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Optimal control of an underwater glider vehicle

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Abstract

The aim of this paper is the trajectory control and navigation of an underwater autonomous mobile robot. The robot discussed in this paper is part of a new class of AUV's (Autonomous Underwater Vehicles) called underwater gliders.The underwater gliders stand out for replacing the thrusters for a mechanism of translation and rotation of internal masses and varying buoyancy, to move around.This new class of vehicles aims to overcome the problem of autonomy, found in other types of AUV's, due to limited battery life. The motion control is accomplished by the linearization of the non-linear model and applied the optimal control strategy known as LQR (Linear Quadratic Regulator). This strategy is applied to the robot control problem to track a reference and the robot control method effectiveness is verified by numerical simulations. The simulations show that the robot was capable to follow the path reference, in a maneuver of diving, in a short period of time. Thus demonstrating that the applied control method is a viable option, especially considering the need for battery saving since the method applied is optimal.

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*Keywords:*Underwater glider; Optimal control; LQR, Mobile Robots.

1. Introduction

Autonomous Underwater Vehicles (AUV's) are used for a wide range of applications, such as ocean survey, environment monitoring, inspections and operation and many others. It relation to existing underwater vehicles, autonomous underwater gliders have a number of important technical advantages: superior spatial and temporal

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measurement possibilities, longer availability and wider operability. Thus, the use of such AUVs can make these tasks more efficient, cheaper and safer [1]. Nowadays there are a number of underwater gliders projects [2], [3]. The most famous are SLOCUM glider [4], “Sprey”glider [5] and the “Seaglider” [6]. They have no thrusters or propellers and have limited external motion control surfaces. These gliders rely only on buoyancy variation and internal mass distribution. It makes them extremely energy efficient. Buoyancy variation is carried out by means of shifting the internal ballast. It leads to gliders vertical motion. Their fixed wings transform this motion into inclined. The internal mass distribution plays a vital role in angles of ascent and descent. Additionally, size and weight of underwater gliders are relatively small in comparison to other classes of unmanned underwater vehicles. All these factors make gliders extremely attractive for oceanographic researches that requires autonomous and long-term operations [2].

An accurate and reliable glider control system should be developed to realize the functionality of the glider and to allow it to conduct ocean sampling with high economic efficiency. In this paper the feedback control was used to improve the glider robustness to uncertainty and disturbances. The nonlinear dynamic model was used to develop the optimal control for underwater gliders with fixed external surfaces that can control their buoyancy and center of gravity (CG). The proposed model is intended to improve upon the existing glider control strategies. The developed approach can be widely implemented in comparisonto exclusively vehicle-specific approaches.

The results were illustrated on a model of a small underwater glider called “MarIam” (figure 1) that was built in Samara National Research University. The CG position is controlled by shifting a lead weight inside a vehicle. MarIam controls its buoyancy by means of varied ballast mass. The results were obtained for MarIam when it operated in the laboratory pool.

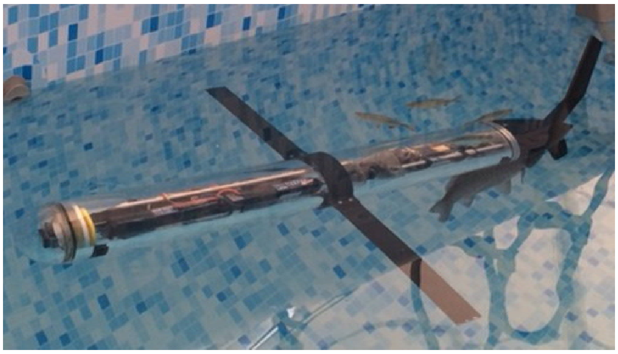

Figure 1: Experimental underwater glider MarIam

2. Glider Dynamics

There is a number of papers on dynamics, stability and control of airplanes, including [7], [8], [9]. They are very useful for theoretical investigations of underwater gliders but these papers do not take into account the added mass forces, variable buoyancy and controlled mass redistribution. These factors play a vital role in glider dynamics.

Paper [10] discuss the time-optimal trajectories for fir fully actuated planar underwater vehicles. The focus of this paper was made on structure of singular extremals and their possible optimality. Papers [11] and [12] focus on the coordinating control of multiple underwater vehicles using artificial potentials and virtual leaders.

This paper adopts the equations of motion for the underwater glider presented in papers [2, 3]. The longitudinal model is obtained from the tridimensional model, considering these equations restricted to the vertical plane.

2.1 Equations of motion