Evaluation of the Pi-SAR Data for Land Cover Discrimination

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Abstract: The aim of this study is to evaluate the Pi-SAR data for land cover discrimination using a standard method. For this purpose, the original polarization and Pauli components of the Pi-SAR X-band and L-band data are used and the results are compared. As a method for the land cover discrimination, the traditional method of statistical maximum likelihood decision rule is selected. To increase the accuracy of the classification result, different spatial thresholds based on local knowledge are determined and used for the actual classification process. Moreover, to reduce the speckle noise and increase the spatial homogeneity of different classes of objects, a speckle suppression filter is applied to the original Pi-SAR data before applying the classification decision rule. Overall, the research indicated that the original Pi-SAR polarization components can be successfully used for separation of different land cover types without taking taking special polarization transformations.
Keywords: Pi-SAR, polarization components, classification, spatial thresholds, speckle, overall accuracy.

1. Introduction

At present, the development stage of remote sensing (RS) is entering a new challenging era, the era of so called Polarimetric and Interferometric Synthetic Aperture Radar (PISAR). PISAR is an advanced imaging radar system that has multifrequency, fully polarimetric and interferometric observation functions. One of such systems is the Pi-SAR (Polarimetric and Interferometric SAR) system, jointly developed by the Communications Research Laboratory (CRL) and the National Space Development Agency of Japan (NASDA). It has fully polarimetric X-band SAR and L-band SAR and the X-band has two receiving antennas located in cross-track direction for interferometric observation and can image the Earth's surface at any time of day or night under any atmospheric conditions [9,10]. Different research activities are being carried out for development of techniques for processing and analyses of the PISAR data. Some significant achievements have already been made in the entropy based classification methods and development of accurate digital elevation models (DEM) and further land surface analyses using the generated DEMs [4,6,7].

One of the principle aims of RS image analyses is to extract reliable thematic information. Thematic information can be extracted in different ways, including manual, automatic and knowledge-based approaches [3]. However, in many cases the users of RS products intend to rapidly and inexpensively associate a ground cover label to each image pixel in the data set. One of the rapid methods for thematic information extraction from RS images is a land cover classification using any of the classification methods. For several decades, digital methods of classification of RS images have been effectively used for land cover mapping and hence, a great number of techniques have been developed [2]. One of the widely known and used classification techniques is the statistical maximum likelihood decision rule. Although there are many other techniques for the land cover mapping using RS data, amongst the user communities, the maximum likelihood classifier (MLC) is still considered one of the most accurate and efficient discrimination procedures, because a pixel classified by this method has the maximum probability of correct assignment. In order to be conducted an accurate labeling of the image pixels, the signatures representing different land cover types in the selected features should be separable (or have a minimum overlap) in a multidimensional feature space [1].

The aim of this paper is to evaluate the Pi-SAR data for discrimination of different land cover types using a standard method. For this end, polarimetric Pi-SAR X-band and L-band data have been used and for the information extraction, the traditional method of statistical maximum likelihood decision rule has been chosen. For the actual classification, the original polarization features and Pauli components of the two bands were used and the results were compared.

2. Test Area and Data Sources

As a test site Sendai city, situated in northern part of Japan has been selected. The selected part of the test site is characterized by such classes as high density urban, residential urban, forest, ground and water, and significant statistical overlaps exist between the classes residential urban and forest as well as between the classes ground and water.

The data used consisted of the Pi-SAR X-band and L-band data acquired on 12 June 2002. The false color composite (FCC) image, created by a combination of the polarization components of the Pi-SAR L-band data is shown in Fig. 1. The polarimetric functions and characteristics of the Pi-SAR system are shown in Table 1.

Fig. 1. Pi-SAR L-band FCC image of the test area (1-High density urban, 2-Residential urban, 3-Forest, 4-Ground, 5-Water) (Red=HH, Green=HV, Blue=VV) The size of the area is about 4.1kmx3.5km.

Table 1. The characteristics of the Pi-SAR system.

	X-band	L-band
Polarization	HH, HV, VH, VV	HH, HV, VH, VV
Frequency	9.55 GHz	1.27 GHz
Wavelength	31.4mm	236mm
Spatial resolution	1.5m	3.0m

3. Classification of the Pi-SAR Data

1) Feature Determination and Selection of Training Samples

In the classification process, it is desirable to include only features in which the signatures of the selected classes are highly separable from each other in a multi-dimensional feature space. In this study, to increase the separation of the signatures in both bands, the polarization components have been transformed by applying Pauli matrices [7] as follows:

1. Pi-SAR-(HH+VV)
2. Pi-SAR-(HV+VH)
3. Pi-SAR-(HH-VV).

For the initial classification, four separate sets of features which consist of the original and transformed polarization components of both X-band and L-band dat a have been selected.

To form the signatures, one to four training samples representing the selected classes have been selected from both images, using a polygon-based approach. The separability of the training signatures was firstly checked on the feature space and then evaluated using Jeffries-Matusita (J-M) distance [8]. Then, the samples which demonstrated the greatest separability were chosen to form the final signatures. Here, for the formation of the signatures of residential urban and forest classes, the training samples selected from two different parts of the image were merged. The final signatures included 100-1965 pixels. For the actual classification, the standard statistical MLC has been used assuming that the classes have the equal prior probabilities [8].

2) MLC using the Original Polarization Features and Pauli Components

The original polarization features and Pauli components of X-band and L-band data were classified using the standard maximum likelihood decision rule. As it was seen from the classified images, the results of the original polarization features and Pauli components in both bands were the same. This means that, the original Pi-SAR polarization components might be used for separation of different land cover types without taking special polarization transformations.

For the accuracy assessment of the classification results, the overall performance has been used. This approach creates a confusion matrix in which the reference pixels are compared with the classes in the classified image and as a result, an accuracy report is generated indicating the percentages of the correspondence [5]. As ground truth information, for each class several regions containing the purest pixels have been selected. The confusion matrices indicated an overall accuracy of 74.27% for both classification results of L-band data and 71.89% for both classification results of X-band data.

As the two classification results of the original polarization features and Pauli components were the same and the classification accuracy of the L-band data was higher than that of the X-band data, for further analysis only the original Pi-SAR L-band polarization components have been used.

3) MLC using Spatial Thresholds

In general, it is very difficult to separate classes if their signature distributions overlap in the multidimensional feature space. In this case, the usage of spatial thresholds can be one of the most efficient approaches for separating the overlapping classes. The spatial thresholds can be determined on the basis of historical data sets stored within a geographical information system (GIS), available ancillary data or from local knowledge about the site. The idea of the spatial threshold is that it uses a polygon boundary to separate the overlapping classes and only the pixels falling within the threshold boundary are used for the classification, thus excluding the class that overlaps with the class to be classified using the threshold boundary. In such a way, the image can be classified several times using different threshold boundaries and the results can be merged. In this study, for separation of the overlapping classes different spatial thresholds were used. As it was seen from the classified image, the performance of the classification decision rule could be significantly improved if proper spatial thresholds are applied in the classification process. The confusion matrix indicated an overall accuracy of 91.21%.

4) MLC using Speckle Suppressed Features

Because of the coherent nature of the monochromatic wavelengths used in microwave RS, the radar images have speckled appearances that influence the interpretation and analysis. In many cases it is desirable to reduce the speckle noise. Specifically, before applying a classification decision rule, it is highly desirable to reduce the speckle, because the reduction of the speckle increases the spatial homogeneity of the classes. In our study, to reduce the speckle, a 3x3 size Frost filter has been used. The Frost filter is one of the widely used speckle suppression techniques and reduces the speckle in the radar images while preserving the edges between different classes of objects [5]. The speckle suppressed original polarization components were classified using the same set of training samples and spatial thresholds. As it was seen from the classification result, some improvements were made in terms of the spatial homogeneity of the selected classes, for example, less homogeneous areas became more homogeneous. The confusion matrix indicated an overall accuracy of 92.15%.

4. Conclusions

The overall idea of the study was to evaluate the Pi-SAR data for land cover discrimination using a standard classification method. For this aim, the original polarization and Pauli components of the Pi-SAR X-band and L-band data were used and as a method for the classification, the traditional method of statistical maximum likelihood decision rule was selected.

As seen from the results of the classification, the original polarization components of the Pi-SAR data can be successfully used for separation of different land cover classes without taking special polarization transformations.

Moreover, as seen from the analysis, the usage of spatial thresholds on both original and speckle suppressed polarization components can significantly improve the performance of the classification and for the accurate classification, proper spatial thresholds should be applied.

Acknowledgement

A part of this work was supported by Grant-in-Aid for JSPS Fellows (02124) and Grant-in-Aid for Scientific Research (A) 14252014.

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