

Penelitian Tentang Kontrol Heading Berdasarkan PID Neural Fuzzy

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Abstract: With the continuous advancement of the Internet of Everything era and the increasing cost of labor, the aquaculture industry is undergoing intelligent changes. A set of technical solutions for heading control is proposed to introduce a fuzzy neural PID controller to the field of heading control of kelp harvesting vessel. Firstly, fuzzy logic and neural network technology are combined, and secondly, fuzzy PID, fuzzy neural PID control strategy model and heading control model are designed through Simulink. Through the simulation results, it is found that the fuzzy neural PID heading controller has small overshoot, small static error and fast response speed.

Keywords: Kelp Harvesting Vessel; Heading Control; Fuzzy Neural PID.

1. Introduction

When the kelp harvesting vessel is operating, it needs to travel to the target position in strict accordance with the planned route, and the ability to accurately control the heading will be the ultimate goal of the system control. The heading control requirements of the system are: firstly, when the ship arrives at the preset steering position, it needs to realize fast heading switching, and the controller dynamically responds to generate commands to be inputted to the actuators. Secondly, when the ship is sailing in a straight line, the system not only has to meet the dynamic response requirements but also has to ensure the stability of the heading, and too large a deviation in the heading will lead to resource loss; finally, if the control accuracy is too harsh, the power components will be changed frequently, which will also cause a test of the mechanical durability. This makes the design of the heading controller very important and difficult to find a balance between control accuracy and mechanical durability. [1]

2. Fuzzy Neural PID Controller Design

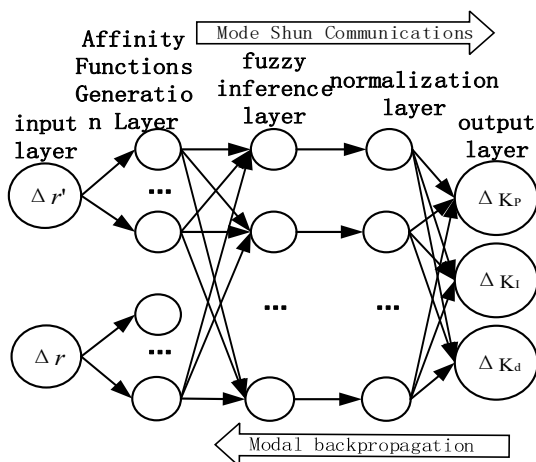


Fig 1. Fuzzy neural network PID network structure

Fuzzy neural network PID network structure [2,3,4] As shown in Fig. 1, the structural design of fuzzy neural network needs to first clarify the number of neurons in each layer and

its input-output relationship. The first layer is the input layer, which contains two neuron nodes with clear physical significance: the system deviation e and its rate of change ec , corresponding to the number of input variables $N = 2$. The input-output relationship of this layer can be expressed as follows:

$$f_1(i) = x_i \quad (1)$$

The second layer is the generating layer of the affiliation function, called the fuzzification layer. In particular, this layer selects the affiliation function to fuzzify the input variables e and ec , which is mathematically characterized as:

$$f_2(i, j) = \exp\left(\frac{(f_1(i) - c_{ij})^2}{(b_{ij})^2}\right) \quad (2)$$

The fuzzy inference layer is used as the third layer, whose neuron nodes correspond to the fuzzy rules one by one, and the product operation is used to simulate the logical computation of the fuzzy rules. There are 49 neuron nodes in the third layer, i.e., $MN=49$. The input and output relation equation are:

$$f_3(n) = f_2(1, i_1) \times f_2(1, i_2) \quad (3)$$

The fourth layer is the normalization layer, which is responsible for normalizing the output of the fuzzy inference layer, and its number of neurons remains the same as that of the third layer (49 nodes). The input-output relationship of this layer is:

$$f_4(l) = f_3(n) / \sum_{p=1}^{49} f_3(p) \quad (4)$$

The output layer, as the last layer of the network, performs defuzzification operations on the normalized data and outputs the modified values of the PID control parameters. This layer contains a total of 3 neuron nodes with the input-output relationship:

$$f_4(l) = f_4 \cdot w = \sum_{j=1}^{49} f_4 \cdot w(w, j) \quad (5)$$

In Eq. (5), w is the connection weights; $r = 1, 2, 3$; $l = 1, 2, \dots, 49$. Therefore, the final output of the fuzzy neural network is the corrected values of the three parameters of the PID controller:

$$\begin{cases} f_5(1) = \Delta K_P \\ f_5(2) = \Delta K_I \\ f_5(3) = \Delta K_D \end{cases} \quad (6)$$

Secondly, the output of the fuzzy neural network PID

$$\Delta u(k) = K_p[e(k) - e(k-1)] + K_i e(k) + K_D[e(k) - 2e(k-1) + e(k-2)] \quad (8)$$

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$$\begin{cases} xc(1) = e(k) - e(k-1) \\ xc(2) = e(k) \\ xc(3) = e(k) - 2e(k-1) + e(k-2) \end{cases} \quad (9)$$

Then Eq. (8) can be converted to:

$$\Delta u(k) = K_p xc(1) + K_i xc(2) + K_D xc(3) \quad (10)$$

The output of the fuzzy neural network PID controller is:

controller is determined. The corrected values of the three parameters of the PID are used as the final output of the fuzzy neural network, which also needs to be summed up with the preset initial values to obtain the output value of the controller:

$$\begin{cases} K_P = K_{P0} + \Delta K_P \\ K_I = K_{I0} + \Delta K_I \\ K_D = K_{D0} + \Delta K_D \end{cases} \quad (7)$$

The PID controller used in this system is incremental control:

$$\Delta u(k) = \Delta u(k) + \Delta u(k-1) \quad (11)$$

3. Simulation and Analysis of Fuzzy Neural PID Controller

In order to verify the advantages of the designed fuzzy neural PID control method in heading control, a heading control simulation model is established based on MATLAB/Simulink software as shown in Fig. 2, which is used to verify the method and design the heading tracking test with and without interference.

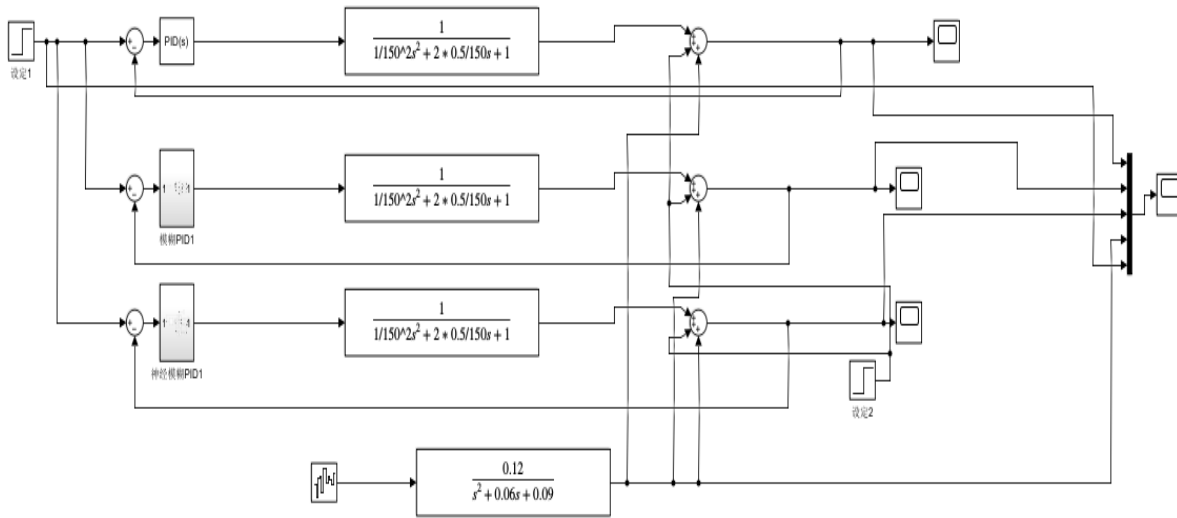


Fig 2. Heading Maintenance Simulation Model

In order to verify the performance advantages of the fuzzy neural PID heading controller proposed in this paper, three groups of controllers (traditional PID, fuzzy PID and fuzzy neural PID) are compared under the same test conditions [5,6,7]. By setting two typical tracking heading angles of 20° and 40°, the performance differences of each controller in terms of overshooting amount, steady state error and regulation time are systematically analyzed [8].

(a) and (b) in Fig. 3 present the heading keeping trend of each control method for the desired heading (20° and 40°), respectively, and Table 1 presents the performance indexes of each control method. From Fig. 3 and Table 1, it can be seen that the three kinds of controllers present a significant difference when the external interference is not taken into account and the given heading is 20° and 40°. The traditional PID controller has the largest overshoot and steady-state error,

the longest regulation time, and the worst performance in each index; the fuzzy PID controller is optimized by the fuzzy rule controller parameters, and there are limitations in the parameter adaptivity, although the overshoot and the regulation time have been improved to a certain extent compared with that of the traditional PID controller, but the performance of the steady-state error control is worse; by contrast, the fuzzy neural PID controller relies on the neural network-fuzzy logic controller, and the fuzzy neural PID controller relies on the neural network-fuzzy logic synergistic optimization mechanism to achieve the simultaneous optimization of the overshooting amount (about 6%), the steady state error (almost 0) and the regulation time (about 14s).

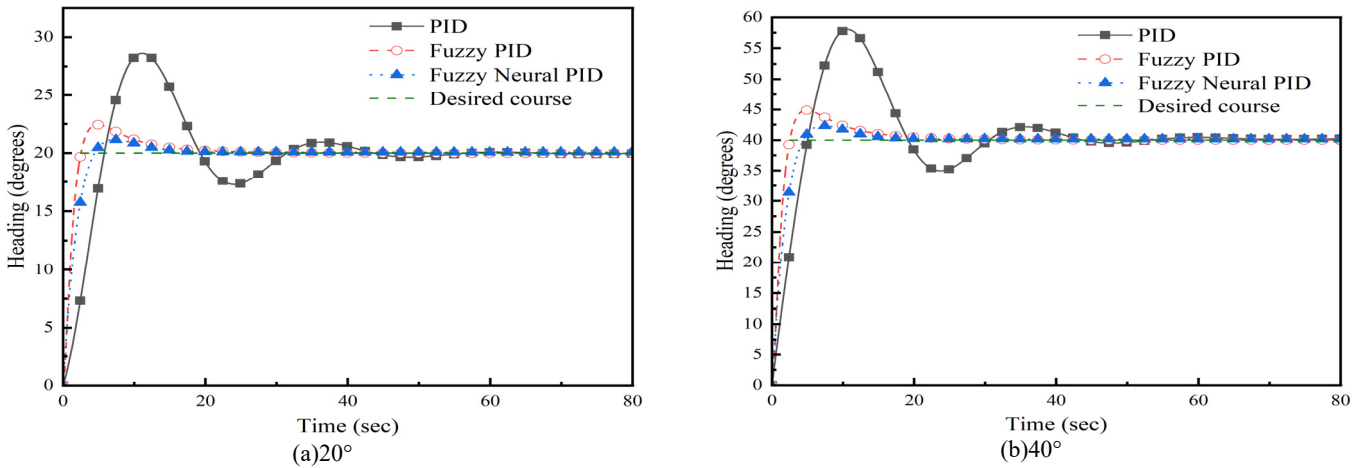


Fig 3. Holding of heading for each control method for different desired headings

Table 1. Comparison of the performance index of each control method

		overtone	statistics	Adjustment time
20°	PID	43%	0.0864	40.5
	Fuzzy PID	12%	0.0791	16.3
	Fuzzy Neural PID	6%	0.0024	13.28
40°	PID	45%	0.1488	41.08
	Fuzzy PID	12%	0.1357	16.5
	Fuzzy Neural PID	6%	0.0011	13.5

4. Summary

In this article, a comparative study of PID, fuzzy PID and fuzzy neural PID control methods is carried out to address the problem of heading control of a kelp harvesting vessel. The response characteristics of the various controllers were analyzed by establishing the control strategy model and heading response model. It is found that the fuzzy neural PID heading controller has small overshoot (about 6%), small static error (almost 0) and fast response (about 14s), and this study lays a technical foundation for the application of high-precision heading control system on real ships.

Acknowledgments

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