Data Fusion Study between Polarimetric SAR, Hyperspectral and Lidar Data for Forest Information

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Canada has 10\% of the world’s forests or 418 million hectares. Remote sensing has become a cost-effective tool in Canada to monitor forest resources and provide valuable geospatial information on the state, distribution, and changes of Canada’s forests. In recent years, many advanced space-borne SAR systems have and will become available, such as ALOS PALSAR, TerraSAR-X and Radarsat-2, which when compared to previously available sensors, offer better spatial resolution, cross polarization and polarimetric parameters. There are potential benefits from integrating L- and C-band polarimetric SAR with hyperspectral optical data. The goal of this research was to develop, implement and demonstrate new methodologies for producing accurate forest information products from fused data sets.

The polarization information contained in quad-pol data sets can be used for measuring forest scattering characteristics and producing classifications for different forest areas for forest typing, clearcut and fire scar discrimination. In this study, ALOS PALSAR Level 1.1 data were acquired over the Greater Victoria Watershed District (GVWD), BC, Canada. Due to substantial topographical relief in GVWD, our emphasis was on integration and fusion techniques with polarimetric SAR, hyperspectral and Lidar data to produce forest classification products. The hyperspectral data were used for computation of high spectral resolution information, such as major forest species and land-cover characterization, and the Lidar data were utilized to generate information related to vertical structure of both the underlying topography (DEM) and the forest structure, providing an improved understanding of topography effects on polarimetric SAR backscatter. The combination of these data sources provided an opportunity to examine the synergy of the fused data for information extraction from polarimetric SAR and the potential of upcoming Radarsat-2 data sets.

An important requirement for our study requires that the polarimetric SAR data be accurately calibrated radiometrically and geometrically. The radiometric calibration of PALSAR Level 1.1 data was initially carried out by the Alaska Satellite Facility (ASF). The correction for the Faraday rotation was estimated from a non-symmetric scattering matrix of the PALSAR data. The Bickel and Bates algorithm was used for the Faraday rotation (about 2 degrees) [1]. Ground topography could be sensed by estimating the polarization orientation shift (POS) angles from both ALOS PALSAR and AirSAR data by using Jong-Sen Lee’s algorithm [2] for polarization SAR data compensation for terrain azimuth slope variation. This algorithm was applied in order to reduce the polarization angle shift effects and facilitate future classification. Within the GVWD area, fine topographic variations and heavy volume scattering prevented accurate calculation of the POS at L-band. The orientation angle shifts image from the PALSAR data was not encouraging due to the L-band scattering characteristics, which were more sensitive to the forest cover and did not penetrate to the ground due to both the tall tree height and dense crown closure over GVWD compared to the P-band AirSAR.
Extensive research was conducted with various methods of polarimetric decomposition to reduce sensitivity to tough topography effects and improve classification results over GVWD. A polarimetric image interpretation technique was introduced by Cloude and used for better differentiation of water surfaces, vegetation and forests in the area. The technique was based on the eigenvector decomposition of the 4x4 coherency matrix. First, the four eigenvalues were first used to calculate the scattering entropy $H$. Secondly, the non-polarized power was calculated as $(\lambda_2 + \lambda_3)$. Here $\lambda_2$ and $\lambda_3$ are the second and third real eigenvalues. Thirdly, the scattering $\alpha$ for the second eigenvector with medium/high entropy was calculated as $\alpha_2$. Finally, the triplet $H$, $\alpha_2$ and $(\lambda_2 + \lambda_3)$ were used as a HSV coding for a RGB image. This technique acts as a “filter” by excluding eigenvalues/eigenvectors that contain most of the topography information to improve identification of the water surface, vegetated area and forest cover and form the basis for further classifications and refinements.

Radiometric correction and image orthorectification were performed on the hyperspectral data acquired for the NASA airborne AVIRIS sensor. The Lidar data from the Terra Surveys / UVic airborne system [4] were corrected and used to create a high resolution DEM (2 meters). The DEM data were transformed into the PALSAR domain by applying a radar simulation algorithm [4]. The simulated radar DEM image is then used to facilitate the collection of GCP’s for orthorectification of the HSV-coding image. The orthorectified HSV-coding image, hyperspectral AVIRIS data and DEM were then fused for a non-parametric classification using LOGIT [5]. This approach yielded better classification results over the challenging topography of GVWD.

The initial classification results using only the PALSAR HSV image had the accuracies of over 70% for the five land cover classes – water surface, forested area, herb graminoids, exposed land (clearcut) and swamp. It had been found that including the relative aspect and slope information derived from DEM improved the classification results further. The advanced technical characteristics of space-borne PALSAR in L-band and Radarsat-2 in C-band with increased spatial resolutions and polarimetric parameters have created new opportunities for forest applications, but also presented challenges to exploit the potential capabilities of such platforms over the rugged mountain terrain of the Pacific Northwest’s high biomass temperate rainforests.


