Fault Tolerant Control for a Fractional Order AUV System

Sneha D. Joshi, Pune University, Pune, India
D. B. Talange, College of Engineering Pune, Pune, India

ABSTRACT

In the last decade Autonomous Underwater Vehicles are used in large number. The control issue of these vehicles is very challenging due to uncertain underwater environment. Conventional controllers may fail during operations especially when changes in the system occur, since it is impossible to re tune the controller in water. Hence the autonomous underwater system must have controller capability to detect, identify and tolerate fault, abort the ongoing mission and return to water surface. In this paper fault tolerant control algorithm is designed and applied to fractional order model of AUV. While designing fault tolerant controller state observer feedback technique is used. It is observed that the fractional order system is stable for fractional order greater than 1 and less than 2 under normal and under actuator failure conditions. For gain optimization of feedback controller LMI approach is used.

KEYWORDS
Actuator, AUV, Fault, Fractional, Model, Robust, Stability

1. INTRODUCTION

For last so many years extensive research is going on Autonomous Underwater Vehicles (AUVs) (Fossen, 1994). AUVs are used in many applications such as subsea monitoring, oil industries, defense applications etc. It is an autonomous system with on board control without an umbilical cable. Numerous control schemes are adopted over the past few years for AUV which includes PID control (Ang et al., 2005), LQR control (Santoso et al.), Fuzzy control (Kim and Yuh, 2001; Sadeghi and Hosseini, 2013), Robust control (Yoerger and Slotine, 1985) and Fractional Order Control (Zhao et al., 2005), etc. These controllers mainly focused on tracking errors to keep AUV on its defined trajectory. It is observed that due to environmental uncertainties there are chances of pulling the AUV out of defined trajectory and requiring more control effort in keeping AUV in its defined trajectory. Later an adaptive control (Dao et al., 2013) strategy for tracking control of AUV was proposed by Li to maintain the AUV in defined trajectory (Yoerger and Slotine, 1991). In uncertain ocean environment AUVs may face faults or failures while performing underwater tasks. Typically the sensors and thrusters are the main sources of failures in AUVs. Thruster fault results in termination of ongoing mission of AUV. This is definitely financially unaffordable as well as time consuming. If actuator fails there is partial or total loss of control action. To overcome actuator faults, one solution is duplicating actuators in the system but in case of AUV it is not feasible due to its large size and high price. Hence robust fault tolerance is achieved through existing actuators only. Therefore robust fault tolerant control is a need in AUV over past few years. Performance of AUV is directly related to pertinence of the mathematical model used for predicting system behavior.

The complexity of optimization problem of controller increases as per the model of the system used for prediction (i.e. linear or nonlinear due to uncertainties). The main practical difficulty is
related to computational accuracy and bandwidth of the feasibility region. The main contribution of this paper is to handle this trade-off between accurate prediction and complexity of optimization problem by proposing a fractional order system with LMI approach. This enhances band width of the controller and reduces computational efforts. Due to proposed method, the optimal control problem gets converted into convex optimization framework. Indeed it is proved that efficient control solutions can be implemented by exploiting piecewise linear model or dividing model into subsystems. The failure conditions are formulated in terms of Linear Matrix Inequalities (LMI) (Adam-Medina et al., 2003). This procedure guarantees an improved solution in terms of performance and stability of the system. The improved system may be difficult to implement due its high sampling rate and for this reason fractional order model is found suitable.

In this paper active robust control strategy is developed to sustain failure of an actuator. Further design of controller for Fractional Order model of AUV is discussed using LMI approach. The paper is organized as follows:

Section 2 gives an idea about literature survey related to fault tolerant control in AUV. Section 3 represents Mathematical Modeling of AUV. Section 4 is on state space representation of fractional order system. In section 5 stability analysis using LMI approach is discussed. Section 6 represents simulation results. In last section concluding remarks and future scope is explained.

2. LITERATURE REVIEW

A research on fault tolerant control in AUV has begun since 1990 (Phillip and Zinchuk, 1990). In later years more concentration was done on sensor and actuator faults in AUV. Fault tolerant control due to actuator or thruster faults is focused in many research papers. Fault tolerant control in AUV propulsion system is considering two vertical and two horizontal thrusters (Omerdic and Roberts, 2004). To improve the reliability of AUV new fault tolerant methods are being developed. Fault tolerant control of fractional order AUV is one of them.

From the stability analysis of fractional order systems, it is seen that using LMI approach the FOLTI systems can be explained in better way. The integer order systems and fractional order systems are equivalent at low frequencies. At high frequencies integer order system does not describe system dynamics at all. Fractional order controller show better transient response when they are applied to fractional order systems.

Fractional order controller was first time designed by Oustaloup. Infinite memory length is proved as great advantage for fractional order system, which helps in modeling and control of dynamic systems.

3. MATHEMATICAL MODELING OF AUV

3.1. AUV Dynamics

Dynamics of AUV is expressed in terms of kinematics and kinetics of AUV. The motion of underwater vehicle is in 6 DOF i.e. in translational and rotational along x, y, & z axes. The notations used for modeling are in SNAME nomenclature (see Table 1). The general motion of vehicle is described by following vectors.

\[ \eta = [\eta_1^T, \eta_2^T]^T, \eta_1 = [x, y, z]^T, \eta_2 = [\phi, \theta, \psi]^T; \]  

\[ v = [v_1^T, v_2^T]^T, v_1 = [u, v, w]^T, v_2 = [p, q, r]^T; \]  

(1)  

(2)
22 more pages are available in the full version of this document, which may be purchased using the "Add to Cart" button on the product's webpage:
www.igi-global.com/article/fault-tolerant-control-for-a-fractional-order-auv-system/151518?camid=4v1

www.igi-global.com/e-resources/library-recommendation/?id=2

Related Content

Extremely Low Frequency Electric Field Emissions for Space Applications: Measuring and Modeling Techniques
www.igi-global.com/chapter/extremely-low-frequency-electric-field-emissions-for-space-applications/199510?camid=4v1a

Energy-Efficient Routing Techniques for Wireless Sensors Networks
www.igi-global.com/chapter/energy-efficient-routing-techniques-for-wireless-sensors-networks/146731?camid=4v1a
Robustness of US Economy and Energy Supply/Demand Fluctuations
[www.igi-global.com/article/robustness-of-us-economy-and-energy-supplydemand-fluctuations/186986?camid=4v1a](www.igi-global.com/article/robustness-of-us-economy-and-energy-supplydemand-fluctuations/186986?camid=4v1a)

System Reliability-based Optimization Method to Solve Unavailability of Electrical Energy
[www.igi-global.com/article/system-reliability-based-optimization-method-to-solve-unavailability-of-electrical-energy/153654?camid=4v1a](www.igi-global.com/article/system-reliability-based-optimization-method-to-solve-unavailability-of-electrical-energy/153654?camid=4v1a)