ACCOUNT OF NAVIGATIONAL HAZARDS WHEN THE SHIP AND THE TARGET ARE AVOIDING COLLISION AT SMALL DISTANCES

Tetiana Kalinichenko
Postgraduate Student[1]
tkatana1002@gmail.com

Yevgeniy Kalinichenko
PhD, Associate Professor, Head of Department
Department of Navigation and Control of the Ship
Odessa National Maritime University
34 Mechnikova str., Odessa, Ukraine, 65029

Olena Tymoshchuk
Doctor of Technical Sciences, Professor[1]

[1]Department of Navigation and Ship Management
State University of Infrastructure and Technologies
9 Kyrylivska str., Kyiv, Ukraine, 04071

Abstract: Successful, fast and high-quality solution of the important problem of ensuring the safety of navigation and navigation leads to a significant improvement in the protection of human life at sea, as well as to a constant reduction in harm to the environment, property and other equally priority production processes in maritime transport.

The navigation of modern large-capacity and high-speed ships of large sizes in cramped and limited areas is complicated by intensive navigation, with a much greater presence of navigation hazards and navigational obstacles that create the prerequisites for the occurrence of complex, non-standard and, sometimes, even emergency situations. Therefore, more than 80 % of all navigational accidents occur every year in cramped and difficult for safe navigation waters, which confirms the great complexity and danger of navigation conditions in cramped and limited waters.

This article is devoted to taking into account various navigational hazards when choosing a safe maneuver for divergence between the ship and the target at small distances between them.

The case of taking into account a point navigational hazard in the case of an excessive approach of a ship to a dangerous target is considered. For a situation of emergency divergence of a ship with a dangerous target, a choice of a safe evasive course is proposed, taking into account the linearly distributed navigational hazard.

The aim of the article is the procedure for analytical accounting of navigational hazards when the ship and the target diverge at short distances.

Keywords: navigation safety, navigation in confined waters, consideration of navigational hazards, prevention of ship collisions at sea, safe evasive maneuver.

1. Introduction

Many works of domestic and foreign scientists are devoted to the problem of ensuring the safe passing of ships. Thus, the basic principles of managing the process of passing ships in a situation of dangerous approach are considered in [1], and work [2] is devoted to the study of methods of locally independent control and it proposes a method for the formation of flexible diverging strategies that take into account the main factors.

The work [3] considers the formalization of the interaction of ships during their dangerous approach and, depending on its type, the choice of a divergence strategy to prevent a collision. An emergency strategy for passing in case of excessive approach of ships was proposed in [4], and a method for choosing the optimal standard maneuver for passing a pair of ships was proposed in [5]. Accounting for navigational hazards and inertia of the ship when calculating the parameters of the divergence maneuver is considered in [6, 7].

In works [8, 9] it is noted that the problem of choosing the optimal maneuver of separation is characterized by a high level of complexity, taking into account the fact that the process of controlling the movement of the ship is multidimensional and non-stationary, and the problem of separation of ships is inherent in a game character. The description of the court divergence process by the methods of the differential difference game is proposed in [10].

In [11], the theoretical justification of the autonomous ship collision avoidance system is presented, it considers the collision avoidance algorithm. The requirements for autonomous navigation are given, taking into account the factors influencing the process of avoiding a collision.

It is shown that research on the automation of ship control can be carried out in the classical or computer version. The classical version is based on mathematical models, while the computer version uses artificial intelligence, i.e. evolutionary algorithms, fuzzy logic, expert methods, neural networks and combinations of these methods.

To assess the effectiveness of the methods of passing ships, it is necessary to consider the possibility of changing the dangerous approach situation by avoiding the maneuvering ship.

2. Methods

Turning to [4], let's note that the problem of emergency divergence was formulated under the assumption that there are no navigational hazards in the area of the supposed maneuvering of ships. The result of the work was the obtained minimax strategy for the behavior of the ship, which consists in turning it towards the direction of the reverse bearing to the target along the shortest angular distance with the maximum angular velocity. Upon reaching the heading equal to the reverse bearing to the target, i.e. $K(t)=\alpha(t)$ the ship further retains the above equality.

However, in the presence of navigational hazards, it may turn out that the chosen minimax course of the ship leads to grounding. In this article, let's consider the issue of choosing the course of a ship in case of an emergency divergence, taking into account the existing navigational hazards. The main types of navigation hazards are point and linear distributed. Therefore, let's first consider the situation when there is a point hazard in the maneuvering area (**Fig. 1**).

The following designations are in **Fig. 1**:

– $\alpha(t)$ – the current value of the bearing from the target to the ship;

– R – the maximum permissible distance of approach of a ship with a point navigational hazard;

– $\alpha_o(t)$ and $D_o(t)$ – the current bearing and distance between the ship and the navigational hazard, respectively;

– $K_{st}(t)$ and $K_{pr}(t)$ – respectively, the current values of the right and left boundary courses of the ship's evasion relative to danger.

As follows from **Fig. 1**, the values of the right and left boundary courses of evasion of the ship $K_{st}(t)$ and $K_{pr}(t)$ are determined by the following expressions:

$$K_{st}(t)=\alpha_o(t)+\arcsin\frac{R}{D_o(t)},$$

$$K_{pr}(t)=\alpha_o(t)-\arcsin\frac{R}{D_o(t)}. \quad (1)$$

Since the value of $D_o(t)$ decreases over time, the boundary rate $K_{pr}(t)$ decreases, and $K_{st}(t)$ increases, with both rates deviating more and more from the $K_{op}(t)=\alpha(t)$. This circumstance determines the choice of the course of evasion K_y from a point danger, given that K_y will be the more effective, the smaller its deviation from $\alpha(t)$.

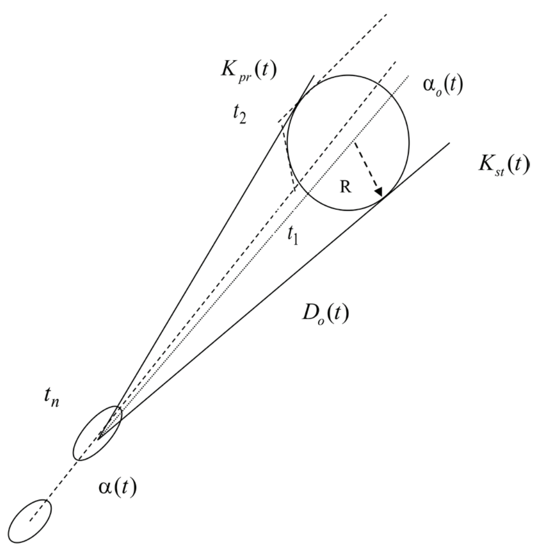

Fig. 1. The case of taking into account point navigational danger

3. Results

Thus, the following two options are possible. First, at the initial time t_n, when the boundary courses ($K_{pr}(t)$ and $K_{st}(t)$) differ the least from α(t), as the deviation course Ky, one should choose the boundary course ($K_{pr}(t)$ or $K_{st}(t)$), which is closer in value to the value of α(t), which is analytically expressed as follows:

$$K_y = K_{pr}(t_n), \text{ at } \left|K_{pr}(t_n) - \alpha(t_n)\right| < \left|K_{st}(t_n) - \alpha(t_n)\right|,$$

$$K_y = K_{st}(t_n), \text{ at } \left|K_{pr}(t_n) - \alpha(t_n)\right| \geq \left|K_{st}(t_n) - \alpha(t_n)\right|. \quad (2)$$

The second option is that the ship follows the optimal course $K_{op}(t)=\alpha(t)$ until the moment t_1 in close proximity to a point navigational hazard, then significantly (by 60–70°) changes its course, preventing it from entering the hazard. The ship follows this course until time t_2, after which it returns to the optimal course $K_{op}(t)=\alpha(t)$. The preference for choosing one of the two options is determined by the initial positions of the ships relative to each other and the danger, the parameters of the movement of the ships, and additional research is required to obtain analytical dependencies.

In the case when there is a navigational linear distributed danger in the area of emergency divergence (**Fig. 2**), the choice of the divergence course is made from the following considerations.

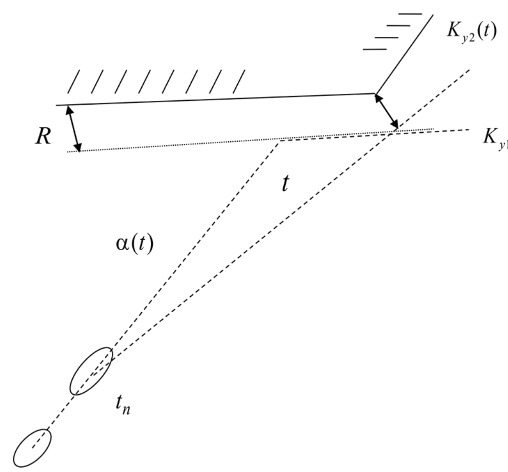

Fig. 2. Choice of a course of divergence in the presence of a linear distributed hazard

4. Discussion

As with the point hazard, there are two alternative diverging strategies. According to the first one, the ship follows the optimal course $K_{op}(t)=\alpha(t)$until time t, after which it follows the course $K_{y1}(t)$ until the end of the linear section of danger. In the case of the second strategy, at the initial time t_n, the ship lies on the boundary course $K_{y2}(t)$ and follows until the end of the divergence. To select the preferred strategy, it is necessary to develop an appropriate analytical procedure.

5. Conclusions

The case of taking into account a point navigational hazard in the case of an excessive approach of a ship to a dangerous target is considered.

The choice of a safe evasive course, taking into account the linearly distributed navigational hazard, is proposed for the situation of an emergency divergence of the ship from a dangerous target.

The necessary analytical conditions are obtained.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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Data availability

Manuscript has no associated data.

References

1. Burmaka, I. A., Pyatakov, E. N., Bulgakov, A. Yu. (2016). Upravlenie sudami v situatsii opasnogo sblizheniya. LAP LAMBERT Academic Publishing, 585.
2. Tsymbal, N. N., Burmaka, I. A., Tyupikov, E. E. (2007). Gibkie strategii raskhozhdeniya sudov. Odessa: KP OGT, 424.
3. Pyatakov, E. N., Buzhbetskiy, R. Yu., Burmaka, I. A., Bulgakov, A. Yu. (2015). Vzaimodeystvie sudov pri raskhozhdenii dlya preduprezhdeniya stolknoveniya. Kherson: Grin' D.S., 312.
4. Burmaka, I. A., Burmaka, A. I., Buzhbetskiy, R. Yu. (2014). Ekstrennaya strategiya raskhozhdeniya pri chrezmernom sblizhenii sudov. LAP LAMBERT Academic Publishing, 202.
5. Safin, I. V. (2002). Vybor optimal'nogo manevra raskhozhdeniya. Avtomatizatsiya sudovykh tekhnicheskikh sredstv, 7, 115–120.

6. Burmaka, I. A. (2005). Rezul'taty imitatsionnogo modelirovaniya protsessa raskhozhdeniya sudov s uchetom ikh dinamiki. Sudovozhdenie, 10, 21–25.
7. Petrichenko, E. A. (2003). Vyvod usloviya suschestvovaniya mnozhestva dopustimykh manevrov raskhozhdeniya s uchetom navigatsionnykh opasnostey. Sudovozhdenie, 6, 103–107.
8. Lisowski, J. (2005). Dynamic games methods in navigator decision support system for safety navigation. Advances in Safety and Reliability. Chap. 17. Balkema Publishers, 1285–1292.
9. Lisowski, J. (2005). Game control methods in navigator decision support system. The Archives of Transport, XVII (3-4), 133–147.
10. Lisowski, J. (2005). Game and computational intelligence decision making algorithms for avoiding collision at sea. Proc. of the IEEE Int. Conf. on Technologies for Homeland Security and Safety. Gdańsk, 71–78.
11. Statheros, T., Howells, G., Maier, K. M. (2007). Autonomous Ship Collision Avoidance Navigation Concepts, Technologies and Techniques. Journal of Navigation, 61 (1), 129–142. doi: https://doi.org/10.1017/s037346330700447x

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