High-Resolution DEM Generation by Nonlocal Filtering of TanDEM-X Interferograms

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Abstract: We present a nonlocal synthetic aperture radar interferometry (InSAR) filter for TanDEM-X bistatic strip map interferograms, with the goal of generating a digital elevation model (DEM) from TanDEM-X interferograms with a higher resolution and accuracy than the default product. The filter is especially tuned for DEM generation as it takes into account the local topography and phase heterogeneity. Simulations and initial real data tests confirm that it significantly outperforms boxcar averaging, the currently employed phase denoising filter in the TanDEM-X processing chain, and circumvents some of the shortcomings of existing nonlocal filters.

We propose an interferometric SAR (InSAR) denoising filter based on the nonlocal filtering principle. The goal is to generate a digital elevation model (DEM) from TanDEM-X interferograms with a higher resolution and accuracy than the standard product, which relies on simple boxcar averaging. In our previous research [1], [2] we noticed the potential of nonlocal filters, but also some of their flaws, which the proposed filter alleviates.

The nonlocal filtering principle exploits that images have an inherent redundancy so that similar patterns are found multiple times. To denoise a pixel a nonlocal filter searches for similar pixels in its vicinity, the so-called search window. Similar pixels are not just identified by themselves but by comparing their surrounding patches. The logic being that similar pixels have similar neighborhoods, leading to a more robust estimate which also preserves textures and details. After all pixels in the search window have been assigned a weight based on their degree of similarity, the actual pixel value is estimated by their weighted average.

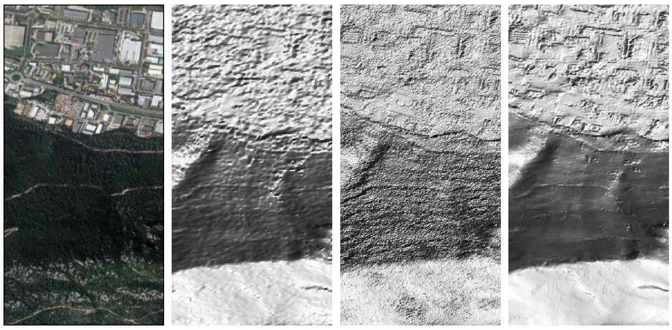
We present in brief the most significant features of the proposed algorithm.

The local fringe frequency caused by the topography is estimated and taken into consideration when searching for similar pixels. This deterministic phase component would otherwise diminish the denoising performance for hills and mountains.

As the noise level hampers the search for similar pixels our method adopts a two-stage approach. The first step consists of regular nonlocal filtering, whereas the second step uses the filtered output of the first to search for similar pixels. The similarity criteria employed in both steps are taken from [3].

The proposed method adaptively selects the patch size depending on the phase heterogeneity index derived in [4]. By doing so the filtering performance increases in homogeneous, where a larger patch size leads to a more accurate estimate, as well as in heterogeneous areas since smaller patch sizes combat the rare patch effect of nonlocal filters.

Fig. 1 shows the shaded reliefs of the generated DEMs from a TanDEM-X CoSSC. Phase denoising was performed by NL-SAR[5] and our proposed method. For comparison we also added the output of the 5 × 5 boxcar filter with 6 m spacing from the default DEM processing toolchain. Both DEMs generated with the nonlocal filters use 3 m spacing as our goal is to preserve finer details and indeed in the industrial site buildings are more clearly visible compared to the boxcar DEM. The benefit of compensating for the topographic phase component is evident in the mountainous region in the lower part.



(a) optical image ©Google (b) boxcar (c) NL-SAR (d) proposed method

Figure 1: Digital elevation models generated from a single TanDEM-X interferogram using a 5 × 5 boxcar filter with 6 m sampling, NL-SAR[5], and our proposed method, both with 3 m spacing

Just like existing nonlocal filters our proposed method provides an improved noise reduction and detail preservation of conventional local filters. Taking into account the phase heterogeneity and topography enhances the filtering performances and can also be incorporated in other nonlocal filtering algorithms. We are also currently in the process of a more exhaustive analysis of the final DEM's accuracy.

References

[1] X. X. Zhu, R. Bamler, M. Lachaise, F. Adam, Y. Shi, and M. Eineder, "Improving TanDEM-X DEMs by Non-local InSAR Filtering," in *EUSAR 2014; Proc. of*, Jun. 2014.

[2] G. Baier, X. X. Zhu, M. Lachaise, H. Breit, and R. Bamler, "Nonlocal InSAR filtering for DEM generation and addressing the staircasing effect," in *EUSAR 2016; Proc. of*, Jun. 2016.

[3] C.-A. Deledalle, L. Denis, and F. Tupin, "NL-InSAR: Nonlocal interferogram estimation," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 49, no. 4, pp. 1441–1452, Apr. 2011.

[4] J. S. Lee, K. P. Papathanassiou, T. L. Ainsworth, M. R. Grunes, and A. Reigber, "A new technique for noise filtering of SAR interferometric phase images," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 36, no. 5, pp. 1456–1465, Sep. 1998.

[5] C.-A. Deledalle, L. Denis, F. Tupin, A. Reigber, and M. Jäger, "NL-SAR: A Unified Nonlocal Framework for Resolution-Preserving (Pol)(In)SAR Denoising," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 53, no. 4, pp. 2021–2038, Apr. 2015.