Integral Backstepping Controller for an Underactuated X4-AUV

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ABSTRACT

The autonomous underwater vehicle (AUV) capability has great important tasks for navigating into abyssal zones and dangerous underwater mission. Mostly AUV has six degrees of freedom (DOF) in motion and is classified in an underactuated system. The underactuated system is a system with fewer inputs than DOF. However, stabilizing an underactuated system is difficult tasks because of the nonlinear dynamic and model uncertainties. Thus, our aim is to obtain control algorithms using Integral Backstepping approach in order to stabilize the X4-AUV. The key idea of Integral Backstepping is to design a virtual controller by working together with the integration of tracking error. Numerical simulation results are given to show the validity and the good performances of the proposed method.

Keywords: Integral Backstepping · Underactuated system · X4-AUV ·

INTRODUCTION

Underwater robotics is an important research area due to its great applications: i.e., from a scientific research of ocean, surveillance, inspection of commercial undersea facilities, military operations and many more. Nevertheless, controlling such system is a challenging task because the dynamic model has nonlinearity and uncertain external disturbances besides difficulties in hydrodynamic modelling. Thus, it attracted further research and attention correlate with underactuated AUV, defined as the system with a fewer number of control inputs than a number of DOF and generally falls in nonholonomic systems.

Control of nonholonomic systems is theoretically challenging and practically interesting. Brockett's Theorem (Brocket, 1983) defined those systems cannot be stabilized to a point with pure smooth (or even continuous) state feedback control, usual smooth and time invariant. A stabilization problem consists of designing control law which guarantees an equilibrium of a closed loop system is asymptotically stable or at least locally asymptotically stable. Therefore, control problems for underactuated systems usually required nonlinear control techniques. There are numerous nonlinear control techniques can be applied for controller and backstepping approach has gained the attention recently.

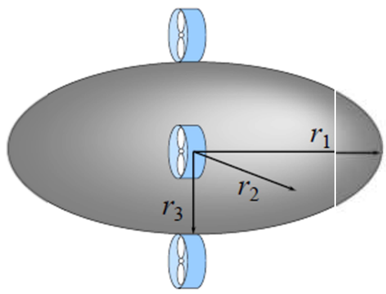

Figure-1. X4-AUV with an ellipsoidal hull shape

A model of X4-AUV with six DOFs and four control input (thrusters) is presented. It categorized in underactuated AUV and has equations of the motion appear as second-order nonholonomic constraints. Zain (Zain et. al., 2010) proposed an X4-AUV with an ellipsoidal hull shape as shown in Figure 1. The slender body of ellipsoidal hull shape make it works efficiently than conventional X4-AUV (Okamura, 2009) in term of drag pressure.

This study proposed an integral backstepping control strategy to stabilize position and angles of an understated X4-AUV. The main idea in integral backstepping controller design is adding the integral of tracking error between the original system input and the input to design as a first step of control strategies. The proposed technique widely applied and effective in stabilizing the quadrotor helicopters which also generally falls into underactuated system (Tahar et.al., 2011), (Bouabdallah and Siegwart, 2007).

In this paper, an integral backstepping is applied to stabilize an underactuated X4-AUV with four thrusters and six DOFs in motion. The X4-AUV is executed by nonlinear control strategy with separate into two parts subsystem: i.e., translational and rotational subsystems. The controller for translational subsystem stabilizes the position and for rotational subsystem achieves the desired roll, pitch, and yaw angles.

COORDINATE SYSTEM

A special reference frame must establish in order to describe the motion of the underwater vehicle. There are two coordinate systems: i.e., an inertial coordinate system (or fixed coordinate system) and motions coordinate system (or body-fixed coordinate system). The coordinate frame {E} is composed of the orthogonal axes $\{E_x\ E_y\ E_z\}$ and is called as an inertial frame. This frame is