On Modeling, Collecting and Utilizing Context Information for Disaster Responses in Pervasive Environments *

Hong-Linh Truong, Atif Manzoor, Schahram Dustdar
Distributed Systems Group, Vienna University of Technology, Austria
{truong, manzoor, dustdar}@infosys.tuwien.ac.at

ABSTRACT

To support collaborative work in disaster responses, various types of context information must be gathered and shared not only within teams at disaster sites, but also among various teams and services in pervasive environments. We propose a representation for describing context information required for disaster responses. This representation is extensible and interoperable enough to include various concepts describing entities existing in disasters and relationships among these entities. We discuss possible techniques based on XML and Web services technologies to gather and share context information among different pervasive applications and services for disaster responses.

Categories and Subject Descriptors

C.2.4 [**Distributed Systems**]: Distributed applications,; H.1 [**Models and Principles**]: Miscellaneous

General Terms

Design, Experimentation, Languages

Keywords

context information, disaster management, mobile applications

1. INTRODUCTION

We have recently faced many large-scale disasters, such as tsunamis, earthquakes, and hurricanes [1], that require large-scale response supports from various organizations and people. Recent advanced technologies, such as ad-hoc networks of mobile devices (e.g., PDAs, smart phones and laptops), have helped simplifying the management of tasks responding to disasters substantially, such as the use of hand-held devices to locate and lead victims to the right rescue paths [6], and fostered the information gathering for disaster responses, such as everyone can easily take pictures of disaster scene. In coordinating disaster response activities, context information about various entities, such as teams, support workers, their capabilities and activities, victims, infrastructures, resources, and devices, is important and useful for dynamic process planning used in the disaster management, geo-information technology-based disaster management [8], and decision making [7]. We refer to the information about the status of these entities as context information.

To support teams to efficiently utilize context information in pervasive environments for their response tasks is a challenging issue. Until now, few works have addressed the monitoring and management context information related to collaborative work in disaster responses. Utilizing context information gathered in disaster responses is still limited due to the lack of an interoperable and extensible model describing context information within disaster scenarios. Potentially, not only professional teams but also ordinary people can easily participate in the gathering and sharing of context information using today's pervasive devices. Therefore, software tools for context information collection and provisioning in disaster scenarios should target to not only professional teams but also normal people in order to harness the mass participation of humans in supporting disaster responses. In this paper, we present (i) an extensible and interoperabile representation for describing context information required for disaster responses and (ii) possible ways to utilize the representation. Other issues like context sensing, context management, and system and network infrastructure, are out of the scope of this paper.

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2. MOTIVATION AND RELATED WORK

2.1 Motivation

Capturing and representing various types of context concepts: In disaster scenarios, more complex contexts are inherent. To support disaster responses, various devices (e.g., wearable sensors and multimedia devices) are used in several activities (e.g., capturing photos, helping victims, locating a building) carried on by different teams. Existing representations of context information are not enough for disaster management because they are not designed to cover disaster scenarios. Context information collected for disaster management is still disparate due to the lack of an interoperable model describing the context information. Therefore, there is a need to develop a novel model describing context information for disaster management. However, many generic concepts for context information exist, therefore, these concepts should be reused.

Fostering user participation in providing context information: One typical property of the disaster response management is that there is a large human involvement. We need to foster user participation in collecting and disseminating context information. Various works have provided different tools for the user to provide information using mobile devices, but these tools need to be integrated and adapted to support the gathering and sharing context information for disaster responses, such as we should provide different forms of context gathering applications (standalone, Web portals, widgets, etc.) atop common communication protocols for mobile phones, PDAs, subnotebooks, and workstations.

2.2 Related Work

Context information in existing pervasive systems: Existing context-aware pervasive middleware and applications provide and exploit various types of context information about *location, time, user activities, user's preferences, profiles of users, devices and networks* [3, 2]. Most existing works are not dedicated to disaster scenarios. They do not address the sharing of context information and the integration of pervasive applications and services spanning the front-end and back-end sites. While many types of domain-independent context information are generic and can be used for disaster responses, such as location and device information, they must be modeled together with disaster-specific context.

Modeling context information in pervasive applications and services: Context information can be modeled by using different representations, such as first order logic and boolean algebra, tuples, XML, RDF, topic maps, and ontologies. In particular, CC/PP (Composite Capability/Preference Profile) can be used to describe context information of capabilities and user preferences and is used in many context-aware middleware and applications. Although existing models provide some generic types of context information, they do not address context inherently in disaster scenarios. Furthermore, some representations, such as based on OWL and tuple spaces, are not suitable for disaster management because it is hard to make these representations to work well with various types of pervasive devices, applications and services.

Using context information to support disaster managements in pervasive environments: The Sahana system[1] has been used in many disasters. It provides Web services for handling information about resources, organization, victims, etc, and a portal for registering such information. It does not support the collection of information from mobile devices and a context information for teamwork. It, however, can be utilized as an external service in our approach. The CIMS framework [5] describes a generic framework for sharing information in disaster management. However, it does not address the modeling and utilization of context information in pervasive devices for disaster responses. The OASIS Emergency taskforce has introduced some specifications, such as EDXL and CAP, to facilitate the data exchange in emergency situations. However, EDXL and CAP do not aim at modeling and representing context information. Some common terminologies in EDXL and CAP are also used in our context model.

3. MODELING CONTEXT INFORMATION IN DISASTER SCENARIOS

Our design of the context model for describing context information in disaster responses is influenced by the W4H classification for context data [4] and existing generic ontologies, such as FOAF, vCard, and OWL-Time Ontology.

The W4H classification for context data [4] presents a domain independent ontology-based context model, which provides a set of general classes, properties, and relations. It has exploited the five semantic dimensions: identity (*who*), location (*where*), time (*when*), activity (*what*) and device profiles (*how*). By applying this classification, we have identified relevant concepts and their properties in disaster management domain for the design of our context model. For example, the *who* in disaster responses can be medical, rescue, volunteer or relief workers. The *where* dimension addresses disaster location whereas the *when* defines time. Activities conducted during disaster responses are an example of the *what* dimension whereas device profiles fit well into the *how* dimension.

[1] http://www.sahana.lk/

The W4H model describes five main elements associated within a context; the five elements are arranged into a quintuple. However, the relationship among these elements vary from applications to applications. To support a different way of accessing context information, we develop a context meta-model based on W4H core concepts shown in Figure 1. This meta-model is designed based on the way how context information could be retrieved in disaster responses. From a person described by the `Who` element, we can determine what is performed by the person (through `perform` relationship) by using `What` (through `use` relationship) as well as `Where` and `When` the person performs (through `in` and `at` relationships, respectively) and the information about the person (through `isKnownBy`). Similarly, a `What` object is linked to `Where`, `When` and `How` objects; a `Where` object can have a sub-object whereas `When` and `How` are atomic. From the context meta-model, we define domain-specific and domain-independent concepts for `Who`, `When`, `What`, `Where` and `How` dimensions to create a context model for disaster responses. Figure 2 describes main concepts and relationships in our context model. In principle, a new context concept can be easily added into the model by defining it as a subclass of an appropriate core element.

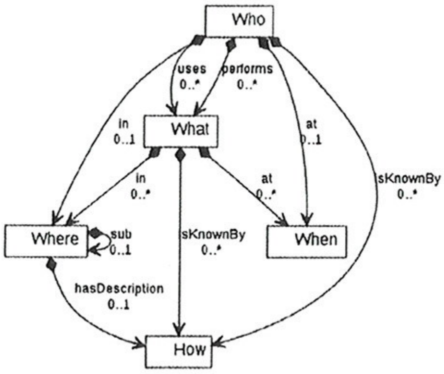

Figure 1: Context meta-model for disaster management

The domain-specific context concepts include disaster and team categories. `Disaster` - a concept in the `What` category - is used to specify the status of a disaster. The disaster intensity and category are described by using a `How` concept. Intensity values can, for example, be low, moderate, and high. Disaster can be categorized into flood, tsunami, tropical storm, landslide, drought, high wind, earthquakes, volcanic eruption, and other hazards. `Disaster` has a relationship with `Site` - a `Where` concept, `DisasterResponse` - a `What` concept - and `Time` - a `When` concept.

With respect to the collaborative work in disaster responses, `SupportTeam` describes a support team of support workers. Multiple teams can involve in a single disaster response. `SupportWorker` describes a team member who performs `Activity` in response to disasters. `SupportWorker` can be divided into `ReliefWorker`, `RescueWorker`, `MedicalWorker` and `VolunteerWorker`. Each support worker is known by his/her `Profile`. A support

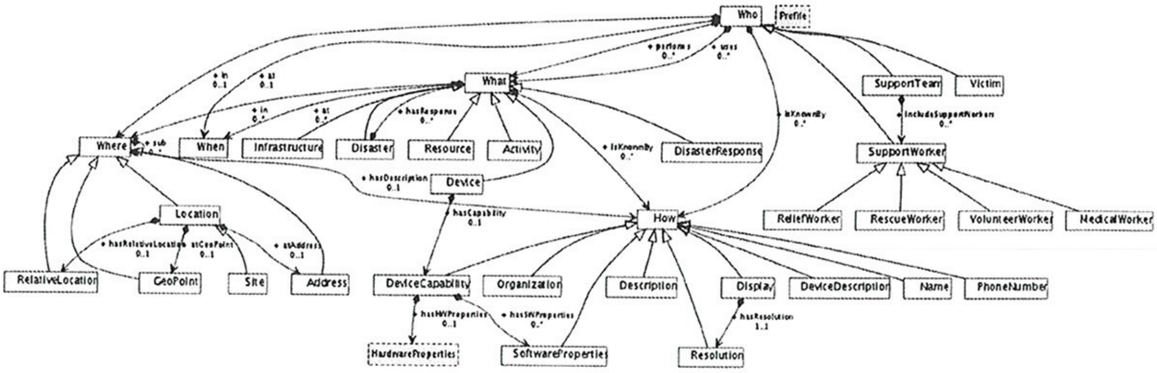

Figure 2: Main concepts in the context information model for disaster responses (visualized by the hyperModel tool)

worker performs collaborative work by executing `Activity` which is described as a `What` concept. Typically, activities are part of a process of actions that a support worker has to do.

Domain-independent common context concepts, such as device profile, human profile, location, and time, are well defined in existing works. Here we just utilize them as a part of the context information for disaster responses. For example, `Profile` is based on FOAF and vCard, `Address` is based the vCard ontology, `Time` is a simplified version of OWL-Time Ontology, and `Device` is based on of existing device ontology FIPA. `Victim` describes information about people at the site who are affected by the disaster. Victim information can relate to treatment needs, e.g., needing first aid and hospitalized, and conditions, e.g., normal or severe, and urgency, such as very high or low. `Resource` will be used by the support worker for carrying on activities in response of disaster or those are available for disaster responses. We describe `Resource` by its name, quantity, and category. Various well-defined resources can be included into this concept, e.g., those defined in the EPRI (Emergency Preparedness Resource Inventory[2]). `Infrastructure` describes the status of fundamental societal structures, such as transportation and communication infrastructure, which strongly impact on disaster responses.

3.1 Context Helpers Libraries for Pervasive Applications and Services

To maximize the participation of humans, the context information should be easily gathered by using different devices, given the above-mentioned concepts. To this end, we generate different context helpers libraries for different types of applications and services. Since we have to consider a wide range of pervasive devices, from normal laptops to subnotebooks to PDAs, we select XML as the data representation because the need to share the context information with different services and applications for disaster responses, such as GIS and notification service, requires an interoperable data exchange model.

We have developed different context helpers libraries based on different configurations (PDAs, subnotebooks, notebooks and desktops). First, Java/C# classes for handling concepts describing in our model are automatically generated from the XSD schema of the context model. However, for PDA configurations, these classes do not support marshaling and unmarshaling Java/C# objects to XML and vice versa, and thus, we have to write custom code for marshaling and unmarshaling XML-based context information. These classes are used together with SOAP libraries to support the development of SOAP-based mobile clients and services for handling context information. Second, we generate libraries for specifying and processing context information in Javascripts, XForm and HTML forms, and JSON which are used in Web-based applications. These libraries are used together with REST-based APIs to support the development of Web-based GUIs and REST-based Web services dealing with context information. (The space limit does not allow us to report our experience on these developments).

[2]http://www.ahrq.gov/research/epri/epriimprep.pdf

3.2 Utilizing the Context Information Model

Many types of context information, such as location, device information, and network, are automatically collected through software sensors implemented as independent services. In the following, we discuss possible methods for gathering context information that is conducted by support workers during the disaster responses. The support worker can use various GUI-based applications to gather information. Depending on the underlying infrastructure, the gathered information, described in XML files, can be stored in a team's context management service before being pushed back to the back-end system. In this case, the context information model provides main vocabularies for the applications to collect the data. Therefore, when describing entities in disaster responses, these applications use agreed terms defined in the model.

Software sensors can also be used to extract context information from application-specific data and to store the extracted context information into a context management system. Depending on specific applications, software sensors can be embedded into the applications during the code development. For example, workers can report information that they observe when conducting their real tasks by using GIS tools (see Figure 3). A GIS tool gets GIS data from the GIS service and displays the GIS data to support workers. However, normally GIS data is pre-defined and does not include contemporary context information gathered at the disaster site. The GIS tool can be extended by enriching GIS data with context information. In this case, when a support worker observes some behaviors, the worker can annotate the GIS-based map. Then, a context sensor can extract context information. This context information together with the reference of GIS objects can be stored into a context management system. Later on, a GIS tool used by other support workers will receive the GIS data associated with the newly-added context information. Thus, GIS tool shows the up-to-date status of the disaster response.

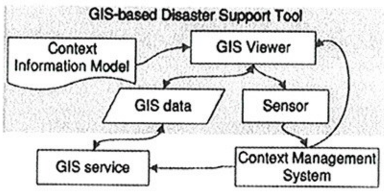

Figure 3: Extracting context information from GIS-based tools

4. PROTOTYPE IMPLEMENTATION

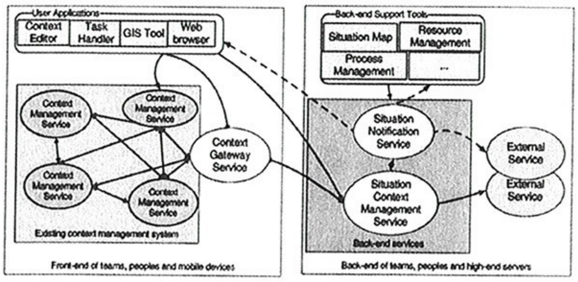

Figure 4: System architecture for sharing context information. Arrowed lines describe the data flow of context information. The arrowed dash lines describe events describing situations.

Figure 4 describes how we envisage context information to be provided to different parties. Based on the context model, various user applications, in the form of Web-based and standalone applications, are developed for different types of users, professionals and normal users, and different types of devices (such as notebooks, PDAs, and subnotebooks). To realize this envisaged integration model, our main idea is to utilize Web services technologies for integrating existing context management systems and other disaster response supporting services, such as SMS, Email and Instant Messages Web services for notifications, and Atom notification feed, HTTP polling, and XQuery-based requests through REST/SOAP APIs for obtaining context information. This realization are currently being implemented in the ESCAPE framework[3].

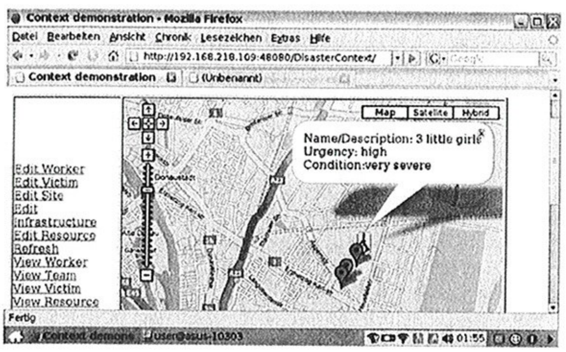

Figure 5: Observing and editing disaster context information

[3] `http://www.infosys.tuwien.ac.at/prototyp/ESCAPE`

Currently, our proposed context model is used in the WORKPAD project[4] and various applications are being integrated with software sensors and context services. The integration of our context model with a Context Editor (used by support workers to enter context information) and a GIS Client for PDAs is performed by our partners in WORKPAD. This integration is tested by a civil protection agency as the end-user. (They are not shown in this paper.) Figure 5 shows examples of observing and editing context information using our illustrative GIS tool based on Google Map. With this tool, context information can be observed and annotated at the same time. Though these tools are different applications in different platforms, they all rely on concepts defined in our context model and illustrate the idea of maximizing human participation in disaster supports by providing different means to gather and share context information.

5. CONCLUSION AND FUTURE WORK

This paper presented a context information model and various techniques for gathering and providing context information to different parties involved in disaster responses. We mainly address software engineering and integration issues for context modeling and provisioning for disaster responses in pervasive environments of Web services and mobile devices. Our future work focuses on integration with other context management services and situation-aware service composition techniques, and conducts performance analysis of our system in a large scale setting.

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