DETECTING REGULAR PATTERNS IN URBAN PS SETS

Alexander Schunert, Uwe Soergel

Institute of Photogrammetry and GeoInformation, Leibniz Universität Hannover, Germany

ABSTRACT

The analysis of SAR data stacks via the Persistent Scatterer (PS) technique has shown to be very effective to estimate deformation and topography in urban settings. With the rise of new high-resolution space borne sensors very detailed information about the observed scene objects can be obtained. But the advance in resolution does not only provide an improvement of the results of known processing schemes, it also offers new possibilities for gathering information about the examined scene. In this paper, the possibility of finding and exploiting patterns of PS along facades in TerraSAR-X high resolution spotlight data is investigated. The idea is demonstrated for the example of finding horizontal lines of PS along a quite regular building facade in the city of Berlin.

1. Introduction

In recent years a new generation of space-born high resolution SAR sensors like COSMO-Skymed or TerraSAR-X have revolutionised the field of radar remote sensing. For instance, it became possible to estimate topography and deformation on a very dense grid exploiting stacks of SAR images. One way to do this is the Persistent Scatterer technique [1,2,6], which is based on the idea to just use strong and long term stable reflectors. In urban environments these scatterers coined as PS often form regular patterns along building facades, which is presumably due to the periodic appearance of building structures inducing strong reflections. In previous work [3,4,5] basic concepts for automatic detection of such patterns have been proposed. The results appear to be quite promising with respect to the quite simple methodology used. In this paper, we initially demonstrate the usefulness of the information contained in the spatial PS pattern employing height profiles over manually selected rows. Finally, the grouping results are compared with ground truth patterns obtained from a photogrammetric building model.

2. Persistent Scatterer

The PS processing scheme used in this work is mainly based on the ideas presented in [1,6]. It is essentially a two-step procedure. In a first step the atmosphere is estimated with the help of a sparse network of very stable points. After removal of the atmosphere the processing proceeds on a pixel by pixel basis employing a periodogram approach to estimate the height of the PS for each candidate pixel under investigation. The main outcome for every PS is its height and inter-image coherence, which describes the quality of the considered point.

Figure 1. Oblique view aerial image of the building under investigation

3. Data set and test area

We used a stack of 20 high resolution spotlight images of Berlin for our investigation. We focus on a specific building exhibiting a regular setup. An oblique view aerial image of this building is shown in Fig. 1. The main feature is obviously the matrix like arrangement of the windows, which leads to regular patterns of bright scatterers in the SAR image (Fig. 2). The colour indicates the height of PS identified in the displayed area exhibiting a sufficiently high inter-image coherence.

4. Height Profiles over horizontal Rows

In order to demonstrate the validity of the idea that the spatial pattern of PS carries useful information, height

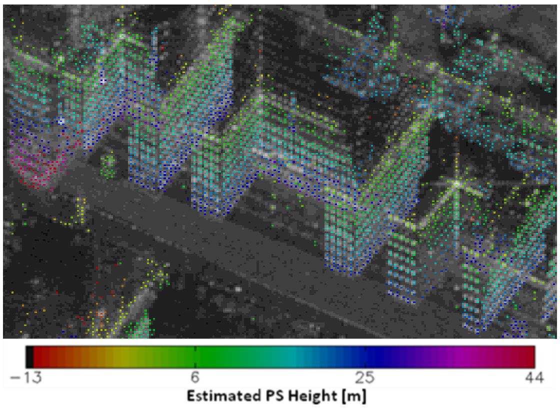

Figure 2. Mean amplitude image of the building under investigation overlaid with the PS identified for Grouping

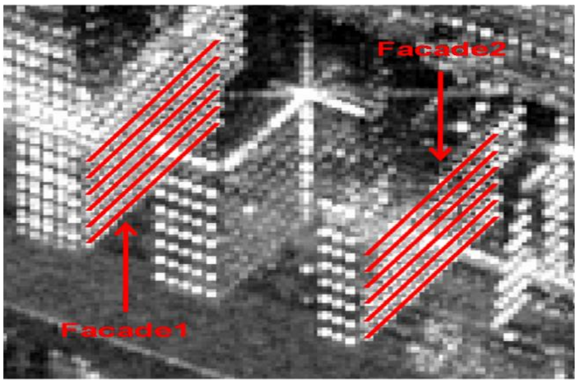

Figure 3. Manually selected profiles overlaid to the SAR amplitude image
profiles over manually selected rows of PS are

examined. The locations of the profiles are displayed in Fig. 3. For the sake of briefness only the profiles at Facade 2 are considered here. These are shown in Fig. 4. The red lines represent the ground truth heights of the rows of windows taken from a photogrammetric model of the building. The black lines indicate the estimated PS heights. At first glance three PS obviously do not fit well. They belong to other building structures and are mapped to the group's location by layover. The first one at a height of approximately 22 meters represents a PS located at the top of another facade. The other two ones are induced by PS located on the double bounce line of another facade (note that the height bias has corrected by matching the corner reflector height to the ground level). This demonstrates that the height has to be used in the grouping process to filter out PS located at a completely different part of the facade.
Another conspicuousness is the offset between the estimated PS heights and the ground truth lines for the upper part of the facade. We have found this behaviour on all parts of the building and we believe that it is some residual scaling error in our PS processing.

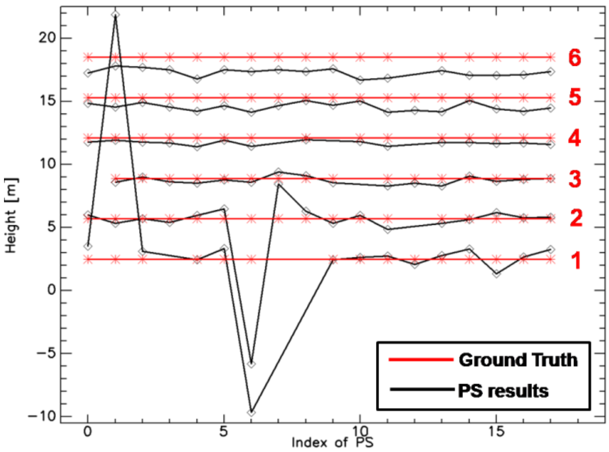

Figure. 4. Height profiles for the lines located at Facade2

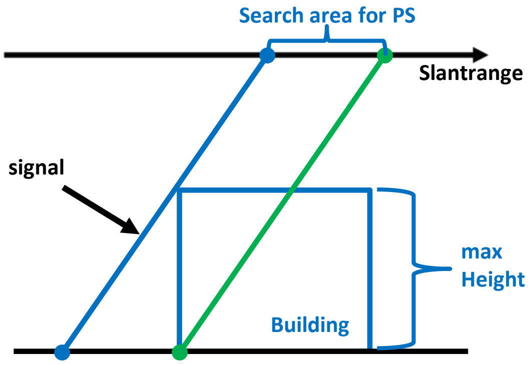

Figure 5. Geometric configuration for the pre-selection of PS based on a simple building model

Besides the blunders and the obvious bias, the lines exhibit a sufficiently constant height. The standard deviation is about 0.5 metre. If one considers a scatterer with a SNR of 20dB and a stack configuration like the one used here, the CRLB for the height estimate would be something around 0.1 metre, using the high SNR approximation stated in [7,8].

5. Grouping

The search for patterns in the PS set is implemented in a classical bottom-up and greedy fashion. The target is to aggregate PS, which most likely form horizontal lines along the investigated building facade.
In a first step primitive object are chosen from the set of identified PS via non maximum suppression, i.e. the PS with the highest inter image coherence in a local neighbourhood is selected. Subsequently horizontal lines are assembled from this set of base primitives. To keep the number of possible combinations small, we introduce a simple geo-referenced building model consisting of the building outline polygon and its maximum height.

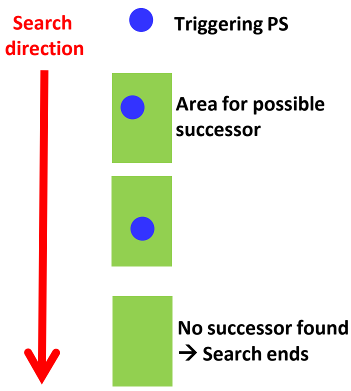

Figure 6. Schematic depiction of the line assembly

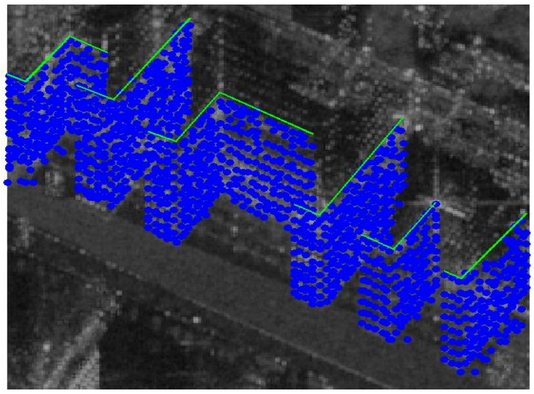

Figure 7. Used building outlines and selected base primitives.

This model determines the search direction and enables us to filter out PS apart from the investigated facade. All PS outside a region defined by the part of the building outline facing to the sensor and the maximum building height are rejected. The geometric setting for that is shown in Fig. 5.

The main grouping step is then carried out along the direction defined by the building outline. Fig. 6 gives an overview of the procedure. First a triggering PS (i.e., a PS to start with) located in the examined row is selected. Then a search area for its successor is defined by considering the expected frequency of the pattern of interest. In order to cope with digitalisation effects, the search area is also extended in the direction orthogonal to the row under survey. If a successor is found in the search area, its height is compared to the triggering PS and only added to the group if the difference is below a threshold. This is done to cope with the aforementioned layover problem. If the PS is added to the group, a new search area is defined and the described procedure is repeated. The process terminates once no successor is found.

To explore all possible alternatives admissible with respect to the algorithms settings, every PS is being tested as triggering PS once. In case a PS is contained in several groups of different spatial frequencies, just the line containing the most PS is kept. A more detailed description and discussion about the grouping procedure can be found in [3].

The PS selected as base primitives after rejection of non building PS together with the used building outlines is shown in Fig. 7. A result of the Grouping is shown in Fig. 8. The groups are marked by lines connecting the selected PS. Colour indicates the mean height of the group. Comparing Fig. 7 and Fig. 8 it is evident, that the result lacks completeness. One reason for that is definitely the inability of our grouping scheme to cope with missing points, which makes the assembly of the line stop at gaps. Another problem, which is the main one in the author's opinion, is the selection of base primitives. Considering the distribution of the PS (after non-maximum suppression) at the facade in the lower left corner of Fig. 8, the pattern is not as regular as it should be in view of the amplitude data.

6. Comparison with Ground Truth

In order to evaluate the grouping results shown in Fig. 8 ground truth has been generated from a photogrammetric model of the investigated building.

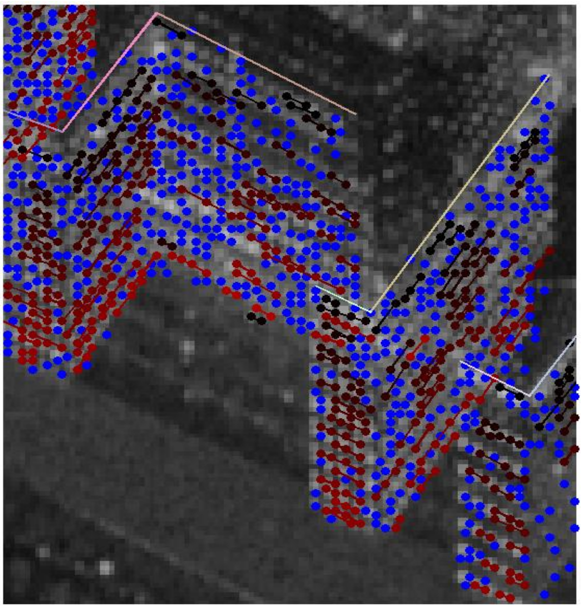

Figure 8. Result of the grouping procedure. The colour indicates the mean height of the group.

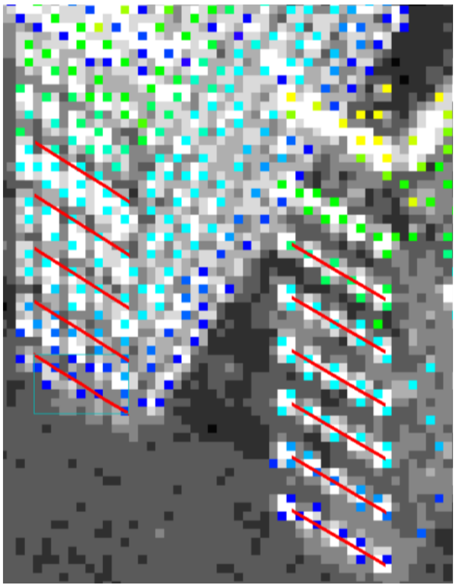

Figure 9. Window coordinates projected to the SAR image geometry together with the PS used as base primitives for grouping.

We hypothesise, that every window induces exactly one bright scatterer caused by the trihedral at one corner of the window sill. To compare the ground truth, which is given in map coordinates, with our grouping results, we projected the window positions (to be more specific the lower left corner of the window in our case) to the SAR image geometry. The result of this is displayed in Fig. 9. The red lines mark the positions of the horizontal lines of windows. The coloured pixels indicate the height of PS left after the non-maximum suppression has been carried out. To remove a residual shift between the lines and the SAR data, which is due to inaccuracies in the radarcoding procedure, a tie point located at the right facade has been used. For the case of this facade, the lines match the amplitude pattern quite well. However, many PS used as base primitives for the grouping, are not located on one of the lines. Furthermore, some bright spots extending over several pixels host two or even three base primitives, which are not located in its centre. This leads to the conclusion that the non-maximum suppression applied to select the most likely PS position is too coarse for our purpose. Since we assume the highest coherence in the centre of a bright spot, which doesn't have to be located in the middle of a grid cell (the SAR data is not oversampled), we will interpolate the most likely PS position in future work.

The situation at the left facade is quite different. While ground truth and amplitude information seem to be aligned at the right facade, the lines at the left facade are at the edge of the bright horizontal structures. It is also noticeable that the rows are much more extended in range direction. In order to determine the possible reason further ground truth was collected in-situ in form of terrestrial photographs. Close-ups of the windows installed in both facades are shown in Fig. 10. While the windows corresponding to the right facade (Fig. 10 (b)) are very plain, the windows build in to the left facade (Fig. 10 (a)) exhibit a vertical structure of unknown material dividing the window in two parts. Furthermore, a horizontal bar close to the windowsill is visible. This setup may lead to different scattering mechanisms mixing up in the visible pattern.

(a) (b)

Figure 10. Close-Ups of the windows the left (a) and the right (b) facade.

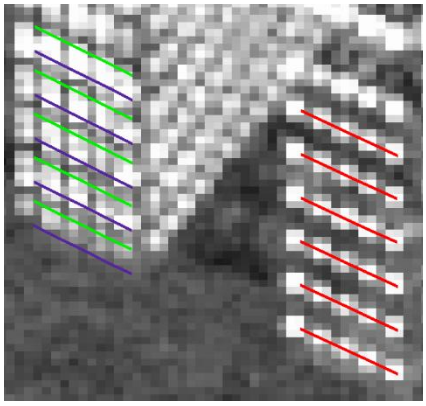

Figure 11. Radarcoded lines. Green and purple mark the lower and upper margin of the windows at the left facade respectively.

To investigate this, the upper left corners of the windows have been added to the ground truth. The result is displayed in Fig. 11. The newly added positions are marked in purple. It is visible that the bright areas seem to be confined between the upper and the lower margin of the windows (i.e. between the purple and green lines).

If the assumption of having two or more scattering mechanisms in a usual setting at facade structures turns out to be true, it would be necessary to identify the scattering mechanisms from the data. This would prevent us from forming groups of PS having different physical nature.

7. Conclusion

We demonstrated the usefulness of the spatial pattern formed by PS along facades in an urban setting and presented a simple algorithm to automatically detect groups. The results are promising, but still lack completeness, which is presumably due to the suboptimal selection of base primitives. Another interesting insight is the possibility that several scattering mechanisms may mix up in a pattern. All of this suggests to have a closer look at the selection of base primitives to firstly get the most likely PS position and to distinguish groups of PS having different physical nature from one another.

8. Acknowledgements

We gratefully acknowledge Dr.-Ing. Manfred Wiggenhagen for being of great help in the calculation of the photogrammetric building model.

[1] A. Ferretti, C. Prati, F. Rocca, "Nonlinear Subsidance Rate Estimation Using Permanent Scatterers in Differential SAR Interferometry", IEEE Trans. Geosci. Remote Sens. , Vol. 38, No. 5, 2000, pp. 2202-2212

[2] A. Hooper, “Persistent scatterer radar interferometry for crustal deformation studies and modeling of volcanic Deformations“, Dissertation, Standford University, 2006

[3] A. Schunert, E. Michaelsen, U. Soergel, “Perceptual Grouping for Persistent Scatterers in urban high-resolution SAR images“, IGARSS 2011, proceedings on CD, 2011

[4] E. Michaelsen, U. Soergel, A. Schunert, L. Dotorski, K. Jaeger, “Perceptual grouping for building recognition from satellite SAR image stacks“, Pattern Recognition in Remote Sensing (PRRS), 2010 IAPR Workshop on, pp. 1-4

[5] E. Michaelsen, A. Schunert, U. Soergel, “Utilizing phase for the grouping of PS in urban high-resolution in-SAR-images“, Urban Remote Sensing Event (JURSE), 2011 Joint, pp. 189-192

[6] G. Liu, S. M. Buckley, X. Ding, Q. Cheng, X. Luo, “Estimating Spatiotemporal Ground Deformation With Improved Permanent/Scatterer Radar Interferometry”, IEEE Trans. Geosci. Remote Sens., 2009, Vol. 47, No. 8, pp. 2762-2772

[7] R. Bamler, M. Eineder, N. Adam, X. Zhu and S. Gernhardt “Interferometric potential of high resolution spaceborne SAR“, Photogramm. Fernerkundung Geoinf., vol. 2009, no. 5, pp. 407-419, Nov 2009.

[8] X. Zhu, R. Bamler, “Tomographic SAR Inversion by L1-Norm Regularization - The compressive Sensing Approach“, IEEE Trans. Geosci. Remote Sens., Vol. 48, No. 10, 2010, pp. 3839-3846