IAF SPACE TRANSPORTATION SOLUTIONS AND INNOVATIONS SYMPOSIUM (D2)
Upper Stages, Space Transfer, Entry & Landing Systems (3)

Author: Dr. Jihyoung Cha
Luleå University of Technology, Sweden, jihyoung.cha@ltu.se

Prof. Élcio Jeronimo de Oliveira
Luleå University of Technology, Sweden, elcio.jeronimo.de.oliveira@ltu.se

ROBUST GUIDANCE AND CONTROL OF LIQUID-PROPELLANT ROCKETS FOR LANDING OF REUSABLE STAGES USING FUZZY PID CONTROL

Abstract

The high cost of rocket technology has led to system reusability developments, particularly in the field of first-stage rockets. With the motivation of decreasing production costs, successful vertical rocket landing attempts by SpaceX and Blue Origin have led the path for autonomous recovery and reusability of rocket engines. After the success of the space companies, recovering and relaunching reusable first stages have demonstrated the possibility of building reliable and low-cost reusable first stages. In the landing process, an optimized trajectory and robust control algorithm of a reusable launch vehicle (RLV), which can be minimized propellant consuming, are needed because the RLV is affected by various uncertainties such as a wind gust, atmospheric condition, or aerodynamic problem. Therefore, it is necessary to obtain an optimized trajectory and design a robust control algorithm to cope with the problems. The instantaneous impact point (IIP) is defined as "a touchdown point, following thrust termination of a launch vehicle calculated in the absence of atmospheric drag effects." In launch operations, the IIP is considered a crash point after an abrupt end of the propelled flight, so the IIP should be calculated and monitored in real-time on the ground facility or the rocket to predict and prevent the potential risk in advance, which can occur around the touchdown point. In other words, the IIP can be used to obtain an optimized trajectory that can minimize the consuming propellants. Since the guidance and control for the landing process of reusable first stages is a specific research field that presents multiple goals and constraints, the fuzzy PID control algorithm is suitable for the system. The algorithm has several robustness strengths, bounded-input, bounded-output (BIBO) systems, and nonlinear systems. In the landing process, the control references generally are thrust magnitude and vector control for velocity control and reaction control system (RCS) or grid-fin for attitude control. We propose a fuzzy PID control algorithm for robust guidance and control of RLV with a liquid-propellant rocket engine (LPRE) in the landing process using an optimized trajectory obtained by the IIP algorithm. To do this, we develop the simplified mathematical model of SLV using LPRE, obtain optimized passage for landing using the IIP method, and design a fuzzy PID control system based on thrust magnitude and vector control to control velocity and grid-fin or RCS to control attitude. We demonstrate the performance through numerical simulation to confirm the control algorithm.