Towards a collaborative method for crisis management

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Abstract. When a natural or a Man-made disaster strikes, crisis managers need reliable and real-time information to enhance their situation awareness and then make quick and effective decisions. Involving multiple and heterogeneous data sources in the collection of such information is of a high usefulness in the crisis response process. In this paper, we propose a method based on a collaborative collection of disaster data in order to enhance decision makers' situation awareness. We propose system architecture of a crisis management system with data analysis and data visualization capabilities.

Keywords: Crisis management, Situation awareness, Data collection, Web mobile application.

1 Introduction

Natural disasters (e.g., tsunami, floods, earthquake, and fire) or Man-made disasters (e.g., terrorist attacks and nuclear explosion) have negative impacts on economy and society, causing multiple human losses, casualties, and property and infrastructure damages. Recently, Irma Hurricane struck Caribbean islands and the southern of the USA on August 30th 2017, resulting 133 deaths (45 direct deaths and 88 indirect deaths) and billions of dollars economic losses according to The National Hurricane Center [1]. Thus, managing these critical situations to reduce crisis impacts and saving lives is crucial and remains a challenge to our community and to the crisis managers especially. Crisis response involves many efforts such as damage assessment, risk assessment, goals prioritization, evacuation of affected population, coordination between crisis stakeholders and resource allocation and mobilization [2, 3]. These tasks are performed in an environment characterized by stress, time pressure and uncertainty. Taking right decisions in such circumstances is a challenging task.

Situation awareness [4] is a key factor to quickly and effectively respond to a crisis situation [5]. To reach crisis managers' situation awareness, task forces (e.g., first responders) are sent to the disaster scene to collect relevant and real-time data and send them to the crisis cell to let decision makers understand what is going on at the crisis scene. However, the limited number and resources of task forces to gather situational disaster data leads decision makers to have a partial view of the ongoing situation. Consequently, they may take inappropriate decisions. Thus, involving multiple and heterogeneous data sources is of a great usefulness to have a comprehensive view and a well understanding of the crisis situation. Crowdsourcing situational disaster data [3] i.e., engaging volunteers, victims, as well as eyewitness in gathering crisis data, seems to be an effective solution to help crisis managers in understanding the situation. This method has proved its efficiency in the 2010 earthquake [6].

In this paper, we propose a method based on a collaborative collection of disaster data in order to enhance decision makers' situation awareness. To do so, we propose a crisis management conceptual framework with data analysis and visualization capabilities.

The organization of this paper is as follows. Section 2 presents a review of related works. A description of our proposed method is outlined in section 3. Section 4 concludes the paper and presents our future works.

2 Related works

To support crisis managers' situation awareness and decision making, many decision support systems and frameworks have been developed to aid decision makers in making effective and timely decisions in order to face the crisis situation. To provide a Common Operational Picture (COP) for crisis managers, Horndahl et al. [7] proposed a reporting system based on dynamic forms to gather situational disaster data using hand held devices. The authors considered in-site stakeholders as the unique data sources. This could lead to have a partial view of the overall situation. Grolinger et al. [8, 9] proposed a knowledge as a service framework for disaster cloud data management. Their system brings two functionalities: The knowledge acquisition function and the knowledge delivery function. The first one gathers data from heterogeneous data sources, process and store them in the cloud environment. The second one answers information requests submitted by service consumers. The input data of their framework are documents (e.g., incident reports, situation reports, disaster plans), data from social media, simulation models, Wireless Sensor Networks (WSN) readings and Web pages. Di-DAP [10], a Disaster Information Delivery and Analysis Platform in disaster management, collects data from online disaster related documents e.g., local news feeds and announcements from government sites, FEMA [11]. To support situation awareness and to avoid being overwhelmed by disaster information, Aid et al. [12] propose a context-aware framework that gathers data from heterogeneous sources and filter them by taking into account the decision maker's context. In this work, situational reports generated from governmental and non-governmental organizations are the framework's input data. Avvenuti et al. [13] implemented a decision support system for the detection and the damage assessment of earthquakes in Italy. Data mining and natural language processing techniques are used to select meaningful sets of tweets and burst detection techniques are employed to detect an earthquake event. Information discovered by their system helps to identify where to concentrate the rescue teams and organize a prompt emergency response. Villela et al. [14] developed a decision support system called RESCUER for crisis and emergency management based on information coming from crowdsources (e.g., work forces and civilians) acquired via mobile application. The role of their DSS is to support crisis managers' situation awareness. Natural language processing techniques were employed to analyze text data and machine learning algorithms were used to analyze images. Basu et al. [15] suggested a decision support framework for damage and need assessment and to enhance decision makers'. To fulfill their task, the proposed system gathers situational disaster data from crowdsources through SMS text messages, analyzes them and generates reports. Finally, we mention the well-known disaster management system Ushahidi[1] that collects georeferenced data, leveraging the power of crowdsources and supports the visualization of such data. An overview of the related works is provided in Table 1. Most of related works adopted few heterogeneous data sources, supported few data types e.g., text and most of the time used NLP techniques for information extraction purpose. In this paper, we propose to consider several heterogeneous data sources, support all data types and employ advanced data analysis techniques e.g., machine learning algorithms in order to give a comprehensive situation awareness to decision makers.

3 Proposed method

In order to help emergency managers to take right decisions in a crisis situation, situation awareness plays a key role to achieve these tasks. Inaccurate, incomplete and outdated information could lead decision makers to take inappropriate decisions [14]. Therefore, inspired by works of [14-16], we propose in this paper a method to enhance crisis managers' situation awareness and to assist them in making effective and timely decisions. Our proposed method consists of 3 steps (see Fig. 1):

- Data acquisition: aims to gather disaster data from several heterogeneous data sources.
- Data analysis: aims to filter, analyze and aggregate gathered data in near real-time. In one hand, this module extracts useful information from unstructured text data using NLP techniques. In the other hand, this component analyzes images and videos gathered from crowdsources, in-site stakeholders and dispatched UAVs using machine learning algorithms.
- Report generation and information presentation: with the help of data visualization techniques e.g., heat maps, this module provides to disaster managers and to the information consumers in general a comprehensive view i.e., a Common Operational Picture (COP) of the ongoing crisis situation and let them retrieve needed information.

3.1 Data collection (step 1)

Adopted data producers. To ensure high reliability and real-time characteristics of the acquired disaster-related data, we choose in-site data producers i.e., those who are present at the disaster scene:

[1] Ushahidi, https://www.ushahidi.com/, last accessed 15/09/2018

– Task forces: firefighters, first responders, medical staff and police.
– Volunteers
– Crowdsources: victims and eyewitness
– Wireless sensor networks and Unmanned Aerial Vehicle (UAV).

Table 1. An overview of the data acquisition and analysis modules of related works

Work	Data collection										Data analysis techniques	
	Data types			Data sources					Collection technique			
	Text	Image	Video	Stakeholders	Victims/ Eyewitness	Web Pages	Social Media	WSN	Web Mobile Application	SMS	Natural language Processing	Machine learning
[7]	X			X					X		-	-
[8, 9]	X			X		X		X	-	-	X	
[10]	X					X			-	-	X	
[12]	X			X					-	-	X	
[13]	X						X		-	-	X	X
[14]	X	X	X	X	X				X		X	X
[15]	X				X					X	X	
USHA-HIDI	X	X			X		X		X		X	X

Data collection process. Since disasters affect masses of people, requiring the involvement of multiple and various organizations and stakeholders, collaboration plays an important role to increase response effectiveness and reduce casualties [17]. Thus, we underline the collaborative aspect in the data collection step. This means that work forces, volunteers and crowdsources e.g., victims also considered as first responders [18] contribute in building a Common Operational Picture (COP).

Using mobile devices and a Web mobile application, these data producers on the one hand are provided with the most updated map-based reports of the ongoing crisis situation (see Fig. 2). On the other hand, they could send relevant, timely, geolocalized and original emergency reports to the crisis management system (see Fig. 3). However, since the disaster scene is highlighted by time pressure, urgency, threat and stress [19], the process of acquiring situational disaster data should be easy, efficient and rapid enough to accelerate the intervention of rescue teams. Therefore, we propose that emergency reports will be mainly in the form of question forms. Additional information about the emergency situation will be provided in the form of free text. We note here that SMS will be used instead of the Web mobile application in case of Internet unavailability.

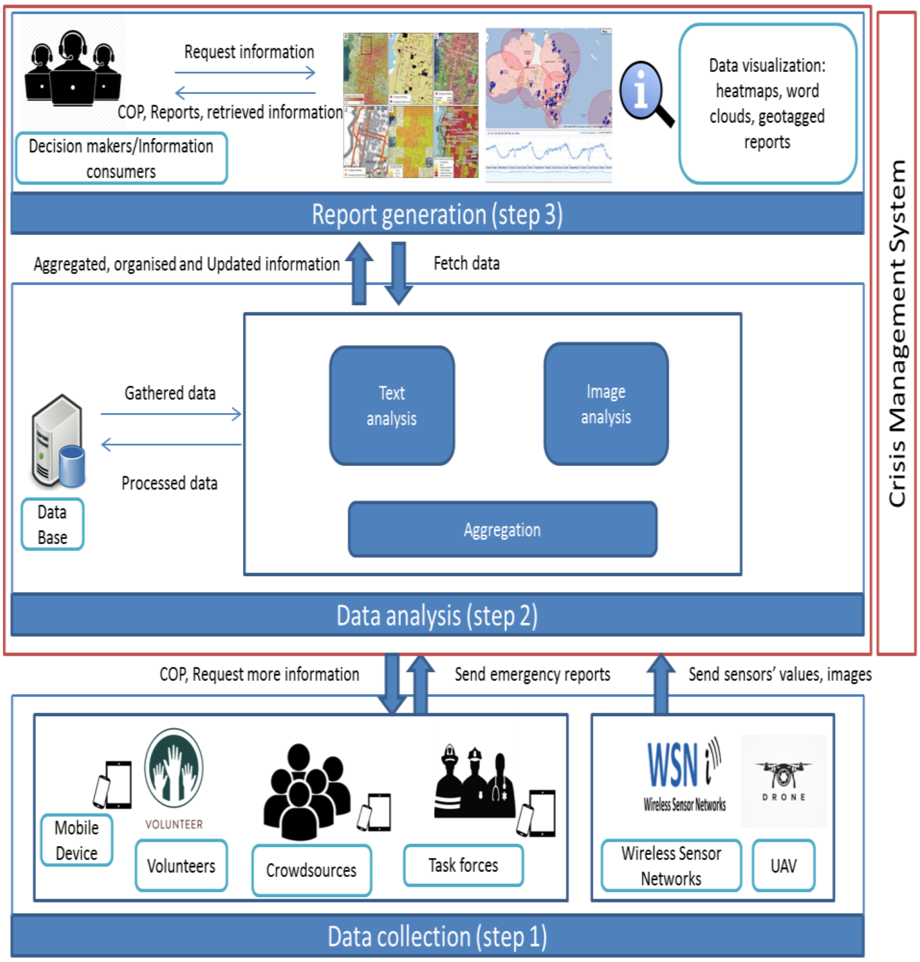

Fig. 1. Block diagram of the proposed method

3.2 Data analysis (step 2)

After gathering situational disaster data and storing them in a database, the system starts the processing step. Text analysis and image analysis components put together the analysis module. Text analysis component uses NLP-based techniques (e.g., tokenization, word cleaning, Named Entity Recognition) to extract structured information from free text as part of the emergency report. Image analysis component uses computer vision and machine learning techniques e.g., Support Vector Machine algorithm to analyze images captured by UAVs or by the mobile device's camera. This will help decision makers to confirm of the emergency type e.g., fire, flood.

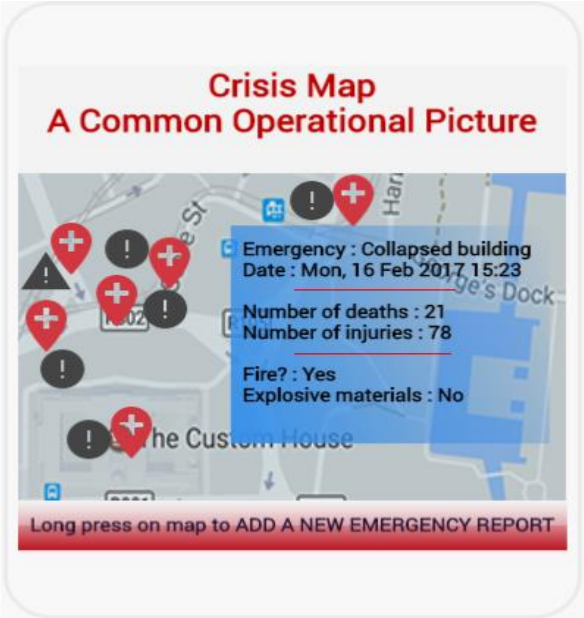

Fig. 2. Crisis map (mockup)

3.3 Report generation (step 3)

In order to enhance decision makers' situation awareness, the crisis management system provides several reports about damage assessment, need assessment, affected zones, resource requirements, etc. With data visualization techniques (e.g., heat maps, word cloud), these reports are presented in a map-based and a user-friendly Web application graphic interface. In addition, in-site stakeholders, volunteers and crowdsources could view generated reports in the Web mobile application (see Fig. 2) but with less details unlike decision makers that have a comprehensive view. This will let them be up-to-date with the ongoing situation.

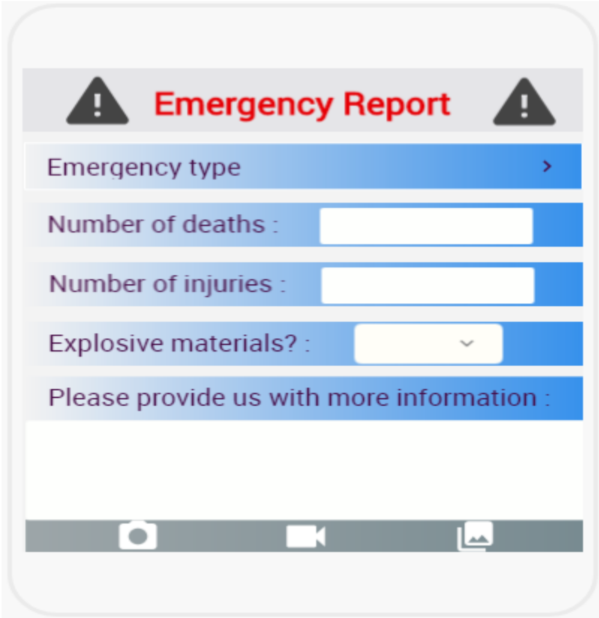

Fig. 3. Emergency report (mockup)

4 Conclusion

This paper presents a method for crisis management based on a collaborative collection of situational disaster data. This latter is performed by several and heterogeneous data sources using a Web mobile application. The purpose of the envisaged system is to enhance decision makers' situation awareness through the generation of summarized reports that could be visualized on a map-based and user friendly graphic interface. Compared with related works, our contributions are: (1) the involvement of different data sources, all of them are present at the disaster scene. This will increase the trustworthiness and the reliability of the gathered emergency reports; (2) situation awareness and data collection functions of the Web mobile application with an interaction mechanism; (3) free text and image data processing capabilities. Future work will include the full development of the Web mobile application. This latter will incorporate three different types of sessions, each one is dedicated for a data producer type i.e., task forces, volunteers and crowdsources. The choice of NLP techniques and machine learning algorithms for data processing will be more investigated for better analysis results.

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