A Study on the Vagueness in sailing rule of COLREGs of Maritime Autonomous Surface Ships

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ABSTRACT

COLREGs are rules to prevent collisions at sea, and are composed based on the Qualitative rule. Despite the rules, maritime accidents continue to occur, and autonomous ships have appeared due to reducing human error of crew and technological development. In this process, the problem of collision avoidance between manned and unmanned ships emerged, and to solve this problem, an automatic collision avoidance algorithm based on COLREGs was developed. However, since COLREGs sailing rule are based on qualitative rules and Good Seamanship, their standards are different, and this standard created a difference between the standards and the crew's collision avoidance situation awareness. Therefore, in this study, the crew's perception of the collision situation based on COLREGs was identification, and the results were analyzed for the sailing rule between manned and manned ships or unmanned and manned ships. The result was analyzed that the navigator showed vagueness about the three collision avoidance models of COLREGs, and that it was different depending on the collision angle.

1. Introduction

The International Maritime Organization (IMO) entered into force in 1977 the Convention on International Regulations for the Prevention of Collisions at Sea (COLREGs) (IMO, 1972). CORLEGs are composed based on the Qualitative rule and Ordinary practice of seamen (Woerner, 2016; Porathe, 2019), and it is a rule that allows ships to navigate safely, avoiding risks centered on the decision-making of sailors at sea (Xue et al.) al., 2019). It is a common assertion that human error is the most important factor in merchant ships that directly affects safety and security at sea (Sharma et al., 2019), and that it is caused by lack of training and workload (Puisa, 2021; Yan et al., 2019). It is a known fact that human error must be reduced in order to reduce maritime accidents. Therefore, in recent years, it is changing from the existing ship operation mode centered on crew members to the unmanned mode (Sepehri et al., 2021; Ahvenjärvi, 2016; Ozturk and Cicek, 2019; Goerlandt, 2020). MASS is being developed through the 4th industrial revolution in technology development in several countries and research institutes (IMO, 2021), and research in the practical stage has recently been reported. If the unmanned and manned ships apply the same collision avoidance model, safe passage can be secured, but otherwise, there is always a risk of collision at sea. Therefore, many studies are developing manned and unmanned collision avoidance models according to COLREGs. The COLREGs classify the risk that a ship may collide into three models as shown in Figure 1 (IMO, 1972). It appears that the give-way vessel and the stand-on vessel, which perform the ship's evasive action according to the relative orientation, respectively, should be performed with the main ship as the center, or cooperative action. Based on this, the recent automatic avoidance algorithm of autonomous ships is based on the collision avoidance model of COLREGs, and this algorithm or system is to strictly follow this Rule. Because COLREGs are based on the Qualitative rule and ordinary practice of seamanship, this study aims to clarify the collision avoidance situation by identifying ambiguities in the navigation interpretation of COLREGs. Differences between collision avoidance models and interpretations should be treated as important because they can lead to direct marine accidents. Therefore, this paper intends to compare and analyze the results by examining the collision avoidance model applied to the existing autonomous ships and the perception of the navigator's collision situation.

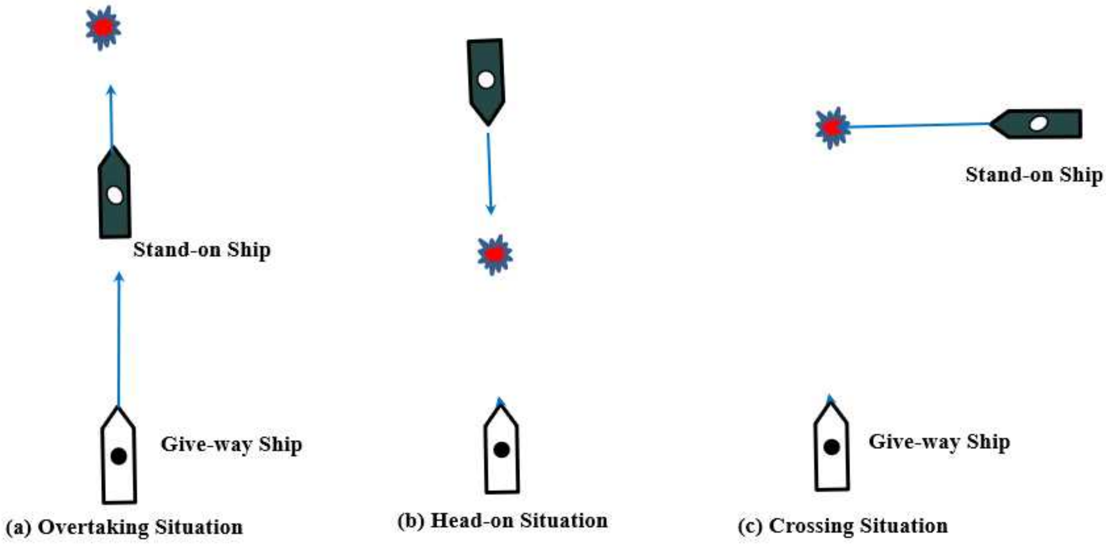

Fig. 1. COLREGs compliance collision avoidance model

2. Method

2.1. COLREGs

The International Maritime Organization (IMO) led to the latest revision of the International Regulations for the Prevention of Collisions at Sea (COLREGS) at an international conference held in London in 1972 to prevent collisions at sea (IMO, 1972). It is a common opinion of seafarers conducting actual voyages that a clear understanding of the regulations of COLREGs is necessary to prevent collision accidents at the time when autonomous vessels are realized (Porathe, 2019). COLREGs are written in general terms to be applied to as many situations as possible (Zhang et al., 2015), and require decision-making based on the experience of seafarers and maritime culture according to the rules (Chauvin et al., 2009). Therefore, it is necessary to check the factors that can cause an ambiguous situation by reviewing the literature on the three collision avoidance model situations and using the actual accident cases. The definition of navigation in the context of within-view of each other of the COLREGs is as follows. In COLREGs Rule 13 (c) and Rule 14 (c), Vagueness arises due to the expression of encountering situations, crossing situations, overtaking situations and crossing situations in any doubt as to whether such a situation she shall act accordingly. do. In addition, even in Rule 16 and Rule 17, a stand-on vessel does not give complete immunity for collision avoidance, and Vagueness occurs at the time of collision avoidance.

Rule 13, Overtaking

(a) Notwithstanding anything contained in the rules of part B, Sections I and II any vessel overtaking any other shall keep out of the way of the vessel being overtaken.

(b) A vessel shall be deemed to be overtaking when coming up with another vessel from a direction more than 22.5 degrees abaft her beam, that is, in such a position with reference to the vessel but neither of her sidelights.

(c) When a vessel is in any doubt as to whether she is overtaking another, she shall assume that this is the case and act accordingly.

(d) Any subsequent alteration of the bearing between the two vessels shall not make the overtaking vessel a crossing vessel within the meaning of these Rules or relieve her of the duty of keeping clear of the overtaken vessel until she is finally past and clear.

Rule 14, Head-on Situation

(a) When two power-driven vessels are meeting on reciprocal or nearly reciprocal courses so as to involve risk of collision each shall alter her course to starboard so that each shall pass on the port side of the other.

(b) Such a situation shall be deemed to exist when a vessel sees the other ahead or nearly ahead and by night she could see the masthead lights of the other in a line or nearly in a line and/or both sidelights and by day she observes the corresponding aspect of the other vessel.

(c) When a vessel is in any doubt as to whether such a situation exists she shall assume that it does exist and act accordingly.

Rule 15, Crossing Situation

When two power-driven vessels are crossing so as to involve risk of collision, the vessel which has the other on her own starboard side shall keep out of the way and shall, if the circumstances of the case admit, avoid crossing ahead of the other vessel.

Rule 16, Action by Give-way Vessel

Every vessel which is directed by these Rules to keep out of the way of another vessel shall, so far as possible, take early and substantial action to keep well clear.

Rule 17, Action by Stand-on Vessel

(a) (i) Where one of two vessels is to keep out of the way the other shall keep her course and speed.

(ii) The latter vessel may however take action to avoid collision by her manoeuvre alone, as soon as it becomes apparent to her that the vessel required to keep out of the way is not taking appropriate action in compliance with these Rules.

(b) When, from any cause, the vessel required to keep her course and speed finds herself so close that collision cannot be avoided by the action of the give-way vessel alone, she shall take such action as will best aid to avoid collision

2.2. Collision Avoidance model of MASS

The application of the collision avoidance model for autonomous ships is largely divided into whether or not COLREGs are considered (Benjamin et al., 2006). The collision avoidance model is shown in Fig. It is divided into sectors as shown in 2, and this sector is determined by the azimuth. Therefore, in this chapter, studies divided by azimuth on autonomously operated ships and collision avoidance algorithms were classified, and the collision avoidance model applied to current autonomous ships was confirmed based on the classification.

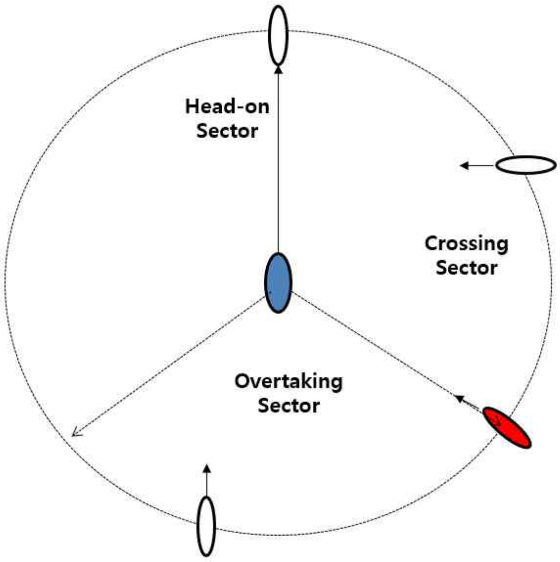

Fig. 2. Collision Sector applying for COLREGs

The result of examining the angle for the sector was divided into Head-on, Crossing, and Overtaking. Head-on ranged from 0 degrees to 120 degrees, Crossing varied from 90 degrees to 168 degrees, and Overtaking varied widely from 12 degrees to 135 degrees. (Li et al., 2021; Pietrzykowski, Wielgosz, 2021; Stankiewicz and Mullins, 2019; Maza and Arguelles, 2022; Silveira et al., 2021; Chun et al., 2021; Hu et al., 2020; Lee et al., 2021; Liu et al., 2019; Mizythras et al., 2021; Rong et al., 2022; Szlapczynski and Szlapczyns, 2016; Yim et al., 2017; Yuan et al., 2021; Zhang et al., 2015; Zhao and Roh, 2019; Zhai and Fu, 2021; He et al., 2017; Chen et al., 2015; Namgung and Kim, 2021; Sun et al., 2019; Shi and Zhen, 2022; Yim and Park, 2021; Hinostroza et al., 2019; Yu et al., 2022; Chai et al., 2017; Chen et al., 2018; Christian and Kang, 2017; Ma et al., 2021; Montewka et al.,2010; Rawson and Brito, 2021; Zhao et al., 2016; Benjamin et al., 2006; Bolbot et al., 2019; Pedersen et al., 2020; Woerner, 2016; Du et al., 2021; Gerlandt et al., 2015; Shaobo et al., 2020; Tam and Bucknall, 2013; Wang et al., 2020 Ha et al., 2021; Mou et al., 2020; Lu et al., 2022; Du et al., 2022; Zhang et al., 2018; Huang et al., 2019; Xin et al., 2021; Liu et al., 2021)

3. Collision situation awareness survey

The recognition of the crew's collision avoidance model specified the situation of the radar screen, which is the most important method to confirm the collision situation at sea. The cognitive identification survey was in the form of a questionnaire and the Likert 5-scale was applied. The subjects of the survey were seafarers, navigators and pilots, and the survey was conducted for half a month. An attempt was made to identify the ambiguity of the collision avoidance model recognized by seafarers using Google Forms.

In each question, No. 1-11 requested identification of the head-on situation and crossing situation, and No. 12-21 requested identification of the overtaking situation and crossing situation. Head-on situation asked for judgment about the situation from 0 to 20 degrees in front as confirmed in 2.2, and Overtaking asked for judgment about the situation through radar screens from 90 to 180 degrees. The answers to the questions were divided into 5 scales, as shown in Table 2.

4. Result and Discussion

A crew collision avoidance model recognition and identification survey were conducted, and the results for a total of 101 people are shown in Fig. Same as 3 and 4. It took a total of 20 days, and the survey was conducted as a revised survey by revising the original survey version with the help of an experienced captain. The scope and content necessary for the face-to-face survey were freely conducted through the participants' voluntary opinions, and the final questionnaire was confirmed through strict confidentiality based on the results of the preliminary survey. It was classified on a Likert 5-point scale for 21 questions, and the median and scatter plots are shown in the figure.

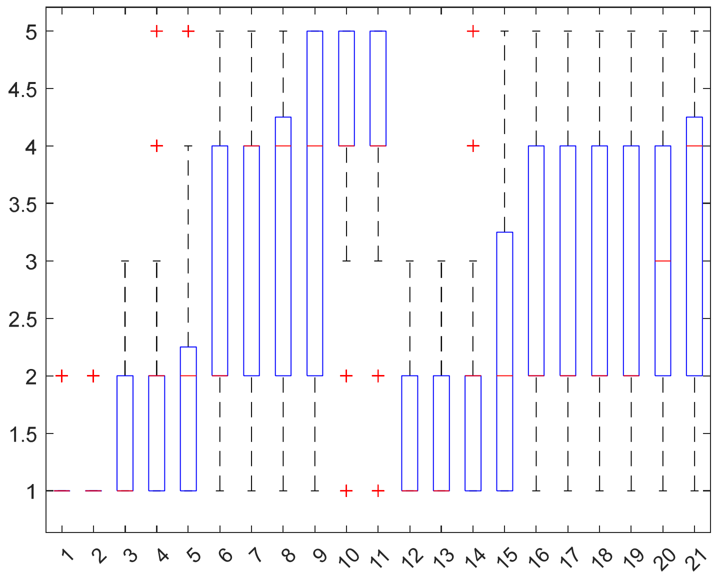

Fig. 3. Result of Survey-1

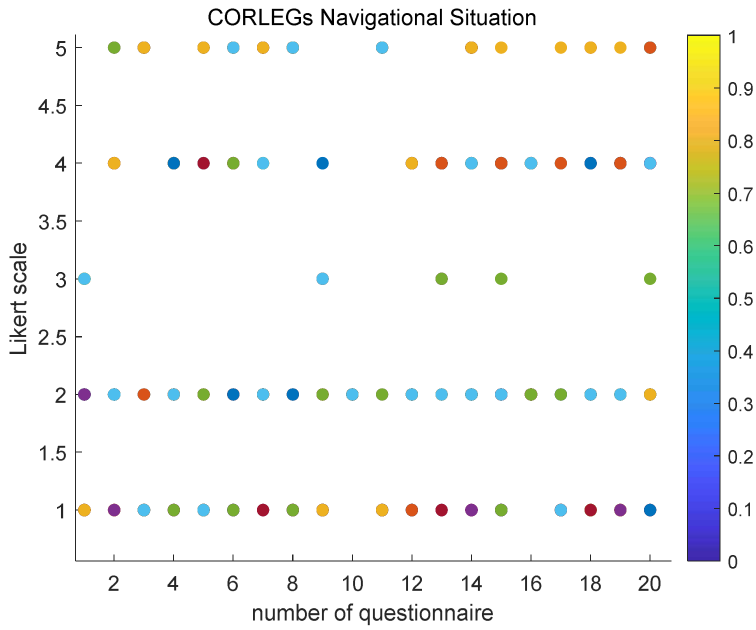

Fig. 4. Result of Survey -2

The correlation analysis results are shown in Fig. Same as 5. It shows the confusion correlation matrix for questions 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, age, tonnage, and rank.

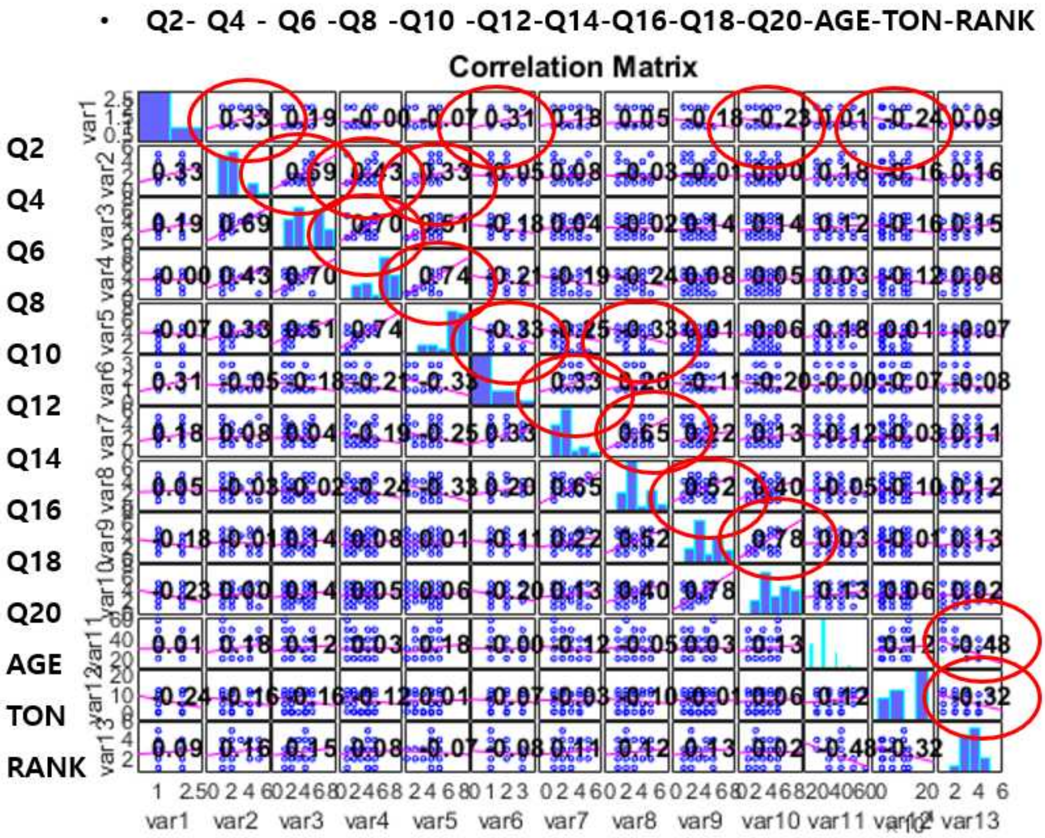

Fig. 5. Result of Correlation Anaylsis

5. Conclusion

The purpose of this study is to clarify the collision avoidance situation by identifying the ambiguity in the navigation interpretation of COLREGs. A collision avoidance model recognition and identification survey were conducted for the navigator, and the results were compared and analyzed in Head-on and Crossing, Crossing and Overtaking situations. As a result of the analysis, the navigators were not sure whether to apply the head-on situation to the vessel approaching from 008 degrees from the straight line or whether to apply the navigation for the crossing situation. The navigators were not sure whether to apply the overtaking situation or the navigation for the crossing situation to the vessel coming from 160 degrees from the straight line. In addition, although navigators tended to apply the approaching crossing situation navigation at 014 degrees to 090 degrees from the straight heading, ambiguity was found in the navigation interpretation due to the large standard deviation. As a result, it is understood that the range in which sailors have confidence in the application of navigation is narrow, and as this ambiguity increases, it is judged that the tendency to avoid the risk of collision by taking an active avoidance action rather than a passive avoidance action is expected to become stronger.

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