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ORBIT CONTROL OF HIGH AREA-TO-MASS RATIO SPACECRAFT USING ELECTROCHROMIC COATING

Abstract

This paper presents a novel method for the orbit control of high area-to-mass ratio spacecraft, such as spacecraft-on-a-chip, future 'smart dust' devices and also inflatable spacecraft. By changing the reflectivity coefficient of an electrochromic coating on the spacecraft, the perturbing effect of solar radiation pressure (SRP) is exploited to enable long-lived orbits and to control formations, without the need for propellant consumption or active pointing.

Recent advances in miniaturisation make the prospect of near-term MEMS-scale satellite missions realistic, employing system devices of length-scale 0.1-10 mm. These spacecraft offer cheap manufacture and launch, and can thus be deployed in large numbers providing multiple perspectives and global live information. The orbits of such satellites are influenced significantly by surface force perturbations such as solar radiation pressure and aerodynamic drag due to their high area-to-mass ratio. Area-to-mass ratio grows quickly as the spacecraft length-scale shrinks.

The aim of this paper is to exploit the effect of orbital perturbations as a means of orbit control. The spacecraft is coated with a thin film of an electrochromic material that changes its reflectivity coefficient when a small current is applied. The change of reflectance alters the fraction of radiation force that is transmitted to the satellite, and hence has a direct effect on the spacecraft orbit evolution.

The spacecraft's reflectance can be switched between two set values twice per orbit. The two arguments of true anomaly where the changes take place are the control parameters in the scenario. The secular change of the in-plane orbital elements induced by SRP is found through a set of analytical expressions, which are a function of the initial condition and the shadow geometry due to eclipses. The optimum control parameters to achieve the mission goal are determined through a closed-loop feedback controller based on a penalty function.

Three applications are introduced. Firstly, otherwise decaying orbits are stabilised and the solution stability is studied and verified through numerical simulation. Secondly, orbital manoeuvres can be performed by exploiting the natural flow in the eccentricity/argument of perigee phase space. Finally, the control of a spacecraft formation through the artificial potential field method formulated in the orbital element phase space is investigated. This method either allows the spacecraft to group closer or space apart within the same orbit or to change the orbital elements relative to each other. This feature could be used in future self organising dust swarm mission concepts.