Spatio-Temporal Domain Adaptation for Earth Observation

Laboratory: LASTIG lab. (Univ Gustave Eiffel, IGN, ENSG), STRUDEL team

Localisation: LASTIG, IGN-ENSG, Saint-Mandé, France

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Salary: ∼1440 euros / month (lectures can lead to a superior amount)

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Development Environment: Linux, Python, PyTorch

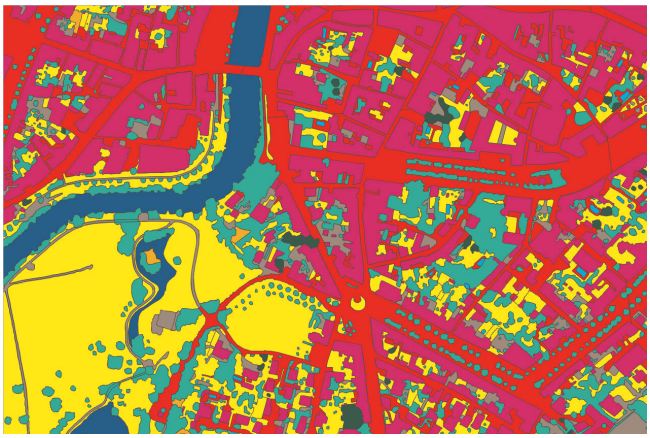
1 Context

The French National Institute for Geographic and Forestry Information (IGN) aims to generate, collect, process, and distribute a massive amount of authoritative geographical data covering the entire French territory. Its missions include producing highly qualified spatial data for public and private actors, and monitoring the anthropogenic impact on the environment: deforestation, impervious surfaces, urban sprawl, etc. Tasks such as land use/land cover discrimation, crop type mapping, or data vectorization have been successfully formulated as machine learning problems, benefiting from the near unlimited access to annotated data made available in open-access by IGN.

However, this endeavor faces a major challenge: each department, region, and country has unique bioclimatic conditions, territory management practices, and land type distribution. This translates in major domain shifts in terms of data, priors, and concepts [5]. Such differences in distribution between training and test sets are known to severely impact the performance of classification algorithms [4], including recent groundbreaking deep learning solutions. This issue is an active field of research in machine learning and computer vision, but remains to be fully developed for Earth Observation (EO) data.

This PhD aims to take advantage of the easy access to annotated data from various domains at IGN to **implement state-of-the-art domain adaptation methods and develop novel approaches** for Earth Observation geospatial imagery.

(a) Very High Resolution Aerial Images.



(b) Pixel-Precise Annotation.

Figure 1: **Annotation sample.** Each image of the dataset is labelled with a 15-classes land cover nomenclature at pixel level (20 cm / pixel), providing the largest and richest training set for land cover/land use classification tasks.

2 Objective

The goal of the PhD work is to develop protocols for training deep learning models that **can easily be adapted to unseen geographic domains**, for which we do have few or no annotations. We will investigate approaches such as meta-learning [6], adversarial approaches [10], and distribution regularizers [9, 1]. Depending on the initial results, self-supervision and self-training approaches may also prove relevant. We will then develop application-specific approaches to leverage the specificities of Earth Observation data and tasks.

The PhD will be organized around several purposes, with the aim of proposing generic approaches that can be applied across Earth Observation related tasks. All employed and created data will be open access, and all code will be open-source. We aim to reach and stimulate the international research community in a domain where very rich multi-class annotated datasets are still missing.

2.1 Terr-IA Project: Country-Scale Land Cover/Land Use Mapping

As part of a push towards full open-access (the "*géocommuns*" policy), the IGN Terr-IA project aims to produce pixel-precise annotations for high-definition aerial images (20 cm/pixel) covering 1,400 km^2 accross 50 *départements* (sub-regions, out of 96 in the metropolitan territory). This constitutes a unique and ideal playground for training and evaluating domain-robust land cover/land use segmentation methods. The annotation dataset also contains vector contours of individual instances, allowing for extension to panoptic / vectorial outputs.

The student will participate in the curation and distribution of the dataset in a machine learning-friendly format. Our goal is to constitute a reference dataset for Earth Observation and machine learning communities alike.

2.2 EuroCrop:Pan-European Crop Mapping

The EuroCrop dataset [8] constitutes the first multi-country dataset for training crop mapping models operating on satellite image time series. We will leverage the expertise of IGN research on deep learning for crop mapping [3, 2] to adress cross-country domain adaptation with state-of-the-art models. A straightforward application is the ability to propose a single solution for continental scale crop mapping, as desired by most Horizon2020 financed consortiums of Mapping and Paying Agencies.

2.3 Increased Domain Adaptation from Multi-Modality

We will leverage the access of multiple data sources in open-access at IGN to assess how a diversity of data sources can be exploited to improve the robustness of multi-modal models to complex domain shifts. In particular, SAR data [7] have shown promising preliminary results due to its imperviousness to illumination and cloud cover conditions.

IGN is currently collecting a high resolution LiDAR acquisition of the entire French Territory that will be open-access. There are obvious synergies between this project and the Terr-IA project that can be exploited through a multi-modal 2D/3D dataset. Finally, IGN has experience with multi-spectral satellite time series, which may prove crucial to learn robust representations of the territories.

3 Tentative Planning

- **Semester 1.** Familiarization with the literature and the Terr-IA dataset. Implementation of domain adaptation baselines for land cover/ land use prediction, and exploration of the different domain shifts present. First paper introducing the dataset in an EO journal.
- **Semester 2-3.** Development of land cover/land use specific approach exploiting the specifities of the task. Writing of a methodological article (Computer Vision/Machine Learning).
- **Semester 4.** Generalization to the crop mapping task.
- **Semester 5.** Generalization to multi-modal inputs / vectorial outputs.
- **Semester 6.** Finishing articles, writing the manuscript.

Profile

- Master 2 student in computer science, applied mathematics, or remote sensing.
- Familiarity with computer vision, machine learning, and deep learning.
- Mastery of Python, familiarity with PyTorch;
- Curiosity, rigor, motivation;
- (Optional) Familiarity with domain adaptation methods;
- (Optional) Experienced with aerial/satellite sensor technology and land cover/landuse prediction models.

Contact

Send a CV and a short letter of purpose (∼20 lines max) stating your interest for this PhD project and the relevance of your experience to `loic.landrieu@ign.fr` and `clement.mallet@ign.fr`.

References

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