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AUTOENCODER-BASED THERMOSPHERIC DENSITY ESTIMATION USING GPS TRACKING DATA

Abstract

The dynamics of space objects in Low-Earth Orbit are strongly determined by the effect of atmospheric drag; at the same time, the evolution of the density of the thermosphere is difficult to model, being highly dependent on both the position and the interactions with space weather, making such force a primary source of uncertainty. However, existing atmospheric density models, both empirical and semi-empirical, do not explicitly provide an estimate of the uncertainty (Bruinsma, 2015): in order to increase the accuracy of orbit determination, real-time estimation of density is required. To do this, in this work we make use of an autoencoder-based grey-box model of the thermosphere, allowing us to obtain a reduced-order representation of the density field. The dynamics of such reduced-order embedding is estimated combining sparse and symbolic regression techniques, taking into account space weather effects and geomagnetic activities. This leads to an explicit nonlinear differential formulation for the evolution of the density field.

Using such grey-box model, combined with GPS and radar satellite tracking data, the global density and its corresponding uncertainty can then be estimated along with the state of selected satellites: the Unscented Kalman Filter is adopted for this. Ultimately, the calibrated density is applied to meaningful test cases in the domains of re-entry and collision avoidance to reduce the probability of endangering operational satellites and to decrease the uncertainty in atmospheric re-entry.

In this work, we assess different methods (e.g., Feng et al., 2014), to estimate the process noise covariance matrix which is not completely known a priori. Moreover, we are establishing the estimation algorithm considering extra states with respect to similar studies (Gondelach, Linares, 2020), related to the attitude and reflectivity of the satellite; this is done to improve the estimation accuracy of the actual front area and the solar radiation pressure perturbation, respectively. Finally, the effect on the estimation of the extra states, as well as of the coordinate selection of the orbit representation, are investigated.