SAR image power calibration by urban texture: Application to the BAM Earthquake using Envisat satellite ASAR data

Babak Mansouri[1]*, Masanobu Shinozuka[2]

Abstract

It is expected that the detection accuracy is improved by scaling the Radar return for buildings orientations in each neighborhood with respect to a reference value. The focus of this paper is on the city of Bam because Envisat ASAR data was available for before and after the Earthquake that occurred on December 26th, 2003, and also because enough reconnaissance findings and high resolution optical image is available for the city to evaluate this research. The majority of buildings in Bam are one-story adobe structures. Therefore, it is expected that the related SAR images reflect less material dependent object detection. The related before and after complex SAR data sets are processed and coregistered. The cross-power values of before-before and before-after sets are computed mutually. Using the results from a SAR simulation case, the data is calibrated for the Sensor-Target orientation with respect to a reference orientation angle. By measuring and weighing the cross-power values of the data pairs a calibrated damage map is produced and compared with the results provided by field investigation and also the results of the previous workshop (*Mansouri et. al. 2004*).

Introduction

In the previous workshop it was shown that by comparing cross-power data of before and after event, it is feasible to create a damage map (*Mansouri, et. al., 2005*). In this study, two sets of before and after SAR data were used from the ASAR sensor of the Envisat satellite. The data are coregistered using a template matching technique. The complex data sets are processed and cross-power values from each two sets are computed. The next challenge is to compute and compare SAR image power levels within a small area (called window) that has the size of a typical building. Moreover, the Sensor-Target orientation plays a major role in the detection of cubical objects (i.e. buildings) that is the RCS (Radar Cross Section) is a strong function of azimuth and elevation in its imaging coordinate system. Therefore, it is desired to calibrate the response of the scene in each window with respect to a default orientation angle. The high-resolution optical Quickbird image of the region of interest is used to locate the buildings and their orientations. Each building cluster (zone) was chosen to indicate only one directional angle. In here, 38 dense urban zones or clusters were selected. Sparse building zones were either omitted or less emphasized.

The detection dominant geometrical shape of these buildings can be represented as dihedral corner reflectors. The RCS simulation of a dihedral corner reflector with 10m by 10m faces is performed that is comparable to the scene features in size, i.e. buildings. The change detection algorithm uses processed SAR values, the orbital information, the zonal building orientation as derived by the optical images (assumed a before event knowledge) and also the calibration curve from the simulation to assess the levels of change in different city zones. The damage maps derived from the Quickbird high-resolution

1) Visiting Researcher at UCI and Senior Project Scientist at ImageCat Inc., Long Beach, CA
2) Professor and Chairman, Department of Civil Eng. University of California Irvine UCI, Irvine, CA

optical images, the results from the reconnaissance team field observation, and the results from the previous research (Mansouri et. al. 2004) will be compared to the findings of this work.

Background

Urban environments can dominantly be represented by an arrangement of more and less regular geometrical shapes such as rectangular plates, dihedral and trihedral corner reflectors. Fig. 1 depicts the setup for a monostatic radar cross-section measurement from the same incident angle as the Envisat antenna. The vertical dihedral corner reflector represents a typical exterior wall adjacent to the pavement.

Table 1 - Envisat ASAR satellite and data specifications

Orbit	Sun-synchronous
Orbit Near Polar Inclination	98°
Orbital Period	101 minutes
Repeat Cycle	35 days
Altitude	800 km
Polarization	VV (for this study)
Radar Frequency Band	C-Band λ=5.6 cm
Incidence Angle	~ 22° at image center

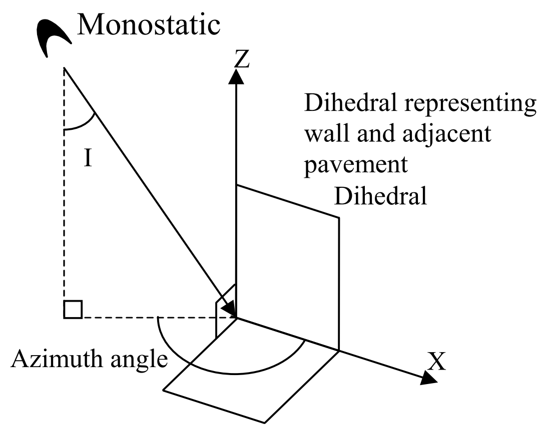


Fig. 1 - Geometric setup for RCS simulation of dihedrals

The case of ***VV*** polarization corresponds to the present data sets and the results from the Radar Cross Section (RCS) simulation is shown as follows.

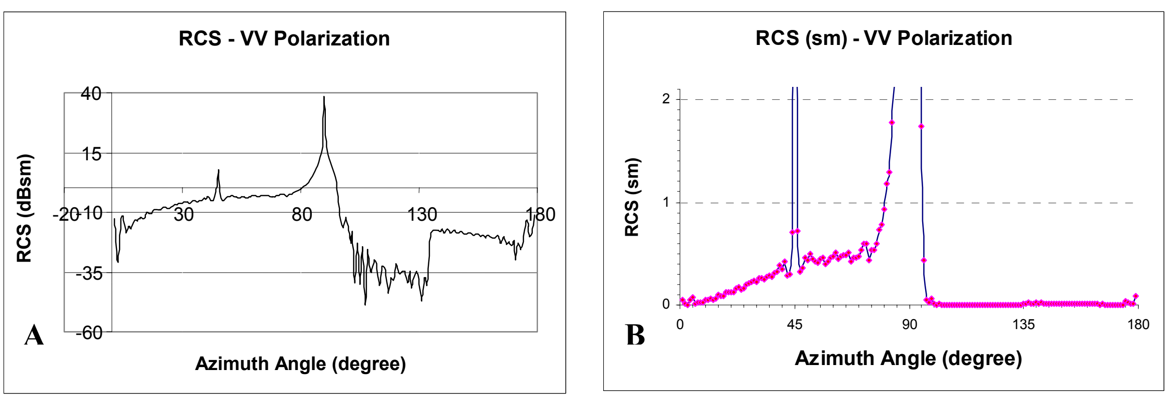


Fig. 2 - RCS simulated for concrete dihedral with 10m by 10m face size

Methodology and Results

For global applicability of this method, it is assumed that enough georeferenced high resolution optical images (aerial or satellite) is available for any region of interest. These data must be processed and RCS calibration weighing numbers must be assigned to each zones. If this process is performed before any disastrous event, excessive processing time and labor intensive work is saved for any intended future rapid post-disaster change/damage assessment objectives.

Creating Urban Zones

This step comprises of the creation of urban zones by building density and orientation via a georeferenced high-resolution image. In this study, the before event optical pan-sharpened Quickbird image acquired on 9/30/03 was used. The operator selects each neighborhood by creating a polygon and clicking on the mouse in a standard GIS or RS application. Each polygon represents a group of densely packed structures having similar orientations. This angle is assigned to the polygon. From the SAR orbit inclination (near polar with 98^o in here), side-looking position of the antenna, the ascending or descending imaging orbit of the satellite and the orientation assigned to each polygon, the SAR sensor-target azimuth angle is computed.

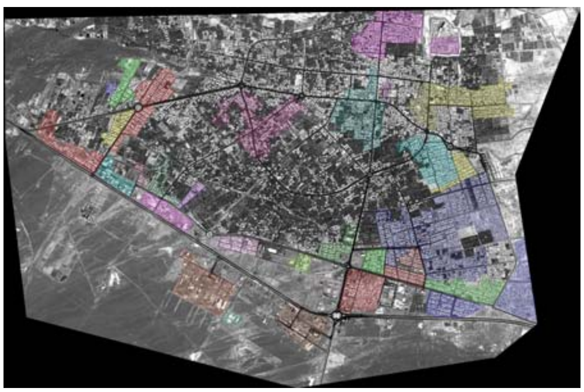


Fig. 3 – Urban Zones extracted from the before Quickbird pan-sharpened image of 9/30/03

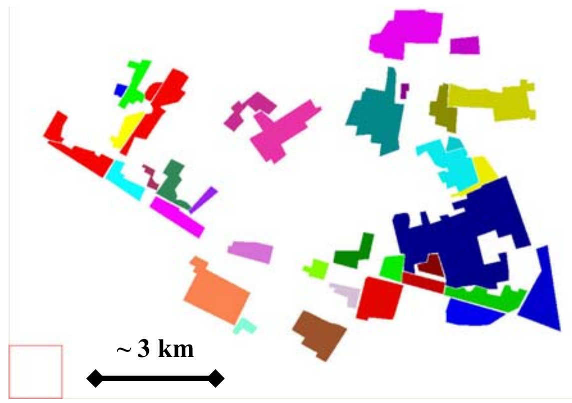


Fig. 4 – Urban Zones – Each zone indicates a similar building orientation

Creating a Calibration Mask

In here, calibration of individual zones using the simulated RCS model (Fig. 2) with respect to a reference value is performed. The product is a calibrated zonal map reflecting the zonal (polygonal) RCS correction coefficient. Also we call this a Calibration Mask.

Damage Detection Index

In this study, two data sets of before and after complex SAR data were used from the ASAR sensor of the Envisat satellite (same as was used in the previous workshop). The data are coregistered using a template matching technique. The complex data sets are processed and cross-power values from each two sets are computed. The computation is performed within a small area (called window) that has the size of a typical building (effective 3 pixels by 3 pixels). This will help to compromise for minute misregistration and also to improve building signature detection. Before-before and before-after cross-power image subtraction and thresholding yields to a change/damage map. This change detection map is then coregistered with the optical high-resolution image in order to compensate for minute image warping that usually occurs when the registration process involves different georeferenced images or techniques.

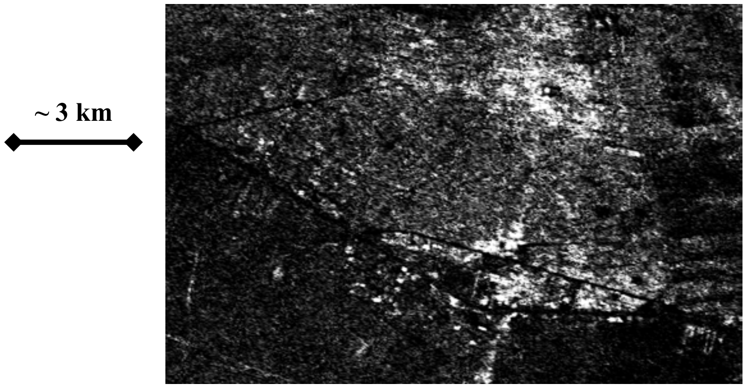
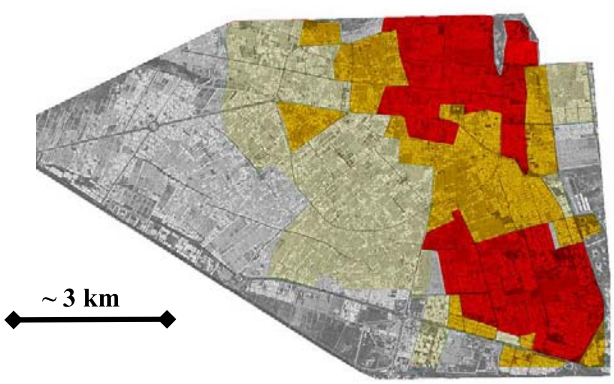


Fig. 5 – Cross-power difference map - Xp(Jun-11-03,Dec-3-03) - Xp(Jun-11-03,Feb-11-04) or Xp(Before I,Before II) – Xp(Before I,After II) - effective window: 3 pixels by 3 pixels

Calibration of Damage Detection Index

The result of masking and scaling the SAR coregistered difference map of the before-before and before-after cross-power map with the Calibration Mask is shown in bellow.

Fig. 6 – Calibrated cross-power difference map – values are reflected within each zone



Percentage of collapsed buildings within area	Zone
20 – 50%	Yellow
50 – 80%	Orange
80 – 100%	Red

Fig. 7 - Damage distribution map of Bam created by the National Cartography Agency of Iran is overlayed on the Quickbird optical imagery

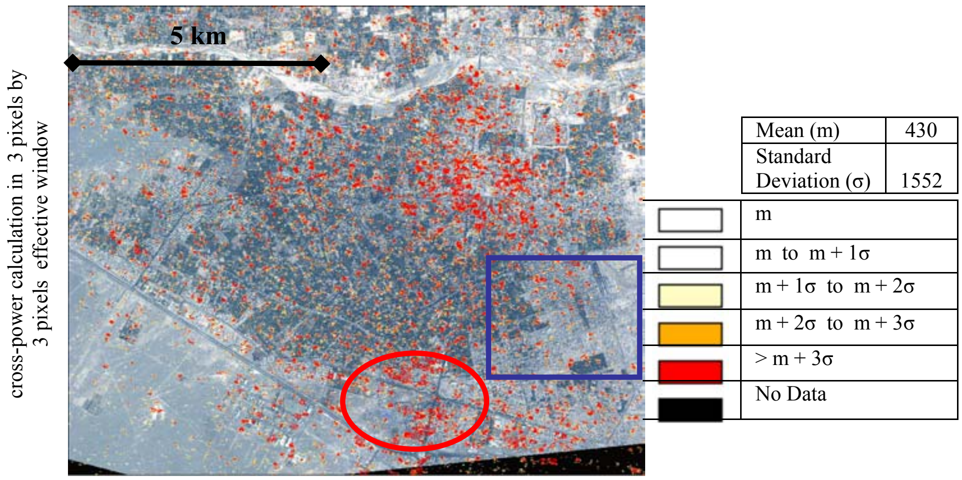


Fig. 8 – Difference in cross-power displayed from yellow (low) to red (high) overlaid on Quickbird image
The results of the earlier work (Mansouri et. al. 2004)

Conclusion

In earlier works (Mansouri et. al. 2004 and Mansouri et. al. 2005), it was shown that cross-power difference of before-before and before-after of a suitable interferometric SAR data pairs can create a change/damage map that explains geometric regional changes in Bam. However, some important zones of the city remained obscure to this index. In this paper, an improvement of the earlier method is explained that comprises of data calibration with respect to urban texture, more specifically the building orientations. As Fig. 6 shows and compares with Figs. 7 and 8 of the earlier work, the South East part of the city that was highly damaged is now detected successfully (depicted in a square in Fig. 6). Also, the change map in the Southern zones (depicted in a circle in Fig. 6) is corrected and reflecting minimal changes as validated by field observation.

Acknowledgment

The support of MCEER, EERI, UCI and Chiba University is appreciated. Envisat is owned by the European Space Agency and ASAR data for BAM was supplied for research purpose. Quickbird is owned by DigitalGlobe Co., Ltd. Quickbird data sets were licensed and provided by EERI and acknowledged.

Reference

- Mansouri B., Shinozuka M., Huyck C. K., and Houshmand B., "Earthquake-Induced Change Detection in Bam, Iran, by Complex Analysis Using Envisat ASAR Data", accepted on June 19, 2005 for publication in Earthquake Spectra, Earthquake Engineering Research Institute (EERI), Oakland, CA.

- Mansouri B., Shinozuka M., Huyck C. K., and Houshmand B., "SAR complex data analysis for change detection for the BAM Earthquake using Envisat satellite ASAR data", 2nd International Workshop on Remote Sensing for Post-Disaster Response, Oct. 7th & 8th, 2004, Newport Beach, California.