Paper:

Development of Web-Based Tabletop Emergency Earthquake Exercise System

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Emergency management personnel must handle many jobs in response to a large earthquake – and this means they must be trained properly. Training is done many ways. In undergoing training, emergency management personnel build their abilities in making appropriate decisions. Traditional emergency management exercises had participants analyze and discuss their duties based more on the printed word than on computer use. Such exercises cannot provide more true disaster background information. These exercises process cannot be recorded in computer database for later review. One strategy for enhancing the immersive exercise experience is using virtual reality simulation technology to build Web-based exercises in emergency earthquake management. In this paper, we present an empirical study on how emergency earthquake exercises are used to design and conduct emergency exercises in JICA-designed emergency earthquake and rescue exchanges between China and Japan. We detail how exercises were designed and done, highlighting immersive aspects. All exercises involved the analysis of computer recordings of each exercise, statements from participants and observations by teachers during exercises. Results indicate that participants can immerse themselves in computer-centered exercises and imagine what it is like to actually be handling that emergency. We found these exercises to be effective in developing participants' abilities to operate in disaster management and suitable for application to emergency earthquake response exercises on all levels of government in China.

Keywords: emergency earthquake exercises, web-based tabletop system, virtual reality simulator

1. Introduction

Large earthquakes may cause sudden, devastating disasters. Their aftermath dictates that governments at all levels respond promptly and effectively. The emergency management personnel involved in emergency responses to such earthquakes must be trained, especially in exercises where they may play a central role. Emergency exercises are approached in many ways, ranging from tabletop exercises to full-scale exercises involving practice runs [1]. The tabletop exercise, for one, is an effective form of scientific decisionmaking. In China, participants in traditional emergency management exercises analyze and discuss issues based more on paper-based media information than on computer-based scenarios. Such exercises cannot provide more true disaster background information. These exercises process cannot be recorded in computer database for later review. One strategy for enhancing the exercise experience is using technology to simulate virtual reality and to build exercise management using emergency Web-based tabletop earthquake exercises.

Researchers worldwide are conducting research on simulating emergency management exercises. Computer hardware and software have been applied to emergency exercises conducted in developed countries, such as emergency management software exercises, record database exercises and scenario simulations. Advanced disaster management simulation created by ETC offers challenging true-to-life virtual environments for training teams in command and disaster management on all levels. Trainees gain the confidence, practical experience and decision-making skills needed to solve real-life incidents [2]. The multilevel ADMS-Command training suite includes an on-scene command room with a 180° immersive theater screen, four field unit positions and an emergency operation center. The VSTEP Company developed RescueSim, a virtual training platform that realistically replicates over 20 different 3D environments used to train in different emergency services and other instances [3]. On-site earthquake rescue simulation used at the national China training base for urban search and rescue activities meets the needs of teams operating earthquake rescue exercises. Among the many different resolution vir-

tual training scenarios are macro seismic disaster scenarios, on-site rescue scenarios, and the ruins of individual operations [4]. These studies are primarily on-site emergency command, decision-making and rescue strategy exercises mostly for on-site emergency management rather than rear commandpost personnel.

Referencing the experience of other countries, especially for Japan's tabletop exercises combined with actual earthquake disaster emergency exercises in China, we developed emergency Web-based tabletop earthquake exercises and exchanges in a China-Japan JICA project. We present an empirical study on how emergency earthquake exercises were used to design and conduct emergency exercises during the JICA emergency earthquake and rescue exchange program between China and Japan.

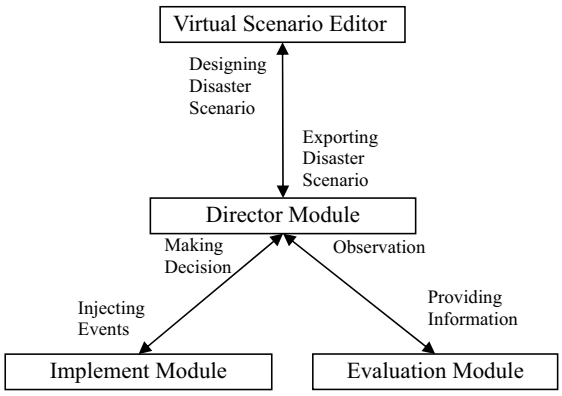

Fig. 1. Emergency exercise modules.

2. Methodology

We developed the first version of emergency Web-based tabletop earthquake exercises on December 12, 2011, then made three system version adjustments from 2011 to 2013. These exercises provide relatively realistic earthquake disaster scenarios and a vivid emergency background. Using exercises for structuring the planning and conducting of emergency management exercises was studied through three exercises during the JICA project consisting of four modules shown in **Fig. 1** – the virtual earthquake disaster scenario editor, the exercise director, the exercise conductor and evaluation.

Virtual earthquake disaster scenario editor is used by emergency management personnel or exercise controllers to design urban 3D scenes, earthquake disaster and secondary disasters events. The editor visually designs virtual 3D cities and emergency events, including disaster scale, the location and extent of secondary disasters, the number of victims, rescue missions and emergency management objectives [5].

The teachers prepare scenarios. Exercises consist of virtual 3D environments, including a chemical plant, residential section and a central business district where dynamic safety and security incidents are created. The teachers select and customize scenarios from a library.

The Director Module controls and runs exercises by the training staff or teacher. The teacher inputs disaster event information. Exercise participants analyze event information through the virtual environment and propose solutions or make decisions using Implement Module. Evaluators oversee exercises and score participant performance by the evaluation module.

Our empirical study is based mainly on three emergency Web-based tabletop management exercises with nearly hundred participants from several Chinese provinces, including Jiangsu, Yunnan and Hebei. Participants were all middle managers in provincial governments working for different administrations. They were responsible for different areas in provincial governments, mainly from emergency offices, seismological bureaus and civil bureaus. Exercise participants were divided into several groups by function. Emergency Web-based tabletop exercises input information automatically during a 1.5 hour exercise. Exercise participants collect information, analyze situations, estimate casualties, handle emergency events, make decisions and propose solutions. Exercise participants used emergency management techniques during the exercise to analyze computer recordings of exercises, written opinions from participants and observation by teachers during exercises.

3. Conducting Exercises

Tabletop emergency management exercise experiences among Chinese and Japanese personnel, we conducted earthquake disaster emergency management exercises relying on JICA's emergency earthquake and rescue project using emergency Web-based tabletop management to deepen understanding of emergency processes, promote disaster response and coordination capacity and applications of tabletop exercises in emergency management preparedness and training. We conducted three exercises during the JICA project, each consisting of three steps – preparing exercises, conducting exercises and evaluating exercises, including disseminating results.

3.1. Step 1 Preparation

Based on actual emergency earthquake response needs and work arrangements, the aims and goals of an exercise first must be defined. That is, who will take part, what problems are to be solved and what the desired effects should be achieved in the exercise. The central criteria for defining aims and goals are the presumed roles and tasks that participants may take in future emergencies (Borell and Eriksson, 2010 [6]). Aims and goals must be clear and specific, defining who, what, where, when, why, and how. These are the starting points for planning and preparing the exercise.

With basic aims and goals defined, the next step is to develop a 3D city and surrounding areas, editing disaster scenarios to be used during the exercise shown in **Fig. 2**. Disaster scenarios are based on the area's geographical location, topography, population, buildings, po-

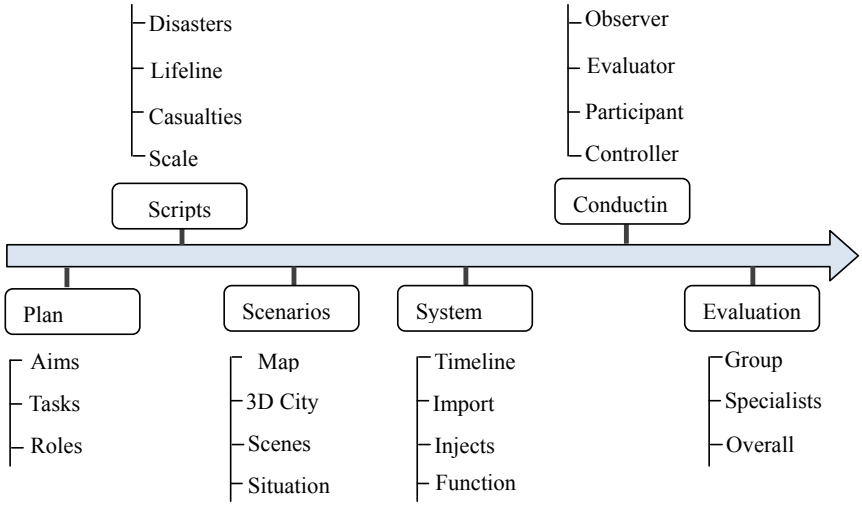

Fig. 2. Web-based emergency exercises.

Table 1. Exercise practice and improvement.

	Date	Participants	Numbers	Sites	Disaster Scenaros	Improvements
Exercise Case1	Feb. 12, 2012	Hebei Provincial Governments	24	China National Training Base for Urban Search and Rescue	M_s6.8 Earthquake; Xingtai city; 20 km; IX Epicenter Intensity.	Web-based Information Injects
Exercise Case2	Jul. 18, 2012	Jiangsu Provincial Governments	32	Jiangsu Provincial Emergency Command hall	M_s6.5 Earthquake; Liyang city; 10 km; VIII Epicenter Intensity.	Virtual Emergency Command Hall; Map potting
Exercise Case3	Mar. 22, 2013	Hebei, Jiangsu,Yunnan Provincial Governments	32	China National Training Base for Urban Search and Rescue	M_s7.6 Earthquake Zhaotong city; 10 km; VIII Epicenter Intensity.	Digital City; Virtual Reality Scenarios; Improved Map Potting

tential risks, hospitals, school supplies, historical emergency earthquake planning and the resources of the earthquake region simulated. Disaster scenarios include disaster scale, casualties, building collapse, secondary disasters, evacuation needs, the degree to which adversely affected areas are isolated, and persons affected, goods distribution, disaster prediction and development. A 2D map of the exercise should be designed reflecting geographical features and disaster area transportation. This map should also reflect locations and relationships of command posts, hospitals, shelters and other important facilities. The hypothesis of the disaster also should learn from the historical earthquake response. Information blank areas, traffic disruption areas, undefined information,, and emergency events, for example, should be instruct trainees to analyze information blank and isolated areas, communicate with each other.

Injection Scripts for individual exercise phases and evaluation forms are the most important material for preparing tabletop exercises. Inject Scripts should be designed based on the emergency timetable, response process, trainee knowledge background and experience learned from practical disaster response. These should include the time, content, information source, targets. Injection time refers to when information is to be injected. Injection type refers to how information is to be injected, e.g., paper-based, Web-based, by telephone injects or by fax. The teacher edit scenario according to Injection Scripts and set event triggered mechanism.

3.2. Step 2 Conducting of Exercises

Three tabletop exercises were conducted during a JICA emergency earthquake exchange program between China and Japan, as listed in **Table 1**.

Each exercise was a one-day event using China National Earthquake Response Support Services instructors. Each event included three phases. Phase 1 was background information introduction of simulated earthquake city and the presumed roles of trainees. Phase 2 was the tabletop exercise. Phase 3 was an evaluation of the exercise. During the simulated earthquake, disaster scenarios were injected automatically based on the Injection Time by Web-based tabletop exercises.

Participants analyzed injected events of virtual environments from a screen in the front of tabletop exercise room and Web-based software given at computer terminals. Participants also proposed solutions or made decisions about emergency events and took notes in Exercise Implement Module. Participants also presented the dynamic decisions process through map plotting. Evaluators oversaw exercise and took notes in Evaluator Module. Observers watched scenes of exercise progress displayed on a screen through the presentation of exercises.

Fig. 3. 3D city Hebei Province exercise.

Fig. 4. 3D city Jiangsu Province exercise.

Fig. 5. 3D city Yunnan Province exercise.

The first exercise was conducted at the tabletop exercise room of China's National Training Base for Urban Search and Rescue on February 12, 2012. Those taking part included 24 emergency managers from Hebei Province government emergency offices, seismological bureaus and civil bureaus. Participants were divided into three groups – a comprehensive coordination group, a relief resettlement group and a professional disposition group. The

simulated M_s6.8 earthquake was set in Xingtai City, Hebei Province shown in **Fig. 3**. The earthquake depth was 20 km and the epicenter intensity IX. Over 50 items information each group received indicating events within 24 hour of the earthquake. The three groups received both the same information, such as seismic parameters, main disaster scenario and rescue phases and different information based on different areas in provincial governments that participants were responsible for.

The second exercise was conducted at the Jiangsu provincial emergency command hall on July 18, 2012. Emergency managers taking part from Jiangsu provincial governments numbered 32. The magnitude of the simulated earthquake was M_s6.5, the location was Liyang City, Jiangsu Province, and the epicenter intensity was VIII, shown in **Fig. 4**. Exercise phases include times within 2 hours of the earthquake, from 2 to 12 hours after the earthquake and 12 to 24 hours after the earthquake. Exercise lasted 90 minutes indicating within 24 hours after the earthquake. Events were injected the same as in the first exercise.

The third exercise was conducted at the tabletop exercise room of the China National Training Base for Urban Search and Rescue on March 22, 2013, Attended by 32 emergency managers from Jiangsu, Yunnan and Hebei Provinces. They were divided into four exercise role groups from Provincial Earthquake Relief Headquarters in Yunnan, Guizhou, Jiangsu, and Central Headquarters. The simulated M_s7.6 earthquake was located on the border between Zhaotong City, Yunnan Province, and BiJie City, Guizhou Province, shown in **Fig. 5**. The temblor's epicenter intensity was VIII. All groups processed emergency events and discussed resource scheduling, event control, formulated measures, comprehensive coordination, social mobilization and media response, finishing by recorded decisions in an exercise database.

3.3. Step 3 Evaluation

As stated above, evaluators oversaw exercise. The evaluation process was recorded in real time highly efficiently. After exercises, evaluation records and emergency decisions about disaster events export data. We also sent reference evaluation forms to participants. Immediately after each exercise, we chaired a discussion evaluation seminar. For two hours, participants, evaluators and observers talked about what they had seen during the Web-based exercise and what they thought of effects and results. They were also asked to fill in a questionnaire. Based on a comprehensive analysis of exercise records and related data, we compared participants' performance and aims of exercise, together with the emergency schedule, and then filed a report.

4. Results

After exercises, questionnaires were sent to participants, observers and evaluators. Observations during the simulated Xingtai earthquake exercise and the questionnaire evaluating phase indicate using Web-based exercises had the following results:

- Participants immerses themselves in exercises and imagined what an actual scene might be like based on videos and pictures of disaster situations displayed on the tabletop exercise room screen.
- Participants understood exercise scenarios better and made better decisions through disaster information based on computer injection the same way as for an actual emergency response.
- Through electronic map plotting, participants presented the dynamic decision process, zooming in and out of electronic maps in detail, recording in database and exporting pictures for future discussion.

In the simulated Xingtai earthquake exercise, some observers suggested that the teacher should improve utilization of the screen and use more information in the form of pictures, videos and text. Some participants thought that map potting should have more layers added and exercises be conducted more simply. The Web-based emergency earthquake exercise was amended to the second version based on exercise feedback. Functions of exercises were improved, included the user interface, emergency procedures, map levels.

After the second exercise, feedback evaluating the exercise indicated that the virtual 3D disaster scenarios gave participants a feeling of actually taking part in practical emergency earthquake responses at a rear command post. Results indicate that participants could quickly immerse themselves in exercises. Some observers stated that map potting marks should be added based on military potting and that the disaster scene sound environments should be improved. Exercises were amended the third version based on suggestions. After the third exercise, observer and participant feedback indicated that using the Web-based emergency earthquake exercises had useful effects and participants had developed their abilities to respond to emergency situations in a limited exercise time better than they had before taking part in exercises. Participants learned disaster situations from the virtual 3D city. The mode of the Web-based exercise was thus valuable to other provincial exercises.

5. Conclusions

Results show that the Web-based exercise was the most successful of our exercises. This suggests that an approach utilizing emergency earthquake exercises as the basis for planning and conducting exercises was successful. It also made the evaluation and organization of exercises easy and convenient. Using the Web-based exercise had meaningful effects on the operation mode, scenario presentation.

Conducting an emergency exercise was successful in helping participants improve their disaster response and coordination capacity, enhancing participant understanding of the emergency earthquake process based on comprehensive, 3D disaster information provided by exercises. Using electronic technology, we plan to use virtual reality technology, 3D modeling and the Web-based system to build a more realistic disaster environment that directly shows disaster scenes and helps participants feel enthusiasm in exercises and develop their abilities to handle emergencies. Processes of exercises were recorded in a database for further review and easy evaluation.

Some 3D events in the preset exercise process did not have to be changed with participants' emergency responses. For exercise evaluations, assessment results should consist of statistics and intuitive charts reflecting exercise effects based on aims and goals. Future exercises should be non-scripted, meaning that there are no predetermined outcomes, and what happens in the system should be based only on participants' decisions. 3D emergency disaster scenes have physics-based simulation (Z. Qinping, 2005 [7]) in which fire, smoke, gas clouds, leaks, etc., spread as they would in a real situation, reacting to influences such as wind direction and speed. All disaster features are based on real-world timing, such as how a person's injuries progress if not treated (W. Broll, 1997 [8]). Exercises should produce high-level immersion (J. Borell, 2008 [9]) in which trainees feel like they are acting in an actual situation (W. Dongming, 2010 [10]) and feel the stress they would feel at such a time. Exercises should score trainees automatically on defined objectives and let instructors completely replay and view an exercise from any angle. A detailed, time-stamped action list presented after an exercise should describe scenario events and actions taken by trainees (L. Ni, 2010 [11]).

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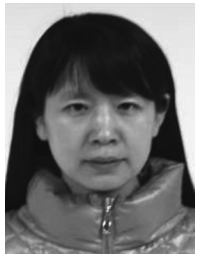

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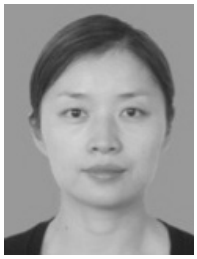

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