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TRANSFORMABLE SPACECRAFT: A SYSTEM WITH VARIABLE-SHAPE STRUCTURE APPLICABLE TO NONHOLONOMIC ATTITUDE CONTROL

Abstract

As an innovative spacecraft system, we propose a transformable spacecraft, which consists of multiple modules connected with each other by hinges. They are equipped with motors that rotate the modules within a certain range of angle. Shape of the modules is arbitrary, and the simplest is panel shape, for example. Supposing a transformable spacecraft consisting of a number of panels, they can be folded to be compact as a whole, unfolded to configure a large plane, and recomposed to configure various kinds of three-dimensional shape. The system enables a single spacecraft to have multiple functions by transforming the shape. One typical example of application is a telescope. Equipped with reflector modules and detector modules, a transformable spacecraft can construct multiple kinds of telescope on orbit, which are different in field of view and focus length. Moreover, panel modules can be utilized as a heat shield protecting the telescope from solar radiation. This innovative concept can be extended to a larger structure in space, even to a spaceport in the future. Another distinctive characteristic of a transformable spacecraft is that it has capability of nonholonomic attitude control. Here we suppose the simplest zero-momentum configuration with three panel modules (A, B, and C) as an example, two pairs of which are connected by hinges (A-B and B-C). When the hinge A-B is rotated by α degrees

first and the hinge B-C is rotated by β degrees second, all the panel modules rotate with respect to the inertial frame so that it satisfies the law of conservation of angular momentum. Next, if the hinge B-C is rotated by -β degrees first and the hinge A-B is rotated by -α degrees second, the spacecraft returns to the initial state as a matter of course. However, in a case where the hinge A-B is rotated by -α degrees first and the hinge B-C is rotated by -β degrees second, the shape of the whole spacecraft returns to the initial state but the attitude is changed even though no external force or torque are applied, which is nonholominc motion. This simple example describes the capability of fuel-free attitude control of a transformable spacecraft. We introduce a concept of a transformable spacecraft and its applications to missions, utilizing the nonholinomic control. For example, combining the nonholonomic motion of and solar radiation pressure, utility of the Sun-Earth Lagrangian points for transformable spacecraft is highly improved.