[PhD Thesis PHY-DEMR-2020-04] Deep learning on synthetic data applied to radar imagery

Thanks to the controlled acquisition conditions, Synthetic Aperture Radar (SAR) radar imagery presents good performance in terms of target recognition, registration, or change of position detection. large-scale change and monitoring [1], [2].

Deep learning techniques can further improve results. However, the lack of a sufficiently varied or large database for learning is a significant problem facing the radar community. The so-called "data augmentation" methods [3] make it possible to artificially increase the number of data in order to improve the robustness of the networks. But they do not prepare deep neural networks for significant variations in geometric acquisition configurations, or for typologies of scenes or variants of targets never measured. The proposed solution proposes to use simulation tools based on physical modeling to build learning databases. The actual data further refines the learning accuracy in a second step.

The objective of the thesis is to know to what extent the simulation used for this purpose improves the algorithmic performance of deep learning. It will also be important to determine through controlled degradations of the simulation tools which are the important phenomena that must be modeled faithfully for this learning to be relevant. The impact of uncertainty on the input parameters necessary for the simulation (materials, 3D models, georeferencing, etc.) will also be assessed.

The simulation method currently present in the EMPRISE simulator [5] is based on the modeling of the physical properties of diffusers present on the scene. This scene is constructed from various elements (photos on site, aerial photos, cadastral information, digital terrain models). The first stage of the work will consist in producing, using the simulation tool, the most realistic possible synthetic images on various landscapes, taking into account the dynamic behaviors relating to each of the types of areas (forests, soils, vehicles, ships, cultivated plots, port, residential areas, etc.) The associated ground truth will be shaped in a manner suited to the intended applications.

In a second step, efforts will focus on the implementation of the different algorithms which it is envisaged to treat by this type of methods: detection of change, recognition of targets, or else the search for a radar sticker within a reference image of different resolution, etc.

The main idea is to use fine-tuning techniques (transfer learning [4]) on networks initially formed on a large dataset obtained by simulation, by continuing training on the smallest dataset of real data which we have. Thus, the pre-trained network will have already learned the relevant functionalities, and will be improved by the diversity of cases allowed by the simulation.

Finally, a last part of the thesis will focus on the evaluation of the performance of these networks and in particular their robustness for use in very different contexts of learning bases (transition from tropical to desert areas, targets not present in the learning basis). The tests will be able to relate both to real data for which we have a ground truth, and to simulated data, which will allow us to test a large number of cases. The simulation will also help to assess the generalization capacity of the network, ie the sensitivity of the algorithm to a change in the acquisition conditions between the training base and that of the test.

The candidate will carry out this thesis at ONERA, in collaboration between two departments, DEMR (Electromagnetism and radar) and DTIS (Information and System), and will thus be able to benefit from the ideal expertise environment to deal with this subject: DEMR has recognized expertise for the simulation of radar images and their use in the context of operational applications, particularly in reconnaissance, while DTIS carries out numerous works on deep learning techniques applied to earth observation images as well as image registration.

This work will be based on real airborne data acquired by ONERA in X and Ku band as well as data from commercial satellites (TerraSAR-X, Sentinel) already available.

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[2] E. Colin-Koeniguer, A. Boulch, P. Trouve-Peloux and F. Janez, "Colored visualization of multitemporal SAR data for change detection: issues and methods," EUSAR 2018; 12th European Conference on Synthetic Aperture Radar, Aachen, Germany, 2018, pp. 1-4.

[3] Jun Ding ; Bo Chen ; Hongwei Liu ; Mengyuan Huang. Convolutional Neural Network With Data Augmentation for SAR Target Recognition. IEEE Geoscience and Remote Sensing Letters (Volume: 13 , Issue: 3 , March 2016)

[4] Esra Al Hadhrami ; Maha Al Mufti ; Bilal Taha ; Naoufel Werghi. Transfer learning with convolutional neural networks for moving target classification with micro-Doppler radar spectrograms. ICAIBD 2018

[5] N. Trouvé, Référent environnement : la démarche collaborative d'EMPRISE, ENVIREM 2019.

[6] Rodrigo Caye Daudt, Bertrand Le Saux, and Alexandre Boulch. Fully convolutional siamese networks for change detection. In 2018 25th IEEE International Conference on Image Processing (ICIP), pages4063–4067. IEEE, 2018.

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