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DESIGN OF ON-BOARD FUEL-OXIDIZER MASS ESTIMATION ALGORITHM FOR TEAMINDUS LUNAR LANDING MISSION

Abstract

TeamIndus (TI)'s Lunar Logistics program envisions multiple lunar missions over the coming years to meet commercial and scientific requirements. TI was one of the five finalists for Google Lunar X-Prize (GLXP). The objective of the mission was to soft land a spacecraft on the surface of moon, explore 500m and relay back high definition imagery. The mission profile of TI's lunar missions can be split into the *orbital phase*, which brings the spacecraft to desired entry conditions for lunar descent, and the *descent phase* which delivers the lander to the desired landing site.

The autonomous powered descent phase is split into multiple phases among which the approach phase is a critical maneuver. In this phase, all inherited dispersions from previous mission phases are nulled and the vehicle is brought to a targeted position and velocity. This is done using a Closed-Loop-Guidance (CLG) scheme. However, the realization of the acceleration demand from CLG into thrust commands for the Reaction Control Thrusters (RCTs) requires an estimate of the spacecraft mass. For this mission, the allowable error tolerance is four kilograms. Tight constraints on mass, cost and schedule requires this problem to be addressed through software. This paper proposes a computationally stable, fast and inexpensive oxidizer-fuel mass estimation algorithm using measurements from an Inertial Measurement Unit (IMU) and RCT thrust commands history. Various aspects considered in this paper include noise, roughness, bias, misalignment and latency of the sensors and actuators.

The impulses and incremental velocities are accumulated and used to compute the total mass of the spacecraft in pseudo real-time (60ms delay). A simplified actuator model which lumps the thruster dynamics and latency is developed for this purpose. The accumulation period is determined dynamically by comparing the incremental accumulated velocity against a preset threshold. This is done so as to ensure high Signal-to-Noise Ratio (SNR). Subsequently, parameter estimation is used to derive thruster specific parameters, namely average thrust, average specific impulse and average Oxidizer-to-Fuel Ratio (OFR) for sixteen 22N Reaction/Attitude Control Thrusters and a 465N main engine. Once the parameters are estimated, mass consumption equations are used to update the oxidizer and fuel masses.

The performance of the algorithm is demonstrated through Monte-Carlo runs of the lunar descent maneuver. This is followed up with sensitivity analysis of the estimated quantities with respect to knowledge errors of spacecraft parameters.