SIMPLIFIED SAR SIMULATION FOR REMOTE SENSING URBAN DAMAGE ASSESSMENT

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ABSTRACT :

This paper focuses on the feasibility of seismic damage detection in urban areas using Envisat Advanced Synthetic Aperture Radar (ASAR) product in conjunction with GIS (Geographic Information System). This sensor produces images with 20 m ground resolution in its Single Look Complex (SLC) imagery mode. Considering this, the fine details of the buildings cannot be detected. But, the signatures of the overall building geometry can be detected. The results of SAR simulations serve to better understand the Synthetic Aperture Radar (SAR) imagery in urban settings and also useful in calibrating highly orientation-sensitive (sensor-target) SAR damage detection indices for earthquake prone locations. In this research, the city of Bam that was devastated by the 2003 earthquake, and the district 17 of Tehran that is prone to potential earthquakes are chosen as the study areas for evaluating the methodology. An urban model is proposed for SAR detection that is based on the radar return from right angle reflectors with various heights and orientations, considering a range of sensor-target directions variations. Specifically, a “Wall Model” (or edge model) is evaluated in here and implemented using urban databases. The results show that important building signatures can be modeled in GIS and detected from the remote sensors as a necessary phase in SAR change/damage detection knowledge and calibrations.

1. INTRODUCTION

Although Envisat-ASAR SLC product is named as “High Resolution” satellite SAR images in remote sensing jargons, but considering the ground resolution of about 20m, building details cannot de detected. Therefore, considering the relative coarse resolution, building signatures that are most relevant in SAR detection in urban settings are of interest. Radar Cross Section (RCS) that is a measure of radar backscattering value are simulated first for typical features (reflectors) using a predefined geometry, electromagnetic properties of the materials and for different antenna-object orientations. These reflectors are formed in reality by the external walls (or the parapets) and the ground (or the flat roofs). In GIS, important geometrical features such as the visible corners and the external walls of the buildings are extracted from the geodatabase. This phase of analysis is assumed to be accomplished before the occurrence of any disasters when enough ground information and urban data can be gathered and refined. By evaluating the LOS (Line Of Sight) of the radar, the satellite orbit inclination, the look angle and the relative orientation of the visible walls (or edges), and considering the pre-simulated angle-dependent RCS curves, a simplistic urban SAR image is simulated. By analyzing the geodatabase, all the external building walls that are most visible and intersect effectively with the rabar beam are selected. Their size and their orientation play major role in the detection (bouncing back to the sensor).

KEYWORDS: SAR simulation, remote sensing, damage assessment, GIS, corner reflector

This process serves also in generating calibration vectors in GIS that are useful in correcting the results of SAR change indices (when comparing the before and after event change indices) obtained from the real sensor such as the case of Envisat-ASAR. In order to evaluate the location, the extent and the severity of the potential earthquake damage, adequate adjustments have to be made to damage indices extracted from the SAR data.

2. METHODOLOGY

Previously, orientation based calibration curves were introduced for SAR damage indices for the BAM earthquake using simulated RCS curves and high resolution optical data such as Quickbird images (mansouri et al. 2005) and similarly for Tehran (mansouri et al. 2006). This calibration masks were produced at building block levels demonstrating the overall zonal texture orientation. But, in this research high resolution city inventory data in conjunction with more sophisticated GIS analysis served in producing calibration layer at parcel level accuracy.

The methodology involves the following major steps:

I. *Acquisition of suitable high-resolution parcel level city data including attributes.*
II. *Geodatabase design & implementation.*
III. *Development of a GIS including "3D analysis" & "Geoprocessing" to extract the visible building edges or walls from the satellite point of view and discarding obscured parts.*
IV. *Using "ArcObjects" & "Visual Basic for Application VBA" for extracting corners' bisectors and their aspect angles with respect to the satellite Line-Of-Sight LOS.*
V. *Geodatabase compilation of the corner inventory.*
VI. *Production of Radar Cross Section simulated curves using electromagnetic computer codes.*
VII. *Calibration layer generation using the above.*
VIII. *Acquisition of SAR data for the area of interest.*
IX. *Pre-processing of the SAR data sets to compute and produce the related indices suitable for change detection.*

In the following sections the processes involved in this research are described.

2.1. Urban Data – BAM

Digital 1:2000 scale map (gathered before year 1995) of Bam that was extracted from aerial stereo-photography was entered in the geodatabase. To update the data, the quickbird images of 2003 (before Bam earthquake) and 2004 (after Bam earthquake) served as to extract building footprints and to complement the database as seen in Figure 1-a. A survey data was gathered after the BAM earthquake and presented in about 1450 zones (building block) as shown in Figure 1-b.

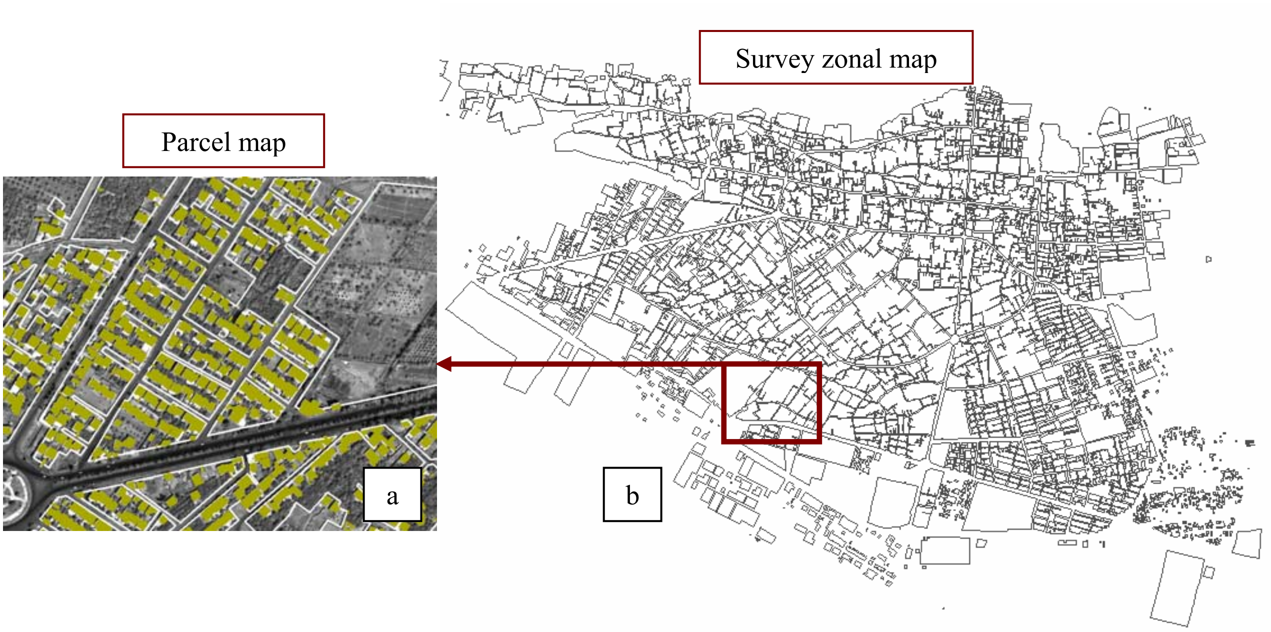

Figure 1 Survey zones created after the Bam earthquake in GIS and detail parcel information extracted from ancillary digital maps

2.2. Urban Data – Tehran District 17

An urban database with parcel information is developed from the city CAD files that are extracted from 1:2000 scale aerial photos (stereography processing). The geo-database includes fine topography pronouncing building heights. City survey data (courtesy of EMCO consultant company Iran) is also used for developing detailed attribute information and to complement the geodatabase. Figure 2 shows the 3D map of the buildings distributed in district 17 of Tehran.

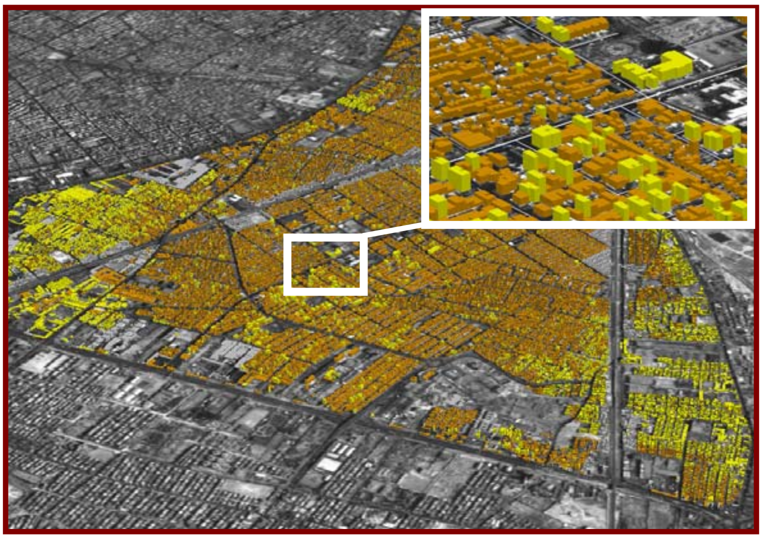

Figure 2 City parcel detail in GIS - extracted from ancillary digital maps and survey data

2.3. RCS Simulation

A computer code has been utilized to simulate the RCS value using electromagnetic laws in far field describing the high orbital altitude of the satellite. The simulation is performed for VV polarization and for each 1 degree azimuth angle increment to cover a full range of possibilities according to Figure 3. This simple reflector shape imitates the external wall-ground combination. As can be imagined such reflectors intercept the radar beam effectively. The effective area intercepting the beam is a function of the incident and azimuth angle and also the wall-ground area. Figure 4 is the computed RCS value (in square meters) with respect to the azimuth angles.

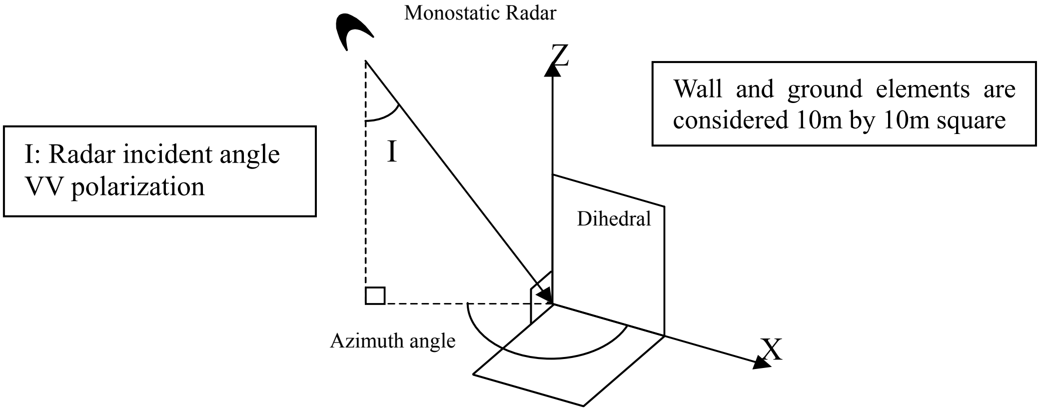

Figure 3 wall-ground (vertical dihedral corner reflector) set up for electromagnetic RCS simulation

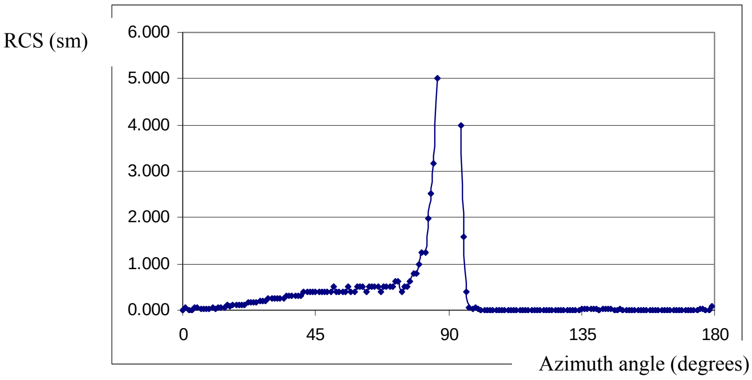

Figure 4 VV polarization angle dependent RCS simulation result related to Figure 3 setup

2.4. Implementing in GIS

In order to apply the method for each parcel, the database (parcel records) was refined as to filter out all the buildings that are obscured. Moreover, analyzing each building footprint sides and corners, and considering different angles shown in Figure 5, an automated process selects the most radar detectable walls of the building. The corresponding azimuth angle is stored for each parcel record as seen in Figure 6. Then, the dedicated algorithm estimates the SAR signature based on the angle dependent RCS values for each parcel then computes the calibration mask.

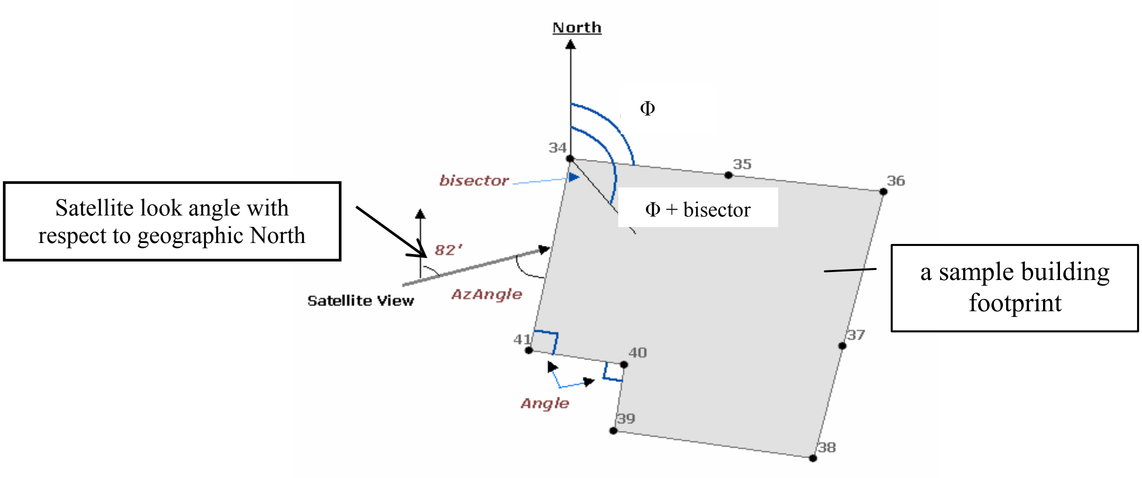

Figure 5 Computation of wall azimuth angles with respect to satellite view angle

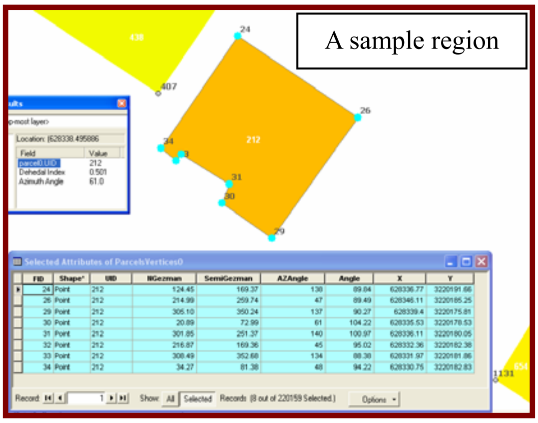

Figure 6 Geodatabase analysis: building corners and walls identification with azimuth angle computation

2.4. SAR Data

Envisat ASAR SLC data was acquired for both Bam and Tehran. Interferometric data sets are most useful when similar SAR images or SAR indices must be compared in different time. These data posses similar look and incident angles and also used for the case of seismic change detection. Four VV polarized interferometric image pairs were acquired for Bam. Table 1 shows the acquisition dates and the interferometric baseline components. Similarly, 4 interferometric data were obtained for Tehran as tabulated in Table 2.

Table 1 Interferometric data pairs acquired for BAM (VV polarization)

Interferometric pair images		Perpendicular Baseline (m)	Parallel Baseline (m)
June 11, 2003	Dec. 3, 2003	473.21	147.98
June 11, 2003	Jan 7, 2004	990.24	422.50
June 11, 2003	Feb. 11, 2004	476.12	133.22
Dec. 3, 2003	Jan 7, 2004	516.85	275.12
Dec. 3, 2003	Feb. 11, 2004	59.06	14.76
Jan 7, 2004	Feb. 11, 2004	519.08	289.88

Table 2 Interferometric data acquired for Tehran (VV polarization)

Mission Date	Perpendicular Baseline (m)	Parallel Baseline (m)
August 3, 2003	0	0
June 13, 2004	544	-186
August 22, 2004	107	-45
April 24, 2005	855	-365

3. RESULTS

For the case of Bam, the azimuth angles are attributed to the parcel record. Figure 7 shows the entire city, the optical very high resolution data as the base map and the color-coded parcels reflecting the azimuth angle. Angles around 82 degrees are close to the maximum radar reception in general. Now in order to compare this with the actual SAR data a SAR image power is constructed. The resolution for the SAR Single Look Complex (SLC) data is 4 meters in azimuth and 20 meters in range. The power image depicted in Figure 8 was first multi-looked in azimuth by a factor of 5 so the final squared pixel measures 20 meters (on ground) in both sides. Similarly, Figure 9 and Figure 10 are obtained for Tehran district 17.

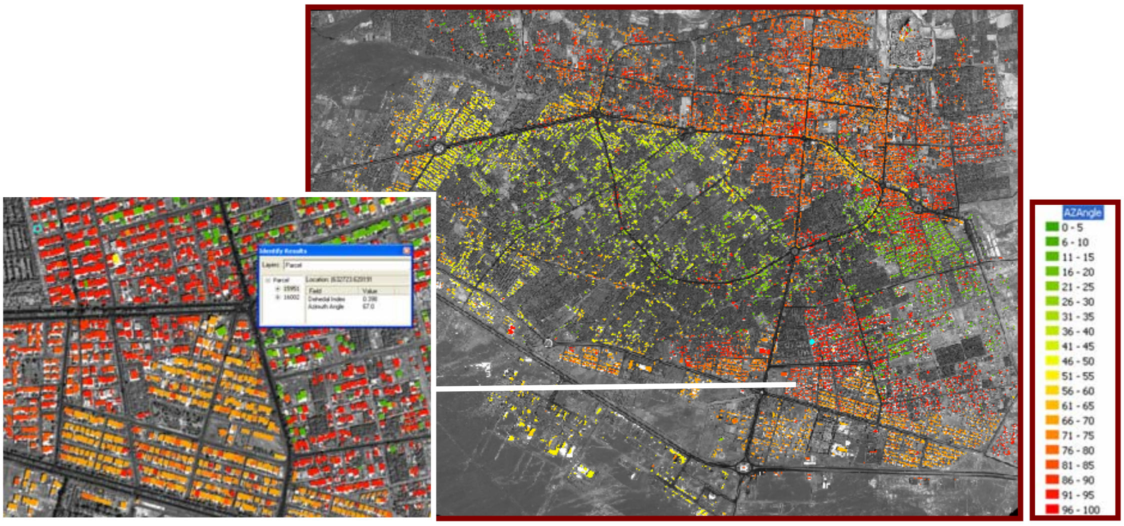

Figure 7 Simplified SAR for the most visible walls – Bam

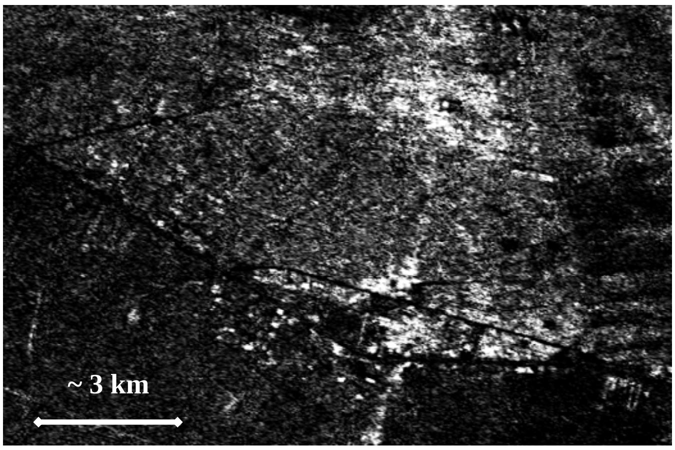

Figure 8 SAR multi-look power image – Bam

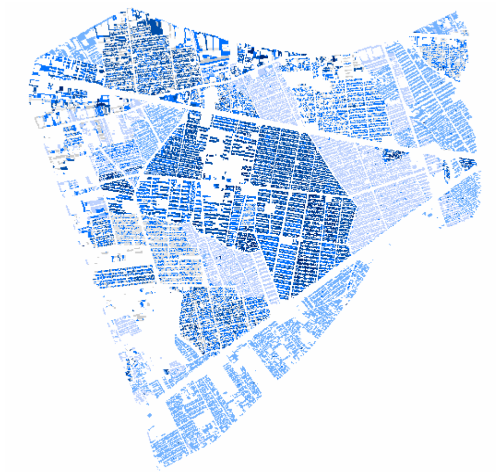

Figure 9 Simplified SAR – Tehran district 17

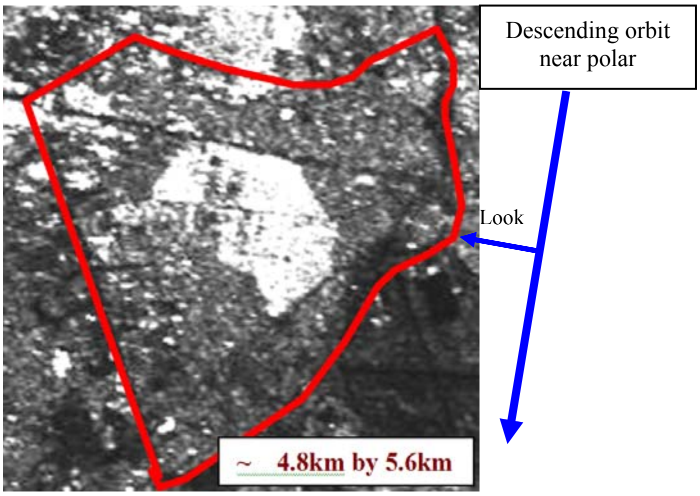

Figure 10 SAR multi look power image– Tehran district 17

5. CONCLUSION

Using our methodology, we have upgraded the city database for Bam and Tehran district #17 using 1:2000 scale digital maps and ground survey data. This database includes updated building inventory at parcel level resolution including height information. The database was analyzed and the simplified SAR return maps for the areas of study were formed based on the visibility of the building external walls and their azimuth orientation with respect to the imaging sensor. In order to compare the simulation cases with the actual data, SAR power images were constructed for the study areas. The results of simulations compare well with the SAR data in general. That is urban settings behave likely as the arrangement of oriented walls in the eye of the radar sensors. There are numerous other urban features that can be detected in radar remote sensing. To name a couple of such features, metallic objects such as cars and right angle trihedral corners have very bright signatures. Considering the Envisat ASAR ground pixel size that is about the size of a building, smaller details are unlikely to be revealed. In seismic rapid damage detection schemes, these knowledge, although rough, help in understanding the SAR return from buildings and will help in creating calibration masks to leverage the values associated to damage indices that can be obtained from SAR imageries. In order to calibrate these indices relative to the site, a weighting layer have been generated that are based on modeled RCS from visible building edges according to the satellite position with respect to the scene.

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