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Author: Prof.Dr. Pini Gurfil
Technion, I.I.T., Israel, pgurfil@technion.ac.il

Mr. Leonel Mazal
Israel Institute of Tecnology, Israel, leo.mazal@gmail.com

CLUSTER-KEEPING ALGORITHMS FOR THE SAMSON PROJECT

Abstract

Satellite Mission for Swarming and Geolocation (SAMSON) is a new satellite mission, led by the Distributed Space Systems Lab at the Technion – Israel Institute of Technology. SAMSON will include three nano-satellites, built based on the CubeSat standard. The mission is planned for at least one year, and has two main goals: (i) Demonstrate long-term autonomous cluster flight of multiple satellites, and (ii) Determine the position of a radiating electromagnetic terrestrial source based on time difference of arrival (TDOA).

The three satellites will be launched together with the same semimajor axis, eccentricity and inclination and separated in orbit to form a cluster with relative distances ranging from 100 m for the closest two, to 250 km for the farthest two.

In cluster flight, unlike traditional satellite formation flying, the satellites do not necessarily have to operate in a tightly-controlled formation; instead, they are required to maintain bounded relative distances for the entire mission. To accomplish cluster flight, it is necessary to develop autonomous, implementable, and robust cluster establishment and cluster-keeping strategies. The current paper describes a new method for cluster-keeping that will be implemented on-board the SAMSON satellites.

Given a cluster of N satellites, it is required to hold the distances between any pair of satellites, between given upper and lower bounds, i.e $D_{\min} \leq d_{ij}(t) \triangleq \vec{r}_j(t) - \vec{r}_i(t) \leq D_{\max}$. Consider two satellites, i and j, orbiting the Earth, under natural perturbations. In general, the inter-distance $d(t)$ will exhibit a drifting pattern. In an unperturbed two-body setup, the cause for this behavior is a difference in the semimajor axes, $\Delta a_{ij} = a_i - a_j$. For the perturbed two-body problem, the scenario is more complex, but still if $\Delta \bar{a}_{ij} \triangleq \bar{a}_i - \bar{a}_j > 0$ then a locally unbounded secular distance growth will be obtained. For cluster flight, this should be avoided, and thus $\Delta \bar{a}_{ij}$ must be controlled.

In this work, the actuators of every vehicle are four cold-gas engines, with constant thrust values T_0, which are aligned with the along-track and cross-track directions. Thus, defining $\mathcal{B} = \{0, 1\}$, the admissible control set for every vehicle is given by $\mathcal{U} = \{\vec{\lambda} \triangleq [\lambda_1\ \lambda_2\ \lambda_3\ \lambda_4]\,|\lambda_i \in \mathcal{B}\}$. In the LVLH frame, the control acceleration exerted on a vehicle is given by

$$\vec{a}_i^{LVLH} = \frac{T_0}{m}\,[0,\ \lambda_1 - \lambda_2,\ \lambda_3 - \lambda_4]^T \tag{1}$$

The cluster-keeping is mainly based on controlling $\Delta \bar{a}_{ij}$ and the differential inclination $\Delta \bar{i}_{ij}$. $\Delta \bar{i}_{ij}$ is controlled in order to avoid large cross-track separations. High-precision orbital simulations as well as preliminary hardware tests will be discussed as well.