EARTH OBSERVATION AND THE DIGITAL HUMANITARIANS

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Executive summary

Emergency agencies, civil protection authorities and non-governmental disaster relief organizations are crucial for timely assistance to affected areas. The effectiveness of disaster relief activities is usually limited by the amount of immediate information such as scarcity of updated reports about caused damages, and the number of people involved. With the objective of improving emergency response, the EODH team was guided by three external institutions that have driven the project's demands: ESRIN, one of the five European Space Agency (ESA) specialized centers in Europe which provided the team with satellite data and the open source software tools to process it; Humanitarian OpenStreetMap Team (HOT), an US-based organization supporting volunteers that work on humanitarian mapping in the context of OpenStreetMap project, encouraged the team to use Free and Open Source Software, as humanitarian work demands; ITHACA, an applied research center

for distribution of IT products and services in support of humanitarian operations, pushed the team to find alternative methodologies to assess damages to buildings in case of bad lighting and cloudy weather conditions. In such way the team strived to aid disaster response activities by developing an integrated software pipeline which is completely free and open source (FOSS) and compatible with all the major platforms. Such pipeline encapsulates in a QGIS Python plugin a sequence of pre-processing and Coherent Change Detection algorithms by hiding the procedures' complexity from the final user. The plugin represents an end-to-end tool for automatic damage assessment, which has been tested and validated on earthquake case studies. A great advantage of this pipeline is that it is both fully modular and fully open source, thus it potentially facilitates any volunteer humanitarian contribution with little effort. This results in a software that can be very useful to the demand drivers as our automatic assessment of damages ensures rapidity in mapping activities, especially when lighting and weather conditions make the use of optical imagery unfeasible. To further aid the objective of improving emergency response, the team tried to integrate the SAR-based damage assessment with the use of user-generated content extracted from social media platforms and more specifically with the usage of Tweets for damage assessment purposes, considering the same case study of the SAR-based approach. All in all, it is expected that in the near future the results and user experience of both approaches might be improved by testing different case studies, publishing the finished plugin on the QGIS Python Plugins Repository to make it available to the whole QGIS community and the source code on GitHub, using computer vision algorithms to automate the analysis of damages in social media photos and enabling the automatic recognition of known places in images posted on social networks.

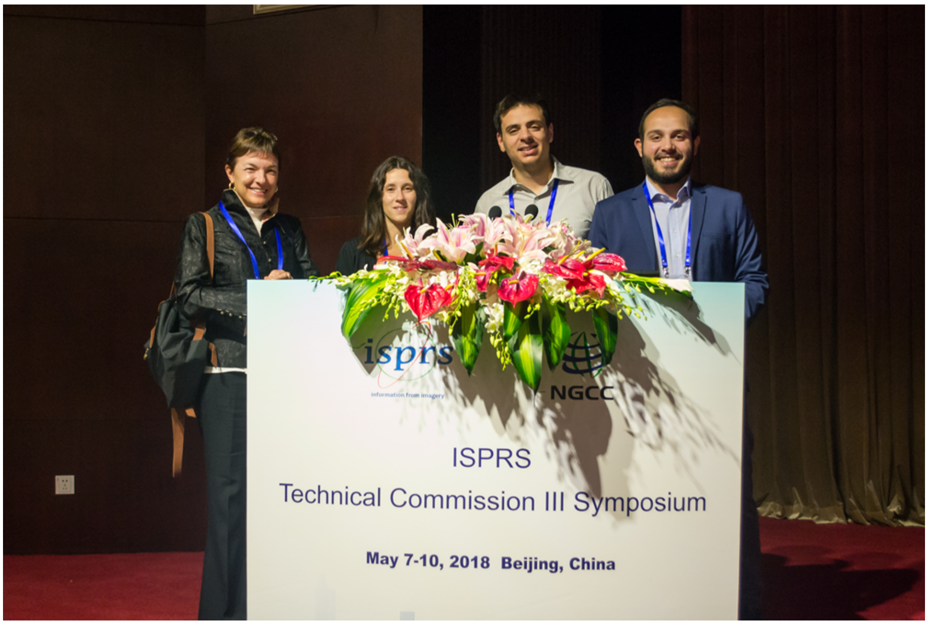
Key Words:

"Remote Sensing", "Damage Assessment", "SAR", "Humanitarian"

Project description written by the Principal Academic Tutor

We live in the era of big data and that means outstanding opportunities to get insight into manifold phenomena that shape or affect our communities and territories. On the other hand, a fair access and use of this information have to be advocated in order to turn data into valuable actions that foster safety, development, and cooperation at any level of the society. These are the baselines on which The Earth Observation and Digital Humanitarians (EODH) project is developed. The EODH project aims at providing cutting-edge tools and methodologies in support of natural and man-made disaster response. This, by taking the best advantage of the new geospatial big data such as satellite imagery and user-generated contents. In particular, the EODH project proposes a semi-automatic procedure to assess damage on buildings and infrastructures in a short time after a disaster strikes. This is achieved by exploiting the frequent-pass Synthetic Aperture Radar (SAR) imagery captured by the European Space Agency (ESA) Sentinel-1 mission, and distributed with an open license by the Copernicus program of the European Commission. Multitemporal SAR imagery stacks are processed using an ad-hoc developed procedure that exploits Free and Open Source Software (FOSS) tools to automatically quantify - by means of Coherent Change Detection techniques - and map building damages. Ancillary information from other big data sources, such as Twitter, has been employed to validate as well as improve the procedure. The central Italy earthquake of 2016 and the 2017 Southern Mexico earthquake were selected as initial case studies.

The EODH project is co-design with leading external partner and stakeholders active in the fields of Earth Observation, disaster management and humanitarian aid. These are namely the ESA Center for Earth Observation (ESRIN), the Humanitarian OpenStreetMap Team (HOT), and the Information Technology for Humanitarian Assistance, Cooperation and Action (ITACHA) that is an Italian research center of applied remote sensing for emergency response. The partners contributed to the project by outlining technical and user requirements for the implementation of the damage assessment procedure.



Part of the EODH team attending the ISPRS Technical Commission III Symposium in Beijing China to present the developed pipeline. From left to right: principal academic tutor Maria A. Brovelli, non-member Monia E. Molinari, member Igor Donevski, and member Leonardo Lo Schiavo.

The outcome of the EODH project consists of a software application that integrates the full data processing pipeline, from the raw SAR acquisitions to the final damage grading map. The application is provided as an experimental plugin of QGIS, one of the premier FOSS Geographic Information System (GIS) platform. This allows a free access to functionalities as well the source code thus potentially enabling users to replicate as well as to improve the procedure. This valuable feature coupled with the exploitation of open Earth Observation represents the main strength of the EODH project, which ultimate goal is to demonstrate the critical role of both open technologies and open data policies in emerging societal challenges such as the disaster management.

The entrance to the IGARSS 2018 conference in Valencia, Spain (image on the right) as photographed by team member Luca Guida (image on the left) as an attendee

Team description by skill

The EODH team was originally composed seven members but reduced to the following three members:

Luca Guida: with his Computer Science and Engineering expertise he contributed with his skills in software engineering and scripting in Python and GNU Octave, as well as application development at creating the QGIS change detection pipeline and further analyze its performance.

Igor Donevski: with his Communications and Computer Networks Engineering expertise he contributed with his skills in signal processing and image processing at analyzing SAR pre-processing and conduct the Twitter image feasibility analysis.

Leonardo Lo Schiavo: with his Communications and Computer Networks Engineering expertise he contributed with his skills in signal processing, application development and image processing, at defining the SAR pre-processing module, validation, and performance analysis.

The EODH team, from left to right, principal tutor Maria Brovelli, Igor Donevski, Luca Guida, and Leonardo Lo Schiavo

Goal

The Earth Observation and Digital Humanitarians project aims at supporting disaster response activities in post-earthquake scenarios by providing buildings damage assessment as relevant information that actors involved in response efforts might exploit to take selective actions. Such assessment is the result of an automatic unitary framework in which open source high-quality satellite imagery given as input is processed by a set of software tools and then the outcomes are visualized in a Geographic Information System. Moreover, the project investigates the opportunity of using contents directly generated by users through social media platforms to integrate and validate the results obtained from the previously presented framework.

Understanding the problem

The main challenge that the team was asked to address was finding new ways to support disaster management activities by leveraging the power of open data sources and User-Generated Content (UGC). In general, disaster response activities require a quick and effective reaction to unforeseen events; right after a flood, a hurricane or an earthquake the main priority is to provide an immediate assistance to the population, but also a timely assessment of damages to buildings and infrastructures in order to promptly restore critical services. Emergency management agencies, civil protection authorities, but also non-governmental disaster relief organizations play a crucial role in the first phases of disaster response, but their action is often limited by the inaccuracy of the available information, or by the scarcity of updated reports about the area affected by the disaster, the actual effects on physical structures, or the number of people involved. The damage assessment process is typically supported by damage surveys carried out by specialists who visit the area affected by the disaster, inspect buildings and other physical structures, and classify the damages occurred. In recent years, UAVs and satellite optical imagery were adopted to assess major structural damages in a faster way, before than technicians could reach the areas stroked by the disaster event. However, the detection of changes by photo-interpretation is not straightforward, while bad weather conditions may harm the quality of these manual assessments, thus limiting the actual applicability of these techniques. Novel techniques are required to address those limitations.

Exploring the opportunities

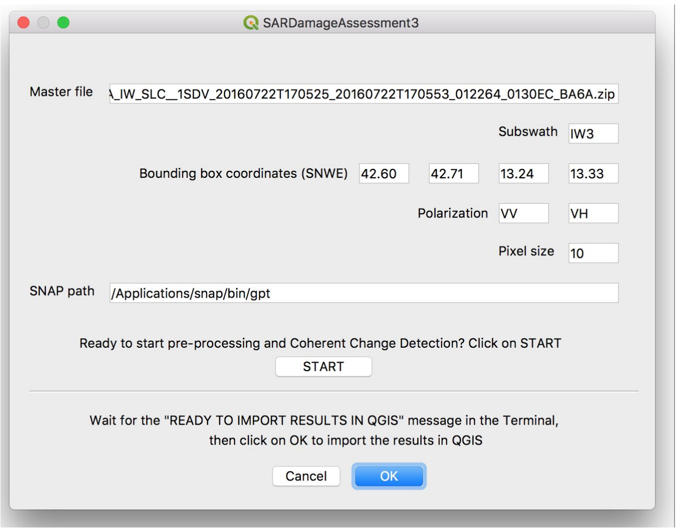
In the recent years, high-quality satellite imagery, such as the one provided by the European Commission in partnership with the European Space Agency (ESA) through the Copernicus Earth observation program is becoming widely available. Moreover, the rise of user-generated content platforms, such as social networks and citizen journalism websites, allows monitoring of events and disastrous phenomena almost in real-time. In addition, the availability of accurate and frequently-updated cartographic resources, such as the ones provided in the form of Volunteered Geographic Information (VGI) through platforms like OpenStreetMap, provides extremely useful information even to non-profit institutions who may want to contribute to disaster relief activities.

The damage assessment procedure was decided upon by investigating the opportunity of using Synthetic Aperture Radar (SAR) imagery as novel damage assessment approach substituting to the traditional detection of changes through photo-interpretation of UAVs and satellite optical imagery. The team was also required to build and test a software exploiting Coherent Change Detection (CCD) algorithms to automatically detect potential damages to buildings and other physical structures by analyzing pre-processed SAR images of the area affected by a seismic event. This approach has an opportunity in being very sensitive to detecting destructions on ground level as proved by the amatrice case study. Moreover, considering that effective disaster management requires up-to-date information about the affected area, the team was asked to extend the aforementioned SAR-based methodology by integrating valuable information about the post-disaster scenario coming from user-generated content platforms and social networks such as Twitter. This approach has great opportunity to solve some peculiar scenarios in disaster relief, given that the local populace uses the technology.

Generating a solution

Having the goal of creating an easily accessible automated buildings damage assessment mechanism, the team decided to create a framework which is available on all the major platforms (Windows, macOS and Linux) and which hides the complexity of the processing by incorporating all the processing steps into a single plugin of the Free and Open Source Software (FOSS) Geographic Information System (GIS) application QGIS, in such a way that both amateurs and experts could download the tool and use it without requiring any specialized hardware or particular expertise. For this the team developed damage assessment mechanism that consists of three steps.

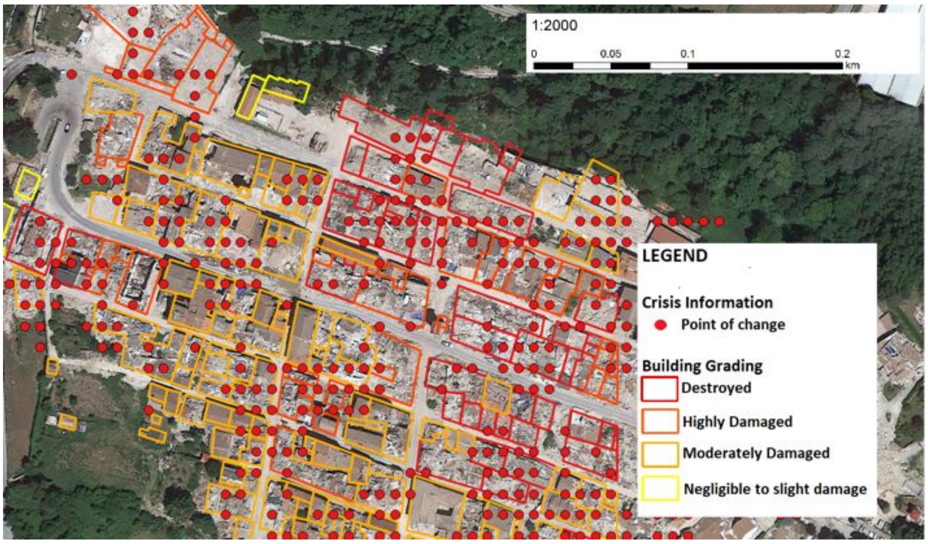
The first step that a user need to undertake manually is the data acquisition step. Here the user decides the area of interest to perform damage assessment on and then manually download from ESA Copernicus Open Access Hub pre-disaster and post-disaster images available along the specified period. The images chosen in this step must be taken by Sentinel-1 satellite according to the Synthetic Aperture Radar (SAR) technology since this kind of imagery ensures better performances also in case of clouds and bad weather conditions in comparison with traditional optical imagery.



The interface of the developed plugin that a user would work on when trying to perform his humanitarian work

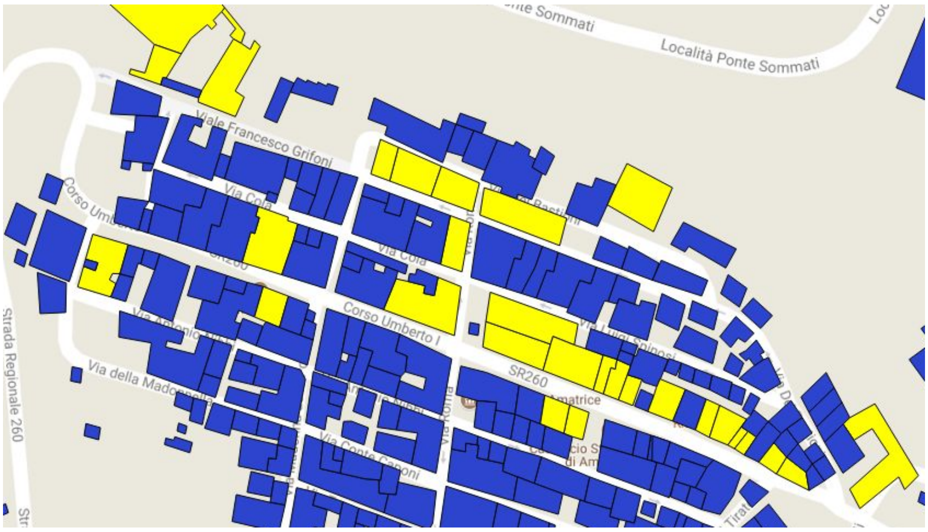
The second step is the processing step: within the QGIS platform, the user simply specifies some parameters before executing the aforementioned plugin, which calls a Python script that is responsible to perform a set of pre-processing operations to the downloaded SAR images in order to create a data unit called interferometric stack. The pre-processing procedure was decided upon careful revision of the available signal processing tools in order to be the input of the Coherent Change Detection (CCD) Algorithm. The CCD run in the FOSS GNU Octave environment and responsible of determining with a given resolution the latitude and longitude coordinates of the points that have changed in the post-disaster images with respect to the pre-disaster images as a way to perform damage assessment. The choice of the usage of a Coherent Change Detection Algorithm in this step is justified by the fact that such class of algorithms allows detecting even very slight changes in the scene, and its main drawback of the high number of false alarms obtained (i.e. undesired and incorrect change detections) is reduced by acquiring as many as possible SAR images over the same area both before and after the disaster event.

The third and final step that a user of the developed solution needs to go through is the visualization step. In this case, the user just confirms to visualize in the QGIS platform on top of a base map provided by OpenStreetMap the points of change detected and obtained as result of the previous step. This is where a humanitarian user would report the possible damages of the unfortunate event to the responsible authorities for review.



The result of a run of the algorithm (red points) over the Amatrice earthquake in comparison with the European Space Agency building damage grading (structure shaped geometries with four different building grading)

Afterwards there were attempts to confirm the data through social media platforms. Using data provided by posts on Twitter, the performance of the evaluation may need to rely on fewer acquisition to reach better precision. In addition, as a long run solution, it can be considered that a computer vision project will allow for full automation of the detection of the images posted to their accompanying text. Of all 252 tweets a guideline called "Procedure for post event analysis of Twitter data for damage assessment" was developed. The goal of this procedure was to trivialize the search for geolocating a location of a captured disaster in order to be later assessed. In the end, the team was able to decide on damages on some buildings.



Successfully geolocated damaged buildings (in yellow) by using the Twitter dataset

Main bibliographic references

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