Point Density Reduction in Persistent Scatterer Interferometry

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Abstract

Persistent Scatterer Interferometry (PSI) is widely used to determine ground deformation rates and histories. The data sets processed are increasing in size due to larger areas considered, higher resolution, and higher point densities. Working with lists of several million points and related networks reduces the computational efficiency. In this paper a method to adaptively reduce the size of the point list is presented. Considering the local point density and a point quality measure points are removed such that the density is significantly reduced in areas of very high density while maintaining the available density in areas of lower density. The main PSI processing is then done for the reduced point list. Later on the result obtained for the reduced list is expanded to the full point list. In several cases this methodology improves the processing efficiency significantly.

1 Introduction

Persistent Scatterer Interferometry (PSI) is widely used to determine ground deformation rates and histories [1] based on stacks of SAR data acquired in repeat orbits. In recent years the data sets considered have increased in size dramatically. Full 100km x 100km frames as well as high resolution TerraSAR-X and Cosmo-Skymed stacks may lead to point candidate lists of several million points.
Depending on the specific implementation of the PSI working with very large point lists can significantly increase the computation time. Here we consider the implementation of Gamma Remote Sensing [2-5] which is also available to the users of the GAMMA Interferometric Point Target Analysis (IPTA) software. Early on in the processing, a point candidate list is determined. Further interferometric processing is only done for these candidate points which reduces the file sizes and computational efforts. Nevertheless, some operations tend to get quite slow for large point lists. Furthermore, the approach is iterative in that many operations need to be conducted several times. The operator needs to check intermediate results, so that the processing cannot be done autonomously in the background. One possible solution to this problem is to reduce the size of the candidate point list considered. For steps as the estimation of residual orbital trends or atmospheric path delays considering only smaller sub-sections of the whole area of interest results in lower quality and possible misfit at the interface between patches. Therefore, maintaining the spatial coverage but reducing the point density might be a better solution.

2 Objective

The objective of our development was to reduce the size of a candidate point list such that overall good spatial coverage is maintained. Furthermore, preferably points of lower quality are removed.

3 Point density

An important parameter in our approach is the point density. We define the point density as the number of pixels per surface area. To estimate the point density for a specific location we count all points within a certain radius of this location and divide it by the circular area considered. The point density estimates depend on the radius selected. Spatially, the point density varies significantly for a typical area processed which includes urban as well as rural areas.
In the point density reduction methodology presented the point density is one important parameter considered. The point density may also serve to characterize PSI results.

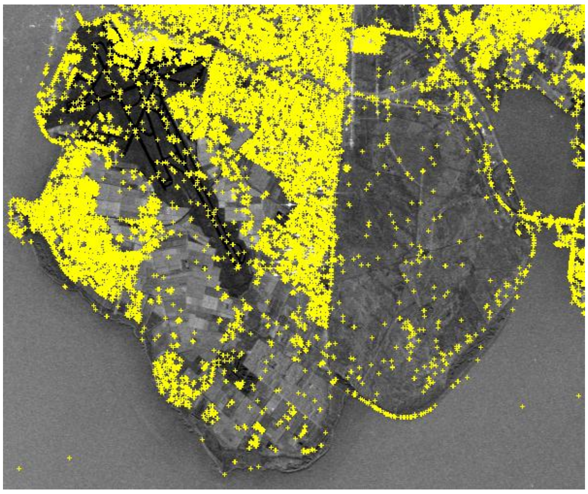
4 Adaptive reduction of point density

4.1 Strategy

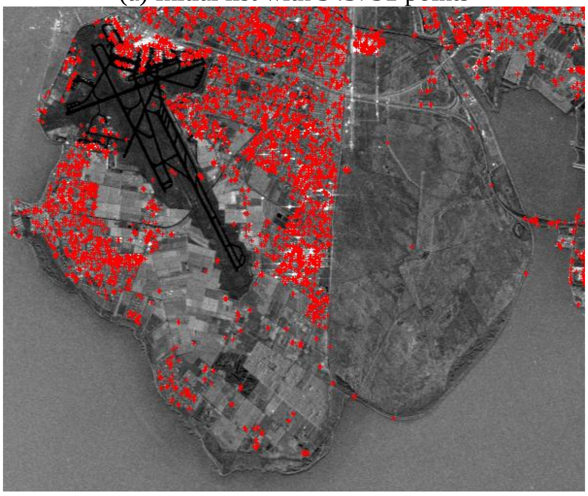
From a given point candidate list, points are removed based on the local point density and a point quality measure. The strategy is to reduce high point densities to an indicated maximum value. In areas with point densities below the chosen threshold no points are removed. For areas where points are to be removed the decision on which points are removed considers the point quality measure provided such that the lowest quality points are removed.

4.2 Example

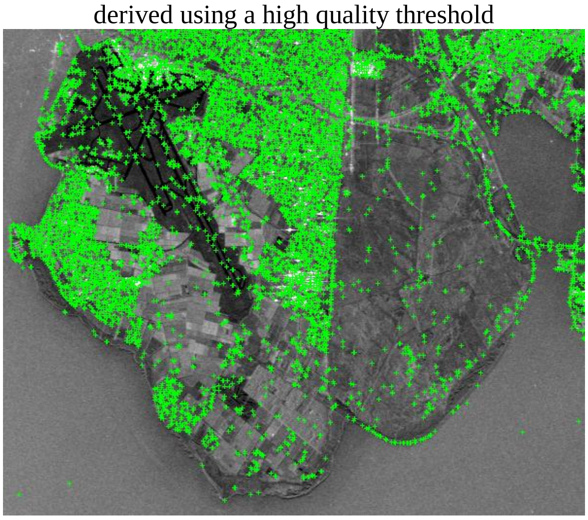
As a first example we consider an ERS stack over Copenhagen and the surrounding area (30km x 32km. Based on the spectral diversity criteria an initial point candidate list of 343751 points is derived. Figure 1a shows a 12km x 10km subsection which includes the Copenhagen airport area. While very high point densities are found over the fully urbanized sections the point density is much lower for vegetated areas and the sea. Using a higher quality threshold can be used to reduce the size of the point list. A major disadvantage of this type of reduction is that many points are lost in the parts with already low densities which further reduces the spatial coverage in these areas. Apart from a poor sampling of the deformation pattern this is problematic for the reliable estimation of parameters as the atmospheric path delay.
A better approach is to reduce the point density as we proposed. Starting from the initial point candidate list of 343751 points and the related spectral diversity quality measure available for each point, we reduce the point density within a circular area with a radius of 50m to a single point. As shown in Figure 1c this reduces the point density in areas of high point density while leaving the point list in areas of lower point density unchanged. This list is clearly better suited for the PSI processing than the list shown in 1b.



(a) Initial list with 343751 points



(b) Alternative list of about 90'000 points derived using a high quality threshold



(c) Point density reduced list of about 90'000 points

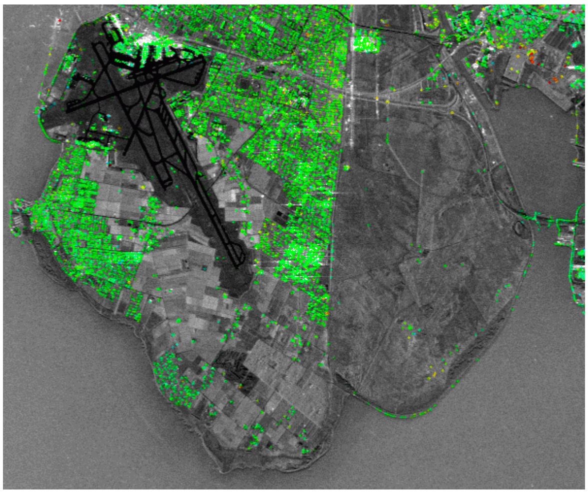
Figure 1 Point candidates for ERS PSI processing over Copenhagen airport section. The list shown in (a) is about 4 times larger than the two other lists. For (b) the list size reduction results in a poor spatial coverage for the mainly vegetated areas. The adaptively reduced point list is shown in (c). It is of similar size as the list in (b) but without reduction of the spatial sampling in the vegetated areas.

5 Using adaptive point density reduction in a PSI processing

For Copenhagen a PSI processing was conducted using 60 ERS scenes between 1992 and 2000. Based on spectral diversity and power variability criteria [2,3] an initial candidate point list of about 900’000 points was determined. Using the adaptive point density reduction approach a reduced size list of about 200’000 candidate points was then derived. For about 150’000 of these points an average deformation rate could be determined. This result is shown in Figure 2 for the same section as used for Figure 1.

After the derivation of the result for the reduced point list the atmospheric phase delays, were interpolated to the much larger initial point list. Furthermore, the refined baselines of the initial PSI processing were used. Without too much additional effort point height corrections, deformation rates, and small corrections to the atmospheric path delay could be derived for about 420’000 points, including the 150’000 points of the initial solution. To see where the additional points are located we show the initial and the final solutions for a small 4.0km x 2.6km section. As expected, the additional points are mainly in the areas with intermediate to high point densities (Figure 3).

Adding this “expansion step” after the derivation of a PSI solution for the reduced size candidate point list ensures that no available points of reasonable quality are lost from the final solution. Working initially with the reduced density point list makes the PSI processing more efficient.



-5 -2.5 0 2.5 5

LOS displacement rate in mm/year

Figure 2 Average displacement rate derived for reduced size point candidate list.

(a) initial solution based on reduced size list

(b) final solution after “expansion” to large list

-5 -2.5 0 2.5 5

LOS displacement rate in mm/year

Figure 3 Average displacement rates of the initial solution derived for the reduced size point candidate list (a) and the a much larger list. Additional values are mainly found in areas of high point densities.

6 Discussion

The example presented in sections 4 and 5 demonstrates that the main objective – reducing the point candidate list size without affecting the spatial coverage – could be met. Thanks to the expansion step this did not affect the quality since it was possible to increase the point density again once important parameters such as the atmospheric path delay were estimated.

This example also shows that there are limits to the possible spatial coverage. In the predominantly vegetated area with low point densities, many points of the reduced size candidate list were lost. Setting the initial quality threshold used to determine this list to a lower value results in more points but also in many more points that are not well suited. Having a dominance of low quality points tends to make the PSI processing less robust. Therefore arbitrarily including many points in vegetated areas is of little use – it is necessary that many of the points are reasonably suited to find a consistent solution.

7 Conclusions

For the PSI processing of large areas or when using stacks of high resolution SAR data large candidate point lists make the processing time intensive. Examining the location of the point candidates showed that point densities are often very high in urban areas but low in non-urban areas. Adaptively reducing the point density in urban areas can be used to reduce the overall candidate list size while still maintaining a good spatial coverage. A simple methodology to do this based on the point density and a point quality measure was presented and successfully applied.

In the examples studied, the point list sizes could typically be reduced by about a quarter of the initial without significant loss of connectivity of the point network. This resulted in a significant increase of the efficiency of the PSI processing. Based on the PSI results for the reduced size point list it was possible to derive a result for the initial list. Interpolating the spatial low-frequency components of the solution to cover all the points in the initial point list is an important step in this expansion of the result.

References

[1] ESA GSE Project Terrafirma, Pan-European Ground-motion Hazard Information Service, http://www.terrafirma.eu.com, 2011.

[2] Werner C., U. Wegmüller, T. Strozzi, and A. Wiesmann, “Interferometric point target analysis for deformation mapping”, Procs. IGARSS 2003, Toulouse, France, 21-25 July 2003.

[3] Wegmüller U., C. Werner, T. Strozzi, and A. Wiesmann, “Multi-temporal interferometric point target analysis”, in: Analysis of Multi-temporal remote sensing images, Smits and Bruzzone (ed.), Series in Remote Sensing, Vol. 3, World Scientific (ISBN 981-238-915-61), pp. 136-144, 2004.

[4] Strozzi T., P. Teatini and L. Tosi, TerraSAR-X reveals the impact of the mobile barrier works on Venice coastland stability, Remote Sensing of Environment, 113: 2682-2688, doi:10.1016/j.rse.2009.08.001, 2009.

[5] Wegmüller U., D. Walter, V. Spreckels, and C. Werner, "Non-uniform ground motion monitoring with TerraSAR-X persistent scatterer interferometry," IEEE Trans. Geosci. Remote Sensing, Vol. 48, 2, pp. 895-904, 2010.

Acknowledgement

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