Study on Automatic Path Following and Collision Avoidance Algorithm for Intelligent Ships

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https://doi.org/10.15017/2534443

出版情報：Kyushu University, 2019, 博士（工学）, 課程博士
バージョン：
権利関係：

（様式２）

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論 文 名　：　Study on Automatic Path Following and Collision Avoidance Algorithm for Intelligent Ships（知能化船のための自動経路追従ならびに衝突回避アルゴリズムに関する研究）

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論 文 内 容 の 要 旨

In recent years, movements have been appeared to convert existing human-operated systems into unmanned systems in many fields such as industry of vehicles and robots since the performance of AI technology has improved. In particular, the International Maritime Organization (IMO) recognized that the IMO should take a proactive and leading role to encourage rapid technological development related to the autonomous ship or unmanned ship. In 98th Maritime Safety Committee (MSC), the IMO introduced the concept of Maritime Autonomous Surface Ships (MASS) and started a regulatory scoping exercise (RSE) to determine whether current international regulations need to be amended for safe operation of MASS. Furthermore, to facilitate the process of RSE, the degrees of autonomy for MASS are organised in 99th MSC.

In general, the voyage of a ship is progressed by following a path which is considered safe while avoiding other ships or obstacles with the potential to cause a collision. Hence, it is necessary to equip with performances of automatic path following and collision avoidance in the fully autonomous ship. In this study, the automatic path following algorithm using fuzzy inference and the automatic collision avoidance algorithm using reinforcement learning are developed in order to come up with the basic research for the fully MASS.

The term MASS has recently been introduced by the IMO, but research on automatic path following and collision avoidance for accomplishing autonomous ships has been in progress for decades. Following the development of autopilot based on PID control, the Line-of-Sight (LOS) guidance system is often used in automatic path following. However, the LOS guidance system requires calculation cost to create LOS set points to be approached by a ship. Furthermore, rudder is manipulated at same timing to enter a new course line because the radius of the circle of acceptance is always constant in the LOS guidance system.

On the other hand, automatic collision avoidance is to sense a risk by the ship herself and to perform avoidance action against objects expected to cause collisions. It is expected that the application of reinforcement learning for collision avoidance problem of ships is a promising way to allow a ship to identify various patterns of surrounding environments and to define behaviours to be taken by herself unlike previous studies.

This thesis consists of six chapters.

In Chapter 1, the background and purposes of this research are introduced.

In Chapter 2, the mathematical models of manoeuvring motion and external disturbance are described in order to carry out numerical simulations which are necessary to evaluate the performance of the developed algorithm.

In Chapter 3, development of automatic path following algorithm is presented. Two components of the algorithm, the waypoint guidance system and the rudder control system, developed by using fuzzy inference are explained through showing fuzzy rules and fuzzy membership functions. A ship equipped with the proposed algorithm is simulated in virtual situations and the results are analyzed.

In Chapter 4, the path following algorithm developed in Chapter 3 is additionally verified in realistic situations. In order to reproduce realistic ship voyage, an actual route planned by ship operators has been used and actual environmental data such as wind and current provided by official institutes are applied as wind and current vectors depending on the present ship's location in real time.

In Chapter 5, automatic collision avoidance algorithm is developed. The evaluation of collision risk and the theory of reinforcement learning which are needed to be established to develop the algorithm are described. Collision avoidance problem is defined as MDP (Markov Decision Process) model in the reinforcement learning and actions to evade collision is evaluated on the basis of COLREGs (International Regulations for Preventing Collisions at Sea 1972). Among the deep reinforcement learning methods, DQN and DDPG are applied and simulations results using the both methods are compared and examined.

Chapter 6 is the conclusions of this study and the possible future research is discussed.