FILTERING AND SEGMENTATION OF POLARIMETRIC SAR IMAGES WITH BINARY PARTITION TREES

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1. INTRODUCTION

SAR Polarimetry (PolSAR) has demonstrated, specially during the last decade, its significance for the analysis and the characterization of the Earth surface, as well as for the quantitative retrieval of biophysical and geophysical parameters. A set of complex radar scattered echoes are coherently processed in order to achieve high spatial resolution. As a consequence of this coherent processing and the fact that each resolution cell is a combination of a certain number of elementary echoes, the received signal is affected by a speckle term. Despite speckle is determined by the scattering process itself, its complexity makes necessary to consider it from a stochastic point of view and then, to assume the speckle term as a noise term. The speckle is a handicap in SAR imagery processing and information extraction and consequently some speckle filtering process is needed.

SAR and PolSAR data are non stationary as they reflect the complexity of the environment. Assuming that all the stochastic processes involved in the filtering process are ergodic, PolSAR filters must adapt to this non stationarity. Most recent state-of-the-art filtering techniques [1][2] are based on this approach, tending to define a different homogeneity neighborhoods for each image pixel. In this paper, we propose to tackle this issue by relying on a region-based multi-scale representation of the image by means of a Binary Partition Tree (BPT) and to perform filtering or segmentation tasks directly by pruning the BPT.

2. BINARY PARTITION TREE

The Binary Partition Tree (BPT) was introduced in [3] as a region-based multi-scale image representation. The BPT contains all the information about image structure at different detail levels in a tree where each node represents a region of the image. The hierarchical edges within the tree represent fusion relations over nodes. Leaf nodes of the tree are the original image pixels and the root node corresponds to a region that covers the whole image. Then, each region of the image can be expressed as the fusion of two smaller regions and can also be part of another bigger region. Between the leaves and the root nodes of the tree there are many different detail levels. This multi-scale structure contains a lot of information about the image structure and may be used for different applications.

As stated in [3], a tree pruning process corresponds to a segmentation over the image. For filtering applications it can be useful to average the information of large homogeneous regions while maintaining small details. The proposed BPT structure can be employed to obtain image regions with different sizes due to its multi-scale nature. With an homogeneity based tree pruning process, a image segmentation is obtained representing the biggest homogeneous regions. By applying the multi-look estimator within these regions a better estimation of the scattering process may be achieved without losing spatial resolution or spatial details. This technique conforms a nonlinear speckle filter capable of high noise reduction.

This approach differs from [1][2] in the way homogeneity is defined. The BPT pruning tries to identify homogeneous regions over the image, not homogeneous neighborhoods for each pixel, so it is a full region-based processing technique. Since one pixel can belong only to one region and it uses non-biased estimators over homogeneous regions, the BPT pruning does not introduce any bias or distortion in the image and full polarimetric information is completely preserved.

3. RESULTS

The BPT has been employed for filtering and segmentation applications using ESAR L-band data from DLR in Oberpfaffenhofen, Germany. The performances of the technique have been compared considering several dissimilarity criteria (between pair of regions) and also various pruning criteria have been analyzed. It has been compared with some of the state-of-the-art speckle filters, such as IDAN [2] and also with the standard Boxcar multi-look filer, with size 9 by 9, for comparison purposes.

Fig. 1 shows the results for three small crops of the original image corresponding to a road area, an urban area and an agricultural area, respectively. Images correspond to the RGB Pauli decomposition where red corresponds to $\|S_{hh}-S_{vv}\|^2$, green to $2\|S_{hv}\|^2$ and blue to $\|S_{hh}+S_{vv}\|^2$. The Boxcar 9x9 filter can perform a good noise reduction but only over homogeneous regions and with an important loss of spatial resolution. This effect is more critical over an urban area, for instance. On the other hand the IDAN filter preserves spatial resolution but the noise reduction is much smaller. It also introduces some bias to the image which can be seen as a darkening over some regions. The BPT pruning can achieve a higher noise reduction as it is shown in the agricultural fields or forests, and also preserve spatial resolution corresponding to small buildings in urban area or road fences.

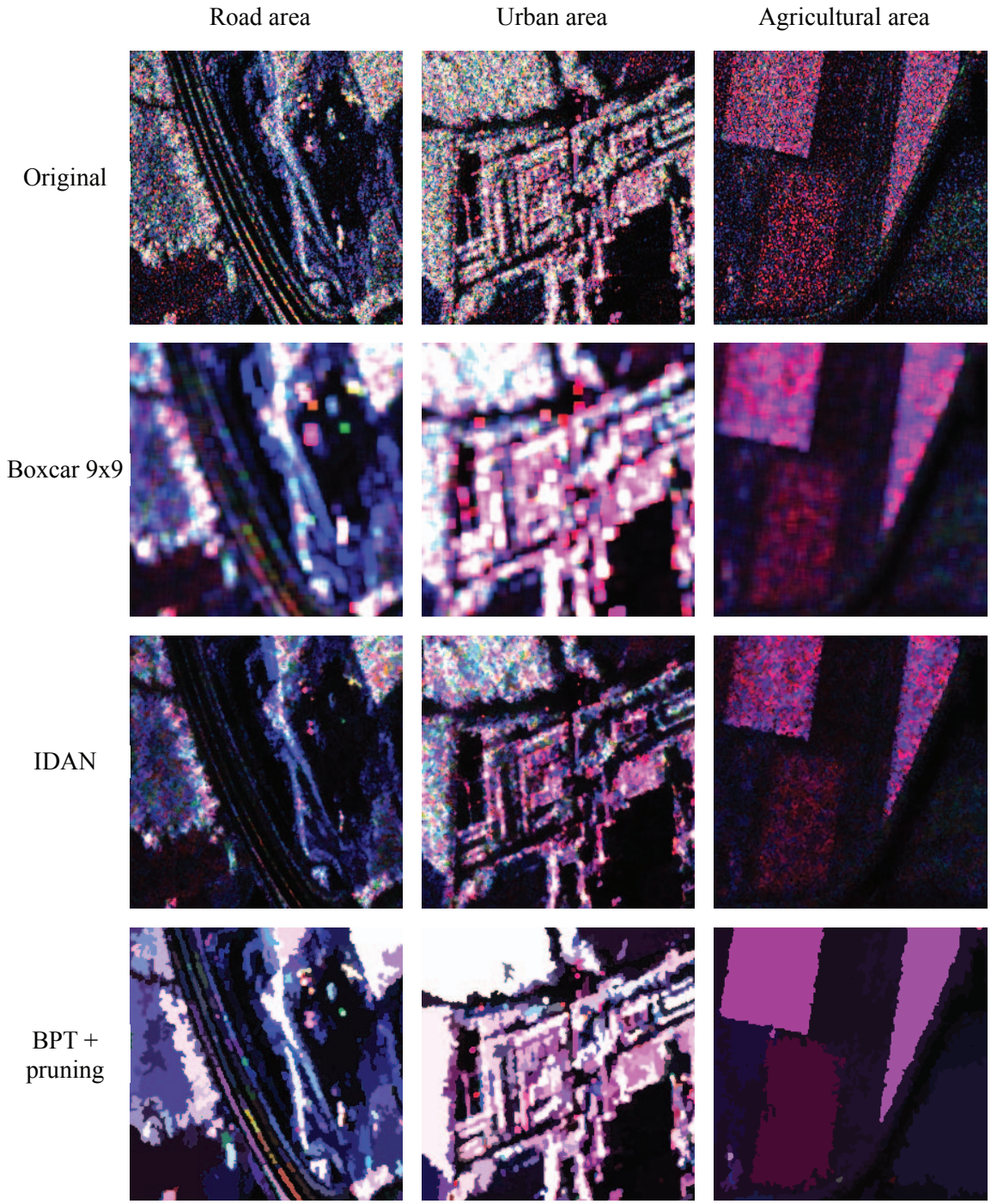

Fig. 1: Comparison of filtering techniques: Boxcar 9x9, IDAN and BPT pruning. Each image represents the Pauli decomposition (The coherence matrix components T_{22} T_{33} T_{11} are assigned to RGB, respectively).

4. CONCLUSIONS

The Binary Partition Tree is a region-based multi-scale image representation that may contain a lot of useful information. As demonstrated by the presented results, it can be satisfactorily employed for SAR and PolSAR data processing. In particular, this work proposes, analyses and validates its application for speckle filtering with an homogeneity based BPT pruning. This technique has demonstrated both a very good spatial resolution preservation and high noise reduction. It is important to highlight that as proposed, the algorithm preserves full polarimetric information and does not introduce any bias or distortion over the data.

This abstract shows the application of the proposed technique with data provided by the DLR's ESAR airborne sensor. The final version of the manuscript will present, evaluate and discuss various dissimilarity and homogeneity measures and it will also contain the application to RADARSAT-2 PolSAR data, as well as to simulated PolSAR data to make possible a quantitative evaluation of the technique performances.

5. REFERENCES

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