Suspension Control of a Robot Fish at the Given Diving Depth

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ABSTRACT

In this paper, the suspension control of a Robot Fish with two 2-DOF pectoral fins, a caudal fin and a volume regulator is introduced. Because the diving depth of the robot fish is related to its volume and the hydrodynamic forces acting on its body, the suspension control is implemented by regulating the attack angle of pectoral fins and the volume of the robot fish body. The attack angle of pectoral fins is regulated by a fuzzy controller, and the volume of the robot fish is adjusted to a certain value according to the given depth. A dynamic model of the robot fish which specifies the robot fish’s descending and ascending motions is established in this paper. The simulation results indicate that the robot fish is able to arrive at the given depth without overshoot and stay at the given depth without oscillating of fins.

KEY WORDS: Diving depth control; robot fish; suspension; fuzzy; dynamic model.

INTRODUCTION

Many design concepts of the robots come from imitation of creatures because nature selection has endowed creatures with excellent adaptability to living environment. For example, the developments of the fishlike biomimetic vehicle named robot fish aim at imitating fishes. The subject of developing a robot fish is a comprehensive field which includes mechanics, biology, hydrodynamics and cybernetics. In order to make the robot fish swim in 3D space, many researchers have studied the robot fish from different aspects such as hydrodynamics of the fish fins and motion control of the robot fish.

In the hydrodynamic aspect, Lighthill (1970) offered a preliminary quantitative analysis of how a series of modifications of the basic undulatory mode, found in the vertebrated (and especially in the fishes), tend to improve speed and hydromechanical efficiency. ‘Elongated-body theory’ was developed in detail for pure anguilliform motion and subjected to several careful checks and critical studies. The theory suggested that reduction of caudal fin area in relation to the depth by the development of a caudal fin into a herring-like ‘pair of highly sweptback wings’ should reduce drag without significant loss of thrust. Blake (1979) used a blade-element approach to analyze the mechanics of the drag-based pectoral fin power stroke in an angelfish in steady forward, rectilinear progression. The analysis denoted that the outermost 40 percent of the fin produced over 80 percent of the total thrust during power and did over 80 percent of total work. In the aspect of control method, Kato (1998 and 2002) developed an apparatus of pectoral fins, and made use of a fuzzy method to control robot fish’s motion of swimming forward, swimming backward and turning in the same position in horizontal plane. Morgansen (2001) presented a model for fish propulsion based on quasi-steady fluid flow. Using this model, they proposed gaits for forward and turning trajectories and analyzed system response under such control strategies. Their models and predictions were verified by the experiments. Jin (2005) presented a novel mechatronics design for a 3D swimming robotic fish, namely MT1 (Mechanical Tail) robotic fish. It has a novel tail structure which uses only one motor to generate fish-like swimming motion using C-bends tail shapes. This design is able to dive over 3 meters deep in water. An effective control method with only 5 parameters is proposed to control its 3D swimming behaviours. Experimental results are presented to show the feasibility and good performance of the proposed control algorithms.

There are less works dealing with the suspension control at a given depth. In order to realize the diving depth control of the robot fish, the depth control methods adopted by the real fishes are considered. These methods mainly include volume regulating by an organ named gas bladder, changing the attack angle of pectoral fins while swimming forward. Many real fish with swimming bladder have the ability of ascending, descending and suspension in the water. The bladder has a gas gland that can introduce gases (usually oxygen) to the bladder to increase its volume and thus increase buoyancy. To reduce buoyancy, gases are released from the bladder into the blood stream and then expelled into the water via the gills (www.answers.com). Herein a novel robot fish with pectoral fins, caudal fin and volume regulator is designed through analyzing the real fishes. Because of the uncertainties and perturbations occurred in fluid environment and the difficulties to establish exact dynamic model, the control strategy must be impregnable to perturbations. Herein a fuzzy controller is employed to control the motion of the robot fish since the fuzzy control theory is derived from human experience and independent of model of the controlled plant.

The rest of the paper is organized as below. Section II presents a prototype and a brief description of the robot fish. A simplified dynamic model of robot fish descending and ascending is introduced in Section III. The following Section IV describes the fuzzy controller in detail. Several simulations are carried out in Section V. Then Section VI comes to some conclusions and future work.

THE PROTOTYPE

The robot fish’s prototype proposed in this paper is shown in Fig. 1. The body of the robot fish consists of two parts: anterior rigid streamlined part which is made from fiberglass. In this body part there are motors, control circuit, sensors, communication module and mechanics. The shape of the anterior part is especially important to reduce pressure drag.