[課程博士・論文博士共通]

博士学位論文内容要旨
Abstract of Dissertation

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論文題目 Title	A study of modeling ship's collision avoidance action using predictive algorithms		

Navigators perform duty assignments to ensure safe navigation and prevent maritime accidents. Maritime accidents are classified into 13 categories. The accidents include collisions, contacts, grounding, flooding, et cetera. Among maritime accidents, collisions are the most frequently occurring type of maritime accident. According to Japan Marine Accident Tribunal (JMAT), collision accidents account for 25% of all accidents. Collision accidents involve the collision itself and give rise to secondary issues like oil spills, casualties, and vessel damage. Therefore, it is essential to find solutions to reduce collision accidents and achieve safe navigation.

A collision accident is a physical collision between encountering vessels. In maritime law, it is defined as an act that causes damage to two or more ships or, people or property on different vessels due to navigational issues. To avoid collision accidents, navigators analyze the situation and consider courses of action. This process applies customary rules known as COLREG (International Regulations for Preventing Collision at Sea). COLREG is the fundamental set of rules used in collision avoidance. The rule has 41 regulations across six categories (Part A to F). They instruct navigators to use all available means to detect collision risks (Rule 5: Lookout). Navigators have no restrictions on their means, but some commonly known ones include DCPA (Distance at the closest point of approach), TCPA (Time to DCPA), navigational areas, performance, vessel specifications, speed, and relative bearing. The factor of individual experience influences the recognition of the risk of conflict using these factors. After recognizing the risk of collision, navigators need to assess the current encounter situation to decide on collision avoidance actions.

The navigation officer of a vessel on underway goes through a four-stage decision making process: information acquisition, situational analysis, decision-making, and action. Subsequently, they utilize personal skills, conventional rules, and knowledge to make avoidance decisions based on the acquired and analyzed risky situations. The collision prevention rules that form the foundation of specialized knowledge define only basic concepts and principles, allowing exceptions based on on-site judgment. Navigators' situational analysis and decisions are subjective and prone to errors. In particular, there have been reports that navigators' CPA-based situational analysis method when observing ARPA radar is unsuitable for predicting collision risks. This is because human experience and knowledge influence the interpretation of information. This error is reported as a significant cause of collision accidents. Various methods for reducing this error, as well as quantifying collision risks, have been reported. Various studies have been conducted on the establishment of collision avoidance algorithms. Such challenges include collision avoidance algorithms, collision risk indices, and domain models. There were challenges to quantify human behavior.

However, the following studies have not yet been performed.

The first is modeling how humans make collision avoidance decisions. Existing studies do not show the reflection of collision avoidance algorithms on human decisions. Furthermore, efforts to reflect human cognitive judgment have been based on data acquired in complex environments within the navigation system. It has been reported that navigation in this region must consider a smaller margin area, path width impact, and UKC impact and may be affected by specific traffic rules. It has also been reported that this area's voyage planning, monitoring, and navigation habits are different. Therefore, there is a need to construct and validate a model that predicts collision avoidance directions by reflecting figures from collision avoidance algorithms based on human-performed navigation data outside of port limit from a different perspective.

Second, modeling the outcome of the navigator's perception of the encounter situation after detecting the collision risk. The decision flow of the navigator regarding collision avoidance was identified. It is reported that the navigator's decisions are subjective and contain errors. Interesting contributions have also been

reported to compensate for errors and thus contribute to safe navigation. The goal is to develop a decision system for collision avoidance that reduces errors. However, some problems have identified an issue in which varying numerical values are utilized in constructing the decision systems outlined in each respective study. Therefore, the need to build and validate a predictive model of the outcome of the navigator's perception of the encounter situation in the context of detecting the risk of a collision has been found.

To illustrate the process of first goal, The ships trajectory data, which are the result of actual human behavior were collected. Based on the collected data, variables that served as criteria for judgment were obtained when the ship avoided another ship. This variable contains the basis for the essential judgment used by navigators and the figures obtained from the collision-avoidance algorithm. Subsequently, the performance was verified by constructing an ensemble classification model that predicted the direction of avoidance. Decision-tree-based bagging model and the AdaBoost models have been used among ensemble models. The reasons for the adoption of the two models are as follows. The former was adopted because the decision tree-based bagging model, unlike the random forest model, does not randomly select the predictors of the model. In addition, the boosting model was used because the ensemble construction method is different from the Bagging model. The AdaBoost model was adopted owing to its relatively simple implementation and the advantages of superior generalization. To explain the process of second goal, human's situation awareness results were collected in the presence of a collision risk. The variables required for the model were constructed using the collected data. Subsequently, a classifier model that predicts human situation awareness results was established, and its performance was verified. Support Vector Machine models have been used. The model is reported to have strength in classifying boundaries. Kernel tricks were applied to implement simple to complex models.

The results of this dissertation are as follows. First, a model was proposed in which human cognitive judgment results were learned with high numerical accuracy. Second, hyperparameters that optimize the accuracy of each model were estimated. Using the Grid-search method, the optimal hyperparameter for each model was identified based on the accuracy of the model. Third, the actual usefulness of each model was verified. As a result of performing ROC-AUC metric verification, a value of 0.9 or more was obtained. So, the usefulness of the proposed model was confirmed. This model is expected to be combined with automated collision avoidance logics.