A REVIEW OF DISASTER MANAGEMENT FRAMEWORKS

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ABSTRACT

Over the past two decades, several disasters have been recorded, leaving behind a number of victims among death and wounded. Disasters can be natural, such as earthquakes, hurricanes, forest fires and tsunamis, or artificial (man-made) such as urban disasters, terrorist disasters and industrial disasters. Several research studies have been conducted in attempts to deal with disasters in three stages: pre-disaster, during disaster, and post-disaster. Generally, disaster management encounters many challenges; however, due to continuous technological improvement, some challenges have been addressed. In many cases, information technology has a major influence ondisaster management success. The Internet of Things (IoT) is one of the key players which can provide a substantial amount of real-time data collected from as number of devices distributed along several geographic locations. In disaster management systems or frameworks, data are considered to be one of the most critical success factors because it represents the backbone of thesystem. In this paper, a review of the most recent data sources and frameworks used for disaster management has been discussed.

Keywords: Information system; Preparedness; GIS; IoT.

INTRODUCTION

The fast and effective responses to disasters save human lives. Disasters can be either natural or man-made. Disaster management is all about mitigation, prevention, preparedness, relief and rescue actions or operations based on the current stage of a disaster. That is, relief actions and rescue activities take place during the post-disaster stage, whereas mitigation, prevention and preparedness activities are related to the pre-disaster stage in order to avoid human and non-human casualties within a prospective area of hazard. Data represents a key factor regarding disaster management success, and thus precise data increases disaster management efficiency.

Data can be collected from multiple sources with several types, one of which can be social media where data can be textual, geo-referenced tags, pictures or videos that somehow provide data about certain crisis. However, in order to ensure data accuracy, misleading data problem should be considered and addressed. IoT is the second data source which provides real-time data. The latter is crucial to have dynamic disaster management initiatives. Despite that smartphones, sensors and other multiple devices represent the hardware part of the IoT system architecture; devices' maintenance and cost represent one of the major challenges.

Other essential data source is geo-spatial data sources. Geographic location helps

Citation Information: Abdelaziz, A., & Mesbah, S. (2021). A review of disaster management frameworks. *Journal of Management Information and Decision Sciences, 24*(S5), 1-10.

determine the disasters' affected area. In addition, GIS provides location information associated with post and tweets on social media. Furthermore, it provides powerful geospatial functions and tools that help plan the optimal distribution of IoT devices, ensuring complete coverage over the area of interest.Moreover, GIS provides robust tools that facilitate evacuation planning.

DISASTER DEFINITION AND EXAMPLES

Some definitions, examples of disasters (quakes, volcanoes, terrorism),; losses for humans and economy. There are several methods to define a disaster. According to the International Federation of Red Cross and Red Crescent Societies (IFRC), a disaster can be defined as an unexpected, dreadful incident that drastically disrupts society and leads to humanitarian, economic, materialistic or environmental damages, exceeding the society's ability to overcome such challenges using its own resources (IFRC, 2012). Another way to define a disaster is a natural, man-made or technological hazard that results in an incident of extensive negative damage in the form of loss of lives, destruction or drastic environmental changes. Examples of natural occurring disasters include earthquakes, floods, accidents, fires, or explosions, whereas man-made disasters can be in the form of explosions, oil leakage, and terrorism (Restas, 2015).

There exist a number of instances where catastrophic disaster occurred around the globe. Some of these disasters are Chan Sala (India) mining disaster., Bhopal (India) gas accident (1984), (1975),Chernobyl (Russia) nuclear accident (1986), 9/11 terrorist attack (USA), Indian Ocean tsunami (2004), Nepal earthquake (2015), and Fort McMurray (Canada) forest fire (2016). Is it worth mentioning that in most of the aforementioned instances, people were not able to take the right actions in order to mitigate the damages of the striking disaster; they were more of observers. Thisis mainly because of the lack of knowledge and experience on how to deal with different categories of disasters, even in the form of minimizing human loss through alerting people beforehand in threatened locations (Ray et al., 2017). Consequently, it is important that people be educated on disastermanagement.

Over the years, more and more people are becoming vulnerable to disasters. In addition, the unpredictability and complexity of such disasters lead to a number of problems while preparing different scenarios and plans of actions. Therefore, better strategies and practices are required in order to minimize the resulting damage of these phenomena; however, this is a challenging task due to the amount of uncertainty associated with disasters in terms of probability of occurrence, location, frequency, complexity, severity, and the resources available and required to determine the locations of demand, supply as well as the prospective damaged infrastructure.

Disasters most of the times strike in areas where humans exist, and disregarding the cause of the incident, such disasters often are either natural (i.e. tsunami, flood, forest fire, lightning, landslide, and earthquake) or man-made (i.e. explosion, industrial, leakage in gas production, leakage in an oil pipeline, and terrorist attacks). Furthermore, despite the technological development, the severity, frequency, and the extent of damage of disasters are increasing over time. After an intense natural disaster, communication, roads, and power sources are usually damages, creating an immediate localized resource shortage as well as socially and economically disordered environments. Additionally, natural disasters have been historically related to consequent social conflicts and increasing poverty levels (Xu et al., 2016).

In attempts to improve human knowledge and interaction about disasters, the last few

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years have witnessed drastically increasing research on the consequences of natural disasters, especially with the tremendous technological development represented by the Internet of Things (IoT). The main reason behind such a trending research is because of an increasing awareness of the potential damage caused by such catastrophic disasters.

DATA SOURCES

In disaster management systems or frameworks, data is considered to be one of the most critical success factors because it represents the backbone of the system. The proposed framework mainly has a number of data sources provides different data types: structured, semi-structured, and unstructured data. The aforementioned data sources are: IoT, GIS, social media, and UAVs.

IoT

One of the main technologies that allows humans to properly interact with disaster occurrence is the IoT. In recent years, IoT technology has paved the way to tackling a number of problems and challenges in different fields, such as industry, security, agriculture, and medicine. Despite the fact the IoT started in 2000, it has recently grabbed considerable attention in approximately all areas of scientific and industrial fields, such as smart-home, health care, entertainment, robotics, and transportation. IoT is formulated to establish reliable communication, monitoring, and management of smart embedded devices with its counterpart (analog objects or 'things'), leveraging interoperability, heterogeneity, distributed processing, and real-time analytics in parallel. Interestingly, IoT is still maturing and evolving over time to become the most hyped concept in the IT world, and it is also promoting the vision of a global infrastructure of networked physical objects, which enables anytime, anyplace connectivity for anything and not only for anyone (Evangelos et al., 2011).

IoT can be defined as a global network that allows communication among human-to-human, human-to-things and things-to-things by providing a unique identity to each and every object (Aggarwal & Das, 2012). Despite the aforementioned IoT definitions, there is no unique, standard definition of IoT by the global community of users. Actually, several groups including researchers, developers, practitioners, innovators, and corporate people that have defined the term in spite of the fact that its origin belongs to Kevin Ashton - an expert in digital innovation field. However, the similarity between most definitions is about data created by people, whereas the next version is about data created by things. Consequently, a better definition of IoT would be: "An open and comprehensive network of intelligent objects that have the capacity to auto-organize, share information, data and resources, reacting and acting in face of situations and changes in the environment" (Madakam et al., 2015).

In order to solve the dilemma of formally defining IoT, the components of any IoT system, from software and a hardware point of view, can be defined. That is, there are four main components of an IoT system: the device (the thing itself), the local network (this can include a gateway, which translates proprietary communication protocols to Internet Protocol), the Internet, and back-end services (PCs and mobile devices, or enterprise data systems) (Micrium, 2019).

Furthermore, IoT system are not complex by nature; however, the process of designing and building them can be rather complex. Despite the fact that there is constant development in the hardware and software component of IoT systems, there are enough tools to build high-quality IoTsystems. Generally, the IoT systems can be divided into two main categories. This first one is

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industrial Iot, where the local network is based on any one of various technologies, and the IoT device will typically transmit data over the global Internet. The second category is commercial IoT, where local communication is typically either Bluetooth or Ethernet (wired or wireless), and the IoT device will typically communicate only with local devices. Consequently, in order to better understand how to build IoT devices, one should first figure out how they will communicate with the rest of the world Micrium, 2019).

It is true that the huge development in embedded devices, along with the availability of the appropriate standard communication protocols have reinforced the building of IoT systems. Moreover, the main communication protocols that enable the emergence of IoT are Radio Frequency Identification (RFID), Wireless Sensor Networks (WSN), Internet protocols and mobile communications (Silva et al., 2013; Li et al., 2015).

A lot of the currently existing content in the IoT has been created through coded RFID tags and IPaddresses linked into an Electronic Product Code network (Graham, 2011), and in the meantime, there are 9 billion interconnected devices which is expected to rise to 24 billion by 2020. Furthermore, according to the US National Intelligence Counsel predictions, Internet nodes may reside in everyday things-food packages, furniture, paper documents and more by year 2025 (Evangelos et al., 2011).

Despite the fact that a number of approaches handle major issues in the incident of disasters, a lotof improvement is quite imperative in several technological and design standards. To achieve this, the current IoT systems offer solution to improve the quality of disaster management, and thus address several challenges including, but not limited to, data analytics, run-time analytics, real- time processing, security, maintenance, and robustness.

Data analytics is one challenging component of IoT-based disaster solutions. That is, based on theproperties of each disaster, the proposed system should have the ability to spatially and temporallyanalyze the collected datasets from different locations at different times, which is even more challenging when contexts, sizes, formats, and semantics are uneven in form and formats. Therefore, having a flawless data analytics platform in terms of cloud service is of utmost importance and should efficiently associated with the current scenario (Dong et al., 2014).

Regarding run-time analytics, disasters are highly dynamic in nature and not controlled by human, and thereby an efficient, real-time solution is essential. Recently, a study proposed solutions for the real-time fault-tolerant systems with the aid of two algorithms, meaning that similar procedurecan be extended to developing real-time decision-making (Yin et al., 2013).

Real-time processing is one of the key requirements in IoT-enabled devices for disaster management system to handle dynamic nature of the disaster, and while some approaches take into consideration real-time processing, IoT based disaster management systems must consider such an essential component (Kopetz, 2011).

Security is one fundamental problem in the Internet these days, and any security attacks are quiteharmful to IoT systems. There are several reasons why IoT systems are susceptible to different security attacks. The first reason is because of the minimal capacity devices (things) in use. Secondly, the openness of the system in such a way that the sensors, actuators and objects are physically accessible, not to mention that most devices will communicate wirelessly (Ravi et al., 2004; Xu et al., 2005).

It is imperative that low-maintenance devices be used in IoT-based disaster management system. Usually, the sensor elements for monitoring disastrous events are deployed in locations that are hardly accessible, meaning that the process of maintaining such sensors is quite difficult.

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It is essential that IoT-based architecture be robust and fault-tolerant such that application can be reliable and sustainable while operating in disasters.

GIS

After the availability of IoT, a large number of geographically distributed devices will be equipped with such a technology, generating real-time data streams transported through communication networks such as Bluetooth, WiFi, LoRaWan, Zigbee, and 5G.

Generally, IoT devices are equipped with several sensors, such as microphones, cameras, gyroscopes, proximity, and light sensors. These sensors generate enormous amounts of data in the form of tuples that are most likely out-of-order with high data rate. Furthermore, a large number of devices are being deployed and embedded in smart cities such that they are expected to revolutionize planning the functioning through control, management as well as the optimization of traditional services, such as intelligent smart parking, digital health, and fleet management (Mainetti et al., 2015; Banos et al., 2016; Sun et al., 2016;)[17-19].

Consequently, the world is transitioning from using conventional GIS platforms to IoT-GIS ones,where IoT devices are linked by methods of communication technologies that are vital to allow real-time smart cities functioning from routinely sensed data (Batty et al., 2012). The basic assumptions formingGIS platforms are being tested because of the proliferation of sensors, intelligent high bandwidth networks and cloud computing. In fact, the inefficiency of conventional GIS platforms is mainly due to the fact that they require heavily coordination of several tasks using limited computing resources. Furthermore, the coordination between such tasks was error-prone and quite time consuming. This is because the task demanded human introversion and supervision to execute, because they were not fully integrated. Conversely, automated analytical tasks should have the ability to continuously process the production of data tuples from devices through a number of tasks running on IoT-GIS platforms. Such tasks can be executed at regular time (i.e. each half hour) as well as being triggered when new tuples arrive at a platform.

Social Media

Recently, extensive research is being dedicated towards exploiting the benefits of social media crowdsourcing to efficiently deal with disasters, such as flood mapping; however, it is not yet a mature area of research and a lot of challenges have to be addressed, especially with the increasing number and frequency of disaster occurrence (Crooks & Wise, 2013). Substantial amounts of damages are resulting from such disastrous incidents that are worth billions of dollars, along with large numbers of deathsand injuries (Lu et al., 2016). Therefore, it is imperative that more efforts be dedicated toward efficiently managing disasters, especially in susceptible regions of the world, such as the mega-cities locatedin the developing countries, where millions of people face the risk of death due to lack of resourcescombined with ineffective handling of emergency situations (Ogie et al., 2019).

Fortunately, the development that social media witnesses over the years can be considered as a vital technology that helps manage disastrous incidents, including attainment of situational awareness, facilitation of crisis communication, and speedy detection of socially disruptive events (De Albuquerque et al., 2015). Furthermore, the richness and diversity of information of time-critical information shared onseveral social media platforms during disaster occurrence provide such a valuable opportunity to exploit the benefit of such spatial and

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temporal information to help manage emergency situations (Granell & Ostermann, 2016).

Lots of attention and effort are being exerted to promoting the so-called “wisdom of the crowd” during disastrous events, and several studies have been attempting to highlight and share the benefits resulting from crowdsourced social media data for disaster management, providing near real-time data, improved crisis communication, cost saving, locational cues where help is needed, and collective intelligence as well as improved situational awareness (Zook et al., 2010; Gao & Klein, 2011; Roche et al., 2013).

In spite of the all the previously mentioned benefits of crowdsourced data of social media during disasters, a number of challenges must be tackled, of which arises the most crucial ones in terms of data quality, validation, and accuracy (Goodchild, 2007). Moreover, examples of the potential drawbacks of social media data include false or non-genuine reports, inferencing of crisis locations from geotagged data, contradictions between crowdsourced amateur opinions and utilizing expert knowledge and, false alarms inherent in confirmed information, poor processing of duplicate reports (e.g., retweets), scalability and interoperability issues, inequality in access to participatory tools (e.g., technology, skills, education), privacy concerns, inadequate features to protect the safety and security of data contributors and relief workers, poor filtering of voluminous data as required for report summarization, and the lack of predictive capabilities to forecast the demand for disaster relief resources at various locations and time (Huang et al., 2010; Zook et al., 2010; Gao & Klein, 2011; Shanley et al., 2013; Brandusescu & Sieber, 2018).

Additionally, a study concluded that the current application that rely on social media data do not have the complete ability to ameliorate the coordination and collaboration among disparate relief organizations (Gao & Klein, 2011). To elaborate, based on previous experiment of using Twitter data in Japan's tsunami disaster, there was quite an obvious lack of efficient methods to rapidly trace and delete information about action that have been taken care of by the authority (Acar & Muraki, 2011). Furthermore, confusion and inconsistency have been noticed as a result of using synonymous hash tags (#) to share similar information on Twitter. Several studies asserted the ethical and legal concerns regarding licensing issues, intellectual property, data access and distribution as well as the liability that arises from negligence in utilizing crowdsourced social media data (Roche et al., 2013; Shanley et al., 2013).

Another main concern is the urge to design for complementarity and adaptability in cases of failure, such as potential failures in the network infrastructure (Huang et al., 2010; Roche et al., 2013). Moreover, Palen and Anderson (2016) discussed the need to consider other potential problems, such as the lack of geotagged data, inadequacies in population representation as a result of poor sampling decisions, heterogeneity in data format, and shortfall in deriving complete meaning as well as value from social media data as a result of failure to capture and process associated contextual information.

UAVs

In recent years, UAVs are being extensively used as data collection platforms for many practical and research applications. Several studies have been exploring the use of integrated sensors mounted on UAVs, forming a valuable data collection platform that can help in all stages of disaster management. Adams & Friedland (2011) presented a valuable review on the benefits and feasibility of using UAVs for disaster management, asserting the benefits of such platforms to mitigate physical risks from disaster monitoring.

In 2020, Nikhil et al. conducted a study on using UAVs for disaster management

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applications. The UAV was equipped with a number of sensors, of which are camera and GPS receivers. Such a system can be used in the pre-disaster, during disaster, and post-disaster stages. The authors tested the system for the pre-disaster stage by taking imagery of vegetation in order to monitor landslide failure. The captured images were processed using MATLAB image processing toolbox to detect the changes in the extent of the vegetation over time. As a result, early warnings can be issued prior to landslide failures, which can be accomplished in the real-time through IoT. During and post disasters, the same system has a huge advantage such that it is ready to fly over the danger locations and capture imagery data. In other words, the temporal resolution of the UAV as a data collection platform is instantaneous, which is not the case when acquiring satellite imagery that can take up to 3 days when disasters strike due to the temporal resolution of satellite imagery. Furthermore, the imagery data captured by the UAV can be processed in the real-time using the well-developed VGG16 convolutional neural networks (Nikhil et al., 2020).

DISASTER MANAGEMENT FRAMEWORK

Auzzir et al. (2014) investigated the challenges of disaster management in the developing and the less-developed countries. As a result, they proposed a conceptual framework for these countries through a public-private partnership (PPP) that is applicable in the developing countries, given that certain conditions between the public sector and the private sector are achieved. These conditions are threefold: mutual coordination, shared risk and benefits, and organizational management. The developed conceptual framework was inspired form similar successful ones implemented in some developing countries, such as India, Turkey, and Malawi. Additionally, the authors recommended that risk mitigation tools (i.e., insurance) should be offered to the private sector, especially the most vulnerable countries that exhibit frequent, sever crisis (Auzzir et al., 2014).

Puthal et al. (2016) proposed an integrated disaster management framework deployed on the cloud. The proposed framework uses the data from all types of sensors in a stream processing fashion, which is convenient for real-time processing unlike batch processing. The framework consists of five main stages, namely collection, evaluation, collation, analysis, and dissemination. Furthermore, one of novel contributions of this study is the security of the framework and the data transmitted using an end-to-end encryption at the level of each data packet before arriving at the data stream manager (DSM).

Nara et al. (2017) developed an innovative a decision support framework for evacuation during wildfires. The novelty of the proposed model arises form modeling the population in a dynamic fashion throughout the day, not just nighttime population which is mostly used in the literature based on census data. The developed framework integrates data from a number of sources: social media, census survey, GIS, volunteer suggestion, and remote sensing data. The developed framework consists of four main stages, namely dynamic population estimation, stage-based robust evacuation planning, social perception analysis, and web-based geomatical analytic platform. The developed framework was tested using Twitter data in San Diego country, which emphasized on the importance of taking the dynamic nature of the population into consideration.

Fahad et al. (2019) proposed a real-time evacuation planning framework to support decision makers during floods. The proposed framework is composed of two main steps. The first one is todevelop a fine-scale hydrodynamic model in order to estimate the flood depth. Secondly,

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traffic routes are modelled using VISSIM software to simulate the optimal evacuation procedure for traffic during the time of floods. The proposed framework was tested based on a simulated case study in the city of Brick Township, where the framework optimized the overall travel time by 6%. The whole framework can be implemented in real-time and can be visualized in a time lapsemodeling using GIS tools.

Jung et al. (2020) proposed a conceptual, intelligent framework for natural disaster management in order to develop the disaster response system in South Korea. The study mainly focused on cold/heat waves and wildfires. Regarding the former, there were no historical data recorded that can be fed into an AI model. As a result, Jung et al. used historical datasets from Europe and USA as their adopted data source, and thereby the result of the model can lead to informed decision about evacuation procedure in the pre-disaster stage. By contrast, when dealing with wildfires the main goal was to act in the post disaster stage. That is, the proposed framework processes surveillance videos captured by cameras and UAVs using a convolutional neural network. This helps predict the extent and direction of flames, and thereby lead to accurate decisions on securingvulnerable population.

Thapa (2021) proposed viable solutions to minimize the disaster management challenges in the developing countries that have very limited resources and poor populations using geospatial tools, such as satellite imagery, Google Earth, and crowdsourcing, which are free of charge and are easily accessible to governments. These tools supplement the straightforward 4R framework: readiness, response, recovery, and reduction. Nepal was the case study as one the developing countries, where a collapsing landslide was monitored using geospatial tools. Typically, one of the most common methods of early warning systems can be in the form a message sent to the smartphones of population, which is not the case in Nepal due to extreme poverty. To tackle this, warning can besent via smartphones, tv news, and the radio, which takes roughly one hour to inform the community.

Comprehensive summary of the literature framework has been described in Table 1.

TABLE 1
COMPREHENSIVE SUMMARY OF THE LITERATURE FRAMEWORK

		Disaster management framework						
Author	Year	Stage			Disaster Type	Data source	Methodology	Was the Model Tested?
		1	2	3				
Auzzir et al. (2014)	2014	✓	✓	✓	Natural	miscellaneous	Public-private partnership	No
Puthal et al. (2016)	2016	✓	✓	✓	Natural & artificial	IoT	Deep learning	Yes
Nara et al. (2017)	2017	-	✓	-	Natural	Multiple	Statistical modelling	Yes
Fahad et al. (2019)	2019	-	✓	-	Natural	Climatic	GIS	Yes
Jung et al. (2020)	2020	✓	-	✓	Natural	Climatic	Deep learning	Yes

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Thapa (2021)	2021	✓	✓	✓	Natural	Images	Imagery analysis	No
1: pre-disaster, 2: during disaster, 3: post-disaster								

CONCLUSIONS

This paper discussed the various data sources used in disaster management including IoT, GIS, social media, and UAVs. Furthermore, the recent studies in the field were presented, depicting their framework and contributions.

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Citation Information: Abdelaziz, A., & Mesbah, S. (2021). A review of disaster management frameworks. *Journal of Management Information and Decision Sciences, 24*(S5), 1-10.