Scientific Journals
Maritime University of Szczecin

Zeszyty Naukowe
Akademia Morska w Szczecinie

2012, 30(102) pp. 170–173

2012, 30(102) s. 170–173

Determination of the right-of-way of sailing ships for use in a navigational decision support system

Określenie pierwszeństwa drogi statków żaglowych dla potrzeb nawigacyjnego systemu wspomagania decyzji

Piotr Wołejsza, Janusz Magaj

Maritime University of Szczecin, Faculty of Navigation
Akademia Morska w Szczecinie, Wydział Nawigacyjny
70-500 Szczecin, ul. Wały Chrobrego 1–2, e-mail: p.wolejsza@am.szczecin.pl

Key words: algorithmization of Colregs, sailing ships, decision support

Abstract
The determination of sailing ship's behavior accounting for the Collision Regulations plays an essential part in the choice of a decision procedure and the verification of its effect in navigational decision support systems. One of the basic aims of such systems is to provide procedures defining the direction of course alterations and/or speed accounting for the regulations in force. There are a number of publications on the subject. Based on the performed analysis of the collision regulations and on navigators' and sailors' knowledge the authors have developed an anti-collision algorithm for close quarters situations in the open sea in good visibility.

Słowa kluczowe: algorytmizacja MPDM, statki żaglowe, wspomaganie decyzji

Abstrakt
Określenie sposobu zachowania się statku żaglowego z uwagi na przepisy prawa drogi odgrywa istotną rolę przy wyborze procedury decyzyjnej oraz weryfikacji wyniku jej działania w nawigacyjnych systemach wspomagania decyzji. Zasadniczym celem jest opracowanie procedur określających kierunek zmian kursu lub/i prędkości z uwzględnieniem obowiązujących przepisów. Istnieje szereg publikacji dotyczących tego zagadnienia. Na podstawie przeprowadzonej analizy przepisów MPDM oraz w oparciu o wiedzę nawigatorów i żeglarzy opracowano algorytm manewru antykolizyjnego dla sytuacji spotkań statków żaglowych na akwenach otwartych w warunkach dobrej widzialności.

Formulation of the problem

One of the main functions of navigational decision support system is the development and presentation of a safe trajectory of a ship in a collision situation. Such systems should be based on the knowledge and experience of experts – navigators. That is why the construction of these systems should be based on an analysis of real decision making processes related to the sea-going ship control.

When a navigational danger appears (object / vessel), the following stages of navigator's behaviour can be distinguished [1]:

1) detection and identification of an object;
2) situation analysis and assessment;
3) selection of the method for solving a collision situation;
4) determination of manoeuvre parameters;
5) performance of an anti-collision manoeuvre;
6) return manoeuvre;
7) control of manoeuvre performance.

The first stage is executed by systems of object acquisition and identification available on board.

In the second stage it can use criteria of navigational situation assessment: closest point of approach, ship domain or indicators of navigational

safety level. In order to develop and execute a preventive manoeuvre it is necessary to determine a set of feasible decisions. This also refers to a return manoeuvre.

The set of feasible decisions is determined by: regulations in force, ship's manoeuvrability and the safety of personnel, ship, cargo and the environment. In this connection, an analysis of a current navigational situation has to account for legal regulations, the ship has to comply with. Based on Rule 12 of the Collision Regulations and navigators' and sailors' knowledge, an algorithm for encounters with sailing ships in open waters in good visibility has been developed. For the correct qualification of the situation, taking wind direction into consideration is of key importance.

Determination of wind direction

The anemometer is a device that automatically determines wind force and direction and delivers these data to a decision support system. The anemometer transmits the following NMEA messages:

$WIMWV – Weather Instrument Wind Speed and Direction. Speed and direction (angle) of real wind.

$WIMWV,37.0,T,11.5,N,A*24

These data denote:
37.0, T – real wind angle;
11.5, N – speed of real wind in knots;
*24 – checksum preceded by a star.

$WIVWR – Relative Wind Speed and Angle.

$WIVWR,82.0,R,11.5,N,5.9,M,21.3,K*64

These data denote:
82.0, R – relative wind angle;
11.5, N – relative wind speed in knots;
5.9, M – relative wind speed in m/s;
21.3, K – relative wind speed in km/h;
*64 – checksum preceded by a star.

From the viewpoint of collision avoidance automation, information on real wind is more important, i.e. information contained in a message starting from $WIMWV. If such data are absent, it should use messages starting with $WIVWR. Then the information on real wind can be obtained by superimposing the relative wind and ship movement vectors. To eliminate single errors in wind direction measurement, the system averages results received from the last ten measurements.

Determination of the right-of-way

The developed algorithm has been incorporated into the algorithm for decision support system algorithm presented in [1, 3] and other works. Rules 13, 14, 15, 16, 17, 18 and 19 were included in the original algorithm. Addition of Rule 12 makes complete the set of rules on passing vessels included in chapters 2 and 3.

To verify the correct operation of the algorithm six test situations were prepared. Northwest wind was assumed in all the situations. All vessels in simulations have a status of "underway sailing".

Situation 1

Our ship: course 000º, speed 5 kn
Bearing on and distance to target 270º, 1 Nm
Course and speed of target 045º, 7 kn

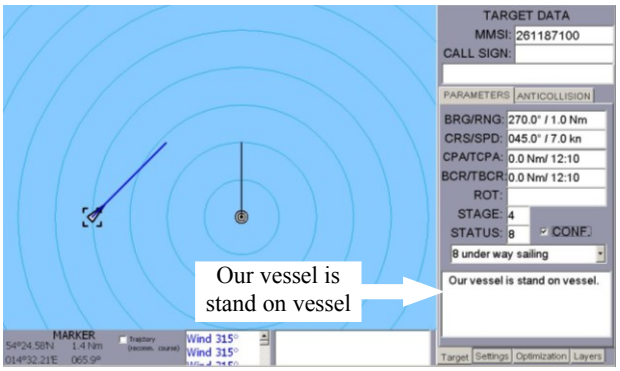
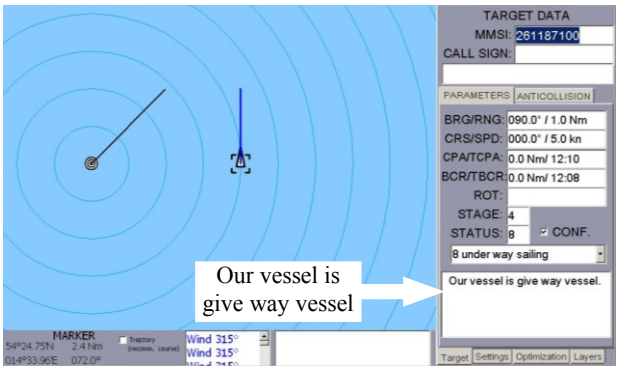


Fig. 1. Qualification of the encounter according to the COLREGs
Rys. 1. Kwalifikacja sytuacji spotkania według MPDM

Situation 2

Our ship: Course 045º, speed 7 kn
Bearing on and distance to target: 090º, 1 Nm
Course and speed of target: 000º, 5 kn



Rys. 2. Qualification of the encounter according to the COLREGs
Rys. 2. Kwalifikacja sytuacji spotkania według MPDM

Situation 3

Our ship: Course 090º, speed 7 kn
Bearing on and distance to target: 044º, 1 Nm
Course and speed of target: 180º, 7 kn

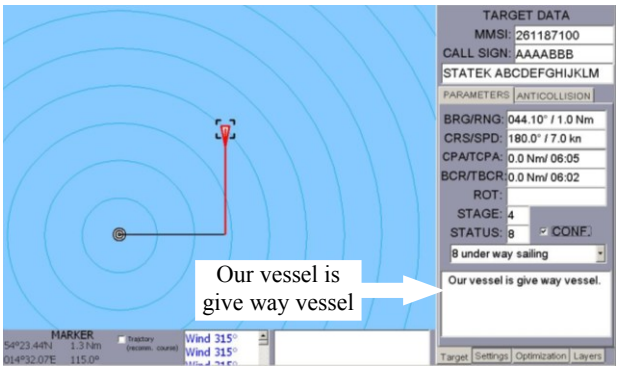


Fig. 3. Qualification of the encounter according to the COLREGs
Rys. 3. Kwalifikacja sytuacji spotkania według MPDM

Situation 4

Our ship: Course 270º, speed 5 kn
Bearing on and distance to target: 224º, 1 Nm
Course and speed of target: 000º, 5 kn

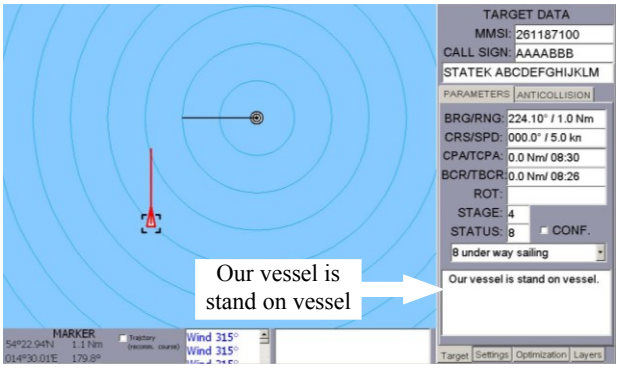


Fig. 4. Qualification of the encounter according to the COLREGs
Rys. 4. Kwalifikacja sytuacji spotkania według MPDM

Situation 5

Our ship: Course 270º, speed 5 kn
Bearing on and distance to target: 000º, 1 Nm
Course and speed of target: 225º, 7 kn

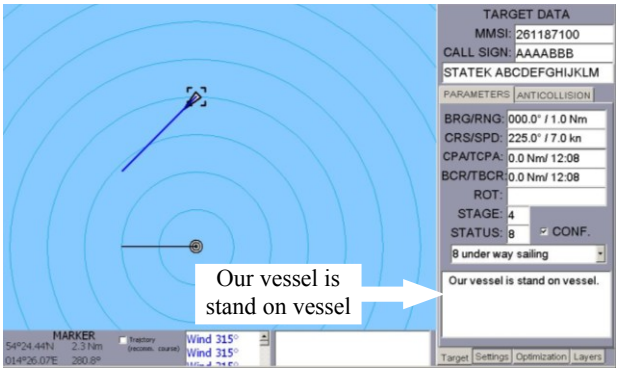
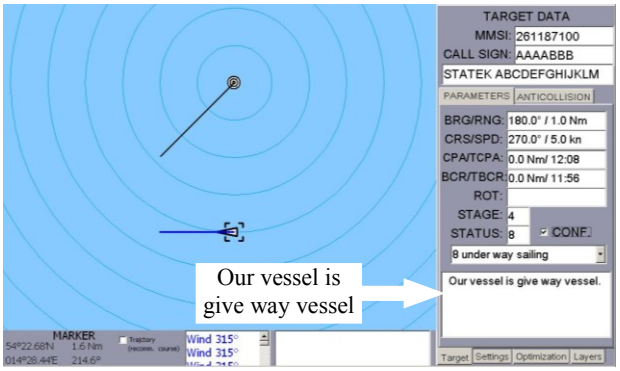


Fig. 5. Qualification of the encounter according to the COLREGs
Rys. 5. Kwalifikacja sytuacji spotkania według MPDM

Situation 6

Our ship: Course 225º, speed 7 kn
Bearing on and distance to target: 180º, 1 Nm
Course and speed of target: 270º, 5 kn



Rys. 6. Qualification of the encounter according to the COLREGs
Rys. 6. Kwalifikacja sytuacji spotkania według MPDM

Conclusions

The above presented situations have been devised to test all possible configurations of encounters involving two sailing ships. In the first situation both ships have wind on port side. Our ship is located to leeward of the target and thus has the right of way. In the second situation both ships also have wind on port side. This time our ship should keep out of the way, as the target is to our leeward. In situation 3 our ship is having port tacks aboard (wind on port side) and should give way to the target having wind on starboard. In situation 4 our ship has the right of way, having wind on starboard side, while the target has wind on port side. In figure 5 both vessels have wind on starboard side. The target vessel should keep out of our way to avoid collision as it is to our windward. In the last situation with both ships on the same starboard tacks, our ship is to windward and therefore should give the way.

In all presented situations the system correctly responded to an encounter of two sailing ships, which confirms the correct operation of the algorithm. The algorithm has been incorporated into the Navigational Decision Support System [2, 7, 8], thus broadening the functionality and quality of the system.

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