A Template-based Methodology for Disaster Management Information Systems

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Abstract

Timely and accurate processing of crisis information and effective communication have been documented as critical elements of disaster relief operations. Despite the lessons learned from previous crises, preparing information for humanitarian assistance and ineffective information sharing remain a recurring and almost impossible task for relief agencies. The purpose of this paper is to propose a template-based methodology to archive past disaster relief operations, create "descriptive" templates for advanced preparedness, and design "normative" templates for fast execution of assistance operations, while reducing miscommunications among aid agencies.

1. Introduction

Given the cosmic nature and the inevitability of human errors, disasters are a distinct reality of every day life. Disasters, both natural and man-made, can strike anytime or anywhere. There are two ways to overcome disasters: the first is to prevent them from occurring, and second to have an emergency system and plan of operation prior to the occurrence of any crisis. In either approach, communications play an important role in disaster management. In most of the disasters in recent history, at some level or another, information was available which could have prevented the disaster from happening. But the information was either possessed by those with authority to act upon it who did not act; or it was possessed by those who did not have the power to act but who did not share them with those who could have. In other cases, information even when received was discounted. Hence, in the future, any system devised to manage disaster emergencies should ensure information flows freely and the decision-makers act on such information without fail.

If a free flowing information system has to be implemented, it may lead to a barrage of paperwork that could be a problem by itself. Decades ago, it was called gathering intelligence, but now it is constant battle to sort and make meaning out of the glut of data. Over the years, the computer has evolved into an effective tool for managing large volumes of data, filtering and processing them into meaningful information readily usable by decision makers (Housel et al, 1986; Nunamaker et al. 1989). With the advent of telecommunications, and due to its versatility and low cost, the Internet has now become the instrument of choice in planning and managing disaster information systems.

This paper proposes a set of design principles and methodologies for information systems for disaster management. The design principles are derived from the requirements imposed by the characteristics of crisis such as urgency and high stress on the people involved.

2. Template-based Information System Design for Disaster Management

A disaster is characterized by the urgency in the responses required for its containment. This urgency, combined with the high consequences of one's choice, places heavy stress on the decision makers, often causing them to make simple errors and sometimes revert to non-optimal behaviors. These characteristics demand the following design principles for an information system for disaster management.

First, the urgency required by disaster management information processing should be done as

prognostically and as off-line and as possible. Potentially relevant information for relieving a given type of disaster should be gathered, filtered, and organized as much as possible before the actual disaster in such a way that any additional information required is minimized without compromising the validity or recency of the information. Otherwise information processing during the disaster, delayed possibly by the breakdown in the communication infrastructure or the searching of relevant information, can in turn delay the action required and induce high costs that could be avoided.

Second, information processing should be as case-based as possible. The best time to prepare for a disaster is after one has been managed whether successfully or poorly. All the details about what worked, what failed, and what could have been done would be fresh in memory.

Third, both the urgency and the error-prone stress require that the system be automated as much as possible but with constant human monitoring and the ability to override. From the implementation perspective, agents and workflow present an excellent way to automate or semi-automate the tasks and the flows while leaving the critical, judgement-intensive tasks to human beings.

A natural corollary of these principles is template-driven processing, i.e., design of a system to support the creation and use of templates for representing, extracting, organizing, and acting on relevant information. A template provides a structured place to find relevant information easier and faster, which is critical in situations of urgency and high stress. A template supports proactive processing of information by providing a checklist of relevant information to look for. Templates make it easier to compare multiple cases and infer generalizations from them. Templates are modular in their addition and organization (Lee, 1997).

As discussed later in this paper, templates can also support the design of a workflow system by providing the information needed for enacting or automating the process, as will be illustrated later. The set of templates used – descriptive, normative, as well as the ones used to specify the agent functionalities – provide design rationales for the resulting system, therefore serving as organizational memory. For example, as the state of art technology advances and the available component technologies cumulate, the agent templates could help us better understand why they were not and whether it makes sense to do so then.

3. Methodology

This section describes the methodology based on the template-driven processing in the design of a crisis management information system. The following methodology summarizes the overall steps:

- Represent each task in a given crisis as a set of *descriptive* templates
- Derive *normative t*emplates from *descriptive* templates
- Embed templates as part of information/action flow in various phases of the crisis management
- Build a case base of crises

Represent each task in a given crisis as a set of descriptive templates

For each of the activities in a given crisis, represent it as a template. Table 1 shows a generic template that can be adapted for a given type of disaster. It provides a standard set of placeholders or slots for representing the details of the activity such as: how it was implemented in terms of further sub-activities (activity decomposition), resource required, whether it was successful or not, as well as the reasons for the outcome.

What:	
Why:	
Where:	
Who:	
When:	
How:	
Activity Decomposition:	
Resource Required:	
Success or Failure:	
Reasons:	
Generalizability (Context-Sensitivity):	

Table 1. A generic “descriptive” template

The next step is to represent each event in a given disaster by filling out the template.

Table 2 shows an instance of the generic template for a particular event during the Kobe earthquake crisis. It is important to note that it is only one of the many descriptive templates representing the Kobe

earthquake. Typically, the analysis and design of a template is based on thorough descriptions of concrete instances of crisis situations and relief operations. Descriptions should be action-driven with envisioned outcomes.

Derive normative templates from descriptive templates

Normative templates are derived from descriptive templates. A normative template, after being validated in the overall context of a given crisis, will be used during a crisis as a checklist for actions or as a node if the corresponding activity is implemented. A successful descriptive template, i.e., a template for an activity that was successful in its outcome, has its "Outcome" slot filled with Success and it can become a normative template by generalizing the values of the descriptive slots such as "Where and When". For example, the "Where" slot of the descriptive template has the value "Kobe, Japan"; however it is generalized to the value "Anywhere" because this type of activity (and the failure) can happen in any type of crisis. Likewise, the Who slot value, "Military", is generalized to "Military or Firefighters or Coast Guard or any other groups nearby trained for emergencies". On the other hand, a descriptive template for a failed activity, i.e., the activity that could have been done better in retrospect, has its "Outcome" slot filled with Failure. It can become a normative template by specifying how it could have avoided the failure in its "Activity Decomposition" and "Resource" slots as well as by generalizing the other slots as in descriptive templates.

Tables 2 and 3 illustrate how a documented situation – in this case, the 1995 Kobe earthquake – can be translated into templates.

.., the central government made a tragic error by not sending troops immediately to rescue more than 1,000 trapped survivors. The Hyogo authority, which covers Kobe, ordered troops at 10 o'clock, four hours after the quake. Kioshi Ozawa, Minister of the Land Agency, in charge of natural disasters in Japan, made an inspection tour of Kobe nine hours after the quake. The first small contingent of troops arrived at Kobe 10 long hours after the quake, but without essential heavy machinery such as cranes, trucks and bulldozers. Inexcusably, the government waited 24 hours before dispatching appropriately equipped forces. Most rescue efforts during the crucial first 24 hours were made by citizens with their bare hands. The eventual response was massive: aircraft, land transport and sea vessels were all used on a large scale. Soldiers spent hundreds of hours combing wreckage for survivors, but it was too late. Mostly they found corpses.

Other mistakes included:

[the] initial failure to control traffic for one full day. All trains and two out of four thoroughfares through the region, linking Eastern and Western Japan, were heavily damaged. Rescue vehicles carrying troops and emergency supplies were forced to share clogged roads with the thousands of private motorists rushing to Kobe to search for relatives. Military personnel and necessities were seriously delayed, exacerbating the shortages of food, water and medicines. In one of the worst cases, a local hospital could serve each patient only one rice ball a day.

(Other initial failures include:
1. Not informing residents where to find water, medical care, or other assistance.
2. Not warning citizens of post-quake dangers. People were allowed to return to teetering buildings and this caused additional casualties.
3. Not issuing instructions to all local governments to offer help to Kobe. As a result, even after massive donations arrived in Kobe, they did not reach refugees in a timely manner because of a shortage of transport and manpower.
4. Not issuing a smoking-ban in shelters. These poorly ventilated buildings soon filled with cigarette smoke causing considerable distress to elderly people and children with respiratory illnesses. Influenza viruses raged through shelters.)

What:	Have the rescue team in as soon as possible
Why:	Rescue those in need of help
Where:	KOBE, Japan
Who:	Military
When:	1995
How:	Send in the troop
Activity Decomposition:	
Resource Required:	Heavy equipments
Success or Failure:	**Failure**
Reasons:	Too late notice, Blocked road, Resource Missing (Initial arrival with no equipment)
Generalizability (Context-Sensitivity):	High

Table 2. An example of a descriptive template for the failure to send the rescue team promptly during the Kobe earthquake.

What:	Have the rescue team in as soon as possible
Why:	Rescue those in need of help
Where:	Anywhere
Who:	"Military or Firefighters or Coast Guard or any other groups nearby trained for emergencies.
When:	Any Disaster where people need to be rescued
How:	Contact (the list of potential rescue parties)
Activity Decomposition:	Direct communication, Block a road, Arrival with equipments needed
Resource Required:	Heavy equipments
Success or Failure:	**Failed**
Reasons:	Too late notice, Blocked road, Initial arrival with no equipment
Generalizability (Context-Sensitivity):	High

Table 3. An example of a normative template for the Kobe earthquake

Embed templates in various phases of crisis management

A typical crisis management can be broken into three main phases (Egelhoff, 1997)

Before Crisis:

- Represent cases as a set of descriptive and normative templates
  - Modify, if necessary, the default template (cf. Table 1) for the case in hand.
  - Use the revised template to represent each activity in the case. Descriptive template describe what happened; Normative templates describe what should have happened.
  - Partially order the filled templates by linking them in temporal sequences where possible
- Organize the represented cases using disaster taxonomies as indices
  - When a disaster actually happens, the cases in the same category as the one happening will be retrieved first. The rationale is that similar disasters will require similar types of information routines and information processing mechanisms
- For the design of an information system supporting a given process
  - Recursively decompose a process of interest
  - For each activity in the decomposition, find normative templates for it
  - If there is no template, then make one and be prepared
  - If there are more than one, decide which one(s) would serve best
  - Confirm, for each template, its appropriateness by checking its context-sensitivity
- Design agent-based workflow using the normative templates
  - Design and implement agents for appropriate parts of the process
  - Design Coordination Mechanisms
  - Design Workflow for the process

During Crisis:

Use the templates along a Disaster Relief/Humanitarian (HA/DR) workflow to optimize execution

After Crisis:

Fill in the templates, especially lessons learned from successes and failures and what could have been done to prevent failures.

Tables 4,5, and 6 provide examples of templates that could be used during the crisis phase. Table describes how the Jalisco crisis occurred. Tables and depict a number of crisis actions to be taken., including the arrangement of the availability of a critical resource. For example, if an issue is concern over shortages of drinking water in a certain area, related questions may go out on the availability of commercial or military sources of water both in and out of the involved country, the infrastructure (roads/vehicles/aircraft) to get water where it needs to go and business/government/military capabilities that could be leveraged to repair/deliver water.

…Jalisco cheese crisis – An unbelievable and grossly insensitive crisis management oversight occurred during the tragic Jalisco cheese deaths in southern California in the late spring of 1985. The contaminated cheese, purchased mainly by Hispanics,

caused more than 30 deaths. A widely publicized poison center hot line, under the auspices of the Los Angeles County Medical Association, was flooded with more than 4,000 calls in three days. But the hot line was staffed with only English-speaking nurses, and the phones were jammed with calls from concerned, confused, scared, and angry Spanish-speaking callers, who could not be helped. [16, p. 60; emphasis in original]

What:	Provide immediate answers to the questions that people might have over the phone
Why:	To enable people perform emergency treatments
Where:	Southern California
Who:	Los Angeles County Medical Association
When:	1985
How:	Establish hotline for the people
Activity Decomposition:	Get people to man the hotline; Train them with appropriate information, Notify 911
Resource Required:	People to man the hotline, reliable and enough telephone connection
Success or Failure:	**Partially Failed**
Reasons:	No non-English speaking hotline representative
Generalizability (Context-Sensitivity):	High

Table 4. A descriptive template for the failure to send the rescue team promptly during the Jalisco cheese crisis

What:	Provide immediate answers to the questions that people might have
Why:	To enable people perform emergency measures
Where:	Anywhere there are non-English potential victims
Who:	Anybody who could be in charge of providing emergency information
When:	Anytime
How:	Establish hotline for the people
Activity Decomposition:	Find out the ethnicity of potential victims, Get people to man the hotline, Make sure that the representatives include some who can understand and help non-English speaking victims, Train them with appropriate information, Notify 911
Resource Required:	People to man the hotline, reliable and enough telephone connection
Generalizability (Context-Sensitivity):	High

Table 5. A normative template for actions during crisis times

What:	Arrange for the availability of a resource
Why:	To make the resource available as soon as possible in enough quantity
Where:	Anywhere with a shortage of a critical resource
Who:	Any organization in charge of coordinating a relief process
When:	Anytime when a critical resource needs to be made available
How:	Assess what other sources of are available for the resource
Activity Decomposition:	Find out the resource availability in the companies and the military nearby, Inquire about the infrastructure (roads, vehicle, aircraft) for transporting the resource, Find out the business/government/military capability to deliver the resource
Resource Required:	The authority to coordinate quick and large scale assessments and arrangement of the resource involved
Generalizability (Context-Sensitivity):	High

Table 6. A normative template for water allocation

Embed template in workflow

At its most basic level, workflow is the automation of an organizational process. It consists in managing the flow of information that runs across the multiple entities involved in a specific organizational process. Workflow applications decompose an organizational process into a number of steps called tasks. In addition to speeding up execution of tasks wherever possible in parallel, understanding of workflow also enables

tracking the status of tasks in progress (Bui and Lee, 1999).

The benefits of implementing a workflow system can be seen at all the levels inside and even outside the company. At the operational level, participants have more control over their processes. Response time from the different actors is reduced and the efficiency of the process improved. Bottlenecks can be easily spotted and addressed. Managers can focus on process improvement rather than supervising the process effectiveness. At the top management level, the information gathered by the workflow system will allow for a rapid evaluation of the importance of the process on day-to-day operations and on the overall productivity. This also ensures a coherent answer each time the organization deals with its clients. Lessons learned from successful implementation of workflow systems suggest that response time and quality of service are improved.

The normative as well as the agent templates can help design a workflow system in several ways.

- A template represents an activity and therefore suggests a node in the workflow.
- The slots of the template specify the information needed for designing the workflow. For example the Activity Decomposition slot specifies the individual activities that compose the process that the template represents; the Who slot specifies the Role of the actor performing the process; the When slot specifies the triggering condition.
- The links among the templates suggest the flow of the workflow, i.e. possible orders in which each task needs to be executed and the conditions that will determine the actual order during the execution.

The following examples provide illustrations. The normative template, "Providing immediate answers to the questions that people might have" that was discussed earlier suggests a node in the workflow because it represents an activity that might take place during the execution of the task, “Determine if the question can be broken down further prior to pushing to subject matter experts." Once the relevance of this template is determined for the current context, its slots provide the further information needed for the design of a workflow. Its “Activity Decomposition” slot has as its values “Find out the water source in the companies and the military nearby”, “Inquire about the infrastructure (roads, vehicle, aircraft) for transporting the water”, “Find out the business/government/military capability to deliver water”. Each of these values suggests in turn an additional node in the workflow that in turn implements this task. The “Who” slot of the template suggests a role for coordinating the availability of critical resources. The Resource slot of the template suggests the resources needed for that role and additional nodes in the workflow to obtain these resources in case they are not immediately available. The “When” slot also suggests a condition under which this node should be triggered during the enactment of the workflow.

4. Summary

In this paper, we have described a template-driven design methodology for a disaster management information system. We have identified three design principles demanded by the characteristics of a disaster (such as urgency and high stress) and argued that the use of templates in the design and use of such a system provides an excellent means to implement these principles. First, templates provide a natural way to process information prognostically and off-line, which is critical for a crisis management system due to the rapid response time required during a crisis. Templates provide checklists for people gathering and structuring information through their fixed slots. They are also modular so that they can be easily added to an existing collection. Secondly, we have illustrated that case-based reasoning is the best way to be prepared for and manage a crisis because of similarity among crises and the quick response time required and that templates provide a natural way to extract and represent information from cases. Third, we have argued that templates help automate or semi-automate a crisis management system by helping to design an agent-based workflow system.

We have then developed a methodology to represent cases as a set of descriptive templates and generalize them to a set of normative templates. The normative templates, in turn, were shown to provide a structured way to represent information, thus minimizing the time required to look up information as well as minimizing the errors often induced by high stress on the people involved during a disaster. The normative templates, in conjunction with the agent-based DSS design methodology (Bui and Lee, 1999) and the coordination theory (Malone et al. 1999), can also be used to support the design of an agent-based workflow system. We have illustrated the methodology with the design of a Virtual Information Center for crisis management.

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