

*5th International Workshop on Remote Sensing Applications to Natural Hazards
10-11th September 2007 Washington DC
Standardizing Remote Sensing-based Damage Assessment*

SAR Remote Sensing for Urban Damage Assessment for Tehran

Babak Mansouri, Disaster Management Dept., IIEES, mansouri@iiees.ac.ir

Masanobu Shinozuka, Department of Civil Eng. UCI, shino@uci.edu

Reza Nourjou, Disaster Management Dept., IIEES, nourjour@gmail.com

ABSTRACT

This paper describes the methodology used in an active research project at the International Institute of Earthquake Engineering and Seismology. It focuses on the damage detection using Envisat ASAR product in conjunction with GIS applications developed for Tehran. An urban model is proposed for SAR processing that is based on the radar return from right angle reflectors with various heights and orientations considering a range of sensor-target directions variations. The study area is district 17 of Tehran municipality since it has been reported to have the highest potential of loss due to predicted earthquakes.

An urban database with parcel information is developed from the city CAD files that are extracted from aerial photos (stereography processing). The geo-database includes fine topography pronouncing building heights. All these form the inventory data in terms of building geometry. City survey data is also used for developing detailed attribute information and to complement the geodatabase.

Four multi-temporal radar data sets have been purchased and the backscattering, complex coherence, self-power and cross-power values are preprocessed, stored and made ready for damage detection analysis (as standby). The idea is that after a devastating earthquake and receiving a suitable SAR data, damage assessment can be performed in the least amount of time. The change detection algorithm on remote sensing data is operational in GIS where all inventory and urban model data are stored and preprocessed.

INTRODUCTION

In this research, different SAR based change detection indices such as the backscattering, complex coherence, self-power and cross-power values are considered for Tehran. Radar Cross Section (RCS) for typical reflectors is simulated using a predefined geometry, electromagnetic properties the materials and for different antenna-object orientations. These reflectors are formed in reality at the intersections of the parapet's corners and the flat roof or formed by the external walls (or the parapets) and the ground (or the flat roofs).

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. SAR Radar Cross Section (RCS) is highly dependent on the object-sensor orientation in its imaging geometry setup. A simplistic model of urban areas is considered for SAR damage indices. A calibration layer is derived from the detailed geodatabase that has been extracted from parcel information. The top corners of the buildings in this district, usually represent 4 corner reflectors. By the evaluation of the satellite orbit inclination, look angle and the relative orientation of the above mentioned corners, and considering the angle-dependent RCS curves, a calibration layer is produced in GIS. That is the orientation of the buildings with respect to the line of sight of the Radar sensor is modeled by the relative aspect angle of each building corner. Similar process has been devised for wall-ground (or parapet-roof) geometries.

METHODOLOGY

Previously, orientation based calibration curves were introduced for SAR data damage indices for the BAM earthquake using simulated RCS curves and high resolution optical data such as Quickbird images [1] and similarly for Tehran [2]. This calibration masks were produced at building block levels demonstrating the overall zonal texture orientation.

In this research we use high resolution city inventory data in conjunction with more sophisticated GIS analysis to produce calibration layer at parcel level accuracy.

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The methodology involves the following major steps:

- a) Acquisition of suitable high-resolution parcel level city data including attributes.
- b) Geodatabase design & implementation.
- c) Development of a GIS including “3D analysis” & “Geoprocessing” to extract the visible building corners from the satellite point of view and discarding obscured parts.
- d) Development of a GIS including “3D analysis” & “Geoprocessing” to extract the visible building edges from the satellite point of view and discarding obscured parts.
- e) Using “ArcObjects” & “Visual Basic for Application VBA” for extracting corners’ bisectors and their aspect angles with respect to the satellite Line-Of-Sight LOS.
- f) Geodatabase compilation of the corner inventory.
- g) Calibration layer generation using RCS simulated curves.
- h) Acquisition of SAR data for the area of interest.
- i) Pre-processing of the SAR data sets to compute and produce the related indices suitable for change detection.
- j) Development of a Ready-To-Operate system based on the developed GIS to generate calibrated damage maps by rapid processing of an “after event” SAR data set.

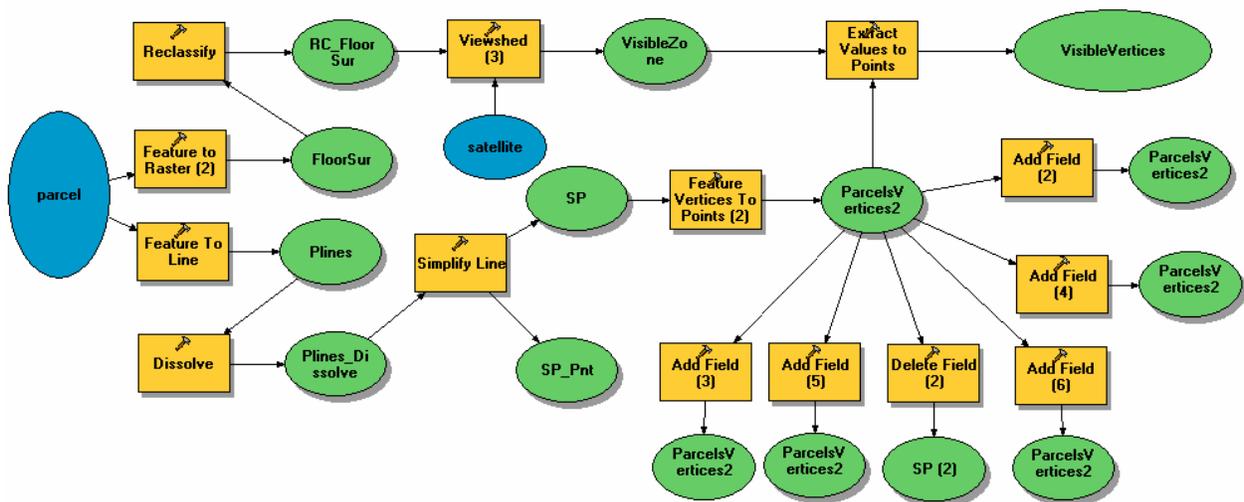


Fig. 1 – Modeling with Geoprocessing tools in GIS

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Fig. 1 shows the work flow related to some part of the modeling process in GIS. This modeling is used in generating a calibration layer. It is also used as a basic step for our simplified site specific SAR return model. In here, perceivable (by the satellite) parcel vertices are extracted and the associated corner geometry is obtained from the parcel data. Then, our dedicated algorithm estimates the SAR return based on the angle dependent RCS values for each corner and computes the calibration layer. Similar conceptual modeling is performed for the building edges. These two general modeling are named as “Corner Model” (Trihedrals) and ”Edge Model” (Dihedrals).

Fig. 2 shows the Land Use map of Tehran comprising of 22 municipality districts. Four VV polarized Envisat ASAR interferometric images of Tehran were acquired according to “Track: 2378” and “Frame: 2889” as it follows:

Table 1 – General Description of the SAR data Sets from Envisat ASAR – descending orbit

Mission Date	Orbit	Parallel Baseline	Perpendicular Baseline	Delta Days
20030803	7446	0	0	0
20040613	11955	-186	544	315
20040822	12957	-45	107	385
20050424	16464	-365	855	630

RESULTS

The resolution for the SAR Single Look Complex (SLC) data is 4 meters in azimuth and 20 meters in range. The data was first multi-looked in azimuth by a factor of 5 so the final squared pixel measures 20 meters (on ground) in both sides. A process of automated georegistration has been applied to the complex data sets. Then, by averaging the first three georeferenced data sets, a temporal multi-look image has been generated (as seen in Fig. 3). This process reduces the speckle noise without worsening the spatial resolution. For SAR extracted damage indices (self power, cross power and coherence), 3x15 complex filtering processes are applied to the SLC data [1,2].

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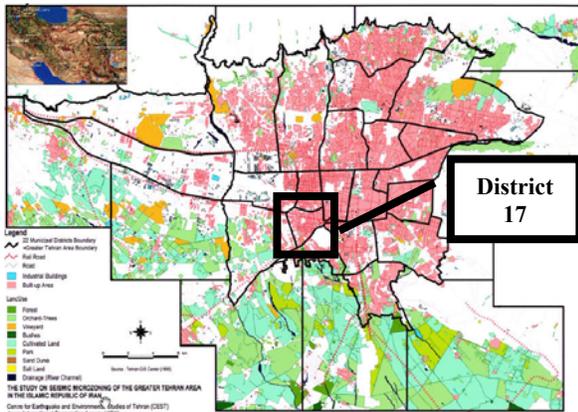


Fig. 2 - Tehran Land Use Map – courtesy of TGIS & JICA

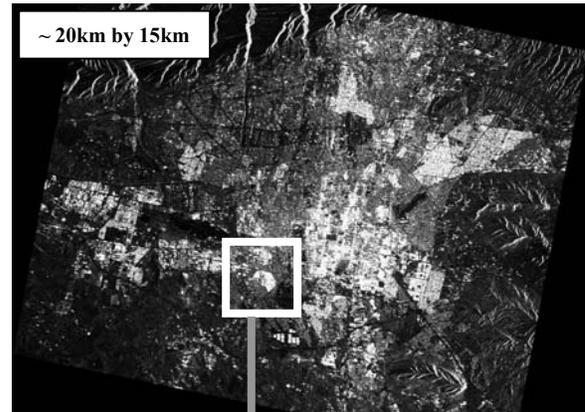


Fig. 3 - Tehran SAR Power Map – Multi-Look



Fig. 4 - Tehran District 17 – Courtesy of Google Earth



Fig. 5 - Tehran District 17 SAR Power Map – Multi-Look

Fig. 4 and Fig. 5 show zonal building patterns and their related SAR returns. In order to investigate the geometry of the patterns and the radar returns, two separated simplified radar detection image have been generated using city parcel data in GIS. This simulation is first performed by taking into account the geometry of the corners of the buildings and second, by considering the edges representing the external wall orientations of the parcels. The results are depicted in Fig. 6 and Fig. 7. As clearly seen and compared with the RCS curves, for the corner modeling, the maximum return corresponds to 45 degrees orientation with respect to the look angle. Whereas for the edge model, parallel arrangement of the buildings with the look direction show

stronger detection. The hybrid model will take both models into account by calibrating and weighing the contribution of these two and producing a resultant value for each parcel. The latter will be used as our calibration layer for damage indices.

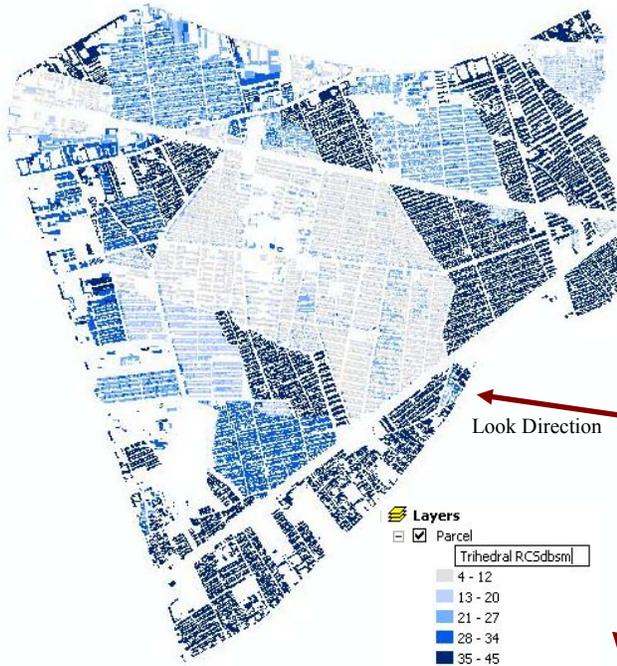


Fig. 6 - District 17 SAR return by Corner Model

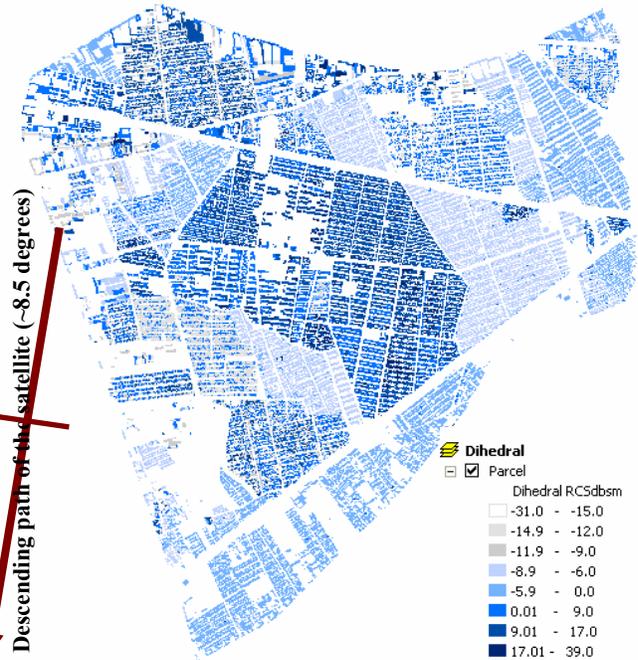


Fig. 7 - District 17 SAR return by Edge Model

Conclusion

Using our methodology, we have upgraded the city database for Tehran district #17. This database includes updated building inventory at parcel level resolution including height information. Four Envisat SAR data have been processed for the area of interest and radar change indices such as self power, cross-power and coherence values have been produced. In order to calibrate these indices relative to the site, two different weighting layers have been generated that are based on modeled RCS from visible building corners and edges according to the satellite position with respect to the scene. The comparison between these models shows that the Edge Model has more overall pronounceable information for the selected site. Nevertheless, the Corner Model will give more minute detail about the parcels. A hybrid model is under development to incorporate both aspects.

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The hybrid layer will be applied to the change detection indices to create calibrated damage maps after a disastrous event.

Reference

- [1] *Babak Mansouri, and Masanobu Shinozuka*, “SAR image calibration by urban texture: Application to the BAM earthquake using Envisat satellite ASAR data”, 3rd International Workshop on Remote Sensing for Post-Disaster Response, 12th and 13th September 2005, Chiba, Japan.

- [2] *Babak Mansouri*, “Remote Sensing and GIS Applications for Urban Risk and Disaster Management for Tehran”, 4th International Workshop on Remote Sensing for Disaster Response (Technology application and deployment for disaster management) 25-26th September 2006, Cambridge, UK

- [3] *Babak Mansouri, and Masanobu Shinozuka*, “Systematic Progress in Earthquake Change Detection in Built Environment Using Satellite Data: From Izmit(1999) to Bam(2003)”, First International Conference on Integrated Natural Disaster Management – INDM – 2006 – Tehran.