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# DESPECKLING OF DUAL-POL GRD SENTINEL-1 IMAGES IN EXTRA-WIDE MODE BY DEEP LEARNING

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## Introduction

The Extra-Wide (EW) mode of Sentinel-1 is very useful for monitoring icebergs and sea ice in the Arctic. Like with other modes of SAR imaging, speckle fluctuations introduce difficulties for image analysis and must be filtered out. Recently, several self-supervised deep learning methods have been introduced [1, 2, 3, 4] and shown to produce high-quality restorations. The approach proposed in this paper extends the SAR2SAR framework [1] to multi-channel SAR data: a multi-inputs multi-outputs denoiser is trained in a self-supervised way to jointly filter Dual-Polarized Ground Range Detected Medium Resolution (GRDM) EW Sentinel-1 images.

## Prior works

Self-supervised strategies provide ways to train a despeckling network in the absence of ground-truth. The SAR2SAR framework [1, 5] requires pairs of SAR images with decorrelated speckle and can be applied both to Single Look Complex (SLC) or GRDM data. It is robust to spatial correlations of speckle (due to spectral apodization and/or the resampling applied to produce GRD Medium Resolution images). Speckle2Void [2] can be applied to single images but it requires spatially decorrelated speckle. MERLIN [3, 4] exploits the real and imaginary parts of SLC images and is robust to spatial correlations of speckle, it can be applied to single images [3] or multi-temporal stacks [4]. Due to the lack of phase information, it cannot be directly applied to GRDM data. SAR2SAR is therefore the most adapted framework to develop a technique for Sentinel-1 GRDM images acquired in extra-wide mode. SAR2SAR training is composed of three phases: in phase A, the network is pre-trained on images corrupted by synthetic speckle; in phases B and C, the network is fine-tuned on real SAR images, learning sensor-specific features (e.g. spatial correlation, content, resolution). The loss function used for training corresponds to the negative log-likelihood derived from Goodman's speckle model [6].

## Proposed joint Filtering

Meraoumia *et al.* [4] have shown that providing a neural network with a multi-temporal stack of the same scene leads to an improvement in the restoration of the reflectivity over single-date approaches. In this work, we propose to perform a joint filtering of dual-pol SAR images: a neural network is trained to predict, in a single forward pass, the despeckled HH and HV images. The joint processing of dual-pol images allows the network to exploit the common information on the underlying scene, leading to a better restoration of the reflectivity than an independent restoration of each polarimetric channel. We define the loss function as the sum of the co-polar and cross-polar restoration losses.

## Experiments

The application of the SAR2SAR self-supervised training strategy requires the availability of pairs of images with decorrelated speckle and limited temporal changes (spatial structures should remain at the same location, yet changes of reflectivity can be handled through a change compensation step). Sea ice undergoes too marked changes to be adapted for SAR2SAR training. We preferred selecting areas over land to perform the training.

We built two multitemporal stacks of Sentinel-1 EW GRD Medium Resolution images (with 8 and 12 images per stack respectively) near the mouth of the river Ob in north of Russia. The dual-polarization images (HH+HV) in the stacks were

observed in summer (August and September) in years 2017, 2018, or 2019, with identical acquisition characteristics and a minimum temporal gap of 12 days. Since land is not covered by snow in these images, there is a significant contrast between the different spatial areas (forests, fields, urban structures, lakes, coastal line, ...) which is beneficial to learn how to restore a wide diversity of spatial structures.

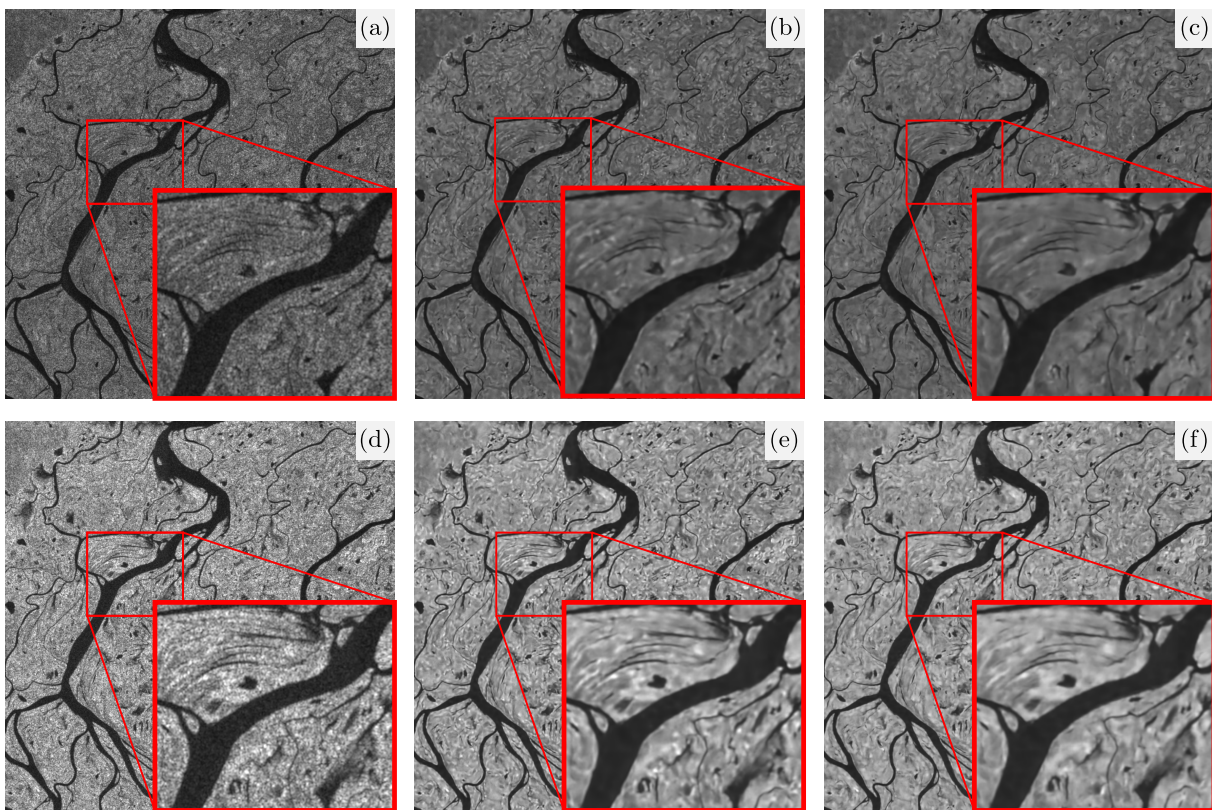
As a baseline, we trained a single-channel despeckling network using the original SAR2SAR method. The proposed method uses a network with the two polarimetric channels as input, so that the network can process jointly the common information and produce better restoration results.

The phase A of the training is done on groundtruth SAR images corrupted by simulated speckle. We accounted for the correlations between the HH and HV images in our simulations to improve the transfer of this network to actual SAR data. The networks are then fine tuned during phases B and C on our stacks of dual-pol Sentinel-1 EW GRDM images.

Restoration results are presented in the Figure 1: it can be noticed that the proposed joint filtering performs better than the original SAR2SAR network at retrieving small structures, such as small rivers.

### Discussion and future work

Joint restoration of dual-pol Sentinel-1 images can benefit numerous applications. We plan to apply it in particular to sea ice images. Beyond speckle noise reduction, a proper correction of thermal noise is also mandatory in order to restore the ice reflectivity and perform the detection and classification of sea ice structures.



**Fig. 1.** Despeckling results on Sentinel-1 EW GRD Medium Resolution images, river Ob, Russia: the first row shows the HH channel, the second row the HV channel. Images (a) and (d): speckled images; images (b) and (e): restored images with an independent processing of the channels; images (c) and (f): proposed joint despeckling. Results shown in this figure correspond to training step B.

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