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Understanding the Mapping Sequence of Online Volunteers in Disaster Response

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Abstract

In recent years, online volunteers have been actively participating in disaster response, thanks to the advancement of information technologies and the support from humanitarian organizations. One important way in which online volunteers contribute to disaster response is by mapping the affected area based on remote sensing imagery. Such online mapping generates up-to-date geographic information which can provide valuable support for the decision making of emergency responders. Typically, the area affected by an disaster is divided into a number of cells using a grid-based tessellation and each volunteer can select one cell to start the mapping. While this approach coordinates the efforts from many online volunteers, it is unclear in which sequence these grid cells have been mapped. This sequence is important because it determines when the geographic information within a particular cell will become available to emergency responders, which in turn can directly influence the efficiency of rescue tasks and other relief efforts. In this work, we study three online mapping projects which were deployed and utilized in 2015 Nepal, 2016 Ecuador, and 2016 Japan earthquakes to gain insights into the mapping sequences performed by online volunteers.

Keywords: Disaster response, crisis mapping, volunteered geographic information

1 Introduction

In recent years, online volunteers have been actively involved in disaster response. On the one side, information and communication technologies allow volunteers to contribute to disaster relief without having to be physically present at the affected areas. On the other side, humanitarian communities, such as Standby Task Force (Meier, 2012a) and Crisis Mapper (Shanley et al., 2013), play an important role in bringing together online volunteers and coordinating their efforts. With the support from technologies and humanitarian organizations, volunteers have made important contributions to 2010 Haiti earthquake (Zook et al., 2010), 2012 Hurricane Sandy in the U.S. (Meier, 2012b), 2013 Typhoon Haiyan in the Philippines (Humanitarian OpenStreetMap Team, 2013), and the 2015 Nepal Earthquake (Hu and Janowicz, 2015).

One important way in which volunteers contribute to disaster response is by mapping the affected areas based on remote sensing images. During the online mapping process, volunteers digitize geographic features which may be missing from the previous maps, as well as update the existing geographic data to reflect the current status (e.g., a road may be blocked after an earthquake). This process generates up-to-date geographic information which can provide valuable support for the decision making of emergency responders. While these volunteer-contributed data may not be of highest quality, they generally satisfy the needs of disaster response (Goodchild and Glennon, 2010).

Since many volunteers may be participating in online mapping at the same time, humanitarian organizations often divide the affected area into cells using a grid-based tessellation. Each online volunteer can then select a grid cell to start the mapping task. While this approach helps avoid editing conflicts and duplications, there is a lack of understanding on the sequence in which online volunteers map the grid cells. Such a sequence is important because it directly determines the time when the geographic information within a particular cell will become available. From our observation, the mapping time difference between two neighboring grid cells can be 4 days and sometimes even longer. In disaster response, the first 72 hours after a disaster have been widely considered as the critical period for rescue tasks. After this period, the survival rate drops dramatically (Fiedrich et al., 2000; Comfort et al., 2004; Ochoa and Santos, 2015). Thus, if the grid cells that contain the critical information for disaster response are mapped first, more people can be potentially saved. Intuitively, selecting cells at random is not an ideal solution, since population, transportation infrastructure, and potential rescue routes should be taken into account.

Consequently, the research question that we would like to address here is *whether online volunteers are mapping grid cells in a near-random order or whether they are following certain strategies?* To answer this question, we examine the volunteer mapping sequences in three different projects, namely the 2015 Nepal, 2016 Ecuador, and 2016 Japan earthquake mapping campaigns. In the following sections, we first describe the studied mapping projects and datasets, then present the analysis methods, and finally discuss the results and conclusions.

2 Studied Online Mapping Projects

The three online mapping projects studied in this research are depicted in Fig. 1. The Humanitarian OpenStreetMap Team (<https://hotosm.org>) is the major organization that provides the mapping platform for online volunteers. As shown in Fig. 1, yellow cells are those that have been mapped by volunteers, and green cells are those that have been both mapped and validated (mapping and validation are performed by different volunteers).

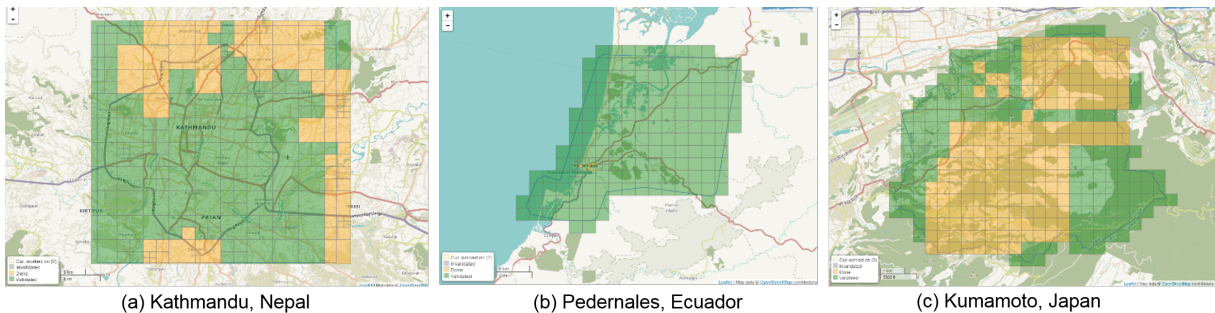


Figure 1: Three online mapping projects studied in this work.

Table 1 summarizes information about the three studied projects. It can be seen that different projects have different numbers of grid cells and participated volunteers. The large number of participants in the Kathmandu project might be explained by the big impact of the 2015 Nepal earthquake: more than 8,000 people died and 21,000 were injured. The cell sizes are predefined by the humanitarian organizations, and can vary among different projects as well as within the same project. The time difference between the earliest and latest mapped cells also varies among the three projects, and in the case of Kumamoto, Japan, a decision maker may need to wait about 76 hours until he/she can obtain the geographic information within the last mapped cell.

Table 1: Information about the three studied projects.

	Kathmandu, Nepal	Pedernales, Ecuador	Kumamoto, Japan
Number of Cells	208	186	340
Varied Cell Sizes	Yes	Yes	No
Number of Volunteers	321	85	52
Earliest Finish Time	2015-04-27 15:20:43	2016-04-23 13:40:13	2016-04-16 21:41:46
Latest Finish Time	2015-04-30 10:57:21	2016-04-25 21:29:25	2016-04-20 01:54:14

3 Analysis Method

To analyze the mapping sequences performed by online volunteers, we retrieved the timestamps when the mapping of the cells has been finished. To examine whether the volunteers are already following certain patterns, we made use of two additional datasets, population and road networks. 2014 LandScan data have been used for population, and road data from OpenStreetMap have been retrieved for the road network. We reproduced the same grid cells based on the three studied projects, and aggregated the population and road length to each grid cell. We then ranked all the grid cells based on the mapping finishing time (from earliest to latest), total population within a grid (from highest to lowest), and total road length within a grid (from highest to lowest).

With the three generated ranks, we examined whether the mapping sequence performed by online volunteers is related to population or road networks using Spearman's correlation coefficient:

$$\rho = 1 - \frac{6 \sum_i d_i^2}{n(n^2 - 1)} \quad (1)$$

where d_i is the difference between two ranks (e.g., the rank based on the mapping time and the rank based on the population), and n is the total number of cells (e.g., 208 for the Kathmandu case).

4 Results and Discussions

The Spearman's correlation coefficients derived from the experiments are summarized in Table 2. It can be seen that the mapping sequences performed by volunteers in the Kathmandu and Kumamoto projects show a *weak to moderate* and significant correlations with the total population and road length. No significant correlations are observed for the Pedernales project, possibly because this project involves a number of cells which cover only the ocean (thereby no population and roads) but which were mapped first by volunteers. To better understand the different rankings for each of the three mapping projects, we also visualize the results as Fig. 2 to 4.

Table 2: Result of the correlation analysis.

	Kathmandu, Nepal	Pedernales, Ecuador	Kumamoto, Japan
Correlation with Population	0.45 ($p < 0.001$)	-0.05 ($p = 0.521$)	0.48 ($p < 0.001$)
Correlation with roads	0.46 ($p < 0.001$)	0.07 ($p = 0.369$)	0.26 ($p < 0.001$)

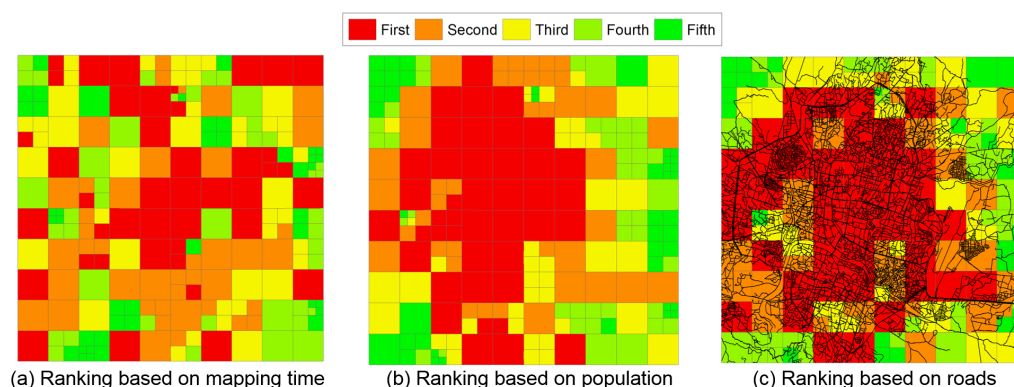


Figure 2: Different rankings for the Kathmandu mapping project.

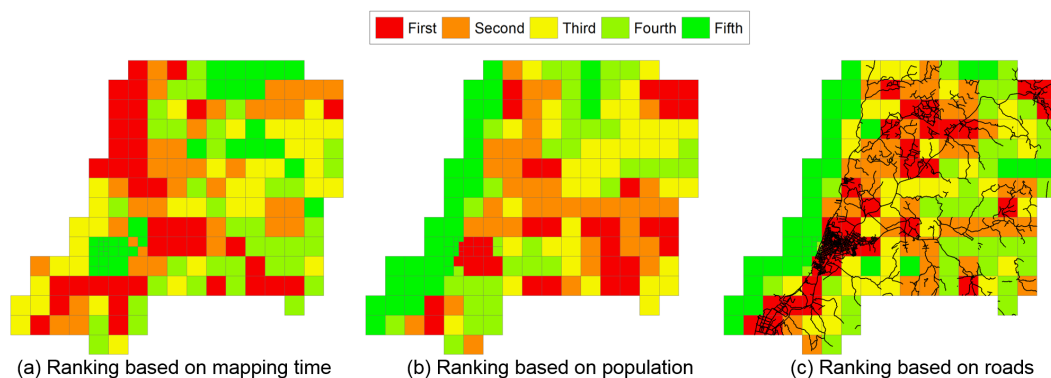


Figure 3: Different rankings for the Pedernales mapping project.

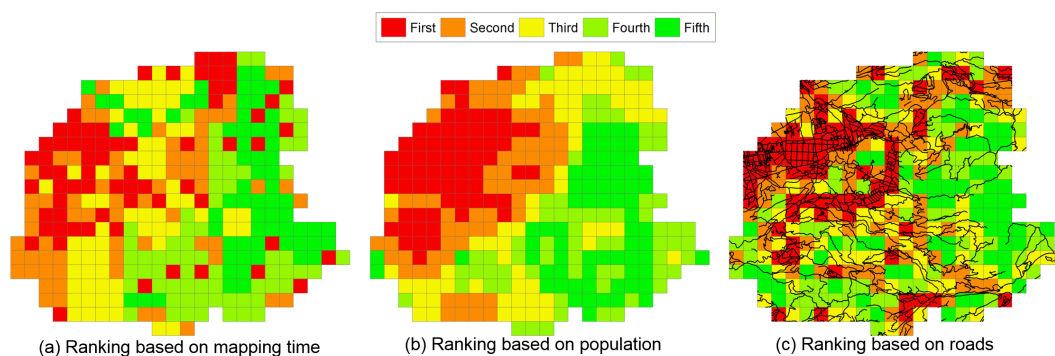


Figure 4: Different rankings for the Kumamoto mapping project.

One can see that the mapping sequence in the Kumamoto project is comparatively similar to the population distribution, whereas the mapping sequence in the Kathmandu shows a weak similarity with

population and road network density. In all three projects, it seems there are some grid cells which were randomly mapped at an early stage (the cells in red color). Overall, we do not observe strong correlations between the mapping finishing time and the population and road networks, indicating room for improvement.

5 Conclusions and Future Work

In this work, we studied the mapping sequences performed by online volunteers in disaster response. Understanding such sequences is important because they determine when the geographic information within a cell will become available to emergency responders. Such time difference can be more than 72 hours, which are beyond the golden period for rescue tasks. Three projects from different countries and different disaster events have been utilized for this study. We described these projects based on the number of grid cells, number of participated volunteers, cell sizes, and earliest and latest mapping finished times. Spearman's correlation analysis has been computed between the mapping sequences and the population distribution as well as the road networks. The results indicate no strong correlation between the mapping sequences and the two additional datasets, thereby pointing to improvements that could be implemented to make disaster mapping more efficient.

Here we have studied three mapping projects (although in total 458 online volunteers were involved in these three projects) and correlated them with two types of additional datasets. More work is needed to understand disaster mapping projects in general and their dynamics over time and study areas. Nevertheless, it is possible that online volunteers may have randomly picked grid cells to start the mapping tasks. Due to the spatial heterogeneity, different grid cells may contain geographic information that is of different importances to the emergency responders. If the grid cells containing more critical information can be mapped first, such information will become available to emergency responders in an earlier stage, which can help potentially save more people. Therefore, we believe that there is a need to prioritize the grid cells based on the values of the contained geographic information, and provide online volunteers with a general guidance for mapping.

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