WIDE AREA CHANGE DETECTION WITH SATELLITE IMAGERY FOR LOCATING UNDERGROUND NUCLEAR TESTING

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With the advent of high resolution optical imagery from commercial earthobservation satellites, the use of remote sensing data for verification of nuclear non-proliferation agreements is becoming increasingly attractive. Non-governmental organizations are routinely publishing high-quality imagery of sensitive nuclear installations round the world, and international verification authorities, such as the International Atomic Energy Agency (IAEA) or the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBO), will also want to make use, directly or indirectly, of this additional open source of information.

Exact location of the sites of underground nuclear explosions is a task eminently suited to satellite imagery, see for example Thurber et al. [1993], Gupta and Pabian [1998] or Canty and Schlittenhardt [2001]. Here both moderate resolutions for detecting signals in very large testing ranges as well as high resolution images for exact interpretation play important roles.

We describe in our paper a particularly sensitive change detection procedure for bitemporal, multispectral satellite imagery which can be used to locate the spall zone of underground nuclear explosions with commercial satellite imagery. The method is based on the multivariate alteration detection (MAD) technique of Nielsen et al. [1998]. Linear combinations of the spectral channels in two images of the same scene are chosen so as to minimize their positive correlation. This leads to a series of difference images – the so-called MAD components -- which are mutually orthogonal (uncorrelated) and ordered according to decreasing variance in their pixel intensities.

Since interesting changes in man-made structures may contribute minimally to the overall variance (as the latter may be dominated for instance by seasonal vegetation differences) it is often the case that such changes turn up in a higher order MAD component. This is because they will be uncorrelated with seasonal vegetation changes, stochastic image noise or other major contributions to the overall change signal. This in fact is one of the nicest aspects of the MAD method: It sorts different categories of change into different image components. Another very important characteristic of the MAD transformation is that it is invariant to linear transformations of the data. This means that if for example the sensors used for the two images have different gains, or if atmospheric haze attenuates the reflectance measurement in one of the images but not in the other, the results of the analysis will be unaffected.

A Bayesian model of the probability distribution of the MAD components intensities is applied to determine automatically the decision thresholds for change and no change. The prerequisite image-to-image registration is carried out automatically with the help contour and corner matching to determine ground control points, followed by nearest-neighbor resampling. The inclusion of higher resolution panchromatic information into the procedure without loss of spectral discrimination is accomplished via wavelet fusion with the multispectral channels. A computer program CDSAT (Change Detection with SATellite imagery), which implements a user-friendly graphical environment for performing the various steps involved, is described briefly.

The technique has been applied successfully to detect the exact position of an underground nuclear test in Rajasthan in 1998, Canty and Schlittenhardt [2001]. In the present paper we discuss further results for tests carried out in Lop Nor, China in the 1990's and at the Nevada test site in the 1980's. Historical LANDSAT TM satellite images are used for change detection. Results are correlated with seismic and ground truth data and conclusions are drawn regarding the applicability of wide area change detection to complement seismic verification of the Comprehensive Test Ban Treaty.

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