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Automated Terrain Classification Using Polarimetric Synthetic Aperture Radar

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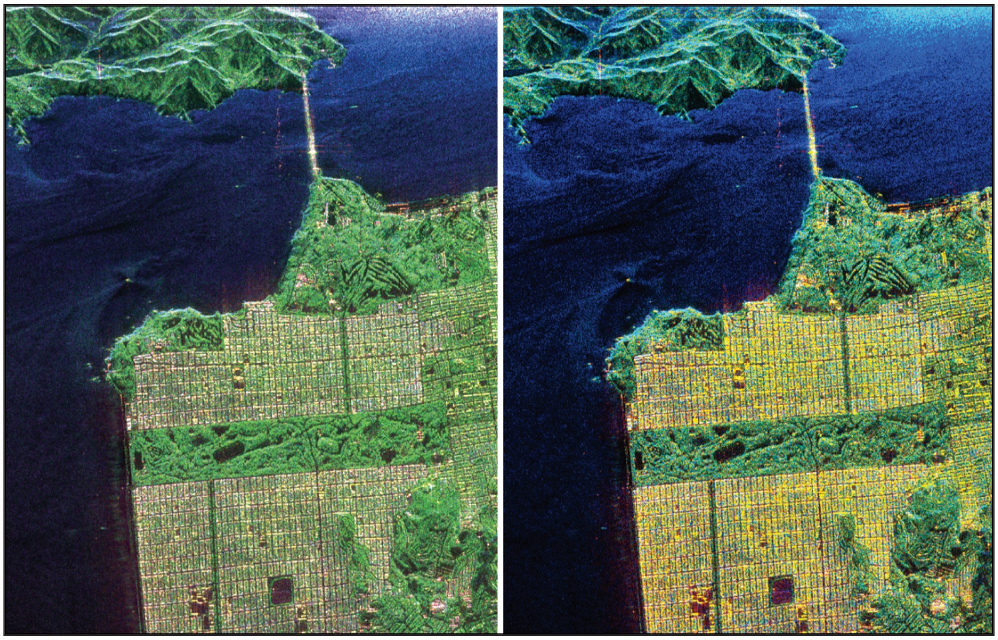
Polarimetric Synthetic Aperture Radar: In the last 30 years, synthetic aperture radar (SAR) has been established as a primary remote imaging instrument for Earth resource monitoring, planetary exploration, and military applications. SAR is an active sensor, illuminating targets with electromagnetic waves that can penetrate through cloud coverage. Consequently, it has all-weather and day/night imaging capabilities. Polarimetric synthetic aperture radar (PolSAR), also known as quad-polarization SAR, measures a target's reflectivity with quad-polarizations: horizontal transmitting and receiving (HH), horizontal transmitting and vertical receiving (HV), vertical transmitting and horizontal receiving (VH), and vertical transmitting and vertical receiving (VV). This is achieved by alternately transmitting horizontal (H) and vertical (V) polarization radar pulses and receiving both H and V polarizations of reflected pulses with sufficiently high pulse repetition frequencies. Unlike single or dual polarization SAR, PolSAR data can be used to synthesize responses from any combination of transmitting and receiving polarizations. This capability provides information to characterize scattering mechanisms of various terrain covers. Open areas typically show surface scattering characteristics, trees and bushes show volume scattering, and buildings, vehicles, and man-made objects have double bounce and specular scattering. This capability enhances the accuracy and detail of terrain characterization.

PolSAR Terrain Classification: Terrain and land-use classification are arguably the most important applications of PolSAR. Many supervised and unsupervised (automated) classification methods have been proposed. Earlier algorithms classify PolSAR images based on their statistical characteristics. Recently, the inherent characteristics of physical scattering mechanisms have been used as an additional advantage by providing information for class type identification. The deficiency of this approach is that the classification result lacks details, because of statistical properties were not used.

Current Research: A new and robust classification algorithm[1] has been developed that preserves the scattering mechanism of each class and uses the statistical properties for retaining the spatial resolution in the classification results. The first step is to divide image pixels into the three categories of surface, volume, and even bounce scattering, by applying the Freeman and Durden decomposition.[2] Pixels in each category are classified independent of pixels in the other categories to preserve purity in the scattering characteristics. A new and effective initialization scheme has also been devised to initially merge clusters by applying a criterion developed based on the Wishart distance measure. Pixels are then iteratively classified by a Wishart classifier using the initial clusters as the training sets within each scattering category. To produce an informative classification map, class color selection is important. Therefore, we have developed a procedure that automatically colors the classification map by using scattering characteristics, categorized as surface scattering, double-bounce scattering, and volume scattering.

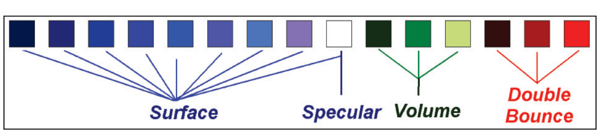
Experiment Result: A NASA/JPL AIRSAR L-band image of San Francisco (Fig. 4) is used to show the applicability of this algorithm for general terrain classification. The spatial resolution is about 10 × 10 m. This polarimetric SAR data has 700 × 901 pixels. The radar incidence angles span from 5° to 60°. This scene contains scatterers with a variety of distinctive scattering mechanisms. Figure 4(a) shows the original POLSAR image, with |HH-VV|, |HV|, and |HH+VV|, for the three composite colors (red, green, and blue, respectively). Figure 4(b) shows the Freeman/Durden decomposition using the magnitude of double bounce $|\boldsymbol{P_{DB}}|$, volume scattering $|\boldsymbol{P_V}|$, and surface scattering $|\boldsymbol{P_S}|$ for red, green, and blue. The classification result is shown in Fig. 5(a) with the color-coded class label shown in Fig. 5(b). We have 9 classes with surface scattering because of the large ocean area. Three volume classes detail volume scattering from trees and vegetation. The double-bounce classes clearly show the street patterns associated with city blocks, and they are also scattered throughout the park areas, associated with man-made structures and tree trunk-ground interactions. The classified image with 15 classes reveals considerably more terrain information than the original image (Fig. 4(a)).



(a) (b)

FIGURE 4
(a) NASA JPL POLSAR image of San Francisco displayed with |HH-VV|, |HV|, and |HH + VV|, for red, green and blue, respectively. (b) The Freeman/Durden decomposition using $|\mathbf{P}_{DB}|$, $|\mathbf{P}_{V}|$, and $|\mathbf{P}_{S}|$ for red, green, and blue.

(a) Classification map



(b) Color-coded class label

FIGURE 5
(a) Final classification map of the San Francisco image into 15 classes. (b) The color-coded class label indicates scattering mechanisms.

Summary: We have developed an effective and automated terrain classification algorithm that preserves scattering characteristics in PolSAR data while still allowing terrain type identification. This algorithm has been found to be applicable to sea ice classification and to rapid detection and deployment in disaster management, e.g., the detection of landslide associated with earthquake and forest fires.

Acknowledgment: DARPA has funded us through a terrain characterization study using a FOPEN (foliage penetration) UHF (233-445 MHz) polarimetric SAR. A FOPEN terrain characterization software package has been developed based on this automated classification technique and is being integrated into a FOPEN Terrain Workstation.

[Sponsored by ONR and DARPA]

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