BUILDING EXTRACTION USING POA FROM POLARIMETRIC SAR

Muneyoshi Kajimoto*[a] and Junichi Susaki[b]

[a]Graduate student, Department of Civil and Earth Resources Engineering, Kyoto University,
C1-1-209, Kyotodaigaku-katsura, Nishikyo-ku, Kyoto, 615-8540, Japan;
Tel: + 81-75-383-3302; E-mail: k.muneyoshi@ay7.ecs.kyoto-u.ac.jp

[b]Associate Professor, Department of Civil and Earth Resources Engineering, Kyoto University,
C1-1-206, Kyotodaigaku-katsura, Nishikyo-ku, Kyoto, 615-8540, Japan;
Tel: + 81-75-383-3300; E-mail: susaki.junichi.3r@kyoto-u.ac.jp

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ABSTRACT: A lot of studies on urban area extraction using with SAR have been conducted. In general, optical sensor is superior in land cover classification to SAR. The disadvantage of SAR in classification is that scattering intensity even in the same land cover is largely different. Then, POA (Polarization Orientation Angle) has been noteworthy that scattering intensity of SAR image is related to POA. If a vertical wall of a building is face to face with sensor, scattering intensity from this building is strong. As a wall rotates from that angle, scattering intensity becomes weak. Even in farmland, this tendency can be seen too. It was difficult to classify non-orthogonal buildings and orthogonal farmland through the conventional way. In this study, POA and four-component decomposition are used to extract urban area from polarimetric SAR. Four components consist of surface scattering, double-bounce scattering, volume scattering and helix scattering. Four components depend on POA. A method is to categorize each pixel into some groups on the basis of POA, and obtain training data of urban area and farmland in each group. In each group, pixels are classified according to the value of four components. The result obtained by using surface scattering or double-bounce scattering was unstable. Therefore, volume scattering is mainly used in this study. Volume scattering is effective in classifying urban area and farmland. Total Power (the sum of four components) is used to remove sea and bare ground. In order to verify the accuracy of urban area extraction, the result obtained by using with SAR and an image obtained by optical sensor were compared. A concrete plane such as a runway was classified correctly into non-building by using with SAR. In the area where buildings and bare ground are mixed, SAR is superior in urban area extraction to optical sensor.

1. INTRODUCTION

Land cover classification is one of the applications in satellite remote sensing. Land cover classification using SAR has been difficult because microwave emitted from SAR depends on the structure of a target more than land cover. Scattering intensity is greatly different even in urban area, if it is backscattered from different buildings whose vertical walls are aligned to different directions. Urban area includes so many buildings. Vertical walls of buildings do not always face toward the same direction. In the case that buildings are aligned with their walls face to face with sensor, intensity scattered from these buildings is strong. Otherwise, scattering intensity is weak. This relation makes land cover classification using only SAR difficult. POA (Polarization Orientation Angle) has been noteworthy because POA is useful for detecting the direction which the wall faces toward. In this study, we focus on extraction of urban area using POA from one temporal Polarimetric SAR image.

2. INDICES USED IN THIS STUDY

Polarimetric SAR data format consists of the complex scattering matrix given by

$$\mathrm{S} = \begin{pmatrix} S_{HH} & S_{HV} \\ S_{VH} & S_{VV} \end{pmatrix} = \begin{pmatrix} a & c \\ c & b \end{pmatrix}$$

assuming that S_{HV} and S_{VH} are equivalent. Furthermore, Coherency matrix expressed by

$$\mathrm{T} = \begin{pmatrix} T_{11} & T_{12} & T_{13} \\ T_{21} & T_{22} & T_{23} \\ T_{31} & T_{32} & T_{33} \end{pmatrix} = \frac{1}{2}\begin{pmatrix} |a+b|^2 & (a+b)(a-b)^* & 2(a+b)c^* \\ (a-b)(a+b)^* & |a-b|^2 & 2(a-b)c^* \\ 2c(a+b)^* & 2c(a-b)^* & 4|c|^2 \end{pmatrix}$$

2.1 POA (Polarization Orientation Angle) (Kimura, 2005)

POA represents the angle between azimuth angle (the direction sensor is moving to) and a vertical wall of buildings (Figure 1).

$$\theta = \frac{1}{4}\tan^{-1}\frac{2\mathrm{Re}(T_{23})}{T_{22} - T_{23}} \quad \left(-\frac{\pi}{4} \le \theta \le \frac{\pi}{4}\right)$$

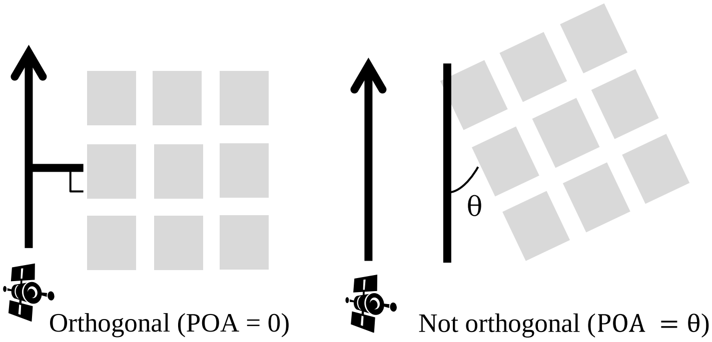


Figure 1. Relation between POA and alignment of buildings

2.2 Four-Component Decomposition (Yamaguchi, 2005)

Four-Component decomposition is the method to decompose an observed backscatter into four components. Four components consist of surface scattering (Ps), double bounce scattering (Pd), volume scattering (Pv), and helix scattering. Four components are calculated from Coherency matrix.

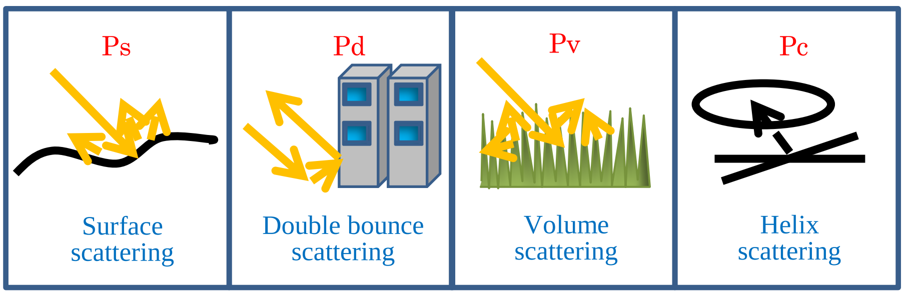


Figure 2. Four components

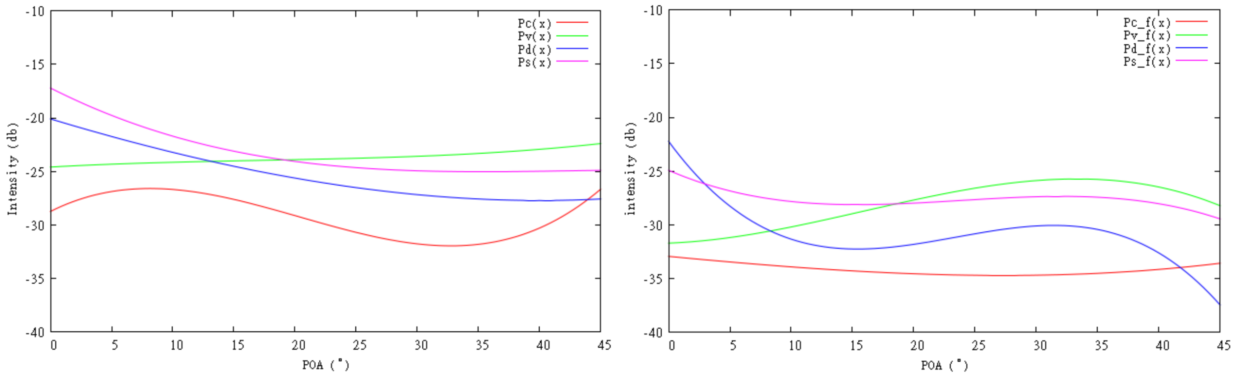
Coherency matrix after rotation (Yamaguchi, 2011) can be obtained by

$$\mathrm{T} = \begin{pmatrix} T_{11}(\theta) & T_{12}(\theta) & T_{13}(\theta) \\ T_{21}(\theta) & T_{22}(\theta) & T_{23}(\theta) \\ T_{31}(\theta) & T_{32}(\theta) & T_{33}(\theta) \end{pmatrix} = [R_p(\theta)][T][R_p(\theta)]^{\dagger}$$

$$[R_p(\theta)] = \begin{pmatrix} 1 & 0 & 0 \\ 0 & cos2\theta & sin2\theta \\ 0 & -sin2\theta & cos2\theta \end{pmatrix} : Rotation\ Matrix$$

3. METHODOLOGY

Figure 3 shows curves of scattering intensity of four components against POA. Four components depend on POA. Volume scattering becomes strong as POA increases. In contrast, surface scattering and double scattering become weak. In general, scattering intensity from urban area is stronger than that from farmland. However, scattering intensity between urban area and mountain area has little difference. In classifying urban area and mountain area, using the power of each component is not valid. Therefore, a method without using four components is needed. In this study, the process of urban area extraction consists of two steps. The first step is classification of urban area and farmland. The second one is classification of urban area and mountain area.



(a) (b)

Figure 3. POA vs. Four components (a) In urban area (b) In farmland
Pink: Ps, Blue: Pd, Green: Pv, Red: Pc

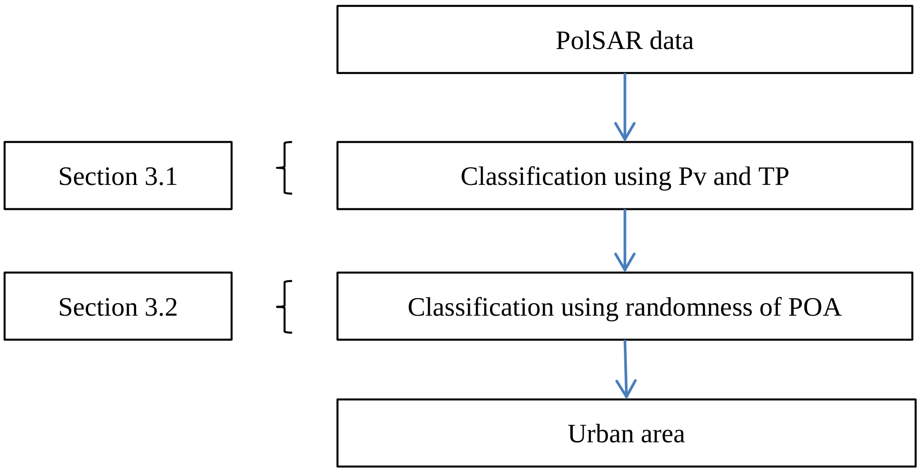
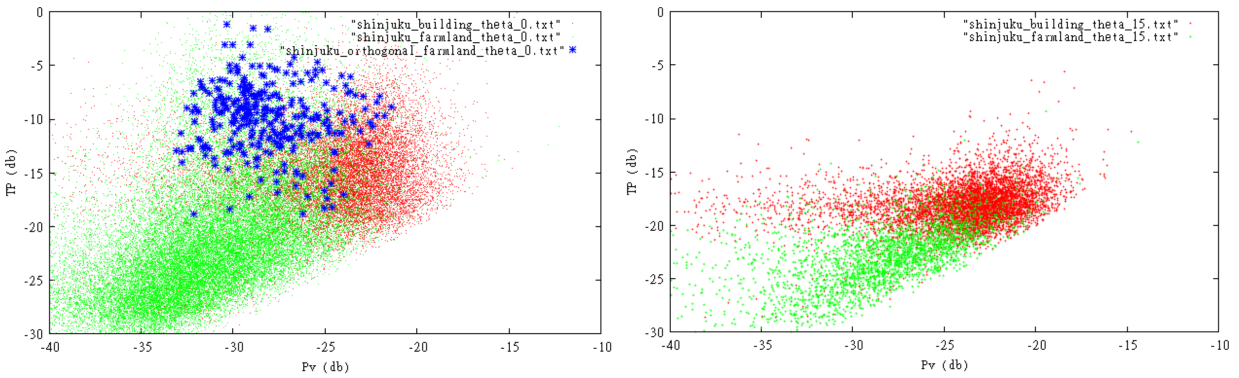


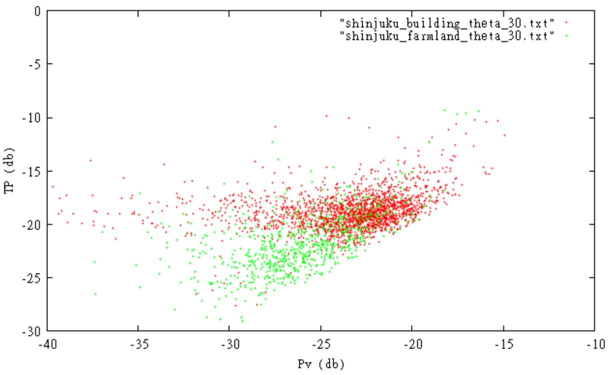
Figure 4. Flowchart of the process for urban area extraction

3.1 Classification of Urban Area and Farmland

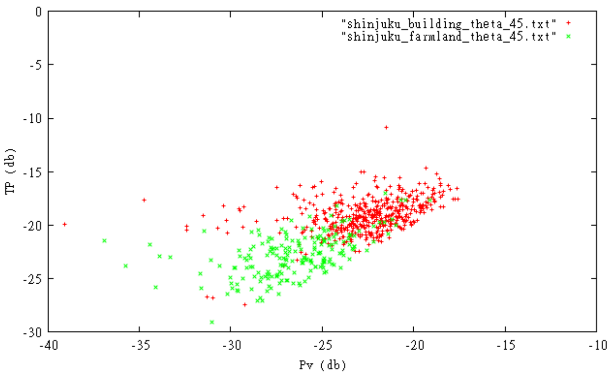
In farmland as well as in urban area, four components depend on POA. It is not effective to apply only one threshold to the whole image in classification of these two land covers. The method to get over this difficulty is the followings. Firstly, each pixel of SAR image is categorized into one of four groups on the basis of POA. Four groups consist of the first (POA = 0), the second (POA = 15), the third (POA = 30), and the fourth group (POA = 45). Each pixel is categorized into a group to which the absolute value of POA is the nearest. Secondly, a threshold is set to each category. By categorization, orthogonal urban area and orthogonal farmland can be compared. Non-orthogonal urban area and non-orthogonal farmland can be compared too. At this point, weak scatterers such as sea or bare ground are classified into a group of farmland.



(a) (b)



(c)



(d)

Figure 5. Distribution in urban area and farmland (in Tokyo) (a) POA = 0 (b) POA = 15 (c) POA = 30 (d) POA = 45
Red: Urban area, Green: Farmland, Blue: Orthogonal farmland

Figure 5 shows the distribution of intensity from urban area and farmland in each group. Total Power (TP) means the sum of four components. Volume scattering is the most effective in this section because variance of volume scattering is the smallest of the four components. Scattering intensity from orthogonal farmland is as strong as that from urban area. Orthogonal farmland is seen only in the first group.

3.2 Classification of Urban Area and Mountain Area

Distribution of urban area and that of mountain area are mostly overlapped as shown in Figure 6. These two land covers cannot be classified by setting the threshold of four components.

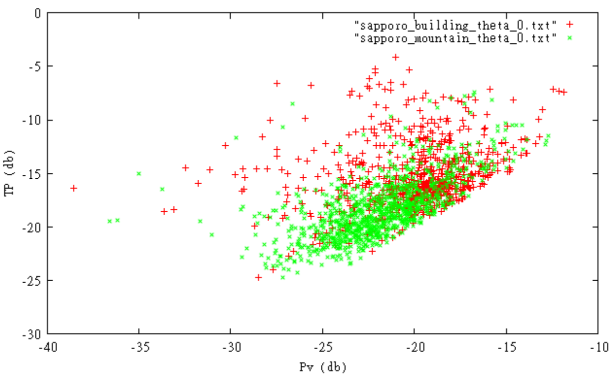


Figure 6. Distribution in urban area and mountain area (in Sapporo)
Red: Urban area, Green: Mountain area

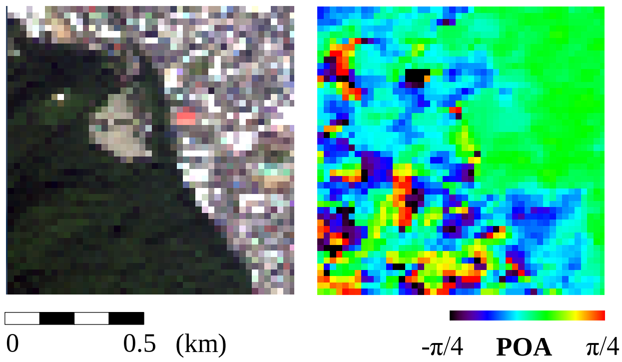


Figure 7. POA in urban area and mountain area

Difference of randomness of POA between urban area and mountain area is effective to classify these two land covers. In most urban areas, buildings are aligned to the same direction, and walls of those buildings tend to form a plane. In urban area, POA in the same city's section are almost equal. In contrast, mountain area is covered with trees or grass, and a plane like a wall of building cannot be seen. Consequently, POA is randomly different in mountain area (Figure 7). By focusing on this difference between urban area and mountain area, it is possible to classify these two land covers. A method is the followings.

1) Each pixel in an image is categorized into one of the five groups based on POA (Figure 8).
2) A window is prepared as the center of the window is located at a pixel in the image (Figure 9 (a)). For each pixel in the window, if the group labels of four (up and down, left and right) pixels are the same as the label of the reference pixel or as the label on both sides, the count goes up by one (Figure 9 (b)). If it is not the case, the count does not change (Figure 9 (c)).
3) The center of the window is reset to another pixel.
4) The operation of 2) and 3) are repeated until the center of a window is located at all pixels in the image.

It is expected that the count is large in urban area, but small in mountain area. In urban area, most pixels in the same section are categorized into the same group or a group on both sides. In mountain area, it is expected that pixels are randomly categorized.

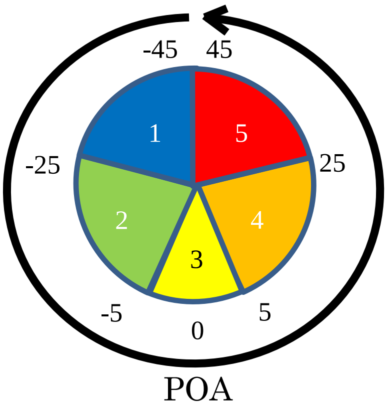


Figure 8. Group label

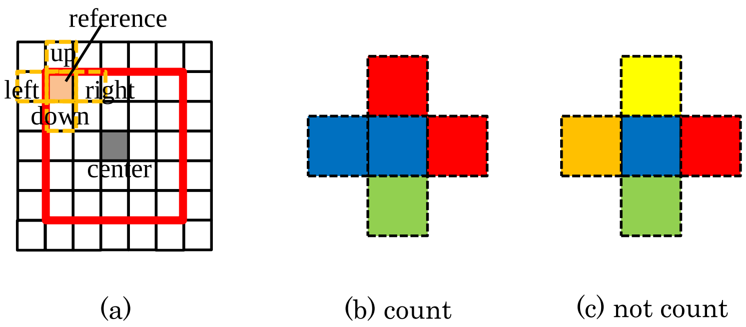


Figure 9. Process of 3.2 (a) Setting of window (Red square)
(b), (c) Examples (the colors used in (b) and (c) correspond to Figure 8

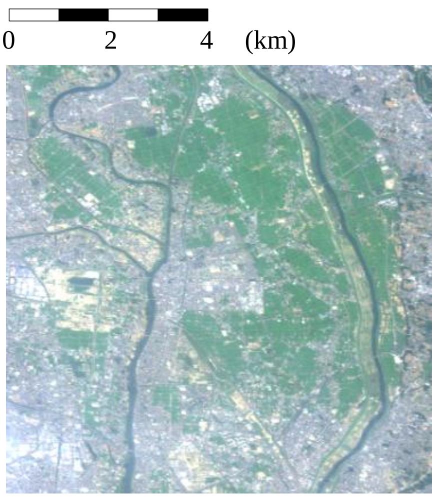
4. RESULT

4.1 Used Data

In this study, Level 1.1 data of ALOS/PALSAR were analyzed. The target areas are Tokyo (4.2) and Sapporo (4.3) in Japan. Tokyo area mainly includes urban area and farmland. Sapporo area mainly includes urban area, farmland, and mountain area. As verification, images of optical sensor, ALOS/AVNIR-2, were used too.

4.2 Result of Classification of Urban Area and Mountain Area

Figure 10 shows the result after classification of urban area and mountain area. The left image was obtained by AVNIR-2, and the right image is the result obtained by using with PALSAR. On the right image, white color means urban area, and black color means non-urban area. On the whole, most of urban area and farm land were classified correctly. By using SAR image, a concrete plane such as a runway was classified into non-urban area. In contrast, it is difficult to classify a runway into non-urban area by using with optical sensor. This is because the spectrum of a runway in optical image is equivalent to that of a building. Moreover, in the area where buildings and bare ground are mixed, extraction of urban area was possible by using with SAR.



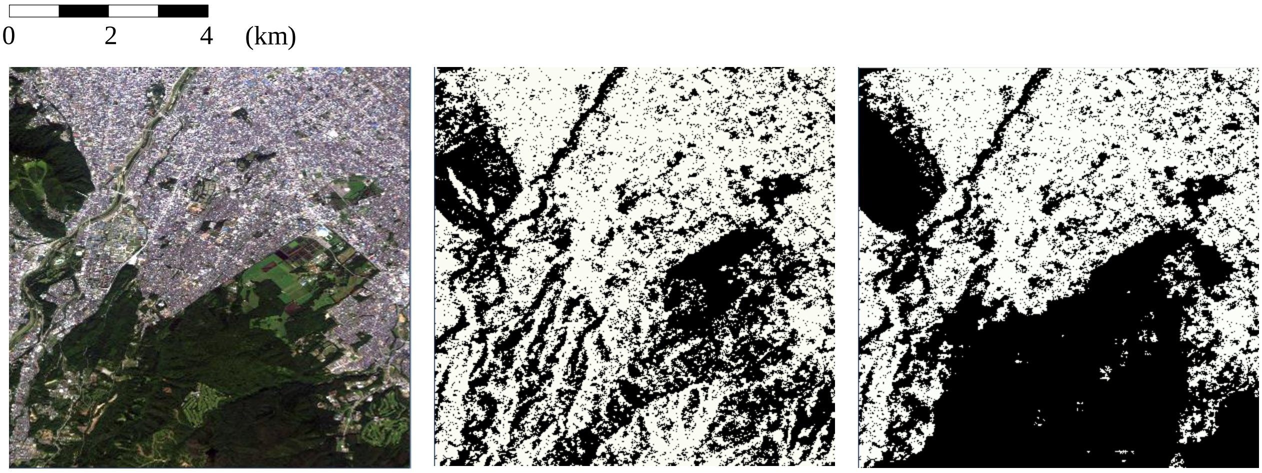
(a)

(b)

Figure 10. Result of urban area extraction (in Tokyo area)
(a) AVNIR-2 (b) Result after 3.1 (White pixel: Urban area, Black pixel: Non-urban area)

4.3 Result of Classification of Urban Area and Mountain Area

Figure 11 shows the result after classification of urban area and mountain area. Most of mountain areas were misclassified into urban area by applying only the method proposed in 3.1 (Figure 11 (b)). Figure 11 (c) was obtained by applying the methods proposed in 3.2 and 3.3. In comparison between Figure 11 (a) and (c), most of mountain areas were classified into non-urban area.



(a) (b) (c)

Figure 11. Result of urban area extraction (in Sapporo area)
(a) AVNIR-2 (b) Result after 3.1 (c) Result after 3.1 and 3.2 (White pixel: Urban area, Black pixel: Non-urban area)

5. CONCLUSION

In this paper, classification method was proposed that effectively extracts urban areas using polarimetric SAR. Pv and TP data, generated using four-component decomposition, are used for the classification. Because they depend on POA, pixels are categorized on the basis of POA and a different threshold for the classification is set to each category. After farmland, sea, and bare ground are excluded applying the thresholds, urban areas are discriminated from mountain areas using randomness of POA. The experimental results demonstrate that the proposed method successfully extracted urban area of the study area.

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