Integral Backstepping Control for Stabilizing an Underactuated X4-AUV

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Abstract

Autonomous Underwater vehicles (AUV) is one of an unmanned underwater vehicle (UUV) that work independently and can be control automatically on board without requiring a cable. The autonomous capability has great important tasks due to navigate in abyss zones and dangerous underwater mission. However, in order to stabilize the system consists of four control inputs and six degree of freedoms (DOFs) is difficult tasks because of the nonlinear dynamic and model uncertainties. This paper presents the stabilization of underactuated X4-AUV using nonlinear control techniques, integral backstepping. The key idea of integral backstepping is to design a virtual controller for each subsystem by associate with integral of tracking error. The effectiveness of the proposed control technique demonstrates by simulation.

Keywords. X4-AUV; Underactuated systems; Integral Backstepping

1. Introduction

There is no doubt that underwater robotics is to be an important scientific area due to its great applications, which vary from scientific research of ocean, surveillance, inspection of commercial undersea facilities and military operations. Nevertheless, controlling such system is a very challenging task because the dynamic model has nonlinearities and uncertain external disturbances besides difficulties in hydrodynamic modelling. Thus, it attracted further research and attention associated with underactuated AUV, defined as system with fewer number of control inputs than number of DOF and generally falls in nonholonomics systems. Control of nonholonomic systems is theoretically challenging and practically interesting. Due to Brockett's Theorem [1] , these systems cannot be stabilized to a point with pure smooth (or even continuous) state feedback control, usual smooth and time invariant. Therefore control problems for underactuated systems usually required nonlinear control techniques. In this paper, we proposed an integral backstepping control strategy to stabilize all postion and angles of an underactuated X4-AUV. An X4-AUV with an ellipsoidal hull shape was studied by Zain [2], in which used four thrusters to control the vehicle without using any steering rudders and falls into class of underactuated AUVs and has nonholonomic features.

2. X4-AUV Dynamic Model

The dynamic equation of X4-AUV is given by:

$$\begin{aligned}
m_1\ddot{x} &= \cos\theta\ \cos\psi\, u_1 \\
m_2\ddot{y} &= \cos\theta\ \sin\psi\, u_1 \\
m_3\ddot{z} &= -\sin\theta\, u_1 \\
I_x\ddot{\phi} &= \dot{\theta}\dot{\psi}\left(I_y - I_z\right) + u_2 \\
I_y\ddot{\theta} &= \dot{\phi}\dot{\psi}(I_z - I_x)\ - J_t\dot{\psi}\Omega\ + lu_3 \\
I_z\ddot{\psi} &= \dot{\phi}\dot{\theta}(I_x - I_y)\ + J_t\dot{\theta}\Omega\ + lu_4
\end{aligned} \tag{1}$$