Disaster Context Modeling for the Creation of Exercise Scenarios

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Abstract: Disaster training and exercises are widely employed to improve preparedness for and the ability to respond to unprecedented natural and man-made disasters. While various types of drills and exercises such as Serious Game, Disaster Imagination Game, and Cross Road have been proposed, less attention has been paid to how to make effective exercise scenarios efficiently. This study develops a disaster context model that provides a foundation for creating new exercise scenarios and describing what happened in actual past disasters. The study also develops a method of creating semi-automatically a new imaginary disaster context that will be used as an assumption in an exercise scenario.

Keywords: Disaster Response Exercise, Exercise Scenario, Context Modeling

1. INTRODUCTION

In many sectors of society, such as governmental agencies, medical institutions, commercial companies, and local communities, disaster drills and exercises play an important role in improving preparedness for and the ability to respond to unprecedented natural and man-made disasters. While various types of drills and exercises such as Serious Game [1], Disaster Imagination Game [2], and Cross Road [3] have been proposed, less attention has been paid to how to create effective scenarios efficiently for such drills and exercises. In fact, the quality of the exercise scenario is heavily dependent on expertise, and the design of scenario requires much cost and many man-hours. This becomes a big obstacle in preparing effective drills and exercises in many organizations that do not have enough know-how and human resources. Another serious problem that hinders the preparation of a disaster exercise is that it is rare, at least in Japan, for many organizations to share the knowledge and experiences gained through the preparation and execution of an exercise, which is partly because there is no easy-to-use technology that supports and facilitates collaboration and knowledge sharing among different organizations and communities.

This paper proposes a disaster context model that provides a framework with which to describe both actual and imaginary disaster contexts and provides a foundation for creating new exercise scenarios. Employing this context model, a method of interactively creating a new imaginary disaster context, which is used as an assumption for the exercise scenario, is proposed.

Section 2 of the paper explains the modeling of disaster context. In this study, the example of disaster medicine and nursing was used for the modeling and development of the proposed methodology. Section 3 introduces a model-based method of creating a new imaginary disaster context and a method of converting a disaster context into a narrative/textual description. In Section 4, a preliminary evaluation of the proposed methodology is described. A conclusion and discussion of future application in collaborative scenario design are presented in Section 5.

2. MODELNG DISASTER CONTEXT

A disaster context in this paper refers to the settings of physical and functional parts of a disaster situation that is related to response activities and the relationships among them. According to reviews and qualitative analyses of existing disaster exercise scenarios, reports on past disasters, and many personal notes on actual disaster experiences, three major components constituting a disaster context—the situation, tasks, and constraints—were summarized. The components were extended further employing existing models and frameworks, which are explained in the following subsections.

A disaster context also refers to the temporal changes in the setting of each component. Figure 1 is a schematic of the framework of disaster context. The snapshot of a context at any point in time is called a scene. A disaster context is thus represented as a series of scenes that contain the conditions of the situation, tasks, and constraints. The details of each component are explained in the following.

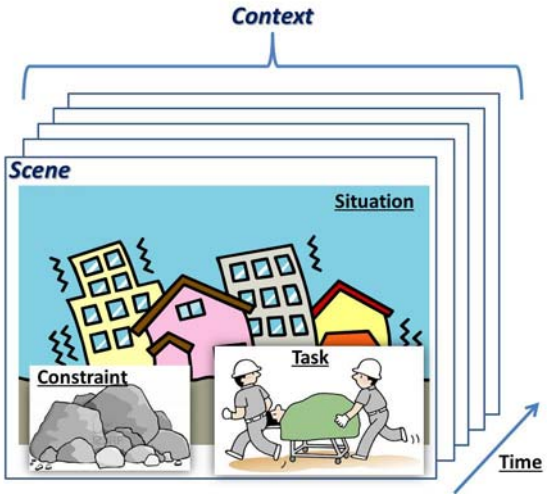

Figure 1: Framework of a disaster context model

2.1. Situation

A situation describes the conditions and statuses of objects and actors in relation to a disaster scene. We further detailed the situation using a general model describing service contexts [4]; the model comprises providers, recipients, tools, the environment, and interactions among them. In the context of disaster medicine and nursing, providers are medical staff such as medical doctors and nurses, recipients are inpatients, outpatients, and their family members, tools are medical tools and devices such as medicines, injectors, wheelchairs, and dialyzers, and the environment is that surrounding these three elements such as hospital rooms and wards.

Figure 2 is a schematic representation of the service context model. The four major model elements were used as the top-level ontology of the situation and were taken as the starting point from which to extend sub-level concepts. Table 1 presents the extended patient model, which has the form of a frame with slots and values. All slots and values were extracted from reports on past disasters, and many personal notes on actual disaster experiences such as those in [5]. The combination of values in Table 1 generates, for example, various types of patient instance such as an injured person, an old person, and a person with chronic disease. Other model elements such as the environment and tools were implemented using the frame model in the same way and were stored in a database of situation elements. A situation is represented by a set of model elements with different values.

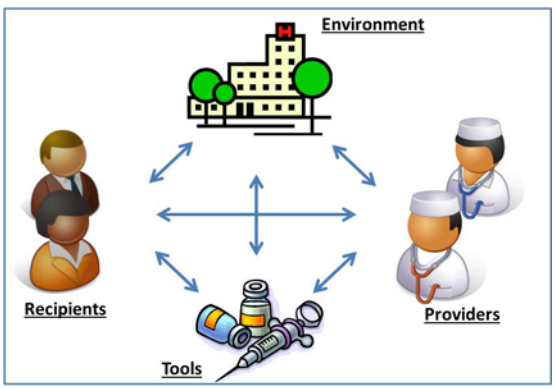

Figure 2: Service context model

Table 1: Patient model

Slot	Values
Age	0, 1–4, 5–9, 10–19, 20s, 30s, 40s, 50s, …
Sex	Male, female
Level of care	1–5
Disease	Cerebral infarction, terminal cancer, COPD, influenza, etc.
Injury	Minor, bruising, laceration, broken bones, etc.
Special conditions	Pregnant, etc.
Ability to walk	Cannot walk, requires a walking stick, requires a wheel chair, etc.
Mental condition	Anxiety, fear, panic, depression, insomnia, etc.
Requirement for an accompanying person	Yes, no

2.2. Task

A task is an action or series of actions carried out to achieve a goal. Tasks are usually hierarchical and situation dependent, and therefore, different tasks need to be performed in different situations and domains. In the example domain, tasks need to be performed in response to the disaster situations at medical intuitions; e.g., confirming and securing the safety of patients and evacuation. The disaster medicine and nursing tasks are listed according to CSCATTT, which covers the major response tasks of command, safety, communication, assessment, triage, treatment, and transportation. Table 2 gives several examples of the tasks categorized by CSCATTT. For the prototype system, 64 tasks were extracted and implemented in the task database.

Table 2: Typical tasks that need to be performed in an emergency

Category	Task	Subtask
Command	Initiate command system	Contact a commander
		Declare an emergency
		Call up appropriate staff
		Confirm the command chain
Safety	Secure own safety	Step away from shelves and windows
		Stand by a thick pillar or get under a table
		Wear a helmet
	Secure safety	Find a search light
		Confirm the safety of patients and visitors
		Prevent fire
Communication	Establish communication	Check communication devices
		Contact headquarters
		Establish communication with other institutions
Assessment	Assess damage	Check for building damage
		Check the availability of the power supply
		Check the availability of dialyzers

2.3. Constraints

Constraints prevent someone from accomplishing tasks as planned or wished. Constraints are situation dependent and emerge in specific disaster situations; e.g., wall collapses, water leaks, and fire. In other words, a constraint can be identified by the relationship between a task and its background situation. Constraints were extracted from reports on past disasters and many personal notes on disaster experiences, categorized according to the concept of performance-shaping factors used in human reliability assessment, and stored in a relational database. In the prototype system, 52 different constraints were implemented in the relational database.

3. CREATING A NEW CONTEXT

The databases of each component were constructed using the above component models of disaster context. The databases store data extracted from the same materials used in the modeling. We also developed prototype database software to support the creation of a new imaginary disaster context. This section describes how a new imaginary disaster context is created using the software. An overview of the procedure is shown in Figure 3. The interactive and tailor-made process is expected to allow users to create a new disaster context for an exercise to be held at his/her hospital with less time and effort. The detail of each step in Figure 3 and the supporting functions are explained in the following subsections.

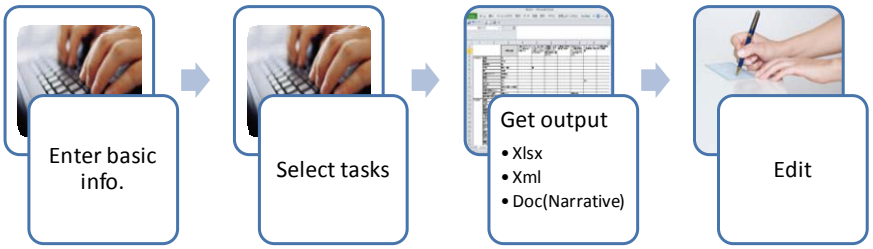

Figure 3: Procedure for creating a new context

3.1. Entering Basic Information

The first step for the user is to enter basic information on the situation assumed for an exercise such as the season, weather, time of occurrence, and numbers of staff and patients. The user can also specify a specific set of values for some slots of the situation model such as a large fire in a patient room. The software then randomly assigns values to the remaining slots of the situation model and creates a complete initial situation. Subsequently, the software creates a changing situation from the initial situation. There are four basic modes of change of a situation: static, escalation, de-escalation, and cyclic. Unless the user specifies one of these modes, one is randomly applied to each variable to create a continuous situation comprising plural situation instances.

3.2. Selecting Tasks

The next step is to select training tasks from the task list stored in the database and to specify the starting time for each task in the context. Once a task is selected, candidate constraints are searched for in the relational database considering the background situation of the task. For example, if windows of the patient room are broken and there are inpatients who need support to walk, while the required task is evacuation, constraints such as the requirements for more supporting staff and special attention to be paid to patients in the evacuation are retrieved from the database.

3.3. Outputting and Editing

When a disaster context is completed through the instantiation of situations, tasks, and constraints, the context is output in xml, xlsx, or doc format. The contents of the output data are shown in Figure 4.

The software has a limited function to maintain consistency among the variables of the situation model when it automatically assigns values, for it is technically difficult to maintain consistency among all values perfectly. For example, if the value of the season is “summer”, then a value “snowing” should be excluded from the candidates for the slot of “weather”. Such simple exception handlings were partly implemented in the prototype but exception rules that are more complicated were not. Instead, we expect users to find and modify such inconsistencies in the output context. Additionally, the user can edit the details of the contents at any step in the procedure.

3.3.1 Narrative Output

One of the useful functions of the software is the conversion of the output into a narrative/textual format. A story structure was designed according to the situation/service model, which provides a framework with which to arrange the order of the description of each model element. For each model element, several "fill-in-the-blank" sentence formats were prepared. Once a disaster context is specified, the textual explanations for the model elements are generated using the sentence formats, and these sentences are then arranged according to the story structure and a whole story describing the context is completed. This function also generates tables that complement the textual explanation. Figure 5 shows part of a story generated by the function.

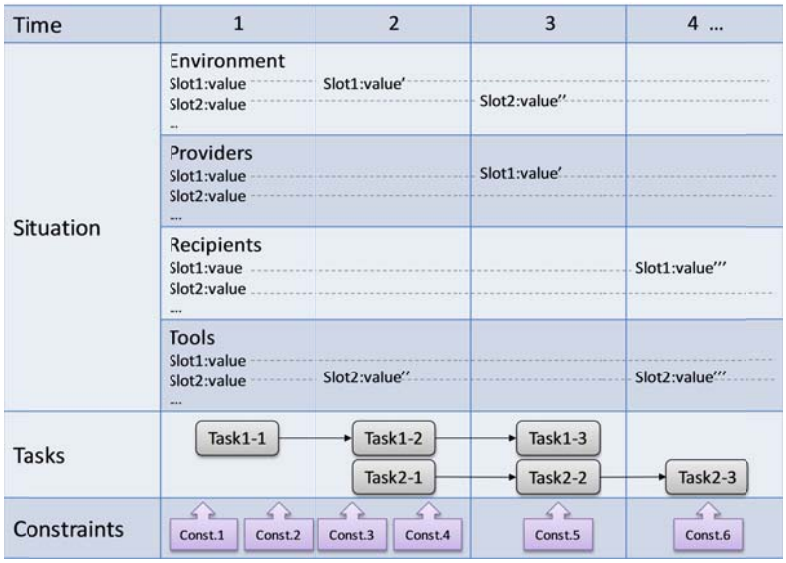

Figure 4: Contents of the output file

On a day in autumn, a level-seven large earthquake strikes near Shizuoka Pref. It occurs about 6pm, while many people are going home. The weather is fine with a moderate wind, and the weather forecast says it will rain tomorrow. There are tens of fires in the area, but because the wind is only moderate, the possibility of the spread of fire is low. Because the earthquake is a subduction earthquake, a tsunami having height of 1 m reaches the coast after 57 minutes. There is a nuclear power plant in the area and already a report of a slight leak of radioactive materials. There is no report of liquefaction. Regarding public transportation, all highways and four main roads are closed. 80% of railway services are stopped or delayed. It will take about 21 hours to reopen highways, but they will only be made available to emergency vehicles. Full restoration of freeways will take 3 days. Full railway services will restart tomorrow afternoon….

季節は秋、平日の帰宅時に震度 7 の海溝型地震が発生した。地震発生時の天気は晴れで弱風、翌日の天気は雨であった。火災は数十件発生したが、弱風のため、延焼の可能性は少ない。海溝型地震であり、1m 程度の津波が 57 分後に到着した。原子力発電所があり、地震発生直後にすでに放射線漏れが確認されている。また、液状化が発生する可能性はない。交通機関に関しては、高速道路は通行止め、一般道路は 4 区間が通行止め、鉄道は 8 割以上が運転見合わせ、もしくは遅延となっている。高速道路が緊急車両のみ通行可となるのは 21 時間後、一般道路が全線通行可能になるのは 30 日後、鉄道は翌日の午後には通常通りの運転となった。

Figure 5: Textual description of a disaster context

4. QUALITATIVE EVALUATION

We conducted a preliminary qualitative evaluation of the proposals by interviewing with subject matter experts (SMEs). We asked four nurses about the validity of the context model and practical utility of the prototype. Before starting the group interview, we demonstrated how to create a new imaginary disaster context using the software and showed several output examples, and we then asked the nurses to make comments. Table 3 gives some of the comments made in the group interview. In general, many positive comments on both the model and output contexts were obtained. Several

valuable suggestions, such as allowing the creation of scenarios with multimedia and extending the software to an online environment, were also made.

Table 3: Comments from SMEs

Context model
- It is helpful that we can view the entire picture of a disaster context. - It is necessary to consider hospital staff other than medical doctors and nurses. - The model does not have sufficiently comprehensive information on medicine and medical devices. - Constraints are better to be divided into two finer categories: comprehension and projection. - The remaining amounts of water and food should be given in units of “day·person” and not “days”.
Output
- It is better to present a disaster through textual descriptions, while numerical information should be summarized in a table. - Pictures and/or video clips should be presented with the textual descriptions. - We can easily make a new context by integrating experiences and expectations.
General comments
- We can consider characteristics of the target region and facility in simulation design. - We would like to see if it would be better to focus on a more specific topic such as triage training. - It would be nice to use the system on the Internet and share the contents with other hospitals.

5. CONCLUSION

This paper presented a disaster context model that aims to provide comprehensive and detailed assumptions for disaster exercise scenarios. The model has three basic elements, which are the situation, tasks, and constraints. A disaster context is represented by a series of snapshot scenes that consist of the instances of these model elements. The paper also presented a method of generating disaster context instances in an interactive and semi-automatic manner. The example context of disaster medicine and nursing was used in developing prototype database software. The software generates imaginary disaster contexts in a hospital by combining data pieces stored in the database and outputs them in xml, xlsx, and textual format. We demonstrated the prototype to four nurses and asked them to evaluate it qualitatively in a group interview. Most comments were positive and there were high expectations of further development.

In this paper, we focused on how to use the context model to create imaginary disaster contexts. However, the model is also expected to be used as a common framework for describing and recording both virtual and actual disaster experiences. The model is therefore expected to provide a foundation for sharing (1) knowledge on past experiences, (2) information on how to design good exercise scenarios, and (3) good examples of disaster preparedness, among different organizations.

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