XXII Brazilian Colloquium on Orbital Dynamics, 2 - 6 December, 2024

CBDO

Ilustração: New Horizons - Plutão - Caronte / NASA

Program and Book of Abstracts

National Institute for Space Research
INPE
Av. dos Astronautas, 1758
São José dos Campos, SP, Brazil

CBDO 131

Study of the Main Challenges in the Use of the Ensemble Kalman Filter in the Attitude Estimation Problem of Spacecraft

Roberta Veloso Garcia (1), Hélio Koiti Kuga (2), William Reis Silva (3), Leandro Baroni (4), Maria Cecília Zanardi (5), Paula C. P. M. Pardal (6)

1. Universidade de São Paulo,
2. Instituto Nacional de Pesquisas Espaciais,
3. Universidade de Brasília,
4. Universidade Federal do ABC,
5. Universidade Estadual de São Paulo,
6. Center of Engineering and Product Development

robertagarcia@usp.br

A space mission involves various requirements that must be taken into account to achieve its objectives with excellence. One of the fundamental requirements is the definition of how attitude estimation will be performed, so that the attitude determination and control subsystem can stabilize the vehicle and orient it in the desired directions during the mission. In this context, the present work aims to present a study on the main challenges that may be encountered when using the Ensemble Kalman Filter (EnKF) to estimate the attitude of spacecraft. These challenges are related to the level of robustness in nonlinear systems, accuracy in representing the system state uncertainty, or whether there is an ideal set of samples (ensemble) to represent the probability distribution of the system state. For the analysis, simulated telemetry and ephemeris data from a satellite with characteristics similar to those of the CBERS-4 (China-Brazil Earth-Resources Satellite) will be considered, and the attitude will be represented by the set of Euler angles.

The Ensemble Kalman Filter (EnKF) was originally proposed by Evensen (1994) as a stochastic or Monte Carlo alternative to the Extended Kalman Filter. The EnKF is an estimation technique that combines numerical model predictions with real observations to improve the accuracy of state estimates in dynamic systems. Essentially, the EnKF replaces the single state prediction of the system with a set (ensemble) of predictions. Each member of the ensemble is a possible realization of the system state, considering initial uncertainties and model errors (Evensen, 2009).

Although studies show that the EnKF is a powerful tool for state estimation in complex dynamic systems, some challenges can be encountered, such as insufficient ensemble size, inadequate updates of state estimates due to underestimation or overestimation of errors, difficulties in highly nonlinear systems, among others.

References
[1] Evensen, G.,"Sequential data assimilation with a nonlinear quasi-geostrophic model using Monte Carlo methods to forecast error statistics", J. Geophys, 143-162, 1994.
[2] Evensen, G., "Data Assimilation: The Ensemble Kalman Filter Springer-Verlag Berlin Heidelberg", 2009.

Poster