

Response to Review 2 Comments

Dear Review 2

Thank you for your report. We are grateful to your valuable comments and suggestions, which helped improve the quality of our manuscript. We have studied your comments carefully and have made modifications and corrections that we hope will meet your approval.

Thank you for your kind consideration of our manuscript.

Yours sincerely,

Haitao Liu

Guangdong Ocean University

Reviewer #2:

This paper presented the “Event-triggered finite-time formation control of underactuated multiple ASVs with prescribed performance and collision avoidance”. This work aims to solve the problem of underactuated multiple autonomous surface vessels, including systematic mass matrix, collision avoidance, maintaining communication distances and prescribed performance. The results provide a comprehensive finite-time formation control method to avoid collisions and maintain communication distance. The contribution can be applied to traffic management in the maritime industry. This paper is relevant and valuable to the readers of Sensors. However, several places need to be revised. There, I recommend publication of this paper subject after major revision. The following changes to improve this paper was suggested.

1) Introduction, the authors need to make a simple definition for “ASVs” because it is the keyword in this work. Also, please give some simple samples to explain why we need to develop ASVs technology.

Response: Thank you for your suggestion. We have added some definitions of "ASVs" in the manuscript, given examples to explain why we need to develop ASV technology and added the following reference. These are listed below:

In recent years, due to the increasing demand for ocean exploration, autonomous surface vessels (ASVs) have been widely used in ocean exploration and exploitation and have played an increasingly important role [1]. However, it has been quite difficult for single autonomous surface vessels (ASVs) to accomplish some exploration tasks, such as large-scale cruising, the formation of combat formations, and complex sea exploration.

[1] Data-Driven Adaptive Disturbance Observers for Model-Free Trajectory Tracking Control of Maritime Autonomous Surface Ships (<https://doi.org/10.1109/TNNLS.2021.3093330>)

2) Please organize the structure for this work at the end of the Introduction. We need more information before reading this reading work.

Response: Thank you for your suggestion. For the convenience of the reader, the structure of this manuscript has been arranged at the end of the Introduction.

The rest of the paper is organized as follows. Section 2 describes the preliminaries and problem formulation. Section 3 describes the formation controller design. Section 4 describes the simulations. Finally, Section 5 gives the conclusion.

3) Although the authors point out the contribution of this work, however, we need to know the difference between this work and others. Please explain what is revolution or brilliant can beyond previous work.

Response: Thank you for your suggestion. We have already set out how this work differs from previous work in the contributions section. This work differs from previous work in the following ways:

- (1) An improved BLF is developed to guarantee both tracking error prescribed transient and steady performance. Different from the existing works in [8, 22], maintaining communication distance and collision avoidance between ASVs is also achieved.
- (2) Compared with the existing works [24], a relative threshold-based event-triggered controller is proposed to reduce the communication bandwidth. Compared with the existing fixed threshold event-triggered controller [25, 26], the relative threshold strategy can achieve fewer stable errors.
- (3) A finite-time event-triggered formation tracking control strategy is proposed to solve the error constraint problem of underactuated multi-ASV formation. In the control system, all signals are practical finite-time stable (PFS), which is different from the existing work on ASV tracking control with constraints [10, 11, 27].

References

8. Liu, H.; Chen, G.; Tian, X., Cooperative formation control for multiple surface vessels based on barrier Lyapunov function and self-structuring neural networks. *Ocean Eng* 2020, 216, 108163. (<https://doi.org/10.1016/j.oceaneng.2020.108163>)
10. Dong, C.; Ye, Q.; Dai, S.-L., Neural-network-based adaptive output-feedback formation tracking control of USVs under collision avoidance and connectivity maintenance constraints. *Neurocomputing* 2020, 401, 101-112. (<https://doi.org/10.1016/j.neucom.2020.03.033>)
11. Zheng, Z., Moving path following control for a surface vessel with error constraint. *Automatica* 2020, 118, 109040. (<https://doi.org/10.1016/j.automatica.2020.109040>)
22. Fu, M.; Yu, L., Finite-time extended state observer-based distributed formation control for marine surface vehicles with input saturation and disturbances. *Ocean Eng* 2018, 159, 219-227. (<https://doi.org/10.1016/j.oceaneng.2018.04.016>)
24. Huang, C.; Zhang, X.; Zhang, G., Adaptive neural finite-time formation control for multiple underactuated vessels with actuator faults. *Ocean Eng* 2021, 222, 108556. (<https://doi.org/10.1016/j.oceaneng.2020.108556>)
25. Dai, S. L.; He, S.; Wang, M.; Yuan, C., Adaptive Neural Control of Underactuated Surface Vessels With Prescribed Performance Guarantees. *IEEE Trans Neural Netw Learn Syst* 2019, 30, (12), 3686-3698. (<https://doi.org/10.1109/TNNLS.2018.2876685>)

26. Li, M.; Li, T.; Gao, X.; Shan, Q.; Chen, C. L. P.; Xiao, Y., Adaptive NN event-triggered control for path following of underactuated vessels with finite-time convergence. *Neurocomputing* **2020**, 379, 203-213. (<https://doi.org/10.1016/j.neucom.2019.10.044>)
27. Peng, Z.; Jiang, Y.; Wang, J., Event-Triggered Dynamic Surface Control of an Underactuated Autonomous Surface Vehicle for Target Enclosing. *Ieee T Ind Electron* **2021**, 68, (4), 3402-3412. (<https://doi.org/10.1109/TIE.2020.2978713>)

4) Page 12, line no. 328 to 337, there are some “errors” in your paper. Please check them before submitting them.

Response: Thank you for your suggestion. We have scrutinized and modified these errors as follows:

In Fig. 3, each ASV tracks its leader while maintaining the desired distance between a group of leaders and followers. The LOS range and angle error satisfy the prescribed performance specification, realize the connectivity of formation control communication and avoid collision, as shown in Figs. 4-5. Figs. 6-8 show the control input with the event triggering mechanism. In Figs. 6-8, the control inputs of each ASV are continuous and chattering-free. The control input of ASV1 based on time-triggered development is continuously updated, as shown in Fig. 9. The tracking performance of the time-triggered control of ASV1 is shown in Fig. 10 and Fig. 11. As shown in Figs. 9-11, compared with time-triggered control, the event-triggered control strategy has better control performance and saves more communication resources. The triggering effect of the proposed event-triggered strategy based on the relative threshold is shown in **Table 3** and shows that the proposed event-triggered strategy can save considerable communication bandwidth.

5) Please present the work environment for your simulation when ship operations at sea or port have many complicated settings; I feel this test could be more workable. Can they be actual employ in ship operations? How about the ship size? Not only figures simulation but also need to present the environment.

Response: Thank you for your suggestion.

In the simulation, the simulation ensures a specific formation of the formation and follows a virtual leader generated by a trajectory. The working environment simulated in this work can be applied to real ship operation scenarios, such as oceanographic surveys and patrols. In this paper, the mass of the ship used is 23.8 kg, and the length is 1.255 m. In practical applications, many complex settings are required for the ASV to perform operational tasks. Due to the limitation of the experimental conditions, the control system has been validated by the simulation in this work, and in future research, the proposed control method will be further applied to ASV practical work scenarios to improve the experimental verification part and further optimize the control system.

This manuscript was edited for proper English language, grammar, punctuation, spelling, and overall style by one or more of the highly qualified native English-speaking editors at American Journal Experts (<https://china.aje.com>).

Thank you for your attention to our manuscript, and we would like to again appreciate your professional and detailed suggestions.