International Journal of Offshore and Polar Engineering (ISSN 1053-5381)

Vol. 15, No. 1, March 2005, pp. 1–6

Research on Patrol Algorithm of Multiple Behavior-based Robot Fish

Haiquan Sang, Shuo Wang, Min Tan, Zhigang Zhang
Laboratory of Complex System and Intelligence Science, Institute of Automation
Chinese Academy of Sciences, Beijing, China

This paper discusses the system of the patrol control mechanism and algorithm of multiple robot fish. A behavior-based control architecture is presented. Basic behaviors are designed for robot fish, and behavior selection strategies are also depicted. The description of the multiple robot fish patrol task and the definition of multiple robot fish patrol modes are given. Then the algorithms for formation-keeping and patrol control are developed. Finally, some experimental results are discussed to testify to the validity of these algorithms.

INTRODUCTION

Biomimetic robot technology is one of the hotspots in underwater robotics research in recent years. Biomimetic robot fish (abbreviated as robofish here on out) is the combo of fish-like propulsive mechanism and robotics technology. It provides a new train of thought to develop an underwater vehicle with high efficiency, high maneuverability and low noise. Such fields as underwater operation, ocean monitoring, marine organisms observing, military surveillance, ocean exploration and exploitation will benefit from it. Many researchers have done a lot of significant work on robofish; their research has mainly concentrated on individual robofish. For example, Barrett, Grosenbaugh and Triantafyllou (1996) developed a self-optimizing motion controller for robofish based on a genetic algorithm, which effectively optimizes swimming performance. Kato and Furushima (1996) carried out an experimental analysis of fish fin motion and performance tests of a pectoral-fin model from the viewpoint of maneuverability of underwater vehicles. Morgansen, Duindam, Mason, Burdick and Murray (2001) considered the design of motion control algorithms for an experimental planar robofish that was propelled by carangiform-like locomotion. McIsaac and Ostrowski (2002) investigated motion planning for an underwater eel-like robot. Due to the complexity, uncertainty and concurrency of tasks, the capability of individual robofish is very limited in some applications. In such cases, a feasible way is to resort to multi-robofish cooperation and coordination for accomplishing the required task. In view of the particularity and complexity of the underwater operating environment as well as distinctiveness of the robofish swimming mode, research results of a multi-robot system based on a mobile robot or industrial robot cannot be directly transplanted to the control of a multi-robofish system. The research on the coordination and cooperation of multi-robofish is an attractive direction in robofish research, and some research work hase been carried out (Yu, 2003). This paper thus focuses on multi-robofish cooperation and coordination to complete special tasks in a complex environment. In this paper, the patrol control mechanism and algorithm are mainly discussed based on the patrol task.

The study of multi-robofish patrol is helpful to the research on coordination and cooperation and also has some promising applications. For example, in a fishery area, birds often prey on the fish in the piscine, but for the sake of ecological equilibrium fishermen cannot kill these birds. The only thing that fishermen can do is to scare them away. In this respect robofish can help fishermen. Robofish can patrol on the water day and night, and they can give off large noises to frighten the birds as soon as they are detected. In the military, robofish can fulfill many tasks, such as patrol and reconnaissance, and underwater information collecting.

A 4-link, biomimetic, carangiform robofish with wireless remote control was developed by the Laboratory of Complex System and Intelligence Science (LCSIS) in 2001. In 2002, the Multiple RoboFishes System (MRFS) was founded by LCSIS for the research of multi-robofish coordination and cooperation. Recently, a 3-link biomimetic carangiform robofish was developed and it was used in the following experiment. The difference between the 4-link and 3-link robofish lies in the number of servo motors: The 4-link robofish has 4 servo motors, and the 3-link robofish has 3. In this paper, a behavior-based control mechanism is adopted to develop the control algorithms and control tactics for the multi-robofish patrol task.

CONTROL ARCHITECTURE OF BEHAVIOR-BASED ROBOFISH SYSTEM

The control architecture of the behavior-based robofish system is presented here. It consists of 6 modules (Fig. 1). The functions of each module follow.

- **The Basic Behavior Set** is used to store a variety of behaviors for a given task. Basic behaviors for the patrol task will be introduced in the next section.
- **The Behavior Decision Module** implements the switch between behaviors and decides on the next behavior on the basis of the current behavior and environment information. In the paper, the module is realized by the patrol control algorithm.
- **The Communication Module** mainly implements information delivery among robofish, realized by the wireless communication board in the MRFS.
- **The Coordination Policy Module** coordinates the behaviors of multi-robofish, such as formation keeping.

Received February 23, 2004; revised manuscript received by the editors October 20, 2004. The original version (prior to the final revised manuscript) was presented at the 14th International Offshore and Polar Engineering Conference (ISOPE-2004), Toulon, France, May 23–28, 2004.
KEY WORDS: Biomimetic robot fish, patrol, behavior-based control system, cooperation and coordination.