Structured classification of structured data: application to remote sensing data

IRISA Vannes, OBELIX Team, France

PhD position to be filled in September 2019

Key-words structured data, structured output, machine and hierarchical learning, remote sensing, optimal transport, convolutional networks.

Context Remote sensing data processing has long been conducted at pixel level, since times when objects of interest were way smaller or at most comparable to a pixels size. The significant developments on the spatial resolution front have led to the emergence of object-based image analysis, that no longer handles every pixel independently, but in contextual groups. In particular, multiscale models such as hierarchical representations (or trees) [1, 2] have been proposed and widely acknowledged as the appropriate solution since they enable us to model efficiently the relations between different image objects at multiple detail levels. In fact, depending on the required level of analysis, it is no longer uncommon for image regions to require multiple labels; *e.g.* a region might be identified as a road at a fine scale, as a residential area at an intermediate scale, or even as town or city at a coarse scale. These labels might be known a priori (supervised classification) or not (unsupervised classification or segmentation). While hierarchical representations inherently encode structural and rich information at several scales, its processing is merely a succession of monoscale analysis, either in an unsupervised fashion where the objective is to produce segmentations, or in a supervised one where classification maps with a set of labels (or a taxonomy of labels) are produced. No scientific solution allows for now a multiscale classification of the multiscale representation.

In the same time, in the machine learning community has emerged new tools to deal with hierarchical representations but they have barely been exploited in the remote sensing community. Structured prediction deals with the prediction of a structured output rather than a single label [3], which is relevant is our case as the structure of the data inherently defines a semantic taxonomy of labels. While supervised classification of flat labels (*i.e.* labels with no dependence between each others) is a marked up research field, hierarchical classification [4] deals with labels organized in a hierarchy. This paradigm suits particularly to multiscale remote sensing data as it allows one to fully take advantage of the inherent hierarchical nature of the representation. Nevertheless, there exists no method that enables the labeling of the nodes of a tree with a hierarchy of labels. Few examples on the literature consider the classification of entire trees by a hierarchy of labels [5] but no individual nodes. Another family of methods focuses to the classification of nodes of the tree, spreading labels from nodes to other nodes [6]. This latter problem is called the *Node Classification* or *Graph Labeling* and arises naturally in many real-life problems that have inherently a network structure, but they do not consider any structured prediction.

Scientific objectives and expected achievements The objective of the PhD is to define a new formulation of the structured classification of structured data problem. Two directions will be explored:

- the prerequisite of classification is the ability to measure in a relevant way the similarity between two nodes or (pieces of) trees. Optimal transport (OT) [7] have inspired a number of recent breakthroughs in machine learning ([8, 9] from people from Obelix team, among many examples in the ML

community) because of its capacity to compare efficiently empirical distributions. The lead of relying on an OT based-formulation of a distance, that deals inherently with structured or hierarchical outputs, shall be explored.

- there is nowdays no way around learning end-to-end solutions that rely on nodes or graph convolution [10]. Solutions that rely on convolutional networks shall be considered.

The solutions shall be able to be embedded in either a supervised (where some labels are available – also known as the node classification problem) or unsupervised (as in the community clustering solutions) approach. A particular emphasis will be put on the developpement of efficient solutions, able to deal with large datasets.

From an application point of view, a special emphasis will be given on remote sensing datasets, but the solution should be applicable to other application domains. Targeted publications will be conferences and journals from both the machine learning and the remote sensing communities.

Research environnement/Location The research will take place in the context of the IRISA laboratory (`http://www.irisa.fr/`), which is a joint research unit between CNRS, INRIA and several Universities and Engineering schools. IRISA conducts research in computer science, applied mathematics and signal and image processing. More specifically, the post-doc will be located in the OBELIX team (Environment Observation by Complex Imagery, `https://www-obelix.irisa.fr/`, which focuses on image analysis, machine learning and data mining, mostly for environmental data and remote sensing, and that is colocated between Vannes and Rennes (France). The PhD will take place in Vannes, a beautiful medieval city of medium size close to the sea (2h30 in train from Paris).
The PhD topic is at the interface of several research themes of the team: classification of hierarchical representation (with the PhD of Yanwei Cui [11]) and optimal transport on structured data (with the PhD of Titouan Vayer). Some of its funding comes from the ANR PRCI project MULTISCALE which stands for MULTI-variate, -temporal, -resolution and -SourCe remote sensing image Analysis and LEarning.

Candidate profile Applicants are expected to be graduated in computer science and/or machine learning and/or signal & image processing and/or applied mathematics/statistics, and show an excellent academic profile. Beyond, good programming skills are expected.

Application procedure Send a resume to Laetitia Chapel (laetitia.chapel@irisa.fr) and Sébastien Lefèvre (sebastien.lefevre@irisa.fr).

References

[1] P. Salembier and L. Garrido, "Binary partition tree as an efficient representation for image processing, segmentation, and information retrieval," *IEEE transactions on Image Processing*, vol. 9, 2000.

[2] M. F. Al-Dujaili, A. and S. Lefèvre, "Graphbpt : An efficient hierarchical data structure for image representation and probabilistic inference," in *International Symposium on Mathematical Morphology (ISMM), Lecture Notes in Computer Science*, vol. 9082, 2015, pp. 301–312.

[3] J.-L. Meunier, "Joint structured learning and predictions under logical constraints in conditional random fields," in *arXiv preprint arXiv:1708.07644*, 2017.

[4] C. N. Silla and A. A. Freitas, "A survey of hierarchical classification across different application domains," *Data Mining and Knowledge Discovery*, vol. 22, no. 1-2, 2011.

[5] Y. Chen, W. Su, J. Li, and Z. Sun, "Hierarchical object oriented classification using very high resolution imagery and lidar data over urban areas," *Advances in Space Research*, vol. 43, 2009.

[6] S. Bhagat, G. Cormode, and S. Muthukrishnan, "Node classification in social networks," *Social network data analytics*, 2011.

[7] C. Villani, *Optimal transport: old and new.* Springer Science, 2008.

[8] N. Courty, R. Flamary, D. Tuia, and A. Rakotomamonjy, "Optimal transport for domain adaptation," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 2016.

[9] T. Vayer, L. Chapel, R. Flamary, R. Tavenard, and N. Courty, "Optimal transport for structured data," in *arXiv preprint arXiv:1805.09114*, 2018.

[10] T. N. Kipf and M. Welling, "Semi-supervised classification with graph convolutional networks," in *ICLR*, 2017.

[11] Y. Cui, L. Chapel, and S. Lefèvre, "Scalable bag of subpaths kernel for learning on hierarchical image representations and multi-source remote sensing data classification," *Remote sensing*, vol. 9, no. 3, 2017.