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SPACE DEBRIS SYMPOSIUM (A6)
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Author: Mr. Alessandro Migliaccio
Alten Sud Ouest, France

Mr. Tittu Varghese Mathew
Switzerland

PRELIMINARY DESIGN OF A FREE-FLOATING MANIPULATOR SYSTEM FOR SPACE DEBRIS MITIGATION

Abstract

The orbital debris environment is composed of metallic fragments with a particle density of 2.8 g/cm3, corresponding to aluminum metal. The majority of large debris bodies in LEO region are constituted by spent stages of Kosmos 3M rocket having cylindrical dimensions of 6.5 m height and 2.4 m diameter. Based on the results from recent studies that five large debris must be removed per year so as to stabilize the growth of debris population, Kosmos 3M stages were identified as the perfect candidate for our ADR mission study. The proposed debris mitigation spacecraft is capable to rendezvous, capture and de-orbit a passive and non-cooperative rocket stage. The spacecraft will be manually controlled from a ground station through supervisory control architecture so as to overcome the problem of time delay. During the rendezvous phase of mission, debris information regarding its attitude, mass, size and shape are uploaded to the spacecraft from existing debris catalogue maintained by the US Space Surveillance System. A deployable serial chain dual-arm manipulator with 6 degrees-of-freedom is envisioned to provide full control over the positioning and orientation of the end-effector. A CPS chain configuration is selected for the anthropomorphic arm – where C denotes Rotary (R) and Prismatic joint (P) at the base sharing the same axis and S denotes a spherical wrist – inorder to achieve the required cylindrical workspace. To allow a three-fingered end-effector to grab onto the edges of the rocket stage adaptor, an under-actuated scheme is selected with double acting actuators and joints kinematically coupled in a fixed way. Electric actuators are placed remote at the base of the end-effector and the motion is transmitted by rigid mechanisms with fixed transmission ratios. Since the shape of rocket stage is known apriori, shape adaptability is not a necessary characteristic. Hall-effect sensors are used to measure the system state and strain gauges to measure the external forces and torques acting on the system. After coupling with the target, the spacecraft-debris combination is put on a ballistic trajectory for re-entry into the atmosphere. This paper will present the results from the feasibility studies of various debris disposal studies, followed by giving main emphasis on the design of robot manipulator and end-effector coupled with trade-offs for selection of actuator and sensor design and finally presenting the results of simulation.