論 文 の 内 容 の 要 旨

論文題目　PolSAR Land Classification System Based on Unsupervised Adaptive Polarization Scattering Signal Processing Using Quaternion Neural Networks
（四元数ニューラルネットワークによる偏波散乱情報の教師なし適応処理に基づくPolSAR地表分類システム）

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PolSAR is an active sensor that observes target by transmitting polarization-controlled microwave and receiving their scattered wave in a polarization-sensitive manner. Since it can observe the target irrespective of the weather condition throughout day and night, various studies have been carried out to utilize PolSAR data for resource management, environmental protection and disaster measures. To realize these, accurate land classification using PolSAR is one of the research goals, which has been receiving a lot of attention.

Since 1990s, a number of PolSAR land classification systems have been reported. The target decomposition methods, which have been studied actively from the beginning of the field, show a high potential of PolSAR land classification. It has become possible to classify the PolSAR-observed areas into several specific categories such as farm, forest, lake and so on, combined with statistical modeling. Machine-learning-based classifiers such as K-means, support vector machine (SVM), fuzzy logic, neural networks, have greatly enhanced the accuracy of the PolSAR land classification.

The target decomposition selects the feature information necessary for land classification from PolSAR data based on the assumption that a unique combination of scattering mechanisms exists for each land category. Model-based decomposition can be introduced as a typical technique of the target decomposition. The three-component decomposition proposed by Freeman and Durden in 1998 represents feature information based on the combination of three scattering mechanisms by deciding that the land surface can be represented by a combination of three simple scattering models, namely, single-bounce scattering, double-bounce scattering and volume scattering. The four-component decomposition proposed by Yamaguchi et al. in 2005 can find an appropriate combination of feature information which is necessary for the classification of special structure by adding helix scattering to the three component decomposition. Various other additional methods have also been proposed such as the deorientation method and the cross scattering model to suppress unevenness in the direction of buildings.

However, since the above methods extract feature information based on a few scattering mechanisms selected by humans, it is sometimes necessary to define new scattering mechanisms that correspond to the change or addition of classification objects. Though the adaptive-classifier having high performance is employed, a high classification performance can not be obtained since the conventional systems are based on features which are not able to express the actual land surface clearly. There would be limitations in those methods in the near future to meet the requirement of various land categories that human beings perceive.

The author aims to achieve the following two goals through this research. First, the author aims to overcome the limitation of the classification targets of the conventional PolSAR land classification system. It can be solved by fully utilizing the polarization scattering information of PolSAR data with various directional Poincare parameters. However, the algorithms for removing unnecessary noise from the Poincare parameters and the land classification methods based on the Poincare parameter are still not established. The author proposes several unsupervised adaptive polarization scattering signal processing methods using quaternion neural networks and realize an unsupervised PolSAR land classification system based on the proposed methods. Second, the author aims to discover new land classes that are not considered classifiable by using PolSAR data. The conventional PolSAR land classification systems can classify only the several simple land classes such as water, forest, and town, so its application range is insufficient compared to the economic burden required for the development and operation of the PolSAR system. Discovering new land classes that can be classified using PolSAR data through this research, will significantly enhance the economic value of the PolSAR system by expanding the scope of data utilization hugely.

In Chapter 2, we propose an unsupervised PolSAR land classification system based on quaternion auto-encoder and quaternion SOM. The proposed system not only distinguishes the PolSAR data without human-predefined land categories, but also labels respective groups by an additional labeling process so that human beings can understand the unsupervised classification results. We confirm that the quaternion auto-encoder is effective in extracting feature vectors suitable for land classification. It enables the proposed system to classify the PolSAR data obtained for the target region accurately and finely. Furthermore, we succeed in discovering more detailed land categories such as furrowed areas, factory areas, and so on, by classifying the ALOS data obtained for Fujisusono region with quaternion SOM having 10×10 neuron array.

In Chapter 3, we propose hierarchical polarization feature generation with self-organizing codebook to realize unsupervised land classification for high-resolution PolSAR data. Since the respective pixels of high-resolution PolSAR data contain the detailed polarization scattering properties obtained from the local land areas, it is hard to realize the accurate land classification based on single pixels. The proposed system generates the self-organizing codebook representing the typical respective pixel signals of high-resolution PolSAR data by using the combination of the quaternion auto-encoder and quaternion SOM. Then, the PolSAR data is scanned by the patch window to generate high-level feature vectors by constructing the winner histogram of the self-organizing codebook. In the experimental results, we confirm that the proposed system performs high-resolution PolSAR land classification without any predefinition or training by human beings. Furthermore, we succeed in discovery of the new land sub-classes which can be discovered only in high-resolution PolSAR data. For example, two kinds of farm areas are classified successfully, and buildings are classified into the center parts and the wall parts in detail. The proposed system makes it possible to fully utilize the detailed polarization scattering properties contained in respective pixels for land classification even if the resolution of PolSAR data keeps being enhanced continuously. This leads to the discoveries of new land categories that can only be found with high-resolution PolSAR data.

In Chapter 4, we optimize the hierarchical polarization feature generation, which has been proposed in Chapter 3, by applying the concept of population coding. Since the method proposed in Chapter 3 is based on the concept of sparse coding, we do not obtain high performance in land classification unless we prepare the suitable self-organizing codebook for the respective observation regions. However, the optimized method based on the concept of population coding shows the stable land classification performance at all times without having to generate the optimal self-organizing codebook. It enables us to utilize the proposed hierarchical PolSAR land classification system flexibly for classification of various observed regions.

In Chapter 5, we report the experimental analysis results of the pixel variation existing in actual PolSAR data of various resolution. Until now, it has been believed that the main cause of pixel variation in PolSAR data is a non-uniform distribution of the local scatterers in the land surface. For this reason, even though the PolSAR data of decimeter-resolution could be observed, it was being considered that the data resolution should be reduced from 10m to 20m based on the real-space-distance to obtain the polarization scattering information suitable for the land classification. However, from the experimental results, we confirm that a non-uniform distribution of the local scatterers in the land surface is not the main cause of pixel variation. And it means that there is no need to lower the resolution of high-resolution PolSAR data in the same level of pixel spacing as low-resolution PolSAR data to apply for land classification. Our experimental results show that the polarization scattering information of the high-resolution data is available for utilization for the land classification fully.

The above research results enable us to fully utilize the detailed polarization scattering properties contained in respective pixels for land classification even if the resolution of PolSAR data keeps getting enhanced continuously. Besides, we can realize the stable classification performance regardless of the type of the observation region. In the future, if the resolution of PolSAR data increases much more, we expect even the classification of the buildings based on their detailed shapes by using the proposed method. Expansion of the classification target that can be classified using PolSAR data, will significantly enhance the economic value of the PolSAR system by expanding the scope of data utilization hugely.