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GAUSS-PSO ALGORITHM FOR TOO SHORT ARC INITIAL ORBIT DETERMINATION FOR GROUND SPOT

Abstract

The paper presents a new approach for the Initial Orbit Determination (IOD) from very short observations of Resident Space Objects (RSOs). The work is in the framework of the development of the system SPOT promoted by the Italian Space Agency. The system SPOT (Star sensor image on-board Processing for orbiting Objects deTection) is composed by On-board SPOT, to detect potential RSOs from the on-board processing of star sensor images against the fixed stars, and the Ground SPOT which receives the observation data to perform the orbit determination and tracking of the RSOs. SPOT is a suitable system to detect small RSO (< 7 mm) that usually cannot be detected by ground-based observations. Due to the relative dynamics between the orbital observer and RSOs, an orbiting object appears as a streak in the star sensor image. As a result, the observation is a too short arc, which makes difficult to solve the initial orbit determination. The paper studies the IOD algorithm of Ground SPOT by devising a modified Gauss' Algorithm for space-based observer. Knowing the orbit of the observer, the measurements of the lines of sight of a RSO are used to find the parameters of the target orbit by the Particle Swarm Optimization (PSO) technique. The PSO is implemented in order to search the solution by minimizing a suitable cost function of the lines of sight.
In the following, preliminary numerical results are given for Sentinel-1A as a space-based observer and SJ-11-02 as a RSO detected in the 19.8 deg FOV of a star sensor in inertial pointing. The observation duration is 28.2 seconds. For a selected epoch of the acquisition, the true range from the observer is 1911.605 km and the state of SJ-11-02 in J2000 reference frame is:

$$\vec{x}_2 = \begin{bmatrix} 2842.476\, km \\ 2250.636\, km \\ 6066.111\, km \\ 6.176\, km/s \\ 2.152\, km/s \\ -3.681\, km/s \end{bmatrix} \tag{1}$$

The classical Gauss' Algorithm, applied to the measurements, gives a range of 0.687 km, while the state

of the target at the acquisition epoch is:

$$\vec{x}_2 = \begin{bmatrix} 3653.441\,km \\ 520.752\,km \\ 6027.244\,km \\ -5.807\,km/s \\ -2.905\,km/s \\ 3.763\,km/s \end{bmatrix} \tag{2}$$

The proposed Gauss-PSO gives, for the same acquisition epoch, a range of 1915.254 km and the target state:

$$\vec{x}_2 = \begin{bmatrix} 2828.506\,km \\ 2247.850\,km \\ 6073.978\,km \\ 6.433\,km/s \\ 0.688\,km/s \\ -3.731\,km/s \end{bmatrix} \tag{3}$$

which have values pretty close to the true state.
The paper presents the theoretical approach of the proposed method and the numerical results for LEO observers.