Marine Integrated Navigational Decision Support System

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Abstract. The article presents a concept of an integrated navigational decision support system for vessel traffic control. The system is based on a joint platform for decision support systems on land and ships. The platform construction is recommended to be based on the shipboard navigational decision support system. The necessary scope of work to build such system is defined. The proposed integrated decision support system NAVDEC fits such concepts as e-navigation, e-maritime and intelligent marine transport systems that reflect global trends in the development of navigational systems, widely using modern information communication technologies.

Keywords: sea transport, navigation, decision support system.

1 Introduction

Information technologies available today open increasing possibilities of building systems supporting decision processes in various fields of human activities. This also refers to maritime transport. The use of information technologies in maritime transport is of key importance from the viewpoint of navigational safety enhancement and transport efficiency.

The complexity of decision making processes results from, inter alia, the need to acquire, analyze and process great amounts of data and from time restrictions while choosing a solution (decision making). This, in turn, makes taking decisions by navigators difficult and may lead to dangerous situations, which is confirmed by reports of marine accidents and disasters. Verdicts of maritime courts indicate that wrong decisions – human errors – are among most frequent causes of marine accidents and disasters that have grave consequences: loss of life and health, material losses due to sinking of or damage to the ship and/or cargo, threats and damage to the natural environment.

Information technologies enable creating efficient navigational equipment and systems that, using complex computing algorithms, gather, process and present navigational information to the navigator. For several years such systems have been used on ships and in shore-based centres. Navigational systems in use today mainly execute information functions and to a certain extent assist in safe ship conduct. They automate the information acquisition from various sources and integration, making navigator's decision easier. Concepts such as e-maritime, e-navigation, Maritime ITS

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[3, 4, 9, 11] show that Information Communication Technology (ICT) will have increasingly wider applications in sea transport. As a result, there is a trend to transform navigational information systems into navigational decision support systems. Their functions, apart from acquisition, integration, processing and presentation of information, include situation analysis and assessment, generation of solution/s to dangerous situations and the recommendation of these solutions to the navigator as well as shore-based traffic personnel responsible for vessel traffic management.

2 The Navigational Decision Support System NAVDEC

2.1 Description of the System

Human errors should be reduced or eliminated wherever possible, in order to provide for possibly high navigational safety level. This can be achieved only by equipping ships and land based centers with tools that, apart from information functions, will work out solutions to collision situations accompanied by adequate explanations. Primary functions of the navigational decision support system are the following:

- automatic acquisition and distribution of navigational information,
- analysis of a navigational situation ,
- alarming of dangerous situations and indicating the current level of navigational safety, based on criteria commonly used by expert navigators,
- solving collision situations, including automatic determination of an optimal manoeuvre and trajectory in collision situations,
- explanation of the optimal manoeuvre choice,
- interaction with the navigator.

Developed at the Maritime University of Szczecin, the navigational decision support system NAVDEC [8, 10] comes as the first navigational tool worldwide that apart from information performs functions typical of decision support systems. Its innovative functionalities, significantly extending the performance of devices generally carried by ships, have now a status of patent applications.

The NAVDEC system supplements the range of shipboard navigational devices. This real time system handled by the navigator monitors its ship and the environment and records information on the present navigational situation. On this basis the system identifies and assesses the navigational situation (processing) and works out solutions (decisions) assuring safe navigation. The correct functioning of the system requires interoperability with shipboard standard equipment and systems such as: log, gyrocompass, ARPA (Automatic Radar Plotting Aids), GNSS (Global Navigational Satellite System), AIS (Automatic Identification System), ENC (Electronic Navigational Chart), sources of current navigational data (Fig. 1). Like to the ECDIS system (Electronic Chart Display and Information System) the NAVDEC (Fig. 2) it provides on-screen presentation of bathymetric data from an electronic chart, an image of surface situation from a tracking radar, positional information from the AIS and GNSS receivers. It also determines movement parameters of targets in vicinity and presents them the navigator.

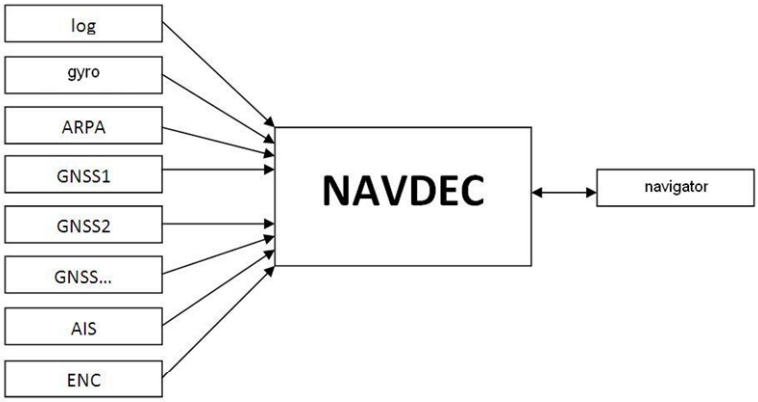

Fig. 1. A diagram of the NAVDEC environment [10]

The data defining navigator's and other ships' (targets) movement parameters make up a basis for effective solutions to collision situations. The accuracy of data presented to navigators is of major importance for their correct situation assessment and decisions to be made. For this reason the NAVDEC system performs the fusion of own ship data (measurements from a number of shipboard GNSS receivers are used) and integration of data on targets from alternative sources (tracking radar, AIS) [1, 10].

Fig. 2. The NAVDEC in use: the m/v Nawigator XXI [10]

Among new features of the NAVDEC is its ability to analyze and assess the navigational situation done in relation to all other or selected targets located within eight nautical miles. This is one of the decision making steps normally taken by the navigator, simply because the situation assessment takes into account relevant regulations. Thanks to the NAVDEC system the navigator is currently advised on the

identification of an encounter situation in compliance with the Collision Regulations. This is a considerable aid, particularly in heavy traffic, although collisions of one-to-one ships in the open sea are known (m/v Gotland Carolina and m/v Conti Harmony in 2009).

When a collision situation is developing, it is the navigator who decides on a safe manoeuvre, the one that solves a given situation. The navigator decides on actions to be taken (alter course and/or speed) and the manoeuvre parameters: moment to begin it and values of course and/or speed alteration. The navigator may specify a safe course, on which the target will be passed at a preset range considered as safe. To date, the NAVDEC has been the only tool worldwide capable of performing this function (Fig. 3). The NAVDEC 'knows' the Collision Regulations [2], principles of good sea practice, as well as criteria used by expert navigators [5, 6, 7, 8]. Apart from one specific solution the system submits, alternative solutions complying with the regulations are also determined (possible range of course and/or speed alterations). Moreover, the system explains why a given is proposed, which refers to all targets or selected ones.

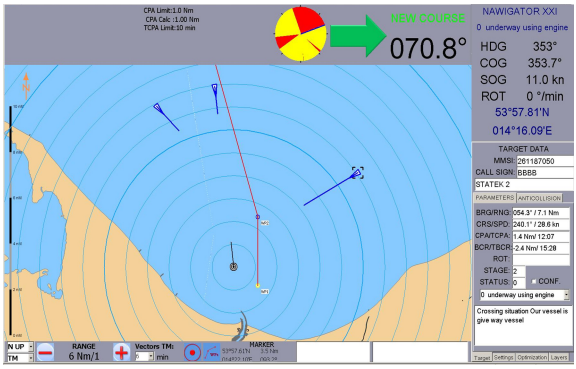

Fig. 3. The NAVDEC interface illustrating a collision situation [10]

Although the system proposes solutions and justifies them, it does not relieve the navigator from responsibility, but make his/her decision much easier to make. However, it is possible to make the ship control automatic by direct connection of the NAVDEC with the autopilot, steering gear, main engine, engine telegraph and controllable pitch propeller.

2.2 Comparative Analysis

Navigational systems installed on ships of the global fleet serve mainly information functions and correspondingly, to some extent provide an aid in safe vessel conduct. However, none of the known systems displays to the navigator ready solutions to a collision situation that are worked out in relation to all vessels in vicinity of their ship. This considerably limits decision support, consequently it limits the effectiveness of collision avoidance.

Today the navigational bridge of a ship is fitted with devices intended to help the navigator to sail safely. The ARPA (Automatic Radar Plotting Aid), a commonly used tracking radar is a marine tool for decision support in collision situations. However, the ARPA is sometimes ineffective due to its numerous limitations.

The NAVDEC has the following advantages in comparison to the tracking radar, presently used on ships for calculating encounter parameters and working out an anti-collision manoeuvre:

- incorporates the Collision Regulations, for both good and poor visibility,
- plans a manoeuvre also for the ship located in the radar blind area,
- the operator is immediately notified about a manoeuvre started by another ship thanks to information on target's rate of turn,
- needs just a few seconds to calculate the encounter parameters. On the other hand, the tracking radar, according to test situations defined by the IMO (International Maritime Organization), after one minute of tracking presents the CPA (Closest Point of Approach) with a one nautical mile accuracy. After three minutes, the maximum allowable error of CPA and TCPA (Time to Closest Point of Approach) calculated by the radar may amount to, respectively, 0.3 Nm and 0.5 minute. These tolerances are given with a 95% probability,
- more accurately calculates the encounter parameters, by:
    - taking account of the ship's size thanks to information on the position of the antenna, received from the AIS (*Automatic Identification System*),
    - use of GPS (*Global Positioning System*) / DGPS (*Differential GPS*) for position determination,
- takes account of the ships' sizes while planning an anti-collision manoeuvre,
- calculates new courses and speeds of own ship, such that other vessels will be passed at a preset CPA.

The ECDIS (Electronic Chart Display and Information System) is another information system commonly used on sea-going ships, often referred to as an electronic chart. Apart from displaying the positions and movement vectors of own ship and targets (vessels in vicinity), it also allows to, inter alia, obtain information on depths, aids to navigation and coastline. However, it is only an information system. The NAVDEC system moves a step forward (Fig. 4). Besides providing the navigator with the same scope of information, necessary for safe navigation, as the ECDIS, NAVDEC recommends ready solutions enabling the ship to safely pass vessels or stationary objects. Moreover, these solutions take into account ship's manoeuvring ability and the present area restrictions, i.e. existing traffic separation schemes, shoreline and safe depths. NAVDEC is, therefore, a very useful decision support system.

NAVDEC was developed to support navigators in decision making on board a sea-going vessel. At present, work is in progress on extending the functionalities of the system. It seems purposeful to undertake work on the introduction of NAVDEC functionalities to Vessel Traffic Services systems (VTS) operating on land.

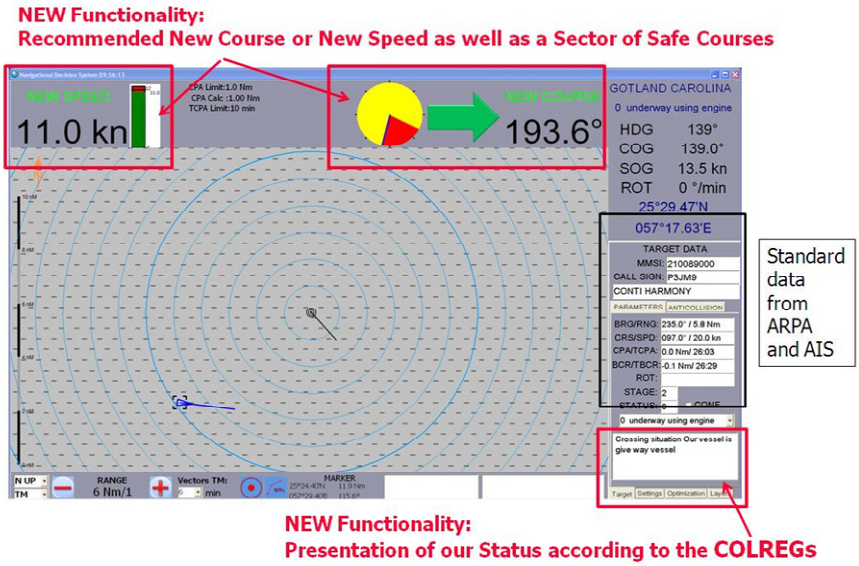

Fig. 4. Innovative functions on the NAVDEC interface [10]

3 A Concept of Integrated Navigational Decision Support System on Ships and in Land-Based Centres

3.1 The Navigational Decision Support System in a Land-Based Centre

VTS systems are information systems installed in centres responsible for vessel traffic monitoring and control. VTS stations were initially equipped with devices such as those on board ships: radars and ARPA systems. Today VTS centres operate specialist systems with such functions as are executed by shipboard systems: ARPA, ECDIS and AIS.

To increase their effectiveness these systems are supplemented with management modules that assist the operator in decision making (VTMS systems). VTMS systems combine three basic services of VTS: information, navigational assistance and vessel traffic management. The extension of system functions mainly refers to the issues of port complex management. Actions are being taken to integrate individual VTS and VTMS systems to enable their co-operation, so that larger areas could be covered within one VTMIS.

The broadening of information systems presently operated in VTS centres by adding the NAVDEC functionalities will enhance the scope of decision support offered by a land-based centre. Such extension will include:

- fusion and integration of navigational data available on board and at a land-based centre,

- analysis and assessment of a navigational situation that account for the Collision Regulations,
- automatic generation of solutions to collision situations, using special computational algorithms, including optimization algorithms,
- explanation of the present navigational situation based on the navigational knowledge base (Collision Regulations, principles of good sea practice, criteria of navigational situation analysis and assessment used by expert navigators),
- justification of the proposed manoeuvre.

This will allow to solve situations involving a group of indicated objects (vessels) in accordance with regulations in force. At the same time, it will be possible to find solutions from the viewpoint suggested by the object operator (Fig. 5), similarly to the NAVDEC system on board vessel.

a) b)

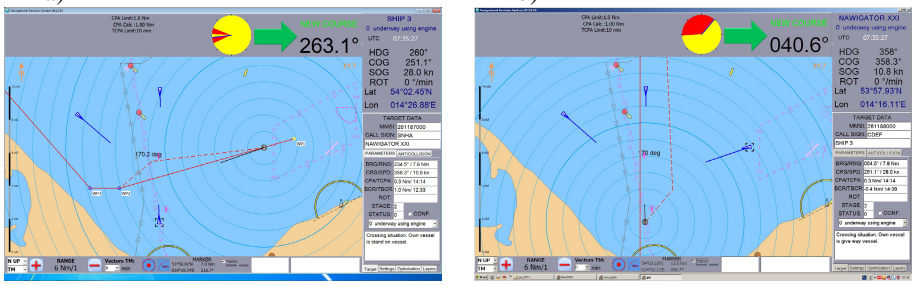

Fig. 5. Presentation of a navigational situation in the NAVDEC system at a land-based entre: a) viewpoint – chosen ship Nawigator XXI; b) viewpoint - chosen ship 3

3.2 The NAVDEC Platform

Safe and effective execution of a transport task involves information exchange and coordination of activities between vessel navigators and land-based centre personnel. There are various consequences of lacking integration of decision support systems on ships and in land-based centres:

1) different scope of available information,
2) possible differences in the identification and assessment of a navigational situation,
3) restricted range of automatic ship-ship and ship-shore-ship information exchange,
4) decision support systems on board and ashore may generate different solutions to the same navigational situation.

All these disadvantages can be eliminated by building a uniform, joint platform of the integrated decision support system NAVDEC, incorporating vessels at sea and land-based centres of vessel traffic management. (Fig. 6).

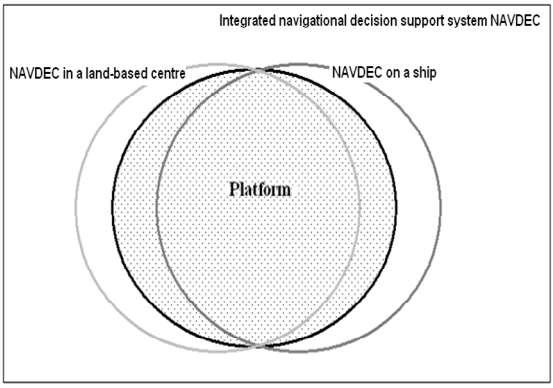

Fig. 6. Integrated navigational decision support system NAVDEC

The platform will include joint modules for shipboard and land-based systems plus tools for the integration of both systems. The joint modules will be, among others, the library of navigational procedures, interpretation of COLREGs, rules and criteria for navigational situation analysis and assessment used by navigators. The platform will also have specialized interfaces that will enable using services that are different for ships and land-based centres. One essential component of the platform should be a subsystem of automatic ship-ship and ship-shore-ship communication. The proposed integrated decision support system NAVDEC will enable automatic communication between users of decision support systems on ships and in VTS centres. It will also incorporate other traffic participants, even if automatic communication with them is not available.

The NAVDEC platform should be equipped with elements that do not exist in either shipboard or land-based decision support system, e.g. interfaces for external systems.

The following actions are required for the development of an integrated navigational decision support system NAVDEC:

- extension and adjustment of the existing NAVDEC modules for shipboard use,
- building of special NAVDEC modules for a land-based centre,
- development of special interfaces enabling using the services different for the ship and land-based centre,
- development of interfaces for external systems,
- development of automatic communication module, including:
  - rules of communication and cooperation between objects (vessels, land-based centres),
  - ontology of navigational information,
  - algorithms of information acquisition and interpretation,
  - algorithms for a dialog between objects,
  - negotiation principles and procedures,

- methods of ontology representation to fit standards used in software engineering,
- relevant knowledge bases,
- operator-system communication model,
- model of the scope and form of information presented to the operator.

Similarly to information systems of this type, the integrated navigational decision support system NAVDEC has to guarantee data storage and transmission security and varied range of personnel access.

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