THE IMPACT OF ADAPTIVE SPECKLE FILTERING ON MULTI-CHANNEL SAR CHANGE DETECTION

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1. INTRODUCTION

One of the most promising applications of synthetic aperture radar (SAR) imagery is change detection. However, the success of change detection algorithms is highly dependent on the type of change being detected. These changes can range from localized introduction of landmines with temporal baselines of a few days to large-scale spatial-temporal phenomena on annual timescales such as Amazon forest health change or crop maturation/harvesting[1, 2]. The algorithms also depend on sensor parameters that affect the radar cross-section (RCS) such as wavelength, resolution, calibration quality, system noise and incidence angle. With the advent of multi-channel SAR systems (multi-frequency and/or polarimetric) new algorithms to improve change detection are being developed. Most of these multi-channel methods are based on the covariance matrix formed amongst the available channels, although only fully polarimetric systems have cross-channel terms.

Regardless of the change detection method used, however, image noise will produce adverse effects that increase the probability of false alarms. To improve the results, the data are filtered to generate multi-looked images with the additional benefit of reducing the variance of parameter estimates. The best algorithms are adaptive filters, most of which are based on the statistics of the data and speckle. The most common approaches combine a fixed number of pixels within a rectangular region based on the detected features within that region, but more robust methods use image segmentation-type techniques to adaptively grow a region of statistically similar pixels [3, 4]. The result is that the equivalent number of looks (ENL) will vary within a SAR image and between images that may be used for detecting change. The impact of these types of filtering techniques on multi-channel change detection have not been well studied, however. The research presented here investigates this impact and compares it to the results obtained with a commonly used fixed window adaptive filter. The goal of this work is to determine the best filtering options for a few types of change detection problems using multi-channel data.

2. APPROACH

To demonstrate the filtering effects, three filtering methods and two multi-channel change detection algorithms are investigated. One change detection algorithm uses a likelihood ratio test based on the Wishart distribution of the covariance matrix [1]. This method, also known as the Bartlett test, essentially compares the ratio of two means (the geometric mean of the determinants to the determinant of the arithmetic mean) to a threshold. Modifying the equation for the log of the test statistic, \( q = \ln Q \), in [1] to account for different number of looks between the two test pixels, \( L_x \) and \( L_y \), and \( p \) channels yields

\[
q = p \left[ (L_x + L_y) \ln \left( \frac{L_x + L_y}{2} \right) - L_x \ln L_x - L_y \ln L_y \right] + L_x \ln |X| + L_y \ln |Y| - (L_x + L_y) \ln |Z| \tag{1}
\]

where \( X \) is the observation at a given pixel such that the estimate of the covariance matrix is \( \hat{\Sigma}_x = \frac{1}{L_x}X \) (similarly for \( Y \) and \( Z = (X + Y)/2 \). The second change detection algorithm is the Contrast Ratio defined using the Rayleigh Quotient [2]. This method is simply defined as \( q = \ln \left( \lambda_{\text{max}} \lambda_{\text{min}}^{-1} \right) \), where \( \lambda \) represents an eigenvalue of the covariance matrix ratio, \( C_{xy} = (\Sigma_x^{-0.5})^H \Sigma_y (\Sigma_x^{-0.5}) \). In both cases, a trinary test hypothesis is used to determine if the change is due to a new

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feature (increased power) or a feature that disappeared (decreased power). In addition, rank estimation is performed on the covariance matrix (the average for the Bartlett method and the ratio for the Contrast Ratio) by comparing the eigenvalues to a noise threshold. For rank less than 3, the equations for $q$ are modified to avoid using the eigenvalues below the threshold. The three speckle filters used are the IDAN, IDAN-LLMMSE [3], and the $7 \times 7$ Lee Refined filter for comparison. The IDAN-LLMMSE uses the IDAN algorithm to identify the neighborhood, but rather than averaging all pixels, a weight is applied to minimize the locally linear mean squared error based on known speckle statistics. This is essentially a hybrid between IDAN and the Lee Refined filter. Fig. 1 shows the change detection improvement with the IDAN method applied to two ESAR images and the impact on the histograms of $q$.

![Fig. 1. L-band ESAR. (a) 1x3 boxcar multi-looked |HH| image (ENL ≃ 3.4) showing corresponding detected changes with the Bartlett test $q_{thresh} = \pm 30$. Blue="new" and Red="old" (b) IDAN filter ($L \in [8, 68]$) with Bartlett test changes $q_{thresh} = \pm 70$. (c) $q$ histograms. Col 1 = Contrast Ratio, Col 2 = Bartlett. Row 1 = 1x3 boxcar, Row 2 = IDAN. The histograms applied to IDAN are trimmed along x axis for comparison with boxcar results.]

In order to quantify the change detection quality, simulated changes are artificially introduced into real SAR images, from the DLR ESAR and the JAXA PALSAR, similar to the approach taken in [2]. However, instead of just creating relatively large rectangular changes in a forest, several much smaller target covariance patches are added in different terrain types. This approach can determine when too much filtering obscures the change. Since the target characteristics are known, a probability of detection can be calculated for a given probability of false alarm. The best combinations are then applied to detect real changes between SAR acquisitions.

### 3. CONCLUSION

The results of this work demonstrate the impact of region growing adaptive filter techniques on multi-channel change detection algorithms. Not filtering enough causes an increase in false alarms, while overfiltering reduces the probability of detection, especially for small scale changes. Region based algorithms, however, can provide an advantage since the number of looks can be significantly increased without losing resolution. This research provides a framework for determining the optimal level of filtering, at least for the algorithms represented here.

### 4. REFERENCES


