PERSISTENT SCATTERER PAIRS (PSP) APPROACH IN VERY HIGH RESOLUTION SAR INTERFEROMETRY

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1. INTRODUCTION

Synthetic aperture radar (SAR) interferometry is a powerful technology for measuring slow terrain movements due to landslides, subsidence, and volcanic or seismic phenomena [1], [2]. The extraction of this information is a complex task, because the phase of the signal is measured only modulo 2π and is affected by random noise and systematic disturbances. The noise is directly related to the decorrelation between the SAR images at different acquisition dates, either because the scene backscattering properties really change in the occurred time (temporal decorrelation), or because the scene is seen from two different positions (spatial decorrelation). Systematic errors are due to the limited accuracies of the orbital data and of the reference DEM used to approximately remove the elevation contribution from the phase, as well as different atmospheric conditions at the various acquisition times.

Due to decorrelation noise, interferometric measurements are usually reliable only on a sparse set of points that remain correlated at different acquisitions, named persistent scatterers (PS), typically corresponding to buildings, infrastructures, or non cultivated and scarcely vegetated terrain. The permanent scatterers method [3], [4], based on the idea of minimizing amplitude and phase dispersions in long series of full resolution SAR images, brought a new way of conceiving SAR interferometry, introducing important advances in the identification of persistent scatterers and the retrieval of their movement. This approach, as well as the methods derived from it, requires an initial selection of PS based on measured radar backscattered amplitudes, and the removal of orbital and atmospheric phase artifacts starting from the already selected PS – a process that can be iterated. The quality and the reliability of the results depend on the density and the distribution of this preliminary selection.

We have recently developed a new approach [5], named persistent scatterer pairs (PSP), for the identification of persistent scatterers (PS) in series of full resolution SAR images, and the retrieval of the corresponding terrain height and displacement velocity. The proposed approach exploits only the relative properties of neighbouring points both for identification and analysis of PS. It is able to overcome the limits of classical persistent scatterer interferometry (PSI), being insensitive to spatially correlated artefacts (atmospheric and orbital artefacts), thus avoiding the need of model based interpolations or fits starting from a pre-selected set of points. The independency from the density of pre-selected points and the exploitation of redundant information makes this approach very robust. The results obtained by the PSP technique in a large set of SAR data show that the proposed approach is very effective, both for the density and the accuracy of the measurements.

With the new generation of very high resolution SAR sensors the number and the density of PS increase dramatically. Weak scatterers that were invisible in low resolution images can now be separated from the clutter and can be promoted to PS. Moreover, working with stacks of very high resolution SAR images allows the precise reconstruction of the 3D position of the persistent scatterers and the structures can be monitored in detail, i.e. it is possible to distinguish different behaviors as a function of the height of a building.

The PSP approach can also provide valid tools for the identification and analysis of distributed scatterers, i.e. scatterers that do not behave like point-like objects, but nevertheless keep a good degree of coherence over time. In fact, the PSP approach can be used to efficiently identify points that are spatially and temporally correlated. Moreover, it must considered that the critical baseline is very large in high resolution data, and spatial decorrelation effects are smaller.

In this work, after resuming the main ideas of the PSP method, we show some results obtained with high resolution COSMO-SkyMed images, and analyze the extension of the PSP method to the identification and analysis of distributed scatterers.

2. METHOD

The central idea of the persistent scatterer pairs (PSP) method is to both identify and analyze PS working only with pairs of points ("arcs"). This makes the methods insensitive to spatially correlated artifacts, removing the need for data calibration and model-based interpolations starting from a preliminary set of measurements obtained by radiometric or low resolution analyses. Therefore, the method is able to overcome some limits of standard PSI analysis and is robust with respect to the density of the PS.

In order to promote a pair of points to be a PSP the multi-temporal coherence is a possible test. In general the test can take into account both amplitude and phase information, and measure the similarity of the statistics of the two points. By applying the arc test to a limited set of arcs connecting close points it is possible to identify several distinct clusters not connected together. Depending on the type of arc test and the threshold applied, this technique allows identifying the seed points for PS selection, or the clusters of distributed scatterers that can be merged to reduce phase noise as for classical differential interferometry. After seeds identification the algorithm try iteratively to include new PS and to connect all disconnected clusters.

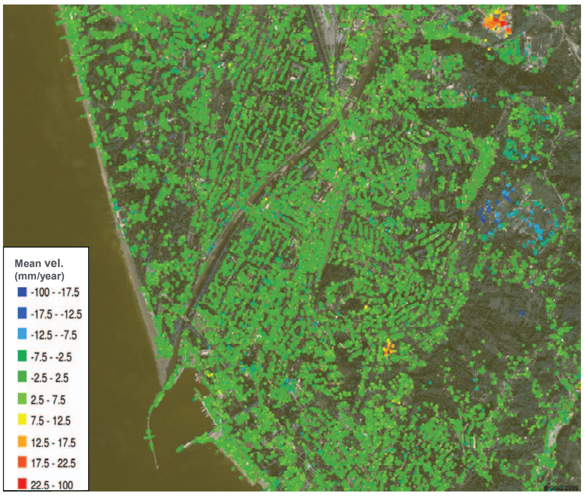

Figure 1: PSP analysis of 35 COSMO-SkyMed images acquired from October 2008 till October 2009 on the city of Sochi, Russia. The coloured dots indicate the identified PS with their mean velocities (along the line-of-sight of the sensor).

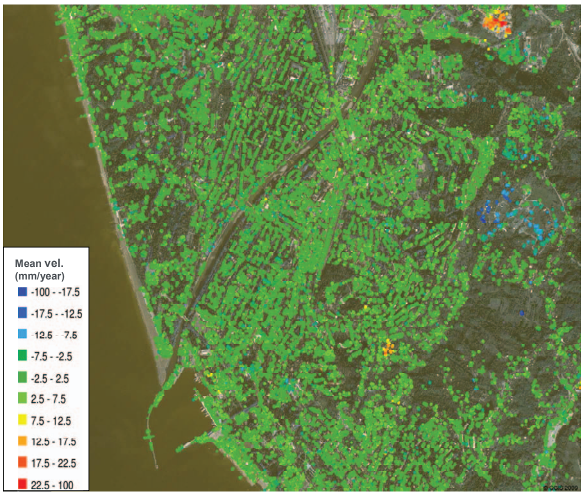

Figure 2: PSP analysis of 35 COSMO-SkyMed images acquired from October 2008 till October 2009 on the city of Sochi, Russia. The coloured dots indicate the identified PS with their mean velocities (along the line-of-sight of the sensor).

After the identification of all coherent scatterers it is possible to reconstruct the displacement and the 3D position of the targets. The increased density of identifiable PS in very high resolution SAR images provides a double benefit: the successive steps become more reliable and the measurements are available on a larger set of points.

3. APPLICATION EXAMPLES

In this long abstract we report some results achieved by using the PSP technique on X-band COSMO-SkyMed data acquired in stripmap mode (3 m ground resolution). Among other things, the analysis demonstrated that, thanks to the high resolution, much more PS can be detected, corresponding to each even small building, rock, etc. Moreover, with many PS typically found for each single structure, it is possible to measure even differential displacements within the same structure (e.g. a building, a bridge, etc.). The PSP analysis was performed on a stack of 35 COSMO-SkyMed images acquired between October 2008 and October 2009 over Sochi, Russia. The acquisition mode was stripmap H4-06, with ground resolution of 3 m x 3 m, polarization HH and incidence angle of 35.5°. Figure 1 shows the mean velocities determined by PSP analysis of the available COSMO-SkyMed data on the city of Sochi, Russia. Figure 2 shows the heights of the identified PS in an area of Sochi, where several tall buildings can be noted, correctly identified by PSP analysis. Figure 3 shows the capability of PSP technique to precisely correct the PS position based on the parameter (elevation) estimated automatically from the processing. Finally, Figure 4 shows the results of the analysis in the harbor area. It is interesting to note that the building

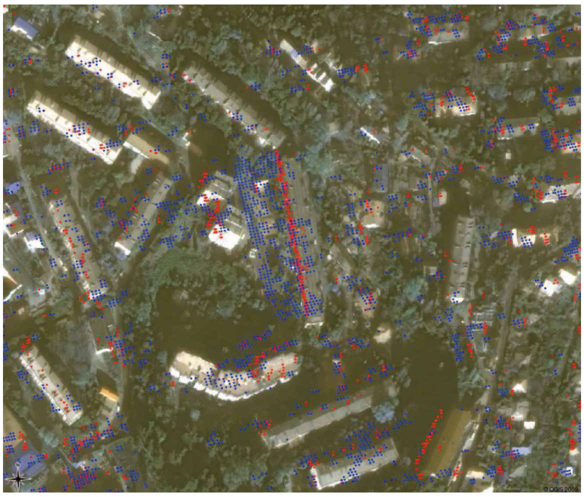
Figure 3: PS precise position determination with PSP technique. Blue dots represent the points before the elevation correction, red points represent the one after correction.

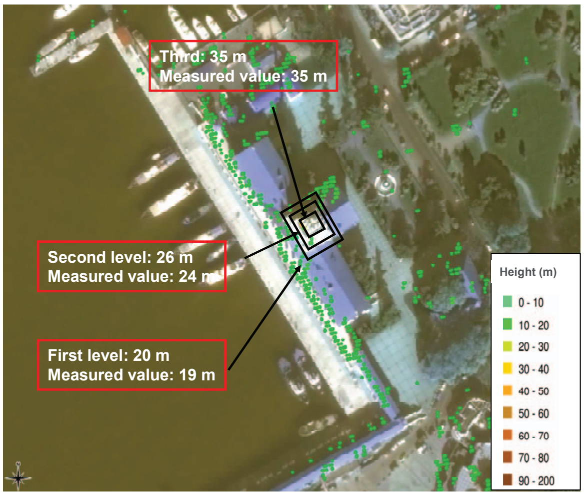

Figure 4: PSP analysis of 35 COSMO-SkyMed images acquired from October 2008 till October 2009 on the harbour area of Sochi, Russia. The coloured dots indicate the identified PS with their heights (over sea level).

identified by the red circle in the figure is crowned by a tower with three tiers and a tip, at 20, 26, 35 and 71 m on the ground level, respectively. This structure can be recognized in the results of the PSP analysis.

3. REFERENCES

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