An Overview of Data Analytics in Emergency Management

KayodeAbiodun, Oladapo

Department of Computer Science,Babcock University, Ilisan-Remo,Ogun State, Nigeria.

Abstract

Series of emergency situations occurring on daily basis has attracted the global attention to emergency management. This has made emergency management an important issues that demand an intensive research to develop more knowledge and technology for effective management. This paper presents a systematic review on the application of data analytics in emergency management and further gives future recommendations.

Keywords: *Emergency Management, Data Analytics, Machine Learning, Data Mining*

I. INTRODUCTION

Emergency situations are unavoidable as it can occur naturally or even could be as a result of human error (man-made). These situations are expected to be managed or otherwise will keep causing a huge damage in the economic and social workflow of the world thus resulting to death, loss of properties and human injury. Emergency management is the critical assessment of any situation both natural and man-made followed active decision making as a roadmap[12]. Emergency management deals with unnatural situations and wild events [14].

Data analytics has the strength to help with the four stages of emergency management that are planning, preparation, response and recovery. This paper discussed a systematic literature review on the application of data analytics in emergency management where it details out on which phase of emergency management the data analytical method is applied using twelve (12)selected articles as a case study.

This paper is organised as follows after the introduction, section II provide the overview of data analytics with an example of its application in emergency management, section III highlights the methodology employed in conducting the research, section IV explains the findings and discussion and the last section draws out the conclusion.

II. LITERATURE REVIEW

A. Data Analytics

Analytics is a paradigm or idea that defined the use of data in driving decision making force and it can be applied in various problem under different identity namely road traffic analytic, text analytics, spatial analytics, risk analytics and graph analytics. Data analytic is the skill of incorporating heterogeneous data that originates from various sources such as sensors, social media, mobile devices etc. in making a logical judgment, predicting alongside to enhance innovation, competitive advantage and finally assist in strategic decision-making. It came into existence under various identity including

Online Analytical Processing (OLAP), Data Mining, Visual Analytics, Big Data analytics and cognitive analytics[3],[8].[11] defined data analytics as the use of raw facts (data) in solving intricate problems that arises in business. He further went into explaining that internal and external data are analysed in other to assist organizational strategy for its performance and support decision making.

B. Facet of Data Analytics

Data analytics can be classified into four aspects: descriptive analytics, diagnostic analytics, predictive analytics and prescriptive analytics.

1) **Descriptive Analytics**
   This give insight into historical data and yet give trends to dig deep into the data for more details using descriptive statistics, interactive data exploration and data mining. Examples are summary statistics, clustering and association rules.

2) **Diagnostic Analytics**
   This is applicable when trying to know why something happened i.e. finding an answer to the "why did it happened question". It is employed by using data mining and data ware housing techniques. Examples are diagnostic assessment, churn reaction analysis and customer health score analysis.

3) **Predictive Analytics**
   This is the most common analytics in use, it uses model to forecast future events (what is likely to happen). Examples are next best offer, church risk and renewal risk analysis.

4) Prescriptive Analytics

This assist in giving attention to issues revealed by diagnostic analytic and also used to increase the probability of event by predictive model. It helps in picking the best solution among a variety of choices based on a known parameters and then suggests how to take advantage of a future opportunities or mitigate a future risk. Examples are best action, next best offer analysis [2],[3].

C. Data Analytics in Emergency Management

The four stages of emergency management are:

1st Stage: Mitigation,
2nd State: Preparedness,
3rd Stage: Response,
4th Stage: Recovery.

The figure 1 below shows the comprehensive emergency management system
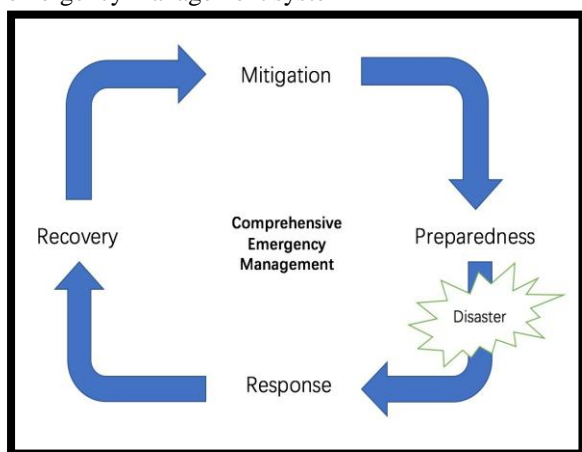

Figure 1: Comprehensive Emergency Management [17].

Data analytics for supporting emergencymanagement include:

- Real-time analysis for decision support system in the first and last stage of emergency management
- Data mining and web semantic in extracting relevant information in all stages of emergency management.
- Database query analysis in extracting relevant information in the second and third stage of emergency management.
- Machine learning techniques in early alerting for the recovery stage of emergency management
- Multimedia analysis in retrieving relevant information for the first two stages of emergency management.
- Data mining on cloud computing in supporting emergency management for all stages of emergency management.

D. Data Analytics Example in Emergency management

The relationship between data analytics and emergency management has attracted various

analytical methods and concept. One of the concept of how data analytical methods has been used in emergency management is shown in Figure II. Smart Emergency Management (SEM) uses computer technologies (data analytics) and social big data to manage critical situations by tracking and monitoring the situation automatically based on context-awareness and real-time data, also using data analytics based on self-determined system to gather knowledge in making a good decision for emergency management with high precision and accuracy.

The framework consist of three concept:

- Social Big Data – which indicates the data source for emergency situation from external sources (physical and social sensors)
- Computing Technologies – shows the use of data analytics (machine learning and data mining)
- Emergency Management – the use of information and knowledge to strategies steps in dealing with emergency event. See Figure II
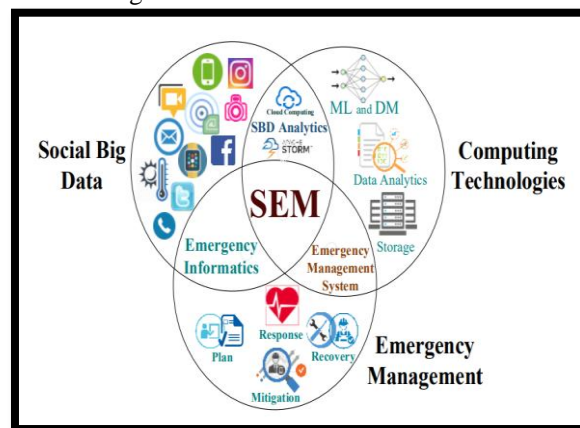

Figure 2: Conceptual component of Smart Emergency Management [14].

III. METHODOLOGY

The research method adopted in this study is the systematic literature review. The literature search was conducted to gather various contributions within the fields of computing science as it relates to emergency management in 2016 using research databases which consist of IEE, Elsevier, ACM digital library, Science Direct alongside Google Scholar alert. The following keywords were used 'Data Analytics', 'Emergency Management', 'Big Data' in the search for keywords, titles and abstracts. The gathered conference and journals papers were analysed based on their theory/concept and method. After screening, only the relevant articles that focus on the application of data analytics in emergency management were used thus reducing the number of papers from 50 to 12.

The selectedarticles were used to give response to the following research questions:

1. Which stage of emergency management was data analytics applied to?

2. How was data analytics applied in emergency management?

IV. FINDINGS AND DISCUSSION

This section provide responses to both questions raised at the concluding part of section 3. The two research questions were given detailed response base on the selected articles.

A. Stages of Emergency Management Were Data Analytics was Applied

The table below shows the stages of emergency management where data analytics was applied to from the selected articles.

S/N	Author	Emergency Management Stages
1	Netten, Van Den Braak, Choenni, & Van Someren[9]	3rd
2	Liu, J. W. S., Lin, F. T., Chu, E. T. H., & Zhong, J. L. [7]	2nd and 3rd
3	Pandey, N., & Natarajan, S. [10]	1st, 2nd, 3rd and 4th
4	Klaithin, S., & Haruechaiyasak, C. [6]	1st, 2nd, 3rd and 4th
5	Takahagi, K., Ishida, T.,	3rd and 4th
	Uchida, N., & Shibata, Y. [16]	
6	Chen, J., Huang, C.-W., & Cheng, C.-W. [1]	1st
7	Jing, M., Scotney, B., Coleman, S., McGinnity, T. M., Kelly, S., Zhang, X., Heyer, G. [4]	2nd and 3rd
8	Jing, M., Scotney, B. W., Coleman, S. A., & McGinnity, M. T. [5]	2nd and 3rd
9	Sakhardande, P., Hanagal, S., & Kulkarni, S. [15]	1st, 2nd, 3rd and 4th
10	Puthal, D., Nepal, S., Ranjan, R., & Chen, J. [13]	1st, 2nd, 3rd and 4th
11	Yusoff, A., Din, N. M., Yussof, S., & Khan, S. U. [19]	1st and 2nd
12	Zhong, L., Takano, K., Ji, Y., & Yamada, S. [20]	2nd and 3rd

Figure 3 gives the summary of application of data analytics in emergency management.This shows that the most applied stage in emergency management is the 3rd stage (Response Stage).
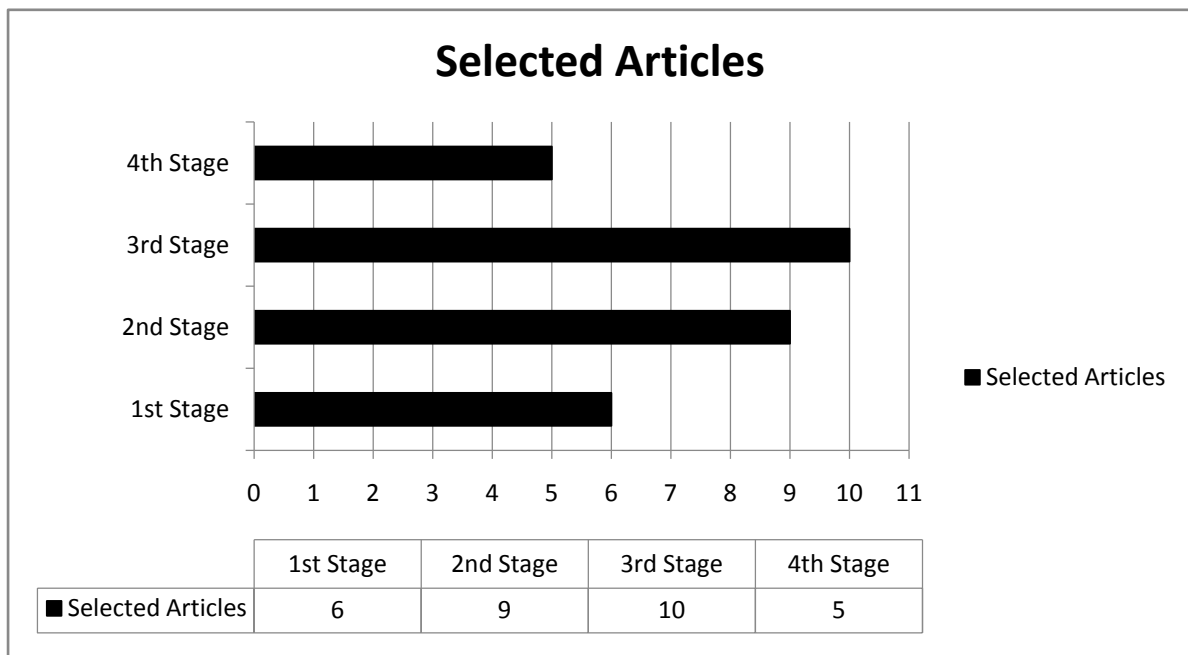

Selected Articles

	1st Stage	2nd Stage	3rd Stage	4th Stage
■ Selected Articles	6	9	10	5

Fig. 3: Summary of application of data analytics in emergency management.

B. How Data Analytics was Applied in Emergency Management

S/N	Author(s)	Application of Data Analytics	Data Source	Analytical Method
1	Netten, Van Den Braak, Choenni, & Van Someren[9]	Applied big data techniques and methods such as Naïve Bayes in collecting, integrating and exploiting desperation among large amount of data at the right speed to the crisis response and mitigation stage of emergency	oral and textual data (like email or texts)	Machine Learning

		management		
2	Liu, J. W. S., Lin, F. T., Chu, E. T. H., & Zhong, J. L. [7]	The main focus was data requirements and reference architecture of intelligent evacuation system (a smart cyber-physical system) which helps in decision making for the first and last stage of emergency management.	Real-time environment data from sensors.	Real-time situation analysis
3	Pandey, N., & Natarajan, S. [10]	Semi-supervised machine learning algorithm was used to develop a classifier that can retrieve relevant information from tweets with the focus on Chennai Flood. The semi-supervised model was used in labelling the unlabelled data after manual labelling of situation and non-situation awareness class. crowdsourcing of information from the public with the use of google sheet to develop an interactive map in locating vulnerable or relief areas by using the Web Map Service (WMS) based on demand and satellite data to visualize the flooded area in aiding decision making during the four stages of emergency management.	Social Media	Data Mining and Web Semantic techniques
4	Klaithin, S., & Haruechaiyasak, C. [6]	Data Mining and web semantic techniques was used to extract and classify traffic information from tweets with machine learning classifier based on Naïve Bayes Model which serve as data source for the four stages of emergency management.	Social Media	Data Mining and Web Semantic techniques
5	Takahagi, K., Ishida, T., Uchida, N., & Shibata, Y. [16]	The application of query analysis in database was used in extracting relevant information for second and third stage of emergency management in the design of common infrastructure system to realize the digitization of disaster information for counter measures by transmitting the information to various disaster communication tools.	Database	Query Analysis
6	Chen, J.-H, Huang, C.-W., & Cheng, C.-W. [1]	Machine learning technique specifically random forest was used to intelligently predict emergency situation through early alerting to mitigate the situation i.e. the last stage of emergency management.	Relational Database	Machine Learning Approach
7	Jing, M., Scotney, B., Coleman, S., McGinnity, T. M., Kelly, S., Zhang, X., Heyer, G. [4]	The combination of text and image analysis in the development of a flood event image recognition algorithm that can be used in preparing and responding to emergency situations.	Database and Social Media	Multimedia Analysis (Content, Text and Image Analytics)
8	Jing, M., Scotney, B. W., Coleman, S. A., & McGinnity, M. T. [5]	The application of multimedia analysis (text analysis, image analysis and support vector machine technique) to the first and second stage of emergency management in retrieving relevant information from social media.	Social Media	Social Media Data Analysis
9	Sakhardande, P., Hanagal, S., & Kulkarni, S. [15]	The concept of data mining techniques and cloud computing in supporting the four stages of emergency management such that sensors and Internet of Things communication technologies can be used in smart city monitoring as well as disaster management through a centralized data acquisition module.	Sensor Data	Data Mining on Cloud Computing
10	Puthal, D., Nepal,	This uses the concept of a cloud-based big	Sensor Data	Data Mining

	S., Ranjan, R., & Chen, J. [13]	data analytics system which focuses on real-time emergency event detection and alert generation by analyzing the data stream (stream processing and batch processing).		on Cloud Computing
11	Yusoff, A., Din, N. M., Yussof, S., & Khan, S. U. [19]	The study uses descriptive analytics in establishing a very weak relationship between the rainfall and water lever then further proposes a predictive algorithm in returning an emergency early warning for preparation and prevention of flooding.	Database	Descriptive and Predictive Analytics
12	Zhong, L., Takano, K., Ji, Y., & Yamada, S.. [20]	The application of big data techniques in estimating disaster of mobile communication system. The techniques was used to estimate spatial and temporal changes of mobile service disruption using data analysis model.	Crowdsourcing, Social Data	Big Data Techniques

Table 2: Application of Data Analytics in Different Stages of Emergency Management

This shows there are many frameworks, model and systems using various data sources in supporting emergency management stages. For this, data analytical methods/techniques application in managing emergency situations is an important contributor for supporting decision making in emergency management based on database and real-time data.

V. CONCLUSION

The challenge of effectively handling emergency situation is a global issue as the usage and advantage of large volume of data source is growing geometrically. This article gives a systematic review of data analytics applications in emergency management. It shows the kind of data been used for managing emergency, the specific stages of emergency that is focused on and the analytical methods in supporting fact-based decision making. It was observed that data analytics approach to emergency management is still on-going within the existing write ups, the findings may act as a starting point and assistance for new methods and have the overview of recent research as it relates to data analytics application in emergency management. Furthermore, there is a need to look into the challenges issues involve in the utilization.

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