Proceedings of the 33rd European Safety and Reliability Conference (ESREL 2023)
Edited by Mário P. Brito, Terje Aven, Piero Baraldi, Marko Čepin and Enrico Zio
 Published by Research Publishing, Singapore.
doi: 10.3850/978-981-18-8071-1_P471-cd

Does Redundant Systems Make a Remote Control MASS Safer

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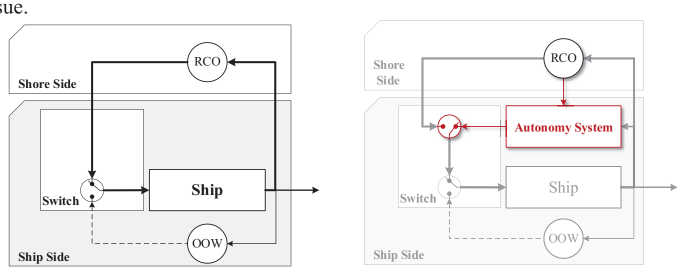
ABSTRACT

Recently, Maritime Autonomous Surface Ships (MASS) have attracted numerous attention, which is expected to improve the efficiency, safety, and environmental friendly of maritime transportation. Remote control ship that is one type of MASS is promising before the ship can be fully autonomous, where the human and autonomy system (machine) are both active in the control loop. For a remote-control MASS, the human operators in Remote Control Centre (RCC) received sensing information from the ship side and sent the control commands such as propeller commands and rudder angle back to the autonomy system on board. The introduction of two control agents, i.e., remote control operators (RCOs) and autonomy systems (AS), increases the redundant degrees of the system, which is expected to overcome the uncertainty and reliability issues of the MASS. However, for one thing, two control agents increase the potential human-machine conflict; for the other thing, the communication delay between the ship and shore intensifies the conflict. Specifically, since RCOs are not on-board ships and the information flow from/to them suffers from the delay, in this case, whether the redundant design will still be valid is lacking answers. To answer the question and investigate the performance of remote control MASS (RC-MASS) with redundant systems in such a communication environment, this paper introduced a simulated environment and tested the performance of RC-MASS with/without AS, which is expected to conclude some tips for the design of remote control ships.

For the RC-MASS without an autonomy system (AS) onboard (see Fig. 1a), the MASS would directly execute the received commands from remote control operators (RCOs). Thus, the behavior of the ship might be out of the expectation of human operations when the ship-shore communication has problems, such as packet loss, delay, etc. In some extreme cases, the office on watch (OOW) on board should take over control. For the RC-MASS with AS onboard (see Fig. 1b), the MASS would judge the safety of the commands. If the command is still valid and safe, e.g., the tracking errors are tolerable, the MASS would directly execute the received command; while if the command is invalid, the autonomy system onboard would take over control. Additionally, when the AS found the encounter scenarios are too complicated to handle, the OOW onboard would be invited to handle the issue.



(a) (b)

Figure 1 Structure of RC-MASS with/without AS

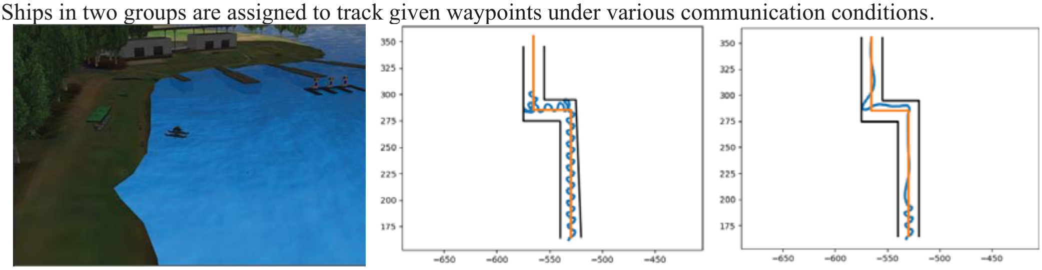
To compare RC-MASS with/without AS, a simulation environment from the ROS platform is used, a catamaran boat with the size of 2.5m*1.6m*1.8m is engaged (See Fig. 2a), and two groups are set:

- Standard Group (SG): the RC MASS without AS onboard is set as SG, which is controlled by RCOs in RCC. In this paper, a Light-Of-Sight PID (LOS-PID) controller is introduced to simulate the controls from RCOs, which would send control commands to ship based on the delayed sensing information from the ship.
- Control Group (CG): the RC-MASS with AS is set as CG, which are control by RCOs in RCC and AS onboard. The AS onboard could judge the tracking errors of the MASS. If the error is acceptable (i.e., xxx meter), the ship would execute the delayed commands from the RCC; otherwise, a LOS-PID controller【3】 onboard using instantaneous information will take over control of the ship.

Table 1. The parameter of the path-following algorithm.

parameter	value
P	3
I	0.8
D	9
Look-ahead distance	10m
The radius of the way-point circle	4m

Ships in two groups are assigned to track given waypoints under various communication conditions.



(a) simulation environment (b) SG with 1s delay (c) CG with 1s delay

Figure 2 Demonstration of Remote Control MASS Simulation

A simulation result of RC-MASS tracking a “Z” path with a 1-second communication delay is shown in Fig.2b-c. The result shows that (1) the redundant system would improve the performance of the RC-MASS. Specifically, if the communication delay is less than 0.3 seconds, the tracking errors are quite small, however, when the delay is longer than 0.8 seconds, the RC-MASS without AS is unable to follow the path. (2) the redundant system does not always improve the performance of the RC-MASS. When the communication delay is small, the performance of the MASS in SG might perform better than that in CG, specifically, the RC-MASS without AS might have fewer tracking errors.

In conclusion, a redundant system would be necessary for RC-MASS when the quality of ship-shore communication is still uncertain; however, the redundant system might not always perform well, especially when the communication delays are low; the design of arbitrator onboard might play a crucial role, which needs further research。

KEYWORDS: Waterborne transport safety; Autonomous ships; Remote control; Redundant system

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