Chapter 7
Fundamental Control for a Manta-Like Fish Robot

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ABSTRACT

This chapter analyzes a propulsive force generated from pectoral fins for a manta-like fish robot, which is one of rajiform-type fish robot in a classification of swimming mechanism of fishes, from fluid dynamics aspects. The fishes of this type swim underwater with two pectoral fins. A diving method is proposed, assuming that some front fin rays are fixed with a constant angle. The usefulness of the method is demonstrated by numerical simulations and an experiment with an actual robot system.

INTRODUCTION

Various kinds of investigation and researches at the inside of the sea or a shoal, such as search of a sea lost article or seabed resources and observation of a marine organism, are being active in recent years. It is inefficient that man itself dives the inside of the sea directly to such a purpose, because there is a corporal limit. On the other hand, carrying out the above work has so far been performed using robot technology, such as ROV (Remotely Operated Vehicle) and AUV (Autonomous Underwater Vehicle) (Yuh, 1994, 2000). However, most of the conventional AUVs are driven by using the propulsive force from the thruster mechanism with a screw (Watanabe & Izumi, 2008; Zain et al., 2013). It is unsuitable for small turn movement at a low speed, and problems, such as damage to the underwater creature by a

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screw, the noise due to the sound which drains water, etc., are also pointed out, though the promotion method by a thruster mechanism is rich in high-speed acceleration and tracking. For this reason, using "the environment-friendly fish-like robot" which focuses on the locomotion mechanism of the fish has been proposed as an alternative technique. For more information related to biomimetic robots and biological inspiration, refer to e.g., Habib, Watanabe, and Izumi (2007) and Habib (2011).

In this chapter, AUVs imitating fishes are highlighted and a manta-like fish robot is introduced. After reviewing existing several fish robots, which are classified according to the swimming mechanism of fishes (Ikeda et al., 2013a), the manta-like fish robot developed in our laboratory is presented (Ikeda et al., 2013b). In particular, a diving method for the manta-like fish robot is proposed, and the usefulness of the technique is examined by calculating the propulsive force by a pectoral fin and by conducting an actual experiment in a pool by using a real robot system (Ikeda et al., 2014).

BACKGROUND

In this section, several fish robots are briefly reviewed according to a classification of swimming mechanism of fishes. For more detailed discussions, see Ikeda et al. (2013a).

Rajiform Type Fish Robots

Rajiform type fish robots represent, for example, manta-like fish robots that achieve the MPF (Median and/or Paired Fin) propulsion and swim in undulatory fin motions.

A prototype of a manta-like fish robot, RoMan-II, was studied in Zhou and Low (2012). The proportions of all body parts approximately follow those of the real manta ray. Note however that the fin width of RoMan-II was slightly smaller than 0.35 wing span because of mechanical limitations, where 0.35 is the scaled ratio of the fin to the wing span about a real manta ray. Such configuration assures enough strength of the large soft fins. The bionic propulsor (i.e., the flapping fin) was designed with three fin rays at each side. Fin rays were parallel-connected and actuated independently by brushless servo motors, where they were made of elastic material, i.e., polypropylene, so as to add compliance motion. They were also designed as uniform strength cantilever beams to reduce the mass without generating structure failure in oscillations. Fin membrane was made of silicon rubber and attached to the three fin rays. The control signals for all the six fin rays were generated by a central pattern generator (CPG) model. In particular, the authors adopted the Hopf oscillator studied in Seo, Chung, and Slotine (2010) as a fundamental pattern generator to establish a CPG model for their manta-like fish robot.

Kato et al. (2008) described the development of two new types of pectoral fins made of elastic materials. The fins were designed to have flexibility and multi-functionality for use not only as propulsive devices in biomimetic underwater vehicles but also in other applications such as grippers, thus avoiding the environmental damage often caused by rigid fins. They developed an actively controlled pneumatic fin and a passively controlled flexible fin. The former consists of silicone with a build-in FMA (flexible micro-actuator) and generates propulsive force by using a lifting motion driven by the FMA, whereas the latter is composed of silicone rubber and generates propulsive force by using a dragging motion. It was experimentally checked that the elastic pectoral fins were able to generate propulsive force and an FEM (finite element method) was used to analyze the behavior of the fins.