Multitemporal Space-borne Polarimetric SAR Data for Urban Land Cover Mapping

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Academic Dissertation which, with due permission of the KTH Royal Institute of Technology, is submitted for public defence for the degree of Doctor in Technology on Friday the 23rd November 2012, at 10:00 a.m. in Sal D3, Lindstedtsvägen 5, entréplan, KTH, Stockholm.
Abstract

Urban land cover mapping represents one of the most important remote sensing applications in the context of rapid global urbanization. In recent years, high resolution spaceborne Polariometric Synthetic Aperture Radar (PolSAR) has been increasingly used for urban land cover/land-use mapping, since more information could be obtained in multiple polarizations and the collection of such data is less influenced by solar illumination and weather conditions.

The overall objective of this research is to develop effective methods to extract accurate and detailed urban land cover information from spaceborne PolSAR data. Six RADARSAT-2 fine-beam polarimetric SAR and three RADARSAT-2 ultra-fine beam SAR images were used. These data were acquired from June to September 2008 over the north urban-rural fringe of the Greater Toronto Area, Canada. The major landuse/land-cover classes in this area include high-density residential areas, low-density residential areas, industrial and commercial areas, construction sites, roads, streets, parks, golf courses, forests, pasture, water and two types of agricultural crops.

In this research, various polarimetric SAR parameters were evaluated for urban land cover mapping. They include the parameters from Pauli, Freeman and Cloude-Pottier decompositions, coherency matrix, intensities of each polarization and their logarithms. Both object-based and pixel-based classification approaches were investigated. Through an object-based Support Vector Machine (SVM) and a rule-based approach, efficiencies of various PolSAR features and the multitemporal data combinations were evaluated. For the pixel-based approach, a contextual Stochastic Expectation-Maximization (SEM) algorithm was proposed. With an adaptive Markov Random Field (MRF) and a modified Multiscale Pappas Adaptive Clustering (MPAC), contextual information was explored to improve the mapping results. To take full advantages of alternative PolSAR distribution models, a rule-based model selection approach was put forward in comparison with a dictionary-based approach. Moreover, the capability of multitemporal fine-beam PolSAR data was compared with multitemporal ultra-fine beam C-HH SAR data. Texture analysis and a rule-based approach which explores the object features and the spatial relationships were applied for further improvement.

Using the proposed approaches, detailed urban land-cover classes and finer urban structures could be mapped with high accuracy in contrast to most of the previous studies which have only focused on the extraction of urban extent or the mapping of very few urban classes. It is also one of the first comparisons of various PolSAR parameters for detailed urban mapping using an object-based approach. Unlike other multitemporal studies, the significance of complementary information from both ascending and descending SAR data and the temporal relationships in the data were the focus in the multitemporal analysis. Further, the proposed novel contextual analyses could effectively
improve the pixel-based classification accuracy and present homogenous results with preserved shape details avoiding over-averaging. The proposed contextual SEM algorithm, which is one of the first to combine the adaptive MRF and the modified MPAC, was able to mitigate the degenerative problem in the traditional EM algorithms with fast convergence speed when dealing with many classes. This contextual SEM outperformed the contextual SVM in certain situations with regard to both accuracy and computation time. By using such a contextual algorithm, the common PolSAR data distribution models namely Wishart, Gop, Kp and KummerU were compared for detailed urban mapping in terms of both mapping accuracy and time efficiency. In the comparisons, Gop, Kp and KummerU demonstrated better performances with higher overall accuracies than Wishart. Nevertheless, the advantages of Wishart and the other models could also be effectively integrated by the proposed rule-based adaptive model selection, while limited improvement could be observed by the dictionary-based selection, which has been applied in previous studies. The use of polarimetric SAR data for identifying various urban classes was then compared with the ultra-fine-beam C-HH SAR data. The grey level co-occurrence matrix textures generated from the ultra-fine-beam C-HH SAR data were found to be more efficient than the corresponding PolSAR textures for identifying urban areas from rural areas. An object-based and pixel-based fusion approach that uses ultra-fine-beam C-HH SAR texture data with PolSAR data was developed. In contrast to many other fusion approaches that have explored pixel-based classification results to improve object-based classifications, the proposed rule-based fusion approach using the object features and contextual information was able to extract several low backscatter classes such as roads, streets and parks with reasonable accuracy.

Key Words