Methods for Assessing the Risk of Approaching Ships as an Integral Part of the Vessel Traffic Control System

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Abstract

The article presents a brief overview of methods for ensuring the navigation safety of vessel traffic, which are divided into three categories: methods of early detection of the collision possibility of ships, methods of maneuvering to avoid a collision and planning trajectory methods of the ship. A detailed theoretical review of methods for assessing the risk of a dangerous approach of ships, associated with ensuring the navigation safety of ship traffic, is carried out in detail. The representation of ship domains is disclosed to assess the risk of a dangerous approach of ships. The work provides links to sources that clarify the presented material.

Keywords

Navigation safety, navigational control methods, risk assessment, ship convergence, "ship domain"

1. Introduction

The science of ensuring safe navigation in the civil and military spheres is in the process of improvement. A global issue in this scientific area is prevention of groundings and collisions of ships. This science examines the aspect of the problem of navigation safety from all sides. Navigation figure 1, since antiquity, as a result, has created problems of navigation safety. Ensuring navigational safety is a task that is a complex multi-level complex.

To solve this problem, the forces are united: manufacturers of maritime navigation aids, international organizations, administrations of states participating in world shipping. The cooperation of these entities forms a system for ensuring safe navigation. Despite such cooperation, a high percentage of ship accidents at sea is an objective reality that cannot be denied and is primarily due to the peculiarities of external and internal factors accompanying navigation, which will always be present regardless of the human factor. The level of state and reliability of navigation in modern conditions, the real accuracy of navigation and the quality of navigation problems is about twice worse than expected. It follows that the complete elimination of the accident rate of ships has no chance. But it is quite possible to influence the number of accidents with the help of various measures and try to achieve its relative maximum reduction for a period that is limited. Such a drop in the accident rate can be achieved up to a certain level, after which the accident rate will inevitably grow again or temporarily stabilize [1]. This conclusion follows from the realities of the present time, which can be characterized:

1. An increase in the volume of water transport
2. The increasing traffic intensity in areas of busy shipping leads to a constant increase in the workload on boat masters

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Figure 1: Water transport

Experimental studies show that the largest number of accidents in water transport occur in the areas of responsibility of ports and on the approaches to them. In this regard, the problem of safe movement at sea becomes most acute in limited waters and cramped navigation conditions [2].

2. Aspects of the tasks for ensuring the navigation safety

One of the seven ancient man-made wonders of the world - the Pharos lighthouse, and the miraculous miracle - the Pillars of Hercules were navigational landmarks on the approaches to Alexandria and Gibraltar and helped mariners prevent their ships from aground. And this is one of the proofs that at that time the knowledge, experience and intuition of the navigator was not enough to guarantee the safety of navigation. In modern conditions when the main cause of maritime accidents is breakdown, damage, or equipment failure. The worst regions in terms of maritime accidents, according to the AGCS report, are the waters of southern China, Indonesia, and the Philippines. Every fourth incident occurs in those areas. Even though Asia remains the most unfavorable region due to the busiest routes and the old fleet. Next come the Eastern Mediterranean and the Black Sea and the British Isles. From the analysis of catastrophes, the existing problems of the safety of navigation becomes acute in limited waters and cramped navigation conditions. As a result, special methods of preventing collisions of ships, introduced into complex technical navigation systems, are in great demand [4,5]. The legal framework at this stage, despite the emergence of unmanned navigation, regulates that the management of a ship is the exclusive right of its captain. In his actions, the boat master is only guided by the information provided by various navigation aids, but the final decision on the movement of the vessel is made only by the boat master. And because of this, it has led to the fact that in navigation, extraordinary approaches to traffic management have developed and are used. Because of this, the methods of ensuring the navigation safety of vessel traffic can be divided into three categories: methods of early detection of the collision possibility (collision risk assessment), methods of maneuvering to avoid a collision (collision avoidance), and planning trajectory methods of the safe movement of the vessel. Brief comparative characteristic these methods:

Method 1. On-board radio and computer systems, which are called on-board collision avoidance systems, have been recognized as highly effective means of preventing collisions in shipping. The English name for these complexes is Collision Avoidance System. The on-board collision avoidance system is a proven system based on the use of surveillance radar signals and other navigational aids. It operates independently of ground equipment and provides information on situations that other vessels can create in various navigational conditions. The collision avoidance system provides information to the officer of the watch on the situation in the navigation area through the provision of visual and voice information, ensures the timely detection of threatening vessels, classifies vessels according to their degree of danger, and issues recommendations for the appropriate maneuver. The collision avoidance system monitors vessels in the surrounding water area within a radius of up to 24 miles from own vessel [3]. Such observation makes it possible to determine the trajectory of the relative movement of each oncoming object, to assess the risk of collision of own ship with other objects. With the help of communication facilities, coordination of planned maneuvers can be carried out with other vessels.

Method 2. The problem of divergence of vessels in the water area is a priority in the management of the vessel. Without disregarding the increasing intensity of traffic on all international water communications, it is possible to ensure a satisfactory level of traffic safety in recent years using innovative means of radio navigation. For this reason, the problem of divergence of ships should be considered only in accordance with the section "Use of automatic radar plotting means".

The main document among the normative ones that determine the reliability of the divergence of ships is the "International rules for preventing collisions of ships at sea" (IRPCSS-72) [6].

These Rules oblige each vessel to carry the appropriate lights and signs, to sound the appropriate sound signals, to use all available means in accordance with the prevailing circumstances and conditions to enable each of them to:

1. To detect in advance the presence of other vessels;

2. To determine the degree of danger in order to identify the existence of a collision hazard;

3. Take into account the mutual obligations when maneuvering the gap;

4. Ensure safe divergence in all visibility conditions.

Method 3. The lack of a quantitative description of the concept of "limited visibility" in the IRPCSS-72 causes a contradiction between R. 19 ("Swimming with limited visibility") and R. 15 ("Situation of intersecting courses in sight of each other") in cases where the visibility range is of the same order of magnitude with D. Having detected in such conditions with the help of the radar an approaching vessel from the right side, a prudent navigator will make way for him, without waiting for this vessel to come within the distance of visual visibility and he will have to act in conditions: the short period of time and minimal space.

In addition, the International Maritime Organization at the United Nations (IMO) in 1978 adopted the Convention on the Training, Certification and Watchkeeping of Seafarers. This Convention defines the minimum requirements for the knowledge and practical skills of boat masters in relation to ship divergence and the use of radar information. IMO has also formulated requirements for programs for radar surveillance, laying and use of automatic radar laying facilities. All this is aimed at increasing the reliability of the divergence of ships.

Method 3. Get answers to the questions: determination of the current coordinates of the vessel in the coordinate system - bearing and distance relative to a given point; determination of the actual trajectory of the vessel's movement, the actual elements of movement, is possible with the help of navigation methods for monitoring the position and movement of the vessel. Evaluation of the trend of the vessel's movement to predict the current coordinates in time, control of the lateral deviation of the vessel from and calculation of the course correction. The listed monitoring tasks are referred to as “Real-time tasks”. The more difficult the navigation conditions are, the shorter the “real time clock” should be. The advantage of each navigation method is determined by the main features of the characteristics: the accuracy of determining the current coordinates of the vessel, the duration of navigation determination and the discreteness of the definitions [7]. Methods of control over the position and movement of the vessel are divided into two groups: "navigational" and "pilotage". With “navigator” control methods based on navigation measurements, the point at which the vessel was located, and depending on the position of this point relative to the line of the given path, solve the remaining navigation problems. The navigational methods include the reckoning of the ship's coordinates, its refinement along one line of position, navigational observations, as well as methods formed by their combinations, including "corrected dead reckoning"

2.1. Security Domains

The area around a ship of a certain radius, shape, and size, not considering geometry, actual dimensions, the current course, into which the oncoming ship should not enter is called the ship's domain. The ship's heading is determined by evaluating the speed vector from radar observations during several turns of the antenna. This definition indicates that the information is not received in real time, but nevertheless this area is called the "navigation safety zone". In methods for assessing the risk of dangerous approach by the foundation, there is a point of the shortest approach of ships (closest point of approach). For navigational safety, the shortest distance is greater than the critical value. The following values are provided: "time of movement to the point of the shortest approach of ships" (time of closest point of approach), "distance to the point of the shortest

approach of ships" (distance to closest point of approach).

Research groups that study the issue of ship collision avoidance use a variety of domains: circular, elliptical, and other complex shapes. The domain boundary is interpreted as a function of the ship's heading angle. At this point in time, to use the security domain, each domain is analyzed separately. Based on this, we can conclude that the domain cannot fully solve all the problems of discrepancy due to strictly defined domain boundaries.

The Goodwin domain model is divided into 3 sectors. The dimensions of the free zone from other objects are different. Depends on the situation in a certain period. The radius of the sectors corresponds to the critical values of the closest approach of ships for each scenario Figure 2.

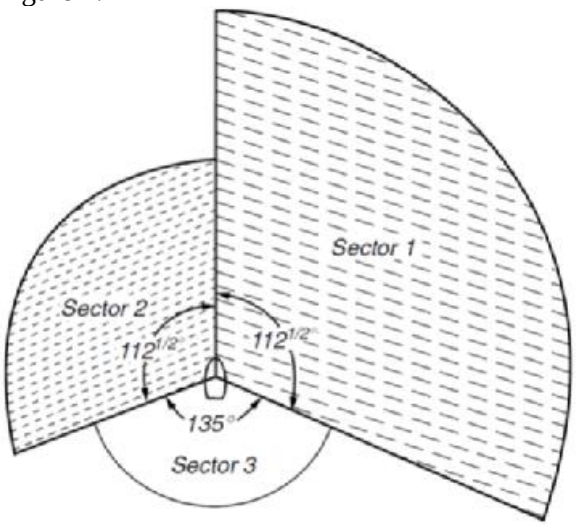

Figure 2: Goodwin domain

Deepening the idea of Goodwin is carried out by the Davis domain, presented in the form of an ellipse with an offset center, divided into sectors. For the navigator, this is an indicator for deciding to perform an evasive maneuver when other objects intrude into the active domain Figure 3.

Caldwell's ship domain is a different configuration depending on the ship's approaching scenario. With oncoming traffic in the domain, the stern part is completely absent. When overtaking, the domain has an ellipsoidal shape.

Tszyu's ship domain is based on neural networks trained by the backpropagation method, which makes it possible to partially consider the influence of the external environment without resorting to complex classical deterministic mathematical models of its description [8].

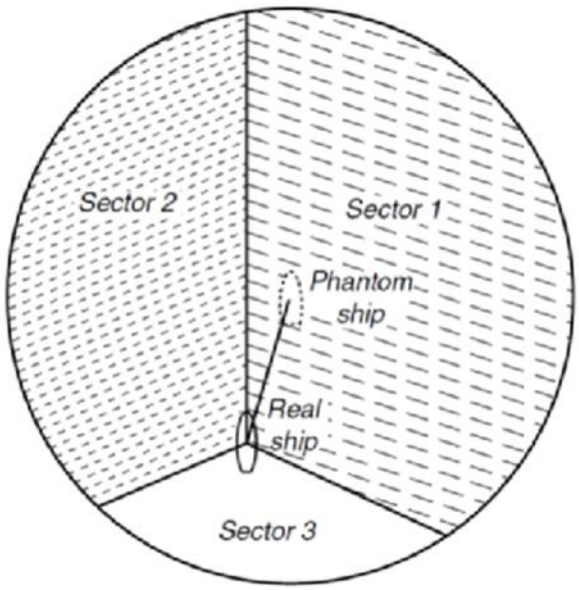

Figure 3: Davis domain

The ship domain proposed by S. V. Smolentsev, A. E. Filyakov considers the navigation features of the navigation area and the hydrometeorological situation. Eliminates the occurrence of false alarms when a vessel enters the safety domain that is moving in the opposite direction in its lane [9]. The position of the security domain boundary is parameterized and depends on the value of one parameter, which is convenient for performing calculations. In addition, the border of the proposed safety zone is smooth, which excludes jumps in solutions for different course angles of entry of targets into this zone [10].

There are groups of our and foreign researchers who are working towards assessing the risk of collision and improving ship domains. An unconventional method for clarifying the situation of approaching ships at sea based on information from an automatic identification system was proposed by Bukaty Vitaly Mikhailovich, Morozova Svetlana Yurievna. Titov A.V., Zaikova S.N., Volynskiy I.A., Khmelnitskaya A.A. in their work the current state and problems of using inland waterways (on the example of the Volga-Caspian Sea shipping canal) and Nitsevich A.A., Melnikov N.V., Khristich D.Yu., Lebedev V.P. in work Collision of ships use the method of M.A. Konoplev, who presents the risk assessment in the form of a fuzzy system.

3. Conclusions

One of the main problems of navigation, namely the navigation safety, remains unresolved,

although the work is carried out by all groups according to the law of a conical spiral.

The article presents a brief overview of methods for ensuring the navigation safety of vessel traffic, which are divided into three categories: methods of early detection of the possibility of collision of ships, methods of maneuvering to avoid a collision and methods of planning the trajectory of the safe movement of the ship. A detailed theoretical review of methods for assessing the risk of a dangerous approach of ships, associated with ensuring the navigation safety of ship traffic, is carried out in detail. To assess the risk of a dangerous approach of ships, the presentation of ship domains of complex figures is given - a dangerous approach of ships.

The work provides links to sources that clarify the presented material.

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