Deep learning and Optimal Transport

Applications to Heterogenous Domain Adaptation in Remote Sensing

2 years Post-doctoral position, IRISA Vannes, France
Opened from beginning of January 2017

Keywords: Optimal Transport, Deep learning, Domain Adaptation, Remote Sensing Imagery

Context. Optimal Transport (OT) provides means of defining distances between probability measures defined in potentially high-dimensional metric spaces. These distances have strong and important properties: *i)* they can be evaluated when only empirical measures of the distributions are observed; *ii)* They can exploit the geometry of the underlying metric space, and provide meaningful distances even when the supports of the distributions do not overlap.

In machine learning, most of algorithms rely on empirical distributions of data and as such computing distances between their different distributions is a crucial task. However, the use of OT distances in machine learning is still in its infancy mainly due to the high computational cost induced by solving for the optimal transportation plan. Recently, new computing strategies have emerged (such as entropy-regularized transport with Bregman projections [1] or stochastic computation [4]) that turn OT distances into more tractable tools. However, and though appealing, those strategies do not scale to large collections of data as encountered in modern machine learning, because their solution is found in solving an optimization problem which number of variables scales quadratically in the number of samples at hand. Yet, new solution can be found that can leverage this issue, by notably estimating a non-linear mapping rather than a probabilistic coupling [5].

Scientific objectives and expected achievements. We propose in this work to learn this mapping with deep learning, that was shown to be a universal function approximant that scales favorably with large collection of data. The first main step of the post-doc will be to analyse, and show on real large datasets, what are the advantages of using a carefully designed neural architecture for this task. As an application problem of interest, we will consider the problem of **transfer learning**, which is a hot topic now, and for which we have already shown that optimal transport constitutes a possible good solution [2, 5, 3].

Continuing in this direction, the post-doc will be in charge of developing **novel concepts, methodologies, and new tools** for solving this problem by leveraging on the theory of optimal transport. He/she will focus on both the theoretical aspects of the problem and its practical implementation in deep neural nets architecture. On the application side, a particular interest will be given to analysis of remote sensing images (RSI), for which transfer learning is a fundamental problem. Hence, in the context of RSI, the drifts observed in the probability density function (PDF) of different images acquired by different captors, at various locations and at different time are due to a variety of factors: different corrections from atmosphere scattering compensation, daylight conditions at the hour of acquisition or even slight changes in the chemical composition of the materials. This also leads to interesting and almost unexplored variants of the transfer learning problem, where the data can live in different spaces and at different resolutions if they are produced by different captors (**heterogeneous domain adaptation**).

As such, the post-doc will extend the state-of-the-art in the area of deep learning systems/Optimal Transport for Machine Learning/remote sensing data. An important part of his/her work will be devoted

to publishing and presenting in peer-reviewed journals and at relevant conferences.

Location/Lab/Collaboration context. These researches 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 post-doc will take place in Vannes, a beautiful medieval city of medium size close to the sea (2h30 in train from Paris). Also, this post-doc project will build upon an existing collaborations with Rémi Flamary (Université of Nice), Alain Rakotomamonjy (Université of Rouen) and Devis Tuia (University of Zurich). As such, short or mid-term stays in these other locations might be envisaged during the post-doc.

Technical aspects. The applied part of the post-doc will lead to development in Python, within the Keras/Theano framework. The candidate will build upon our python toolbox for optimal transport (POT : `https://github.com/rflamary/POT`). He/she will benefit from the expertise of the other members of the team, as well as ongoing collaborations with other academic partners on this subject. Depending on his/her interests, a participation to writing of proposal on french an EU calls for projects will be considered.

Required Qualifications. Non-french student or at least 12 months outside of France before the application is a mandatory condition for this position. PhD in Computer Science, Machine Learning, Computer Vision, Imaging Science, Remote Sensing, or related discipline. Experience developing image/signal processing algorithms, classifiers, and eventually software for remote sensing systems and applications. Experience applying deep learning and pattern recognition methods to remotely sensed data, imagery and video is a plus. Comfortable training and/or fine-tuning convolutional neural networks (CNNs) using popular deep learning libraries and toolkits. Strong Python or Matlab, and/or other prototyping and software development skills. Demonstrated ability to publish and communicate technical work in highly-regarded technical journals or other technical forums. The candidate is expected to be self-motivated and able to work collaboratively in a team environment with scientists and engineers representing a variety of different backgrounds, skills, and experience levels. Excellent oral and written communication skills with ability to communicate technically-complex ideas to both scientific and non-scientific audiences.

Brut Salary: $\sim$ 3000 € per month (including health care)

Application procedure:
Send a resume + CV to ncourty@irisa.fr, remi.flamary@unice.fr and alain.rakoto@insa-rouen.fr

References

[1] J.-D. Benamou, G. Carlier, M. Cuturi, L. Nenna, and G. Peyré. Iterative Bregman Projections for Regularized Transportation Problems. *SIAM J. Scientific Computing*, 2(37):A1111–A1138, 2015.

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[4] A. Genevay, M. Cuturi, G. Peyré, and F. Bach. Stochastic optimization for large-scale optimal transport. In *Advances in Neural Information Processing Systems (NIPS) 29*, pages 3432–3440. 2016.

[5] M. Perrot, N. Courty, R. Flamary, and A. Habrard. Mapping Estimation for Discrete Optimal Transport. In *Advances in Neural Information Processing Systems (NIPS) 29*, Barcelone, Spain, December 2016.