Activity Report 2022

Team OBELIX

Environment Observation through Complex Imagery

D6 – Signal, Image, Language

1 Team composition

Head of the team
Nicolas Courty, Professor, Université Bretagne Sud

Université Bretagne Sud staff
Laetitia Chapel, Assistant Professor
Luc Courtrai, Assistant Professor
Chloé Friguet, Assistant Professor
Sébastien Lefèvre, Professor
François Merciol, Assistant Professor
Minh-Tan Pham, Assistant Professor
Charlotte Pelletier, Assistant Professor
Frédéric Raimbault, Assistant Professor

Associate/external members
Thomas Corpetti, Senior researcher (DR), CNRS
Romain Tavenard, Professor (since September 2022), Université Rennes 2

Post-docs
Abdelbadie Belmouhcine, Game of Trawls project
Javiera Castillo Navarro, April-July 2022, 6P project
Hoàng-Ân Lê, since January 2021, OWFSOMM and ROMMEO projects
Hugo Gangloff, until August 2022, Game of Trawls & Semmacape projects
Diego Di Carlo, since July 2021, Dynalearn project

PhD students
Renan Bernard, ARED grant, since October 2021
Javiera Castillo Navaro, CNES/ONERA grant, until March 2022
Manal Hamzaoui, ANR grant, since November 2019
Kilian Fatras, ANR grant, defended November 2021
Iris de Gelis, CNES/Magellium grant, since January 2020
François Painblanc, ANR grant, since January 2020
Jean-Christophe Burnel, RB/FEAMP grant, since September 2020
Huy Tran, ANR grant + chaire Polytechnique, from March 2021
Paul Berg, ANR grant, from November 2021
Guillaume Mahey, ANR grant, from November 2021
Corentin Dufourg, CNES/RB grant, from October 2022

Visiting student
Getachew Workineh, Salzbourg University, March 2022 - June 2022
Matteo Ciotola, Università degli Studi di Napoli Federico II (Unina), November 2022 - January 2023

Research engineers, technical staff

Marion Jeamart, ANR OATMIL, October 2021 - March 2022

Master and DUT students

Simon Donike (Master thesis, Univ. Bretagne Sud), co-supervision with Nicolas Audebert (Cnam) and Dirk Tiede (University of Salzburg)
Adebowale Daniel Adebayo (Master thesis, Univ. Bretagne Sud), co-supervision with Silvia Valero (CESBIO) and Stefan Lang (University of Salzburg)
Vitoria Barbosa Ferreira, (Master thesis, Univ. Bretagne Sud), co-supervision with David Sheeren (DYNAFOR) and Stefan Lang (University of Salzburg)
Corentin Dufourg, INSA Rennes, Research Master
Luke Abougit, ISE Rennes, Research Master

2 Overall objectives

2.1 Overview

The overall objective of the Obelix team is the analysis of remote sensing data. In such a context, available data form a massive amount of complex, multidimensional and structured observations. Our objectives are to design and exploit **new artificial intelligence techniques** to leverage on this type of data and develop tools that help in **providing a digital twin of the Earth and understanding critical aspects of the impact of human activities on Earth planet**, such as climate change, biodiversity decline, urban growth, disaster prevention/recovery or monitoring of human living conditions or activities. Expected scientific outputs cover both theoretical and computational aspects of machine learning and computer vision dedicated to those problems, as well as applied and thematic contributions in the field of remote sensing.

2.2 Scientific foundations

2.2.1 Handling the specific nature of Remote Sensing data.

The remote sensing data have a specific nature: they are usually available in large quantities, but generally with only few labels. Some parts of the data may be missing (*e.g.* because of cloud covering) or corrupted by noises. Associated labels can furthermore be inexact or inaccurate because labelling strategies are generally inaccurate; their inherent nature change between captors. Also, large discrepancies can be observed between learning datasets and testing sets for a large number of reasons (time of acquisition, atmospheric conditions, etc.). We plan to devote a significant part of our research to the fundamental learning problems involved in those specific learning settings. This include for instance domain adaptation, data imputation, robust learning with label noise, few-shot or multi-task learning. Learning architectures will be primarily deep neural networks but not restricted to, as they might not always be the best solution to tackle those problems.

Example: *In a context of semantic segmentation of remote sensing data, one option to build a learning set is to derive labels from existing cadastral vector plans, that may suffer from registration issues with the observed image. This induces noise in the learning set labels, which negative effect on the final accuracy can be mitigated provided that the learning loss is robust to such noise. Finding computationally tractable robust optimization schemes in deep architectures, together with theoretical conditions of success, is still an open-subject in the machine learning community, and calls for further developments.*

2.2.2 Structured data

Most of the data usually inherits from structured components, that highlight preexisting links or correlations/causality mechanisms. Those can be found in the intrinsic nature of the data (such as time series, graphs or trees). Taking the structure into account in learning or prediction scenarii, by defining proper metrics (e.g. based on sound mathematical theories such as optimal transport), embedding schemes or deep architectures (such as graph convolutional neural networks) will be considered;

Example: *A popular way to analyse remote sensing images is to rely on the object-based image analysis (OBIA) framework, where at each spatial scale specific objects of interest are extracted through segmentation, before being classified usually with some rule-based approach. However, such a methodology requires to set a high number of parameters (thus preventing its transfer to another dataset) and does not lead to a pure multiscale framework. In this context, an appealing alternative is to represent an image through a tree-based structure embedding its nested segmentations, before applying a unique classification procedure able to cope with regions from multiple scales, possibly inferring multiple labels corresponding to the land use classes that can be observed at various spatial scales. However, classification of structured data such as trees remains an open problem, especially when the processed tree is very large and contains numeric attributes; furthermore, there is not yet any robust method able to build a relevant tree structure from any kind of image.*

2.2.3 Generative modeling (GANs and beyond)

Generative modeling with neural networks has received a lot of attention in the machine learning community over the last years, through models like Variational Auto-encoders, Generative Adversarial Networks or Normalizing flows. While the use of generative modeling is mainly focused toward the generation of samples of high-dimensional objects such as images, their practical use in real applications is still in its infancy. In the context of remote sensing, we plan to use those models to tackle problems such as transfer across modalities (heterogeneous domain adaptation, or multi-modal image fusion), super-resolution, or inverse reconstruction problem with deep priors (for cloud removal applications for instance). We also consider to use those architectures for modeling physical processes. In this last case, the generation process not only relies on statistical constraints, but also on physical ones (which can be the case in super-resolution for instance, where one makes physical assumptions between the observation scales);

Example: *In a context of learning from a dataset which was acquired from a different modality (e.g. spatial and spectral resolution) than the image over which the inference is conducted, one needs some ways to adapt the learning information to tackle the observed data. This problem, known as heterogeneous domain adaptation, can benefit from generative models such as cycleGANs or normalizing flows, provided that they can operate between different modalities (i.e. different metric spaces). This is a challenging task, for which barely no solution exist at the moment, from both theoretical and algorithmic standpoints.*

2.2.4 Physics-driven Machine learning

As far as the underlying observed phenomena are physical by nature, learning tasks can leverage on existing physical models (usually in the form of PDEs) to better conduct the analysis. Coupling physical models and deep architectures (either by construction, such as neural ODEs, or by regularization schemes) will be considered. Also, in a reverse direction, recent parallels between how information is flowing in deep neural networks and statistical physics/PDEs have been made. We plan to get a better understanding of machine learning models by modeling them as interacting physical systems;

Example: *We consider here the improvement of the spatial resolution (i.e. super-resolution) of satellite images of temperatures (in the ocean or in urban/rural areas). Though some approaches have enriched neural networks with "physical layers" able to ensure some basis of physics, they are not designed to properly handle physical quantities, which can be critical for real applications. In this super-resolution context, we plan to constrain the generation process by the introduction of basic differentiable blocks of physical laws.*

2.2.5 Computational aspects

Last but not least, we will focus on efficient computational schemes for processing and analyzing large scale remote sensing data, towards a goal of green AI. Expected outputs will include novel algorithmic tools for efficient and scalable processing of big earth data, energetic efficiency of the machine learning models (by quantizing or compressing neural nets for instance), and also initiating new research axes such as combining quantum computing and machine learning for remote sensing applications.

Example: *The success of deep networks is due, among other factors, to the complexity of their underlying models (millions of learnt parameters). Training such models requires the availability of high-performance GPUs, usually far more powerful than the more conventional or embedded hardware that can be used for their inference. Since generic models usually fail to achieve perfect results in real-life scenarios due to the domain shift between the training and testing data, being able of lightly retraining the model in the deployment environment is sought. Designing very lightweight networks and networks updating schemes running on conventional/embedded hardware are challenging tasks, still largely unexplored in the community.*

2.3 Application domains

OBELIX activities contribute to Digital Twin Earth and as such aim to visualize, monitor and forecast natural and human activity on the planet in support of sustainable development.

AI tools for Copernicus The EU's EO *Copernicus* Program aims to deliver massive amounts of open remote sensing data (Petabyte scale), that can be exploited especially in its six thematic services, namely atmosphere, marine environment, land monitoring, climate change, emergency management, and security. Copernicus offers new opportunities for EO analytics, but also raises challenges related to high spatial resolution, dense time series, multiple modalities, etc. In this context, the Obelix team will design and scale-up its AI tools to make them usable by Copernicus services, e.g. land and human-settlement monitoring and climate change study at large-scale.

Climate change monitoring AI can help the monitoring and forecasting of the impacts of climate change locally (inside cities for example) and can be an appealing solution to generate reliable simulations, diagnostics and forecasts of critical situations (heat waves, pollution events for example). The anticipation of such sudden climatic events is crucial for the protection of population (UN indeed expects that more than 70% of world population will live in cities by 2050). At the moment to understand the local climate, climatologists rely on *Local Climate Zones* (LCZ) introduced in 2012 by Steward and Oke. LCZ consist of a categorization of local morphology into 17 different classes (depending on imperviousness, density of housings, vegetation etc), each of them being specific in term of local climate. Though largely used, there is no consensus about the existing classification that has been defined on the basis of US landscapes. AI will help both in the definition of more consistent LCZ and in their cartography at global scale to help the prevention of local sudden events.

Coastal and Ocean monitoring Given its geographical location on the seaside, UBS has a long experience in research activities related to the sea and the coast, now structured in its centre of excellence "Sea & Coast". OBELIX plays an active role in these activities through collaborative projects focused on maritime megafauna monitoring from aerial, underwater, and in-situ observations with partners such as OFB (French Biodiversity Agency), IFREMER (French Research Institute for Exploitation of the Sea), and FEM (Institute for Energy Transition dedicated to Marine Renewable Energies); or coastal dynamics analysis in the context of global warming.

AI for social good Obelix team will actively seek and engage in projects which goals are focused toward using artificial intelligence to address societal issues and improve the well-being of the world (also known as AI for social good), through remote sensing. Such applications generally consider the challenges for developing countries to maintain sustainable development, food and water security, and disaster relief, as well as supporting humanitarian action. As a good example, mapping large-scale socioeconomic indicators, such as poverty or education level, from high-resolution satellite imagery, is challenging because the information is not directly observable from the image, and one need to consider more complicated inference schemes, involving structural or causal dependence, to perform such tasks.

3 Scientific achievements

3.1 Optimal Transport for machine learning and remote sensing

Participants: Nicolas Courty, Chloé FriguetLaetitia Chapel, Paul Berg, Renan Bernard, Romain Tavenard, Huy Tran, Clément Bonet.

Following our works on optimal transport for domain adaptation initiated in 2014, we developed an activity centered around the theme of optimal transport for machine learning. This research axis is mainly supported through ANR AI Chair OTTOPIA led by Nicolas Courty, and Labex COMINLABS project DynaLearn.

Optimal transport for heterogeneous transfer learning Domain adaptation is a field of transfer learning where the training data (source) and the test data (target) come from different domains. The data in these two domains have therefore different underlying distributions, and the learned model should be adapted so that it can be used on the target data with good performance. We present here a domain adaptation algorithm to adapt heterogeneous domains, *i.e.* described by different features. The developed method uses optimal transport to map the distributions of the two domains and its implementation is illustrated on benchmark data. This work has been presented in [28] and is the base of a collaboration with Valérie Garès (INSA Rennes, IRMAR) through the supervision of Renan Bernard's PhD thesis (since october 2022).

Optimal Transport for structured data This line of work explores how the optimal transport distance can be used in the case where the distributions are defined in different metric spaces, making the initial formulation of the optimal transport problem uneffective.

- **Semi-relaxed Gromov-Wasserstein divergence with applications on graphs**. Comparing structured objects such as graphs is a fundamental operation involved in many learning tasks. To this end, the Gromov-Wasserstein (GW) distance, based on Optimal Transport (OT), has proven to be successful in handling the specific nature of the associated objects. More specifically, through the nodes connectivity relations, GW operates on graphs, seen as probability measures over specific spaces. At the core of OT is the idea of conservation of mass, which imposes a coupling between all the nodes from the two considered graphs. We argue in this paper that this property can be detrimental for tasks such as graph dictionary or partition learning, and we relax it by proposing a new semi-relaxed Gromov-Wasserstein divergence. Aside from immediate computational benefits, we discuss its properties, and show that it can lead to an efficient graph dictionary learning algorithm. We empirically demonstrate its relevance for complex tasks on graphs such as partitioning, clustering and completion. Published at ICLR 2022 [33]

- **Template based Graph Neural Network with Optimal Transport Distances**. Current Graph Neural Networks (GNN) architectures generally rely on two important components: node features embedding through message passing, and aggregation with a specialized form of pooling. The structural (or topological) information is implicitly taken into account in these two steps. We propose in this work a novel point of view, which places distances to some learnable graph templates at the core of the graph representation. This distance embedding is constructed thanks to an optimal transport distance: the Fused Gromov-Wasserstein (FGW) distance, which encodes simultaneously feature and structure dissimilarities by solving a soft graph-matching problem. We postulate that the vector of FGW distances to a set of template graphs has a strong discriminative power, which is then fed to a non-linear classifier for final predictions. Distance embedding can be seen as a new layer, and can leverage on existing message passing techniques to promote sensible feature representations. Interestingly enough, in our work the optimal set of template graphs is also learnt in an end-to-end fashion by differentiating through this layer. After describing the corresponding learning procedure, we empirically validate our claim on several synthetic and real life graph classification datasets, where our method is competitive or surpasses kernel and GNN state-of-the-art approaches. We complete our experiments by an ablation study and a sensitivity analysis to parameters. Published at Neurips 2022 [34]

- **Aligning individual brains with Fused Unbalanced Gromov-Wasserstein**. Individual brains vary in both anatomy and functional organization, even within a given species. Inter-individual variability is a major impediment when trying to draw generalizable conclusions from neuroimaging data collected on groups of subjects. Current co-registration procedures rely on limited data, and thus lead to very coarse inter-subject alignments. In this work, we present a novel method for inter-subject alignment based on Optimal Transport, denoted as Fused Unbalanced Gromov Wasserstein (FUGW). The method aligns cortical surfaces based on the similarity of their functional signatures in response to a variety of stimulation settings, while penalizing large deformations of individual topographic organization. We demonstrate that FUGW is well-suited for whole-brain landmark-free alignment. The unbalanced feature allows to deal with the fact that functional areas vary in size across subjects. Our results show that FUGW alignment significantly increases between-subject correlation of activity for independent functional data, and leads to more precise mapping at the group level. Published at Neurips 2022 [31]

Efficient Gradient Flows in Sliced-Wasserstein Space Minimizing functionals in the space of probability distributions can be done with Wasserstein gradient flows. To solve them numerically, a possible approach is to rely on the Jordan-Kinderlehrer-Otto (JKO) scheme which is analogous to the proximal scheme in Euclidean spaces. However, it requires solving a nested optimization problem at each iteration, and is known for its computational challenges, especially in high dimension. To alleviate it, very recent works propose to approximate the JKO scheme leveraging Brenier's theorem, and using gradients of Input Convex Neural Networks to parameterize the density (JKO-ICNN). However, this method comes with a high computational cost and stability issues. Instead, this work proposes to use gradient flows in the space of probability measures endowed with the sliced-Wasserstein (SW) distance. We argue that this method is more flexible than JKO-ICNN, since SW enjoys a closed-form differentiable approximation. Thus, the density at each step can be parameterized by any generative model which alleviates the computational burden and makes it tractable in higher dimensions. Published in TMLR 2022 [3]

Learning to Generate Wasserstein Barycenters Optimal transport is a notoriously difficult problem to solve numerically, with current approaches often remaining intractable for very large scale applications such as those encountered in machine learning. Wasserstein barycenters - the problem of finding measures in-between given input measures in the optimal transport sense - is even more computationally demanding as it requires to solve an optimization problem involving optimal transport distances. By training a deep convolutional neural network, we improve by a factor of 60 the computational speed of Wasserstein barycenters over the fastest state-of-the-art approach on the GPU, resulting in milliseconds computational times on 512x512 regular grids.

We show that our network, trained on Wasserstein barycenters of pairs of measures, generalizes well to the problem of finding Wasserstein barycenters of more than two measures. We demonstrate the efficiency of our approach for computing barycenters of sketches and transferring colors between multiple images. Published in JMIV 2022 [9]

3.2 Deep Neural Networks for Complex Data

Participants: Sébastien Lefèvre,.

The group is playing a leading role in the field of deep learning for Earth Observation (AI4EO) since 2015. We are pursuing this activity and deal with the specific challenges raised by EO data (e.g. low resolution, multiple modalities, non-standard image data, etc.).

Object detection and tracking In the context of the SEMMACAPE project, the team has explored how to shape the problem of unsupervised or weakly-supervised object detection as an anomaly detection problem. The training set is then limited to some background images (containing no objects) to allowo the model to learn the normality. Several novel methods were designed and successfully applied to animal detection from aerial imagery: an extension of PaDIM including Masked Autoregressive Flow [2], and some extensions of Variational Auto-Encoders (VAE) considering Vector Quantization [25, 39, 24] and Gaussian Random Fields [40]. We have also taken benefit of recent developments in computer vision, to propose novel object detectors, that achieve very good performances using supervised contrastive learning together with mutual guidance [11], and knowledge distillation applied to multimodal data leading to a modality distillation framework [35]. Beyond these pure methodological works, we have also shown that object detection could be successfully used to monitor dead trees from drone imagery [15]. In the context of the Game of Trawls project, the task of object detection was combined with object tracking to design novel networks that build upon the well-known DeepSORT algorithm, leading to a fully deep solution [18, 19] that was further improved to ensure robustness [20].

Semi-supervised semantic segmentation The PhD thesis of Javiera Castillo-Navarro on semi-supervised semantic segmentation ended with several key contributions: a first, large-scale dataset specific for this task (MiniFrance, [4]), and that was further extended to form the 2022 edition of the main challenge in the field, namely the IEEE GRSS Data Fusion Contest [7, 8]. Beyond multi-task models [4], a specific attention was paid to generative models and more precisely to energy-based models, with their first use in Earth Observation [5]. Besides, in a multimodal scenario, first outcomes from the PhD thesis of Jean-Christophe Burnel consist in a self-training framework able to reuse a network pretrained using a single modality, to train a novel multimodal network without needing new annotations [22, 21, 23].

3D points clouds and elevation data The Siamese KPConv deep network introduced in the PhD thesis of Iris de Gélis was successfully applied to change detection on cliffs, in order to identify erosion and accumulation areas [6]. While this approach processes directly 3D points clouds, the rasterization strategy previously developed in the PhD thesis of Florent Guiotte was combined with a Generative Adverserial Netwowrk (GAN) to perform Digital Terrain Model (DTM) generation from a point cloud

[10]. Elevation can also be estimated from space using optical imagery, and we show the relevance of a semantic segmentation architecture in this context, with some application on coastal bathymetry [13]. Finally, we also address the task of mapping a digital elevation model (DEM) rasterized from aerial LiDAR point cloud on the aerial imagery using a contrastive learning-based approach [16]. These two last works were outcomes of Erasmus Mundus Joint Master Degree students hosted in the group in 2021.

3.3 Hierarchical Models for Efficient Analysis of EO Data

Participants: Laetitia Chapel, Manal Hamzaoui, Sébastien Lefèvre, Minh-Tan Pham,.

The group has brought numerous contributions in mathematical morphology, especially on tree-based representations from which efficient algorithms can be derived. This research axis is mainly supported through ANR MULTISCALE.

Learning with hierarchies Few-shot learning (FSL) aims at making predictions based on a limited number of labeled samples. We have focused on few-shot remote sensing scene classification which aims to recognize unseen scene categories at training stage from few or even a single labeled sample at test stage. Although considerable progress has been achieved in this topic, less attention has been paid to leveraging the prior structural knowledge. In more details, we learn transferable visual features by introducing in the learning process the class hierarchy which encodes the semantic relationship between the classes, defining hierarchical prototypes that allow us to encode the different levels of the hierarchy. This work was presented at the International Conference on Pattern Recognition and Artificial Intelligence [26] and has received the best paper award.

Learning-based hierarchies We have also extended the multiscale paradigm of attribute profiles to the more general framework of hierarchical watersheds. By doing so, we have explored the semantic knowledge provided by labeled training pixels during different phases of the watershed-AP construction, namely within the construction of hierarchical watersheds from the raw image and later within the filtering of the resulting hierarchy. The method was validated on two applications, namely land cover classification and building extraction using optical remote sensing images [12].

3.4 Time series analysis

Participants: Laetitia Chapel, Nicolas Courty, Chloé Friguet, Romain Tavenard, Charlotte Pelletier, Sébastien Lefèvre.

The group also focus on learning on time series, leading to several publications.

Measuring the similarity between time series

Measuring a distance or similarity between two multivariate time series is of prime interest in a variety of applications, including machine learning, but can be very difficult as soon as the temporal dynamics and the representation of the time series, i.e. the nature of the observed quantities, differ from one another. We have proposed a novel distance accounting both feature space and temporal variabilities by learning a latent global transformation of the feature space together with a temporal alignment, cast as a joint optimization problem. It has been presented in [30] and a publication is under consideration.

Among other contributions, we define a differentiable loss for time series and present two algorithms for the computation of time series barycenters under this new geometry. This work has been published in Transactions on Machine Learning Research [17].

Multivariate time series Elastic measures have been widely used to compare univariate time-series data. However, multivariate time series are more commonly used in practice. To extend state-of-the-art multivariate time series classification, we extended eleven elastic measures to the multivariate case and we proposed a new ensemble of nearest neighbors with this metrics [41].

Domain adaptation and generalization between satellite image time series The group pursues its work on learning with less supervision from satellite image time series (SITS). In this context, we have proposed a new unsupervised domain adaptation technique, TimeMatch, which explicitly learns the temporal shift between two SITS [14]. The proposed method relies on self-supervised training to adapt a source-trained model to the target domain. We also tackle the domain generalization problem from SITS data by proposing thermal positional encoding for attention- based crop classifiers [29].

4 Software development

4.1 Software development

In compliance with ACM requirements, most of our research code is being made available through `http://github.io/myrepository` for reproducibility purposes.

In addition, the team contributed to the following pieces of software.

4.1.1 POT

Participants: Nicolas Courty, Laetitia Chapel, Romain Tavenard, Kilian Fatras, Huy Tran.

`POT` is an open source Python library that provides several solvers for optimization problems related to Optimal Transport for signal, image processing and machine learning. It has more than 1M downloads (as of January 2023) and 1700 stars on github. In 2021, we have received a support from CNRS to develop this software in the context of the national AI plan, with two engineers working part time on the development of the toolbox. We have also published a paper on it in JMLR Software

Website and documentation: `https://PythonOT.github.io/`

Source Code (MIT): `https://github.com/PythonOT/POT`

4.1.2 tslearn

Participants: Romain Tavenard.

`tslearn` is a general-purpose Python machine learning library for time series that offers tools for pre-processing and feature extraction as well as dedicated models for clustering, classification and regression. It follows `scikit-learn`'s Application Programming Interface for transformers and estimators, allowing the use of standard pipelines and model selection tools on top of `tslearn` objects. It is distributed under the BSD-2-Clause license, and its source code is available at `https://github.com/tslearn-team/tslearn`.

4.1.3 Triskele

Participants: François Merciol, Charles Deltel, Luke Abougit.

`TRISKELE` stands for Tree Representations of Images for Scalable Knowledge Extraction and Learning for Earth observation. Triskele is an open source C++ library that provides several algorithms for building hierarchical representation of remote sensing images. It also includes usefull fonctionnalities to produce sobel or NDVI layers and Pantex index as well. (CeCILL-B licence)

Source Code (IRISA): `https://gitlab.inria.fr/obelix/triskele/`

4.1.4 Broceliande

Participants: François Merciol, Charles Deltel.

`Broceliande` is a software for classification of remote sensing images. It uses TRISKELE and Random Forests. This software is used in industrial environnements to produce land cover mapping drive by EU projects. (CeCILL-B licence).

Source Code (IRISA): `https://gitlab.inria.fr/obelix/broceliande/`

4.1.5 Korrigan

Participants: François Merciol, Charles Deltel.

`Korrigan` is a software to search patches in remote sensing databases based on Pattern Spectra.The goal is to offer data mining on big remote sensing image data bases. (CeCILL-B licence)

Source Code (IRISA): `https://gitlab.inria.fr/obelix/korrigan/`

5 Contracts and collaborations

5.1 International Initiatives

5.1.1 MULTISCALE - PCRI 2019-2022

Participants: Laetitia Chapel, Sébastien Lefèvre, Thomas Corpetti, Minh-Tan

Pham, François Merciol.

- Project type: ANR PRCI Tubitak
- Dates: 2019–2022
- PI institution: UBS
- Other partners: Costel Rennes 2, Gebze technical Univ., Istanbul technical univ.
- Principal investigator: Laetitia Chapel
- web: https://people.irisa.fr/Laetitia.Chapel/multiscale/

MULTISCALE is a research project that aims at providing a complete and integrated framework for multiscale image analysis and learning with hierarchical representations of complex remote sensing images. While hierarchical representations of RS images has led to an effective and efficient scheme to deal with panchromatic or at most multiband data, their application to complex data is still to be explored. In addition, despite their ability to encode structural and multiscale information, their so far exploitation have not reached beyond a mere superposition of monoscale analysis. In this context, the MULTISCALE project defines new methods for the construction of hierarchical image representations from multivariate, multi-source, multi-resolution and multi-temporal data, and provides some dedicated image analysis and machine learning tools to perform multiscale analysis. The new methodology will be implemented in various toolboxes used by the community to favor the dissemination of the results. Success of the project will be assessed by benchmarking the proposed framework on two remote sensing applications. Substantial breakthroughs over classical methods are expected, both in terms of efficiency and effectiveness.

5.2 National Initiatives

5.2.1 SESURE - SEntinel time series SUper REsolution

Participants: Charlotte Pelletier (project coleader).

- Project type: CNRS GdR ISIS - Projet exploratoire
- Dates: 2021–2023
- PI institution: IRISA
- Other partners: Nicolas Audebert (Cnam)

The SEntinel time series SUper REsolution (SESURE) project is interested in developing super-resolution approaches for satellite image sequences that make the most of the temporal structure of the data. By exploiting deep learning on the mass of Sentinel-2 data acquired in France since 2015, SESURE will make it possible to infer a subpixel structure of pixels in different colours. Unlike methods of the current state of the art, which is often limited to evaluations on synthetic data, the project will rely on

SPOT-6 and -7 open data as a reference for high-resolution images and Sentinel-2 for low-resolution image series. SESURE aims to quantify the informational gap between Sentinel-2 time series and very high-resolution RGB SPOT acquisitions. In particular, we will study the existence of transformations, reversible or not, allowing to pass from one modality to another, and thus to solve the frequency-resolution dilemma currently faced by the computer vision community in remote sensing.

5.2.2 ANR JCJC DeepChange

Participants: Charlotte Pelletier.

- Project type: ANR JCJC
- Dates: 2021–2025
- PI institution: CESBIO
- Other partners: Silvia Valero (CESBIO)

Accurate and up-to-date land cover information constitutes key environmental data for developing efficient policies in this era of resource scarcity and climate change. New Satellite Image Times Series offer new opportunities for detecting land cover class transitions. Nevertheless, the challenges of the "Big Data" have become imminent for the exploitation of this massive flow of data. Deep generative models are one of the most promising tools for big data analysis. The use of such models has just started to emerge in the remote sensing. In this project, Generative Adversarial Networks and Variational Autoencoders want to be explored to face common remote sensing challenges, which are the lack of reference data and the exploitation of complex and heterogeneous information. The originality of the project relies on the development of new online change detection methodologies by using generative models, which incorporate the temporal

5.2.3 DynaLearn - Labex CominLabs 2020-2023

Participants: Nicolas Courty (project leader), Clément Bonet, Diego di Carlo, Thomas Corpetti.

- Project type: Labex CominLabs
- Dates: 2020–2023
- PI institution: UBS
- Other partners: IMT Bretagne, LMBA
- Principal investigator: Nicolas Courty, François Rousseau (IMT)
- web: https://project.inria.fr/dynalearn/

Neural networks are powerful objects used in machine learning, but poorly understood from a theoretical point of view. A recent line of research consist in studying the flow of information through or in these networks through the lens of dynamical systems and their associated Physics. The Dynalearn project aims at contributing on those aspects in a two-fold way:

- By exploring how dynamical formulation of learning process can help in understanding better learning deep neural architectures, as well as proposing new learning paradigms based on the regularization of the flows of information;
- By leveraging on novel neural architectures and available data to devise new data-driven dynamical simulation models, with applications in Earth Observation and Medical Imaging.

5.2.4 MATS - ANR/JCJC 2019-2023

Participants: Romain Tavenard (leader), Laetitia Chapel, Thomas Corpetti, Nicolas Courty, Chloé Friguet, François Painblanc (PhD).

- Project type: ANR JCJC
- Dates: 2019–2024
- PI institution: Univ Rennes 2
- Principal investigator: Romain Tavenard
- web: http://rtavenar.github.io/research/projects/mats.html

A huge trend in recent earth observation missions is to target high temporal and spatial resolutions (e.g. SENTINEL-2 mission by ESA). Data resulting from these missions can then be used for fine-grained studies in many applications. In this project we will focus on three key environmental issues: agricultural practices and their impact, forest preservation and air quality monitoring. Based on identified key requirements for these application settings, MATS project will feature a complete rethinking of the literature in machine learning for time series, with a focus on large-scale methods that could operate even when little supervised information is available. In more details, MATS will introduce new paradigms in large-scale time series classification, spatio-temporal modeling and weakly supervised approaches for time series. Proposed methods will cover a wide range of machine learning problems including domain adaptation, clustering, metric learning and (semi-)supervised classification, for which dedicated methodology is lacking when time series data is at stake. Methods developed in the project will be made available to the scientific community as well as to practitioners through an open-source toolbox in order to help dissemination to a wide range of application areas. Moreover, the application settings considered in the project will be used to showcase benefits offered by methodologies developed in MATS in terms of time series analysis.

5.2.5 OTTOPIA - ANR Chair on AI 2021-2025

Participants: Nicolas Courty (project leader), Chloé Friguet, Minh-Tan Pham, Charlotte Pelletier, Huy Tran, Paul Berg, Renan Bernard.

- Project type: ANR Chair on AI
- Dates: 2021–2025
- PI institution: UBS
- Other partners: CNES, PicTerra, Wipsea, Ecole Polytechnique, EPFL
- Principal investigator: Nicolas Courty

Earth Observation, whether it be by satellites, airborne captors or drones, allows a better understanding of the dynamics of environmental systems or our human society. It is a decisive tool to measure the impact of mankind on earth. In the last 50 years, the fast development of spatial missions and of the technology of the associated captors yields an unprecedented amount of data, largely under-exploited. Artificial intelligence can become a major help toward exploiting this wealth of information, by automatizing tasks cantoned to human operators, or even combining them to produce novel knowledges. Yet, the earth observation data come with specific challenges not only related to their volume but also their complexity. The OTTOPIA Chair project proposes to tackle some of them through the prism of Optimal Transport theory applied to machine learning. This mathematical tool makes it possible to apprehend the data through their distributions, and no longer as a sum of distinct individuals. Following significant advances in computational aspects, it has recently emerged as a tool of choice for multiple learning problems. We propose to exploit its principles on four challenges: 1. multi-modality and considering the heterogeneity of the data at transfer of learning, 2. Learning with few data, possibly corrupted by label noise, 3. Security of AI algorithms in Earth observation; and 4. Visual Question Answering, i.e. interacting with remote sensing data through natural language questions. The contributions of the Chair will naturally aim at fundamental developments in AI but also new applied methodologies for which a strong industrial transfer potential is envisaged.

5.2.6 OWFSOMM - ANR/FEM 2020-2023

Participants: Sébastien Lefèvre (scientific cochair), Minh-Tan Pham.

- Project type: PIA (CORED MRE-ITE 2019)
- Dates: 2019–2022
- PI institution: UBS
- Other partners: FEM, OFB, CEFE, Pelagis, WIPSEA, EDF Renewables, ENGIE Green, EOLFI, RWE Renewables, Ifremer

- Principal investigators: Georges Safi (FEM), Sébastien Lefèvre, Aurélien Besnard (CEFE / CNRS)
- web: www.france-energies-marines.org/projets/owfsomm

The project OWFSOMM (Offshore Wind Farm Surveys Of Marine Megafauna: standardization of tools and methods for monitoring at OWF scales) aims to provide, (i) a method for conducting a robust inter-calibration of surveys at sea from mobile platforms using historical and novel technologies and, (ii) an AI suite to optimize the use of multiple sensors in order to improve their efficiency in detecting, identifying and characterizing marine megafauna.

5.2.7 Game of Trawls - FEAMP 2019-2022

Participants: Luc Courtrai, Sébastien Lefèvre, Jean-Christophe Burnel (Engineer/PhD), Abdelbadie Belmouhcine (Postdoc), Hugo Gangloff (Postdoc).

- Project type: FEAMP 2014-2020 : 39 5 (Fonds europeen pour les affaires maritimes et de la peche).
- Dates: 2019–2022
- PI institution: Ifremer (Lorient)
- Other partners: Marport France SAS, Comité des Peches Maritimes du Morbihan
- Principal investigator: Julien Simon, Ifremer
- web: https://wwz.ifremer.fr/peche_eng/Le-role-de-l-Ifremer/Recherche/Projets/Description-projets/GAME-OF-TRAWLS

The main goal of the project is to allow future fishing boats to detect in real-time, with a network of sensors, the different species of fish before catching them to sort them in the trawl and thus limit discards. We will focus on underwater detection and recognition of fish species. Our data are diverse: underwater images, history of captures in a logbook, multi beam sounders, GPS, depth sensors, temperatures, . . . We therefore propose to design neural networks specialized in the detection and tracking of objects, taking advantage of multimodal data input while also taking care of efficiency for real-time processing of these data

5.2.8 SEMMACAPE - ADEME 2019-2023

Participants: Sébastien Lefèvre (project leader), Minh-Tan Pham, Hugo Gangloff (Postdoc).

- Project type: ADEME (Appel projet "Energies durables")

- Dates: 2019–2022 (extended to May 2023)
- PI institution: UBS
- Other partners: France Energies Marines (FEM, Brest), Office Francais de la Biodiversité (OFB, Brest), WIPSEA (Rennes), IFREMER (Sète)
- Principal investigator: Sébastien Lefèvre
- web: http://semmacape.irisa.fr/

The analysis of the development impacts of a Marine renewable energies project generally requires aerial observations of marine megafauna (marine mammals and birds) to better characterize the species that frequent these sites. The Semmacape project aims to demonstrate the relevance of software solutions for processing and analyzing aerial photographs to ensure the automated census of marine megafauna. The importance of such monitoring has been reinforced by the need for impact studies, which are required for any wind power project subject to environmental authorization. Computer vision has undergone a recent upheaval with "deep learning" in the form of deep convolutional networks. The application of these networks to aerial images for the automated observation of marine megafauna is promising, but adaptations of existing algorithms are to be expected. In particular, these animals evolve in a context (sea) characterized by a highly variable visual content, which is detrimental to the performance of these deep networks. The Semmacape project aims to respond to these scientific obstacles in order to provide a technological leap forward in the field of aerial census of marine megafauna and its application to the environmental monitoring of offshore wind farms. The main gain will lie in the completeness of the observations, while minimising the risk of identification errors and allowing a reduction in analysis time.

5.2.9 6P - ANR/PRCE 2019-2023

Participants: Sébastien Lefèvre (WP leader), Thomas Corpetti, Javiera Castillo-Navarro (postdoc).

- Project type: ANR PRCE
- Dates: 2019–2023
- PI institution: G&E (Bordeaux)
- Other partners: EPOC (Bordeaux), ISPA (Bordeaux), BRGM (Orléans), Avion Jaune (Montpellier)
- Principal investigator: Florian Delerue, G&E Lab., ENSEGID, Bordeaux

SixP aims: i) to characterize the variation of plant-plant interactions along gradients of metal phyto-availability, while explaining the specific role of metallicolous species in these interactions; ii) to better identify the effects of multiple stress factors on these interactions; iii) to specify the plant functional strategies at stake; and iv) to assess the effect of plant-plant interactions at the community scale. The project will be implemented in several mine tailings in the PyrÃ©nÃ©es at different altitudes (in the montane zone, and at the subalpine-alpine zone). At each site, several areas will be specified from peripheral low-contaminated areas towards tailings centers corresponding to a gradient of metal phyto-availability. The first three research directions will then be addressed by experimentations manipulating species in interaction. As for the last direction, the combination of very high resolution airborne data (lidar, multispectral images) covering the studied areas with in situ observations in a deep learning framework will be used to map species distribution and their geomorphological position. Spatial patterns of the different interacting species (aggregation vs repulsion) will exhibit the effects of plant-plant interactions on the long-term.

5.2.10 ROMMEO - SAD 2022-2024

Participants: Minh-Tan Pham (PI), Hoang-An Le.

- Project type: SAD Région Bretagne 2021.
- Dates: 2022–2024
- PI institution: UBS
- Principal investigator: Minh-Tan Pham

The objective of the project ROMMEO (Robust multitask learning via mutual knowledge distillation for earth observation) is to perform and combine knowledge distillation with a multitask learning (MTL) framework applied to EO data. Our objective is to develop a robust and compact model which is able to simultaneously perform several tasks with high accuracy. First, such a model can be trained from different data sets without fully annotated labels for all task, which is relevant for remote sensing data with lack of data annotations. Then, knowledge distillation can be mutually performed in order to capture and share complementary features from each task-specific large model. The ROMMEO model is aimed to reach state of the art performance on certain EO tasks such as semantic segmentation, object detection and scene understanding. More importantly, it is expected to become a high-impact solution with low computational and environmental costs not only in remote sensing, but also in other research domains.

5.2.11 PARCELLE - CNES TOSCA 2018-2022

Participants: François Merciol, Thomas Corpetti, Sébastien Lefèvre, Charlotte Pelletier, Luke Abougit.

- Project type: CNES TOSCA
- Dates: 2018-2020
- PI institution: CESBIO (Toulouse)

- Other partners: DYNAFOR, TETIS, LaSTIG, LETG, ESPACE-DEV, LIVE, Agro ParisTech
- Principal investigator: Mathieu Fauvel (CESBIO / INRAe)

The PARCELLE project aims to foster shared developments on the iota2 processing chain that serves as the technical solution to provide national-level land cover map from 2016 to 2018. Within this project, we are more specifically dealing with the integration of multiscale, spatial descriptors to improve the iota2 classification performances. We consider both wavelet-based descriptors and attribute profiles (and their recent variants). The latter will be achieved by extends our software libraries (e.g. TRISKELE) with python wraper.

5.3 Bilateral industry grants

- Nicolas Courty CIFRE PhD thesis of Bjöern Michele with Valeo.AI
- Sébastien Lefèvre PhD thesis of Iris de Gélis cofunded by Magellium and CNES

5.4 Collaborations

National collaborations

- LITIS (Université de Rouen Normandie, Université du Havre Normandie and INSA Rouen Normandie), through a collaboration (supervision of the Phd of Guillaume Mahey and the internship of Haoran Wu) with Gilles Gasso.
- IRMAR (INSA Rennes), through a scientific collaboration with Valérie Garès (MCF Statistics) (supervision of the Phd of Renan Bernard and the internship of Marion Jeamard)
- LIRIS (Lyon), with Nicolas Bonneel and Julie Digne (around the PhD of Théo Lacombre)
- ENS (Lyon), Ecole Polytechnique / CMAP (Palaiseau), UJM (Saint-Etienne) in the context of the OATMIL and OTTOPIA projects

International collaborations

- Univ. Salzburg through several internship cosupervisions in the context of the Master Copernicus in Digital Earth, and the visit of Getachew Workineh Gella
- Aarhus University through the visit of Joachim Nyborg
- Monash University (Australia), Faculty of Information Technology, through two Ph.D. co-supervisions with Geoffrey I. Webb (Professor in computer science)
- EPFL (Sion), collaboration with Devis Tuia

- TU Munich, through the collaboration with Konrad Heidler (PhD student) and his supervisors
- University of Naples – Federico II, through the visit of Matteo Ciotola (PhD student)
- Technical University of Kenya, through the supervision of the PhD thesis of Anne Osio

6 Dissemination

6.1 Promoting scientific activities

6.1.1 Scientific Events Organisation

General Chair, Scientific Chair

- Nicolas Courty: CAP/RFIAP 2022
- Chloé Friguet : Statlearn'22 (Cargèse, France) : challenging problems in statistical learning
- Thomas Corpetti, Minh-Tan Pham, Sébastien Lefèvre: MACLEAN'22: ECML-PKDD Workshop on Machine Learning for Earth Observation

Member of the Organizing Committees During the 2022 year, most of the member of the team were involved in the organization of the CAP/RFIAP 2022 conference, that was held in Vannes in July 2022[1]. CAP is one of the natiuonal french event on machine learning, while RFIAP is more dedicated to Pattern Recognition and Computer Vision. CAP/RFIAP was jointly sponsored by SSFAM (Société Savante Francaise d'Apprentissage Machine) and AFRIF (Association Francaise pour la Reconnaissance et l'Interprétation des Formes). The event gathered more than 150 participants.

- Charlotte Pelletier:
  - Workshop EarthVision: large scale computer vision for remote sensing imagery at CVPR 2022
  - Workshop Pattern Recognition and Remote Sensing (PRRS) at ICPR 2022
  - Special session on time series analysis at ICPRAI 2022

6.1.2 Scientific Events Selection

Chair of Conference Program Committees

[1] `https://caprfiap2022.sciencesconf.org`

Member of Conference Program Committees

- Chloé Friguet: Colloque Francophone International sur l'Enseignement de la Statistique (CFIES)

Reviewer

- Nicolas Courty: NeurIPS, ICML, ICLR, CAp
- Laetitia Chapel: NeurIPS, ICML, AISTATS, IGARSS, CAp
- Chloé Friguet : JdS'22, CFIES'22
- Sébastien Lefèvre: ECML-PKDD, IGARSS, EarthVision, NLDL, EGC
- Minh-Tan Pham: ICIP, Earthvision, MACLEAN, IGARSS
- Romain Tavenard: ICLR, CAp, GRETSI, ICPRAI

6.1.3 Journal

Member of the Editorial Boards

- Chloé Friguet : Associate Editor of Statistique et Société (Société Française de Statistique)
- Charlotte Pelletier : guest editor of the special issues: Advancing deep learning for time series analysis in Remote Sensing of Environment, Advances in Deep Learning Techniques for the Analysis of Remote Sensing Time Series in Remote Sensing, Machine-Learning Approaches for Geoscience Modelling: Soil, Crop, Environmental Properties and Processes in Geosciences KeAI.
- Sébastien Lefèvre: Associate Editor, IEEE Transactions on Geoscience and Remote Sensing; Editorial Board Member, Remote Sensing; Editorial Board Member, ISPRS International Journal of Geo-Information
- Minh-Tan Pham: Member of Editorial Board of Digital Signal Processing, Elsevier

Reviewer - Reviewing Activities

- Laetitia Chapel: Machine Learning, Springer; IEEE Transactions on Neural Networks and Learning Systems; photogrammetry and remote sensing; IEEE Transactions on Pattern Analysis and Machine Intelligence
- Chloé Friguet : Statistique et société
- Charlotte Pelletier: Machine Learning, Springer; Data Mining and Knowledge Discovery, Springer; Knowledge and Information Systems, Springer; IEEE Transactions on Geoscience and Remote Sensing; IEEE Geoscience and Remote Sensing Letters; Remote Sensing of Environment, Elsevier; Remote Sensing MDPI; ISPRS

Journal of Photogrammetry and Remote Sensing, Elsevier; International Journal of Applied Earth Observations and Geoinformation, Elsevier; IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing

- Nicolas Courty: ISPRS Journal of Photogrammetry and Remote Sensing, IEEE Transactions of Geoscience and Remote Sensing, IEEE Transactions on Pattern Analysis and Machine Intelligence, IEEE Transactions on Neural Networks and Learning Systems, Journal of Machine Learning Research (JMLR), Transactions on Machine Learning Research (TMLR)
- Minh-Tan Pham: IEEE Transactions on Geoscience and Remote Sensing; IEEE Geoscience and Remote Sensing Letters; MDPI Remote Sensing; ISPRS Journal of Photogrammetry and Remote Sensing
- François Merciol: MDPI Remote Sensing, MDPI Information, MDPI Electronics

6.1.4 Invited Talks

- Nicolas Courty: Invited talk at Valeo.AI on Sliced Optimal Transport distances for non-Euclidean geometries
- Nicolas Courty: Invited talk at the workshop 'Measure-theoretic Approaches and Optimal Transportation in Statistics', entitled 'Sliced Optimal Transport distances on Manifolds: Spherical and Hyperbolical cases
- Nicolas Courty: Invited talk at NaverLabs Europe on Optimal Transportation for Signal Processing on Graphs
- Nicolas Courty: Invited talk at the workshop 'Signal Processing on Graphs' at CIRM (Marseille).
- Nicolas Courty: Keynote at the conference Discrete Geometry and Mathematical Morphology (DGMM)
- Nicolas Courty: School on Statistical and Geometric Divergences for Machine Learning (Rennes). Introductory course (6h) on optimal transport
- Nicolas Courty: Invited talk at the SMAI MODE days in Limoges (May)
- Charlotte Pelletier at Data Science@CESBIO. May 2022. *Unsupervised domain adaptation for satellite image time series.*
- Charlotte Pelletier at TREES Research Lab - National Institute for Space Research (INPE). November 2022. *How to automatically produce crop-type maps from high-resolution satellite images time series?*
- Charlotte Pelletier at IRIMAS (Université Haute Alsace). November 2022. *Unsupervised cross-region adaptation by temporal shift estimation.*
- Charlotte Pelletier at 7ième Rencontre de la Statistique : environemment et climat, organised by LMBA (UBS). *Automatic mapping of the land surfaces from Earth observation time series*

- Laetitia Chapel at Centre Henri Lebesgue research school on "statistical and geometric divergences for machine learning", Rennes. *Unbalanced Optimal Transport and OT between metric spaces*
- Sébastien Lefèvre: Invited talk at Technical University of Munich: *On the bias of some popular EO datasets*
- Minh-Tan Pham: Talk, From supervised to unsupervised deep learning for automatic detection of marine megafauna, MACLEAN workshop, CAP/RFIAP, Vannes.
- Romain Tavenard: Invited talk at Flanders AI Research program on *Matching Structured Data.*
- Romain Tavenard: Invited talk at at Centre Henri Lebesgue research school on "statistical and geometric divergences for machine learning", Rennes. *Optimal Transport and Graphs*

6.1.5 Leadership within the Scientific Community

- Charlotte Pelletier is the chair of the working group on temporal geospatial data understanding of the International Society for Photogrammetry and Remote Sensing (ISPRS) (TCII/WG5)
- Charlotte Pelletier is the co-chair of the technical committee 7 on remote sensing and mapping for the International Association of Pattern Recognition (IAPR) (TC7)
- Thomas Corpetti, Minh-Tan Pham, Sébastien Lefèvre: Chairs of the MACLEAN action within GDR MADICS

6.1.6 Scientific Expertise

- Laetitia Chapel: member of the *comité d'évaluation scientifique* 23 (Intelligence Artificielle) for ANR; member of the *comité d'évaluation scientifique* for the bilateral call CREST / ANR (Japan).
- Sébastien Lefèvre: expert panel *W&T5 (Informatics & Knowledge Technology)* for FWO (Flemish Belgium); expert group *Downstream R&D for Copernicus Security Service* for the EU; expert *R&D Tax Credit – CIR/JEI* for the Ministry of Research; expert *RESTART 2016–2020 Programmes for RTDI* for RIF (Cyprus); expert *Scholarships & Projects* for FNRS (Walloon Belgium); expert *CIFRE* for ANRT; expert *AAP Normandie Émergent* for ANR / Normandy Region

6.1.7 Research Administration

Scientific organisations
The team was involved in the organization of CAP/RFIAP 2022 (see previous paragraph).

- Sébastien Lefèvre: member of the Executive Board of the National Society for Pattern Recognition and Computer Vision (AFRIF)
- Sébastien Lefèvre: member of the Scientific Council of the Natural Regional Park of the Gulf of Morbihan
- Sébastien Lefèvre: member of the Scientific Council of the Scientific Interest Group BreTel (remote sensing in Brittany)
- Charlotte Pelletier: member of the Scientific Council of the Scientific Interest Group BreTel (remote sensing in Brittany)

Recruitment Committees

- Nicolas Courty: member of a Recruitment Committee in Computer Science (ENSAI, Rennes).
- Laetitia Chapel: member of a Recruitment Committee in Computer Science (Univ. Rouen).
- Chloé Friguet: member of a Recruitment Committee in Statistics (Univ. Rennes 2) and in Computer Science (INSA Rennes).

6.2 Teaching, supervision

6.2.1 Teaching

For reseachers, all activities are given. For professors and assistant professors, only courses at the M. Sc. level are listed.

- Laetitia Chapel
  - Master Copernicus in Digital Earth - geodata science specialization (Univ. Bretagne Sud): machine learning for EO (6h)
- Chloé Friguet
  - Master Biomolécules, Micro-organismes et Bioprocédés (Univ. Bretagne Sud): Biostatistique, (20h)
- Charlotte Pelletier
  - Master in computer science and statistics engineering (Univ. Bretagne Sud): algorithmique des données (42h)
  - Master Copernicus in Digital Earth - geodata science specialization (Univ. Bretagne Sud): math and computer science refresher (6h), machine learning (12h), deep learning (18h), practical workshop (25 h)
- Nicolas Courty
  - machine learning, Deep learning in Master in Computer science and Statistics engineering, Univ. Bretagne Sud, Vannes France

  - Deep Learning and High-Performance computing, Copernicus Master in Digital Earth, Univ. Bretagne Sud, Vannes France
- Sébastien Lefèvre
  - Computer vision, Copernicus Master in Digital Earth, Univ. Bretagne Sud, Vannes France (45h)
- Minh-Tan Pham
  - Computer vision, Copernicus Master in Digital Earth, Univ. Bretagne Sud, Vannes France (21h)
- Romain Tavenard
  - Python programming (24h, MSc in Data Science, Univ. Rennes 2), NoSQL databases (24h, MSc in Data Science, Univ. Rennes 2), deep learning (20h, MSc in Data Science, Univ. Rennes 2 and EDHEC Business school, Lille), Machine Learning for Time Series (15h, MSc in Smart Data, ENSAI, Rennes)

6.2.2 Supervision

- PhD in progress:
  - **Renan Bernard**, Optimal transport and causality, 2022-2025, Nicolas Courty, Chloé Friguet and Valérie Garès (INSA Rennes, IRMAR)
  - **Jean-Christophe Burnel**, Deep Learning for Remote Sensing in Resource-Constrained Environment, 2020-2023, Sébastien Lefèvre, Laetitia Chapel
  - **Iris de Gélis**, Deep learning for change detection from 3D point clouds, 2020-2023, Sébastien Lefèvre, Thomas Corpetti
  - **Corentin Dufourg**, Learning and analysing spatio-temporal objects from satellite image time series, 2022-2025, Charlotte Pelletier, Sébastien Lefèvre
  - **Manal Hamzaoui**, From Euclidean to Hyperbolic Spaces: Rethinking Hierarchical Classification of Remote Sensing Scene Images, 2019-2023, Sébastien Lefèvre, Laetitia Chapel, Minh-Tan Pham, in the context of ANR Multiscale
  - **Guillaume Mahey**, Unbalanced Optimal transport for out-of-sample detection, 2021-2024, Laetitia Chapel, Gilles Gasso (INSA Rouen)
  - **François Painblanc**, Classification algorithms for time series, 2019-2022, Romain Tavenard, Laetitia Chapel, Chloé Friguet
  - **Clément Bonet**, Optimal Transport Flows in machine learning, Nicolas Courty with LMBA (Francois Septier) and IMTB (Lucas Drumetz)
  - **Huy Tran**, Comparison of incomparable spaces, 2021–2024, Nicolas Courty with Karim Lounici and Rémi Flamary (Ecole Polytechnique/CMAP)
  - **Paul Berg**, Robust representation learning from self-supervised distillation and domain adaptation in remote sensing, 2021-2024, Nicolas Courty, Minh-Tan Pham
  - **Rémi Cornillet**, Optimal Transport for tensor factorization, 2021-2024, Nicolas Courty and Jérémy Cohen, in the context of ANR JCJC LoRaIA.

- **Bjöern Michele**, Domain Adaptation for Semantic Segmantation of point clouds, 2022-2025, Nicolas Courty and Valeo.AI (CIFRE contract)

- PhD / HDR defended during the year
  - HDR of **Laetitia Chapel** (May 2022)
  - PhD of Javiera Castillo-Navarro (March 2022)

6.2.3 Juries

- Nicolas Courty: PhD jury member of Herilalaina Rakotoarison : 'Contributions Ã AutoML: optimisation des hyper-paramètres et méta-apprentissage', (Université Paris-Saclay, June 2022)
- Nicolas Courty: PhD jury member of Yusuf Yigit PILAVCI: 'Algorithme de Wilson pour l'Algèbre Linéaire Randomisée', (Université Grenoble Alpes,November 2022)
- Nicolas Courty: PhD jury member of Tranh Huan: 'Record linkage and analysis of linked data with application in French national health data system', (INSA Rennes, December 2022)
- Nicolas Courty: PhD jury member of Yasser Boutaleb : 'Egocentric Hand Activity Recognition', (Centrale-Supélec Rennes, December 2022)
- Nicolas Courty: PhD jury member of Mourad El Hamri : 'Structural Optimal Transport for Domain Adaptation with Theoretical Guarantees', (Université Sorbonne-Paris-Nord, December 2022)
- Nicolas Courty: HDR jury member of de Julien Rabin : 'Formulations du Transport Optimal pour les Problèmes Inverses en Imagerie', (Université de Caen-Normandie, December 2022)
- Laetitia Chapel: PhD jury member of Thibault Séjourné (ENS Paris, France)
- Laetitia Chapel: PhD jury member of Alexandre Eid (Université Lyon 1, France)
- Chloé Friguet: PhD jury member of Dingge Liang (INRIA Nice, France) - *Modèles probabilistes profonds pour les systèmes de recommandation et le clustering de réseaux.*
- Sébastien Lefèvre: PhD jury member of Gaétan Bahl (Université Côte d'Azur, June 2022)
- Sébastien Lefèvre: PhD jury member of Yuansheng Hua (Technical University of Munich, June 2022)
- Sébastien Lefèvre: PhD jury member of Emna Amri (Université Savoie Mont Blanc, June 2022)
- Sébastien Lefèvre: HDR jury member of Thomas Lampert (Université de Strasbourg, July 2022)

- Sébastien Lefèvre: PhD jury member of Yuqing Hu (IMT Atlantique, December 2022)
- Sébastien Lefèvre: HDR jury member of Adrien Chan-Hon-Tong (ONERA / Université Paris Saclay, December 2022)
- Charlotte Pelletier: PhD jury member of Tsegamlak Terefe Debella (Univ. Haute Alsace, IRIMAS, France)
- Charlotte Pelletier: PhD jury member of Gaston Lenczner (ONERA, France)
- Romain Tavenard: PhD jury member of Jingwei Zuo (UniversitÃ© Paris-Saclay, France)
- Romain Tavenard: PhD jury member of Youssef Achenchabe (UniversitÃ© Paris-Saclay, France)

6.3 Popularization

- Nicolas Courty: Conference on Artifical Intelligence, along the projection of a movie '5 nouvelles du cerveau' from Stéphane Bron, during the 'Rencontres du Cinéma Européen' (Vannes, April 2022)
- Sébastien Lefèvre: Conference on Artifical Intelligence for Earth Observation ("Intelligence artificielle et satellites : observer (pour protéger) notre planète"), wihtin the Planète Conférence cycle of UBS (Vannes, February 2022)

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