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Interferometric SAR Coherence Classification Utility Assessment

D. A. Yocky
Sandia National Laboratories
P.O. Box 5800, MS1207
Albuquerque, NM 87185-1207, USA
Telephone: 505-844-5188, Facsimile: 505-844-4484, Email: dayocky@sandia.gov

ABSTRACT

The classification utility of a dual-antenna interferometric synthetic aperture radar (IFSAR) is explored by comparison of maximum likelihood classification results for synthetic aperture radar (SAR) intensity images and IFSAR intensity and coherence images. The addition of IFSAR coherence improves the overall classification accuracy for classes of trees, water, and fields. A threshold intensity-coherence classifier is also compared to the intensity-only classification results.

INTRODUCTION

Classification using SAR imagery endeavors to segment the data into classes in an automated or semi-automated fashion. Recent research has shown utility in dual-pass SAR intensity and coherence to identify trees [1,2,3]. These dual-pass data, along with the subsequent height map, may provide estimates of tree type, age, and density.

Other researchers have developed classification techniques based on SAR intensity features including fractal dimension, local texture statistics, co-occurrence matrices textures, and modeled SAR intensity parameters. A comparison of these techniques for classes of water, trees, urban, plowed field, and unplowed field classes showed that the Gaussian multiplicative autoregressive parameters provided the best classifier for the given classes on ERS-1 data sets [4].

In this paper, we present the results of comparing the Gaussian random-field SAR intensity classification with IFSAR intensity and coherence classification on a ground-truthed data set. Supervised maximum likelihood classification of tree, water, and field classes used features from both approaches. We also include a IFSAR intensity-coherence threshold classification for further comparison.

SUPERVISED CLASSIFICATION

The United States Department of Energy's Airborne Multisensor Pod System (AMPS) and Sandia-built 15 GHz IFSAR collected 1-m resolution data in slant range and azimuth over the Rio Grande bosque, south of downtown Albuquerque, New Mexico. The bosque has riparian vegetation skirting the Rio Grande with agricultural fields nearby. The deciduous trees had emerging leaves. The IFSAR coherence and phase difference were calculated and the SAR intensity resampled to give orthorectified ground plane resolution of 2-m. Twenty abutted azimuth patches construct the image. Fig. 1 shows the intensity and Fig. 2 the resultant coherence. Final classification statistics exclude one noisy coherence strip (3rd from the left).

AMPS collected high-resolution color photographs of the bosque that were digitized. The imagery was segmented into tree, water, and field classes for ground truth. Buildings, roads, and ditches amongst the trees and fields were ignored.

Fig. 1: SAR intensity image of Rio Grande bosque.

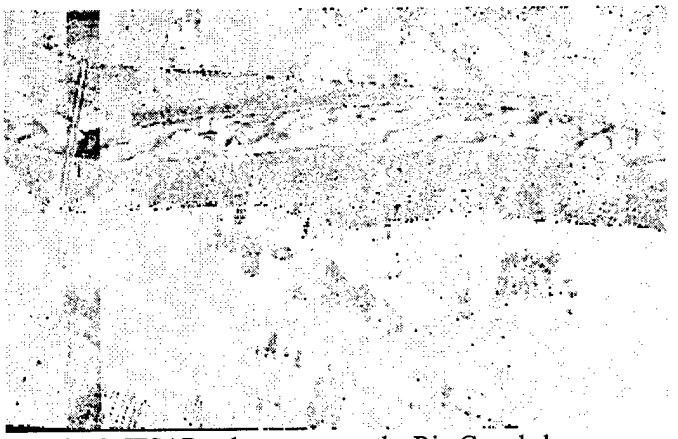

Fig. 2: IFSAR coherence over the Rio Grande bosque.

DISCLAIMER

The Gaussian autoregressive model of the SAR data assumes the observed image can be represented by a white-noise-driven multiplicative system. With a multiplicative spatial interaction neighborhood support of [0,-1], [-1,-1], and [-1,0] the model provides five parameters to model the SAR intensity. Calculation of least square estimates [5] for these parameters used a 9x9 sliding window.

Maximum likelihood supervised classification training areas were selected for tree, water, and field classes apart from the ground truth data area. From the training areas, class signatures were generated for both the multiplicative autoregressive parameters and the IFSAR intensity and coherence. Figs. 3 and 4 are the respective classification results. Tables 1 and 2 are the corresponding confusion matrices.

The multiplicative autoregressive classification has problems separating fields and trees as evidenced by 10.69 percent trees classified as fields and 12.53 percent fields classified as trees in Table 1. Similarly in Table 2, the IFSAR classifier labels 8.71 percent tree pixels as fields and 15.06 percent field pixels the tree class. The IFSAR outperforms the SAR model by 16 percent (83.87 versus 67.88 percent) in average accuracy, although the large Null classes influence the SAR model results.

Simple post-processing with a 5x5 median filter improves the IFSAR classification, eliminating many noisy class results caused by the antenna pattern and speckle in the imagery. Table 3 presents the corresponding confusion matrix.

Figure 3: SAR model classification results. Light-trees, medium-fields, dark-water, black-Null.

Alternate training sites were investigated in hopes of improving the SAR model performance by reducing the Null class. The results in Table 1 are the best for the 9x9 window. However, a 3x3 sliding window was used successfully towards the same goal. The resulting confusion matrix is Table 4. It shows a 8 percent improvement over the 9x9 results, but still suffers from a large Null class.

All of the classifiers suffer from the antenna pattern in the images. Some of the misclassification results are due to the absence of building and road classes in the ground truth. Some tree and field misclassification may be attributed to sparse tree canopies and consequent radiation penetrating to the ground.

Fig. 4: IFSAR classification results. Light-trees, medium-fields, dark-water, black-Null.

Table 1: Confusion matrix for SAR model classifier.

Class	Pixels	Null	Trees	Water	Fields
Trees	48,614	16.56%	72.60%	0.15%	10.69%
Water	29,898	26.60%	0.07%	73.33%	0.00%
Fields	82,758	29.02%	12.53%	0.73%	57.72%
Average accuracy: 67.88%					

Table 2: Ground truth confusion matrix for IFSAR classifier.

Class	Pixels	Null	Trees	Water	Fields
Trees	48,614	0.46%	87.61%	3.22%	8.71%
Water	29,898	3.59%	3.19%	86.46%	6.77%
Fields	82,758	0.54%	15.06%	6.85%	77.55%
Average accuracy: 83.87%					

Table 3: Median filtered IFSAR confusion matrix.

Class	Pixels	Null	Trees	Water	Fields
Trees	48,614	0.00%	91.10%	1.81%	7.09%
Water	29,898	1.96%	0.99%	92.25%	4.80%
Fields	82,758	0.07%	10.13%	4.32%	85.48%
Average accuracy: 89.61%					

THRESHOLD CLASSIFICATION

Tree canopies can exhibit lower coherence due to the target's extended ensemble of reradiators [2,6]. This drop in coherence and relatively high intensity returns from tree canopies provides the ground work for a simple classifier without training sites and maximum likelihood calculations.

Previous AMPS IFSAR collects established high, medium, low, and null intensity and coherence threshold levels. Figure 6 shows the classification map and Table 5 is the confusion matrix results.

It is evident from Figure 6 and Table 5 that the threshold approach is very sensitive to the aperture rolloff that reduces the overall accuracy. The field class has the worst performance. Threshold adjustment may improve this result. Post-processing with a 5x5 median filter increases the average accuracy to 87.11 percent.

CONCLUSIONS

A comparison between supervised maximum likelihood classification using SAR intensity model parameters and IFSAR intensity and coherence showed the IFSAR data features provide higher classification accuracy when classifying trees, water, and fields in the given data set. IFSAR coherence provides the increased accuracy since the SAR intensity was common to both approaches. The best maximum likelihood results show the IFSAR features give 13.5 percent higher classification accuracy compared to the SAR intensity model parameters.

A simple IFSAR thresholding scheme eliminates the need for user-selected training sites and permits automating the classification. The threshold classifier results are less accurate compared to the supervised IFSAR classifier, but still outperforms the overall intensity-only classification by 5.7 percent

Table 4: Ground truth confusion matrix for 3x3 SAR model.

Class	Pixels	Null	Trees	Water	Fields
Trees	48,614	13.60%	81.43%	0.61%	4.36%
Water	29,898	22.98%	0.54%	74.46%	2.02%
Fields	82,758	13.45%	10.95%	3.13%	72.47%
Average accuracy: 76.12%					

Table 5: Confusion matrix for threshold IFSAR classifier.

Class	Pixels	Null	Trees	Water	Fields
Trees	48,614	0.89%	88.99%	6.76%	3.36%
Water	29,898	3.45%	1.33%	92.62%	2.60%
Fields	82,758	1.49%	17.18%	17.38%	63.95%
Average accuracy: 81.85%					

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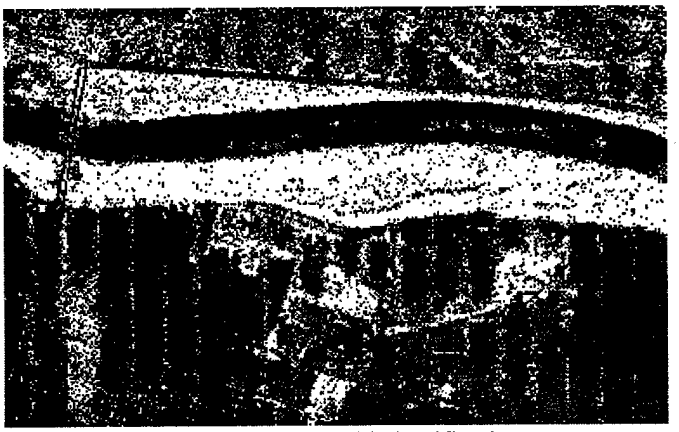

Figure 6: IFSAR threshold classification map.

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