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Biology-inspired Precision Maneuvering of Underwater Vehicles (Part 4)

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This paper describes the results obtained in the fourth year of a multi-year program to demonstrate the utility of replacing cumbersome thrusters with a suite of oscillating fins designed to optimize the hovering and low-speed maneuverability of an underwater vehicle. This paper discusses the guidance and control of an underwater vehicle equipped with 2 pairs of oscillating fins in water currents. The rear pair of oscillating fins mounted in the horizontal plane of the original underwater vehicle were reconfigured in the vertical plane. The maneuverability performance in the horizontal plane from the point of turning in a hovering condition and the ability to guide and control around a cylinder in water currents are compared between the original vehicle and the remodeled one.

INTRODUCTION

Existing underwater vehicles, whose motion is controlled by thrusters and wings, exhibit poor performance not only in hovering and turning in a vertical or horizontal plane over intricate seabed terrain in strong currents, but also in dexterous manipulation under floating conditions. Study of the locomotion of aquatic animals can provide new insights into maneuverability and stabilization for underwater vehicles. This paper focuses on the biomimesis of aquatic animals as a source for developing a new device for maneuvering underwater vehicles.

Numerous studies have focused on fish fins and their motion as a model for axial undulation and fin oscillation for propulsion (Barrett et al., 1999; Kumph et al., 1999; Triantafyllou et al., 2000; Anderson et al., 2001; Nakashima et al., 2002). However, due to the prevalent use of screw-type thrusters, the application of axial undulation and fin oscillation as the main thrusters for underwater vehicles is not straightforward. A major drawback of these screw-type thrusters is the sudden generation of a thrust force when the underwater vehicle is hovering, which leads to imprecise control of the position and attitude of the vehicle and of its manipulators. Because many types of fish use oscillating pectoral fins for maneuvers at low swimming speeds (Lindsey, 1978), utilization of the pectoral fin motion could possibly overcome the drawbacks of screw-type thrusters. Such observations have inspired the development of vehicles with flapping foils and other fish-like control devices attached to rigid cylinders (Bandyopadhyay et al., 1997; Hobson et al., 1999; Kato, 2000a; Kato et al., 2000b; Kato, 2002a; Chiu et al., 2004; Licht et al., 2004).

This research program aims at improving and making use of our understanding of biologically inspired maneuvering systems to expand the operational envelope of marine vehicles. It consists of advanced research in unsteady hydrodynamics and innovative approaches to bio-aquatic vehicle control and hardware development for demonstration and performance evaluation.

In our previous paper (Kato et al., 2005), we discussed the guidance and control of an underwater vehicle named PLATYPUS equipped with 2 pairs of oscillating 3-Motor-Driven Mechanical Pectoral Fins (3MDMPF) in the horizontal plane, and we carried out experiments in a water tank to demonstrate its potential application to the field of inspection of underwater structures in a coastal region.

To increase the maneuverability of the vehicle in water currents, we reconfigured the alignment of the rear 3MDMPF of PLATYPUS by setting the fins in the vertical plane.

This paper compares the maneuverability between the original vehicle and the remodeled one from the viewpoints of the azimuth rate in the hovering condition and guidance and control near a cylinder, to testing how well the vehicles would be able to inspect a surface in water currents.

REMODELED UNDERWATER VEHICLE EQUIPPED WITH 2 PAIRS OF MECHANICAL PECTORAL FINS

The fuselage of the original PLATYPUS vehicle is 1.36 m in length, 0.12 m in diam and 14.5 kg in mass. The original vehicle is equipped with 2 pairs of 3MDMPF in the horizontal plane. We reconfigured the alignment of the rear mechanical pectoral fins of the original PLATYPUS vehicle by setting those in the vertical plane, as shown in Fig. 1. Each pectoral fin has a chord 0.1 m in length and a span of 0.08 m. A cylindrical float is attached to the fuselage to adjust its buoyancy. The vehicle has tilt sen-

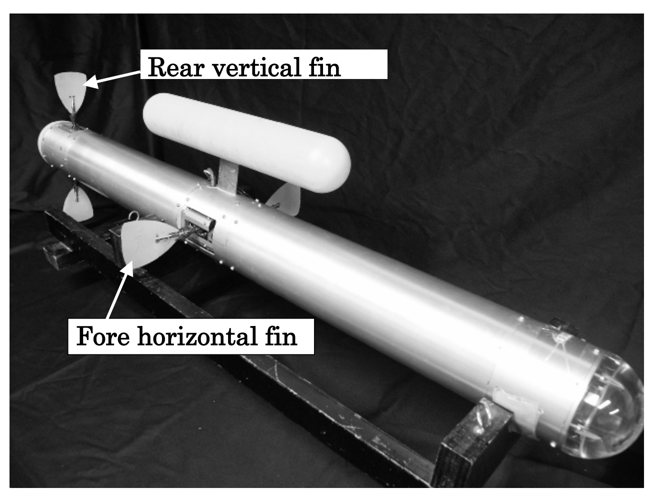

Fig. 1 Photograph of remodeled PLATYPUS

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KEY WORDS: Underwater vehicle, precision maneuvering, biology-inspired.