Assessment of the situation of convergence of ships at sea on the basis of COLREG

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Abstract. The problem of estimating the navigational situation in case of convergent ships at sea is considered. The algorithm of estimation of a situation of approach of ships according to COLREG is offered with use of the information on mutual positioning and elements of movement of ships. An algorithm for determining the mutual responsibilities of ships on the basis of information on the navigational status of ships obtained by AIS, and the situation of their convergence is proposed. The complex estimation of situation in a group of ships is offered in the form of a full connected directed graph of situations defining the degree of danger and mutual obligations according to COLREG of each of the ships in this group.

1 Introduction

This paper deals with one of the most important problems of navigation, the safe divergence of ships at sea. An aspect of this complex problem is the task of assessing the rendezvous situation. This paper deals with the situation assessment based on COLREG, as well as determining the degree of danger of vessel collision. This task will be performed automatically by the situation assessment module as part of the automatic vessel rendezvous system.

Assessment of situation in normal visibility situation shall be carried out in accordance with Section 2 "Navigation of vessels in sight of each other", in particular Rules 13, 14, 15, 16 and 17 [5].

The situation assessment module must determine on the basis of measured parameters what navigation situation is realized for each of the vessels in sight, as well as give a comprehensive assessment of the navigation situation. At that point fuzzy logic is used. And also tasks of identification of mutual obligations of ships, based on rules of Section 2 "Navigation of ships being in sight of each other", in particular on a Rule 18 [10] are considered and realised.

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2 Methods and materials

Based on the COLREG section 2 rules "Navigation of vessels in sight of each other", the following encounter situations have been identified and are described in Table 1 [5, 6].

Table 1. List of navigation situations according to COLREG

ID	Linkup situations
A	Situation of convergence on each other
B	Cross-course situation on the right
C	Cross-course situation on the left
D	Situation overtaking the target
E	Situation overtaking our vessel
F	The situation of off-course
G	Situation on a parallel course
H	Situation by a parallel counter course

The following rules from section 2 have been allocated to the list of navigational situations. Navigation of vessels in view of each other:

Rule 13: Overtaking.
Rule 14. Situation of approaching ships coming straight at each other.
Rule 15. Situation of crossing courses.
Rule 16. Actions of a ship giving way.
Rule 17: Actions of a ship that is giving way.

2.1 List of measurable navigation parameters

The list of measurable parameters includes those that can be obtained from, or calculated from, shipboard systems. These data include:

K_o - own ship's course,
K_c - target course,
KY_c - course angle,
KY_o - course angle from the target to our vessel.

2.2 The task of identifying the navigational situation from given navigational parameters for two ships

This problem is solved using indistinct boundary methods. For this purpose, an indistinct parameter nechlog [1] is introduced. It defines the indistinct area around the boundary of the situation.

The knowledge of the encounter situations is contained in the generated knowledge base. They define the clear boundaries of the situations. The use of fuzziness allows to blur these boundaries. Thus, two encounter situations (with their own weights) are possible at sector boundaries simultaneously [2, 3].

In the module of situation estimation by values of measured navigation parameters a situation or a pair of situations with their weights is defined.

$$< KY_o, KY_c > \rightarrow \{< Sit_1, P_1 >, < Sit_2, P_2 >\}$$

Sit_1, Sit_2 - Linkup situations;

P_1, P_2 - the probabilities of the situations;

In the case of a sector boundary, the set will contain two encounter situations with corresponding weights.

A schematic of the algorithm for determining an encounter situation is shown in Figure 1

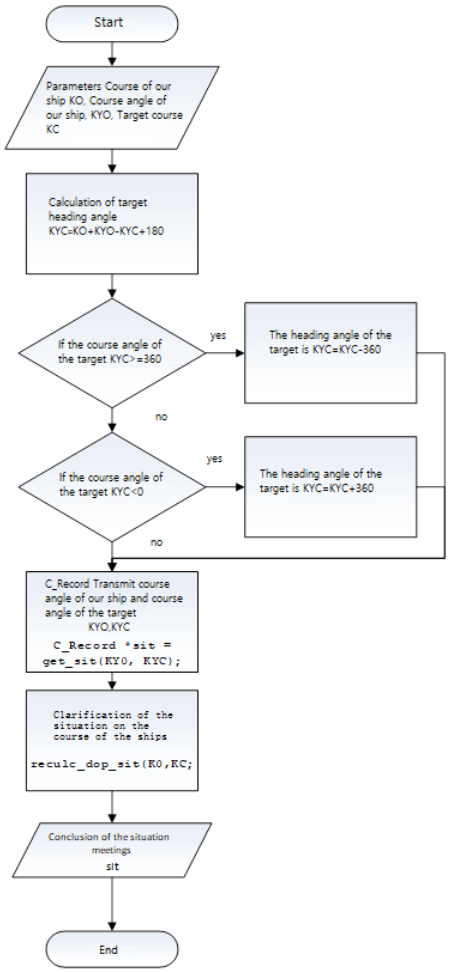

Fig. 1. Aggregated algorithm for calculating an encounter situation.

2.3 Mutual obligations of the vessels

Under the International Regulations for Preventing Convergence at Sea (COLREG-72) an algorithm for identifying the mutual responsibilities of ships has been developed, based on the rules of Section 2, "Navigation of ships in sight of each other", in particular Rule 18.

COLREG identifies the mutual responsibilities of ships of different statuses when they meet.

The priority algorithm is constructed as a decision tree based on measured vessel speed V and its navigational status, which can be obtained from the AIS system. Based on this data, the vessel status is determined according to COLREG [7, 8].

The scheme of the COLREG status determination algorithm is shown in Figure 2

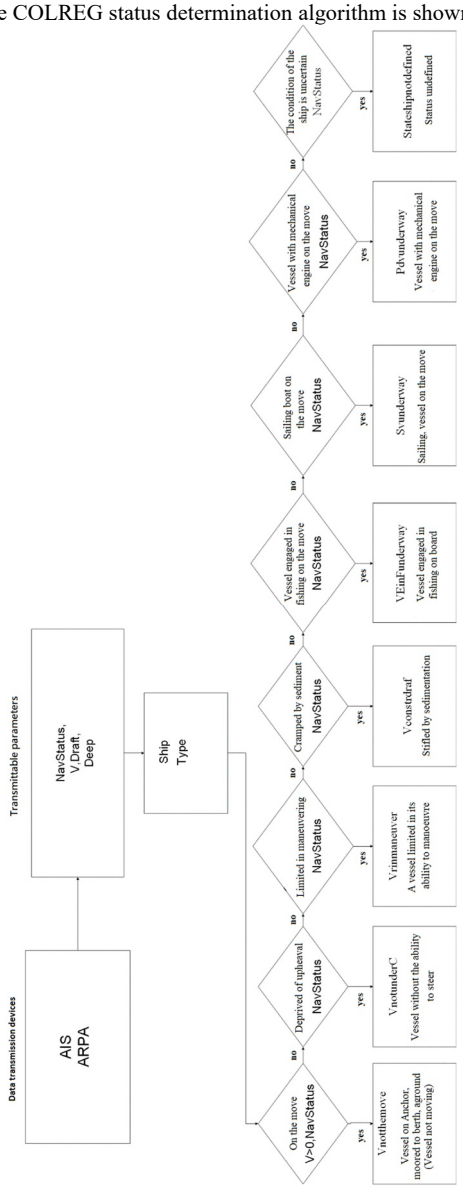

Fig.2. Scheme of the algorithm for ship status determination

3 Results

Taking into account the above information and analysis of the statuses of all target ships (and considering the own ship's status), the mutual responsibilities of all ships involved in the situation with respect to each other can be determined.

Figure 3. shows the mutual responsibilities of vessels under Regulation 18 (COLREG).

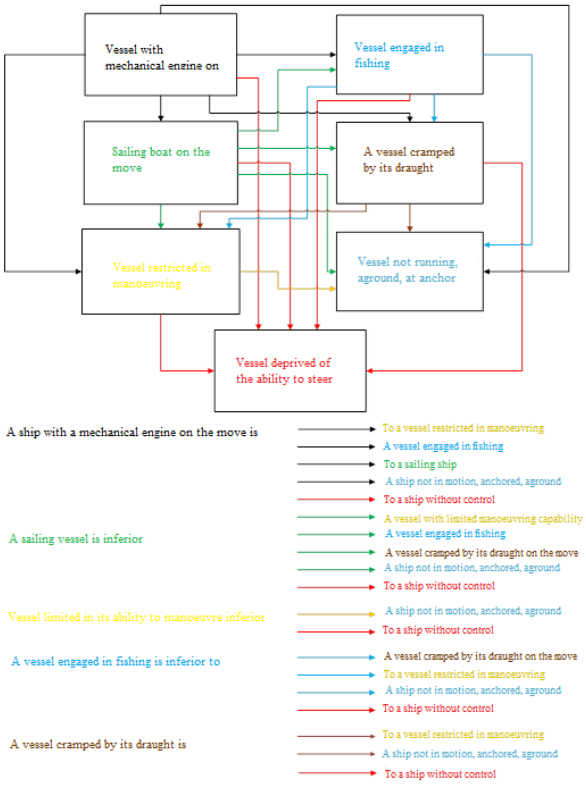

Fig. 3. Mutual responsibilities of the vessels under COLREG

In addition, the task of determining the mutual danger of target ships moving relative to each other is solved. As a result, a fully connected directed graph of the relationship between all target ships is constructed. This graph depicts:

- the mutual responsibilities of the vessels according to COLREG,
- the degree of danger (on a <RYG> scale) with respect to each other.

The output of such a graph will allow the navigator to adequately assess the close approach situation according to COLREG [11].

An example of a situation graph is shown in Figure 4.

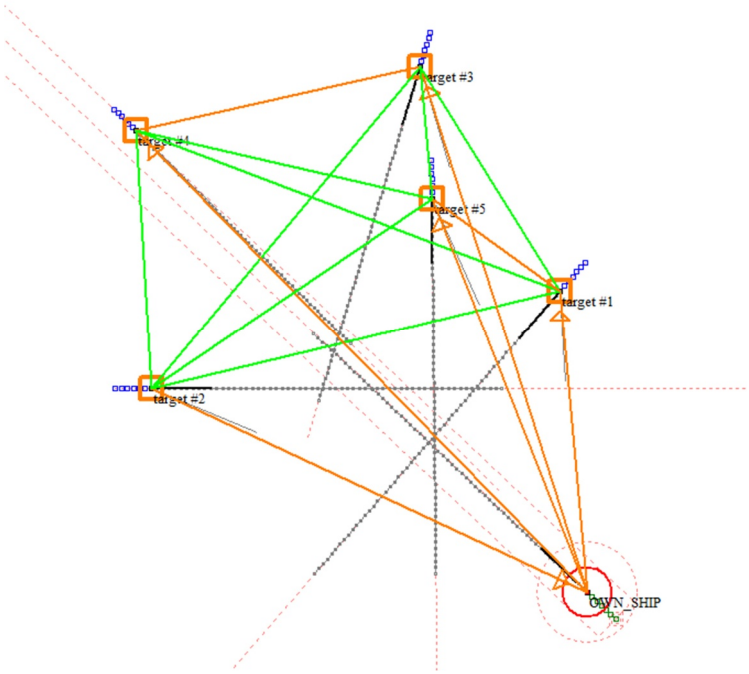

Fig. 4. Example of a situation graph for several ships

A scale of three categories RYG = <RED><YELLOW><GREEN> (<hazardous><attention><safe>) is used to assess the degree of hazard for each of the objects of the combined set I. Each potentially hazardous object (target ship, navigational object) is assigned to one of the categories depending on the established vessel safety zones, calculated shortest approach parameters, and the dynamics of these parameters. For this purpose, two zones are introduced: danger zone (convergence at a distance of less than D^* is considered dangerous and should be avoided) and the heightened attention zone (close to a distance of less than D^{**}, but more than D^* is considered to be potentially dangerous and requires the attention of the navigator). In addition, time T^* is introduced as the "horizon" of hazardous event accounting. The parameters T^*, D^* and D^{**} are substantially dependent on current sailing conditions and own ship's characteristics, and must be determined and set by the automatic vessel divergence system.

4 Conclusion

Algorithms for estimation of a situation of mutual approach of ships according to COLREG rules on information on navigational statuses of ships, and also parameters of movement of ships are offered in work. The issue of estimation of a degree of danger of approach of ships is considered. On the basis of the presented algorithms the complex estimation of a navigating situation in the form of the directed graph of situations can be constructed.

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