Self-Supervised Anomaly Detection in complex-valued SAR imaging

Laboratoire d'accueil: ONERA / SONDRA

Period: October 2024 to September 2027

Description of the PhD thesis:

Deep anomaly detection methods leverage neural networks to automatically extract crucial data features, mapping high-dimensional data into a more manageable, lower-dimensional latent space, thereby significantly enhancing anomaly detection performance. One standard method for anomaly detection is to utilize Autoencoders (AE) for data encoding and reconstruction, detecting anomalies based on reconstruction errors [S. Sinha, 20, S. Mabu, 21]. Due to the presence of speckle noise in SAR images, [M. Muzeau, 2022] proposed to denoise SAR images using the MERLIN algorithm [E. Dalsasso, 2021b] based on the *noise2noise* principle [J. Lehtinen, 18, E. Dalsasso, 21a]. This pre-processing step leads to better compression in the latent space, subsequently improving the detection performance. Further extension in [M. Muzeau, 23] proposed to guide the Adversarial AE (AAE) in the training process by filtering anomalies using an RX detector [I. S. Reed, 90].

On the other hand, self-supervised learning leverages pretext tasks to extract supervised information from unsupervised data, thereby learning valuable feature representations for downstream tasks such as classification, object detection, and segmentation [M. Caron, 21]. Self-supervised anomaly detection methods acquire data representations by creating supervised pretext tasks. The key to constructing these pretext tasks is to guide the model in learning a specialized representation suitable for anomaly detection, distinct from the general representation obtained through unsupervised learning.

This Ph.D. aims to investigate the above-mentioned methods for SAR anomaly detection, exploiting SAR diversities: polarimetric and interferometric channels [Pottier, 09], multi-bands, and multi-looks representation [A. Mian, 19]. Particular attention is dedicated to the phase information of the complex-valued SAR images, which is crucial to assessing the spectral (range-azimuth) bandwidth and keeping the coherency in polarimetric and interferometric channels.

The Ph.D. student will rely on the previously developed open-source library (https://github.com/NEGU93) developed in [Barrachina, 19] for complex-valued radar data and based on Tensorflow although recent developments of the PyTorch framework now allow for processing complex-valued tensors with differentiable computational graphs. Using this library, it is possible to address and analyze any recent

Machine Learning components like Autoencoders, Transformers, etc., through challenging theoretical methodologies (SAR denoising, self-supervised learning, characterization of latent spaces, etc.).

The Ph.D. student will be hosted at the SONDRA laboratory (joint international laboratory between CentraleSupélec, ONERA, DSO National Laboratories, and National University of Singapore) in Paris-Saclay campus in Gif-sur-Yvette and at the MATS research unit (Advanced Methods in Signal Processing) of the Electromagnetism and Radar Department at ONERA's Palaiseau site. Due to the international visibility of the lab, some overseas exchanges with Singapore could be easily considered. The SONDRA laboratory may finance any conference travel by the doctoral student.

Throughout his thesis, the Ph.D. student will be trained in signal processing (detection, estimation), deep learning processing, and other subjects by following training courses offered by the STIC doctoral school.

This Ph.D. thesis is expected to start next October 2024. A M2R internship is also possible on the same topic.

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