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PROPOSITION DE SUJET DE THESE

Intitulé : Complex-Valued Generative Adversarial Networks for SAR Imaging Applications

Référence : **Domaine-DEMR-2023 -Numéro d'ordre**
(à rappeler dans toute correspondance)

Début de la thèse : 01/10/2023	**Date limite de candidature :** 01/06/2023

Mots clés

Neural Network, Generative Adversarial Network (GAN), SAR Imaging

Profil et compétences recherchées

Titulaire d'un master 2 ou d'un diplôme d'une école d'ingénieur.

Connaissances requises :

-Traitement du signal, traitement statistique du signal

-Méthodes d'apprentissage, Réseau de neurones et apprentissage profond

-Matlab, Python

Présentation du projet doctoral, contexte et objectif

Intitulé de la thèse : Complex-Valued Generative Adversarial Networks for SAR imaging applications

Context: In the Machine Learning domain, generative modeling, encountered, for example, in Generative Adversarial Networks, is an unsupervised learning task that involves automatically discovering and learning the regularities or patterns in input data. This model can so be used to generate new sets of data characteristic of the original dataset.

The idea of using these potential tools is to generate artificial SAR images (or another kind of radar signal) with solid physical representation and interpretation. For that purpose, we must carefully take care of the so-called physic-aware Artificial Intelligence developments to guarantee that what is done is proper relative to the physical phenomena. Keeping the phase information is crucial to synthesizing new SAR images during the SAR image generation. Complex-valued methodology developments are then needed to build physic-aware machine learning and have recently been developed [J. A. Barrachina 2022]. Hence, corresponding generated complex-valued SAR images could be built to keep the phase information relative to the range bandwidth, the azimuth bandwidth, the phase difference relationship in polarimetric and interferometric channels, etc. Another interest in working with the complex-valued SAR image is to directly generate the spectrum of SAR images in which the phase information is fundamental to reconstructing the spatial image. The advantage of working in the spectral domain is that it effectively takes into account radar characteristics such as bandwidth and sub-look constraints which can potentially approximate the real SAR image.

The radar and SAR applications could benefit from these new developments. Realistic generation of SAR images that take into account the diversities of source images could then be possible:

- Generation of new higher resolution (range and azimuth) SAR images from the lower ones (super-resolution),
- Generation of images sharing different spatial sources of information: urban, agricultural areas, forest, etc.,
- Generation of full-pol SAR and/or Interferometry SAR images from mono-channel SAR images,
- Generation of new SAR datasets to analyze the performance of SAR algorithms (detection, change detection, classification) and to enhance the performance of SAR-based Machine Learning algorithms (data augmentation).
- Semantic segmentation (conditional GANs like CycleGAN [T. Karass 2021] or image translation (e.g. SAR to RGB).

This approach can be a solution to limit SAR experimentations. The physical characteristic of complex-valued SAR images will render possible operations such as coherent detection of targets, coherent change detection between images, times-series SAR images exploitation, polarimetric classification, and interferometry.

This internship aims to develop tools devoted to developing new unsupervised Machine Learning schemes for keeping a solid physical representation and interpretation of the generated SAR images. The Ph.D. student will rely on the previously developed open-source library (https://github.com/NEGU93) developed by J. A. Barrachina for complex-valued radar data. Using this library, it is possible to address and analyze any recent Machine Learning components like Autoencoders, Transformers, etc. through challenging theoretical methodologies (Optimal Transport, Wasserstein distance, characterization of latent spaces, etc.).

The Ph.D. student will be hosted at the SONDRA laboratory (CentraleSupélec, ONERA, DSO, National University of Singapore (NUS)) 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. Throughout his thesis, he will be trained on signal processing (detection, estimation), deep learning processing, and other subjects by following training courses offered by the doctoral school.

SONDRA and ONERA Supervision:

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References:

[1] J. A. Barrachina, Complex-Valued Deep Neural Networks for Radar Applications, Ph.D. Thesis, Paris Saclay University, 6 December 2022.

[2] T. Karras, M. Aittala, S. Laine, E. Häärkönen, J. Hellsten, J. Lehtinen and T. Aila, Alias-Free Generative Adversarial Networks, Advances in Neural Information Processing Systems, 34, NeurIPS 2021.

[3] Q. Sun, X. Li, L. Li, X. Liu, F. Liu and L. Jiao, "Semi-Supervised Complex-Valued GAN for Polarimetric SAR Image Classification," IGARSS 2019 - 2019 IEEE International Geoscience and Remote Sensing Symposium, 2019, pp. 3245-3248.

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[8] Y. Giry-Fouquet, A. Baussard, C. Enderli, T. Porges, "SAR image generation using GANs with azimuth constraints for target classification," Proc. SPIE 11870, Artificial Intelligence and Machine Learning in Defense Applications III, 118700D (12 September 2021).

Collaborations envisagées

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