Forecasting Ionospheric Process Noise Using Long Short-Term Memory Network

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SUMMARY

Accurate ionospheric corrections generated by a precise point positioning real-time kinematic (PPP-RTK) provider can significantly improve the user integer ambiguity resolution (IAR) performance, enabling faster and more precise global navigation satellite systems (GNSS) positioning. However, to reduce the transmission rate of the corrections being sent to the user, ionospheric corrections are often delivered to users with latency. In such cases, the accuracy of user positioning depends on the dynamic model used to time-predict ionospheric corrections, as implemented in the Kalman filters of both the PPP-RTK provider and the user. This dynamic model inherently includes a degree of uncertainty, governed by the process noise variance of the corrections, which has a direct impact on the positioning accuracy. Therefore, specifying the process noise variance accurately is critical to minimizing the prediction error of ionospheric corrections. Although nominal values for the ionospheric process noise are commonly used, they can degrade the IAR performance and significantly reduce ambiguity-fixed positioning accuracy. Data-driven estimation of ionospheric process noise from GNSS observations significantly improve the IAR performance and ambiguity-fixed positioning accuracy. However, in scenarios where a user station has a historical record of ionospheric process noise, forecasting the process noise becomes a practical alternative. This study evaluates the forecasted ionospheric process noise and investigates its effect on IAR performance. We propose an approach based on a Long Short-Term Memory (LSTM) neural network to forecast ionospheric process noise, given an existing set of estimated values. LSTM models are particularly effective at capturing the ionosphere's dependencies on solar and geomagnetic activity, seasonal variations, and past ionospheric behavior. The model was validated using data from globally distributed GNSS stations, demonstrating low RMSE values (below 0.11 mm/√sec) across diverse geographic locations. The experiments confirmed that forecasted ionospheric process noise is a viable alternative to data-driven values, ensuring high IAR success rates. By providing reliable forecasts, this approach enables improved positioning accuracy and precision.