Soil Moisture Estimation from Multi-dimensional SAR Data

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Synthetic Aperture Radar (SAR) sensors provide high-resolution and weather-independent images of the Earth surface offering sensitivity to geometrical and dielectric properties. Current and planned satellite missions with large coverage and short revisit times make SAR a promising tool for continuous soil moisture monitoring.

SAR signal over vegetated areas includes the backscatter of the ground and the vegetation. To accurately estimate the soil moisture, the methods should take into account the vegetation backscatter. Physical models address this by having different components that model both the ground and the vegetation contributions [1]. The model components take physical parameters as an input and predict the SAR signal. In order to avoid ambiguous model inversion, the total number of parameters is limited by the number of observables. Current approaches typically use physical models with a small number of parameters unable to fully capture the complexity of real scenarios.

To allow inversion of more complex models with a larger number of parameters, we propose to increase the observation space by jointly processing several data dimensions such as spatial, temporal or polarimetric information. The key idea is to share certain model parameters across the data dimensions keeping the number of parameters smaller than the number of observables. To illustrate the approach, we present a method to estimate soil moisture from a combination of polarimetric and spatial data. Given a small spatial image patch with polarimetric data for each pixel, we assume a constant soil moisture across the patch, while letting other parameters like vegetation backscatter intensity vary from pixel to pixel.

The model inversion is formulated as an optimization problem where the physical model is represented by a differentiable function that maps parameters to the predicted backscatter. Parameters can then be estimated by minimizing the difference between observed and predicted data in an iterative fashion by gradient descent. The minimization is performed with PyTorch taking advantage of automatic differentiation and advanced optimizers.

We evaluate the proposed method on high-resolution airborne F-SAR data obtained by DLR over vegetated agricultural areas during the CROPEX campaign. With a larger observation space more input parameters can be uniquely inverted allowing to use more complex and accurate physical models.

References

[1] Irena Hajnsek et al. "Potential of Estimating Soil Moisture under Vegetation Cover by Means of PolSAR". In: *IEEE Transactions on Geoscience and Remote Sensing* 47.2 (2009), pp. 442–454.