AUTOMATIC COLLISION AVOIDANCE WITH MANY TARGETS, INCLUDING MANEUVRING ONES

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Introduction. The company Kongsberg Maritime (Norway) announced the start of work on the world's first automated cargo sea vessel commissioned by YARA Porsgrunn. The vessel will be used to transport the company's products by sea in automatic control mode. Such a seagoing vessel practically does not require a crew, and it can be safely called the world's first unmanned seagoing robot ship. Elements of automatic control will be integrated into all systems of the designed marine vessel, including electric drive, batteries, navigation and motion control systems. Launching and commissioning is scheduled for 2018, from 2019 the ship will be used to transport cargo by sea in semi-automatic control mode, and starting from 2020, the seagoing ship will perform scheduled flights without the participation and control of the crew. One of the main programs of automated management, under the management of which the sea vessel-robot will work, is the AUTOSEA program. It includes a lot of software sensors to prevent collisions of ships on waterways.

In addition to Kongsberg Maritime, the well-known concern Rolls-Royce, which received a research grant from Tekes this year, is also involved in automating the management of maritime vessels. As part of the project, Rolls-Royce should develop the infrastructure of land-based marine control centers and an artificial intelligence-based system for controlling and directly controlling the automated robots themselves [1]. On the eve of 2019, Rolls-Royce announced the successful testing of a cargo marine vessel equipped with an autonomous movement system developed by the company. The test results are impressive, and the company's plans are intriguing. Over the next six years, the company intends to create a completely autonomous vessel that will move independently from the moment it leaves the port of loading to its final destination, the port of discharge. To control the vessel at the sea crossing, the company developed the Rolls-Royce Ship Intelligence system, which consists of cameras and sensors located around the vessel and designed to scan the environment for the presence of adequate hazards and approaching objects. To test the effectiveness of the Rolls-Royce Ship Intelligence system in practice, Rolls-Royce concluded a contract with the Finnish company Finferries. The test took place near the city of Turku (Finland), 144 kilometers west of Helsinki. The Rolls-Royce Ship Intelligence system technology was introduced on the Falco ferry, 53.8 meters long. Thanks to the system, the ferry independently carried out the flight task of transfer from the port of Parainen to the port of Nauvo. In carrying out a voyage task in the opposite direction, the port of Nauvo - Port Parainen, the company used the remote control - the operator successfully operated the ferry "Falco", being at a distance of 48 km. Rolls-Royce President Mikael McEnin announced that autonomous maritime vessels are no longer a concept, but have become fully operational technology. According to Mats Rosin, Director General of Finferries, autonomous sea vessels will increase the safety of maritime transport [2].

The company Rolls-Royce also announced plans to create a unique unmanned vessel equipped with the latest technology. The ship, 60 meters long, will be able to reach a maximum speed of up to 25 knots, be in autonomous navigation overcoming a distance of up to 3,500 nautical miles and carry out important (including military) missions of up to 100 days, including patrols, pursuit, tracking, search for mines and etc. The propulsion system includes two Rolls-Royce MTU 4000 generators and provides the vessel with 4 megawatts of electricity. An array of solar panels can feed batteries for a long time. The vessel is equipped with a huge number of modern technologies, including artificial intelligence, a small army of unmanned drones, as well as an array of all sorts of sensors necessary for orientation of the ship in space. The vessel itself will be able to detect other vessels and, if this is required by the combat mission, avoid meeting with them. Special equipment will allow the ship to detect even enemy submarines hiding at great depths. The creators of the future vessel believe that unmanned vessels will make it possible to seriously save on the management of the vessel, as well as reduce the risks associated with human factors [3].

The relevance of research. Installed on most modern ships systems of automatic radar plotting (ARPA) are not in the full sense of the automatic, as they imply the presence of a person in the control loop. In addition, the ARPA does not allow avoid collisions with maneuvering targets [4–6]. Analysis of other open sources also showed that the above results allow to diverge automatically with one target, or with several non-maneuvering targets. This article discusses the issues of divergence with many targets, including maneuvering one, in a fully automatic mode. In view of the above material, this area of research is highly relevant.

Formulation of the problem. It is necessary:

– develop the software, algorithms and software module of one of the tasks of automatic control - automatic diversion with many goals, including maneuvering;

– create on the simulator, in the program "Navi Trainer Instructor", exercises for testing the software module of automatic rocking with many maneuvering targets in various conditions;

– check the operation of the automatic rocking module for many purposes, including maneuvering, in a closed circuit with the Navi Trainer Instructor simulator.

Fig. 1 shows the informational scheme of modeling objects.

Block 7 is a model of the onboard controller, in modules 7.1.–7.n of which the tasks of automatic control are solved. The exchange algorithm 8 accepts input signals of linear velocity measuring devices 9, angular speed 10, course 11, bearing and distance to each target 12 and transmits them to processing modules 7.1.–7.n. The control signals Kn1 (required course), Vn1 (required speed) from the outputs of the onboard controller 7 are fed to the autopilot 3 and telegraph 6 in order to form control actions on the vessel. In addition to controlling the effects on the ship, disturbances from wind and currents, generated by unit 1, also act. Under the influence of control and disturbing influences, the model of the vessel changes the parameters of its movement. Block 2 models the movement of targets. The relative position of the vessel and targets is determined by the comparator 5, the output signal of which is used by the radar model to form bearings and distances to the targets.

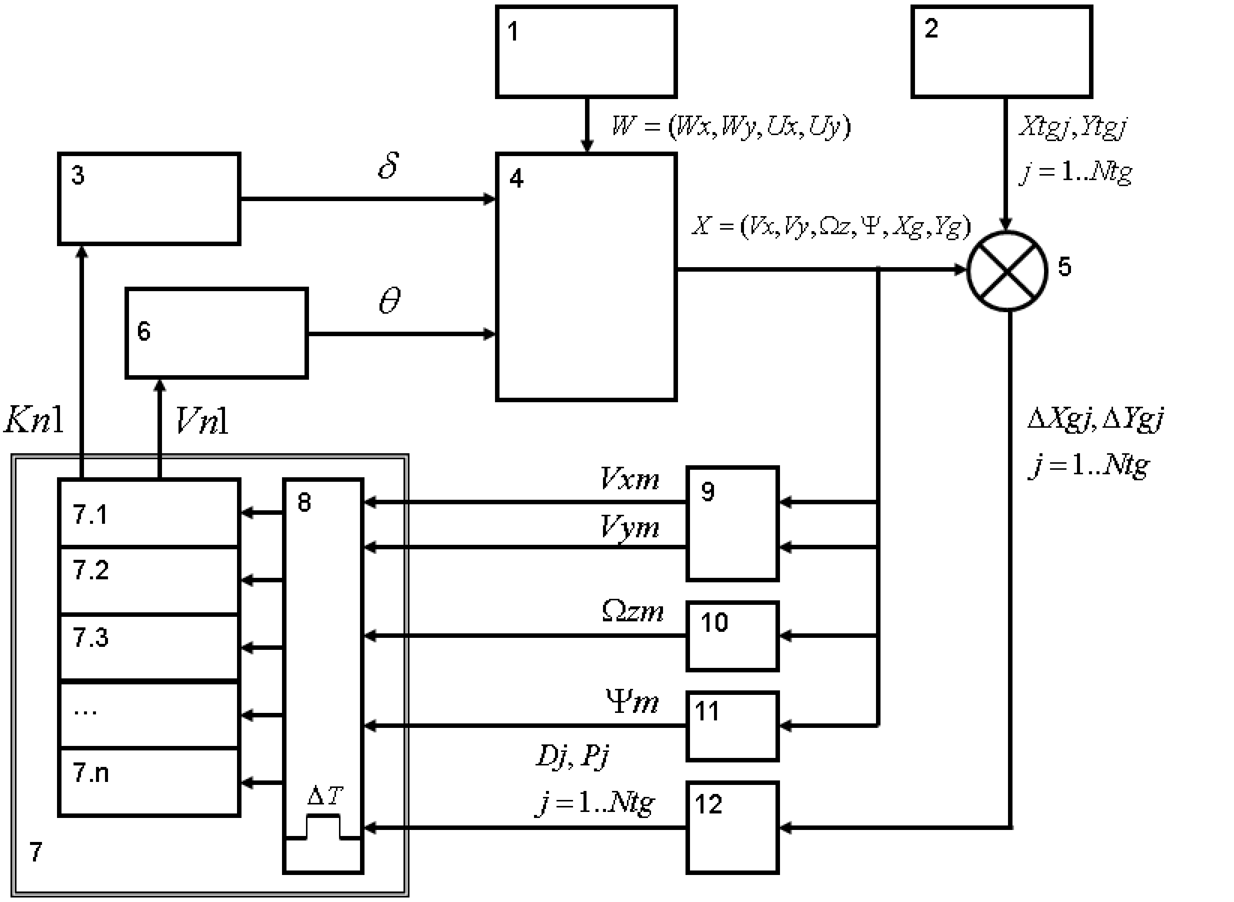

Fig. 1 – Information Scheme of Modeling Objects

Figure 2 shows a diagram of the discrepancy with one target.

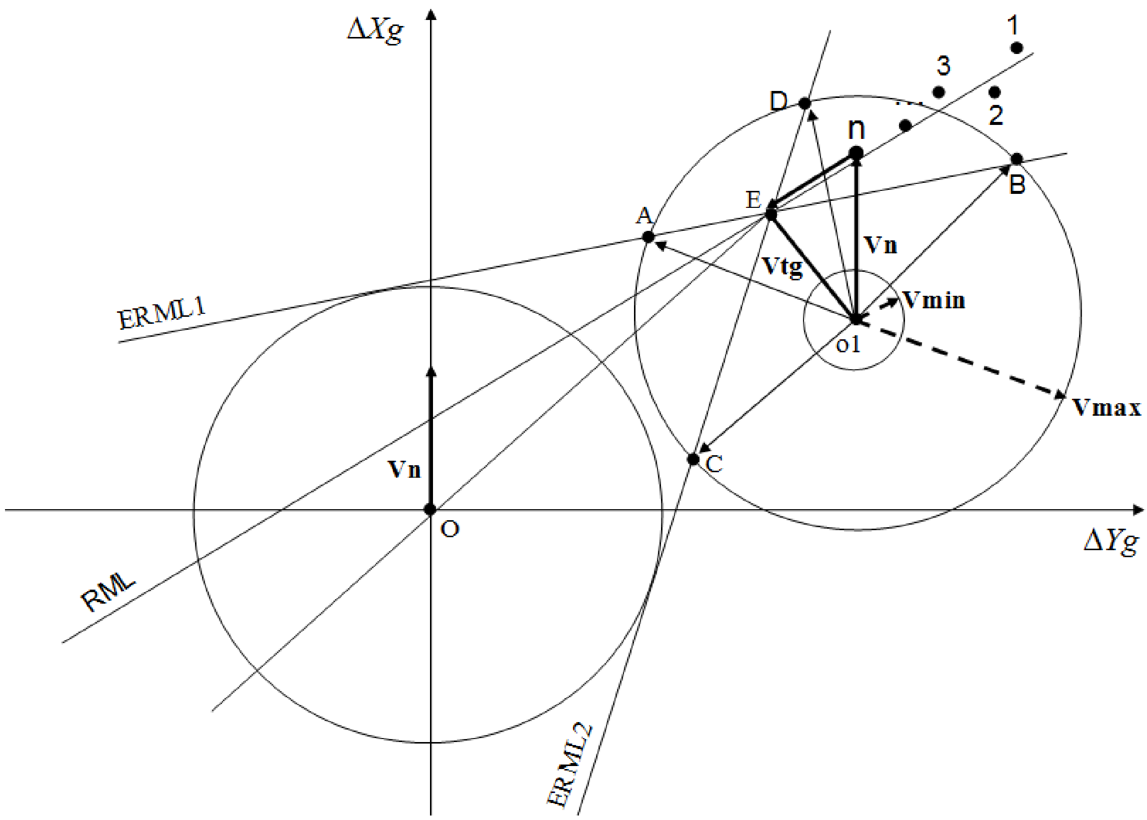

Fig. 2 – Diagram of the discrepancy with one target.

The control area between Vmax and Vmin, without sectors of dangerous courses (SDC) AEC and DEB, is the area of permissible controls for the divergence with one target, only in case of location the vector Vn in this area the relative speed's vector don't directed into the SDC. In Fig. 2, the area of admissible controls consists of 2 subdomens AED and BEC without a circle Vmin.

Areas of allowable control of divergence with all targets are obtained by combining the areas of allowable divergences with each target separately.

$$\Omega = \Omega_1 \bigcap \Omega_2 \bigcap ... \bigcap \Omega_{Ntg} .$$

Because the analytical description of the domain of admissible controls is difficult, the authors proposed:

– the areas of permissible controls build numerically in the onboard controller, which will allow to obtain complex forms for any number of targets;

– the areas of permissible controls build with the step of solving the task in the onboard controller, which will allow to take into account any changes the movement of the vessel and targets, and therefore avoid collisions with maneuvering targets.

To construct the areas of admissible control for divergences with the *j*-target $\Omega j, j = 1..Ntg$, take the test vectors of divergens at the grid nodes of their possible changes $\overline{V_T} = (V_T * \cos K_T, V_T * \sin K_T)$, for each test vector calculate the relative speed's vector with the *j*-target, which is checked for belonging to SDCj.

If the membership condition isn't met, the test vector is valid for divergence with this target $\overline{V_T} = (V_T * \cos K_T, V_T * \sin K_T)$. For the described method, the authors obtained a patent for a utility model [14].

Results of research. Module of automatic divergence with many targets, including maneuvering one, was tested on an imitation stand of modeling. This module is located in the model of the onboard controller 7, which through the local computing network is connected to the "Navi Trainer Professional-5000" simulator (modules 1–6, 9–12). In the "Navi Trainer Instructor" program [11] of the instructor's workplace created a task (selected a navigation area, own ship, 5 dangerous targets, speeds and variable trajectories for all targets, weather conditions, etc). The safe distance is 0.5 miles.

Fig. 3 shows a view from the visualization channel of the simulator in the process of divergence.

Fig. 4 shows the areas of permissible controls during divergence with dangerous targets (marked in green).

As can be seen from the above fragments, the shapes and sizes of the areas of admissible controls are constantly changing. It happens through position changes the vessel and targets, including maneuvering.

Fig. 5 shows the radar screen at the end of the divergence.

Information from the radar screen confirms the absence of threats from targets. As can be seen from the above data, the divergence operation is almost complete.

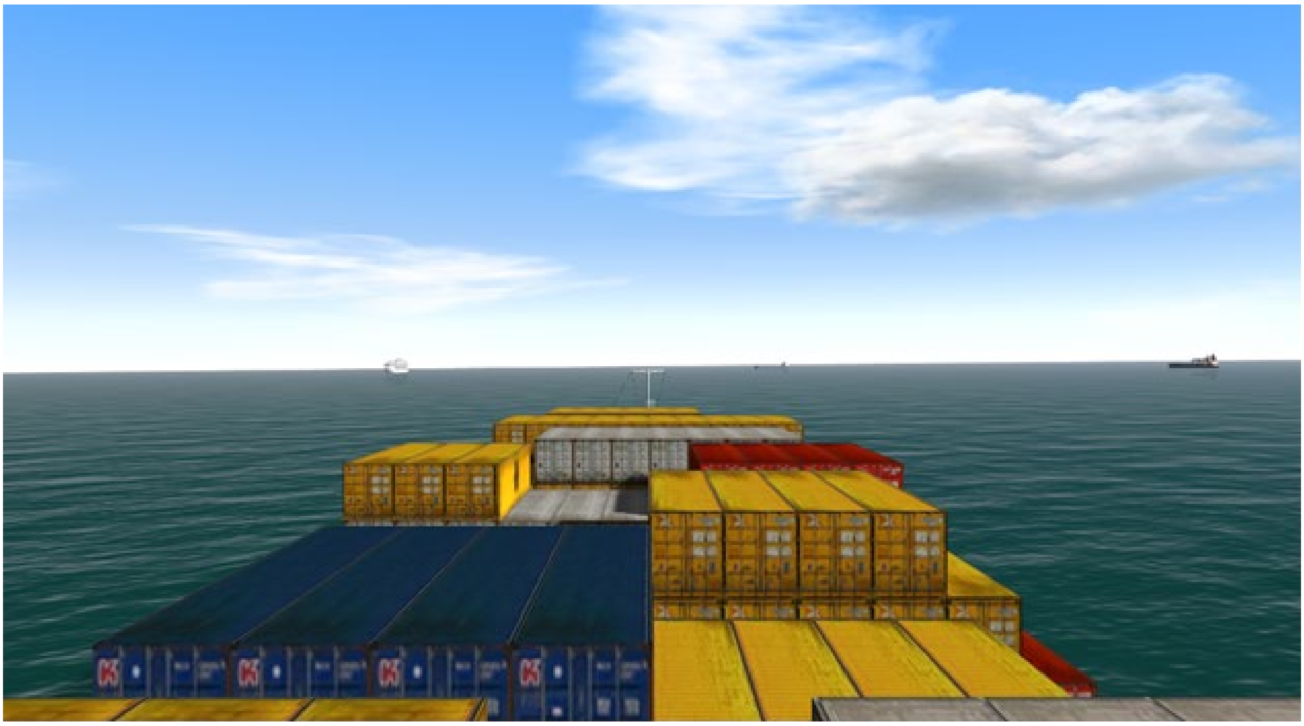

Fig. 3 – View from the visualization channel

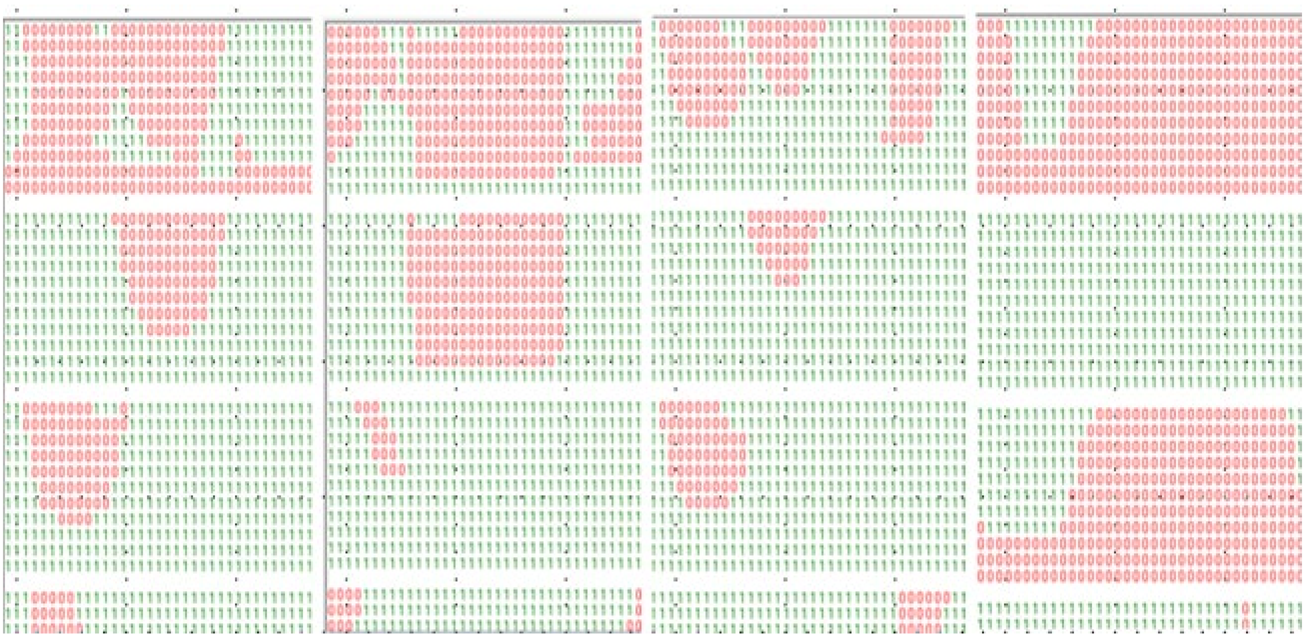

Fig. 4 – Areas of permissible controls in the process of divergence

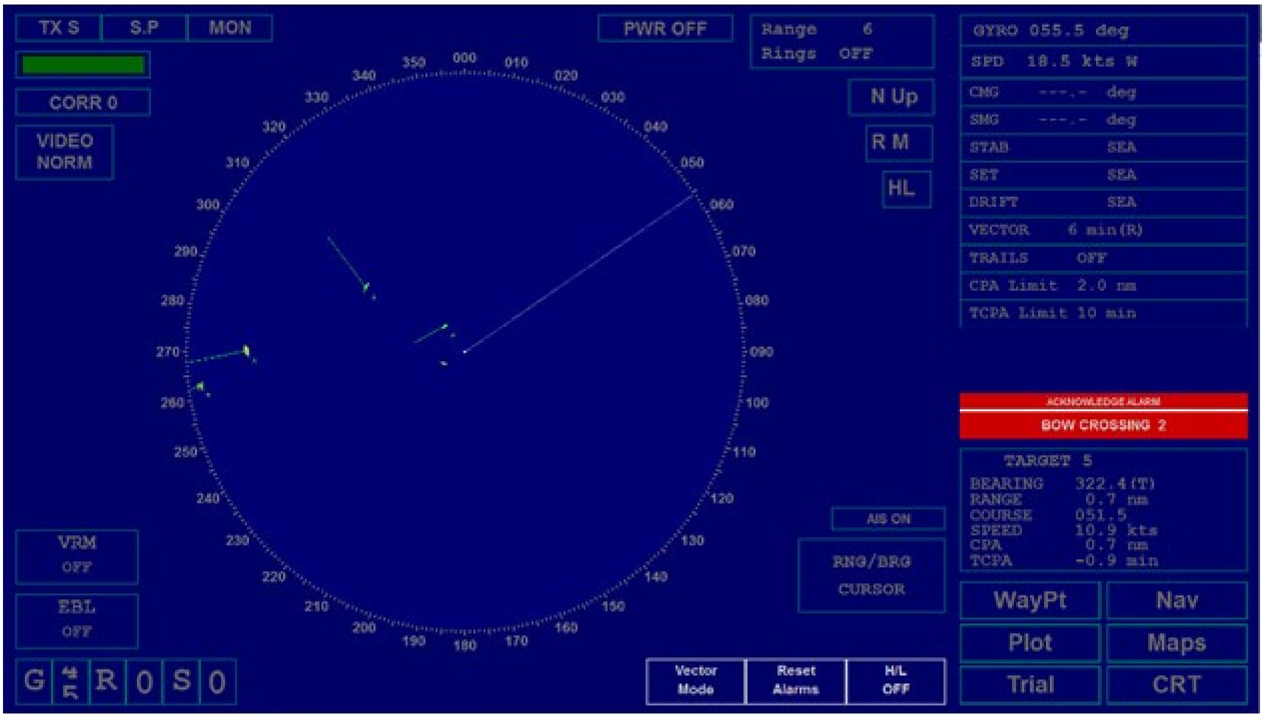

Fig. 5 – The radar screen at the end of the divergence

Conclusions. In this theses were announced the results of creating a module of divergence with many targets, including maneuvering ones, in a fully automatic mode, namely:

– developed software, algorithms and software module for automatic divergence with many targets, including maneuvering ones;

– on the simulator, in the program “Navi Trainer Instructor”, exercises were created for testing the program module of automatic divergence in various conditions;

– the work of the automatic divergence was tested in a looped circuit with the “Navi Trainer Instructor” simulator.

The results of conducted research showed that the created module allows to avoid collisions with many targets, including maneuvering ones, in a fully automatic mode.

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