Semi-supervised and Multi-label Classification of Remotely Sensed Images

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Abstract

The rapid increase in the availability of remotely sensed imagery (RSI) offers unprecedented opportunities for advancing Earth and space sciences, yet also poses significant challenges. Central among these challenges are the need to deal with complex, multi-label annotations, where images are annotated with multiple semantic categories, which can additionally be organized into hierarchies. As labels become more complex, we face ever more limited availability of labeled data, and the need to exploit unlabeled data at scale.

We present our recent work and advances in semi-supervised and multi-label classification of RSI. Along one dimension, the newly developed methods can handle tasks where data have annotations of different complexity, including the tasks of multi-class, multi-label and hierarchical multi-label classification. Along another dimension, they can work in fully supervised or partially supervised settings, where RSIs can be fully labeled, partially labeled or unlabeled.

The proposed approaches combine ideas from semi-supervised learning of trees and tree-ensembles for multi-level classification (MLC), on one hand, and deep neural networks (DNN), on the other hand. We start with using deep networks as convolutional feature extractors together with trees and tree ensembles for MLC. We then integrate key ideas from SSL of tree-based models within end-to-end approaches (such as masked autoencoders) to perform semi-supervised MLC on RSIs. We finally combine the use of vision transformers, graph neural networks, and self-supervised learning to perform SSL for hierarchical MLC on RSIs.

Experimental evaluation shows clear benefits from using unlabeled in addition to labeled data, as well as additional benefits from exploiting existing label hierarchies. The proposed approaches significantly outperform existing semi-supervised approaches in scenarios where labeled data are scarce. This makes them especially relevant to large-scale Earth observation tasks where annotation bottlenecks are common.

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