Nahrybelnyi, Ya.A. & Nosova, H.V. (2021). Identification of marine emergency response of electronic navigation operator. Radio Electronics, Computer Science, Control, №1, P. 208 – 223. DOI:10.15588/1607-3274-2021-1-20.

12. Nosov, P.S., Popovych, I.S., Cherniavskyi, V.V., Zinchenko, S.M., Prokopchuk, Yu..A., Makarchuk, D.V. (2020). Automated identification of an operator anticipation on marine transport. Radio Electronics, Computer Science, Control, № 3, P. 158 – 172. DOI: https://doi.org/10.15588/1607-3274-2020-3-15.

13. Nosov, P.S., Zinchenko, S.M., Popovych, I.S., Ben, A.P., Nahrybelnyi, Ya.A. & Mateichuk, V.M. (2020). Diagnostic system of perception of navigation danger when implementation complicated maneuvers. Radio Electronics, Computer Science, Control, № 1.

14. Zinchenko, S.M., Nosov, P.S., Mateichuk, V.M., Mamenko, P.P., Popovych, I.S. & Grosheva, O.O. (2019). Automatic collision avoidance system with multiple targets, including maneuvering ones. Bulletin of University of Karaganda. Technical Physics, № 4(96), P. 69 – 79. DOI: 10.31489/2019Ph4/69-79.

15. Zinchenko, S.M., Nosov P.S., Mateychuk, V.M., Mamenko, P.P. & Grosheva, O.O. (2019). Automatic Collision Avoidance with multiple targets, including maneuvering ones. Radio Electronics, Computer Science, Control, № 4, P. 211 – 221. DOI 10.15588/1607-3274-2019-4-20.

16. Zinchenko, S.M., Mateichuk, V.M., Nosov, P.S., Popovych I.S. & Appazov, E.S. (2020). Improving the accuracy of automatic control with mathematical meter model in on-board controller. Radio Electronics, Computer Science, Control, pp. 197-207. DOI: https://doi.org/10.15588/1607-3274-2020-4-19

17. Zinchenko, S., Moiseienko, V., Tovstokoryi, O., Nosov, P., & Popovych, I. (2021). Automatic beam aiming of the laser optical reference system at the center of reflector to improve the accuracy and reliability of dynamic positioning. In: Proceeding of the Fourth International Conference on Computer Science, Engineering and Education Applications (ICCSEEA'2021), January 23-24, 2021, Kyiv, Ukraine.

18. Zinchenko, S., Tovstokoryi, O., Nosov, P., Popovych, I., Kobets, V. & Abramov, G. (2020). Mathematical support of the vessel information and risk control systems. CEUR Workshop Proceedings, Vol. 2805, P. 335 – 354. http://ceur-ws.org/Vol-2805/paper25.pdf.

19. Zinchenko, S., Ben, A., Nosov, P., Popovych, I., Mateichuk, V. & Grosheva, O. (2020). The vessel movement optimisation with excessive control. Bulletin of University of Karaganda. Technical Physics, №3(99). DOI 10.31489/2020Ph3/86-96.

20. Zinchenko, S., Ben, A., Nosov, P., Popovich, I., Mamenko, P. & Mateychuk, V. (2020). Improving the Accuracy and Reliability of Automatic Vessel Motion Control Systems. Radio Electronics, Computer Science, Control, № 2, P. 183 – 195. DOI: https://doi.org/10.15588/1607-3274-2020-2-19.

21. Zinchenko S. M., Mamenko P. P., Grosheva O. O., Mateichuk V. M. (2019) Automatic control of the vessel's movement under external conditions.

Naukovyi Visnyk HDMA, №2(21),P. 10 – 15. DOI: 10.33815/2313-4763.2019.2.21.010-015.

22. Zinchenko, S., Mateichuk, V., Nosov, P., Popovych, I., Solovey, O., Mamenko, P. & Grosheva, O. (2020). Use of Simulator Equipment for the Development and Testing of Vessel Control Systems. Electrical, Control and Communication Engineering, Vol. 16(2), P. 58 – 64. DOI: 10.2478/ecce-2020-0009.

23. Носов П.С., Тонконогий В.М. Використання компонентів мислення експертними системами, як фактору адаптивного впливу в автоматизованих навчальних системах // Тр. Одес. политехн. ун-та. — Одесса: ОНПУ, 2005. — Спецвыпуск. — С. 101 – 105.