Development of a Dam-break Flood Emergency Information System

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ABSTRACT

This paper presents a new information system, SAGE-B, structured to support all fundamental data related to dams and the elements associated to an emergency in case of a dam-break flood. Data such as information about the population located in the areas at risk or the vehicles available for rescue that are located in the areas impacted by the predicted flood are always changing. In order to support an effective update of the required information for emergency management, an emergency information system was conceived and proposed. This paper describes the motivation for this research and the basic requirements from an emergency management perspective. The platform has a modular architecture, developed in open and free technologies, which allows a continuous development and improvement. Examples of future developments include a multichannel emergency warning system, flood wave real-time forecast and dam-breaching real-time monitoring models.

Keywords

Emergency planning, Emergency preparedness, Emergency Information Technology.

INTRODUCTION

Disaster and/or emergency management is defined as a cycle of activities including mitigation, preparedness, response and recovery. Mitigation efforts refer to those activities which reduce the vulnerability of society to the impacts of disasters. Preparedness efforts refer to those activities which make the government and disaster agents prepare for responding to a disaster, if it occurs. Response refers to the activities necessary to address the immediate and short-term effects of a disaster, which focus primarily on the actions necessary to save lives, to protect property, and to meet basic human needs. Relief, search, rescue, disaster fighting, medical service, permit control, sheltering, evacuation, law enforcement and many others are samples of disaster response activities. Recovery efforts refer to those activities that bring communities back to normal (such as infrastruture and house reconstruction) and they should be developed toward meeting mitigation and preparedness needs.

Mitigation and preparedness activities assume a crucial part, especially in emergency planning, which includes disaster definition scenarios; elaboration of resources lists and its characterization and categorization relevant to emergency response; and definition of actions to pursue using those resources according to the defined scenarios. The planning of the search and rescue activities constitutes an important part of the Civil Protection tasks. In most cases, the planning related to the disasters risk minimization is based in emergency plans. In Portugal, in the context of dam-break floods risk, the safety control, the emergency planning and the response management is regulated by law in large dams. This regulation states that those dams must have breach analysis and flood wave studies, flooding risk zones maps, and alert and warning systems. All these activities are included in the dam emergency plans that are an important tool in an emergency response situation.

MOTIVATION

The aim of disaster response is to restore normal life as quickly as possible, with the initial stage of emergency response being both critical and immensely stressful (Williams et.al, 2000). The initial setting up of a critical

Reviewing Statement: This paper represents work in progress, an issue for discussion, a case study, best practice or other matters of interest and has been reviewed for clarity, relevance and significance.

control centre, the facilitating of mutual aid between the emergency services, the establishment of a cordon management system, and the formulation of wider communication structures are all initial elements of an emergency response. One of the successful outputs is rapid action, because response time is important for crisis situations and emergency services (Inam, 1999). Therefore, any problem or delay in information gathering and management has negative impacts on the quality of decision-making and hence on the quality and success of disaster response.

The disaster response processes complexity and its dynamics, allied to the volume of data/information to manage, either in a planning phase or in an emergency situation, suggests the use of information technology (IT). IT provide an efficient framework for communication, learning, and action in complex systems (Comfort, 1999), and can help in disaster response, improving the information management in collecting information, analyzing it, sharing it, and disseminating it to the right people at the right time. Thus, IT can improve the response by helping people making better informed decisions. Valid and timely information sharing is also critical in emergency response operations (Corbacioglu and Kapucu, 2006).

In recent years, governments have increased resources for the development of web-based emergency response systems. Former studies have shown the great complexities in the design of this kind of systems (Kyng et.al, 2006). A few IT systems have been defined to manage emergency situations, including the HUODINI (Fahland et.al, 2006), a platform for the integration and visualization of heterogeneous information for disaster management, which also integrates social networks systems information, and Sahana FOSS, a Free and Open Source Disaster Management System which was conceived during the 2004 Dec Asian Tsunami (De Silva et.al, 2006). The evolution and widespread use of information systems makes them the adequate tools to address these challenges in a dynamic way, overcoming the constant outdating of paper-based, fixed emergency plans.

REQUIREMENTS ANALYSIS

For dam-break flooding accidents or dam incidents, the safety management, the emergency planning and the actions to pursue are regulated in Portugal, through the national dam safety Decree-Law 11/90 that is applied to dams with heights above 15 meters or water capacity larger than 100 000 cubic meters of. This regulation states that these dams must have rupture risk analysis studies, flood propagation studies, risk zones mapping and alert and warning systems. All these elements are part of the dams' emergency plans.

The emergency plans are elaborated with the direct cooperation of the National Civil Protection entity and Dam Owner, and must be approved by several national authorities, such as Fire-fighters Service and Water Institute. The emergency plans must also contain a set of procedures related to hydro-meteorological monitoring, to dam structure observation and to the dam hydraulics. It should also include detailed information on the people and assets located in the downstream valley, and the nearby resources available for rescue in case of an emergency.

In the context of the dam-break flooding, the dams' emergency plans are the basis of the development of the emergency information system herein described, SAGE-B. The large volume of information and the dynamic nature of the data within the emergencies plans suggest the need for the development of an information system to manage this data and to support the plans' update. The goals of the information system, to the information needed for support in the emergency context, and the actors of the system must be identified in the emergency management system requirements analysis

Information System Goals

An information system must contain: (i) the general requirements of any emergency situations support system; and (ii) specifically, the requirements that allow dam-break flood emergency situations support. The main goals of SAGE-B are to provide an information repository with the list of the elements at risk, the mean and resources available, as well as the geographical positioning of these elements, and, based on all that data, the support in the development and maintenance of the emergency plans.

SAGE-B can ease and help to specify the contents of the emergency plans in a structured, cohesive and not redundant way, namely in the responsibilities and actions to pursue. This type of methodology provides validity and validation of the emergency plan and, in the end, better decision support, which can be complemented through computational emergency simulations system or just real emergency drills. The system provides a set of functionalities in order to manage automatically the gathered information, and making it easy to the system actors (essentially, emergency agents) to access that data and make decisions out of it.

Use Case Actors

It is important to develop a thorough requirements analysis phase. The systems' interpretation and description by potential users and developers almost always differ, so it is usual to apply modeling techniques that specify the system in the most complete, rigorous and coherent possible way (Silva and Videira, 2001).

In SAGE-B's specification, Unified Model Language (UML), was used as a modeling language which is accepted as a standard by software engineers in the definition and development of complex systems. In the requirements analysis phase, it was important to identify the end-users, the system actors, and to start to elaborate the several use cases diagrams for the requirements.

The potential users of the SAGE-B system were already described in the existing emergency plans. In case of an emergency, operational centers at a national, regional, and county-wise will be activated, depending on the nature, severity and extension of the effects of the phenomenon. The personnel and the Head of the National Civil Protection authority, the safety forces, the army forces, the maritime and aeronautics authorities, the Medical Emergency National Institute, the Portuguese Red Cross, the firefighters corporations, the health services, the social security institutions and the private safety and health services, may also intervene in an emergency situation. So, SAGE-B must also support information broadcast to remote locations, usually geographical dispersed, and make it available according the different profiles of access. Figure 1. shows the hierarchy between the users referred previously.

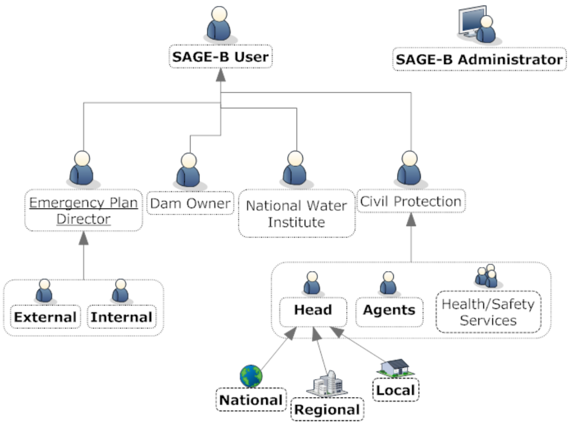

Figure 1. Potential SAGE-B users profiles

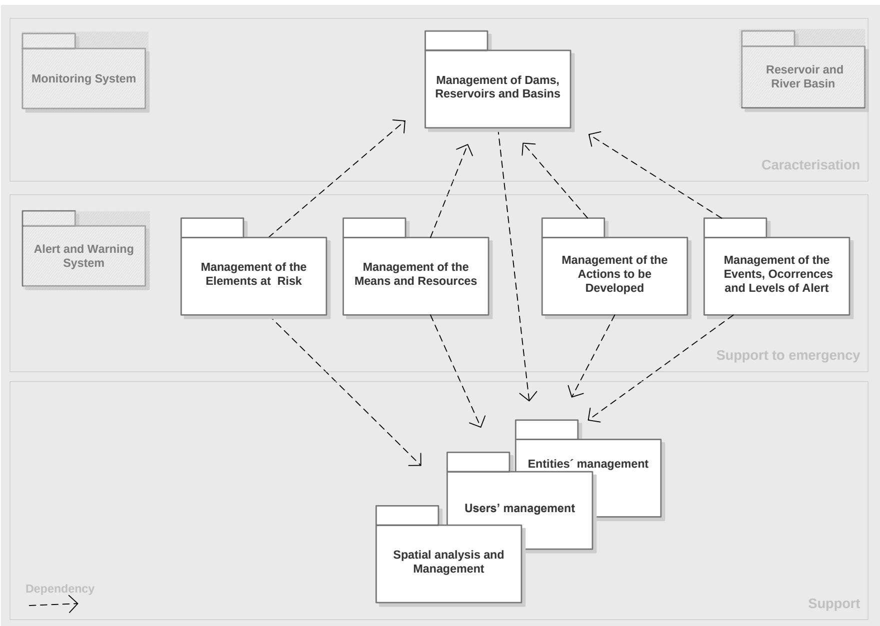

Figure 2. Structure of SAGE-B Information System Modules

SAGE-B Modules

The complexity of an emergency management information system demands that it should be decomposed in smaller domains with less complexity. SAGE-B was thus decomposed in three domains: (i) dams, reservoirs and hydrographic basins characterization; (ii) emergency management support; and (iii) information system general support. Within SAGE-B information system, which will also be integrated with a flood emergency simulator, the three domains were structured in 11 modules, eight being internal modules (Figure 2). The other three are possible add-ons, to expand the system in the future. They include: i) Reservoir and River basin data that are included in the National Water Resources Information System (SNIRH, http://snirh.inag.pt); ii) Dam Monitoring System; and iii) Dam Alert and Warning System.

SAGE-B DEVELOPMENT

Overview

SAGE-B development started in 2005, some of the modules were implemented as a proprietary Web Service based on an MySQL database and a PHP-based interface (Serrano, 2005) but the system lacked interoperability and needed to include GIS support. To support further improvements, SAGE-B was adapted to a new framework based on Sahana (http://www.sahana.lk) (De Silva, 2006). Since Sahana FOSS met some of the requirements defined for SAGE-B, on the Management of the Actions to be Developed, the Management of the Events, Occurrences and Alert levels, and the Management of Means and Resources to respond to the emergency, and including a Web GIS (Geographic Information System) support, a new SAGE-B was developed to take advantage of the Sahana.

Sahana FOSS is built in PHP with MySQL database (a PostgreSQL database is also available), which can provide an environment to reuse most of the work that previously done. The modular framework behind the Sahana Web Interface allowed SAGE-B developers to build their dam specific (and emergency related) modules independently from those that already exist, and, at the same time,to have a similar and customisable look and flexibility. The modular framework deployment process allows for the user's choice of the displayed modules.

Figure 3. describes the high-level architecture of a SAGE-B real application, linked to the emergency entities and a dam alert and warning system, and shows how potential users interact with its hardware and software.

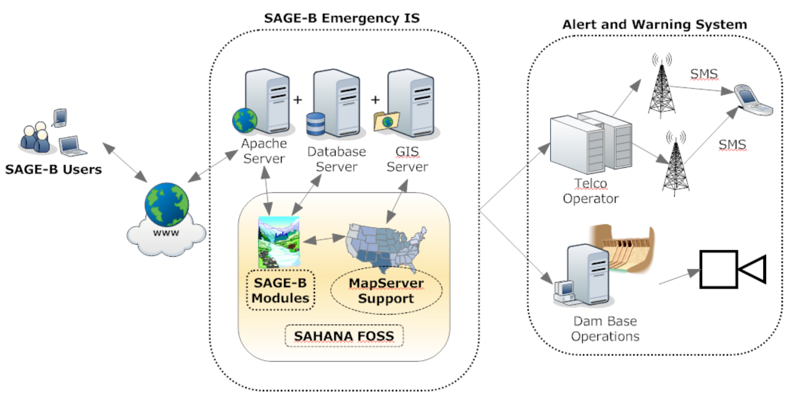

Figure 3. SAGE-B High Level Architecture

GIS Support

Management of the aftermath of the disasters, and disaster preparedness and mitigation involves dealing with heterogeneous information. Much of this information contains spatial components, requiring spatial analysis and visualization. A Geographic Information System (GIS) is a system for capturing, storing, analyzing and managing data and associated attributes that can be used for planning and decision-making. In SAGE-B, GIS support is an important requirement to help the Emergency Entities to spatially manage real-time incidents, or, for example, to consult the dam-break flood plains maps.

Sahana FOSS directly supports of the access to spatial information through Google Maps and OpenLayers. Google Maps is a non-commercial web mapping service application and technology. OpenLayers is an open source JavaScript library for displaying map data in web browsers. It provides an API for building rich web-based geographic applications based in map data inserted by the user. Although OpenLayers offers more interaction options than GoogleMaps, neither of them can be considered a consistent GIS as both of them rely on the system having continuous access to the web. So, other alternatives were also implemented.

SAGE-B also utilises MapServer, an open source development environment for constructing spatially enabled Internet applications (University of Minnesota, 2003). A limitation of many present GIS-based Web services (including Google Maps and Openlayers) is the lack of interoperability and failure to comply to standard Web mapping specifications. MapServer supports several scripting languages, including PHP, Perl and Python, and its notable features include: fully customizable with template driven output; feature selection by item/value, point, area or another feature (basic spatial query); supports tiled raster and vector data; map element automation (scalebar, reference map, and legend); scale dependent feature drawing and application execution; and on-the-fly projection.

CONCLUSIONS AND FUTURE RESEARCH

A new open-source and open-standards compliant emergency information system for dams, SAGE-B, was developed and applied to a Portuguese large dam. It incorporates a complete and large knowledge in dam-breaking emergencies, based on existing emergency plans.

Even though it is already a complex and quite complete system, SAGE-B is an initial phase towards a broader scope emergency response system, as other modules can be developed and be integrated in the near future. Several studies in IT use for emergency situations are currently underway, including its use for preparing agents to respond to a disaster and looking for ways to potentially reduce the loss of life and property. For instance, rather than using only sirens to warn the population, a multichannel emergency warning system is being developed which will use two non-traditional media: text messages through the public mobile phone network (Palha-Fernandes, 2008) and multimedia messages through the digital television network. Other possible modules include flood wave real-time forecast or dam-breaching real-time monitoring models and an evacuation management module based on multi-agent simulations.

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