

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

Nong CHEN and Ajantha DAHANAYAKE

*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.

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

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relief/response organization can change dynamically, due to the unpredictable nature of disasters throughout the course of a disaster. The tasks and roles of the relief/response organizations will change, and therefore their information needs will change accordingly [25]. The centralized design principle satisfies a user's information needs by bundling information from heterogeneous databases. The dynamically changing nature of crises coupled with the diverse types of crises that can occur, may require a complete redesign of an application to meet the information needs for each possible crisis situation.

In summary, there is a need to develop a new crisis response information system based on a more flexible design principle, which is:

- (1) capable of providing relief/response organizations with a role related picture of the crises development in a time critical manner.
- (2) capable of satisfying changing information needs flexibly.
- (3) capable of structuring advanced technologies and available technical infrastructures in a meaningful way to realize dynamic changing user information needs during a crisis response flexibly.
- (4) extendable when a relief/response organization is required to join relief/response activities.

Building on the advantages of a service-oriented approach when designing information systems in dynamic, distributed and heterogeneous environments, we propose a new conceptual design for role-based, situation-aware information seeking and retrieval during a crisis response situation. This new service-oriented architecture allows relief/response organizations to reconfigure information seeking and retrieval applications during crisis response activities to meet their specific information needs. This is done by combining required plug-and-play services according to the relief/response organizations' perceptions of the crisis situation with respect to their information requirements.

The conceptual design presented in this paper will contribute to the field because:

- it offers a way to satisfy dynamic changing information needs in a flexible way, while simultaneously adapting to and using advanced information technologies and technical infrastructure.
- it provides a new way of thinking about retrieval of time critical, role-based, situation-aware information during the crisis response process.

Our conceptual design is presented and explained in section 2. A test case, taken from an ongoing EU research project, is presented in section 3. We evaluate our

approach in section 4 and present our conclusions and discuss future work in section 5.

## 2. CONCEPTUAL DESIGN

### 2.1 Information needs

The literature shows that there is a deepening understanding of the concept of information needs and its role in information seeking and retrieval. In this section, we identify the factors that trigger information acquisition to fulfill a user's information needs in the domain of crisis response.

Taylor [22] and Belkin [1] argue that users' characteristics determine the information needs of users. Dervin's "situation-gap-use" model [7] indicates that people first need to establish the context for information needs, i.e. the situation. After that they may find a gap between what they understand and what they need to make sense of the current situation. According to Dervin's theory of sense-making, information seeking and retrieval is one of the actions people will take to narrow the gap between their understanding of the world and their experience of the world. Wilson's macro-model of information-seeking behavior proposes that information needs arise from people's environments, social roles and individual characteristics [29]. Wilson's extended model [30] presents a complete picture of factors affecting information needs, including psychological, demographic, role-related or interpersonal, environmental and source characteristic aspects [30]. Wilson defines the work task as a central component in information behavior [29]. The concept of task has gained increasing attention as it provides an important clue to help us to understand why people seek information, what type of information they need, and how they are going to use the information [1]. As a consequence, the work task has become a central factor for determining a user's information needs, see e.g. [29] [2] [24]. Järvelin, et al argue that information retrieval research needs to be extended towards including more contexts, and that information seeking research needs to be extended to include tasks [13]. Byström, et al's model of task-based information seeking focuses on how work tasks affect the task performer's choice of information sources and information types [2]. Similar findings are presented in [24], whose focus is how work tasks affect information types, search strategies and relevance assessment. Combining these approaches, we can distinguish three types of influencing factors used to determine user information needs: (1) user's self characteristics, e.g. user's personality, knowledge, personal interest and preferences; (2) user's roles and (work) tasks in the society, e.g. user's professional roles connected with occupied positions, and

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.

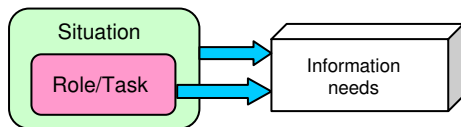


Figure 1: Personalized information needs

## 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.

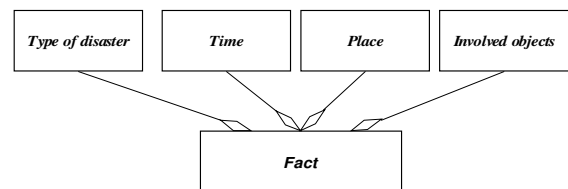


Figure 2: Meta-model of a Fact

This model can then be explained as below.

- *Type of disaster*: at a container terminal, disaster types can be fire, explosion, leakage, etc.
- *Time*: There are two type of Time, i.e. a time point, e.g. 3:20pm, or a time interval, e.g. 1:00am to 2:00am, or summer. The choice of time type depends on disaster type.
- *Place*: the place is the physical location, i.e. a region, e.g. an area in the docks, on a ship.
- *Involved objects*: in the crisis situation, involved objects include personnel, properties, or a combination of these two.

A fact can be described as a combination of type of disaster and any or all of the other three concepts. For instance, the possible facts observed from a disaster in a container terminal might be described as ‘a chemical fire, at area (a), at 17:00’, ‘an explosion in building (n)’, ‘people have suffered burns’, ‘a person has fainted in building (n)’, ‘road (x) is blocked by an overturned truck’, etc. The type of disaster is the key concept used to describe facts. The description of facts is exclusive. For instance ‘a chemical fire, at area (a) at 17:00’ and ‘a chemical fire, at area (b), at 17:00’ would be defined as two different facts although only the location of the fire differs. Facts cannot be divided into sub-facts.

### Scenarios as a means to understand the situation

Perceived facts are direct observations made in the crisis environment. They do not provide narrative descriptions of the crisis situation. Therefore, facts do not supply sufficient information for users to fully understand the situation. To support the second level of the users’ SA, we use the concept of scenario.

In the context of crisis response, we define a *scenario* as a *short story reflecting a crisis situation*. A scenario describes known outcomes, and the casual relationship of a group of determined facts. For instance, the scenarios of the disaster example given in the previous paragraph can be described as ‘a chemical fire in area (a) blocks road (x)’. ‘The chemical fire causes an explosion in building (n)’. ‘People were burnt because of the chemical fire’, and ‘the gas caused by the chemical fire has poisoned people.’ Known scenarios in the crisis response are used as historical information that can be analyzed to support level 2 of the users’ SA process during a crisis response. Unknown scenarios can be detected by combining known facts from historical scenarios.

### Deriving information needs from SA

Situations indicate a problem, or a group of problems that users should solve during the crisis response period. These

problems initialize the users’ information seeking and retrieval activities, determining the information needs. A *situation* is defined in our research as a *state of affairs of users’ special or critical significance during the course of a crisis response with respect to their professional roles*. We claim that the situation can be derived by detecting users’ professional role relevant scenarios, i.e. from those scenarios that directly or indirectly involve the users. Direct involvement in scenarios means that users take actions during a crisis response in their professional role. Indirect involvement in scenarios means that the scenarios influence users’ actions during a crisis response.

Problems arise in a situation. In the context of crisis response, users perceive the problem they need to solve when their situation is described clearly. When the problem is detected and understood, the users will take actions to solve this problem. Before they can take any action to solve the detected problem, a need for information arises. *Information needs are information elements required for users to solve the problems faced in a crisis situation when performing professional roles*. For example, the problem of a user performing the role of fireman in the previous example would be ‘extinguishing the chemical fire in area (a)’. Before he or she takes any action to extinguish the fire, there is a need for information. Information needs are identified using the scenarios that constitute the situation. The user with the problem to ‘extinguish the fire’ will need to know: What type of chemical fire am I dealing with? What sort of equipment/materials should I use to deal with this type of chemical fire? when he or she is directly involved in the scenario ‘the chemical fire causes an explosion in building (n)’. Indirect involvement of in the scenario ‘a chemical fire in area (a) blocks the road (x)’ will give rise to new information needs. The fireman needs to know how to avoid traffic to reach the disaster site. When sufficient information needs have been identified and structured in a meaningful way during a crisis response, a user will be able to take actions to solve the problem. We present the SA process in our research in the Figure 3

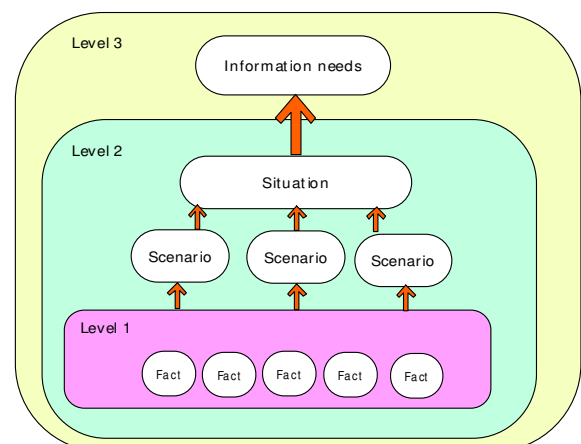


Figure 3: SA process

## 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.

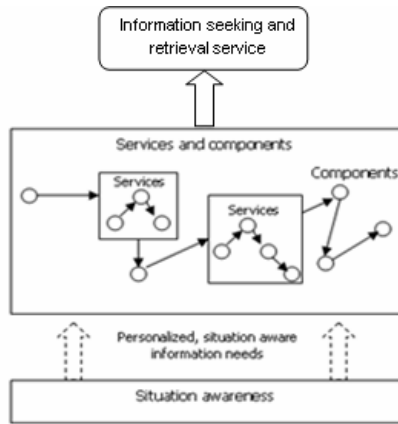


Figure 4: Service-oriented Design Approach

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.

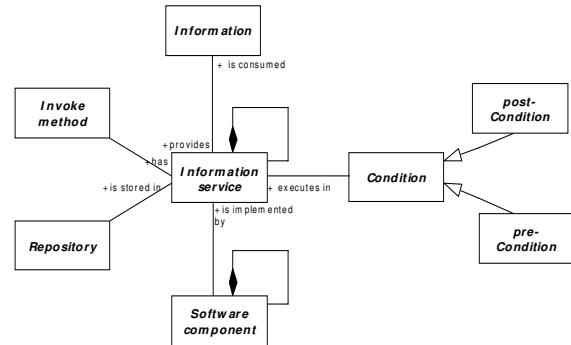


Figure 5: The concept of information service

### 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*

of actions in a crisis situation. Defining a task as a piece of work indicates that it has (1) a performer; (2) a meaningful purpose; and (3) an undertaken context [12] [1]. This is also a definition that emphasizes the conceptualization of tasks from the actor perspective and the social context of task performance [5].

Crisis response has a social context, where involved organizations or organizational units undertake tasks according to their professional roles in a crisis response process. We define *the involved organizations or organizational units as actors*. For instance, the actors involved in crisis response might be firemen, police forces, and hospitals. Each actor has a list of professional roles in the context of crisis response. A role is defined in the dictionary as “a function or part performed especially in a particular operation or process”. Obviously, a role is a function relevant concept. *The professional role of an actor in a crisis response context is defined in terms of functions an actor must provide in a crisis response process*. Therefore, actors are exclusive, and are detected based on the functions they provide, i.e. their professional roles. A task is performed when an actor adopts one of its professional roles. The reason an actor undertakes a task is to provide required functions in a crisis situation. A task can be composed of smaller tasks. At the level of a simple task, it is constituted of a series of interconnected actions. The meta-model of the task concept can be found in Figure 6.

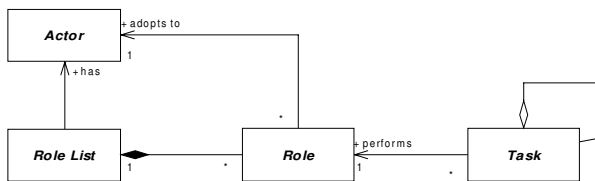


Figure 6: Actor , role and task

A task is performed in a situation, where an actor is required to adopt one of its professional roles. According to the definition of a task we proposed, tasks are distilled from an actor’s professional role, i.e. from the functions an actor can provide in a crisis response situation. In a crisis response situation, the functions an actor can provide are relatively stable. However a situation is a dynamic concept, as supported in the SA process defined in section 2.2. It is not feasible to define task on the level of a specific situation. This is because a crisis situation may require a solution that consists of many tasks performed by many different actors, and this diversity cannot be predicted in advance. A crisis situation changes dynamically as a disaster develops. Therefore, defining tasks on a set of facts are more tangible and reliable. Since a task can be composed of smaller tasks, the required tasks to solve a problem in a detected crisis situation can be composed of sub-tasks which can be identified using relevant facts.

Tasks are undertaken in a process used to formulate the solution of an existing fact. We present the relationship between a task, fact and solution in Figure 7.

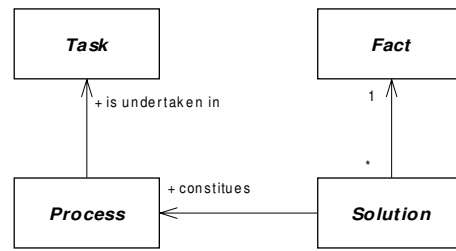


Figure 7: Fact, task and solution

### 2.4 The meta-model of role-based information seeking and retrieval in crisis response

We used the concepts defined in the previous sections to formulate a meta-model of role-based situation-aware information seeking and retrieval on the basis of the service-oriented system design principle. The meta-model is presented in Appendix 1. We will now present a case study using our conceptual design.

### 3. CASE STUDY

We tested the conceptual design by applying it in a real life case. The case study presented in this section was taken from an ongoing EU research project. In this section, we present the general background to this case study and sketch our implementation of the prototype.

#### 3.1 Case background

The container terminal described in this case study is one of the largest and most important harbor infrastructures in the world. Risk prevention and emergency response have become increasing important, especially after recent global terrorist activities and a number of national disasters. The container terminal has tested a ‘dynamic map’ to provide an interface for its crisis response team inside the harbor. In a closed system, information handling and provision is a fair and manageable task [4]. However, depending on the scale of the disaster, crisis response in this harbor can involve many layers of government from local to national, commercial organizations, volunteer organizations, media organizations, and even citizens” [17]. Furthermore, global collaboration for natural disaster recovery and anti-terrorism cooperation has encouraged the management of this container terminal to take part in a global information network to share information with other crisis experts and professionals. Therefore, the management intends to build a more flexible and extendable crisis management information platform to provide all authorized and involved actors with access to their role-based, situation-



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.

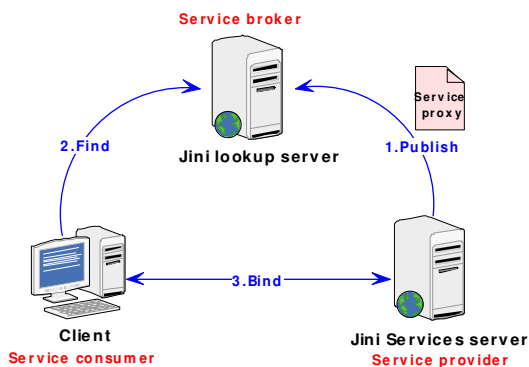


Figure 8: Prototype Architecture

### 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<sup>3</sup> as the portal software, and embedded Tomcat 5.0<sup>4</sup> 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<sup>5</sup>.

### 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 minor differences within the returned list. Furthermore, a simple crisis can go on to

<sup>3</sup> Information about liferay can be found from <http://www.liferay.com/web/guest/home>

<sup>4</sup> Information about Tomcat can be found from <http://tomcat.apache.org/>

<sup>5</sup> Information about MySQL can be found from [www.mysql.com](http://www.mysql.com)

become a very complicated situation, which will further increase the large number of facts that can be observed. Users will need to answer the following questions: What facts can be utilized as a start point and how can we handle the inter-relationship between the observed facts? These questions may confuse the users; moreover, answers to these questions will bias the information acquisition results. The conceptual design will relieve users from having to deal with this complexity.

It is better to use historical information taken from past crisis situations as the starting point of the information acquisition process, i.e. to derive an unknown situation from known situations. We divided historical information on situations into different categories based on theme. This allowed the users to be immediately directed to the category of a similar situation. The user is able to choose a similar situation from a situation description, and the scenarios of the selected situations are retrieved from the personalization database and displayed to the user. Users select relevant scenarios according to the scenario description. The facts of the selected scenarios are then retrieved and displayed to the users. When users select relevant facts from the returned list, they start their SA processes to constitute their picture of the current situation. Once all the facts have been selected and formulated in a correct order, a fact-solution-task linkage as shown in Figure 7 of section 2.3 is used to determine the required information services. The service discovery process starts after the required tasks have been identified and linked in a specific order. Tasks are used as keys to search for the required information services provided by the different organizations. When a task is selected, a service search template is generated. The search template is constituted of three attributes: actor, role and task. A selected task generates this service search template by filling in the actor name, role name and task name. The service search template is sent to the jini lookup server to look for the relevant information services based on actor name, role name and the services descriptions. All the information services of a selected task are returned to the users. Information service name, information service description, service status and location are returned to the users. It is the users' responsibility to figure out their required information services based on the returned service information. The implementation can be found at <http://kishen.ercotravel.nl/>. Newly detected situations, scenarios, facts, solutions, and tasks can be added to the tables in the personalization database as historical information. Since the portal communicates to the personalization database each time a user sends a request, newly added historical information can be immediately utilized.

When the crisis situation is not complicated, it is more efficient to start the information acquisition process by

using facts. For instance, if only a few facts have been observed, a user can search for similar facts based on the keyword "type of disaster". The users can identify the relevant facts and organize the retrieved solutions and their constituting tasks into a logical order based on their observations. In this way, the information seeking and retrieval service can be configured quickly.

#### 4. CONCEPTUAL & FUNCTIONAL EVALUATION

Our work is related to work being done in 'ubiquitous computing'. Research in ubiquitous computing mainly focuses on 1) how to provide users with personalized information or services based on users' profiles, or 2) how to provide services or devices with situation awareness ability to adapt the service behaviors or device behaviors according to various situations, or 3) a combination of the above.

Yau, et al's work is one of the new and representative works in the field. They propose an efficient information retrieval technique for mobile Internet by combining situation-based adaptation and profile-based personalization by generating user profile with the situation awareness capability of handheld devices [26]. They subsequently apply the idea for information retrieval in [26] into service discovery in [27], where they present a model for situation awareness in service-based systems. Based on this model, situation-aware agents are developed to incorporate situation-awareness and adaptive coordination in service-based systems [27]. Yau et al go on to use their model in an example, which they call "ship rescue", and to demonstrate the suitability of their model for use in the field of crisis response and management.

The focus of Yau, et al's work is service discovery and coordination, and they define the concept situation as the execution condition of a service or a group of services, which is similar to our concept fact in our design. However they do not provide a solution for supporting users' SA process when they discover services to satisfy their information needs in a crisis situation.

We define the concept situation as the user's situation, i.e. crisis situation if applied in the context of crisis response. Based on Endsley's SA three-level model, the concept situation in our design is capable of supporting a relief/response organization as it analyzes and envisions an unpredictable and dynamic crisis situation. Beside the concept situation, we include tasks as an important factor for determining a user's information needs. Our task model is capable of inferring users' information needs in a crisis response according to their professional role(s) and relief/response tasks during a crisis response. Thus, users' role-based, situation-aware information needs during a crisis response can be sufficiently inferred, and well-structured in



a meaningful way. We believe that our concepts provide a more specific and a wider ability of deriving users' actual information needs in this type of applications.

The development of an early prototype demonstration showed us that our conceptual design is capable of satisfying users' dynamic information needs flexibly during a crisis response. In an unpredictable and dynamically changing crisis situation, users' information needs change when they perceive the need for different relief activities as the crisis evolves. For instance, when a chemical fire leads to an explosion, or to a riot, the information needs of a user adopting a police force role may change from how to control the traffic, to how to disperse personnel, and to how to control the riot. Built on our situation model and task model, the prototype is able to infer and construct a user's changing information needs during a crisis. While based on the service-oriented design principle, our prototype is able to flexibly support the reconfiguration of information seeking and retrieval services to access to the required information.

Our conceptual models of situation and task can support both service reuse and information reuse. The prototype has shown that the reuse of services in the configuration of information seeking and retrieval applications is possible. The process of selecting and configuring required services is determined through the reuse of historical information. The situation model supports the reuse of information on situations, scenarios and facts to infer the crisis situation. The exploration of an unknown situation is done through the reuse of facts and scenarios. In this situation, the task model supports information reuse to infer a user's role-based information needs in order to select services and configure them.

Additionally, the development of an early prototype demonstration showed us that future system extension is feasible. The service-oriented design principle supports the realization of an independent service implementation and service model. Therefore, it provides for the possibility of a future system extension when more relief/response organizations are required to join the crisis response. Our conceptual model is able to provide clear guidance for a newly joined relief /response organization to share its information services and to construct its own role-based, situation-aware information seeking and retrieval services. In addition, due to the possibility to build up the interoperability between jini, webs service, and other service-oriented standards, more commercial and scientific information software and applications can be added to our prototype if they can be implemented in one of the service-oriented standards. This is a very important and necessary improvement to better support information seeking and retrieval during a crisis response. For instance, computational calculations for chemical pollution, which

was built as a Grid based on a web service standard, could be used and integrated into the system as information services.

Our conceptual design is independent of the implementation technologies. Because of the conceptual underpinning, we were able to implement our prototype by using a very low cost system, free portal software and free service-oriented middleware. Our prototype is just one of a number of possible implementations of our design. It is also possible to rebuild the whole system by using other implementation technologies, for instance, web service.

## 5. CONCLUSION & FUTURE WORK

Information acquisition, in the event of a crisis response in a container terminal or any other industrial complex facility, is a complicated, multi-actor involved, collaborative process. Fast access to all relevant information is paramount for an effective and quick response to a developing disaster. A distributed, heterogeneous, information-intensive crisis environment and the dynamic nature of a crisis require that the information seeking and retrieval system used should serve in a flexible manner, in order to satisfy relief/response organizations when they need to retrieve their role-based, and crisis situation relevant information to support their relief activities. Development of new ICT technology and other achievements means that it is possible to provide mature technical support for crisis situations in the shape of dynamic, tailored information. However, we lack a proper conceptual model that can be used to structure the advanced technologies and available technical infrastructures in a meaningful way to realize high level, dynamically changing user information needs flexibly during a crisis response.

In this paper, we presented our conceptual design for role-based, situation-aware information seeking and retrieval during a crisis response in a container terminal. Our situation model is capable of supporting users to analyze and envision, and to infer the unpredictable and dynamic crisis situations that relief/response organizations face, using historical situation information. Our task model is capable of personalizing users' information needs in a crisis situation according to their professional role(s) and relief/response tasks during a crisis response. The combination of the situation model and task model will allow a user's role-based, situation-aware information needs to be determined during a crisis response, to be sufficiently inferred, and to be well structured in a meaningful way. Simultaneously, applying a service-oriented design principle in our conceptual design allowed us to realize an independent service implementation and service modeling, and to quickly configure information acquisition applications to satisfy users' dynamic information needs flexibly by choosing the required services. During the configuration and reconfiguration of the information

seeking and retrieval service, both the information and services are reused. Therefore, we believe that our conceptual design provides a possible solution to building a bridge between high-level functional requirements and low-level technology availability. Moreover, our conceptual design provides a possibility for future system extension. Newly joined relief/response organizations can share their information and construct their own role-based situation-aware information seeking and retrieval service according to the clear guidance provided by our conceptual design. Simultaneously, advanced information software or applications can be easily added into the systems when they are packaged as services. Our conceptual design is proposed

as an implementation independent way. Based on the conceptual underpinning, we were able to implement our prototype using low cost software. This prototype can also be rebuilt by using other advanced ICT technologies and infrastructures.

The next step of our research will be to focus on how to reduce the time to action in a crisis response situation through implementing an effective information coordination service for situation aware process orchestration [11].

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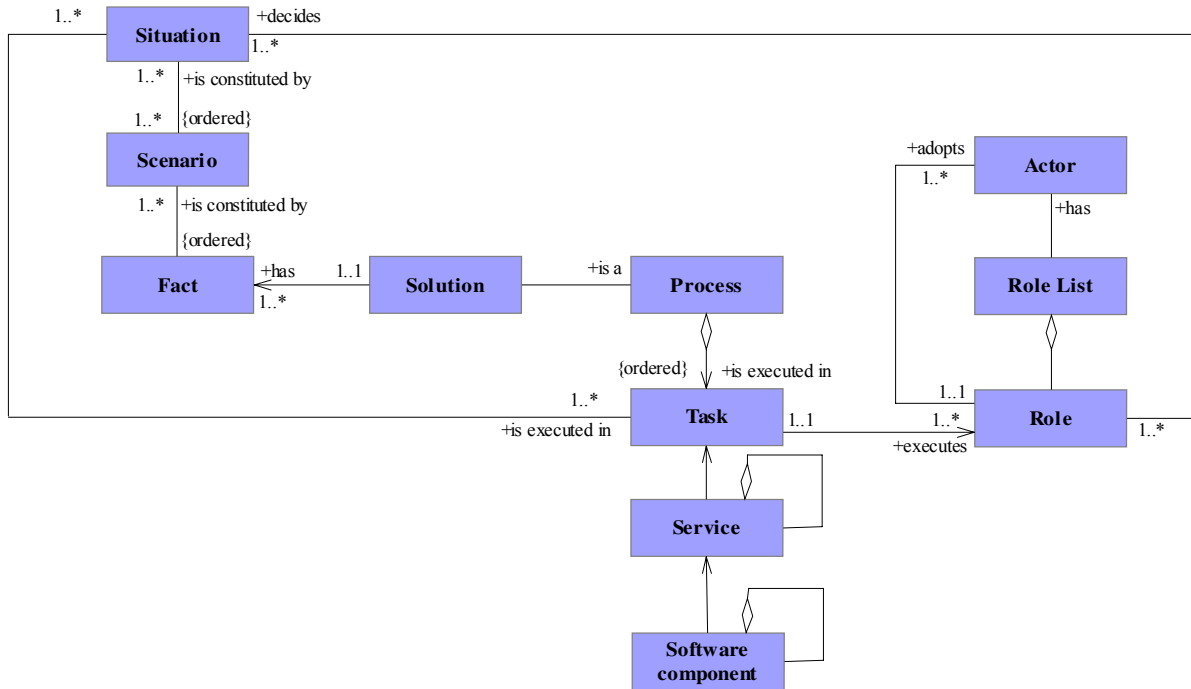
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**Appendix 1: the Meta-model of personalized situation-aware information seeking and retrieval**



**Appendix 2: Table 1**

Actor	Role	Task	Information service name	Information service description	Service status	location
Chemical expert	Air pollution evaluator	Evaluate poison gas	IS1- $SO_2$	Provide $SO_2$ relevant calculation results; Input of the amount of $SO_2$ is required.	Available	URL
			IS2- $H_2S$	Provide $H_2S$ relevant calculation results	Unavailable	URL
	Water pollution evaluator	Evaluate	...	...	...	...
		...	...	...	...	...