Intelligent Optimized DP for Marine Vessels Under Thruster Saturations via Finite-Time Disturbance Observer

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Abstract*—The dynamic positioning of marine ships is gradually becoming the core technique to perform ocean herculean tasks. This article focuses on the problem of optimal fuzzy output-feedback tracking control for dynamic positioning of marine vessels simultaneously with model uncertainties, unknown disturbances, unavailable velocities, and thruster saturations. The control scheme is built by integrating a fuzzy velocity observer, a finite-time disturbance observer, a dynamic auxiliary system, the optimal control strategy with the dynamic surface control. The fuzzy velocity observer is constructed to obtain the unavailable velocities without requiring the certain model dynamics. The finite time disturbance observer is established to estimate the unknown disturbances. The dynamic auxiliary system is designed to compensate for thruster saturations effects. By incorporating these methods, a disturbance rejection adaptive controller is designed with dynamic surface control. The optimal compensation term is inserted to minimize the cost function of the tracking error system by adaptive dynamic programming (ADP). It is shown that the optimal control consisting of the adaptive controller and the optimal compensation term guarantees that all signals in the closed-loop dynamic positioning system are bounded. The contributions can be summarized in three points. (1) In contrast to the existing nonoptimal DP control methods, based on the traditional disturbance observer, the proposed finitetime disturbance observer-based optimal control can not only shorten the disturbance estimation time but also guarantee the cost function of the DP system is minimum. It is shown that the optimal control consisting of the adaptive controller and the optimal compensation term guarantees that all signals in the closed-loop. (2) In contrast to the conventional DP output feedback control methods with velocity state observers, the proposed fuzzy Luenberger-like observer does not require the priori knowledge of model dynamics and is effective under noised position measurements in the ADP control framework. (3) In contrast to the ADP-based optimal dynamic positioning controller, the physical limitation of maximum forces and moments of thrusters is addressed in the proposed optimal control scheme. A dynamic auxiliary system is utilized to compensate the effect of thruster saturations, which can make this algorithm more suitable for practical engineering. Finally, simulation results demonstrate the effectiveness of the proposed optimal control scheme. The comparative results demonstrate that the proposed optimal DP controller has the better tracking performance, less the conservativeness and requires the less control forces and moment. This is attributable to the proposed optimal DP controller being integrated with the fuzzy velocity observer, the FDO, and the dynamic auxiliary system. In our future work, we will continue our research in terms of rejecting cyber attacks for marine dynamic positioning.

***Index Terms*—Dynamic positioning, adaptive dynamic programming, finite-time disturbance observer, optimal control.**