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INTEGRATED ATTITUDE AND SHAPE CONTROL FOR ORIGAMISATS WITH VARIABLE SURFACE REFLECTIVITY

Abstract

OrigamiSats, a new concept in solar sailing, are origami spacecraft with reflective panels which, when flat, operate as a conventional solar sail. Shape reconfiguration, i.e. "folding" of the origami design, allows the OrigamiSat to change operational modes, performing different functions as per mission requirements. For example, a flat OrigamiSat could be reconfigured into the shape of a parabolic reflector, before returning to the flat configuration when required to again operate as a solar sail, providing propellant-free propulsion.

The aim of this paper is to investigate the integrated attitude and shape control of OrigamiSats using variable reflectivity facets. Previous work [1] has demonstrated through numerical simulation that OrigamiSat reconfiguration can be triggered by varying the acceleration due to Solar Radiation Pressure (SRP) on each facet, thus inducing folding of the origami pattern. While the principle of SRP-induced shape reconfiguration has been demonstrated, it was found that the attitude and folding dynamics are highly coupled. This paper aims to further investigate the problem by performing numerical simulations of different Origami fold patterns with the aim of developing some more general results for the shape control strategy, and to better understand how attitude control can be integrated with shape reconfiguration.

Following Ref. [1] the multibody dynamics of the problem are derived, with the OrigamiSat modelled as a collection of rigid panels connected at vertices of the origami pattern. The force due to SRP is determined using raytracing, to consider the effect of inter-facet reflections and/or shadowing. Initial attempts at shape control have shown that, for a pyramidal OrigamiSat consisting of four triangular facets, a proportional derivative (PD) control law could be used where the error function is defined by the facet angles and the control variables are the facet reflectivities. The paper will contain results of simulations in which an attitude control law is integrated with this PD shape-control. This involves adjusting the panel reflectivities to shift the centre-of-pressure of the OrigamiSat, resulting in a rigid-body type rotation. Results of simulation for a variety of OrigamiSat designs will be presented, which will be used to determine whether the strategy is feasible or whether additional attitude control actuation will be necessary for these spacecraft.

[1] Russo, A., Robb, B., Soldini, S., Paoletti, P., Bailet, G., McInnes, C. R., Reveles, J., Sugihara, A. K., Bonardi, S., Mori, O., "*Self-reconfiguring 4D-printed OrigamiSat: a New Concept for Solar Sailing*" Submitted to Frontiers in Space Research, (2022)