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Machine learning-based regional slant ionospheric delay model and its application for PPP-RTK

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The precise point positioning-real-time kinematic (PPP-RTK) method achieves fast convergence in global navigation satellite system (GNSS) positioning and navigation. Correcting slant ionospheric delays is crucial for this purpose. The conventional way of obtaining slant ionospheric corrections at the user end involves generating an ionospheric map using a first-order polynomial function or interpolating using methods such as IDW and Kriging. However, with these approaches is challenging to obtain precise and stable ionospheric corrections especially during ionospheric disturbances, potentially degrading the positioning solution even with augmentation. Fortunately, machine learning has the capability to capture complex and non-linear characteristics of diverse data, offering a potential solution to this issue.

In this study, we aim to improve the accuracy of slant ionospheric delay models using machine learning and evaluate them in PPP-RTK. Initially, we extract highly precise slant ionospheric delays from carrier-phase measurements after ambiguity resolution for two regional GNSS networks in Switzerland and the South of China. Then, we employ the Gaussian Process Regressor to interpolate epoch-specific and satellite-specific slant ionospheric delays, utilizing latitude and longitude as features. Two different approaches are tested: the direct interpolation from reference stations and the indirect interpolation from a gridded map. Our results indicate that the accuracy of interpolated ionospheric delays using machine learning is higher than with conventional methods, including IDW and Kriging. Finally, we evaluate PPP-RTK positioning results with ionospheric corrections from the different interpolation methods, revealing that the machine learning method exhibits superiority in both positioning accuracy and convergence time over conventional methods.