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10th European Conference on Synthetic Aperture Radar, Berlin, Germany

Adaptive Multi-looking for Long Term Monitoring of Critical Infrastructure

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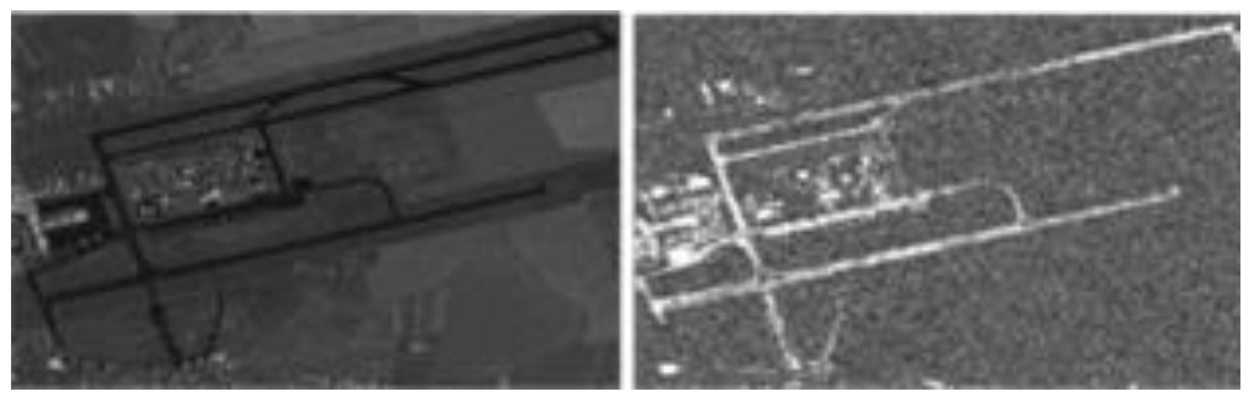
Abstract - Efficient long term monitoring of critical infrastructure is a difficult task, due to the presence of decorrelation artifacts, especially in non-urban areas. This tends to be an important drawback, given the errors that appear dur-ing the unwrapping phase, leading to unreliable deformation maps. The minimization of the artifacts' influence is performed by enhancing the phase estimate using a spatially adaptive multi-looking algorithm. Subsequently, a deformation estimation of linear motions is performed using a stacking-based approach. Results are presented on a database of 32 SLC SM TerraSAR-X images acquired over the area of Bucharest, Romania.

Long term monitoring of critical infra-structure is usually performed using coherent multi-temporal InSAR techniques, such as Persistent Scatterer Interferometry (PSInSAR) [1] and Small Baseline Sub-set Algorithms (SBAS) [2]. These methods try to overcome the limitations induced by large baseline values by using points that exhibit long-term phase coherence, known as persistent (PS) or distributed (DS) scatterers. However, the incidence of such points in non-urban areas is low, due to the reduced number of scatterers with sufficiently large coherence values. A typical procedure for the improvement of coherence estimates is given by performing a multi-looking filtering of the interferometric phase. Adaptive techniques can be used to select pixels with similar statistical properties before the averaging step.

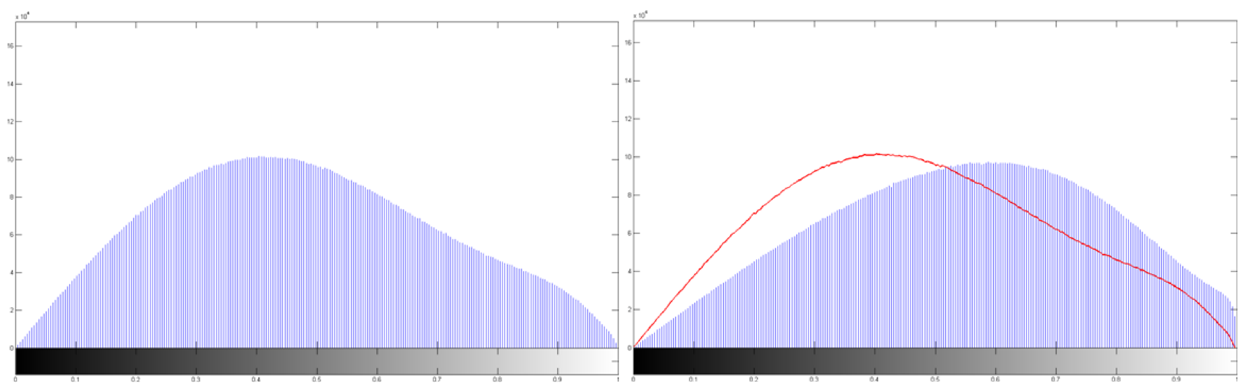


Incoherent averaging of SAR image stack amplitude (left) and results of the ML observed on the coherence estimate of the same area (right).

Spatially Adaptive Phase Filtering - The selection of statistically homogenous areas is performed based on the amplitude statistics of the SLC data, which have been demonstrated to conserve the interferometric phase information of the analyzed targets [5]. We employ a goodness-of-fit approach based on the Anderson-Darling test which identifies similarities between the temporal distributions of pixels in a vicinity extracted using a sliding window.

$$A^2_{N,N} = \frac{N}{2} \sum_{x \in (x_p, x_q)} \frac{(\hat{F}_p(x) - \hat{F}_q(x))^2}{\hat{F}_{pq}(x)(1 - \hat{F}_{pq}(x))}$$

Anderson-Darling GoF test



Coherence distribution before (left) and after (right) phase filtering. An increase of 3.6% in the total number of pixels which are selected for the phase un-wrapping step (coherence > 0.4) can be observed.

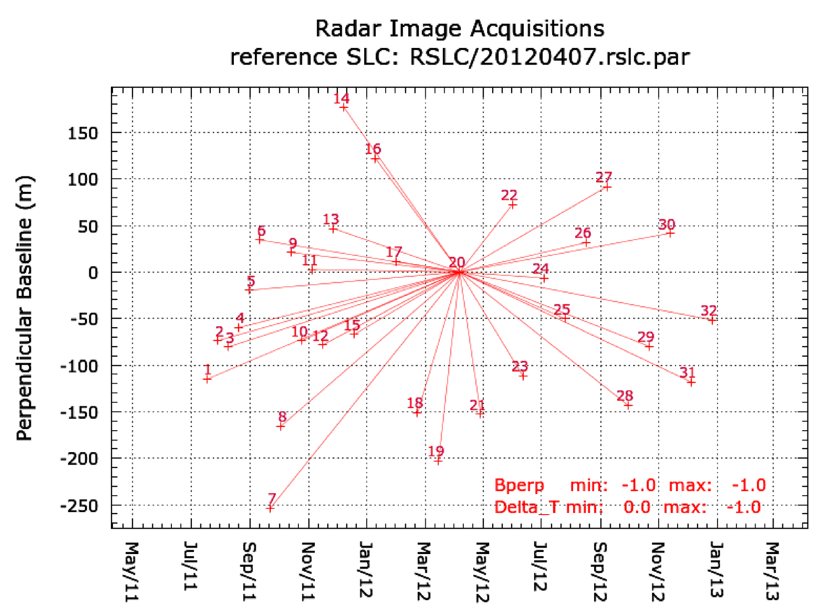
Extraction of Deformation Profiles – The average deformation rate is extracted by applying a stacking algorithm [4] which helps mitigate the influence of the atmospheric effects associated to long term monitoring of critical infrastructure. A deformation profile of the analyzed region is obtained in the hypothesis of linear displacements present in the data.

$$\phi_{rate} = \frac{\sum_{j=1}^{M} \Delta t_j \phi_j}{\sum_{j=1}^{M} t_j^2}$$

Deformation phase rate

$$v_{disp} = \frac{\lambda \cdot \phi_{cum}}{4\pi \cdot t_{cum}}$$

Average displacement velocity

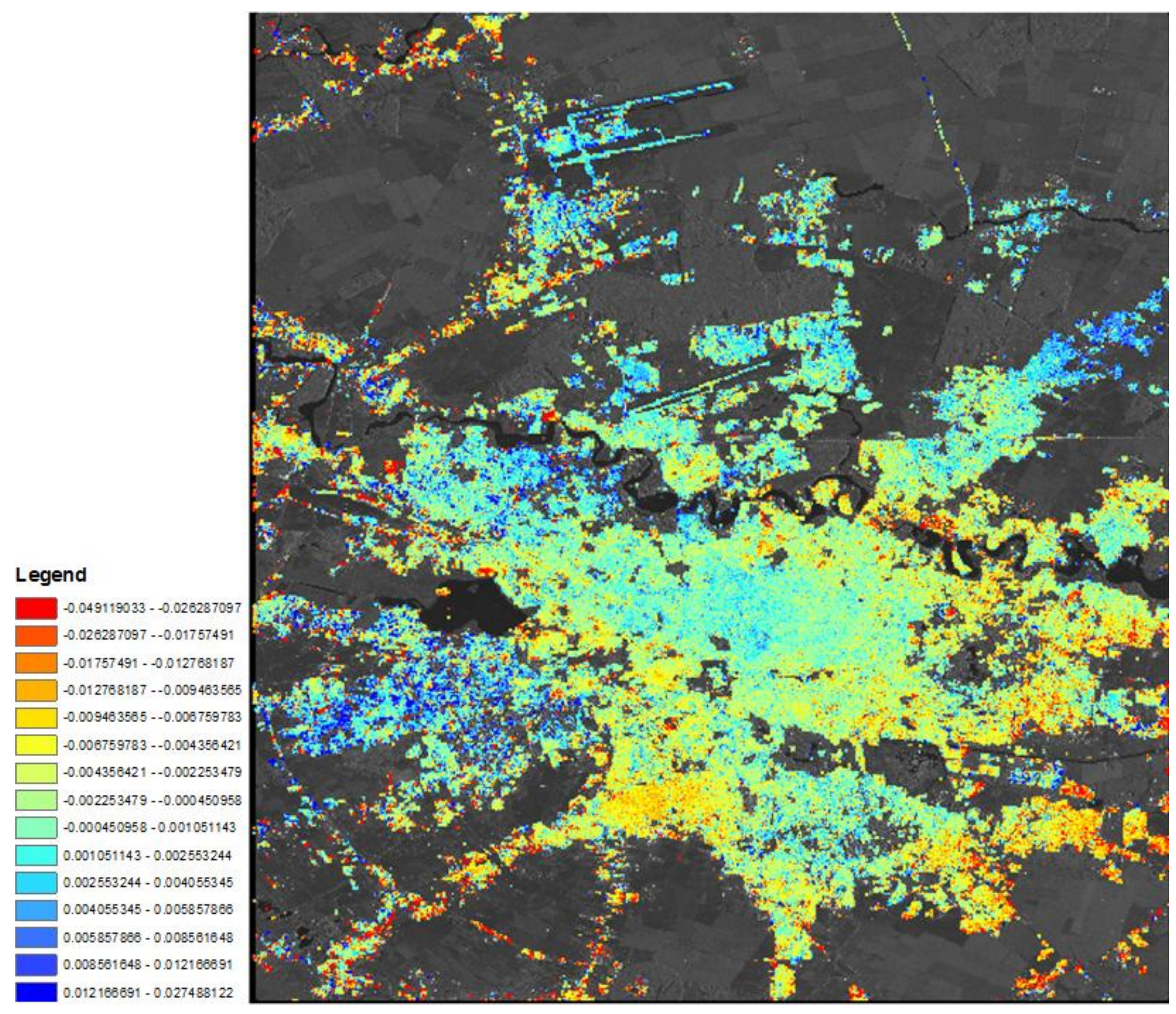


Interferometric perpendicular baselines were computed using a single reference image (07.04.2012). The selection of this master keeps the baselines small with an absolute maximal value of 250m and medium value of 46.7m.

Experimental setup - The proposed methodology has been tested on a dataset consisting of 32 SLC TerraSAR-X images, acquired over the area of Bucharest, Romania. The data spans a 16 months' time interval, between July 2011 and December 2012. The dataset is unevenly sampled in the temporal domain, with images acquired every 11 or 22 days. All acquisitions are characterized by a descending orbit and HH polarization.

An example of area with critical infrastructure and difficult monitoring is the area of the Henri Coanda Airport and its surroundings. As Romania's largest airport, great interest arises from its long term analysis

Results and conclusions - The SLC TerraSAR-X data was processed based on a single reference master image (07.04.2012). Following the generation of differential interferograms, an adaptive filtering with 200 looks of the phase estimate is performed based on a map depicting statistically homogenous areas. The influence of the atmospheric induced artifacts is mitigated by the application of a stacking algorithm to the data, which renders a deformation phase rate and variation for the image pixels. Following an additional integration step, the average displacement velocity along the LOS is extracted. A small deformation trend in the West-East direction was detected and extracted for the entire region.



ACKNOWLEDGEMENT The work has been partially funded by the Sectoral Operational Programme Human Resources Development 2007-2013 of the Romanian Ministry of Labour, Family and Social Protection through the Financial Agreement POSDRU/107/1.5/S/76903. This work was supported by a grant of the Romanian National Authority for Scientific Research, CNCS – UEFISCDI, project number PN-II-ID-PCE-2011-3-1027.

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