JSCDSS An International Journal

http://www.jscdss.com
Vol.7 No.1 February 2020: 13-18
Article history:
Accepted 06 February 2019
Published online 06February 2019

Journal of Soft Computing and Decision Support Systems

E-ISSN: 2289-8603

Optimum Design of a Dynamic Positioning Controller for an Offshore Vessel

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Abstract

In this paper, an optimal LQG controller is designed to achieve proper dynamic position stabilization on an offshore vessel. The designed control loop operates in the presence of noise from the measurement of sensors, environmental perturbations of waves, winds, and ocean currents. The intended offshore vessel has two side actuators to generate the required torque. The designed controller includes state feedback and an extended Kalman filter. In this study, an additional variable in the system state space is used to improve the performance of the LQG controller in the presence of noise. The results of the simulations performed in the content software show the efficiency of the proposed method compared to the conventional LQG control method. The results of simulations performed in MATLAB reveal a better efficiency of the proposed method compared to the traditional LQG control method.

Keywords: Dynamic position stabilization, Offshore vessel, LQG optimal controller, State feedback, Extended Kalman filter, Ocean current

1. Introduction

Using the issue of dynamic position stabilization (DP) is relevant to the controlling of nonlinear system operators in a surface watercraft for low speed maneuvering or floating maintenance. Operators that produce the control signal on watercraft are generally categorized in two types of propellers and thrusters. Dynamic position stabilization systems have been used commercially on marine watercraft for about 60 years. The mathematical model of the dynamic motion of watercraft, in general, has six degrees of freedom. System modeling based on physical equations along with statistical approaches is conventional methods for constructing an applicable state-space equation for controller design (Golparvar et al., 2016; Modir et al., 2016; Ho et al., 2013; Balchen et al., 1980). Izadi et al (2016) provided a model-based approach combined with the extracted signal from the system to define a realistic mathematical model of an actuator. The extracted model is used not only in the controller design, but also it can be used in applications like fault detection and isolation (Izadi et al., 2017). In the modelling of the offshore vessel for this research, the conventional model based on the physical equation is used. The reason for this approach is the simplicity of the controller design process. In addition, the nonlinearity of the system is not considerably affective on the designed controller performance in the linearized zone (Shahri et al., 2020; Shindgikar et al., 2020; Karimi Shahri et al., 2019; Kelareh et al., 2019; Taremi et al., 2019; Izadi et al., 2017; Izadi et al., 2016; Sørensen, 2011; Fossen & Strand, 1999; Sørensen et al., 1996; Balchen et al., 1976). Especially in (Taremi et al., 2019), the authors investigated an approach to design a tracker by fuzzy polynomial control law. In the proposed method, the nonlinearities of the system are considered. Therefore, the proposed design approach is applicable to a wide range of systems. Floating stabilization is often considered along the x and y axes and the yawing around the z-axis. Hence, most of the studies conducted on stabilizing the dynamic position of the control system have an equation of motion with three degrees of freedom (Ho et al., 2013; Balchen et al., 1980). The first dynamic positioning system uses a PID controller with a series of low-pass and band-stop filters.

Kalman filter theory and optimal control methods have been used to improve the performance of the control system. One of the most commonly used optimal control methods for float position stabilization is the LQG method, which includes an LQR controller and a Kalman filter (Sørensen et al., 1996; Balchen et al., 1976). In general, Kalman filters are used to estimate the state values in the presence of measurement noise and calculating the feedback control gain. For the best performance of this controller, the values of designed gains should be adjusted according to the operating conditions of the offshore vessel. Real-time modification and updating of these gains in the designed controller add complexity to the system and has specific implementation conditions (Fossen & Strand, 1999). In order to detect and remove system noise, different