Sequential multi-ship encounter scenarios for testing automatic collision avoidance systems

Simulation-based digital testing is considered a fundamental step and approach for safety testing of autonomous vessel collision avoidance systems. It provides a cost-effective means to simulate a wide range of scenarios, facilitating quantitative performance assessments and enabling traceable detection of failures. In the construction of safety-critical scenarios for testing, besides basic single-ship encounter scenarios, attention has increasingly turned to the complex encounter scenarios involving multiple ships and their systematic construction. Existing solutions primarily focus on situations where the tested vessel encounters multiple other vessels simultaneously. However, in scenarios occurring within high-density traffic areas, such as intersection areas in narrow waterways, the maneuvering space of the tested vessel may be constrained by surrounding vessels or result in other close-quarters situations. The background vessels in these scenarios, although not directly encountered in the initial setup with the tested vessel, are still vital components of safety-critical scenarios. Their systematic construction has yet to be fully discussed. This article categorizes such scenarios as Sequential Multi-Ship Encounter Scenarios and proposes a scalable automated scenario generation method, aiming to enhance the diversity of digital collision avoidance testing scenarios.

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Simulation-based digital testing stands as an indispensable cornerstone and methodology in ensuring the safety of autonomous vessel collision avoidance systems. This approach not only offers a cost-effective avenue but also empowers the construction of a diverse array of scenarios, allowing for comprehensive quantitative performance assessments, the meticulous identification of potential failures and targeted enhancement of autonomous vessel collision avoidance systems for specific waters. Beyond the basic pairwise-ship encounters, the testing landscape has witnessed a growing emphasis on the intricate challenges posed by complex scenarios involving multiple ships.

While current solutions predominantly concentrate on situations where the tested vessel interacts with multiple counterparts simultaneously, the intricacies of high-density traffic areas, particularly in constrained spaces such as intersection zones within narrow waterways, warrant special consideration. In these environments, the maneuvering space of the tested vessel may be severely restricted by the proximity of surrounding vessels, while also potentially giving rise to other close-quarters situations.

Notably, the vessels sharing the same navigational space, though not directly involved in the initial setup with the tested vessel, play a pivotal role in shaping safety-critical scenarios. However, the systematic construction of these background vessels within such constrained scenarios remains a less-explored facet. To bridge this gap, this study introduces the concept of Sequential Multi-Ship Encounter Scenarios and proposes an innovative, scalable automated scenario generation method. The primary objective is to elevate the richness and complexity of digital collision avoidance testing scenarios, particularly in instances where the tested vessel navigates through high-density traffic environments.

By categorizing and addressing Sequential Multi-Ship Encounter Scenarios, this proposed method seeks to offer a more comprehensive testing framework that mirrors the real-world complexities faced by autonomous vessels. Through this approach, the automated scenario generation aims to capture the dynamic interactions and constraints imposed by surrounding vessels in high-density traffic areas, thereby contributing to a more robust and thorough evaluation of collision avoidance systems. In essence, this initiative strives to propel the evolution of simulation-based digital testing, ensuring that autonomous vessels are equipped to navigate diverse and demanding scenarios with unparalleled safety and efficiency.