Collaborative mapping response to disasters through OpenStreetMap: the case of the 2016 Italian earthquake

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Digital humanitarians represent the current generation of volunteers, providing timely contributions in the form of digital map data in the aftermath of natural disasters. Starting from the tragic 2010 earthquake in Haiti and thanks to the success of the OpenStreetMap (OSM) project, the presence and coordination of these volunteers have grown incredibly over the past years. This work investigates the dynamics of the mapping process and the nature of the OSM volunteers who contributed map data after the 2016 earthquake in Central Italy. The analyses show that existing OSM users were the majority of those contributing to the mapping activity, with less edits performed by new users. The collaborative mapping process was efficiently coordinated through a dedicated platform and the area hit by the earthquake was significantly edited in OSM after the disaster.
***Keywords**: collaborative mapping, disaster management, earthquake, OpenStreetMap*

Risposta collaborativa alla mappatura di eventi disastrosi tramite OpenStreetMap: il caso del terremoto in Italia del 2016. *I digital humanitarians rappresentano la nuova generazione di volontari, capaci di fornire contributi tempestivi sotto forma di dati geografici all'indomani di disastri naturali. A partire dal tragico terremoto di Haiti nel 2010 e grazie al successo del progetto OpenStreetMap (OSM), la presenza e il coordinamento di questi volontari sono cresciuti incredibilmente negli ultimi anni. Il presente lavoro analizza le dinamiche del processo di mappatura e la natura dei volontari di OSM che hanno generato dati geografici dopo il terremoto nel Centro Italia del 2016. Le analisi mostrano che gli utenti OSM già esistenti prima dell'evento hanno contribuito in modo predominante, mentre quelli registrati al progetto dopo l'evento hanno contribuito in misura minore. Il processo di mappatura collaborativa è stato efficacemente coordinato attraverso una piattaforma dedicata e l'area colpita dal disastro è stata editata significativamente in OSM.*
***Parole chiave**: mappatura collaborativa, gestione dei disastri, terremoto, OpenStreetMap*

1. Introduction

Natural disasters have always marked the history of humankind. Recent years have witnessed an increase in both their frequency and magnitude at a global level, often with tragic consequences when events strike in developing or underdeveloped countries where authoritative geographic information is either not available or not accurate and up-to-date (Poiani *et al.*, 2016). However, in contrast to the past, the activities falling under the umbrella of disaster management (Hodgkinson and Stewart, 1991) can currently benefit from the flourishing of collaborative mapping practices based on citizens' provision of geospatial datasets, which have been described with a variety of terms including crowdsourcing, Volunteered Geographic Information (VGI), Participatory Sensing and Citizen Science (See *et al.*, 2016). In the specific context of disaster management, these practices have seen a new player entering the scene: the so-called digital humanitarians, i.e. the networks of technology volunteers crowdsourcing timely information during crises response (Meier, 2015).

The main platform around which humanitarian efforts revolve before and after disasters is OpenStreetMap (OSM, http://www.openstreetmap.org), the world's openly-licensed geospatial database created by volunteers, which is nowadays used by a myriad of actors and applications (Mooney and Minghini, 2017). The open nature of OSM makes it highly suitable for disaster mapping, as shown by the response after the earthquakes in Haiti in 2010 and Nepal in 2015 (see e.g. Soden and Palen, 2014; Poiani *et al.*, 2016). However, OSM mapping in countries prone to many natural hazards is challenged, among other reasons, by limited broadband connection, lack of GPS devices, technical skills and support from organizations, governments and academia (Latif *et al.*, 2011). In the context of natural disasters, the coordination of volunteers' mapping efforts is operated by the Humanitarian OpenStreetMap Team (HOT, https://www.hotosm.org), which was formed right after the Haiti earthquake. The HOT's

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Tasking Manager (TM, http://tasks.hotosm.org) is the software platform used everyday by hundreds of volunteers to perform remote mapping by digitizing geospatial objects (mainly roads and buildings) on top of satellite imagery. This remote work clearly complements the local knowledge of people who are physically present in the disaster area. With these premises, the purpose of this study is to investigate the OSM collaborative mapping process that took place after the earthquake occurred in Central Italy in August 2016. This is done by analysing the number, nature, provenance and amount of contributions of the active OSM volunteers.

The remainder of the paper is structured as follows. Section 2 examines related work in the field of OSM collaborative disaster mapping. Section 3 introduces the Italian case study and describes the experimental work performed through the analysis of the OSM database history and the related results. Section 4 concludes the paper and provides recommendations on how contributors' response can be facilitated and increased.

2. Related work

Started after the Gaza crises in 2009, the use of OSM for collaborative disaster mapping has raised interest in the academic community since the Haiti earthquake in 2010. In the aftermath of that disaster, the contribution of volunteers' mapping was shown to be pivotal to deliver relief efforts in a place where databases on population, infrastructure, location and assets were lacking. Thanks to the distribution of up-to-date imagery and the mobilization of remote mappers from around the world, a geospatial infrastructure for Haiti was built to ground disaster response (Zook *et al.*, 2010). The mapping efforts for disaster relief were extended beyond the event by HOT, with the aim to make the map locally owned and maintained to keep pace with the changing socio-physical environment and as a tool for facing future threats (Shemak, 2014; Soden and Palen, 2014).

Similarly to the work presented in this paper, by extracting information from the OSM database, Poiani *et al.* (2016) studied how the collaborative mapping was coordinated before and after the Nepal earthquake in 2015. Due to the major dimension of the event and the coordination led by HOT, the study highlighted huge amounts of edits performed by both new OSM mappers and participants to the so-called mapathons. These are short social events where both experienced OSM mappers and beginners meet and contribute data to the project (Ebrahim *et al.*, 2016). In a study carried out on 26 HOT campaigns, Dittus *et al.* (2016) highlighted that most of the contributors are already active at the time of the disaster, a small percentage of experienced mappers are reactivated because of the event and first-time mappers provide major contributions which are often biased by quality issues. As a further example, Palen *et al.* (2015) studied the OSM volunteers' contributions after the onset of the 2013 Typhoon Yolanda (or Haiyan) in the Philippines. The authors found a 3-fold increase in the number of mappers since the Haiti event, which could be explained by both the growth of the OSM community and HOT's organizing effort, e.g. thanks to the introduction of the TM that reduced the overlapping and conflict of edits.

HOT's cooperation with other organizations has led to projects aimed at preventive mapping in countries that are high vulnerable to epidemics, political crises and natural hazards and where maps do not exist. As an example, Médecins Sans Frontières, the British and American Red Cross and HOT have launched a project to add 200M addresses to OSM in crowded towns, villages and refugee camps where digital maps are missing, to facilitate medical care (Feinman, 2014). Similarly, mapathons were organized by the American Red Cross and HOT to fight the 2014 Ebola outbreak in Western Africa (Moeller and Furhmann, 2015). Recently, a partnership between HOT and Digital Globe has launched a malaria elimination campaign in Southern Africa, Southeast Asia and Central America (https://www.hotosm.org/projects/malaria_elimination_campaign).

3. The Italian case study

On August 24, 2016, at 03:36 AM (local time) a M_L 6.0 earthquake (M_W 6.0) struck an extensive portion of the Central Apennines between the towns of Norcia and Amatrice (see Figure 1). The epicentre was located near the town of Accumoli. The area was struck by several earthquakes in historical times (1627, 1639, 1672, 1703) (INGV Working Group on Amatrice earthquake, 2016). The 2016 earthquake caused 299 victims and almost 400 injured people. Several other shocks occurred during the following weeks and other earthquakes struck adjacent areas in the Central Italy during the following months on October 26 (M_L 5.4), October 30 (M_L 6.5) and January 18, 2017 (4 main subsequent shocks, M_L 5.1, 5.5, 5.4, 5.0).

The data analysed and discussed in this article refer only to the first event (August 24, 2016). In fact, this was the main driver for the activation of the Italian OSM community's mapping efforts. The first edit in the map was made at 05:44 AM, while the first message on the Italian OSM mailing list was sent at 06:56 AM (https://lists.openstreetmap.org/pipermail/talk-it/2016-August/054643.html). The collaborative mapping response started with the activation, at 11:02 AM, of the first task (Project 13) in the OSM TM instance managed by Wikime-

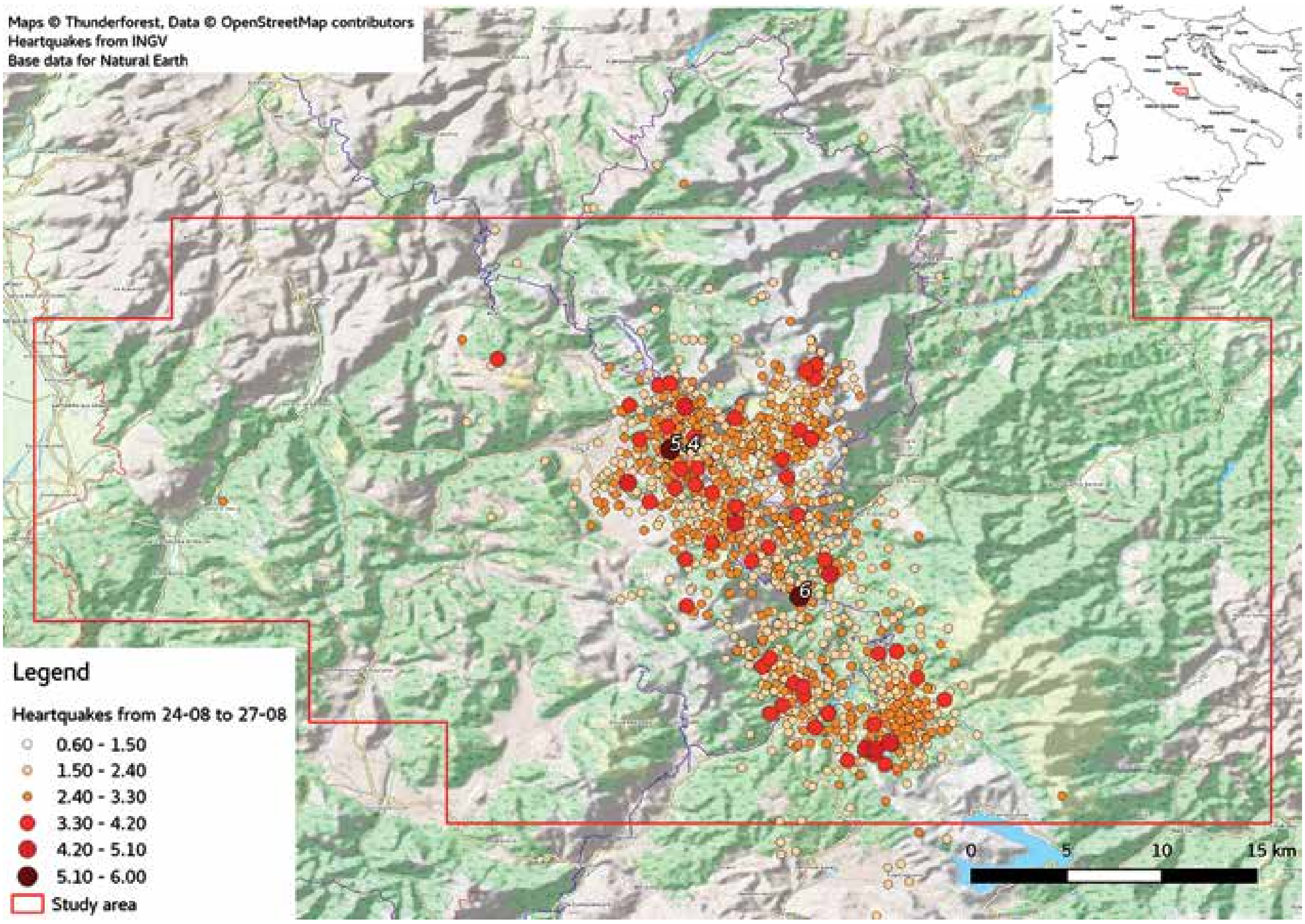

Fig. 1. Seismicity registered from August 24 to August 27 in the study area. The two darker red points identify the epicentres of the main shocks at 03:36 AM and 04:33 AM on August 24, 2016.
Sismicità rilevata dal 24 al 27 agosto nell'area di studio. I due punti più scuri corrispondono agli epicentri delle scosse più forti delle 03:36 e 04:33 del 24 agosto 2016.

dia Italia (the Italian association promoting Wikipedia and the other Wikimedia projects in Italy and, since 2016, the Italian OSM chapter) to improve the basemap of the area with the pre-earthquake information (http://osmit-tm.wmflabs.org/project/13). This was followed by the activation of other two TM tasks: Project 14 (http://osmit-tm.wmflabs.org/project/14) and Project 15 (http://osmit-tm.wmflabs.org/project/15). It must be said that, due to the small dimension of the area, the presence of an already well-coordinated national community and the activation of tasks in the Italian TM managed by Wikimedia Italia, no additional tasks were activated on the HOT's TM. Thus, the primary community of OSM volunteers addressed was the Italian one. Finally, a strong interaction was activated with the European Commission COPERNICUS Emergency Mapping Service (http://emergency.copernicus.eu/mapping/copernicus-emergency-management-service) with the purpose of adding to OSM the information derived from the remote sensing assessment of damages on buildings and roads published in a specific activity created by COPERNICUS Emergency Mapping Service for the earthquake in Central Italy (http://emergency.copernicus.eu/mapping/list-of-components/EMSR177).

3.1. Methodology

The analyses are primarily based on the OSM full history planet file (http://planet.openstreetmap.org/planet/full-history), which contains the full editing history of the OSM database. Thanks to the Osmium Tool (http://osmcode.org/osmium-tool), the OSM planet file was cut both spatially (on the same geographic area of Project 13 in the OSM TM, which also included the areas of Project 14 and Project 15) and temporally (on the whole year 2016). In other words, the resulting file contained the full history from the beginning to the end of 2016 of all the OSM objects included in the area of interest, i.e. all their versions and changes (in geometry and attributes), the user(s) who made the changes and the timestamp of each change. This file was then imported into a PostgreSQL database (https://www.postgresql.org) enabled with the

PostGIS spatial extension (http://postgis.net), using the osm2pgsql tool (http://wiki.openstreetmap.org/wiki/Osm2pgsql). The analysis was also performed on the OSM tile log (http://planet.openstreetmap.org/tile_logs), a text file containing the number of visits to each map tile (https://en.wikipedia.org/wiki/Tiled_web_map). To run the analysis, an open source Python script named OsmEventAnalyst was created (https://github.com/osmItalia/OsmEventAnalyst). In parallel, user contributions from the TM of Wikimedia Italia were also investigated.

3.2. Results and discussion

Throughout 2016, 506 OSM users have made at least one edit in the study area. These users were divided into five classes according to their OSM history: existing users who modified the area only before the event (EB), existing users who modified the area both before and after the event (EBA), existing users who modified the area only after the event (EA), users registered to OSM after the event who made the first edit outside the study area (AO), and users registered to OSM after the event who made the first edit inside the study area (AI). Results show that the existing users contributing OSM edits in the study area in 2016 were about the 90% of the total: they included EB (40.1%), EBA (11.7%) and EA (38.5%). Among the users registered to OSM after the event, the majority (36 users, corresponding to 7.1% of the total) were AI and only 13 (2.6% of the total) were AO. This shows an overall positive response to the event from the OSM Italian community.

Figure 2 (a) shows the evolution of the daily number of OSM users performing edits in the study area after the earthquake of August 24, 2016. A peak is clearly visible on August 24 and 25, followed by about two weeks of intense OSM mapping. After that, the activity remained almost silent until the second earthquake (October 30) when another peak is visible. Figure 2 (b) shows instead the daily number of OSM edits according to the user categories presented above. Most of the edits were clearly performed by the OSM users already registered before the earthquake (EBA and EA), while little contributions were provided by new users. Interestingly, while for the first earthquake the contributions of users who were already active before the event (EBA) are less than the contributions of users “attracted” after the event (EA), the proportion is inverted (contributions of EBA greater than those of EA) for the second earthquake. A possible reason might be that EA are mostly not local people driven by humanitarian concerns who after the first event were more motivated than EBA in contributing to the mapping activity. Conversely, the second event has attracted a higher number of local contributors.

The results highlight that the collaborative mapping effort was driven by already experienced users. Conversely, new users had probably not enough experience and practice to be able to significantly contribute to the mapping activities. To analyse the mapping performed through the TM of Wikimedia Italia, the lists of OSM contributors available for Projects 13, 14 and 15 were first extracted. These include only the contributors who have marked as complete at least one of the sub-areas of each Project (see http://learnosm.org/en/coordination/tasking-manager for details), i.e. they do not include

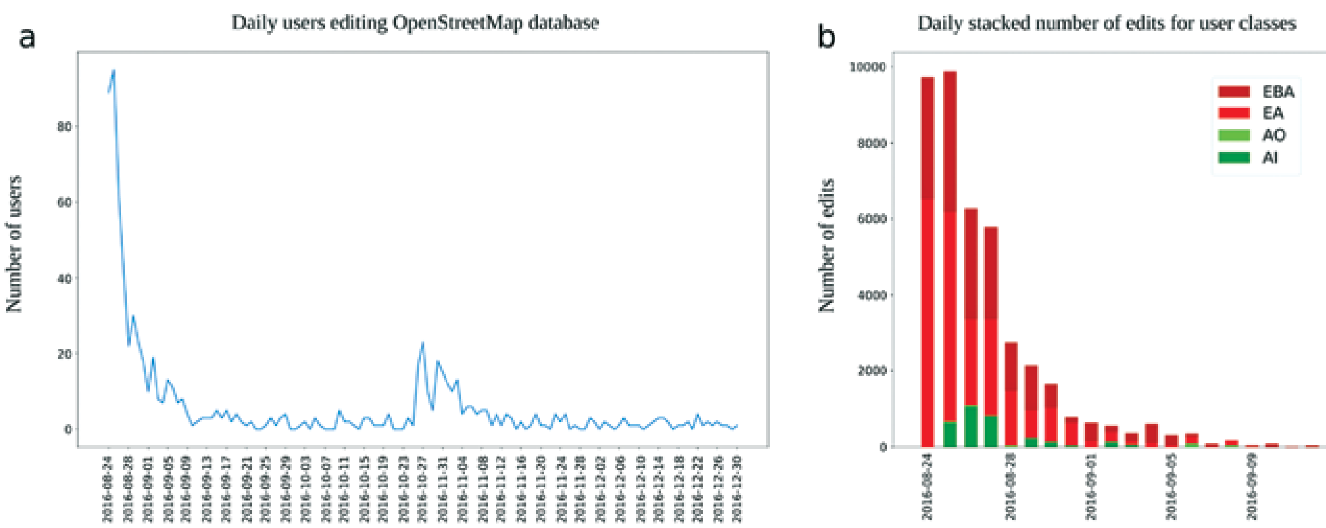

Fig. 2. Daily number of users editing OSM in the study area (a); stacked daily number of OSM edits per categories of users after the earthquake of August 24, 2016 (b).
Numero giornaliero di utenti che hanno editato OSM nell'area di studio (a); numero giornaliero di modifiche a OSM per categorie di utenti dopo il terremoto del 24 agosto 2016 (b).

all the contributors who have made at least one edit in the study area. The latter are traditionally much more than those who have marked as complete the project sub-areas. Comparing the OSM usernames of the 94 contributors who marked as complete the sub-areas of Projects 13, 14 and 15 with the usernames of the contributors extracted from the OSM full history planet file, results show that the 94 TM users included most of the users active in the aftermath of the first earthquake (to which Projects 13, 14 and 15 were related) and overall they contributed the 63% of the total OSM map edits in the study area during the whole 2016. Taking into account that the contributors active through the TM were more than the 94, this confirms that the TM is a very important driver and aggregator for disaster-related mapping.

The analysis of the OSM data in the study area reveals that most of the objects (~90%) were not modified after the earthquakes and the objects with more changes are linear data, followed by point and polygon data. Almost all the edited objects were created before the first event, which is in line with the fact that they were edited afterwards to reflect the damages or changes caused by the earthquakes. The number of OSM objects with changes in geometry was approximately the double of those with changes in the attributes (or tags). Finally, the analysis of the OSM tile log files in the study area shows an expected peak on August 24, 2016. Visualization of the tiles corresponding to the city centre of Amatrice (WGS84 lon-lat coordinates 13.2891755, 42.6292367) reveals that before the event the area was almost not visited at all in OSM, while it was still visited after months from the event.

The detailed results of this analysis on OSM data, including additional plots and graphs, are available at http://www.geodati.fmach.it/osm_paper_geam.html.

4. Conclusions

Over the recent years, OSM has become a catalyst for the collaborative mapping response after natural disasters. This work has investigated the response of OSM volunteers after the earthquake events occurred in Italy in 2016. The analyses show that these events have mainly stimulated the existing OSM users to improve the quantity and quality of data in the event area, while few new users have contributed to the mapping efforts. In addition, the study has shown that the area hit by the earthquakes has gained a lot of OSM-related interest in terms of both visualization and new data added after the disasters.

A number of lessons were learned from this experience. First, the availability and activation of a TM instance (like the one of Wikimedia Italia in the case study analysed) is crucial to coordinate volunteers' efforts and especially to prevent the conflicts traditionally generated when many users edit the same area in the aftermath of a disaster. The availability of post-event satellite imagery is crucial as well to increase the accuracy, the up-to-dateness and, in general, the fitness-for-use of the OSM data created/edited by volunteers. After the Italian earthquake, OSM data were used on the field by rescue workers, fire fighters and the Civil Protection. Despite this is a very successful result, in a future outlook the situation might be still improved, e.g. by further strengthening and coordinating the OSM national community; by encouraging institutions to make use of the OSM basemap on their official websites to advertise and promote the project, to adopt policies based on releasing open geospatial data (not only after disasters) and enabling their reuse in OSM; and by enhancing the contacts between the OSM community, the Civil Protection and the Copernicus Emergency Management Service to optimize the channels for data/information exchange.

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