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Role-based Situation-aware Information Seeking and Retrieval for Crisis Response

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Abstract

Crisis response is an information intensive process, which produces and consumes large quantities of information from, and for, different relief/response organizations. The traditional centralized IT system design principle dominantly used to address inter-organizational information retrieval over boundaries is no longer feasible due to its lack of flexibility and adaptability to deal with dynamically changing information needs caused by the unpredictable nature of a crisis. In this paper we present our ongoing research regarding a new service architecture for information seeking and retrieval, which offers a new way of thinking about seeking and retrieval of role-based, situation-aware information in the context of a crisis situation.

***Index terms*--information seeking and retrieval, crisis response, situation awareness**

1. INTRODUCTION

Managers of container terminals and other industrial areas have to prepare for unforeseen natural or man-made crises, like leakages, explosions, earthquakes, riots and even terrorist threats. Escalation to the level of a disaster can happen in minutes, as in the case of a fire in an area where millions of liters of oil and other flammable or hazardous materials are stored [3]. Timely and effective disaster response is therefore extremely important. Any delay in response time can increase the number of victims of a disaster, and a fast response can reduce or prevent subsequent economic losses and social disruption [17]. Effective response to a developing disaster requires fast access to all the relevant information required to deal with the ongoing situation, and thus is the key concern of our research. We will use a specific example of a container terminal in this paper, but our work has relevance for all potential crises in industrial situations.

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Information acquisition in the event of a crisis in a container terminal is a very complex process. Depending on the scale of the disaster, crisis response in a container terminal will range from dealing with a small scale problem, in which several organizations are involved, to a full scale crisis, in which multiple organizations are required to resolve and to prevent escalation of the crisis.

Information relevant for a crisis response may be dispersed across heterogeneous, high volume, and distributed information resources. Furthermore, such unpredictable crisis situations require the dynamic establishment of a "virtual team" consisting of the various relief/response organizations. In response to an ongoing dynamic crisis situation, membership of the "virtual team" can change accordingly depending on the type of crisis, its magnitude and how it develops. New relief/response organizations will join the "virtual team" when their services are needed, while others will leave when their response goals have been achieved. Distributed, dynamic and heterogeneous environments make it difficult for relief organizations to find and retrieve their organization role specific, and crisis situation relevant information to inform their crisis relief activities.

To solve this problem, many container terminals have built networked crisis response platforms to connect all crisis relief/response organizations, and to allow them to access, share and exchange information. One example of such a platform is called the dynamic map, which has been utilized and tested at some container terminals. This platform allows relief/response organizations to oversee the disaster area and its surroundings, and to anticipate future developments regarding the crisis [3]. The dynamic map provides an efficient way of improving information acquisition in a distributed and dynamic crisis environment. However, these platforms only serve to distribute uniform information to all the relief/response organizations involved in a crisis. It is difficult for an individual organization to select and retrieve information that is specifically relevant for its role and its rescue activities. This can cause delays in information retrieval for its relief/response tasks. Moreover, such networked platforms are built based on the centralized design principle. This traditional approach, which addresses inter-organizational information accesses over boundaries, is no longer the best principle to use when dealing with a dynamic crisis environment. This is because the information needs of the

their role-related tasks; and (3) the environment, or situation.

In the field of crisis response, information seeking and retrieval can be characterized as a problem solving process since the purpose of information acquisition is to deal with and solve problems arising during the unfolding of a disaster in a timely manner. Users' role-based information needs are formed when users become aware of the crisis situation, the professional role they need to adopt, and the work tasks they need to execute. Information needs change as users' situation changes in response to the crisis situation, and this directly influences users' judgment regarding information relevance. Individuals' personal interests and preferences may not strongly influence their information needs but their personality or knowledge may influence their search strategies. Although different users may have different knowledge levels about their professional role, we consider that their knowledge is inherent in the professional roles they perform within their work situations. We assume that the users are well trained, and that they have enough knowledge to detect their information needs based on their professional roles. Therefore, users' role-based information needs in crisis response are determined by the disaster situation they perceive, and the tasks they need to execute when adopting one of their roles in their perceived situation. We show this argument in Figure 1.

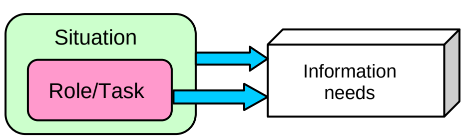

Figure 1: Personalized information needs

2.2 Situation awareness (SA)

The concept of situation awareness (SA) is usually applied to operational situations, especially in the fields of Artificial Intelligence, Agent-based Systems, Crisis Management, Military, etc. , where people must gain SA to perform their operational tasks [9]. The objective of SA is to establish a consistent awareness of situations to allow specific users to better perform their tasks. As a result, research in the field of SA focuses mainly on supporting users to be aware of their situation so that they can make an informed decision about future actions [9].

Endsley's SA framework [10] provides a set of well-defined concepts, which have been utilized across a wide variety of domains. Endsley et al formally define SA as "the perception of elements in the environment along with a comprehension of their meaning and along with a projection of their status in the near future" [10]. This definition breaks down into three separate levels [9].

- *Level 1—perception of the elements in the environment*
- *Level 2—comprehension of the current situation, and*
- *Level 3—projection of future status.*

These three levels reflect the process of how people become mentally aware of their situations. Although today's advanced IT technology can replace a huge amount of information processing work, until now, it cannot replace a human's mental information processing process. Therefore, an information seeking and retrieval system may provide support for the users' SA process if the situation is one of the determinant factors for determining users' information needs.

It is not feasible to specify all possible instances of crises situations due to the dynamic and unpredictable nature of disasters. Detecting situations based on collected historical data is required. A similar argument is made in [9]'s three levels of SA model, where the situation is derived from known information. To provide users' role-based, situation specific information in a crisis response, an information seeking and retrieval system needs to provide collected historical data or information to support the different levels of users' SA processes. The question what historical data or information is required at different levels of a SA process for realization becomes important, and leads to the following question: what information can be used to describe and model a situation in the context of crisis response?

Fact as the element perceived in the crisis environment

The first step in a SA process is to perceive the elements present in the environment. In a crisis environment, the information elements that can be directly perceived are those that cover the questions: What type of disaster? Where is the disaster? When did the disaster happen? Who are involved? And what properties, i.e. hardware, buildings, docking areas, are we dealing with, etc. The answers to these questions describe the things that are known to have happened or to exist, i.e. facts. We define the concept *fact* in the context of crisis response as *things that are known to have happened or to exist in a crisis environment*. Therefore, the information describing those things that have happened or that exists, can be abstracted and conceptualized as: type of disaster, time, place and involved objects. We present the meta-model of a fact in Figure 2.

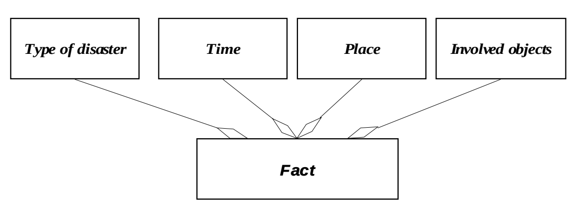

Figure 2: Meta-model of a Fact

2.3 Service-oriented Approach

A service-oriented design principle offers a solution for building complex, dynamic and distributed information systems. Services are implemented on the basis of well-defined service behaviors and interfaces. Services can be implemented by using various open specifications, open source toolkits and standards [16]. This design principle is suitable for the distributed, dynamic and heterogeneous crisis response environment. Using the service-oriented system design principle, a solution for the detected information needs can quickly be reconfigured in a dynamic crisis situation using a composition of encapsulated, replaceable and reusable services [21]. In our research, we regard information seeking and retrieval as a service, which we call "information seeking and retrieval service". We assume that its implementation is a combination of groups of services or components in a specific order based on detected situations. We visualize this in Figure 4.

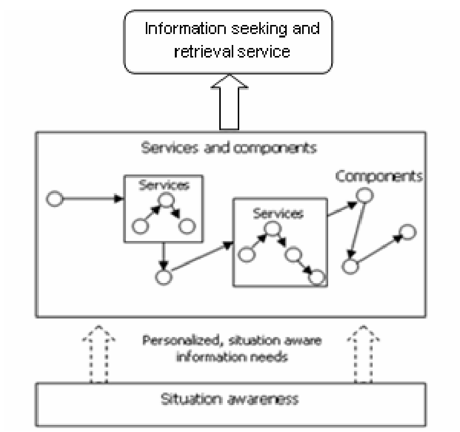

Figure 4: Service-oriented Design Approach

Based on this design principle, we will further define the concept of service in the context of information seeking and retrieval in a crisis response, and we will explain the composition of this service.

The service concept

There are many definitions of a service in the field of service-oriented approaches [19] [21]. In the initial phase of our work, a service is planned and designed in such a way that it has a specific functionality and it is very simple, but added together, services can perform relatively complex tasks. This informal definition offers the basic requirements for the definition of a service in the service-oriented approach.

A service must offer a specific functionality. As mentioned before, the solution to a detected problem is constituted by a service or a combination of services. In our design, the specific functionality a service must offer is that it provides information. We therefore define *the services that consume information and provide information as information services*. We assume that the solution to satisfy a user's information needs is constituted by an information service or a group of information services. The information provided by a group of services is a collective outcome of all involved information services instead of a simple combination of outcomes of each service. Information services can be assembled and composed by smaller information services. The required operation and output of a simple information service is realized by grouping a specific collection of information retrieval software components. The information services are stored in a repository. Each information service has an invoke method. Each service is executed when the pre-condition is fulfilled. After execution the condition of this service is changed. This is called a post-condition. We present the service concept in Figure 5.

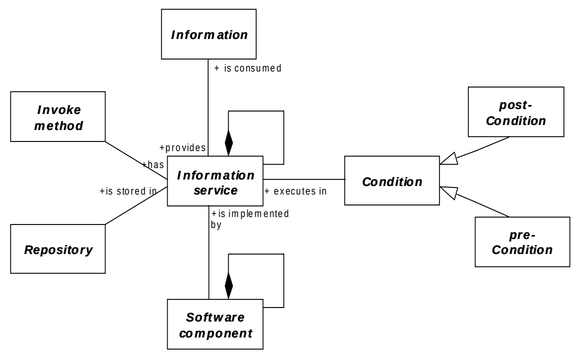

Figure 5: The concept of information service

The task concept

We mentioned in the section 2.2 that users' information needs must be satisfied before they take any actions to solve a problem identified in crisis response. Information needs arise when user have insufficient information to perform their actions. The actions users need to take, are conceptualized as a 'task', or a 'work task' as defined in [7] [24].

In the research on task-oriented information seeking and retrieval, a task is viewed either as an abstract construction or as a concrete set of actions [12] [1]. Viewing a task as an abstract construction is used in research, where a task is utilized as a description to enable focus on individual differences [12] [1]. We claimed in the previous section that we do not take individual interests and preferences into account as influencing factors to determine information needs during a crisis response. Therefore, we take the view that a concrete set of actions can be used to define a task. We regard a *task as a specific piece of work, in which a person or a group of persons undertake a series*

aware information to facilitate their task performance during a crisis response situation.

Since the development of a complete system is not yet feasible, due to the difficulty of building trust between the various crisis relief/response organizations, and getting them to share their information, we built an early demonstration to show that it would be possible to build such a service-oriented architecture to provide role-based, situation-aware information seeking and retrieval services for crisis response.

We utilized three computers in our prototype implementation shown in Figure 8, representing the service consumer, service provider, and service broker in a SOA respectively. We implemented this prototype based on Jini technology.

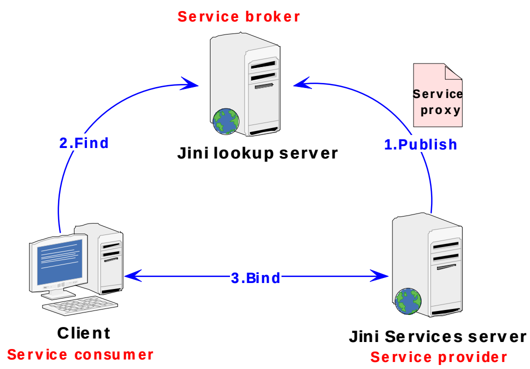

Figure 8: Prototype Architecture

Jini service provider & Jini lookup server

The information provided by the relief/response organizations involved was encapsulated as information services as mentioned in the section 2.3. We believe there are four main actors in any crisis response situation listed below.

(1) ***Police***: There are different police forces at this container terminal, such as the national police force, the water police, and the harbor police, and they all have different tasks during a crisis response.

(2) ***Medical workers***: In an emergency situation, there is a chance that there will be victims who need immediate medical treatment. This will be done by paramedics who are experienced in helping victims at the location of the disaster.

(3) ***Firemen***: Firemen should try to control and extinguish any fire as soon as possible. A small fire can quickly become a full blown crisis if it is not put out promptly.

(4) ***Chemical Experts*****:** These experts are, for instance in charge of measuring the amounts of chemical gas in the air during a crisis situation, and giving an indication of the dangers for other emergency workers. They are also required to provide an oversight of hazard developments for all personnel and actors when a crisis is underway.

We implemented several information services for these 4 actors as jini services in our prototype. These jini services must be registered on a jini lookup server. The requested registration information is shown in Table 1 in Appendix 2. We used a simple example from a chemical expert to display what and how information services are registered in the jini lookup server. Table 1 presented in Appendix 2 is implemented in a database of the jini lookup server.

Client PC

On the client PC, we used Liferay 4.0 [3] as the portal software, and embedded Tomcat 5.0 [4] as the web server to build the "crisis response and management portal". We built two databases, a user administration database and a personalization database, which were used to support role-based information seeking and retrieval applications running on this portal. The user's role-based profiles, stored in user administration database, were used to control their information access. The personalization database was built based on the meta-model presented in section 2.4, where previous existing crisis situations, their constituting scenarios, scenarios' constituting facts, facts' solutions, etc, were stored in the tables of situations, scenarios, facts, solutions and tasks as historical information. The personalization database was implemented in MySQL [5].

User interface design

User interface design is very important to facilitate users and to help them to generate their role-based information seeking and retrieval service, and to access relevant crisis information. In the crisis response, facts can be directly observed from the environment. It is a very intuitive idea to utilize facts as the starting point of an information acquisition process, and it also matches the previously defined SA process.

However, a myriad of different facts can be detected and defined during a crisis response, and this number increases continuously. It is not a complex task for a database to record and handle such an amount of information, but it will be a demanding task for a user to extract facts relevant to themselves from those with miner differences within the returned list. Furthermore, a simple crisis can go on to

[3] Information about liferay can be found from http://www.liferay.com/web/guest/home

[4] Information about Tomcat can be found from http://tomcat.apache.org/

[5] Information about MySQL can be found from www.mysql.com