Depth Control of AUV with Residual Buoyancy and Residual Moment based on Adaptive Fuzzy Control

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ABSTRACT

In order to prevent the uncontrollable influence of residual buoyancy and residual torque on the motion control of AUV, a depth control method of AUV under unbalanced state is proposed. The control system is mainly composed of three parts: imbalance estimation algorithm, depth controller and AUV kinematics and dynamics model.

To simulate the depth control effect of an underwater vehicle under unbalanced conditions, a mathematical model can be developed based on the principles of fluid mechanics, control theory, and kinematics. An adaptive fuzzy controller based on expert experience is designed and the depth control effect diagram is given. Compared with the traditional double closed-loop PD controller, the adaptive fuzzy controller has better control effect. The residual buoyancy observer is added to eliminate the trim angle caused by the imbalance of the submarine's direct navigation at fixed depth, thus saving energy.

KEY WORDS: AUV, Residual buoyancy, equilibrium, Adaptive fuzzy control, Buoyancy balance control system

INTRODUCTION

As an important substitute and executor of human activities in the ocean, especially in the deep sea, AUV has been widely used in scientific research, ocean operations, salvage and lifesaving, and its application prospects are very broad. According to the needs of the development of marine resources, the utilization of the sea is expanding to the deep sea and the open sea; (Ferguson, 1998) AUV is developing towards multi-task and autonomy. (Lillemoen, 2014) When the multi-mission AUV is sailing in a long distance, the ocean temperature, sea water density and the dynamic system of the AUV body may change, resulting in the change of the buoyancy of the AUV and the imbalance of the buoyancy.

When the AUV is affected by the residual buoyancy during underwater navigation, (Tangirala, 2007) it will cause the AUV to have a certain pitch angle during underwater fixed depth navigation to overcome the impact of the residual buoyancy. (Zhang, 2021) This phenomenon causes the AUV to increase the navigation resistance, increase the energy consumption and reduce the AUV's range.

This paper provides a residual buoyancy state observer, which can reduce the resistance of AUV during underwater navigation and save energy. It is used to eliminate the trim angle and then increase the range of AUV during underwater fixed-depth navigation. This paper also provides an adaptive fuzzy depth and attitude controller for long range AUV. Compared with the traditional double closed-loop PD controller, this controller has better control effect.

TRADITIONAL DOUBLE CLOSED-LOOP PD CONTROL

The traditional double closed loop PD control structure is divided into two layers, and its controllers are PD controllers. The outer ring input is the depth deviation. After PD control, the output is the desired pitch angle. This element is used as the inner ring input. After PD control, the output is the desired elevator angle. The control system block diagram is shown in Figure. 1.

Fig. 1 Structure of double closed-loop PD control

The figure includes a vertical plane motion controller, an attitude sensor and a depth sensor. The attitude sensor detects the attitude of the AUV during underwater navigation, and the depth sensor detects the depth of the AUV during underwater navigation. The vertical plane motion controller is used to control the depth determination movement of the AUV in the vertical plane.

The AUV under-driven fixed depth navigation control based on the PD control strategy is adopted for the vertical plane fixed depth navigation. The inner loop controls the pitch, and the outer loop controls the depth. The depth control and the pitch control in the double closed loop control both adopt the PD control strategy. Through the depth control calculation, a desired pitch is generated. The desired pitch is used as the input of the pitch control, and a desired elevator angle is generated based on the pitch deviation. The AUV is driven by the elevator to navigate at the specified depth;