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Design of Control System for Submarine Receiving and Playing Based on Fuzzy Control

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Abstract. In the process of retrieving and releasing deep-sea submersible, it is required that the retrieving winch should have constant tension control function to reduce the impact of wave fluctuation on the submersible. In this paper, a constant tension winch control system based on fuzzy control is established, and the system is simulated and analyzed. The simulation results show that the system can meet the actual operating conditions, and has good dynamic and steady-state performance.

1. Introduction

Water and recovery of underwater submersible ROV is one of the key links that can accomplish the task, ROV is a very expensive instrument. When working, a crane is required to be placed in an underwater position. But when it falls, the strenuous wobble of the hull causes the cable to move up and down like a rubber band. If there is no wave compensation system, it may eventually lead to cable breakage and ROV loss. Similar accidents have occurred many times.

In order to improve the stability and safety of the submersible, it is very important to choose a suitable control system. The traditional PID controller has simple structure and strong robustness, but there is a contradiction between tracking setpoint and disturbance rejection ability, so that the system cannot get the best control effect[1]. Now the control algorithm replaces the single PID to control the situation. The improved PID control, fuzzy control, optimal control, neural network control, adaptive control, robust control and other control methods are applied to make the tension control system develop towards higher control accuracy[2-6]. In this paper, a fuzzy adaptive PID controller is designed, which makes the submersible with high dynamic performance and automatic adjustment during the process of collecting and releasing.

Wave compensation is actually a kind of speed compensation. That is, the main feedback is the speed, which compensates for the change of the load speed caused by the wave effect, and ensures the lifting of the load at a predetermined speed. At the same time, the displacement and acceleration are required as reference conditions to confirm the law of velocity change and the position in the spectrum.

2. Active Wave Compensation Scheme

Active wave compensation technology is a new hoisting technique, which is accompanied by the increasingly developed and frequent offshore operations. The wave compensation system has been widely used in foreign ships and offshore platforms, and has become an essential technology in the field of marine engineering. It occupies a very important position[7, 8]. Compared with the mature



situation of foreign wave compensation technology, the domestic research and application in this field are relatively backward.

Because MRU detects the speed of the hull at this time, the wave compensation needs to be synchronized. That is, when MRU sends the detected ship heave speed signal to the winch, it is also necessary to send the acceleration signal of the wave heave and change. At the same time, the system must constantly compare the compensation error at the first time, that is, the difference between the lifting speed detected by MRU and the actual speed of winch. The three factors determine the wave heave speed that winch needs to compensate.

The basic units of the system are motion reference unit (MRU) and force sensor, which are used to detect ship displacement, wave velocity, cable pressure and tension, and transmit data to the computer control system. According to the current ship error and the rate of error change, the computer control system gives the control signal after computation, and transfers it to the hydraulic drive system (hydraulic motor). According to the size of the control signal, the hydraulic system determines the size and direction of the valve's opening, so as to determine the speed and steering of the hydraulic motor. The hydraulic motor drives the mechanical execution system (winch) to complete the wave compensation function, at the same time, the detection system constantly feedback the measured load, the actual displacement of the ship, the tension of the rope and other parameters to the computer control system. According to the error and error rate of change, the computer control system calculates the size of the next cycle control signal and transfers it to the hydraulic system to control the next cycle. Velocity signal detection diagram in wave compensation process is shown in figure 1.

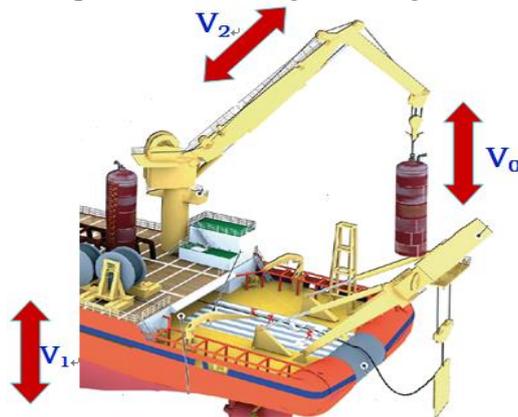


Figure 1. Velocity signal detection diagram in wave compensation process.

The closed loop fuzzy PID control algorithm for the heave compensation is shown in equation (1).

$$V_1 + V_2 - V_0 = \delta \rightarrow 0 \quad (1)$$

In equation (1), V_1 is the ship lift speed, V_2 is the speed of the motor, V_0 is the speed of the goods and δ is adjustment error.

3. Fuzzy Adaptive Tuning PID Control Principle

The fuzzy controller uses the system error E and the error change EC as the input statement variable, so it has the function similar to the conventional PID controller. The system using this kind of fuzzy controller can obtain good dynamic characteristics, but the static performance cannot be satisfactory, and the static error cannot be eliminated. It is known from the linear control theory that the integral control can eliminate the steady state error, but the dynamic response is not very good. The dynamic response of the proportional control is fast, and the proportional integral control can not only obtain high steady state accuracy but also have high dynamic response. Therefore, the PID control strategy is introduced into the fuzzy controller to form the fuzzy PID control[9, 10]. It is a way to improve the steady-state performance of the fuzzy controller. At present, this kind of composite controller has many forms, and its working principle is also different.

The core of the fuzzy PID control design is to sum up the technical knowledge and practical experience of the engineering designers, and to establish a suitable fuzzy rule table. The fuzzy control table with three parameters, ratio coefficient, integral coefficient and differential coefficient being adjusted respectively is obtained.

The schematic diagram of its control is shown in figure 2.

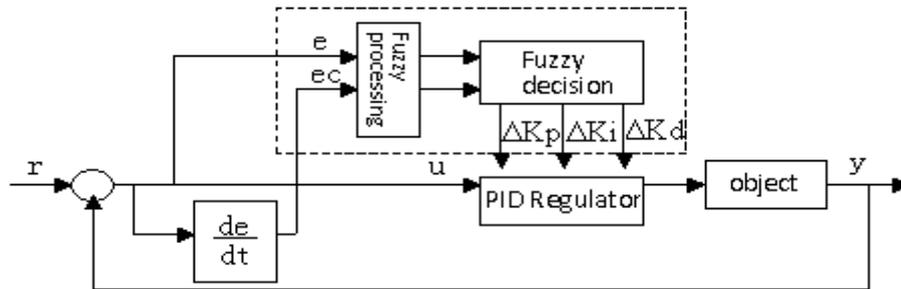


Figure 2. Schematic diagram of fuzzy adaptive PID control.

3.1. Determine the Input and Output and its Membership Function

The input amount is e and the variation rate EC , the output is the variation of PID control parameters ΔK_p , ΔK_i and ΔK_d . The fuzzy sets of the input error quantity e , the error change amount ec and the output quantity ΔK_p , ΔK_i and ΔK_d are all $\{NB, NM, NS, ZO, PS, PM, PB\}$, their domains are $\{-6, -5, -4, -3, -2, -1, 0, 1, 2, 3, 4, 5, 6\}$, therefore, a discrete set of 13 integer elements is formed. The input and output are all trigonometric membership functions, and their membership is zero at a given range.

3.2. Determine the Fuzzy Control Rule Table

The core of fuzzy controller design is to establish an appropriate fuzzy rule table based on expert knowledge and practical experience, and get the fuzzy control table of three parameters of K_p , K_i and K_d . The fuzzy rule table of ΔK_p , ΔK_i and ΔK_d is shown in table 1.

Table 1. Fuzzy control rule table.

ec \ e	NB	NM	NS	ZO	PS	PM	PB
NB	PB/NB/PS	PB/NB/NS	PM/NM/NB	PM/NM/NB	PS/NS/NB	ZO/ZO/NM	ZO/ZO/PS
NM	PB/NB/PS	PB/NB/NS	PM/NM/NB	PS/NS/NM	PS/NS/NM	ZO/ZO/NS	NS/ZO/ZO
NS	PM/NB/ZO	PM/NM/NS	PM/NS/NM	PS/NS/NM	ZO/ZO/NS	NS/PS/NS	NS/PS/ZO
ZO	PM/NM/ZO	PM/NM/NS	PS/NS/NS	ZO/ZO/NS	NS/PS/NS	NM/PM/NS	NM/PM/ZO
PS	PS/NM/ZO	PS/NS/ZO	ZO/ZO/ZO	NS/PS/ZO	NS/PS/ZO	NM/PM/ZO	NM/PB/ZO
PM	PS/ZO/PB	ZO/ZO/NS	NS/PS/PS	NM/PS/PS	NM/PM/PS	NM/PB/PS	NB/PB/PB
PB	ZO/ZO/PB	ZO/ZO/PM	NM/PS/PM	NM/PM/PM	NM/PM/PS	NB/PB/PS	NB/PB/PB

The fuzzy PID controller adjusts the calculation equation of PID parameters, as shown in equation (2).

$$\begin{aligned}
 K_p &= K'_p + \Delta K_p \\
 K_I &= K'_I + \Delta K_I \\
 K_D &= K'_D + \Delta K_D
 \end{aligned}
 \tag{2}$$

In equation (2), K'_p , K'_I and K'_D are the initial set of PID parameters, while K_p , K_I and K_D are the three outputs of fuzzy controller, and the three control parameters of PID can be automatically adjusted according to the state of the controlled object.

4. Simulation

Set up the simulation block diagram as shown in figure 3.

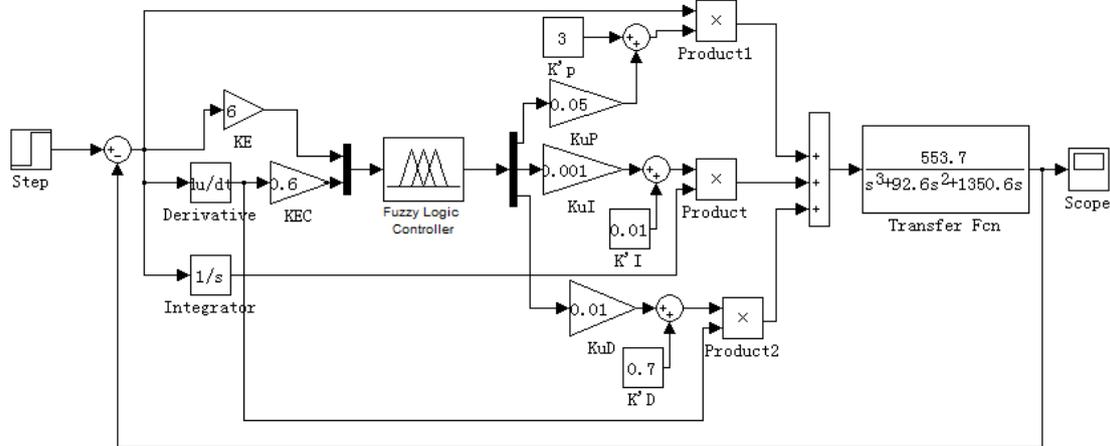


Figure 3. Fuzzy self tuning PID control simulation diagram.

The simulation contrast curve of PID control and fuzzy self-tuning PID control can be obtained as shown in figure 4.

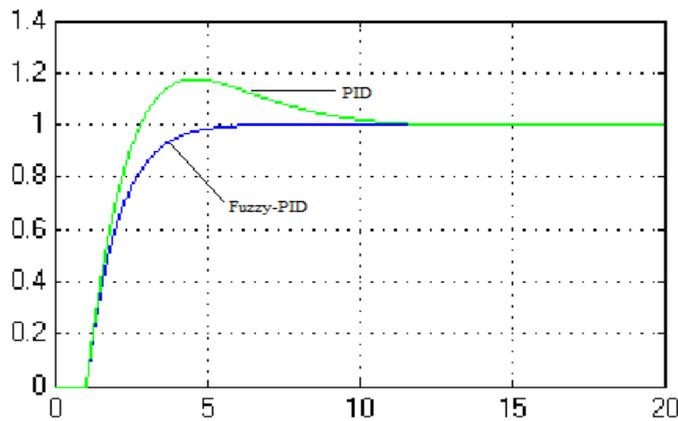


Figure 4. System simulation diagram.

Through the simulation experiments of the two control methods about PID and fuzzy PID, different simulation curves of control effect are obtained. Comparison of the two can be seen in the response curve, such as: fuzzy PID control compared with PID control, with faster and more accurate response, smaller overshoot, oscillation and less adaptability, more robust, more suitable for the platform of complex condition control system control.

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