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ABSTRACT

This paper proposes a process-based method for generating virtual test scenarios for near-shore maritime autonomous surface ships (MASS) collision avoidance tests. The method includes a scenario complexity index to provide different difficulty levels of virtual test scenarios for different test requirements, reducing the test volume while ensuring coverage and reliability requirements. The scenario database generated by this method reflects the frequency of real-world scenarios and meets the requirements of virtual test realism. This method can improve the efficiency and reliability of MASS testing, with potential future improvements in the complexity evaluation matrix and statistical analysis of vessel maneuvering ability.

KEY WORDS: Maritime autonomous surface ships, ship virtual test, deconstruction, generation method, scenario complexity

INTRODUCTION

In recent years, maritime autonomous surface ships (MASS) have gained wide attention and research for its remarkable advantages in safety, efficiency and economic benefits, and the intelligence level of maritime autonomous surface ships is constantly being improved (Wróbel et al., 2017). At the same time, the limitations of traditional physical test areas in the test of intelligent collision avoidance system of MASS are gradually highlighted. Compared with traditional ships, MASS are under greater pressure of information processing during operation, therefore, in order to fully verify the safety and stability of MASS, more tests should be conducted on test ships under different scenario conditions (Rødseth and Burmeister, 2015). However, the traditional test areas are limited by the spatial and economic constraints which meaning that they can only make tests on the limited typical intelligence collision avoidance test scenarios. It is not enough to cover most of the cases the tested ship may encounter (Pedersen et al., 2019). By contrast, the virtual test system is not limited by the physical environment, can cover more application environments, and can provide more comprehensive and reliable test scenarios for MASS collision avoidance system in a more economical and efficient way. Test scenario database as one of the main bodies of MASS virtual test system, its authenticity and comprehensiveness have a crucial impact on the credibility of MASS collision avoidance test.

Currently, the virtual testing of MASS is still in its early stage and lacks unified standards and regulations. According to the generation principle, there are mainly three scene generation methods: scenario variation generation, scenario learning generation and scenario combination generation. In this paper, a process-based scenario generation method is proposed. This method first generates a scenario database based on real-world data and then randomly generates test scenarios according to probability distribution. The method can reflect the data and randomness of the real world, but it may not cover all possible scenarios or ensure reproducibility, and is greatly affected by data quality and model complexity. Scenario learning generation method combines virtual simulation with real world tests to evaluate the functions and performance of autonomous ships (Yang et al., 2020). This virtual-real interactive testing method can provide realistic feedback and reduce costs, but may have technical challenges or security risks. Scenario combination generation method uses process models to describe the behavior of autonomous ships and generate test scenarios according to predefined rules (Wang et al., 2022). Compared with the previous two methods, this process-based scenario combination generation method has weaker ability to reflect real scenarios and is difficult to generate dangerous scenarios. But overall, it is more reliable and controllable, can cover various scenarios and ensure consistency, and has the ability to reproduce specific scenarios. This process-based virtual test scenario generation method has been relatively mature in the research of autonomous vehicle testing. Ulbrich et al. (2015) studied from the semantic logic of scenarios and established a scenario structure based on environment, dynamic elements, and their mathematical logic relationships, which can better describe the scenario of the test environment. Menzel, Bagschik and Maurer (2018) defined a scenario..