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

Damage observation  

ground truth

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

<table>
<thead>
<tr>
<th>Percentage of collapsed buildings within area</th>
<th>Zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 – 50%</td>
<td>Yellow 1</td>
</tr>
<tr>
<td>50 – 80%</td>
<td>Orange 2</td>
</tr>
<tr>
<td>80 – 100%</td>
<td>Red 3</td>
</tr>
</tbody>
</table>

~ 3 km

(Damage Distribution Map Courtesy of Iranian Cartography Agency)  
(Quickbird image - courtesy of Digital Globe)
Monostatic polarization independent RCS
Radar Cross Section for concrete corner reflectors:

Simulated RCS

- RCS (VV Polarization)
- RCS (HH Polarization)

Method algorithm

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

Creating georeferenced Zonal map

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 coregistration with optical data used

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

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: \( X_{\text{power}} = \left| \sum_{k} \sum_{l} C_k C_l^* \right| \)

- Coherence (complex): \( Coh = \frac{\left| \sum_{k} \sum_{l} C_k C_l^* \right|}{\left[ \sum_{k} \sum_{l} C_k C_l^* \right]^{1/2} \left[ \sum_{k} \sum_{l} C_k^* C_l \right]^{1/2}} \)

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

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

\[ X_{p(\text{Jun-11-03,Dec-3-03})} - X_{p(\text{Jun-11-03,Feb-11-03})} \]

Block statistics average of difference in cross-powers

(25 pixels by 25 pixels aggregation)

Block Statistics

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

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

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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.


