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NAVIGATION DECISION SUPPORTING SYSTEM (NAVDEC) — TESTING ON FULL MISSION SIMULATOR

ABSTRACT

The known navigational systems in use and methods of navigational decision support perform information functions and as such are helpful in the process of safe conduct of a vessel. However, none of these known systems provides a navigator with ready solutions of collision situations taking account of all the vessels in the proximity of own ship, where the Collision Regulations apply. Another shortcoming of these systems is that they do not explain the assessment of a navigational situation and proposed manoeuvre parameters. Results of testing in simulation condition of NAVDEC — new Navigational Decision Supporting System developed by research team of prof. Pietrzykowski [Pietrzykowski et al., 2012a], [Pietrzykowski et al., 2012b] — were presented in this paper.

Keywords:
supporting system, collision avoidance, simulation.

INTRODUCTION

Developed at the Maritime University of Szczecin NAVDEC system is a decision support tool for navigating that performs alongside providing information typical tasks for decision support systems. NAVDEC is an important complement to navigational equipment of the ship. Is a real-time system operated by the navigator. Its proper functioning requires interaction with devices and systems on the ship. The standard configuration of the vessel include: log, gyrocompass, radar, echo sounder, ARPA, GNSS (Global Navigational Satellite System), such as GPS (Global Positioning System) or DGPS (Differential Global Positioning System). In addition, AIS,

ECDIS, GMDSS. In the version being developed following sources of information are in use: log, gyrocompass, radar/ARPA, GPS and DGPS, AIS and ENC (Fig. 1).

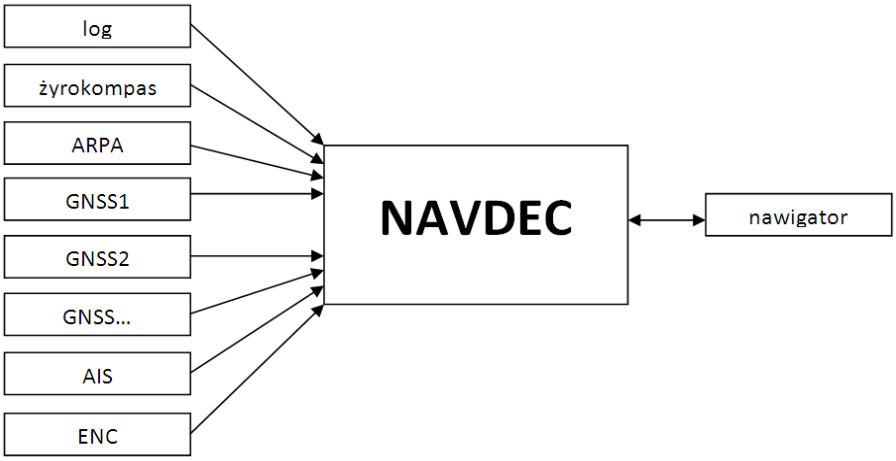

Fig. 1. Data sources for decision supporting system [own study]

The system architecture distinguishes modules (packages): information (registration decode and interpret messages from the system and external devices), event identification, analysis and evaluation of the situation, the choice of maneuver, traffic prediction, management, knowledge base and library navigation procedures.

Due to the nature of the system (real-time system) was isolated module (package) management. In addition, isolated user interface, which is part of the system visible to the navigator. The basic interface features were found: 1) imaging navigational situation using ENC, 2) communication user - the system, 3) a presentation of the proposed system solutions.

Presented system belongs to a group of critical systems. This means that the operation of the product and time regimes perform certain tasks depends on the safety of people, the ship, its cargo and the environment. Therefore, special attention has been paid to create the testing process for the system. One of the stages of the testing of these systems are laboratory tests carried out using the appropriate simulators. Their aim is to verify the proper operation of the different situational scenarios, including accuracy of the calculations performed by the system. From the point of view of the operation of collision avoidance systems particularly important are calculations of the ship encounter parameters.

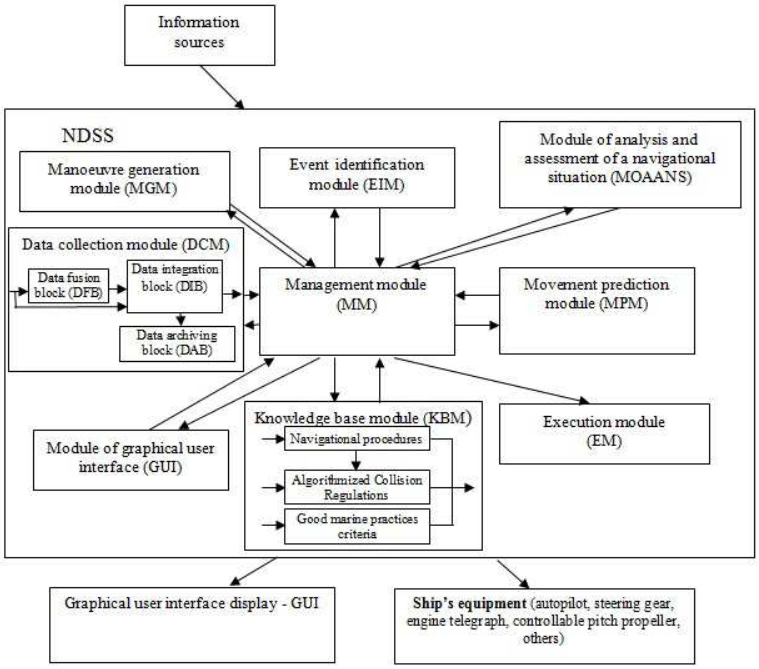

Fig. 2. Architecture of decision supporting system [own study]

REQUIREMENTS

At present there are no requirements obliging sea-going vessels to be equipped with a decision support system that would assist navigators in collision situations. Consequently, vessels do not carry such systems. Besides, manufacturers of navigational equipment and specialized software are not interested in developing and implementing decision support systems as ship-owners show no demand for them. Unfortunately, most shipping companies share an opinion that if a device or software is not required by law, it will not be purchased.

In this connection, it seems purposeful to launch a widespread campaign aimed at decision makers promoting mandatory installation of a navigational decision support system. The navigator able to use a system that correctly qualifies a situation in compliance with the COLREGs and submits possible solutions would not make errors as was in cases presented in papers [Banachowicz et al., 2007], [Gralak et al., 2010], [Magaj et al., 2007], [Magaj et al., 2010]. It goes without saying that the implementation of such systems would enhance the safety of navigation.

SIMULATION TEST — BED

Simulation studies of NAVDEC system have been carried out in the Centre of Navigational Technologies, located in Marine Traffic Engineering Centre at Maritime University of Szczecin (Fig. 3).

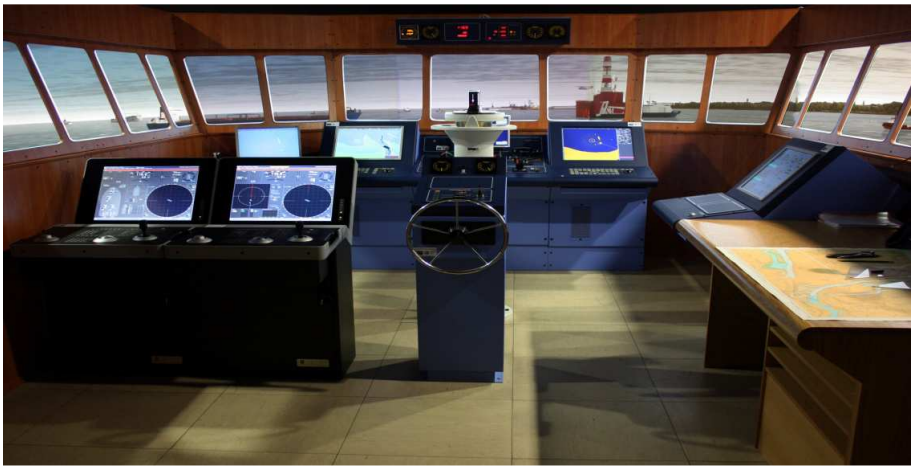

Fig. 3. CNT full mission ship's bridge simulator [photo by author]

Centre of Navigational Technologies (CNT) deals with design and implementation of innovative navigation systems on ships (seagoing and inland), identification and verification of the parameters of mathematical models of ship motion in the units with dynamic positioning systems (DP), the development of methods for qualitative and quantitative description of vessel traffic in the restricted areas, particularly: determining the optimum parameters of waterways and hydrotechnic structures for a given type of ship operated in various external conditions, the determination of optimal parameters for each type of ship in the reservoir and shipping conditions there (the study of the possibility of new vessels on the existing waterways); determine the width and traffic parameters on waterways (optimization of parameters for the traffic control system from the waterway and navigation conditions there), assessment of safety of navigation and the definition of security measures on the waterways, the verification of the legal aspects of navigation on the waterways.

The investigation was carried out to assess the advantages of the new functionality of the tested ee-INS (e-Navigation enhanced Integrated Navigation System) [Gralak, 2012]. The NAVDEC simulation experiment was conducted with using the:

— full mission shiphandling simulator with 270° visualization and live marine ship equipment;
— two multi task shiphandling simulators with 120° visualization and mix of real and screen-simulated ship-like equipment;
— dedicated, certified hardware and software to establish the simulator — system communication.

All hardware and software is forming the Polaris System from Kongsberg Maritime AS which was granted DNV certificate for compliance or exceeding the regulations set forward in STCW '95, section A-I/12, section B-I/12, table A-II/1, table A-II/2 and table A-II/3) [Gralak et al., 2010]. The CNT has been also accredited as an DP Operator Training Centre in accordance with the Nautical Institute standards.

Obtained accreditations, confirm the full compatibility of simulated events, interactions and behaviors and allow for a reliable verification of the system's operation in relation to reality. Vessels' parameters recording functionality was used in anti-collision analysis and to carry out the validation of calculation algorithms, implemented to the NAVDEC system.

TESTING SCENARIOS

Navigational Decision Support Systems, like other navigational systems shall be liable to certification. This is a complex problem. It is necessary to prepare procedures and rules for approval process as well as requirements and test methods. These shall take into account specific of the system, its role in navigation process and others. The issues like responsibility, proper functioning and handling of the system shall be taken into account. During the research initial proposals to be included in requirements for approval were formulated as follows:

— the system shall be able to calculate solutions for: sectors of recommended courses, for actual settings of CPA, TCPA and present weather conditions (visibility) for 40 vessels in pre-defined 5 seconds time period;
— the system shall present qualification of encounter situation according to COLREGs for each selected target separately and explain from which Rule it comes from;

— the system shall display Recommended Trajectory i.e. route from present position to the next waypoint which enables to pass other targets on presumed CPA;
— the system shall be able to correctly calculate encounter parameters i.e. CPA, TCPA.

The aim of testing NAVDEC on full mission simulator was to verify if it fulfills a/m criteria. For this reason following scenarios were prepared.

Models of vessels used for simulation

The models of vessels were designed in the 3D environment with using the special graphics creating tool – Multigen Creator and its' hydrodynamic databases with Hydrodynamic Modelling Tool and Ship Database Manager [Gralak et al., 2010].

Table 1. Models' parameters [own study]

				
Assigned to:	OS	TGT 1	TGT 2	TGT 3
Type	Cargo	Ferry	Conteiner	Pilot Boat
Loading condition	Ballast	Ballast	Loaded	Ballast
LOA [m]	149	35,5	202,4	30,2
Breadth [m]	22,05	9,6	31	10
Draught [m]	3,37 / 6,93	1,2	9,2	2,5
Max speed [knots]	16,93	33,5	24,7	29,9
Displacement [t]	20767	106	33750	54
Type of rudder	Normal	Waterjet	Normal	Normal
Maximum angle [°]	35	30	35	35
Hard-over to hard-over [s]	27	8,7	28	13
Type of engine	Diesel	Diesel	Diesel	Diesel
Maximum power [kW]	7080	3360	46820	900

Models selected for the experiment are characterized by diversity in terms of the navigation and maneuvering parameters (tab. 1). Such an assumption to the studies was to test the NAVDEC system in the possible widest configuration of vessels' rendezvous.

Scenario No. 1

Own ship

OS COG=000^0; SOG=11.1kn

Positions of three targets in relation to **OS**

TG1 COG=251^0; SOG=31.0kn; BRG=054^0; RNG=9.0Nm

TG2 COG=180^0; SOG=11.1kn; BRG=000^0; RNG=8.9Nm

TG3 COG=131^0; SOG=27.0kn; BRG=323^0; RNG=9.4Nm

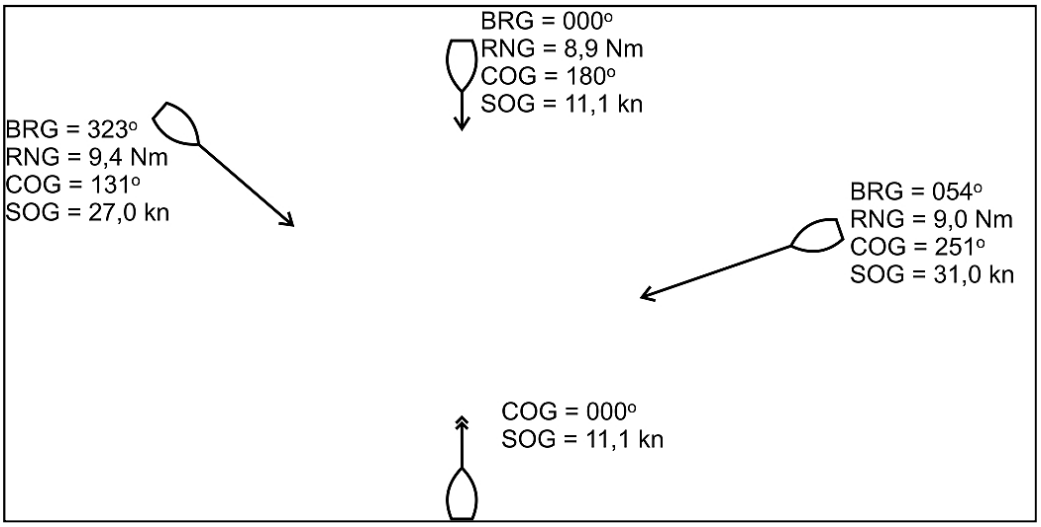

Fig. 4. Location of vessels in scenario No. 1 [own study]

Scenario No. 2

Own ship

OS COG=180^0; SOG=10.5kn

Positions of three targets in relation to **OS**

TG1 COG=102^0; SOG=17.7kn; BRG=243^0; RNG=8.6Nm

TG2 COG=000^0; SOG=19.5kn; BRG=180^0; RNG=11.5Nm

TG3 COG=315^0; SOG=33.5kn; BRG=147^0; RNG=12.2Nm

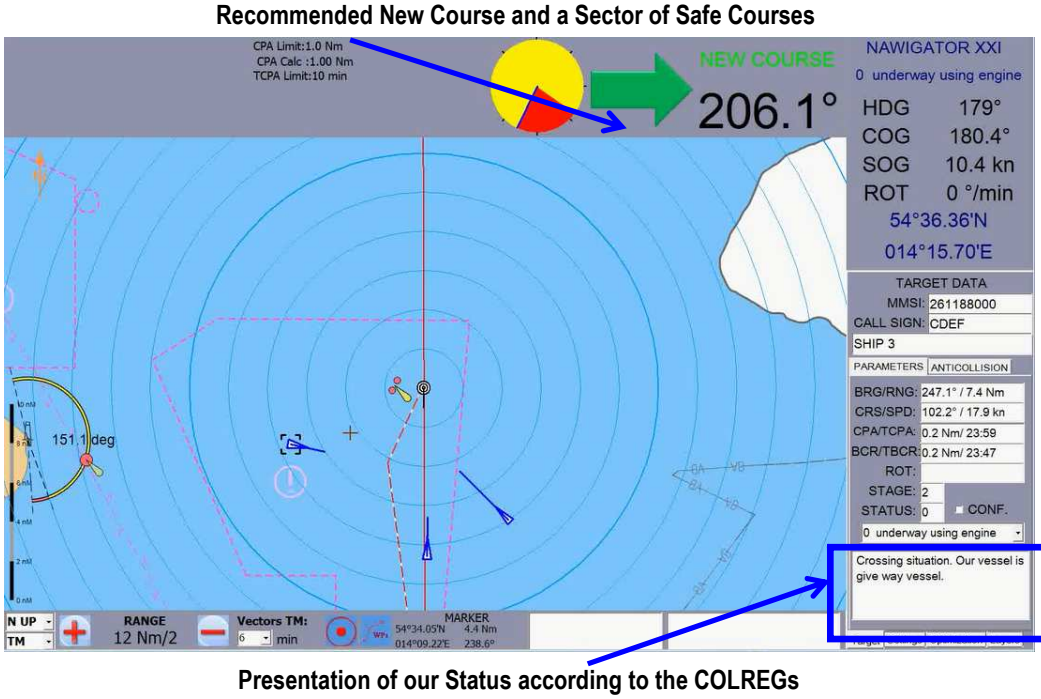

Fig. 5. Location of vessels in scenario No. 2 [own study]

Scenario No. 3

Own ship

OS COG=000^0; SOG=15.8kn

Positions of three targets in relation to **OS**

TG1 COG=270^0; SOG=24.0kn; BRG=045^0; RNG=5.1Nm

TG2 COG=000^0; SOG=11.0kn; BRG=045^0; RNG=2.5Nm

TG3 COG=180^0; SOG=18.0kn; BRG=002^0; RNG=7.7Nm

In scenario 3 targets are have different relative position to own ship, than in scenario No. 2.

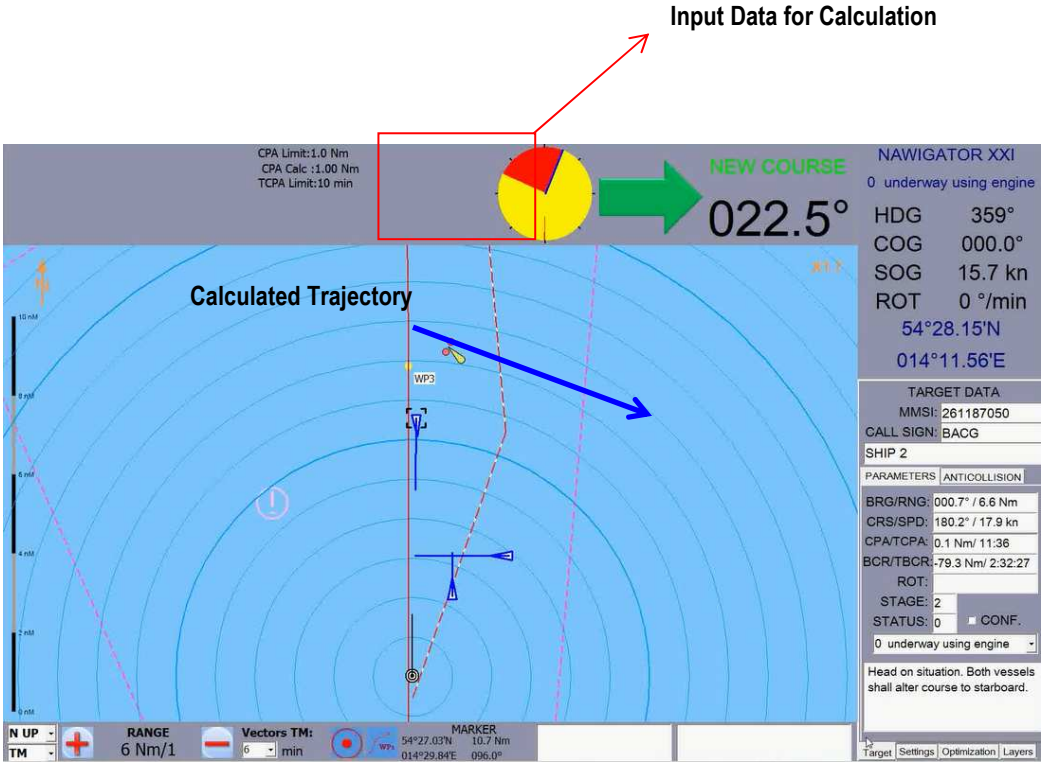

Fig. 6. Location of vessels in scenario No. 3 [own study]

Scenario No. 4

Own ship

OS COG=000^0; SOG=15.8kn

The bearing to forty targets is 000^0. Distances to them are between 3 and 5 Nm. There are on course 180^0.

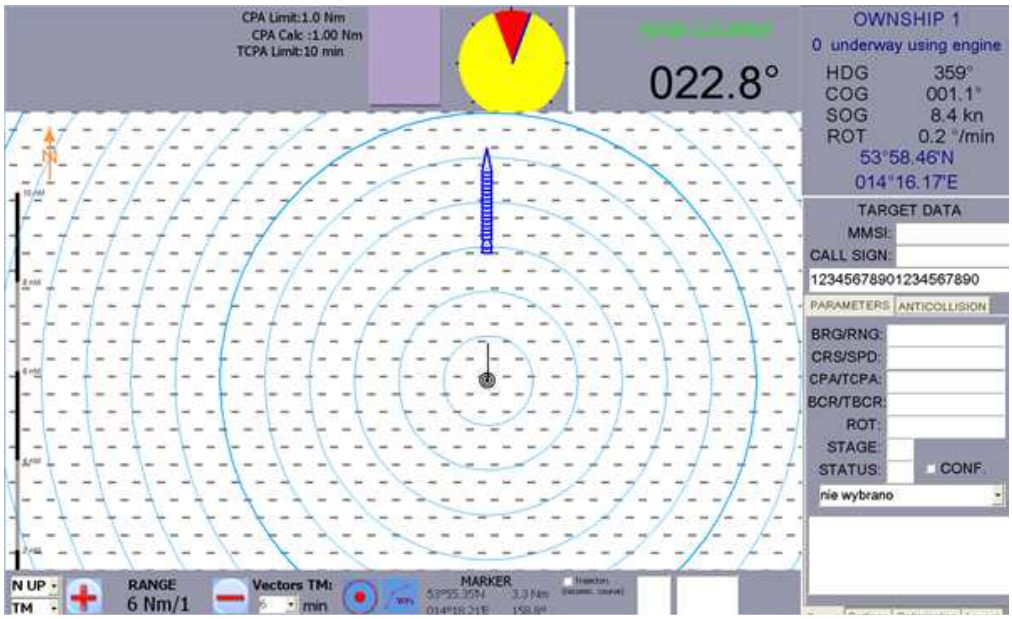

Fig. 7. Location of vessels in scenario No. 4 [own study]

CALCULATION OF ENCOUNTER PARAMETERS

Basic criterias for the assessment of the navigational distance are Closest Point of Approach (CPA) and Time to Closest Point of Approach (TCPA). They are commonly used in Automatic Radar Plotting Aids (ARPA). [Kazimierski, 2011].

$$CPA = \frac{X_{wz}\, VY_{wz} - Y_{wz}\, VX_{wz}}{V_w} \tag{1}$$

$$TCPA = \frac{X_{wz}\, VY_{wz} - Y_{wz}\, VX_{wz}}{V_w^2} \tag{2}$$

where:

VX_{wz}, VY_{wz} — relative speed vector components;

X_{wz}, Y_{wz} — distance between vessels counted along x and y axes, respectively;

V_w — relative speed.

Determination of the ship's own course for the passing of an object at a given distance is possible depending on the analytical [Lenart, 1999]:

$$\operatorname{tg}\frac{\phi}{2} = \frac{A_{DCPA}\,V \pm \sqrt{(A_{DCPA}^2 + 1)\,V^2 - B_{DCPA}}}{B_{DCPA} - V} \tag{3}$$

$$A_{DCPA} = \frac{X_{wz}\,Y_{wz} \pm CPA\sqrt{D^2 - CPA^2}}{X_{wz} - CPA^2} \tag{4}$$

$$B_{DCPA} = A_{DCPA}\,V_x - V_y \tag{5}$$

gdzie:

V — own ship speed;
X_{wz}, Y_{wz} — distance between vessels counted along x and y axes respectively;
V_x, V_y — components of the velocity vector of own ship;
D — distance between vessels;
ψ — new course which enables to pass other targets on presumed CPA.

In a similar way it is possible to determine the speed of own ship, which enables to pass other targets on presumed CPA.

To verify correctness of CPA and TCPA calculation, results received from NAVDEC and Simulator were compared. Polaris Simulator were chosen for comparison because it meets the requirements of STCW Convention, is certified by DNV and Nautical Institute, which guarantees the correctness of the simulation of traffic as well as calculation of encounter parameters set by the simulator. Total number of 9261 records were registered. Statistically speaking CPA calculated by NAVDEC was over 36 meters smaller than CPA received from Simulator. This is because NAVDEC takes into consideration size of ships when calculating CPA. This is also advantage from safety point of view i.e. the smaller CPA, the more attention is paid by navigator for particular collision situation. The biggest difference between CPA received from Simulator and that calculated by NAVDEC was 0.2 Nm. This case occurred only 7 times (out of 9261). The biggest difference between TCPA received from Simulator and that calculated by NAVDEC was 9 minutes. All cases, when the difference between TCPAs was greater than 5 minutes occurred when the calculated TCPA was greater than 100 minutes. In such case, we cannot talk about risk of collision. So, from the safety point of view, it is not relevant. Moreover most of navigation equipment do not display such big TCPA. Message 'TCPA > 99 min' is displayed in the most common solution. In more than 99% difference between TCPA received from Simulator and that calculated by NAVDEC

was less than 1 minute, and average difference was '–3' seconds. It means that TCPA calculated by NAVDEC was smaller than that received from simulator, what is another advantage from the safety point of view.

RESULTS

Testing of NAVDEC on Full mission simulator was carried out in area free of navigational dangers in four different scenarios. Results, in general, are positive. In details system correctly calculates encounter parameters like CPA and TCPA. Displayed parameters were each time compared with CPA and TCPA calculated by simulator and average difference in CPA was 36 meters and in TCPA 3 seconds. Moreover system correctly calculates new, safe courses which lead to pass other targets on assumed 1 Nm (Fig. 5–7). Passing distance was verified on simulator. There was no situation that difference between assumed and passing distance was greater than 0.1 Nm. The system presents qualification of encounter situation according to COLREGs for each selected target separately and explain from which Rule it comes from (Fig. 5–6). Moreover NAVDEC displays Recommended Trajectory i.e. route from present position to the next waypoint which enables to pass other targets on presumed CPA (fig.6). The last, but not least, the system is able to calculate sectors of recommended courses, for actual settings of CPA, TCPA and present weather conditions (visibility) for 40 vessels in pre-defined 5 seconds time period (Fig. 7).

CONCLUSIONS

Results show that system is helpful and effective in solving collision situation. Particularly it can be very useful for inexperienced navigators like those who took part in collision between m/v Gotland Carolina and m/v Conti Harmony [Magaj et al., 2009]. All initial tests were carried out and results were positive. This is why next tests will be carried out in real condition in dense traffic and restricted areas on sailing vessel Dar Młodzieży (on the route from Bremerhaven to Dunkirk).

In the future, the simulation experiments can be used to determine the navigators' workload, by using the NASA-TLX method [Gralak et al., 2012].

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STRESZCZENIE

Znane, będące obecnie w użyciu systemy nawigacyjne, jak również metody nawigacyjnego wspomagania decyzji pełnią funkcje informacji i jako takie są pomocne w procesie bezpiecznego prowadzenia statku. Żaden z tych znanych systemów nie dostarcza jednak nawigatorowi gotowych rozwiązań sytuacji kolizyjnej z uwzględnieniem wszystkich statków znajdujących się w pobliżu oraz odpowiednich przepisów międzynarodowych. Inna wadą istniejących systemów jest to, że nie podają one oceny sytuacji nawigacyjnej i proponowanych parametrów manewru. W artykule przedstawiono wyniki testowania w warunkach symulowanych systemu NAVDEC — nowego nawigacyjnego systemu wspomagania decyzji tworzonego przez zespół badawczy prof. Pietrzykowskiego.