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PLATFORM DESIGN OF COLLABORATIVE EMERGENCY MANAGEMENT USING BIG DATA

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Abstract. *The purpose of this paper is to illustrate the structure, process, interoperability, and tools for the realization of the collaborative emergency management (EM) platform using big data. First, it analyzes the characteristics, especially the processes before and after using big data in EM. Secondly, it defines a structure of a collaborative EM with stakeholders of public, non-profit and private organizations, as well as social media and personal citizens and communities. Finally, it discusses several key technologies and implementing strategies to support the collaborative EM platform engaging and utilizing big data. Above all, the platform it proposed can enable EM to utilize information both from organizations and personal citizens, which means the data sources in EM will be expanded from official data to social media data.*

Keywords: Collaborative emergency management, Platform design, Big data, Scenario analysis, Semantic Web

1. **Introduction.** In recent years, widespread service interruptions caused by a variety of emergencies and disasters have brought a series of social safety and security problems. Public increasingly expects better public sector leadership before, during and after catastrophic disasters, with adequate emergency management (EM) systems [1]. The massive numbers of public, nonprofit, private organizations, media, citizens and community involved in catastrophic disasters require extensive ability to have horizontal, as well as vertical, coordination. It makes the decision process of EM more complex, and the consequences of wrong decisions are far more serious and expensive. Especially, with the rapid growth of intelligent and mobile devices and their applications, big data (data coming from various channels including sensors, satellites, social media feeds, photos, video and cell phone GPS signals) from social media, which is heterogeneous, is becoming increasingly important and valuable. Social media and big data will have great impacts on the process and effectiveness of EM services [2]. Therefore, it is necessary to develop EM platforms for the support of flexible planning, emergency event detecting and rapid responding using big data, both from the perspectives of process and methodology. The development of these systems should include a new structure as well as process, and should be based on some key information technologies, e.g., data collecting and storing, semantic analyzing and emotional modeling to big data, and event detecting using big data. These technologies will enable their adequate, efficient and effective functioning.

In EM, emergencies always mean those extreme events that can injure or kill large numbers of people, do extensive damage to property, and disrupt community life. Conventional EM systems are bureaucratic which means to rely heavily on relatively rigid

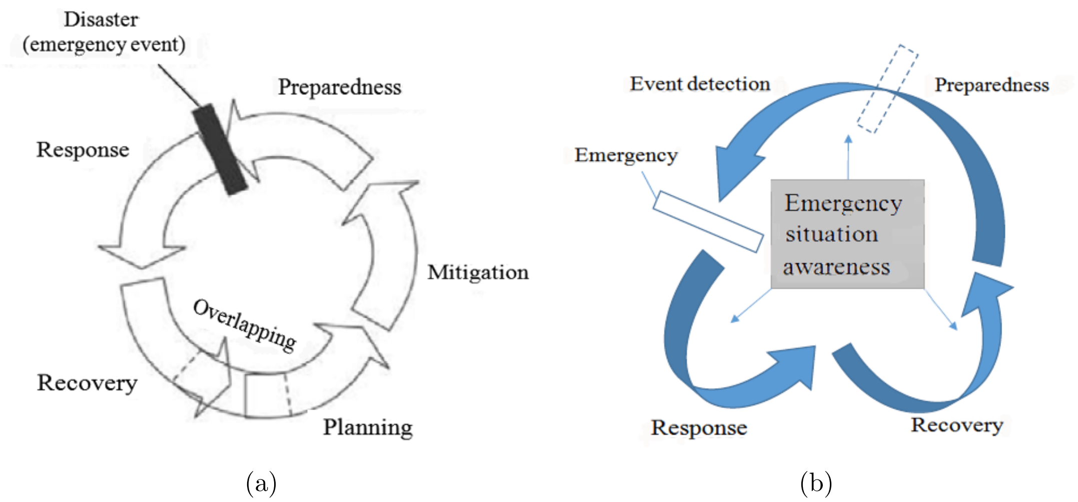

Figure 1. Phases in an emergency management system

plans, exact decision protocols, and formal relationships that assume uninterrupted communications. In such a conventional EM system, a typical process is more likely to involve the following stages: planning, mitigation, preparedness, response and recovery [3], as described in Figure 1(a). Under such a circumstance, the effectiveness relies on routine attention to preparedness, agility in response to daily stresses and catastrophes, and the resilience that promotes rapid recovery. We can find some achieved work focusing on system design [4] and typical process of EM such as planning [5], and response [6]. The work made contribution to conventional EM both in theory and practice. However, conventional EM always focuses on official data from departments and organizations, and seldom puts emphasis on personal data from social media. It is evident that social media can enhance emergency situation awareness [2], which can simplify the efforts of the following components.

(1) Preparedness & event detection. Compared with passive preparedness in traditional EM, social media can enhance information sharing, which will improve emergency preparedness more positive by monitoring and detecting emergencies as they occur or even before they happen [7]. For example, using Twitter data and focusing on a real-life case of forest fire, [8] aimed to demonstrate its possible role to support the activities of emergency planning, risk and damage assessment. [9] thought Twitter as a distributed sensor system and analyzed the spatial and temporal features of the Twitter feed activity responding to a 5.8 magnitude earthquake.

(2) Response. Using big data, the effective responses in such situations are reliant on the availability of archived information. And the availability of real-time location-aware information, as well as the ability to effectively integrate and utilize information available with different autonomous agencies are crucial to effective decision making and resource deployment for responding to crises [10,11].

(3) Recovery. In recovery, big data can help to arrange rescue workers, routes and relief supplies, so that the loss of the post-crisis will be minimized [12]. In addition, by handling large personalized data and tracking the personality crisis-related needs, EM can push more targeted assistance and services [13].

Therefore, the research objective of this paper is to present a system architecture for leveraging social media to enhance EM. It provides definition of structures and processes and key technologies and methodologies for diagnostics, supervision and detection and prediction in the collaborative EM platform using big data. It differs from existing systems in the following aspects.

1) Data sources are expanded from office data to social media data.
2) Utilizing big data, the process is simplified to 3 stages, as shown in Figure 1(b).
3) Using data from social media, it supports more stake holders: public, nonprofit and private organizations, and citizens and community.

2. **System Architecture.** The architecture of the collaborative emergency management system is shown in Figure 2.

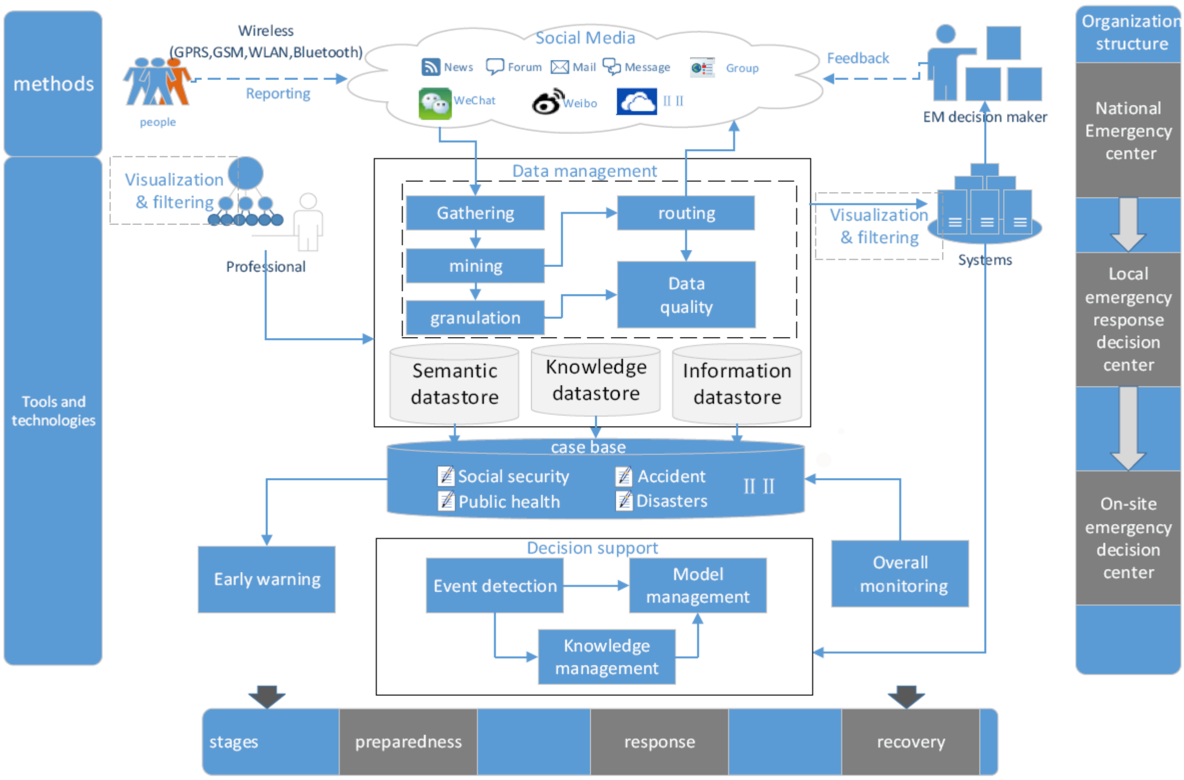

FIGURE 2. The architecture of collaborative emergency management system

The system comprises subjects and services for responding to emergency with appropriate infrastructure of information, the interoperability system and their mutual communication.

Subjects for response to emergency can be found among the national emergency center, local emergency center, and on-site decision center. It has been the key point of emergency decision management that efficient and unified emergency joint mechanism should be established. Especially, it is urgent to set up and improve effective communication and cooperation mechanism between departments for realizing resource sharing and integration. China has enacted more than 60 laws and regulations for responding to natural disasters, accidents, public health emergencies and social security incidents. Certain provinces also issued local regulations and rules for EM. Multi-level regulations indicate fundamental legal system for dealing with various emergencies has already been established in China. It provides a legitimate basis and legal guarantee for the effective implementation of collaborative EM.

Interoperability system is the basic module of the model and it enables a transparent approach to data coming from different sources. Generally, interoperability refers to the ability of two systems to inter-exchange information. In the process of emergency management, such ability is of paramount importance, concerning the fact that all subjects for response to emergency possess their own information systems and that access to other subjects' data is necessary for efficient quality-decision making within one subject. Nevertheless, it can lead to an enormous amount of information in the system. For solving the problem, adequate informational and communicational infrastructure has to be built. It is also necessary to apply efficient methods of storing, accessing, searching, and properly using a large amount of knowledge and information.

3. Key Technologies Discussion.

3.1. **Scenario analysis method.** The scenario analysis technique is used to build the scenario database for collaborative emergency management, identify and determine important driving factors affecting future platform demand and ability level. Through analysis and qualitative description of the factors, we can identify and distinguish what development direction each scenario will represent. In the collaborative EM platform, the procedure of scenario analysis includes the following 4 steps, taking an earthquake disaster as example.

(1) Discover the fundamental operating mechanism of emergency system and build its corresponding structure for earthquake, including common stages and rescue plans. This may be handled by local or national response decision center.

(2) On the one hand, the trend of current earthquake situation is analyzed by data management in Figure 2; thus, overall development situation could be deduced. On the other hand, through the current analysis, uncertainties and key factors that will have great influence on earthquake response (time, population, terrain, traffic, etc.) will be explored, and the processing measures should be decided through case base in Figure 2.

(3) Through the above two aspects of work, the foundation for next scenario configuration is established. Then, considering causal relationship between the factors, several typical paths of system development are decided, and corresponding scenarios will be emphasized. Meanwhile, the interrelationship of the factors that might have impacts on the probability of each scenario should be analyzed and determined.

(4) Based on the scenario settings in the third step, for those links influenced more greatly by uncertain factors, the mechanism of their actions to the subject should be studied. And reasonable quantitative model for predicting all possible contingencies of each link should be built. Based on the above, according to the consideration of all links and probability of each scenario, prediction results can be acquired through the decision support shown in Figure 2.

3.2. **Mining and reasoning technologies of Semantic Web.** The quickness and the intelligence of search in scenario database and plan database are the primary requirements for matching between scenario and EM activities. It is difficult for users to retrieve related resources and realize the semantic information sharing of resources using traditional search method. The application of data mining by Semantic Web should focus on the following aspects.

(1) Data mining. Data from social media are characterized by complexity and heterogeneity. And the data contains complex relationships and dependencies, which imposes strong limitations on the data models that can be used and the scope of information that can be discovered.

(2) The development of a model of big data which captures its relevant features, properties and constraints. In particular, metadata such as replies, mentions, references, keywords, timestamps and geo-location, have to share a common structure for information mining and information quality processing. Through analyzing the features of information resource in scenario database, standardized metadata extraction method could be established, which can be used to extract the metadata for scenario and plan of an emergency and store them in the metadata database.

(3) The construction of ontology in various fields of emergency. It intends to firstly develop an ontology to structure emergency-related data through big data from social media sources (based on standards like SIOC, MOAC or FOAF) and then develop a scalable Semantic Data Store that implements that ontology. Secondly, the development of a model to describe domain-related information for emergency services is built. The purpose is to model concepts like "incident descriptions", "alerts" or "requests".

(4) Establishing the intelligent inference mechanism. For effective semantic inference and retrieval, domain ontology established needs to be imported as an internal expression pattern of inference engine. The main task is the creation of a mapping between the two: domain-related information to information from social media. This captures the associations between emergency-related information and processed social media data. Thus, the ontology will enable semantic analysis and data mining for the detection of patterns, incidents, unusual events and to discover correlations.

4. **Conclusions.** A collaborative emergency platform using big data has been built up, which defines emergency services with appropriate infrastructure, characteristics of interoperability and information process, as well as some key technologies (data mining, ontology and semantic data store, scenario analysis) for implementation. The platform can enable EM to utilize information both from organizations and personal citizens, which means the data sources in EM will be expanded from official data to social media data. The limitations are primarily related to model implementation and evaluation, since there are no suitable emergency databases. And further research should result in the concrete processes of emergency event detection and situation awareness in stage of emergency preparedness and response.

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REFERENCES

[1] N. Kapucu, Planning for disasters and responding to catastrophes: Error of the third type in disaster policy and planning, *International Journal of Public Policy*, vol.3, nos.5-6, pp.313-327, 2008.
[2] C. Reuter, T. Ludwig, M. A. Kaufhold and T. Spielhofer, Emergency services' attitudes towards social media: A quantitative and qualitative survey across Europe, *International Journal of Human-Computer Studies*, vol.95, pp.96-111, 2016.
[3] L. Stojmenov, B. Predic, A. Stanimirovic and M. Stankovic, Emergency management in local community environment using geographic information systems, *Proc. of the 8th International Conference on Dependability and Quality Management*, Research Centre DQM, Cacak, Serbia, pp.63-74, 2005.
[4] F. Zhang, S. Zhong, S. Yao, C. Wang and Q. Huang, Ontology-based representation of meteorological disaster system and its application in emergency management: Illustration with a simulation case study of comprehensive risk assessment, *Kybernetes*, vol.45, no.5, pp.798-814, 2016.
[5] M. B. Lock, C. Fansler and M. Webb, Evolutionary emergency planning: Adding resilience through continuous review, *International Journal of Risk and Contingency Management*, vol.5, no.2, pp.47-65, 2016.
[6] J. Zhang, G. G. Hegde, J. Shang and X. Qi, Evaluating emergency response solutions for sustainable community development by using fuzzy multi-criteria group decision making approaches: IVDHF-TOPSIS and IVDHF-VIKOR, *Sustainability*, vol.8, no.4, pp.291-298, 2016.
[7] J. Yin, A. Lampert, M. Cameron, B. Robinson and R. Power, Using social media to enhance emergency situation awareness, *IEEE Intelligent Systems*, vol.27, no.6, pp.52-59, 2012.
[8] Edison Research, *The Social – Habit Frequent Social Networkers*, http://www.edisonresearch.com/home/archives/2010/06/the_social_habit_frequent_social_networkers_in_america.php.
[9] C. Andrew et al., #Earthquake: Twitter as a distributed sensor system, *Transactions in GIS*, vol.17, no.1, pp.124-147, 2014.
[10] Y. Bendavid, H. Boeck and R. Philippe, Redesigning the replenishment process of medical supplies in hospitals with RFID, *Business Process Management Journal*, vol.16, no.6, pp.991-1013, 2010.

[11] H. Gibson et al., Combining big social media data and FCA for crisis response, *2014 IEEE/ACM 7th International Conference on Utility and Cloud Computing*, 2014.

[12] R. Kitchin, The real-time city? Big data and smart urbanism, *Geo Journal*, vol.79, no.1, pp.1-14, 2014.

[13] D. Yates and S. Paquette, Emergency knowledge management and social media technologies: A case study of the 2010 Haitian earthquake, *International Journal of Information Management*, vol.31, no.1, pp.6-13, 2011.