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Optimal Measurement Strategies for Target Tracking by a Biomimetic Underwater Vehicle

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ABSTRACT

The purpose of this study is to develop a navigation and control system for a biomimetic-autonomous underwater vehicle (BAUV) to track a target. A Bayesian method, using an extended Kalman filter, combining localization and environmental mapping by a BAUV is implemented. This strategy selects the best sensor measurement by choosing one of several forward-looking directions. BAUVs' body moves in a cyclic pattern, so a cheap echo sounder may be installed on the head of the BAUV to detect environmental features, without the need to use expensive scanning devices. The localization and environmental mapping problem is then transformed into a nonlinear two-point boundary value problem. The optimal policy is to maintain the accuracy of the predicted states and to approach minimal cost of observation by solving the control problem. A line-of-sight guidance law which drives the BAUV to the target is used. A method that controls the motion of the body/caudal fin and pectoral fins of the BAUV is proposed for the target tracking. The estimation, measurement, and control process are integrated to form a working system. Experiments performed using a testbed BAUV confirm the effectiveness of the proposed method.

KEY WORDS: biomimetic; underwater vehicles; tracking; navigation

INTRODUCTION

Undersea vehicles, including autonomous underwater vehicles (AUVs), have become important in undersea inspecting and surveying. However, poor propulsive efficiency and maneuverability while hovering remain challenges to AUV designers. Biomimetic AUVs (BAUVs) mimic natural fish that have been evolving for thousands of years. Fish have a remarkable ability to remain very stationary and turn tightly and quickly. The shapes of fish are appropriate for swimming in water. The BAUV as a fast and highly maneuverable vehicle is promising for the design of future underwater vehicles.
The swimming skill of fish is a valuable reference for designers of future underwater vehicles. For example, fish can rapidly, with the radius of 10% to 30% of body length, turn and vary the advancing direction[Colgate,2004]. By contrast, ordinary ships or underwater ships must turn around slowly by radius of about ten times of the ships' lengths. Therefore, fish-like underwater vehicles are suitable to be used as highly maneuverable underwater trackers. The purpose of this study is to develop such a system to facilitate a biomimetic underwater vehicle as a tracker to track a target.
The work of present author in the biommetic autonomous underwater vehicle development focused on the control of body and/or caudal fin (BCF) and median and/or paired fins (MPF) movements. Chiu *et al.*(2000) simulated the undulatory motion of a flexible slender body. Guo *et al.* (2003) developed an optimal body-spline to enable the BAUV to swim forward. Guo *et al.* (2005) developed a method for coordinating body segments and paired fins, and thus to control the motion of a BAUV. Guo *et al.* (2004a, 2006) combined turning motion with forward-swimming motion to design a control system to track waypoints.
For the modeling of maneuvering objects, random walk velocity models are widely used as a common model in maneuvering target tracking, where very little is known about target maneuvers. Rago *et al.*, (2000) presents a random walk process for the target velocity model. Introduction to the guidance law for underwater vehicles can be found in Naeem *et al.*, (2000). For the development of measurement policies, most of the optimal control and estimation theories can be found in Anderson *et al.*, (1990), and Grewal *et al.*, (2001). Athans (1972) presents the formulation of a class of optimization problem dealing with selecting, at each instant of time, one measurement provided by one out of many directions. Each measurement has an associated measurement cost. Guo *et al.*, (2004b) also presents optimal measurement polices for a biomimetic underwater vehicle which can be obtained by minimizing a cost function.
Section of MODELING presents the kinematic and measurement models for the tracker and target. An estimation scheme is also presented using the structure of an Extended Kalman filter. Optimal measurement policies and guidance law formulation are then given in the MEASUREMENT POLICIES and CONTROL section, respectively. The purpose of the proposed optimal measurement strategy is to minimize the uncertainties of the target states intelligently. The descriptions of hardware are illustrated in section EXPERIMENTS. Experiments conducted in a water tank using the optimal measurement strategy and guidance law are also described. Finally, concluding remarks are given in CONCLUSION.