

Aligning Large-Scale Remote Sensing Images using Neural Networks

Keywords: machine learning (deep learning), image processing, registration

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Context: The latest generation of satellite-based imaging sensors (Pleiades, Sentinel, etc.) acquires big volumes of Earth's images with high spatial, spectral and temporal resolution (up to 50cm/pixel, 50 bands, twice per day, covering the full planet!). These data open the door to a large range of important applications, such as the planning of urban environments and the monitoring of natural disasters, but also present new challenges, related to the efficient processing of high volumes of data with large spatial extent.

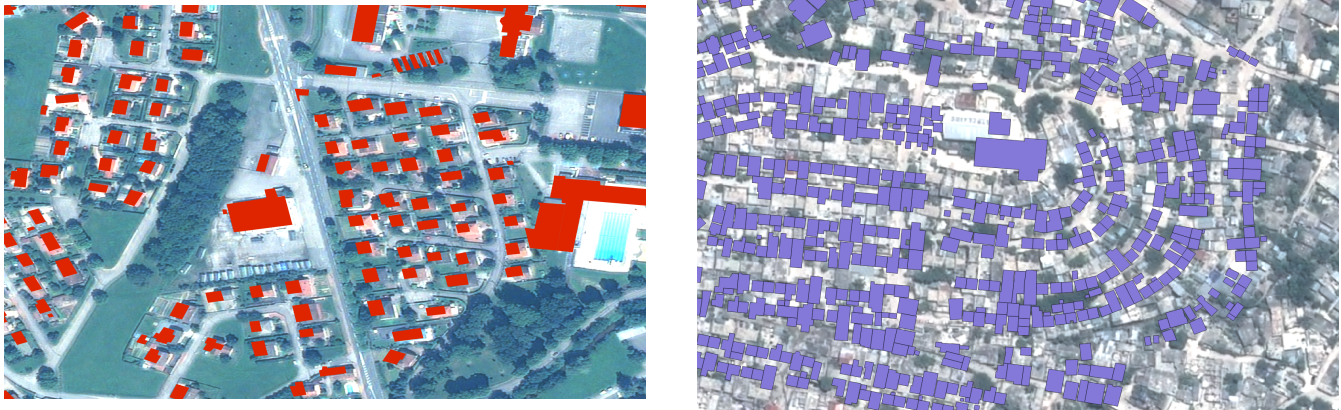


Fig. 1: Example of satellite images (©CNES) and available misaligned maps.

Subject: Recent works have shown that convolutional neural network (CNN)-based [1], or deep learning, methods succeed in getting detailed classification maps from aerial data [2,3]. However, a sensitive point regarding CNNs is the amount of training data required to properly learn the network parameters. A large source of free-access maps, such as OpenStreetMap, have recently become available; it could be thus used to train classifiers to produce maps. However, in many areas the coverage is very limited or nonexistent, and an irregular misregistration is prevalent throughout the maps (see Figure 1 for an example of satellite images and available misaligned maps).

In this project, we aim to propose a data alignment framework for large-scale remote sensing image classification. In particular, we will explore CNN architectures to learn how to align maps with satellite images. We will also evaluate how the introduced alignment of training data impacts classification accuracies.

Goals:

- formulate mathematically the machine learning problem, as the one of finding the function which associates to each

image the 2D deformation field that best aligns it to its segmentation map. The criterion to optimize includes a term quantifying the quality of this alignment, as well as a regularizer penalizing fast variations of deformation fields, since we expect deformation fields to be smooth. The parameters are then optimized by gradient descent.

- propose a suitable neural network architecture. In principle, sufficiently large neural networks can learn *any* function, however in practice the optimization is much easier when the neural network architecture is designed for the problem to solve. Here, the neural network would greatly benefit from knowing that its output (the deformation field) acts on the pixel locations of its inputs (image and map). The network could be feedforward (giving the answer directly) or recurrent (imitating an iterative process, improving the alignment at each step). Also, the spatial smoothness of deformation fields could be enforced explicitly by choosing a relevant representation.

Validation: The developed algorithms will be validated for the analysis of Pleiades multispectral remote sensing images with very high spatial resolution.

References:

- [1] Y. LeCun, L. Bottou, Y. Bengio and P. Haffner, “Gradient-Based Learning Applied to Document Recognition,” *Proc. of the IEEE*, vol. 86, no. 11, pp. 2278-2324, 1998.
- [2] M. Volpi and D. Tuia, “Dense Semantic Labeling of Sub-Decimeter Resolution Images with Convolutional Neural Networks,” *arXiv preprint arXiv:1608.00775*, 2016.
- [3] E. Maggiori, Y. Tarabalka, G. Charpiat and P. Alliez, “Convolutional Neural Networks for Large-Scale Remote Sensing Image Classification,” *IEEE TGRS*, in press, 2016.

Requirements for the student:

- Mathematics (functional analysis, derivatives, probabilities, statistics)
- Good C++ or python coding skills
- Interest in or knowledge of image processing, optimization (gradient descent), machine learning
- Fluency in English