Study of Binary Partition Tree Pruning Techniques for Polarimetric SAR Images

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Abstract. This paper investigates several pruning techniques applied on Binary Partition Trees (BPTs) and their usefulness for low-level processing of PolSAR images. BPTs group pixels to form homogeneous regions, which are hierarchically structured by inclusion in a binary tree. They provide multiple resolutions of description and easy access to subsets of regions. Once constructed, BPTs can be used for a large number of applications. Many of these applications consist in populating the tree with a specific feature and in applying a graph-cut called pruning to extract a partition of the space. In this paper, different pruning examples involving the optimization of a global criterion are discussed and analyzed in the context of PolSAR images for segmentation. Initial experiments are also reported on the use of Minkowski norms in the definition of the optimization criterion.

Keywords: Binary Partition Tree · PolSAR · Graph-cut · Pruning · Speckle noise · Segmentation

1 Introduction

The application of Binary Partition Trees (BPTs) [18] for remote sensing applications such as Polarimetric SAR (PolSAR) [2] and hyperspectral images [20,21] is currently gaining interest. BPTs are hierarchical region-based representations in which pixels are grouped by similarity. Their construction is often based on an iterative region-merging algorithm: starting from an initial partition, the pair of most similar neighboring regions is iteratively merged until one region representing the entire image support is obtained. The BPT essentially stores the complete merging sequence in a binary tree structure. Once constructed, BPTs can be used for a large number of tasks including image filtering with connected operators, segmentation, object detection or classification [18,3]. Many of these tasks involve the extraction of a partition from the BPT through a graph cut.

In this paper, we focus on low level PolSAR image processing tasks. We study in particular the interest of a specific graph cut called pruning in this context.

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We discuss and evaluate various pruning techniques formulated as the search in the BPT of a partition optimizing a certain criterion. The criteria we analyze take into account the specific nature of PolSAR data and the presence of speckle noise resulting from the coherent integration of the electromagnetic waves. The main contributions of this paper compared to [2,3,17] is the proposal of new pruning strategies for PolSAR images as well as the objective evaluation of the resulting partitions thanks to a set of realistic simulated PolSAR images where the underlying ground truth is available [8].

The paper is organized as follows: Section 2 is a short introduction on PolSAR data. Section 3 discusses the BPT creation and its processing with graph cut. Four pruning criteria useful for segmentation of PolSAR images are presented in section 4 and evaluated in section 5. A preliminary study of the interest of Minkowski norms in the definition of the optimization criterion is presented in section 6. Finally, conclusions are reported in section 7.

2 PolSAR Data

Synthetic Aperture Radars (SAR) are active microwave imaging systems. They are becoming increasingly popular for Earth observation because they work independently of the day and night cycle and of weather conditions. A SAR system essentially transmits an electromagnetic wave and records its echo to localize targets. In order to achieve a high spatial resolution, narrow beamwidth or equivalently large antennas are necessary. SAR systems deal with this issue by making use of the relative motion between the sensor and the target. As the radar moves, it repeatedly illuminates the target with electromagnetic pulses. The echoes are coherently recorded and combined in a post-processing that synthesizes a very large array and creates a high resolution image. The speckle noise results from the coherent addition of the scattered electromagnetic waves and is considered as one of the main problems for the exploitation of SAR data.

In the early 90’s, multidimensional systems were developed. They provide complex SAR images \( [S_1, S_2, \ldots, S_m] \) by introducing some sort of diversity. An important example is Polarimetric SAR (PolSAR) [5,13] where the diversity is based on considering different polarization states for the transmitted and received electromagnetic waves. This makes SAR data sensitive to the target geometry, including vegetation, and to the dielectric properties of the target. For every resolution cell, a PolSAR system measures the scattering matrix:

\[
S = \begin{bmatrix}
S_{hh} & S_{hv} \\
S_{vh} & S_{vv}
\end{bmatrix}
\]

(1)

where \( h \) and \( v \) represent the horizontal and vertical polarization states and \( S_{pq} \) for \( p, q \in \{h, v\} \) denotes the complex SAR image where the reception (transmission) polarization states is \( p \) (\( q \)).

Since the dimensions of the resolution cell are normally larger that the wavelength of the electromagnetic wave, the scattered wave results from the coherent combination of many waves. This coherent addition process is known as the