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

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Scope

- High resolution Optical image to visualize textures (manual)
- Simple urban model: unidirectional arrays of dihedral corner reflectors identify specific zones
- RCS simulation of a typical building size dihedral corner reflector - calibration curve
- Both Optical (pre_processing) and SAR remote sensing (pre_ & post_processing) for change detection
- Image processing and change detection algorithms developed
- Ground truth and earlier works (previous workshop) as reference validation/comparison
- Basis for future research – more sophisticated urban modeling, different location and data – Process Automation

Background

- Rapid diagnostic and damage assessment can potentially reduce both human and economic losses
- Earthquake induced change/damage is focused for BAM (Dec./26/2003 magnitude 6.5)
- Urban area change/damage detection algorithm uses Quickbird high resolution optical image & Envisat ASAR satellite data

Background BAM from space

Ikonos Satellite image (courtesy European Space Imaging)

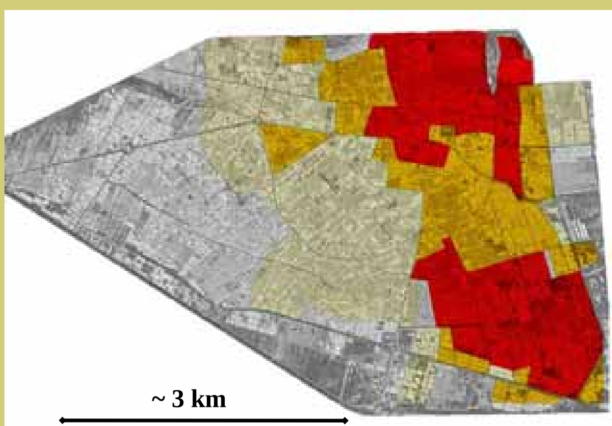
Background BAM from helicopter

(courtesy of Dr. Teymoorian)

Background BAM from helicopter

(courtesy of Dr. Teymoorian)

Damage observation ground truth



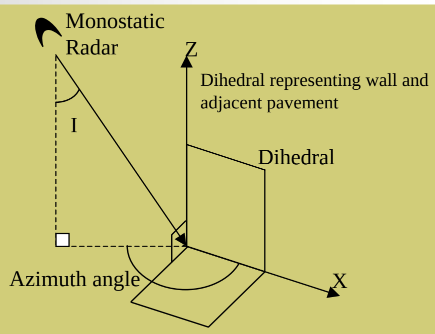
Percentage of collapsed buildings within area	Zone
20 – 50%	Yellow 1
50 – 80%	Orange 2
80 – 100%	Red 3

Observed Distribution of Building Damage in BAM overlayed on Quickbird optical image

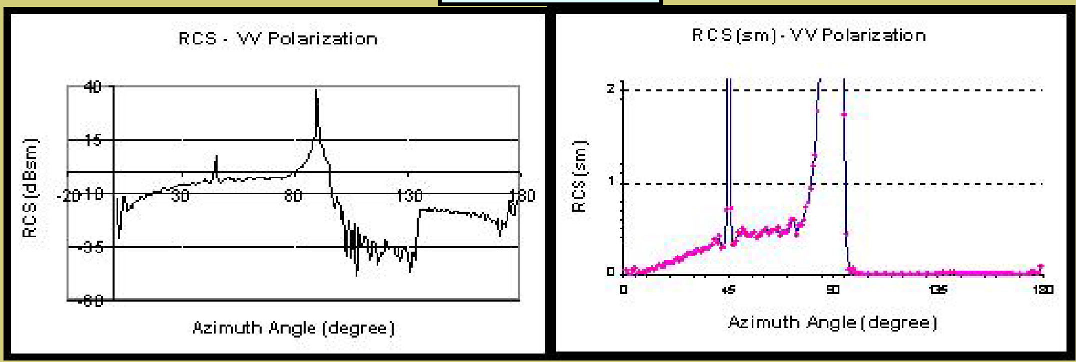
(Damage Distribution Map Courtesy of Iranian Cartography Agency)
(Quickbird image – courtesy of Digital Globe)

Method RCS Simulation

Monostatic polarization independent RCS Radar Cross Section for concrete corner reflectors:



Simulated RCS



Method algorithm

High resolution optical data:
Texture (array angle) assignment for individual zones

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Creating georeferenced Zonal map

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Simulated RCS curve:
Zonal calibration coefficient

Master SAR complex data

Slave SAR complex data

↓

Data co-registration and geo-referencing
-Envisat ASAR BEST toolbox
-Complex Template Matching algorithm

↓

SAR Cross-Power maps: Bef-Bef & Bef-Aft
Difference of "before-before" and "before-after" case
Coregisteration with optical data used

↓

Regional and zonal damage assessment:
Scaling of SAR X-Power difference maps

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Damage assessment result comparison using ground truth (observed data)

Method algorithm formulae

- SAR intensity: $$SAR = 10 \ \log_{10} \sqrt{(i^2 + q^2)}$$
- SAR cross-power: $$X\_power = \left| \sum_k \sum_l C_1 C_2^* \right|$$
- Coherence(complex): $$Coh = \frac{|\sum_k \sum_l C_1 C_2^*|}{\left[\sum_k \sum_l C_1 C_1^*\right]^{1/2} \left[\sum_k \sum_l C_2 C_2^*\right]^{1/2}}$$

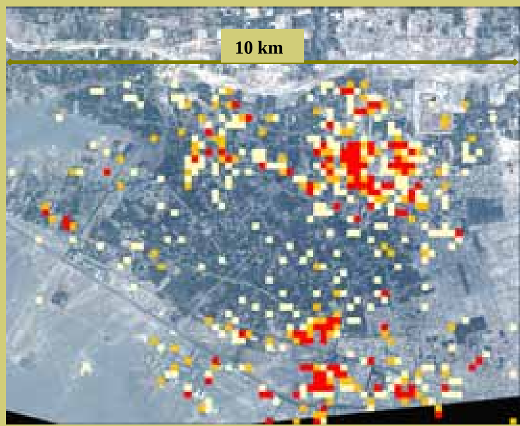
Method damage maps

- Corner reflector effect and Cardinal effect are significant in urban areas
- SAR self-power is high for corner reflectors
- SAR cross-power difference of Before-Before and Before-After as preliminary damage map

- RCS simulation as calibration curve
- High resolution optical => zonal orientation angle assignment
- RCS calibration curve to correct the damage map for each zone

Results cross-power difference

Damage map data Overlaid on Quickbird images



Difference in cross-powers displayed from yellow (low) to red (high) (color sliced by standard deviation differences)

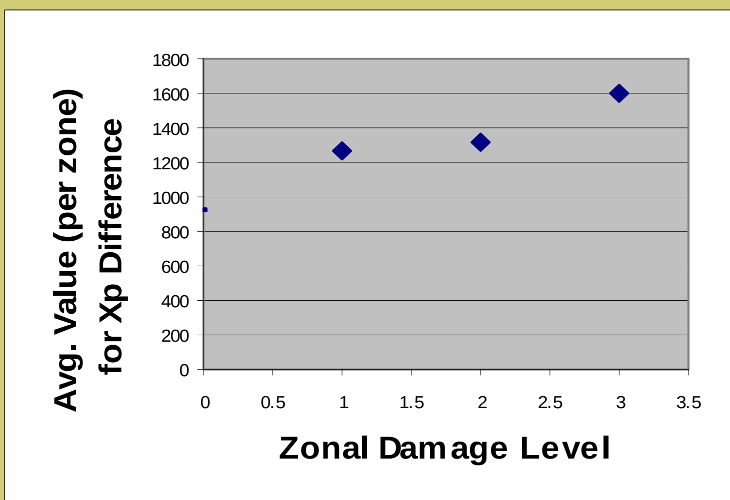
Xp(Jun-11-03,Dec-3-03) - Xp(Jun-11-03,Feb-11-03)

3x3 effective window size

Block statistics average of difference in cross-powers

(25 pixels by 25 pixels aggregation) Block Statistics

Results cross-power difference

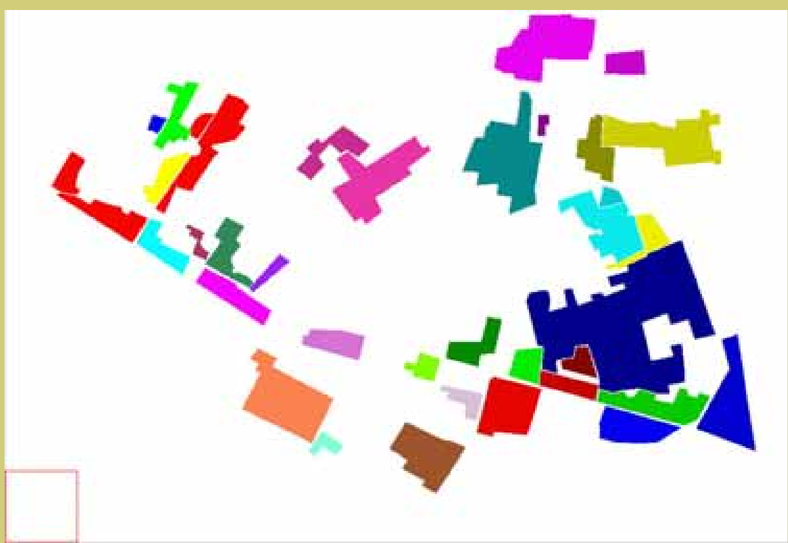


Aggregation (average) of the cross-power difference computed within the same GIS polygons (zones) of the observed damage for Bam

Results Quickbird – Zonal map

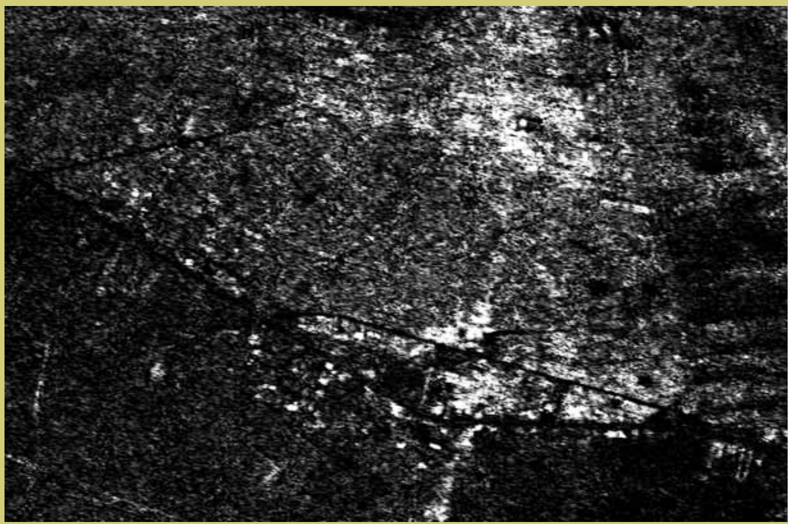
Urban Zones extracted from the before Quickbird pan-sharpened image of 9/30/03

Results cross-power difference



Urban Zonal Map – Each zone indicates a similar building orientation

Results cross-power difference

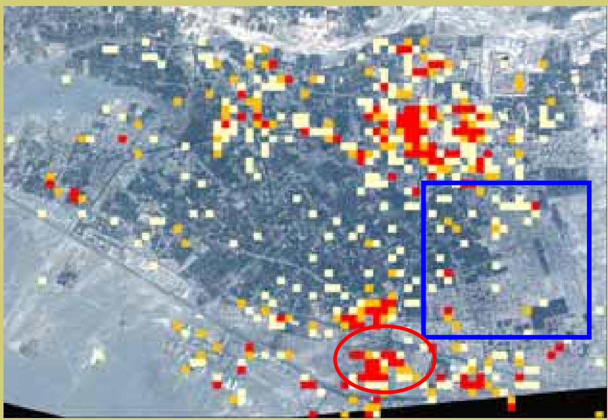


Cross-power difference map - Xp(Jun-11-03,Dec-3-03) - Xp(Jun-11-03,Feb-11-04)
or Xp(Before I,Before II) – Xp(Before I,After II)
Effective window: 3 pixels by 3 pixels

Results cross-power difference

Calibrated cross-power difference map
values are reflected within each zone

Results cross-power difference



Block statistics average of difference in cross-powers

Calibrated cross-power difference map

"False Alarm" corrected in Damage Detection sense

Damage Detection improved

Conclusion/discussion

- Algorithms : RCS calibration of Cross-power difference of bef-bef & bef-aft
- Building size and orientation knowledge used for calibrating SAR returns for each city blocks – High Res. Quickbird image used
- Calibrated Cross-power difference map successful for direct urban feature damage assessment
- All hard hit areas detected - improvement to earlier work [ref. 2]
- SAR damage maps acceptable match to observation map
- Vegetation limits damage detection in general - limitation improved by pre-processing and urban masking using high resolution optical image
- SAR remote sensing techniques effective in post-earthquake damage detection

Acknowledgment

- Chiba University – Japan
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- Earthquake Engineering Research Institute (EERI)
- University of California Irvine (UCI)

Reference

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

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

3. "Building change/damage detection in Seymen-Turkey using ERS SAR data", B. Mansouri, B. Houshmand, and M. Shinozuka, Submitted for SPIE 2001, 8th Annual International symposium on Smart Structures and Materials, Newport Beach, CA, Spie paper number: 4330-03.

4. "Damage detection in urban areas by SAR imagery," M. Shinozuka, R. Ghanem, B. Houshmand, and Babak Mansouri, Journal of Eng. Mech. ASCE 2000, April, 2000, pp 769-777.

5. "Feasibility of damage/change detection in civil structures by SAR imagery: Proof of concept study using SAR simulation," M. Shinozuka, R. Ghanem, B. Houshmand, and B. Mansouri, SPIE 2000 conference, Newport Beach, California.