Privacy-preserving and ressource-efficient federated learning for ship detection from satellite imagery

Postdoc position (16-18 months)

Expected starting: June 2026

Keywords

Federated learning, privacy-preserving machine learning, differential privacy, deep learning, classification, object detection, remote sensing, satellite imagery, Earth observation

Context

Maritime surveillance is a major application area of Earth Observation, playing a critical role in environmental protection, maritime safety, and the detection of illegal or unregulated activities at sea. Recent advances in machine learning have significantly improved ship detection capabilities in satellite imagery, notably through the use of deep neural networks applied to optical and SAR data. In practice, however, such data are often distributed across multiple institutions, satellites, and jurisdictions, and cannot be easily centralized due to legal, security, or privacy constraints. Moreover, satellite data are inherently heterogeneous, with significant variations in sensor modality, spatial resolution, and acquisition conditions. Federated Learning (FL) offers a promising paradigm for collaborative model training without sharing raw data. Nevertheless, the application of FL to object detection in satellite imagery remains largely unexplored and raises a number of important scientific challenges. Model updates exchanged during federated training may leak sensitive information, while communication and computational costs can quickly become prohibitive when training large detection models on distributed clients. In addition, domain heterogeneity across clients can significantly degrade performance if not properly handled. The aim of this project is to address these limitations by developing privacy-preserving and resource-efficient federated learning approaches tailored to the specific constraints of ship detection from multi-source satellite images.

Objectives

The overarching objective of the postdoctoral research is to design federated learning methods that enable accurate ship detection while minimizing privacy risks and resource consumption. The project seeks to incorporate formal or empirical privacy guarantees into federated object detection frameworks, reduce communication and computational overheads on both client and server sides, and ensure robust performance across heterogeneous sensing conditions. A strong emphasis will be placed on experimental validation using realistic satellite datasets and operationally relevant scenarios.

Expected Work Program

- **Privacy-Preserving Federated Learning** The research will first focus on privacy-preserving **federated learning for object detection**. This includes the analysis of privacy risks associated with federated training, such as gradient leakage and inference attacks, and the integration of

Differential Privacy mechanisms at either the client or server level. Particular attention will be paid to understanding and characterizing the trade-off between privacy protection and object detection performance, as well as to the impact of heterogeneity across clients. Depending on progress and interest, the work may also include extensions toward **federated domain adaptation** approaches to tackle distribution shifts from multimodal image data.

- **Resource-Efficient Federated Training** A second axis of the project will address resource efficiency in federated training. The postdoctoral researcher will investigate strategies to reduce communication costs, for example through compressed, quantized, or sparse model updates, as well as adaptive client participation schemes. Computational efficiency will also be explored, including the design or adaptation of lightweight object detection architectures that are suitable for federated settings. These developments will be complemented by an analysis of convergence behavior and efficiency under constrained communication budgets and non-identically distributed data.

- **Application to Ship Detection from multi-source satellite images** The developed methods will then be applied and evaluated in the context of satellite ship detection. Experiments will consider multi-source satellite imagery, including both optical and SAR data, and will assess the robustness of the proposed approaches under domain shift, such as the introduction of new sensors, regions, or acquisition conditions. The results will be compared against centralized, non-private, and non-federated baselines. Whenever possible, the project will aim to follow reproducible experimental practices and contribute to open-source implementations.

Required background and skills

- PhD in Computer Science or related domain with **experience and strong publications** in image processing, computer vision and applied machine learning
- Excellent programming skills in Python (familiar with one of deep learning packages, such as PyTorch, is a must.)
- Experience with privacy-preservation machine learning (federated learning, differential privacy) would be a plus.

Supervision and Collaboration

The successful candidate will join the OBELIX research group (`www.irisa.fr/obelix`) from IRISA (UMR 6074), which is located in the UBS (Université Bretagne Sud) campus in Vannes 56000, France. He/She will be mainly supervised by **Dr. Minh-Tan Pham**[1] (Associate Professor at UBS, MCF-HDR). This position is part of the European Horizon AXOLOTL[2] project, for which exchanges with Cypriot researchers are planned. Moreover, we also plan a potential collaboration with **Prof. Ngoc-Son Vu**[3] (Full Professor at University of Technology of Troyes).

Application

Position to be filled as soon as possible, **for an expected starting date in June 2026**. If your background matches the requirements and you are motivated by the topic, Send your detailed CV (with list of publications) + Cover letter to {`minh-tan.pham`}`@irisa.fr`. Potential candidates will be contacted for interview. The recruitment process will also include a security clearance procedure coordinated by the Haut fonctionnaire de défense et de sécurité (HFDS).

[1] `https://sites.google.com/site/mtanpham89/`
[2] `https://www.cmmi.blue/axolotl/`
[3] `https://scholar.google.fr/citations?user=Fw14qXwAAAAJ&hl=en&oi=ao`

References

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