

ANALYSIS THE STRESS STATE OF MARINE NAVIGATORS BASED ON FORMAL CONDITIONAL CONVERGENCE AND FUZZY SETS

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Introduction. The problem of identifying stress in marine navigators during navigational watchkeeping, unfortunately, is not solved by strengthening the watch and observation methods [1-5]. This is due to the time limit of chief mate, the lack of full-time psychologists and specialized automated by intelligent control systems [6-9]. At the same time, the unification of automated measurement methods with the corresponding conclusions does not give accurate results due to large difference in the reactions of marine navigators regarding situations [10-13].

All this indicates the need to develop new approaches that allow us to get closer to accurate identification of navigator's stressful situation, considering a wide range of factors influencing the stress occurrence [14-17].

The main material of the study. During the experiments, psychophysiological data were obtained, which indicate the occurrence of peak stress loads and the subsequent critical decline in activity, which leads to risk of marine accidents (Fig. 1). Considering the difficulty of explicitly identifying the decline in activity, we will use formal approaches based on conditional convergence with respect to the given graph [18].

(S, p) - metric space for which (Ω, F, P) , where is a set of functions such that $X, X_n : \Omega \rightarrow S$, where are X_n - random elements S .

If we accept that S is the space of the navigator's stress state, and the S' indicators of view identification devices are:

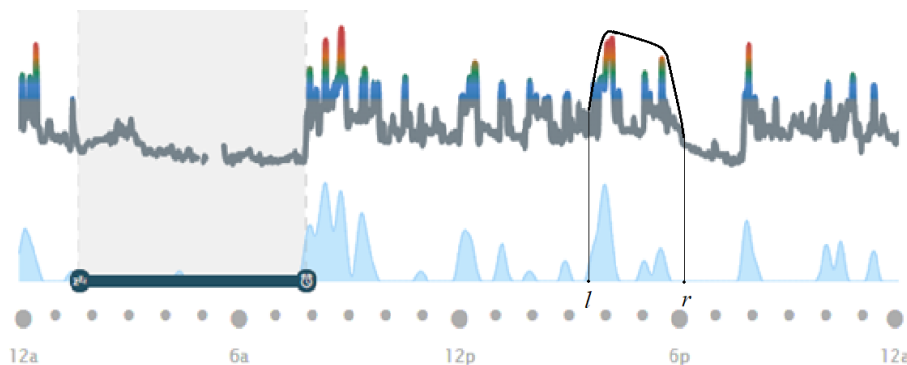


Fig. 1. Graph of the formation of a stressful situation

Thus, the stress state is conditionally measurable, $h : S \rightarrow S'$. The question arises, to what extent do stress indicators affect the adequacy of decision-making regarding the navigation situation? For which situations there is a strong dependence, and in which it is weak, $X_S \xrightarrow{d} X_{S'}, f^{(X_S)} \rightarrow f^{(X_{S'})}$ at $f_{S' \rightarrow \square}^{(X_{S'})}$.

Then a class of situations arises for which an implicit, "weak" dependence of causes and effects is observed. Despite this, due to the psycho-physiological features of each navigator, the curve graph has a trajectory in which individual fragments represent an approximation of causes and effects relative to observed navigation situation (Fig. 2.). Such fragments have signs of self-

similarity, which indicates that the dynamics of formation the stress curve is close to the Wiener process, of form: $W_{(t)} - tW_{(1)} = W_{0(t)}$, which can be represented as a Brownian bridge [19].



Fig. 2. Screenshot of the navigation situation

It is possible to determine the boundaries of a fragment in conditions of continuous time if you set the condition when: $Fr(W(\cdot) | |w(1)| \leq \varepsilon) \xrightarrow{\varepsilon \rightarrow 0} Fr(W_0)$. At the same time W_0 , the conditional zero is nothing more than a conditional minimum, defined as the psycho-physiological state of rest of navigator, the absence of stress. Determining the boundaries of this state $\sup_{\text{inf}} W_0$ is a separate scientific interest, which will be considered in further research.

However, $\sup W_0$, already defines the boundary, after which the stress of navigator arises in each individual case t_i . Then we can assume that the “splash”, indicating a stressful state, will look like a Brownian excursion: $\sup W_{ex}(t_i) = (|W(l+t(r-l))|) / \sqrt{r-l}$. Where r and l are the trajectory fragment time constraints defined as stress affecting navigational safety. It is important to note that the time range $\Delta t_{l...r}$, is a unique identifier of navigator, based on previous experiments, additionally characterizing the strength of stress in terms of r :

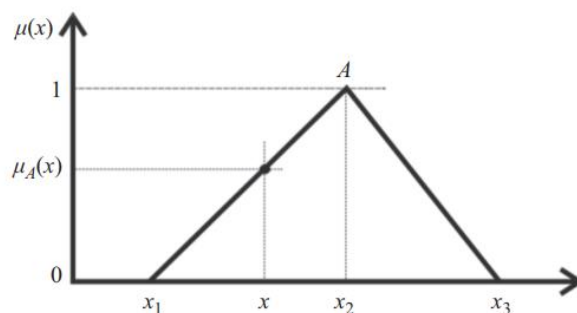
$$r = \sup \leq t_{\text{stress}} \rightarrow \sup (W(t+S) - W(S)) > 0.$$

Having determined the stress values over time, it will be possible to correlate the limit that $t_{\text{stress}}^{\text{max}}$, with a high degree of probability, entails a sharp decline in activity - the "psychological stupor" of navigator (PSN). Each of these cases with respect to a single navigator can be considered as a form of a Brownian bridge, which can later be formalized as a polynomial of form [20]:

$$L(x) = \sum_{i=0}^n y_i l_i(x), \quad l_i(x) = \prod_{j=0, j \neq i}^n \frac{x - x_j}{x_i - x_j}, \quad l_i(x_j) = \begin{cases} 0, & j \neq i, \\ 1, & j = i. \end{cases}$$

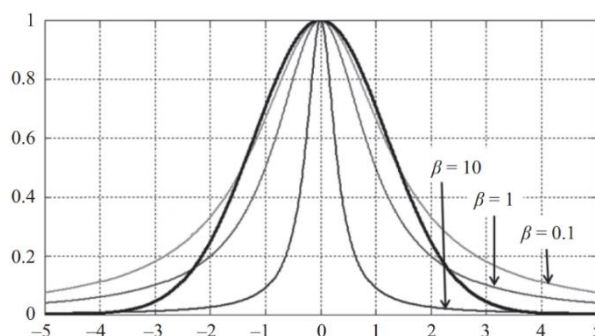
Using this approach, with a sufficient sample, it becomes possible to identify PSN with a high degree of probability. This approach is appropriate to apply in the case of laboratory testing on navigation simulators. This will make it possible, under ideal conditions, to isolate the form and formally express it for primary analysis. However, in the conditions of real watchkeeping on a sea vessel, this approach is ineffective, due to fact that we cannot control all the input factors that formation affect of stress trajectory. In these situations, it would be advisable to use fuzzy membership functions from the most “coarse” to those close the harmonic of signal [21-24]:

$$\mu_A(x) = \begin{cases} \frac{|x| - |x_1|}{|x_2| - |x_1|}, & \text{for } x_1 \leq x \leq x_2 \\ \frac{|x_3| - |x|}{|x_3| - |x_2|}, & \text{for } x_2 \leq x \leq x_3 \\ 0, & \text{otherwise} \end{cases}$$



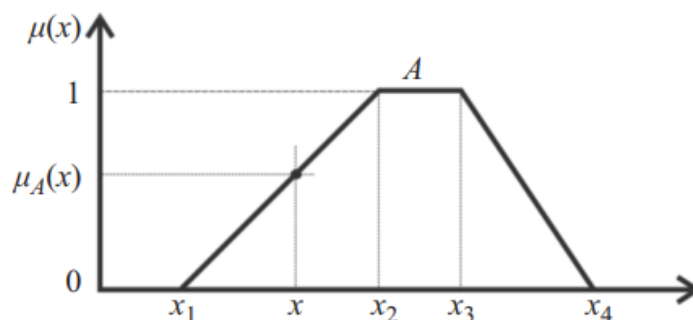
$$\mu_A(x) = e^{-\frac{1}{2} \left(\frac{x-x_p}{w} \right)^2}$$

$$\mu_A(x) = \frac{1}{1 + \beta(x-\alpha)^2}$$

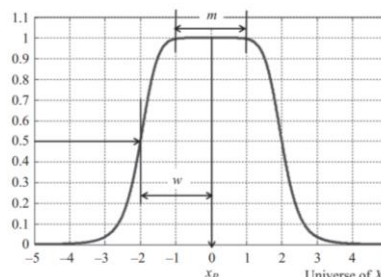


In turn, the transition to membership functions that are “closer” to Brownian bridge trajectory is a more difficult task.

$$\mu_A(x) = \begin{cases} \frac{|x| - |x_1|}{|x_2| - |x_1|}, & \text{if } x_1 \leq x \leq x_2 \\ 1, & \text{if } x_2 \leq x \leq x_3 \\ \frac{|x_3| - |x|}{|x_3| - |x_2|}, & \text{if } x_3 \leq x \leq x_4 \\ 0, & \text{Otherwise} \end{cases}$$



$$\mu_A(x) = \frac{1}{1 + \left| \frac{x-x_p}{w} \right|^{2m}}$$



The use of indicated membership functions will simplify the process of identifying stress states that pass into the PSN of each individual navigator.

Conclusion. The proposed approach will allow in the future to use a fuzzy controller that allows you to make control actions during the navigational watch. However, it should be taken into account that the selection of membership functions for a whole class of navigator reactions is a difficult task. This will require a series of experiments and in-depth analysis in the future with the involvement of specialists in the field of medicine and automatic control systems.

References:

1. Nosov P., Cherniavskiy V., Zinchenko S., Popovych I., Prokopchuk Y., Safonov M. Identification of distortion of the navigator's time in model experiment // Bulletin of University of Karaganda. Instrument and experimental techniques, 2020. - № 4(100). P. 57-70. <https://doi.org/10.31489/2020Ph4/57-70>.
2. Nosov P., Cherniavskiy V., Zinchenko S., Popovych I., Prokopchuk Y., Safonov M. Identification of distortion of the navigator's time in model experiment // Bulletin of University of Karaganda. Instrument and experimental techniques, 2020. - № 4(100). P. 57-70. <https://doi.org/10.31489/2020Ph4/57-70>.
3. Nosov, P. S., Cherniavskiy, V. V., Zinchenko, S. M., Popovych, I. S., Nahrybelnyi, Y. A., & Nosova, H. V. (2021). Identification of marine emergency response of electronic navigation operator. Radio Electronics, Computer Science, Control, (1), 208–223. <https://doi.org/10.15588/1607-3274-2021-1-20>.
4. Shevchenko, R., Popovych, I., Spytka, L., Nosov, P., Zinchenko, S., Mateichuk, 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, 538-554.
5. Plokhikh, V., Popovych, I., Zavatska, N., Losiyevska, O., Zinchenko, S., Nosov, P., & Aleksieieva, M. (2021). Time Synthesis in Organization of Sensorimotor Action. BRAIN. Broad Research in Artificial Intelligence and Neuroscience, 12(4), 164-188. <https://doi.org/10.18662/brain/12.4/243>.
6. Nosov P.S., Zinchenko S.M., Ben A.P., Nahrybelnyi Ya. A., Dudchenko O.M. MODELS OF DECISION MAKING BY A NAVIGATOR UNDER IMPLICIT AGREEMENTS WITH COLREG RULES // Науковий вісник Херсонської державної морської академії: науковий журнал. – Херсон : Херсонська державна морська академія, 2019. – № 1 (20). – С. 31-38.
7. Popovych, I., Borysiuk, A., Larysa Z., Fedoruk, O., Nosov, P., Zinchenko, S. & Mateichuk, V. (2020). Constructing a Structural-Functional Model of Social Expectations of the Personality. Revista Inclusiones, Vol: 7 num Especial, 154-167.
8. Nosov P., Krapivko G., Ben A., Safonov M., Zinchenko S. Disabling the dynamic positioning of the vessel as a cause of the negative influence of human factor in maritime transport. МНПК пам'яті професорів Фоміна Ю. Я. і Семенова В. С. (FS - 2019), 24 – 28 квітня 2019, Одеса – Стамбул – Одеса. Pages 309-315.
9. Nosov P., Palamarchuk I., Zinchenko S., Popovych I., Nahrybelnyi Y., Nosova H. Development of means for experimental identification of navigator attention in ergatic systems of maritime transport // Bulletin of University of Karaganda. Technical Physics, 2020. - № 1(97). P. 58-69. <https://doi.org/10.31489/2020Ph1/58-69>.
10. Зинченко С.Н., Носов П.С., Грошева О.А., Маменко П.П., Матейчук В.Н. Управление судном в условиях внешних воздействий. Materials of the XI “Modern information technologies in

transport, MINTT-2019” May 28-30, 2019 Kherson, Ukraine. С 177-178.

11. Зинченко С.Н., Носов П.С., Грошева О.А., Мащенко П.П., Матейчук В.Н. Избыточность по управлению как количественная мера маневренности судна. Materials of the XI “Modern information technologies in transport, MINTT-2019” May 28-30, 2019 Kherson, Ukraine. С 97-99.

12. Gritsuk, I., Volkov, V., Mateichuk, V., Gutarevych, Y., Tsiuman, M., & Goridko, N. (2017). The Evaluation of Vehicle Fuel Consumption and Harmful Emission Using the Heating System in a Driving Cycle. SAE International Journal of Fuels and Lubricants, 10(1), 236–248.

13. Носов П.С., Тонконогий В.М. 3D-оценивание траектории обучения студента // Тр. Одес. политехн. ун-та. — Одесса: ОНПУ, 2007. – Вып. 2(28).– С. 129-131.

14. Zinchenko S.M., Mateichuk V.M., Nosov P.S., Popovych I.S., Appazov E.S. Improving the accuracy of automatic control with mathematical meter model in on-board controller // Radio Electronics, Computer Science, Control, 2020. - № 4. – P. 197-207. <https://doi.org/10.15588/1607-3274-2020-4-19>.

15. Zinchenko, S. M., Ben, A. P., Nosov, P. S., Popovych, I. S., Mamenko, P. P., & Mateichuk, V. M. (2020). Improving the accuracy and reliability of automatic vessel motion control system. Radio Electronics, Computer Science, Control, (2), 183–195. <https://doi.org/10.15588/1607-3274-2020-2-19>.

16. Nosov, P. S., Popovych, I. S., Cherniavskiy, V. V., Zinchenko, S. M., Prokopchuk, Y. A., & Makarchuk, D. V. (2020). Automated identification of an operator anticipation on marine transport. Radio Electronics, Computer Science, Control, (3), 158–172. <https://doi.org/10.15588/1607-3274-2020-3-15>.

17. Zinchenko S., Nosov P., Mateichuk V., Mamenko P., Popovych I., Grosheva O. Automatic collision avoidance system with many targets, including maneuvering ones // Bulletin of University of Karaganda. Technical Physics, 2019. - № 4(96). P. 69-79. <https://doi.org/10.31489/2019Ph4/69-79>.

18. Asmussen, S. and Hering, H. (1983). Branching processes. Boston: Birkh" auser.

19. OpenLektorium. Сходимость случайных деревьев и процессы Гальтона-Ватсона. 2013 [URL: <https://www.youtube.com/watch?v=2BURmdY9FMc&t=3s>].

20. Hule, Harald. (1977). Polynomial normal forms and the embedding of polynomial algebras. <https://doi.org/10.1016/B978-0-7204-0725-9.50020-4>.

21. Fuzzy Logic Toolbox™ User's Guid / Revised for Version 2.3 (Release 2017b).

22. Ismail H. Altaş. Fuzzy Logic Control in Energy Systems. 2017. The Institution of Engineering and Technology, London, United Kingdom.

23. Jang J.S.R., Sun C.T., and Mizutani E. Neuro-Fuzzy and Soft Computing: A Computational Approach to Learning and Machine Intelligence. Upper Saddle River, NJ: Prentice Hall; 1996.

24. Altas I.H. ‘Bulanık sayı fonksiyonlarının bulanık denetime etkileri’. Elektrik Elektronik Bilgisayar Mu"hendislig'i 7. Ulusal Kongresi; Ankara, Turkey, 1997. pp. 55–58.