Framework Design for Operational Scenario-based Emergency Response System

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ABSTRACT

The present paper introduces a scenario-based framework design for connecting emergency response system with human behavior analysis and social information processing, which aims at improving its comprehensive capability in dealing with unexpected situations caused by physical, social and psychological factors during a crisis. The overall framework consists of four function modules: scenario awareness, scenario analysis, scenario evolvement and scenario response. A detailed function design for each module is presented as well as the related methodologies used for integration of four modules. The contribution of this paper includes two aspects. One is realizing the integration of incident evolution, information-spreading and decision-making by taking account of physical, social and psychological effects during emergency. The other is improving the efficiency of decision-making through dynamic optimization process.

Keywords

Emergency response system, scenario, human behavior, information technology, decision-making.

INTRODUCTION

Various natural disasters and incidents, such as hurricane Katrina, Haiti earthquake and epidemics, Japan earthquake and nuclear crisis, caused the loss of human lives and properties in the affected areas, as well as panic, fear and doubt emotion spreading all over the world. One reason is that the near omnipresence of contemporary media makes it very easy to access to site information in great detail. In the past few years, the rising popularity of social media presents a great challenge and opportunity to traditional emergency management, which focuses insufficient attention on public opinion and information dissemination. Take the train crash accident in China an instance, two high-speed trains collided on a viaduct near Wenzhou city (located in South China) in the evening of July 23rd, 2011. The crash killed 40 people and injured 172 others and left hundreds of passengers in need of rescuing. In the first few hours after accident, Sina weibo (Chinese twitter) users made great efforts on spreading information with the content of asking for help, searching family members, donating blood, which was very helpful for emergency management. However, situations began to turn worse after the public was outraged by a spokesman from the railway ministry, who gave an inappropriate explanation of accident cause. Various queries spread quickly through weibo network and led to great outrageous in public. This case highlights the need to improve the capability of information awareness and communication with general public considering social media and human behaviors.

The existing research on this topic can be summarized into three categories. The first is group behavior analysis, which mainly involves group identification, dynamic behavior and social network analysis. Most studies related to emergency management focus on online groups. Hughes et al. (Hughes, Palen, Sutton, Liu and Vieweg, 2008) examined the phenomenon of on-line social convergence and analyzed the development of group behaviors during emergency. The second is information processing on public opinion, especially Internet opinion data. Various types of web crawlers have been developed to collect useful text messages on websites and such technology improves dramatically in recent years (Zhou and Li, 2009). The last is the rule of information

dissemination in social networks. Altshuler and Pan (Altshuler, Pan and Pentland, 2012) proposed an information diffusion model to predict future trends based on the analysis of past social interactions, which could be extended to a large-scale social network.

Though there is much literature addressing human behavior and social information analysis in the area of crisis management, there is a lacuna of literature that integrates above issues to emergency response system. Most current systems focus on dealing with sensed information from physical world in affected areas and less attention on social and psychological effects on unaffected areas. This study proposes a scenario-based framework design for connecting emergency response system with human behavior and social information analysis. The integration of incident evolution, information spreading and decision-making will be realized in the newly designed emergency response system.

SCENARIO

The term scenario is primarily used in two ways: one is to predict the occurrence of a set of events, and the other is to forecast plausible futures when emergency conditions are present. Thus, the objective of scenario awareness is to understand the current situation of an emergency and get the critical information that is helpful to predict the future trend. In this study, information acquisition and diffusion rely on the Internet of Things, which is considered as the fusion of physical and information world (Ning and Hu, 2012). Critical information is extracted from massive data sources according to information requirement study and classified into the corresponding categories for scenario generation.

There are a few types of scenario-generation techniques developed by researchers from different areas, Bishop et al. (Bishop, Hines and Collins, 2007) summarized eight main categories of techniques for creating scenarios: scenario techniques/judgment, baseline/expected, elaboration of fixed scenarios, event sequences, back-casting, dimensions of uncertainty and cross impact analysis. This study uses event sequences and back-casting as the main methods to create scenarios.

Regard to evolvement methods, the evolvement of physical scenario can be implemented using event-chain analysis (Ji, Weng and Zhao, 2009) and case-based reasoning (Boris, Obenschain and Patnaik, 2004), which both underscore the needs of learning lessons from the history cases. The social scenario for tracking public opinion and human behaviors is deduced by social network computing and modeling (Cachia, Compario and Costa, 2007). In some cases, the physical scenario and social scenario are difficult to separate. This study introduces a developed social computing method that combines artificial systems, computational experiments and parallel excitation (Wang, 2007) to simulate the development of complicated scenarios.

FRAMEWORK DESIGN

Scenario Awareness

The main task at scenario awareness phase is data mining processing. The information sources are classified into three categories: physical domain, social domain and psychological domain. At the physical level, structured and unstructured data that relate to time, location, environment, infrastructure, population, communication, and emergency equipment and service, are collected by various distributed sensors located in a city with the support of cloud service in the future to connect and share information with each other. Critical information will be filtered out from the massive data and used for building initial scenario which can represent the real situation of an emergency as well as rescue mission. At the social level, social-media data that have close relation with public opinions during emergency, such as news, reports, articles, and messages from various types of websites, are main concerns of social scenario awareness. Psychological awareness focuses on human's cognition and response under adverse circumstance, especially group behaviors at a large scale. The captured psychological information will be integrated to physical and social information.

The corresponding application system is developed on basis of the Internet of Things, which consists of awareness module, network transmission module and visualization module, as shown in Figure 1. For awareness module, the framework design combines the GIS-based physical awareness with social network and psychology analysis. A social network sensor and psychological GIS, which is respectively used for monitoring the spreading and contents of public opinions and distribution of social vulnerability in different areas, are added into a fundamental GIS platform.

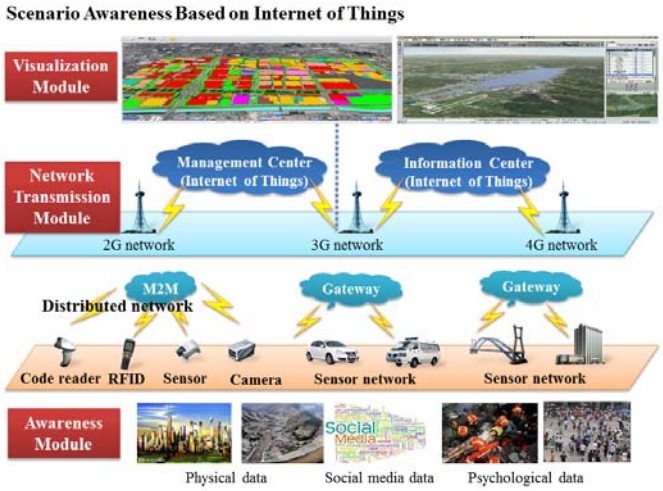

Figure 1. Framework Design for Scenario Awareness based on the Internet of Things

Scenario Analysis

Establishing a scenario which can capture the critical characters of real crisis requires the integration and fusion of physical, social and psychological data from various information sources. Thus, the main challenge at scenario analysis stage is to solve the problem of multi-source data integration. An information requirement study based on the case study is conducted to figure out specific information needs of emergency decision-makers, affected people and general public during crisis. Data from different dimensions (physical, social and psychological) will be organized and updated according to information requirements. As shown in Figure 2, three types of information flow will be built to describe and analyze the overall situation. The first is established with physical information collected from affected areas, which should be updated very quickly in order to keep pace with the progress of crisis. The second is used for tracking suggestions/behaviors of general public which is supported by social network topology modeling. The last is developed to record response activities, especially decision and action implemented by government. The first two types of information flow aim at providing a full view of emergency situation to decision-makers in order to make effective response plans. The last is designed to track and validate the process of management. In a word, framework design for scenario analysis underscores the integration among information technology, human behavior and crisis management.

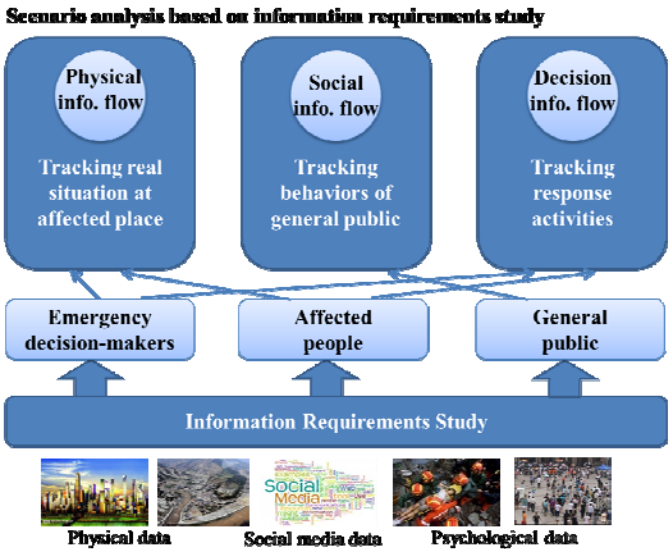

Figure 2. Framework Design for Scenario Analysis Module

Scenario Evolvement

Scenario evolvement is the most important part of overall framework design and undertakes the task of

predicting the trend of current emergency and suggesting possible solutions. The scenario used for describing emergency itself is evolved by the methods of event-chain analysis and case-based reasoning. Different event-chain models will be developed to evolve the incidents, e.g., one incident upgrades and triggers other incidents. Case-based reasoning is another way to determine the evolution of incident. Furthermore, the lessons from historical cases can make contribution to address similar problems in new emergency. The public opinion evolvement includes two parts: group behaviors analysis and evolution analysis of emergency. Group behaviors analysis concentrates on tracking emotion changes of a group, such as netizens, by comparing with a set of psychological indicators. Evolution law analysis focuses on how information disseminates, including identifying messages that catch more attention and depicting information spreading network. Figure 3 displays the framework design for scenario evolvement part, which is designed as feedback controlling by taking account in the event-chain development, information dissemination and human behavior.

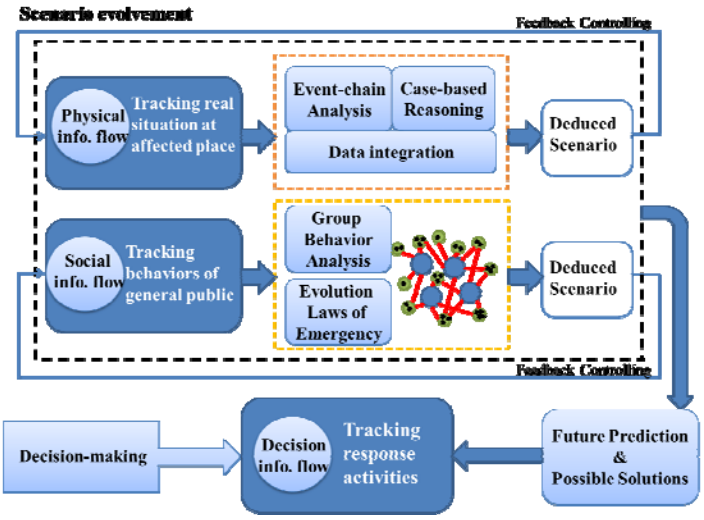

Figure 3. Framework Design for Scenario Evolvement Module

Scenario Response

Emergency response is a continuous process which underlines comprehensive communication and coordination among various organizations including fire, police, health, NGO and emergency agency, etc. Considered as the most important body of emergency management, emergency agency plays a role of overall coordination, scheduling and decision-making in order to make effective and efficient response in time.

In this study, scenario response includes two-level contents: one is decision making, the other is command and control. Decisions, which should be adaptive to dynamic occurrence of emergency, highlight the necessary of scenario evolution. Therefore, in order to achieve optimized decision, three information flows mentioned early should be updated with repeated computing and simulations every once in a while. Simulation results and corresponding solutions will be discussed by decision-makers with support of decision integration. A tool such as a hall for group discussion can provide an intelligent and friendly discussion platform for group decision-making. Communication and coordination between different organizations will be added into scenario analysis which is used for tracking effectiveness of the response.

Overall Framework Design

Different from current ERP systems that focus on physical world, the framework design for ERP in this study introduces psychological behavior analysis and social information processing to emergency management. Figure 4 presents the detail of overall framework. At every stage of an emergency, the development of event and public opinion is present with two scenarios, which are used for tracking situation changes in physical and social domain respectively. Scenarios are continually updated along with timeframe and simulated to get deduced scenarios. Prediction results and possible solutions conducted by scenario evolvement are used to guide decision-making. These decisions are imported to a third scenario to record response activities for further validation and optimization.

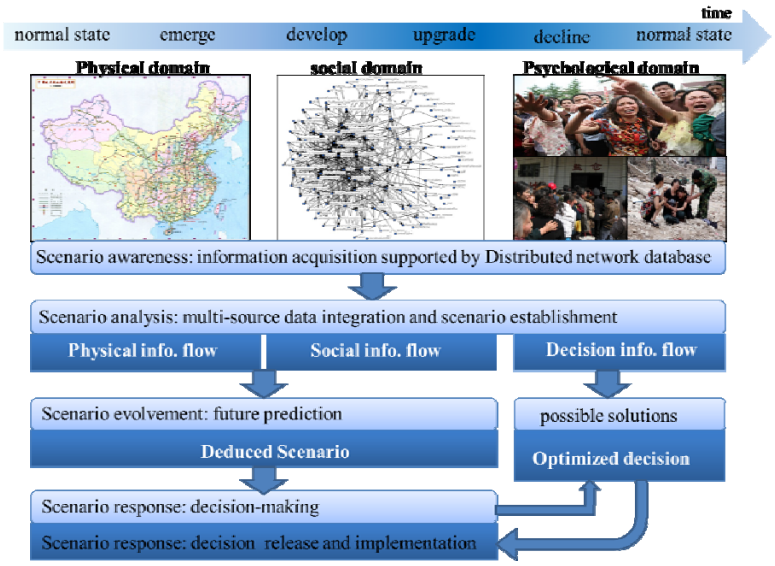

Figure 4. Overall Framework Design for Emergency Response System

CONCLUSION

This paper introduces the framework design of a scenario-based emergency response system which aims at improving its perceptual capability of various types of information, including damage information, public opinion, human behavior and other related information, and providing an overall view of incident development in physical, social and psychological domains. The framework design consists of four parts including scenario awareness, scenario analysis, scenario evolvement and scenario response. Function design for each part and related methodologies are introduced in detail. This framework design has two aspects of innovation: one is realizing the integration of incident evolution, information dissemination and decision-making; the other is developing an optimization solution for decision-making process.

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