Research on Decision-Making Criteria for Collision Avoidance of Autonomous Ships in Restricted Areas

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論 文 名　：　Research on Decision-Making Criteria for Collision Avoidance of Autonomous Ships in Restricted Areas
（制限水域を航行する自律航行船舶の衝突回避のための意思決定基準に関する研究）

区　　分　：　甲

論　文　内　容　の　要　旨

For maritime safety, it has been continuously tried to reduce collisions between ships at sea through various studies and revisions of regulations in marine field. But collisions still happen constantly at sea. In order to prevent collisions between ships, the International Maritime Organization (IMO) has enacted the International Regulations for Preventing Collisions at sea (COLREGs) and it has been continuously revised. The COLREGs states obligation of a ship in specific situations. When ships are encountered, obligations of a give-way ship and a stand-on ship are assigned to each ship. However, the COLREGs does not specify when and how to act in detail.

Because of the ambiguity of the COLREGs, interpretation of the phrases specified in the rule may differ from one person to another. This means that navigator's collision assessment cannot be objective. On the other hand, the advent of autonomous ships is expected recently. Since autonomous ships will be sailed by artificial intelligence (AI), objective collision assessment criteria are necessary for safe navigation. However, there are few studies suggesting criteria of numerical values for collision assessment. This study will interpret the COLREGS from the viewpoints of engineering and social sciences to provide specific values for AI decision-making in autonomous ships. What this study intends to suggest are "safe distance between two ships passing each other" stated in Rules 8 and 16 of the COLREGs and "timing of collision avoidance cooperative action by a stand-on ship" stated in Rule 17.

Safe distance is examined based on seafarers' awareness values which are obtained through interviews with them. Through engineering approach, many definitions of the safe distance have already been studied in form of ship domains. However, studies on criteria of the safe distance considering human awareness are rare and artificial intelligence is developed by learning human patterns. Therefore, ship domains research based on human awareness is necessary. In addition, by analyzing the awareness values of seafarers, this study finds out which awareness value has significant influence to form safe distance of each seafarer.

Avoidance action timing of a stand-on ship is also examined in this research. Simulations

of manoeuvring motions of two ships which have roles of stand-on ship and give-way ship respectively in situations where a collision cannot be avoided with an action of a give-way ship are conducted. Based on the simulation results, the action timing of a stand-on ship when cooperative collision avoidance action is required is proposed.

This thesis consists of six chapters.

Chapter 1 introduces the background and purpose of this study.

Chapter 2 presents a methodology for determining seafarers' awareness-based ship domain. It addresses how to examine the awareness values of seafarers and how their awareness values are formed. Situation awareness (SA) theory and cognitive science are introduced to analyze the awareness values. Therefore, SA theory and cognitive science are also explained.

In Chapter 3, a brand-new ship domain model based on the awareness values of seafarers is proposed. The ship domain model is compared and analyzed with other existing ship domain models to examine its practicability. Parameters that have significant influence on the formation of the awareness values of seafarers are analyzed through the SA theory and cognitive science.

Chapter 4 demonstrates the computation method for presenting cooperative avoidance action timing of a stand-on ship. The action timing of a stand-on ship is generated through simulations of two ships which in encountering situations. For conducting the simulations, scenarios of encountering situations, ship's trajectory data, and a collision assessment (CA) model are required. Therefore, the way in which the scenarios are set up and how the CA model is designed are explained. Ship trajectories are obtained by solving equations of ship motion numerically. Related ship's motion equations are also shown.

In Chapter 5, the results of collision assessment through the simulation studies are analyzed. In addition, reliability of the CA model is also verified. Finally, the cooperative action timing of a stand-on ship is proposed in the given scenario.

Chapter 6 summarizes the conclusions of this research and discusses future work related to this study.