ASTRODYNAMICS SYMPOSIUM (C1)
Attitude Dynamics (2) (4)

Author: Mr. Jian-Feng Shi
MDA Corporation, Canada

Prof. Steve Ulrich
Carleton University, Canada

A DIRECT ADAPTIVE CONTROL LAW USING MODIFIED RODRIGUES PARAMETERS FOR ISS ATTITUDE REGULATION DURING FREE-FLYER CAPTURE OPERATIONS

Abstract

A direct adaptive control law is developed for a robust ISS attitude regulation during robotic capture of a free-flyer by the Space Station Remote Manipulator System (SSRMS). The proposed output feedback direct adaptive controller is developed from the Simple Adaptive Control (SAC) theory, and makes use of the Modified Rodrigues Parameters (MRP) to formulate the Euler-Lagrange system into a non-linear square state-space model. The adaptive control gain matrix contains a stabilization component that is adapting to the output tracking error, as well as two ideal model-based feedforward components to improve the tracking performance. All adaptive control gains are obtained from an integral and proportional term. An almost strictly passivity-based approach is adopted to guarantee the analytical closed-loop stability via Lyapunov's direct method. Furthermore, asymptotic stability is demonstrated by LaSalle's invariance principle for non-autonomous systems.

The proposed method was tested on the MacDonald, Dettwiler and Associates (MDA) Space Station Portable Operations Training Simulator (SPOTS), a high-fidelity multibody flexible dynamic simulation facility. SPOTS represent the main dynamic simulation tool used by Canadian Space Agency (CSA) for Mobile Servicing System (MSS) operations and planning for the International Space Station (ISS). Specifically, the SPOTS software support MSS flight software verification, partial operation procedure development and checkout, real-time flight support, and end-to-end berthing operations. Some examples of past ISS operations analyzed by SPOTS include ISS assembly, battery box change-outs, manipulator to manipulator payload hand-offs, NASA Robotic Refueling Mission (RRM) tasks, MSS robotic free-space and contact tasks, and SpaceX Dragon, Orbital Science Corp. Cygnus, JAXA HTV capture and releases. SPOTS capability includes flexible body dynamics, orbital mechanics, contact dynamics, encapsulated flight software, and integrated robotic models from CSA, JAXA, NASA, and Roscosmos.

SPOTS simulation results are provided for two scenarios: (1) a simple single body spacecraft attitude control, and (2) an ISS free-flyer capture of a SpaceX Dragon like space vehicle. The second scenario includes flexible manipulator and free-flyer vehicle.

To summarize, this study takes the SAC theory and adapt it to the SPOTS simulation environment. It examines the adaptive controller performance in a complex simulated environment setting. This comprehensive paper provides the theory as well as simulation results to highlight the improved performance and robustness to parametric and dynamics modeling uncertainties of the proposed novel attitude control approach compared with a Proportional-Derivative controller.