Remote Sensing to assessment aftermath of earthquake damages, focusing in Urban Structures

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M A E A R T E - Institute Mario Gulich
1 Justification

2 Contents
   - Why urban areas
   - Knowledge
   - Latest Charter activations
   - Methods and techniques to assess

3 Conclusions
Earthquake disaster is one of the most serious natural disasters, is the second problem in order of importance from disaster of evolution fast.

March 25: Guatemala y El Salvador ML (6.2; 5.8 y 4.9)
The last hundred years the CRED\textsuperscript{1}, has posted the percentage of deaths for earthquakes was around 2.2\% over than storms, volcanic eruptions, landslides, avalanches and forest fires.

\footnote{CRED: The Centre for Research on the Epidemiology of Disasters www.cred.be/emdat}
By the middle of the 21st century, the urban population will almost double, increasing from approximately 3.4 billion in 2009 to 6.4 billion in 2050.²

²United Nations, 2011
Earthquake:

Is a sudden vibration or trembling in the Earth. More than 150,000 tremors strong enough to be felt by humans occur each year worldwide. Most earthquakes are produced along faults, tectonic plate boundary zones.

Lima: The epicenter is the location on the surface directly above the earthquake’s focus. The focus is superficial, when it occurs (up to 70 km deep). If occurs between 70 and 300 km is called intermediate and if greater depth:
**Magnitude:**

Measures by seismographs. Richter logarithmic scale.

Local magnitude (ML), commonly referred to as “Richter magnitude;”
Surface-wave magnitude (Ms);
Body-wave magnitude (Mb); and
Moment magnitude (Mw).

All magnitude scales should yield approximately the same value for any given earthquake.
Intensity:

Refers to 12 levels of Modified Mercalli intensity. It is expressed in Roman numerals. This scale is proportional, if it is IV is twice II. Measures the strength of shaking produced by the earthquake at a certain location. Intensity is determined from effects on people, human structures, and the natural environment.
### Escala de Mercalli

<table>
<thead>
<tr>
<th>Nivel</th>
<th>Descripción (Español)</th>
<th>Descripción (Richter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Casi nadie lo ha sentido.</td>
<td>2,5 En general no sentido, pero registrado en los sismógrafos.</td>
</tr>
<tr>
<td>II</td>
<td>Muy pocas personas lo han sentido.</td>
<td>3,5 Sentido por mucha gente.</td>
</tr>
<tr>
<td>III</td>
<td>Temblor notado por mucha gente que, sin embargo, no suele darse cuenta de que es un terremoto.</td>
<td>4,5 Pueden producirse algunos daños locales pequeños.</td>
</tr>
<tr>
<td>IV</td>
<td>Se ha sentido en el interior de los edificios por mucha gente. Parece un camión que ha golpeado el edificio.</td>
<td>6,0 Terremoto destructivo.</td>
</tr>
<tr>
<td>V</td>
<td>Sentido por casi todos; mucha gente se despierta. Pueden verse árboles y postes oscilando.</td>
<td>7,0 Terremoto importante.</td>
</tr>
<tr>
<td>VI</td>
<td>Sentido por todos; mucha gente corre fuera de los edificios. Los muebles se mueven, pueden producirse pequeños daños.</td>
<td>8,0 Grandes terremotos. o más</td>
</tr>
<tr>
<td>VII</td>
<td>Todo el mundo corre fuera de los edificios. Las estructuras mal construidas quedan muy dañadas; pequeños daños en el resto.</td>
<td></td>
</tr>
<tr>
<td>VIII</td>
<td>Las construcciones especialmente diseñadas dañadas ligeramente, las otras se derrumban.</td>
<td></td>
</tr>
<tr>
<td>IX</td>
<td>Todos los edificios muy dañados, desplazamientos de muchos cimientos.</td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>Muchas construcciones destruidas. Suelo muy agrietado.</td>
<td></td>
</tr>
<tr>
<td>XII</td>
<td>Destrucción total. Se ven ondulaciones sobre la superficie del suelo, los objetos se mueven y voltean.</td>
<td></td>
</tr>
</tbody>
</table>

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3 Differences between scale of measures. Physical.net
Worldwide distribution of earthquakes
Damages assessment:

Is the determination of quantitative or qualitative value of damages related to a concrete situation. Includes before and after.

\[ P_D \% = \frac{NDB}{NB} \times 100 \]  

(1)

Where:

NBD: Number of the damaged buildings
NB: Number of buildings
Urban areas:

... Urban place is a spatial concentration of people whose lives are organized around nonagricultural activities. **The essential characteristic here is that urban means nonagricultural.** It is a function of (1) sheer population size, (2) space (land area), (3) the ratio of population to space (density or concentration), and (4) economic and social organization.
Remotely sensed data can provide a valuable source of information at each of these stages, helping to understand spatial phenomena, and providing scientists and authorities with objective data sources for decision making.
Latest Charter activation by Earthquakes

2012
8 November Earthquake Guatemala
7 September Earthquake in southern China
15 August Earthquake in Iran

2011
24 October Earthquake in Turkey
18 September Earthquake, Landslide, Sikkim - North East India
11 March Earthquake in Japan
22 February Earthquake in New Zealand
19 January Earthquake in Pakistan
2010
14 April Earthquake in China
8 March Earthquake in Turkey
27 February Earthquake and tsunami in Chile M 8.3
13 January Earthquake in Haiti
5 January Earthquake in Solomon Islands

2009
30 September Earthquake in Indonesia
16 September Earthquake in Indonesia
8 June Earthquake in Saudi Arabia
9 January Earthquake and landslide in Costa Rica
Latest Charter activation by Earthquakes

2008
3 November Earthquake in Pakistan
23 July Earthquake in Hirono, Japan
11 May Earthquake in China
5 February Earthquake in Rwanda

2007
22 November Earthquake in **Chile** M 7.7
16 August Earthquake in **Peru** M 8.0
26 April Earthquake, landslides, exceptional waves in **Chile** M 6.2
4 April Earthquake in Afghanistan
3 April Earthquake, Tsunami in the Solomon Islands
6 March Earthquake in Indonesia
When the disaster arises

Assessment of damages *is not an option it is a needed* and remote sensing appear as expression of the new power and development of traditional geospatial related disciplines.
In some cases we cannot use RS to assess damages.

Structure damages less than VI by Mercalli, it is not possible to detect.
In some cases we can not use RS to assess damages.

Structure damages upper than VI by Mercalli, it is possible to detect using RS.
<table>
<thead>
<tr>
<th>Sensor</th>
<th>Advantage</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>e.g. Spot, Landsat, Ikonos</td>
<td>Images are easy to understand and to interpret High revisit frequency</td>
<td>Obscured by cloud and smoke Limited to daylight hours</td>
</tr>
<tr>
<td>SAR e.g. ERS Radarsat</td>
<td>Day and night images capability Penetrate clouds and smoke High revisit frequency</td>
<td>Interpretation is complicated Subject to considerable noise</td>
</tr>
<tr>
<td>LIDAR</td>
<td>Frequency by demand Accuracy in vertical an hz.</td>
<td>Expensive</td>
</tr>
<tr>
<td>Sensor examples</td>
<td>Techniques</td>
<td>Advantage</td>
</tr>
<tr>
<td>-----------------</td>
<td>------------</td>
<td>-----------</td>
</tr>
<tr>
<td>Ikonos</td>
<td>manually</td>
<td>Depend on interpreter knowledge</td>
</tr>
<tr>
<td>Quickbird</td>
<td>or visually</td>
<td>Non repeatable</td>
</tr>
<tr>
<td>SPOT, ASTER</td>
<td>interpretation</td>
<td></td>
</tr>
<tr>
<td>ALOS</td>
<td>Spectral classification</td>
<td>Rapid interpretation over large area to detect debris</td>
</tr>
<tr>
<td></td>
<td>Semivariogram</td>
<td>Requires few spatial resolution</td>
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<tr>
<td></td>
<td>other textural classifiers</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Image differences. debris</td>
<td>Location and extend imagery co-registered Used on Panchromatic and Radar back-scattering</td>
</tr>
</tbody>
</table>
Examples of new findings in GeoEye satellite images during the evaluation of the UNOSAT road disruptions dataset, Haiti 2010
A network-based analysis of the impact of structural damage on urban accessibility following a disaster: the case of the seismically damaged Port AuPrince and Carrefour urban road networks. Road network with located road blocks (a), correspondent graph network (b), and three components (green, gray and red vertices) resulting from the splitting of road segments (X marks) in correspondence of debris’ location (c). Flavio Bono, Eugenio Gutiérrez 2011.
Light at night. It can serve to assessment damages post earthquakes. Needs multitemporal images to detect reductions of light concentration after earthquakes.

Lecciones aprendidas del Sur. Instituto Nacional de Defensa Civil INDECI 2009
Model V-I-S: V for green vegetation, I includes surface pavement as well as impervious roofs, and S represents exposed soil.

Trend of V-I-S from pre-earthquake to post-earthquake conditions, Izmit, earthquake of August 1999. Turkey (Kaya et al. 2004), employed SPOT-X (20m), Remote Sensing of Urban and Suburban Areas, Springer 2010
Thermal and microwave detection of earthquakes and faulting as an alternative to mapping earthquake damage, several studies have sought to characterize short-term temperature increases immediately prior to earthquakes.

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<tr>
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<th>Advantage</th>
<th>Disadvantage</th>
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<tbody>
<tr>
<td>ASTER</td>
<td>Split window</td>
<td>Precursor to earthquake activity</td>
<td>Relatively low spatial resolution of thermal sensor</td>
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<tr>
<td>MODIS</td>
<td></td>
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<tr>
<td>AVHRR</td>
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</tbody>
</table>
Thermal data in seismic studies

Were first used in Russia. Such studies were carried out in Russia, Japan and China.

Prior to an earthquake, crustal deformation is due to a stress field. It is a known fact that increases in pressure leads to an increase in temperature. There are microcracks, the gases trapped in these pores escape and create a localized green house effect and thus create a thermal anomaly near earth's surface.

The anomalies appeared a few days to a few hours before the earthquakes. The increase in temperature ranges between 4-10°C. These anomalies are seen to disappear after the earthquakes.
Thermal Remote Sensing Technique in the Study of Pre Earthquake Thermal Anomalies, Arun K. 2005. Thermal channel 4 of NOAA-AVHRR satellite data was used to calculate the LST.

Time series Land Surface Temperature (LST) maps prior to the earthquake of 26 January 2001 in Bhuj ($M_w$7.9), India. Thermal anomaly over the region appeared on 14 January 2001 and was seen to be maximum on 23 January 2001.
Thermal Remote Sensing Technique in the Study of Pre Earthquake Thermal Anomalies, Arun K. 2005. Thermal channel 4 of NOAA-AVHRR satellite data was used to calculate the LST.

AVHRR-NOAA time series data show thermal anomaly before the 26 December 2003 BamEarthquake in Iran. The maximum anomaly was seen on 24 December 2003, two days before the earthquake.
DInSAR (Differential Interferometric Synthetic Aperture Radar) is generally accepted as the best method for earthquake associated deformation mapping; LiDAR (Light Detection and Ranging) provides the highest resolution DEM available for fault interpretation; and very high resolution optical data will provide the best imagery for damage assessment of buildings and infrastructure.

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<th>Disadvantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>JERS-1, ERS 1/2, ENVISAT</td>
<td>Differential interferometry</td>
<td>Surface deformation, High precision, High resolution, Some new sensors</td>
<td>Depend on DEM accuracy, High precision only available in areas without dense vegetation</td>
</tr>
<tr>
<td>ALOS, PALSAR, Terra SAR-X</td>
<td>Back-scattering</td>
<td>Very good approximations</td>
<td>Requires of SAR techniques</td>
</tr>
<tr>
<td>Radarsat 1/2, Cosmo-SkyMed</td>
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</table>
Example of deformation of an area using interferometry
Specular reflection will happen on flat roof and produce a weak backscattering (a). Single bounce reflection will happen on tilted roof faced the radar beam and produce the strongest backscattering (b). However, diffuse reflection will happen on the debris of collapsed buildings and produce a low backscattering (c).\(^5\)

\(^5\) Extracting damages caused by the 2008 Ms 8.0 Wenchuan earthquake from SAR remote sensing data Yanfang Dong, Qi Li, Aixia Dou, Xiaoqing Wang.
Schematic figure of the repeat pass satellite observation geometry and backscattering characteristics of buildings. And Schematic figure of the backscattering characteristics of orderly uniform buildings with flat roofs and their damages.
Building damages, extraction of sample blocks in Dujiangyan

The GIS data of blocks and buildings are extracted from a pre-earthquake QuickBird image acquired on July 22, 2005: (a) aerial photograph of Hehuachi residential area acquired on May 18, 2008; (b) Backscattering coefficient image of TerraSAR-X of Hehuachi residential area acquired on May 15, 2008; (c) building damage information of sample city blocks extracted from TerraSAR-X image; and (d) index map showing the location of study blocks in Dujiangyan city.
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</tr>
</thead>
<tbody>
<tr>
<td>PALSAR</td>
<td>Volumen of landslide by earth movement</td>
<td>Quantitative estimation of volumetric depositions and ground change</td>
<td>Requires both before and after imagery to be accurately co-registered</td>
</tr>
<tr>
<td>Terra SAR-X</td>
<td>Fault locations and elevation displacement</td>
<td></td>
<td></td>
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<tr>
<td>SPOT</td>
<td></td>
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<td></td>
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<tr>
<td>Ikonos</td>
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<tr>
<td>Quickbird</td>
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<tr>
<td>LiDAR</td>
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</table>
Conclusions

- Remote sensing it is important in every element on Disaster management cycle. Remote sensing provides a rapid method of assessing the magnitude of hazard impacts, areas most affected, and where key transport and other infrastructure links have been disrupted or destroyed.

- It is not possible to recommend a single data type or processing solution that will work under all conditions. This is a broad field of applications where some techniques will work better under some circumstances than another. But Recently, some studies attempted to detect damage at the scale of a single building unit, using both high-resolution optical and SAR images.

- Advances in remote sensing applications for regional science in urban settlements have occurred in several areas as crime and nighttime lighting relationships, urban land cover and socio-economic change relationships; population density estimation, house value modeling, land surface temperature relationship with socio-economic parameters; urban morphology and socio-economic parameters.

