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Earthquake damage assessment based on remote sensing data. The Haiti case study

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Abstract

Haiti was hit by a devastating earthquake on 12 January 2010. Timely triggering of the Earth Observation satellites, and absence of cloud cover, allowed to acquire very high-resolution satellite imagery over the main affected areas within a few hours of the disaster. ITHACA performed a first damage assessment based on remotely sensed data, to support the emergency response activities carried out by the humanitarian agencies.

This paper aims to highlight not only the adopted methodology and the main cartographic outputs, but also the operational procedures required to make well known analysis techniques effective in an application context.

Keywords: earthquake, remote sensing, damage assessment, Haiti, rapid mapping.

Introduction

"*Rapid impact assessment after a catastrophic event is crucial for initiating effective emergency response actions*" [Brunner et al., 2010]. The acquisition of field data, supporting the aforementioned impact assessment, in areas hit by severe earthquakes is indeed a hard task, mainly due to the restricted physical accessibility of the affected areas (i.e. unpredictable road conditions, landslides and soil fractures, lack of means of communications with the affected population, panic, growing of diseases, lack of food and water, hazards due to instable buildings). To cope with the accessibility and time constraints issues, "*the use of EO (Earth Observation) data in earthquake contexts, especially for damage assessment purposes, has been widely proposed and a number of results have been presented after every event, mostly based on optical data and manual interpretation*" [Polli et al., 2010].

The goal of this paper is to show how well established optical remote sensing techniques allow to carry out earthquake damage assessment in a very short time, exploiting the synergic capabilities of geospatial tools and instruments such as EO satellites, Web mapping, GIS software and volunteer mapping. The main issues faced will be discussed and possible solution to improve the adopted approach will be proposed.

Case study

The 12th of January 2010 Haiti was hit by a catastrophic earthquake of magnitude 7.0 Mw, with an epicentre near the town of Léogâne, approximately 25 km (16 miles) West of Port-au-Prince, the Haiti's capital. The earthquake caused major damage in Port-au-Prince, Jacmel and other settlements in the region. Amongst the widespread

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devastation and damage throughout Port-au-Prince and elsewhere, vital infrastructures necessary to respond to the disaster were destroyed or severely damaged.
Thankfully, timely triggering of the Earth Observation satellites, and absence of cloud cover, allowed to acquire very high-resolution satellite imagery over the main affected areas within a few hours of the disaster. GeoEye satellite acquired the first satellite imagery the day after the quake (13 January 2010), with a Ground Sample Distance (GSD) of 50 cm. The Google Crisis Response Team made the imagery immediately and universally accessible as base layers in Google Earth and Google Maps (also as KML and GeoTiff files).
The DigitalGlobe company triggered its own high resolution satellite constellation (World-View 1 and 2, Quickbird) and completely covered Haiti in 5 days (from the 13th to the 17th of January). The imagery was distributed by means of OGC Web Services and as KML and GeoTiff files by the Digital Globe Crisis Event Services.
The decision to provide free access to the data allowed to overcome licensing issues that may interfere with rapid response activities. It was possible to use the imagery to extract the features of interest required to produce early impact maps supporting the emergency response activities, without any licensing constraints even for the derived information.
15 cm imagery were then acquired starting from the 17th of January and again distributed by Google. High resolution SAR radar imagery as well as thermal and LiDAR data were widely acquired over the main affected areas.
It is therefore evident why "*This event will also be known as one of the first events where technology (especially high-resolution imagery) was embraced at such a large scale in a real operational sense. Almost from the very onset of the disaster, high-resolution satellite imagery was available to provide the first glimpse of the devastation caused by this earthquake*" [Eguchi et al., 2010].

Damage assessment

ITHACA, thanks to the cooperation with the United Nations World Food Programme (UN WFP) HQ and WFP staff deployed in the field, was involved in the satellite based damage assessment. Although several automatic or semi-automatic remote sensing based techniques exist to identify collapsed building after an earthquake, the calibration stage of such methods is a time consuming procedure and the accuracy is not completely predictable. It was therefore decided to adopt a manual interpretation approach in order to have results as reliable as possible. Due to the huge amount of data available, the resolution of the imagery and the tight time constraint, it was obvious that a coordinated volunteer approach was the only possible solution.

Adopted methodology

ITHACA identified a methodological framework aimed at responding to the following needs:

1) to involve a large number of volunteers with experience in the field of photogrammetry and remote sensing and proved skills in interpreting vertical images;
2) to work with free software with limited requirements and capable to manage open data formats;
3) to have a minimal set of technical specification on the features of interest to be pinpointed on the images;
4) to allow an easy, quick and effective coordination of the volunteers, including management and merging of each single output.

The identified methodology addresses the aforementioned issues, specifically:

1) the Italian Association of Professors and Researchers in the field of Geomatics (AUTEC) was directly involved in the call for volunteers;
2) the Google Earth virtual word platform was adopted;
3) a short document highlighting the main instruction to be followed by each volunteer was edited and shared;
4) a GIS procedure was set up in order to:
   – divide the area of interest in grid cells and take note of the ones already assigned or completed, allowing to have a near-real time view of the status of the work and supporting the coordination activities;
   – merge all the outcomes produced by the different volunteers, including possible import/export activities;
   – synchronize the damage assessment dataset with the WFP Spatial Data Infrastructure (refer to section SDI of the present paper).

Specifically, each volunteer was requested to focus on the following features of interest: collapsed/damaged buildings, road network accessibility, spontaneous camps, landslides. The analysis was based on a multi-temporal change detection activity between the satellite data acquired before and after the event (the analysis was updated in the following days exploiting the availability of 15 cm aerial images). The identified point features were then submitted to the coordinator in KML/KMZ data format.

Main outputs

The typical output of the damage assessment activity is a cartographic product, that helps the decision makers to answer questions such as how much food aid is needed, and support the WFP staff in the field in finding the best way to deliver it to the hungry population. The damage assessment results have therefore to be combined with updated, reliable and easily accessible reference base datasets, that are indeed key factors for the success of emergency operations. Short-term emergency response capacities, long-term risk reduction, development and environmental protection activities are sectors where a Spatial Data Infrastructure (SDI) may strongly improve efficiency.

SDI

The term Spatial Data Infrastructure is often used to denote the relevant base collection of technologies, policies and institutional arrangements that facilitate the availability of and access to spatial data. An SDI provides a basis for spatial data discovery, evaluation, download and application for users and providers within all levels of government, the commercial sector, the non-profit sector, academia and the general public. SDIs facilitate access to geographically-related information using a minimum set of standard practices, protocols and specifications. SDIs are commonly delivered electronically via internet.

In the framework of a collaboration established with UN WFP, ITHACA has developed an SDI platform conceived for responding to humanitarian emergencies, especially in the early stages, in every portion of the globe. Due to ITHACA/WFP competences and technical and accessibility constraint to data sources, datasets included and made available through WFP SDI are generally at low or medium scale (up to an equivalent of 1/250.000). If this constraint is generally acceptable when dealing, in the first stages of the emergency response, with large

scale disasters (e.g. floods and windstorms), in case of earthquake events the consequences have an high spatial variability that requires detailed reference data, especially for infrastructures and buildings. Data with such characteristics are generally not easy to retrieve, mainly due to licensing constraints in developed countries. In developing countries lack in data availability and/or inadequate levels of update are the critical factor [Bishop et al., 2000].

Volunteer mapping

In the context of Volunteer Geographic Information (VGI) [Goodchild, 2008], initiative such as OpenStreetMap and Google Map Maker are having a tremendous impact, providing detailed and updated data available for emergency response, even if adopting completely different licensing policies. In fact, OpenStreetMap provides data under the Creative Commons licensing terms, while Google Map Maker is the only owner of the produced data, that are made available during emergencies but with specific constraints.

The disrupting effect of both initiatives is to embark in the emergency response effort a wide community of volunteers that, thanks to the simplicity of the provided tools and to the high levels of services interoperability, contribute to the cause by acquiring huge amount of new data by means of manual interpretation of recent satellite or aerial images or by means of instruments such as GPS/GNSS receivers. The effectiveness of that approach is demonstrated by burst of data acquired over Port-au-Prince, and more generally over Haiti, in the very first days after the earthquake (Fig. 1).

Data distribution

Volunteer based datasets and field data were included into the WFP SDI platform and allowed to perform detailed spatial analysis and to produce maps based on personalized templates (Fig. 2). Those maps, as well as the vector data, were distributed by consolidated communication networks such as: pre-defined mailing lists, downloading services made available on several web sites coupled with search engines, dissemination in several emergency response dedicated web sites by means of GeoRSS technology.

Due to the size of the event and for the interest of an enlarged community for accessing to geographic data, a specific WebGIS application was designed and implemented, including editing capabilities on specific datasets.

Figure 1 – OpenStreetMap coverage on Port-au-Prince before (left), as of 15 February (middle) and as of 26 February (right) . Data source: OSM.

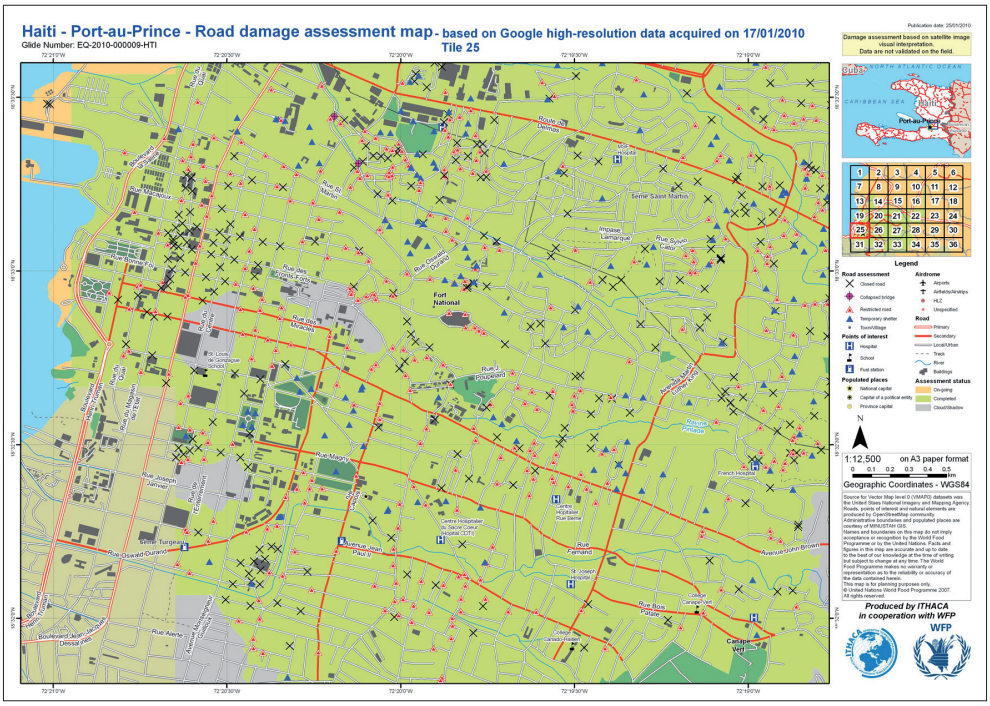

Figure 2 – Example of map based on the performed damage assessment.

Conclusions

The response to the Haiti earthquake clearly demonstrated that remote sensing played a crucial role during the damage assessment phase.

From the data acquisition point of view, it was indeed evident the capability of the satellite data providers and space agencies to timely trigger the satellite constellation and to effectively and quickly distribute the imagery. From the data processing point of view, the use of automatic or semi-automatic classification techniques was limited in the first days after the earthquake and provided indications of the level of damages only at block/grid level and not at building level. Furthermore, the analysis was mainly based on optical remotely sensed data, since thankfully there was a very low cloud coverage during several days after the earthquake. It should be important to strengthen the research lines focused on the use of SAR radar data (both amplitude and phase information) for damage assessment purposes and not only to estimate the ground displacements. Concerning the accuracy of the identified damages, recent studies [Saito et al., 2010] highlighted that vertical imagery (and in certain conditions also oblique ones) may be limiting in discriminating the level of damage of some buildings. In the summary of the 2nd International Workshop on Validation of geo-information products for crisis management, it is explicitly reported that a validation of a "joint damage assessment (using airborne images) performed with around 6000 geo-tagged photos collected in the field gave an overall accuracy of 60% only". It is therefore crucial to rely also on information acquired in the field, especially by means of GPS/GNNS devices allowing to geo-tag the acquired information [Ajmar et al., 2010]. Volunteer contribution was crucial for mapping both large scale reference datasets, to be

use as backdrop in the map products, and in identifying the damages on the remotely sensed data. Concerning the volunteer damage assessment, during the Haiti experience it was clear the need for automatic tools/applications supporting the coordination activities, that otherwise are indeed time consuming and may slow down the release of the analysis results. Coordination should be also taken into account in order to avoid any duplication of efforts among different bodies working on the damage assessment. Finally, it is important to highlight that the identification of the features of interest is an activity that should be carried out before the event, taking into account the different needs of different type of users. E.g. during the response to the Haiti earthquake all the involved actors immediately focused on the collapsed buildings (crucial information for the SAR teams and detailed assessed during the recovery stage), but after a few days WFP specifically requested updated information on the road network accessibility and on the location of the main spontaneous gathering areas, to better organize the food distribution activities in the field.

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