Constrained Tensor Decompositions for Polarimetric Time Series Change Analysis

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Synthetic Aperture Radar (SAR) sensors provide data in polarimetric, interferometric, temporal, and spatial dimensions depending on the acquisition setup. With the increasing availability of multi-dimensional SAR data the joint processing and information extraction from several data dimensions grows in relevance. Some existing works already combine two data dimensions for different tasks. For example, forest height inversion methods [2] jointly use polarimetry and interferometry, the Sum of Kronecker Products (SKP) decomposition [3] exploits polarimetry and tomography, polarimetric change detection [1] combines the polarimetric and temporal dimensions, and convolutional neural networks [4] for land cover classification can use spatial and polarimetric features.

We propose a decomposition framework for multi-dimensional SAR data that allows an arbitrary number of data dimensions and is based on the Canonical Polyadic (CP) tensor decomposition. The decomposition is formulated as an optimization problem allowing precise control over the shape and properties of the output factors. We take into account the specifics of SAR data by adding constraints for physical validity and interpretability.

In order to demonstrate our approach, we formulate a decomposition for polarimetric time series using the proposed framework. The algorithm decomposes a stack of polarimetric coherency matrices into R components, each defined by a polarimetric and a temporal factor. We then use the factors to evaluate F-SAR data in X, C, and L bands obtained over agricultural areas during the CROPEX 2014 campaign. We analyze the evolution of four different crop types and the changes in the signal related to the growth, drying, fruit maturation, and harvest. The obtained factors describe the changes in the crops in a compact way and show correlations to certain crop parameters. The results are visualized using the polarimetric change matrices proposed in [1] and show additional fine-grained changes in comparison to the original method.

The decomposition framework is an extensible and promising tool for joint information extraction from multi-dimensional SAR data. It can be used to improve existing methods or extend them with new data dimensions. For example, implementing the SKP decomposition using the framework allows to obtain more than two components, or enables to integrate an additional data dimension such as time. Furthermore, it is possible to integrate physical models into the data-driven tensor decomposition approach. The framework implementation builds on top of PyTorch and supports automatic differentiation and optimization in the complex domain. This simplifies the decomposition design, facilitates experiments with different data dimensions, and allows to concentrate on the choice of the constraints or interpretation of the factors.

References

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