Simple Man-made Object Classification Approach Using The Correlation Coefficient in Circular Polarization Basis

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1. Introduction

Wide area terrain monitoring or classification is one of the most important applications in Polarimetric Synthetic Aperture Radar (POLSAR) sensing. In particular, man-made object extraction is a subject of great interest. The power decomposition [1], [2] and the polarimetric correlation coefficient [3], [4] are the well-known useful target classification techniques. For complex urban area monitoring, however, it is sometimes difficult to distinguish the man-made objects as buildings or houses from other natural distributed ones, since the polarimetric scattering feature from the man-made objects is strongly dependent on the direction or orientation of their alignment. When the man-made objects are obliquely aligned to the radar illumination direction, the classification accuracy of the above mentioned techniques may become low, since the useful polarimetric indices for classifying the man-made objects (strong double-bounce scattering and large correlation between the circular polarized components) is no longer observed from the target areas.

Recently, an accuracy improvement of the classification for the obliquely aligned man-made objects has been reported by utilizing the modified correlation coefficient [5], [6]. The modified correlation coefficient is obtained by normalizing the conventional correlation coefficient in the circular polarization basis by that under the reflection symmetry condition. So it enhances the return from the non-reflection symmetry areas, in which there exist lots of the oblique man-made objects, and enables us to precisely detect or classify the oblique targets. On the other hand, by utilizing the modified coefficient only, one often encounters an alternative problem that the scattering contributions from the orthogonally aligned man-made objects are underestimated.

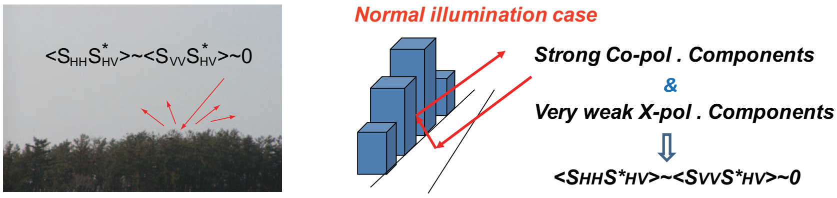
In this paper, we propose a simple man-made object classification algorithm based on the correlation coefficient approach, to accurately classify the man-made objects not only orthogonally but also obliquely aligned to the radar illumination direction. We here make use of both the conventional and modified correlation coefficients. *The total power* is utilized in the simple classification algorithm as an additional parameter for choosing the appropriate polarimetric index, *i.e. conventional correlation coefficient or modified one?* It is verified from the image analysis for L-band Pi-SAR data that the present classification algorithm based on the combination between the correlation coefficients and the total power leads us precisely classify the man-made objects, regardless of the direction of their alignment.

2. Polarimetric correlation coefficient

The correlation coefficient for the co-polarized components in LR circular polarization (LR) basis is defined as

$$\gamma_{LL-RR} = \frac{\langle S_{LL} S_{RR}^* \rangle}{\sqrt{\langle |S_{LL}|^2 \rangle \langle |S_{RR}|^2 \rangle}} = \frac{\langle 4|c|^2 - |a-b|^2 \rangle - j4\Re e\langle c^*(a-b) \rangle}{\sqrt{\langle |a-b+j2c|^2 \rangle \langle |a-b-j2c|^2 \rangle}}, \tag{1}$$

where a, b, c are the scattering matrix components for HV linear polarization basis as $a = S_{HH}, b = S_{VV}, c = S_{HV}$. Also, $*$ and $\langle\cdot\rangle$ denote complex conjugation and ensemble average (multilook) processing, respectively. Under the well-known reflection symmetry condition $\langle ac^* \rangle \sim \langle bc^* \rangle \sim 0$, the correlation



(a) (b)

Figure 1: Two types of reflection symmetry conditions

coefficient can be expressed as

$$\gamma_{LL-RR}(0) = \frac{\langle 4|c|^2 - |a-b|^2 \rangle}{\langle 4|c|^2 + |a-b|^2 \rangle}. \tag{2}$$

Now, according to Ref. [5], by normalizing Eq.(1) by Eq.(2), we can derive the modified correlation coefficient as

$$\gamma'_{LL-RR} = \frac{|\gamma_{LL-RR}|}{\gamma_{LL-RR}(0)}. \tag{3}$$

The value of Eq.(3) may become almost unity for the reflection symmetry condition (for natural distributed areas), and larger than unity for no reflection symmetry condition (for urban complex areas). Hence, in POLSAR image analysis, one can utilize γ'_{LL-RR} as a useful marker for classfying the man-made objects. This classification scheme using γ'_{LL-RR} may be effective when the objects are aligned obliquely to the radar illumination (range) direction.

3. The reflection symmetry for orthogonally aligned man-made objects

The reflection symmetry condition, $\langle ac^* \rangle \sim \langle bc^* \rangle \sim 0$, is generally held for natural distributed scatterers, as shown in Fig.1(a), However, similar polarimetric feature can also be observed in urban complex. As depicted in Fig.1(b), when the man-made objects are orthogonally aligned to the direction of the radar illumination, the strong co-polarized scattering components, which may produce the predominant double-bounce scattering, are observed, while the cross-polarized ones are hardly generated from the orthogonal structures. Resultantly, for urban areas including lots of the orthogonal man-made objects, the reflection symmetry condition may be satisfied, and γ'_{LL-RR} becomes almost unity as for natural vegetation areas.

4. Simple man-made target classification algorithm

In order to resolve the problem discussed in the above section, we shall propose a simple modification of the classification algorithm by utilizing the total received power TP. As shown in Fig.2, the present algorithm is quite simple. First, by applying the criterion $\gamma'_{LL-RR} < -1.2$, we extract the particular pixels having the reflection symmetry feature. Furthermore, in addition to $\gamma'_{LL-RR} < 1.2$, under the condition that TP is larger than -5dB, one can recognize the extracted pixels as those for the orthogonally alligned man-made objects, because the strong TP values are generated from local dihedral structures of the orthogonal scatterers. In the case with strong TP, we choose γ_{LL-RR} for more precise man-made object classification ("$2\gamma_{LL-RR}$" is actually utilized in the image analysis of Fig.3 (d)). Whereas, natural distributed scatterers may show small TP values, so that γ'_{LL-RR} is chosen as the classification index when $TP < -5$dB.

5. Results of the POLSAR image analysis

In this section, let us check the validity of the proposed simple man-made object classification algorithm of Fig.2. By utilizing the fully polarimetric L-band SAR data (Pi-SAR data) around Niigata University,

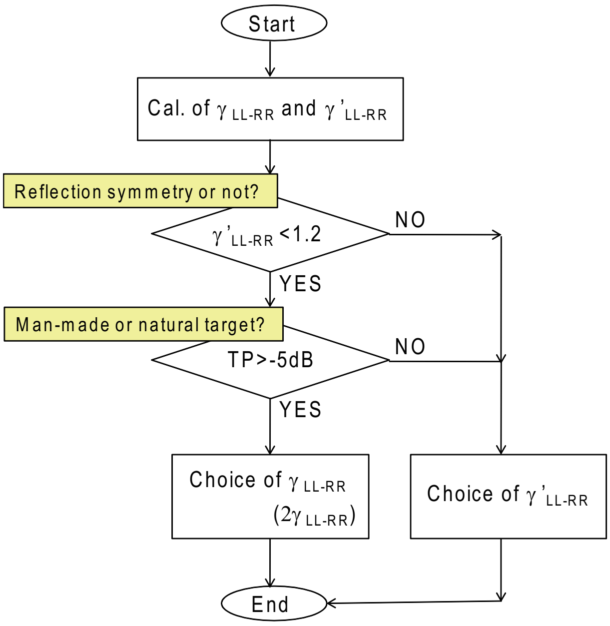


Figure 2: Simple man-made target classification algorithm

we carry out the POLSAR image analysis. The resolution and the averaging size for the images are 2.5 m by 2.5 m and 5 by 5 pixels, respectively.

Figure 3 (a) shows the color composite image obtained by the power decomposition scheme, where each color is coded as follows. Red color is painted for the double-bounce scattering P_d, green is for the volume scattering P_v, and blue is for the surface scattering P_s. The red color spots for P_d are caused by dihedral structures between the orthogonal man-made objects and ground surface, so one can easily classify the objects by extracting the red color pixels. The orthogonally aligned man-made objects can also be classified from the image obtained by the correlation coefficient γ_{LL-RR} in the circular polarization basis, as shown in Fig.3 (b). However, these polarimetric indices (Strong P_d and large γ_{LL-RR}) do not serve any clues for precisely classifying the man-made objects obliquely aligned to the range direction. For such oblique cases, one can verify from Fig.3 (c) that the modified correlation coefficient γ'_{LL-RR} is very practical, although it decreases the returns from the orthogonal man-made objects (See the yellow circle parts in Fig.3 (c)). The present simple algorithm in Fig.2 takes advantage of the good points of both γ_{LL-RR} and γ'_{LL-RR}. It can be verified from Fig.3 (d) that by applying the proposed algorithm, one can easily and accurately classify the man-made objects not only orthogonally but also obliquely aligned to the radar illumination direction.

In the future work, further modification of the proposed classification algorithm using γ_{LL-RR} and γ'_{LL-RR} will be carried out not only for man-made object classifcation but also for monitoring of water area change in wetland [7].

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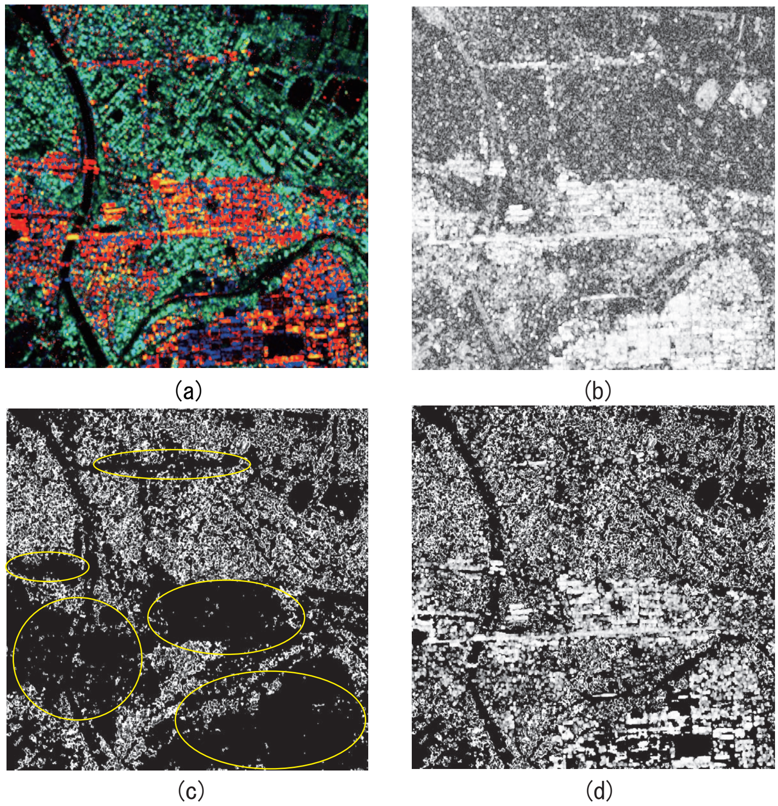

Figure 3: Results of POLSAR image analysis around Niigata University, Japan (L-band Pi-SAR data). (a) Color composite image (Red:P_d, Green:P_v, Blue:P_s) (b) Correlation coefficient γ_{LL-RR} in LR basis (c) Modified correlation coefficient γ'_{LL-RR} (d) Composite image of γ_{LL-RR} and γ'_{LL-RR} according to the present algorithm in Fig.2

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