Fuzzy Automatic Disturbance Rejection Control Technology of Underwater Auto Trolley

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ABSTRACT
In this paper, a fuzzy auto disturbance rejection control is proposed for the UAT (underwater auto trolley) based on fuzzy observer and fuzzy controller, which have an obvious advantage compared to ADRC. Considering the disturbance, accuracy and nonlinearity for the UAT system, a fuzzy observer is proposed. It is more effective and precise compared with ESO (extended state observer). In addition, in order to reduce the number of designed parameters and avoid the bed influence by the fast function (Sun, 2010), we provide a fuzzy controller. The fuzzy controller in this paper is more flexible and reduce the number of design parameters effectively.

KEY WORDS: Fuzzy observer, ADRC, Underwater auto trolley, Fuzzy control.

INTRODUCTION
UAT (Underwater Auto Trolley) is a kind of Underwater carrying trolley, which include Self-driven trolley type or flexible cable traction type. The former is driven by a battery and has less research currently. The latter is pulled by a flexible cable, and has some research on motion control (Zhao, 2015; Xun, 2018). With the development of batteries and motor control technology, the UAT becomes more and more popular. UAT belongs to the previous type and it is a special vehicle which run in stationary rail. When the UAT worked in the complex marine environment, stable speed is necessary. Hence, the research on the accurate speed control method will be of important significance. The UAT is a typical complex nonlinear system including disturbance, due to the ocean current waves (Chu, 2017). So there are two important question, the first is how to resolve the nonlinear control, on the other hand is how to eliminate the disturbance.

At present how to design sample economy and effective nonlinear controllers is of important research significance. There are some modern controller focus on nonlinear question, such as fuzzy controller, adaptive controller, slide controller and neural network controller or their cross combination. Beside the disturbance widely and bring adverse effects, we can design observer to monitor the disturbance and adopt compensation control to reject disturbance (Li, 2014).

Since 1970s, many effective disturbances estimation techniques have been developed, such as ESO (extended state observer) and DO (disturbance observer). DO was initially put forward by (Ohishi, 1987). ESO was proposed by (Han, 2009), and was fundamental of ADRC (Auto disturbances rejection control). The ADRC has been used to attenuate the effects of externs disturbance in control system (Xia, 2007; Sun, 2007).

The ADRC can observe the ‘total disturbance’ by the ESO, which include mathematic model error, extended disturbance. The nonlinear system including disturbance can reduce to a linear system without disturbance by the ESO so that it is easy to control via traditional PID algorithm. But there is another question if the observer has big delay and estimate error. It is no useful to compensate. As a result the accuracy and real-time of state observer play a great role. With the developed of fuzzy logic, it can approximate arbitrarily well a highly nonlinear system. So fuzzy disturbance observer (FDO) is proposed (Kim, 2002), and the real-time depended on the number of rules of fuzzy system. This paper compares of fuzzy observer and ESO characteristics, analyzes their accuracy. In addition, in order to improve the robustness and make PID control law more effective, a nonlinear function is proposed for PID parameter (Han, 2009) in the conventional second-order ADRC for permanent magnet synchronous, but it have many parameter to design and there is speed limits question under the fast function. (Zuo, 2016) proposed a novel integrated design for positon and speed loops, the method is planning speed with the price of degraded dynamic performance. In order to reduce the number of design parameter and avoid constraints by the fast function, this paper considered that make fuzzy controller to replace nonlinear PID.

Motivated by the aforementioned observation, in this paper a fuzzy auto disturbance rejection control is proposed for the underwater auto trolley based on fuzzy observer and fuzzy controller. The main contribution of the paper are as follow:
1) Since the disturbance and nonlinear for the UAT system and the demand of accuracy, an adaption fuzzy observer is design. Different from ESO, it is more effective and precise.
2) For the nonlinear control, a fuzzy controller is design. It is more