OPTIMIZATION OF TRIANGULAR FORMATION FLYING CONFIGURATIONS UNDER THE CIRCULAR AND ELLIPTIC THREE-BODY PROBLEM DYNAMICS MODELLING

Fabio Ferrari(1) **and Michelle Lavagna**(2)
(1)(2)*Department of Aerospace Science and Technology, Politecnico di Milano, via La Masa 34, 20156 Milano, Italy, +39 02 23998365, [fabio1.ferrari;michelle.lavagna]@polimi.it*

Highlight

The paper wants to introduce the novel concept of formation flying ballistic dynamics about periodic orbits near collinear libration points in the Circular and Elliptic Restricted Three-Body Problems.

Abstract

Spacecraft Formation Flying in the proximity of libration points associated to a three-body system represents one of the most promising applications for space mission design. It provides the designer with the flexibility of having more than one flying platform to answer mission requirements and of exploiting the three-body trajectory design techniques to lower transfer and station keeping costs. Among others, observation, telecommunication and exploration missions can greatly benefit from this peculiar coupling. The design of classical spacecraft formations is usually characterized by a highly challenging trajectory and station keeping problem solving, to satisfy tight requirements on relative dynamics between each member of the formation. The exploitation of low acceleration regions such as the proximity of equilibrium points associated to a three-body system opens a new range of design opportunities, as three-body dynamics can be conveniently used to reduce such trajectory and station keeping needs.
Control strategies to maintain formations of spacecraft under three-body dynamics are being widely studied in the last decades, but very few studies of free relative motion between the spacecraft under this chaotic and unstable dynamics exist. The present work aims to pursue previous studies on natural triangular formations of spacecraft under the Circular Restricted Three-Body Problem (CR3BP) [1] and under the more accurate model provided by the Elliptic Restricted Three-Body Problem (ER3BP) [2]. An equilateral triangularly-shaped formation of spacecraft is assumed as a representative geometry to be studied. Initial configurations, which provide good performance in terms of formation keeping, have been investigated and key parameters, which mainly control the formation dynamics within the three-body system, have been identified. The evolution of spacecraft formation in the proximity of collinear libration point periodic orbits (Halo and Lyapunov orbits are considered) is studied. The analysis has been performed under several degrees of freedom to define the geometry, the orientation and the location of the triangle in the synodic rotating frame: one parameter defines the size of the triangle and five parameters describe unequivocally its location and orientation in the rotating frame. The initial condition set includes all degrees of freedom considered in the analysis. Formation keeping performance is quantified by defining two performance indexes, to monitor shape and size changes of the triangular formation and to compare them against the desired dynamical behavior of the formation. The aforementioned works presents the effect of different initial conditions sets on natural formation keeping performance. This work

aims to find optimal solutions in terms of initial condition sets which guarantee the maximization of performance factors. The optimization is performed using a global optimization algorithm from the domain of soft computing, to exploit its great capability of investigating a large range of potential solutions in parallel, starting from not informed initial guess to maximize performance factors, whose mathematical expression is provided analytically. This would provide enhanced tools to the mission designer, suitable to design the mission analysis of triangularly shaped formations in the proximity of libration points orbits, providing cost effective solutions in terms of formation keeping needs.

Preliminary results highlight the importance of the initial orientation of the formation, as well as of the chosen orbit the formation is evolving about, on the evolution of the relative dynamics, both in the circular and in the elliptical problem. On the other hand, initial size of the formation seems to have very little influence on formation keeping performance.

1. References

[1] Ferrari, F. and Lavagna, M. "Formation Flying and Relative Dynamics Under the Circular Restricted Three-Body Problem Formulation." Spaceflight Mechanics 2014, Roby S. Wilson et al. (Eds.), pp. 185–204, 2014.

[2] Ferrari, F. and Lavagna, M. "Triangular Formation Flying Under the Elliptic Restricted Three-Body Formulation." 65th International Astronautical Congress, 2014.