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# Artificial Intelligence-Aided Extended Kalman Filter for Magnetometer-Based Orbit Determination

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**Abstract :** This work presents a robust, light, and inexpensive algorithm to perform autonomous orbit determination using onboard magnetometer data in real-time. Magnetometers are low-cost and reliable sensors typically available on a spacecraft for attitude determination purposes, thus representing an interesting choice to perform real-time orbit determination without the need to add additional sensors to the spacecraft itself. Magnetic field measurements can be exploited by Extended/Unscented Kalman Filters (EKF/UKF) for orbit determination purposes to make up for GPS outages, yielding errors of a few kilometers and tens of meters per second in the position and velocity of a spacecraft, respectively. While this level of accuracy shows that Kalman filtering represents a solid baseline for autonomous orbit determination, it is not enough to provide a reliable state estimation in the absence of GPS signals. This work combines the solidity and reliability of the EKF with the versatility of a Recurrent Neural Network (RNN) architecture to further increase the precision of the state estimation. Deep learning models, in fact, can grasp nonlinear relations between the inputs, in this case, the magnetometer data and the EKF state estimations, and the targets, namely the true position, and velocity of the spacecraft. The model has been pre-trained on Sun-Synchronous orbits (SSO) up to 2126 kilometers of altitude with different initial conditions and levels of noise to cover a wide range of possible real-case scenarios. The orbits have been propagated considering J2-level dynamics, and the geomagnetic field has been modeled using the International Geomagnetic Reference Field (IGRF) coefficients up to the 13th order. The training of the module can be completed offline using the expected orbit of the spacecraft to heavily reduce the onboard computational burden. Once the spacecraft is launched, the model can use the GPS signal, if available, to fine-tune the parameters on the actual orbit onboard in real-time and work autonomously during GPS outages. In this way, the provided module shows versatility, as it can be applied to any mission operating in SSO, but at the same time, the training is completed and eventually fine-tuned, on the specific orbit, increasing performances and reliability. The results provided by this study show an increase of one order of magnitude in the precision of state estimate with respect to the use of the EKF alone. Tests on simulated and real data will be shown.

**Keywords :** artificial intelligence, extended Kalman filter, orbit determination, magnetic field
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