A new spatio-temporal graph neural network method for the analysis of GNSS geodetic data

Mostafa Kiani Shahvandi and Benedikt Soja

1Institute of Geodesy and Photogrammetry, ETH Zurich, Zurich, Switzerland (mkiani@ethz.ch)
2Institute of Geodesy and Photogrammetry, ETH Zurich, Zurich, Switzerland (soja@ethz.ch)

Graph neural networks are a newly established category of machine learning algorithms dealing with relational data. They can be used for the analysis of both spatial and/or temporal data. They are capable of modeling how time series of nodes, which are located at different spatial positions, change by the exchange of information between nodes and their neighbors. As a result, time series can be predicted to future epochs.

GNSS networks consist of stations at different locations, each producing time series of geodetic parameters, such as changes in their positions. In order to successfully apply graph neural networks to predict time series from GNSS networks, the physical properties of GNSS time series should be taken into account. Thus, we suggest a new graph neural network algorithm that has both a physical and a mathematical basis. The physical part is based on the fundamental concept of information exchange between nodes and their neighbors. Here, the temporal correlation between the changes of time series of the nodes and their neighbors is considered, which is computed by geophysical loading and/or climatic data. The mathematical part comes from the time series prediction by mathematical models, after the removal of trends and periodic effects using the singular spectrum analysis algorithm. In addition, it plays a role in the computation of the impact of neighboring nodes, based on the spatial correlation computed according to the pairwise node-neighbor distance. The final prediction is the simple weighted summation of the predicted values of the time series of the node and those of its neighbors, in which weights are the multiplication of the spatial and temporal correlations.

In order to show the efficiency of the proposed algorithm, we considered a global network of more than 18000 GNSS stations and defined the neighbors of each node as stations that are located within the range of 10 km. We performed several different analyses, including the comparison between different machine learning algorithms and statistical methods for the time series prediction part, the impact of the type of data used for the computation of temporal correlation (climatic and/or geophysical loading), and comparison with other state-of-the-art graph neural network algorithms. We demonstrate the superiority of our method to the current graph neural network algorithms when applied to time series of geodetic networks. In addition, we show that the best machine learning algorithm to use within our graph neural network architecture is the multilayer perceptron, which shows an average of 0.34 mm in prediction accuracy. Furthermore,
we find that the statistical methods have lower accuracies than machine learning ones, as much as 44 percent.