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Author(s):
Gou, Junyang; Rösch, Christine; Shehaj, Endrit; Chen, Kangkang; Kiani Shahvandi, Mostafa; Soja, Benedikt; Rothacher, Markus

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Improving the Accuracy of GNSS Orbit Predictions using Machine Learning Approaches

Junyang Gou, Christine Rösch, Endrit Shehaj, Kangkang Chen, Mostafa Kiani Shahvandi, Benedikt Soja, and Markus Rothacher
ETH Zurich, Institute of Geodesy and Photogrammetry, Department of Civil, Environmental and Geomatic Engineering, Zurich, Switzerland (jungou@ethz.ch)

Precise orbit determination is vital for the increasingly vast number of space objects around the Earth. Moreover, accurate orbit prediction of GNSS satellites is essential for many real-time geodetic applications, including real-time navigation. The typical way to obtain accurate orbit predictions is using physics-based orbit propagators. However, the prediction errors accumulate with time because of insufficient modeling of the changing perturbing forces. Motivated by the rapid expansion of computing power and the considerable data volume of satellite orbits available in recent years, we can apply machine learning (ML) and deep learning (DL) algorithms to assess if they can be used to further reduce orbit errors.

In this study, we focus on the orbit prediction of GNSS constellations. We investigate the potential of using different ML and DL algorithms for improving the accuracy of the ultra-rapid products from IGS. As ground truth we consider the IGS final products, and the differences between the ultra-rapid and final products are computed and serve as targets for the ML/DL methods. In this context, we combine the advantages of physics-based and data-driven ML/DL methods. Since the major errors of GNSS orbits are expected to be caused by the deficiency of solar radiation pressure models, we consider different related parameters as additional features to implicitly model the solar impact, such as the $C_{0,0}$ terms of global ionosphere maps. In order to accurately model the effect of solar radiation pressure on the radial, along-track and cross-track components of the satellite orbit system, the geometric relation between the Sun, the satellite and the Earth are also considered. Furthermore, the performances of different ML/DL algorithms are compared and discussed. Due to the temporal characteristics of the problem, certain sequential modeling algorithms, such as Long Short-Term Memory and Gated Recurrent Unit, show superiority. Our approach shows promising results with average improvements of over 40% in 3D RMS within the 24-hours prediction interval of the ultra-rapid products.