Collaborative Post-Disaster Damage Mapping via Geo Web Services

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Collaborative Post-Disaster Damage Mapping via Geo Web Services

by

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Abstract

To mitigate the consequences of increasingly frequent disasters across the globe, better real-time collaborative disaster management tools are needed. In particular better stakeholder collaboration would allow the integration of different types of data from diverse sources, thus strengthening analytical capabilities and decision making for disaster response. When a disaster occurs, satellite imagery can provide reliable information quickly to assess the situation and the extent of damage. The International Charter “Space and Major Disasters”, in conjunction with intermediary agencies, provides for space resources to be available for disaster response. It is widely seen as a successful example of international humanitarian assistance following disasters, showing a growing number of activations and provision of image-derived information. However, the Charter is also facing challenges in its operation, especially with respect to accurate information delivery and type based on varying stakeholders and lacking integration and feedback of information from the affected area.

This project, therefore, seeks to offer a solution to the current challenges by moving away from static map data provision to a more dynamic, distributed and collaborative environment by use of Geo Web Services. Geo Web Services brings together vast stores of data from heterogeneous sources, along with geospatial services that can be mashed-up and be used to create better information. The project looks in depth how heterogeneous disaster management agencies can work together in a loosely coupled environment and create new synergies.

A prove-of-concept was developed to demonstrate the importance of Geo Web in collaborative mapping and real-time information dissemination by utilizing open source products aided by User Generated Content and Volunteer Geographic Information. A Geo Web Service architecture showed that geocollaboration and real time disaster mapping and management is feasible within the disaster domain. The project further compares other available virtual disaster viewers, and gives solutions and recommendations for the adoption and implementation of the architecture.

Key words: *Geo Web Services, Web Syndication, Web 2.0, Mashup, Crowd-sourcing, User Generated Content, Ambient Computing, Ubiquitous Sensors, Neogeography tools, Interoperability, Service Oriented Architectures, geocollaboration, convergence, democratization.*

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CIP- Critical Infrastructure Protection
CNES- Centre National d'etudes spatiales
CONAE- Argentina's Commision Nacional de Actividades Espaciales
CSA- Canadian Space Agency
DLR- German Aerospace Center's
DMC-Disaster Monitoring Constellation
ESA- European Space Agency
GeoDRM- Geospatial Digital Rights Management
GeoRSS-Geographically Encoded Objects for RSS feeds
GEOSS- Global Earth Observation System of Systems
GDACS- Global Disaster Alert and Coordination System
GMES- Global Monitoring for Environment and Security
GML- Geographic Markup Language
IASC- Inter-Agency Standing Committee
JAXA- Japan Aerospace Exploration Agency
JRC- Joint Research Centre (JRC)
MCEER- Multidisciplinary Center for Earthquake Engineering Research
NOAA- National Oceanic and Atmospheric Administration
OASIS- Open Advanced System for dISaster and emergency management
OSOCC- On-Site Operations Coordination Centre
SERTIT- Service Regional de Traitement d'Image et de Teledetection
SDI- Spatial Data Infrastructure
SOA- Service Oriented Architectures
SOAP- Simple Object Access Protocol
UDDI- Universal Description, Discovery and Integration
UNDAC- United Nations Disaster Assessment and Coordination
UGC-User Generated Content
UNGIWG- United Nations Geospatial Information Working Group
UNITAR- UN Institute for Training and Research
UNJLC-United Nations Joint Logistics Centre
UNOCHA-United Nations Office for Coordination of Humanitarian Affairs
UNOOSA-United Nations Office for Outer Space Affairs
UNOSAT-UN Operational Satellite Applications Programme
USGS- United States Geological Survey
VDV-Virtual Disaster Viewers
WSDL- Web Service Description Language
ZKI- Center for Satellite Crisis Based Information

1. Introduction

1.1 Background and Significance

The prevalence of global and regional natural disasters across the globe attests to the fact that there is need for real time collaborative disaster damage mapping and management techniques. Earth observation plays a crucial role in reducing the loss of life and property from natural and technological disasters. Climate change and in particular global warming has contributed significantly to the prevalence of disasters. A long term and sustainable disaster reduction strategy requires a better understanding of the relationship between disasters and climate change. Climate change scenarios suggest that new types of hazards will emerge in the decades ahead and that existing hazards may be magnified. By making it possible to integrate different types of data and information from diverse sources, collaborative post-disaster will strengthen analytical capabilities and decision making for disaster response. The development of near-real time Earth Observation systems and geo-information techniques has contributed significantly to support the management of major technical and natural disasters, as well as humanitarian emergency response. To minimize the impacts of these natural and technological disasters, concerned organizations require accurate information regarding the geographic extent of the affected areas, both during the outbreak and shortly after the suppression of the event within the shortest time possible (Gitas et al, 2007).

The International Charter for “Space and Major Disasters” under the theme “Space benefits for humanity in the twenty-first century” (Stevens, 2008), has been a champion in providing a unified system for space data acquisition and delivery to those affected by disasters with ultimate aim of helping mitigate the effects on human and property loss on the principal of goodwill, best effort and common good of humanity (Ito, 2005). The Space Charter was initiated under the auspices of European Space Agency (ESA), Canadian Space Agency (CSA) and French Space Agency (CNES) following the Third United Nations Conference on the Exploration and Peaceful Use of Outer Space (UNISPACE III) in 1999 and later embraced other space agencies after its operation on 1st November 2000 (Inglada and Giros, 2004).

Table 1. Charter Members and their space resources. Source: (Voigt et al, 2007) and (Charter, 2008).

Member	**Space Resources**
European Space Agency (ESA)	ERS, ENVISAT
Centre National d'etudes spatiales (CNES)	SPOT
Canadian Space Agency (CSA)	RADARSAT
Indian Space Research Organisation (ISRO)	IRS
National Oceanic and Atmospheric Administration (NOAA)	POES, GEOS
Argentina's Commision Nacional de Actividades Espaciales (CONAE)	SAC-C
Japan Aerospace Exploration Agency (JAXA)	ALOS
United States Geological Survey (USGS)	Landsat
DMC International Imaging (DMC) 1. Centre National des Techniques Spatiales (Algeria) 2. National Space Research and Development (Nigeria) 3. Tubitak-BILTEN (Turkey) 4. BNSC and Surrey Satellite Technology Limited (UK)	 1. ALSAT-1 2. NigeriaSat 3. BILSAT-1 4. UK-DMC

The Charter aims at providing a unified system of space data acquisition and delivery to those affected by natural or man made disasters through Authorised users. Each member agency has committed resources to support the provisions of the Charter and thus helping to mitigate the effects of each disaster on human life and property. The Charter's activities have managed to establish a working response mechanism to disasters by providing transformed information and know-how for disaster management (Ito, 2005). The basic principle behind the Charter is to provide image derived information to all countries affected by natural and technological disasters under a single node or point of contact. Noted inefficiencies go beyond the mandate of the Charter, issues of data policy and cost are the limits to data provision. The Charter stipulates that all afflicted states have access to data for free. It frees all users from bearing the high cost of satellite images, which are instead borne by the individual partner members on a best effort basis. The costs vary based on the provider and the category of the user. Free or reproduction cost is conditional and allowed to limited users. The Charter in itself under the Remote Sensing principle stipulates that once the primary and processed data are produced, the sensed state has ultimate access to the data on a non-discriminatory basis and on reasonable terms.

Despite successes, such as an increasing number of activations, better visibility, and more reliance of decision makers and disaster response professionals on such space data, the Charter is also facing challenges in many areas of its operation, especially in accurate and timely data delivery. Data flow is mono-directional, meaning there is no participatory collaboration between the members, stakeholders and end user, resulting in a situation where resources and knowledge are insufficiently well coupled. There is a need to move away from project based static data provision to dynamic enterprise distributed and collaborative environment. Geo Web services can bring together vast stores of data of many types along with geospatial services that can interact and be used to create better information. Segmented disaster management agencies can be able to work together in loosely coupled environment and create new synergies. The goal of this project is to assess if new technologies such as Geo Web services can be a sustainable solution to these problems.

1.3 Problem Definition

The rampant occurrence of disasters in the recent years due to climate change and global warming have resulted in loss of life and property, subsequently, increasing the costs of response. The disaster management cycle (mitigations, preparedness, response and recovery) is fundamental in combating disaster related challenges. The International Charter, intermediary organizations, NGO's and industry are involved in disaster response. Disaster response is action taken immediately before, during and just after a disaster. The goal of the response is to save lives, minimize property damage and enhance recovery from the incident. Disasters are responded to by emergency personnel, relief workers, humanitarian organisations, government agencies and International organisations at local, regional and international levels. These stakeholders in the disaster continuum have evolved over years and have responded to disasters and emergencies. Major improvements in space-based disaster response was realised after the formation of the International Charter "Space and Major Disasters" in 1999 bringing in many players in the provision of image derived information for post-disaster damage assessment. Many countries without satellite or space-based information can now receive disaster related information from the Charter and allied members.

The growing use of geodata from satellite imagery to spatial data integration has increased timely disaster response, rehabilitation and reconstruction. The UN Institute for Training and Research (UNITAR) Operational Satellite Applications Programme (UNOSAT), together with *Service Regional de Traitement d'Image et* *de Teledetection* (SERTIT) and German Aerospace Center's (DLR) Center for Satellite Crisis Based Information (ZKI), has been in the forefront in leading edge geo-information service provision in humanitarian mapping and post-disaster management, especially in third world countries, where the national stakeholder humanitarian organisations receive maps in print oriented Portable Document Format (PDF). The website has been designed mainly to disseminate mapping products to users and to provide access to map resources and data to thousands of experts in the disaster domain. Users and experts in the field access the website to download or view on line emergency mapping products. This approach fails to meet the varying needs of different stakeholders not even allowing them to add additional information. The images are typically analyzed in western countries (Kerle, 2008), without input and feedback from the affected region. These maps are needed by different users and at different times, and are ideally produced with a specific user group in mind. They are prepared far away from, and without a direct communication link to the disaster area (Kerle and Widartono, 2008). This is definitely what is lacking and an ultimate challenge. The divergent entities should have regulated access and opportunity to extract and utilise information from them and incorporating the disaster relief community as the major actors and recipients.

Despite the breakthrough in providing image derived information, the Charter lacks a framework for collaboration, synergy and feedback from major stakeholders in disaster response. There is concerned need for a synergy and collaborative framework within the many stakeholders across the divide involved after any major disaster at near-real time. The Charter provision of image derived information alone without knowledge from the field does not provide sufficient information of a given disaster situation. Misinterpretation of data may result when done outside the region. There is need to involve the local organisations and experts in validation and analysis in order to avoid delivery and provision of inaccurate information. The aim of this project is to bring divergent organisations together in contributing and reinforcing a network of a timely and accurate disaster relief and management information.

Despite the growing number of activations with a good number of post-disaster damage products, there exists a complicated Charter data usage, the original imagery is not free as such and also cannot be used after the initial disaster. The data are not available to divergent end-users based on their data format needs and requirements. The Charter's free provision of disaster information via open platforms is limited by its mandate and legal framework. There is need of establishing a distributed system architecture with clear standards for processing and interpretation. An appropriate application framework has to be developed to enable several stakeholders in various locations to add value and work on the same disaster map unlike the current idiosyncratic datasets. The Geo-spatial e-Collaboration in emergency response should be technically feasible with extensible elaborate spatial querying and image processing. The process should be adaptable to regional and thematic specificity of typical disaster emergency response.

Collaborative damage mapping requires situation assessment from existing and new dataset, impact assessment with post-disaster imagery and organisation of post-disaster peak workloads. This project is poised towards multi-stakeholder data access, editing, verification and validation, and mash-up with their dataset to create their own products. The dissemination of disaster information should meet user needs without compromising quality, timely provision, technical hitches and general logistics. This collaboration initiative can only be achieved where distributed services act as a geospatial one-stop for seamless data management. A unified system allows fast collation and analysis of distributed dataset with expert knowledge. Satellite and other monitoring instruments alone cannot meet disaster response initiatives, hence, there is a need to link infrastructure with ground networks as envisaged in the Global Earth Observation System of Systems (GEOSS) architecture. Geo Web services will open up a cornucopia of services for a long term, comprehensive and high quality EO system in support of critical decisions. The development of global, regional and national nodes is not an exception for these disaster management organisations. This project seeks sustainable solution to a collaborative framework that will allow various stakeholders in different locations cooperate and work together on the same map**.** The main focus is to design a suitable framework of services and client solutions for a collaborative disaster mapping system.

1.4 Research Objectives

The objectives of this research are as follows:

1. 4.1 General Objective

The general objective of this study is to assess the relevance and importance of Geo Web services in disaster management and design suitable architecture for a collaborative post-disaster damage mapping system.

1.4.2 Specific Objectives

a) To design a suitable framework and architecture for a collaborative disaster mapping system
b) To identify the gaps in the current Charter activities in data dissemination and disaster management.
c) To assess appropriate standards and specifications for a collaborative disaster mapping system.
d) To assess if Spatial Data Infrastructure (SDI) is a solution to collaborative disaster mapping.
e) To assess if Geo web services is a solution to collaborative post disaster damage mapping

1.5 Research Questions

a) Are there any real time disaster management systems which allow collaboration within disaster management agencies?
b) Is the general humanitarian synergy and collaboration lacking? If yes, what is the way forward?
c) Are there appropriate standards and specifications for a collaborative disaster mapping system?
d) Are Spatial Data Infrastructures (SDI) a solution to collaborative disaster management?
e) Are Geo Web Services a solution to collaborative post-disaster damage mapping?

1.6 Organization of the Thesis

Chapter one is a brief background, problem statement, research objectives and questions of the research. Chapter two is a comprehensive literature review on disaster response and the concept of Geo Web Services. Chapter three covers methodology and materials used in the research. Chapter four covers the results from the adopted methodology and analysis of the results, chapter five entails discussion and finally chapter six involves conclusions, recommendations, limitations and future work.

2. Post-Disaster Damage Response and Management

2.1. Introduction

Disaster Risk Management (DRM) is rapidly gaining recognition in the disaster management field by virtue of its many attributes of bringing data and information providers, collaboration and policy into a powerful confluence (Kapucu, 2008). The comprehensive approach involves mitigation, preparedness, response and recovery phases. A proactive mitigation approach is more effective and economical compared to recovery and rebuilding efforts during disaster aftermath. The approach requires attention to a diversity of stakeholders and to developing rapid responses to natural and technological disasters. There should be a clearly articulated and comprehensive framework for creating and energizing new disaster preparedness, mitigation, recovery, and reconstruction institutions that span the whole gamut of natural and related technological disasters (Kapucu, 2008). DRM generally involves developing innovative approaches to mitigating and sharing the burdens from natural and technological disasters.

2.2. Disaster Response

Disaster response is a phase of disaster management cycle, aimed at alleviating human loss and suffering. It includes the mobilization of the necessary emergency and relief services in the disaster area. Effective coordination of disaster response is crucial when many organizations respond within the shortest time possible. Collaboration between international, regional and national organizations is essential and, therefore, collaborative mechanisms must be developed and implemented (Kapucu, 2008) especially in disaster response and recovery.

When people are affected by a disaster, satellite imagery, airborne data (Kerle et al, 2008) and many other space resources are available covering a wide range of technical specifications and utilities (Zhang and Kerle, 2008), provides a reliable tool to quickly assess the situation and damage caused to infrastructure on the ground. The time saved in such cases is substantial, an advantage of acquiring visual references on the ground before deploying field teams and exposing them to unknown risk. Satellite imagery reveals substantial information of areas that may be too remote, too large or simply under restricted access for security reasons (Bjorgo et al, 2008). Satellite image analysis and processing is done by intermediary organizations on behalf of the Charter and tasked with rapid post-disaster damage mapping and data dissemination to humanitarian organizations, government agencies and the public within the disaster region.

There has been development in satellite image provision from low resolution in the past to current high resolution imagery with the impact of cloud coverage overcome by radar that can penetrate clouds and darkness during night acquisition. More satellites with higher level of details will become available in the near future for civilian use, hence improving access to this valuable source of information. Imagery from space is a useful complement to information gathered from the ground since it gives an overview of disaster extent, damaged structures and general condition of diverse disasters on the ground. There has been drastic development of space based disaster information in the last decade from local level agencies to a unified Space Charter in 2000 and emergence of intermediaries and the inception of regional and international efforts like Global Monitoring for Environment and Security (GMES) and Global Earth Observation System of Systems (GEOSS).

2.2.1. Role of the Charter

The Charter endeavours (1) to make their satellite resources available, (2) to supply, during period of crisis, emergency organizations, essentially the national civil protection agencies, with a coordinated and free of charge access to space systems, (3) to contribute to the Charter implementation tasks (Mahmood, 2004). The Charter is operated by a number of space agencies and provides meaningful mapping and analysis products to the civil protection and relief organizations at appropriate scale in time and space. The agreement comes from the recognition that no single operator or satellite can match the challenges of natural disaster management. Each member agency commits resources to support the provisions of the Charter, helping to mitigate the effects of disasters on human life and property. It aims to provide a unified system of space data acquisition and delivery to those affected by natural or technological disasters through authorized users.

The role of the Charter is to promote cooperation among space agencies and system control segment operators in the utilization of the space resources for making a contribution towards the response to natural disasters. The uniqueness of the Charter lies in a single point of contact and a coordinated approach to space supported disaster relief offered by the Charter members. The Charter covers the response phase of a disaster, and the contributions of the member agencies are limited to satellite data at a predetermined processing level. Any value adding and information extraction from the data is the Charter member agency's own initiative since the country recipients have no mandate and capacity to add any value. Data acquisitions from multiple sensors, both passive and active, onboard the participating satellites are carried out with high planning priorities, and information products are delivered with short turnaround through pre-identified user (Mahmood, 2008). To date, the Charter has been activated 182 times with a significant number of disasters worldwide and events of regional importance.

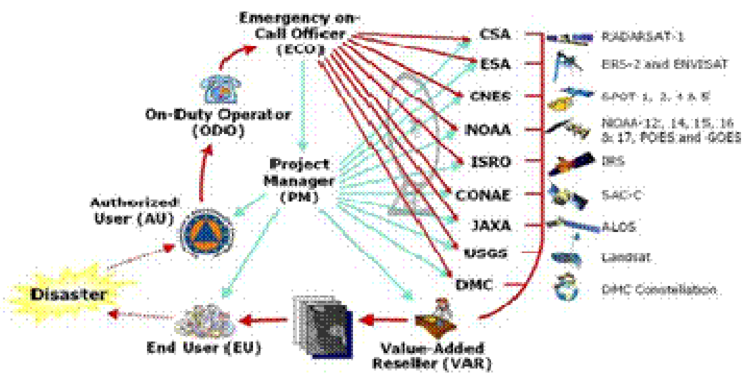


Figure 1. Operational loop of the International Charter "Space and Major Disasters" (Source: Mahmood et al 2008).

As shown in Figure 1, a 24 hour duty operator receive requests and refers it to the Emergency On-Call Officer (ECO) who analyses the request by interaction with the Authorized User, and prepares an archive and satellite tasking acquisition plan using available space resources. The ECO prepares an elaborate record of the request, and determines the data source and space sensors appropriate to cover the disaster. The ECO then suggests a draft plan to the appropriate agency for execution. Data acquisition and delivery takes place on an emergency basis, and a Project Manager, who is qualified in data ordering, handling and application, assists the user throughout the process. The satellite data from a variety of sensors are acquired and processed and the information products are generated on a priority basis (Mahmood, 2008).

The speed of data and information delivery may still be improved in the context of the Charter, as natural, humanitarian or technical disaster often cannot be predicted in space and time and thus requires maximum responsiveness to maximize mitigation efforts. The actors in the domain of satellite-based response, value added resellers and the humanitarian community may improve their mutual coordination and cooperation to allow best use of existing systems and mechanisms and to exploit their synergistic potential to the maximum level possible (Voigt et al, 2007). Such coordination shall address technical and organizational matters, as well as information sharing via a common system.

2.2.2. Product Necessity

In spite of robust developments in the domain of satellite imagery provision towards disaster management (Zhang and Kerle, 2008), it is important to note that no emergency response unit or persons worker can work with raw satellite imagery. It takes a very careful processing, analysis, mapping, and interpretation process by Value Adding Resellers to generate the required situation maps which can be read and understood by non-satellite expert users. This is important in simplifying the map output and incorporating non-experts in decision making and relief coordination. Involvement of users from all walks of life with varying professional backgrounds in participatory disaster damage mapping, input, reporting and field validation is important in enhancing the spirit of collaboration and outreach.

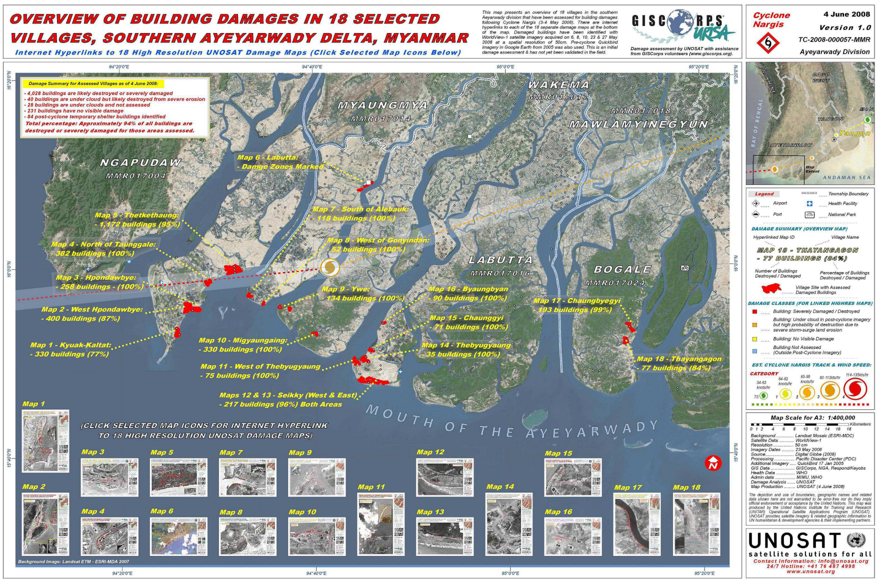


Figure 2. Sample map showing hyperlinked overview of building damages in 18 selected villages, Ayeyarwady Delta, Myanmar (4th June 2008), (Source: UNOSAT)

It is evident that neither sophisticated image analysis and processing nor mapping capacities or geographic information system (GIS) skills alone provide a meaningful disaster related information service to crisis response staff and within operational scenarios (Voigt et al, 2007). Unless it is possible to operate the whole crisis support service cycle, linking EO systems, information extraction, and dissemination without interrupts, space-based disaster response will not have a positive impact on disaster-relief operations (Voigt et al, 2007). There have been drastic changes in quality of analysis and map provision since the inception of the Charter and increase in its activations over time. From the provision of simple maps, for example, its first activation of Floods in North East France in 2001, to increased sophistication of situation and inventory maps within the shortest time in recent years has improved the speed of disaster response. The technical development in disaster maps analysis has increased its reliability and understanding based on its detailed information and high quality cartographic standards. For instance, in the wake of Cyclone Nargis that struck Myanmar in May 2008, Satellite images were produced within hours indicating the path an impact of the cyclone, and within days a range of quality images indicating the extent of standing flood waters and destruction of villages were available.

2.2.3. Recent Developments and On-Going Activities

The Charter can be conceptually embedded in a wider risk reduction and disaster response framework. The Global Earth Observation System of Systems (GEOSS) works with and builds upon existing national, regional, and international systems to provide comprehensive, coordinated Earth observations and vital information for society. GMES as the GEOSS European contributor has been operating and running related services after its inception. The purpose of GEOSS is to achieve comprehensive, coordinated and sustained observations of the Earth system, in order to improve monitoring of the state of the Earth under its nine societal benefit areas (GEOSS, 2005). GEOSS strives to meet the need for timely, quality long-term global information as a basis for sound decision making, and enhances delivery of benefits to society. GEOSS brings efficient dissemination of information through better coordinated systems for monitoring, predicting, risk assessment, early warning, mitigating, and responding to hazards at local, national, regional, and global levels with the use of satellite, *in situ* and ground-based networks.

The GMES concept was initiated in 1998 and endorsed by the EU and European Space Agency (ESA) Councils in 2001 (EU, 2004). GMES seeks to tackle issues related to environment and security with the advanced technical and operational capability offered by terrestrial and space borne observation systems. It is a direct response to the growing concerns amongst policy makers to ensure in a timely manner access to information on the environment at global, regional and locals scales. The GMES under the Living Planet Program has been built under the five phases of the entire ESA sentinel mission, which form part of the GMES Space Component, collect robust, long-term climate-relevant datasets. The Living Planet Programme comprises a science and research element, which includes the Earth Explorer missions, and an Earth Watch element, which is designed to facilitate the delivery of Earth Observation data for use in operational services. It is based on observation data received from Earth Observation satellites and ground based information. These data are coordinated, analysed and prepared for end-users. This is done by RESPOND, a tranche of ESA's GMES Service Element projects with an alliance of European and International organisations working with the humanitarian community to improve access to maps, satellite imagery and geographic information. RESPOND is funded to produce thematic and damage maps on behalf of its consortium to the humanitarian community accessed via a map catalogue and world map interface.

Other organizations, such as United Nations Operational Satellite Applications Programme (UNITAR), UNJLC, *Service Regional de Traitement d'Image et de Teledetection* (SERTIT) and German Aerospace Centre (DLR), Global Map Aid and Map Action amongst others are also involved in disaster mapping, risk reduction, monitoring and emergency response on regional and global scales. The Joint Research Centre (JRC) Support to External Security (SES) in collaboration with UN organizations and service development under GMES, focus on collaborative Geo-information capturing to support emergency response (Lemoine, 2007). It has built a Global Disaster Alert and Coordination System (GDACS) that provides near real-time alerts about natural disasters and tools to facilitate response coordination, map catalogues and with a Virtual On-Site Operations Coordination Centre (Virtual OSOCC). The major technological breakthrough here is the distributed access to geospatial data by analysts with an extensible architecture to interface image processing, visualization with mash up on Google Earth, even though the wider humanitarian organizations on the ground are not involved in map production.

The German Aerospace Center (DLR) has set up a dedicated crosscutting service, Center for satellite-based Crisis Information (ZKI), to facilitate the use of its Earth-observation capacities in the service of national and international response to major disaster situations, humanitarian relief efforts, and civil security issues. It is also tasked with processing of satellite images for disaster response on behalf of the

Charter. The establishment of various international coordination bodies in recent years has improved the disaster response related cooperation within the Earth-observation community worldwide (Voigt et al, 2007). DLR/ZKI operates within this context with a close network with civil security, humanitarian relief organizations, Space Charter, and other space agencies in disaster management arena.

New initiatives and incubator projects are in progress for emergency risk and disaster response in many countries and regions. Major international working project examples include the ORCHESTRA, OASIS and WIN projects which are already reporting results of their research (Herrmann, 2008). ORCESTRA was initiated to meet the current challenges of cross border environmental risks within systems and services. It is part of a milestone achievement towards data harmonization, data models and common systems in disaster response and management. The Wide Information Network (WIN) integrated project that develops an interoperable info-structure as a major element of the future Single European Information Space that concerns Improving Risk Management and the Environment. It tries to connect available technologies and risk management systems by establishing a mechanism to interconnect the different data systems and actors.

The Open architecture for Smart and Interoperable networks in Risk management based on In-situ Sensors (OSIRIS), an Information Society Technology FP6 EU funded project aligned with GMES, cover the monitoring and risk management phases in crisis situations. It provides an intelligent and versatile Sensor Web Enablement (SWE) services architecture that acts as a plug and play of *in-situ* sensors and interoperable networks. It provides Service Oriented Architectures (SOA) based on standards and delivering functions ranging from in-situ observations to end-user services. The Open Advanced System for dISaster and emergency management (OASIS), with an objective of “Improving Risk Management”, part of EU-FP6 project which aims at defining and developing IT framework based on an open and flexible architecture and using standards that forms the basis of a European Disaster and Emergency Management System. Its Tactical Situation Object (TSO) standard has data in coded format that can be exchanged between independent systems delivering and displaying information to end-users in their preferred readable format, language and platform.

ReliefWeb under the UNOCHA umbrella and AlertNet as part of Reuters Foundation also facilitate the exchange of disaster information through news alerts RSS feeds and Humanitarian Profile Maps (HPMs). These profile maps are designed to offer a comprehensive, precise and timely visualization of complex humanitarian situation for a particular area of interest to the humanitarian community, in order to respond to disasters, for informed decision making and provision of valuable information to end-users. They are developed primarily for countries and regions affected by ongoing complex humanitarian emergencies and by a large number of natural disasters in quick succession. These maps include information and data prioritized according to the nature and scale of the situation. These organisations act as a link between the charter and the end-users and therefore help in the transfer of information to emergency personnel on the ground. Such organizational improvements are of greater value than the mere launching of many satellites (Zhang and Kerle, 2008) in space without better coordination on the ground.

2.2.4. Efforts by Industry

There are private companies involved in disaster management and recovery. ImageCat Inc., RapidEye and TerraSAR focus on post disaster response. There exists Public Private Partnership (PPP) between the private sector, UN, Charter and NGOs in disaster response and management. These PPP's are important in bringing in a pool of resources, technology, expertise and combined efforts towards rapid disaster response.

The Virtual Disaster Viewer (VDV) being developed by ImageCat Inc. offers an alternative method of rapid and robust damage assessment, based on expert interpretation of satellite imagery, validated later against field observations. Working within a specially designed online tool developed in MS Virtual Earth, disaster experts are assigned specific areas or tiles of the affected areas to review and provide their assessment by comparing before and after high-resolution satellite images acquired by DigitalGlobe and Geoeye imagery companies. Initial information gathered includes the number and size of damaged structures and the location and scale of humanitarian relief operations.

With limited access to the disaster zone, disaster experts and reconnaissance teams around the World can be able to help in the response, by providing a detailed assessment of the unfolding scene. VDV, once implemented, will help in disaster reconnaissance, providing the global earthquake and humanitarian communities with an assessment of damage and human loss for an event that otherwise may never be well understood. VDV is a prototype project still undergoing testing and implementation phases. This project is of commercial interest and therefore might have limited usefulness in humanitarian efforts.

2.2.5. Gap Analysis

The production of high quality maps with high cartographic standards by different intermediary entities is a good idea only that the optimized print friendly maps do not meet the needs of many end-users. Most of these damage maps are produced on best-effort-basis by response organisations and are typically non-participatory and lack vital feedback from the field (Zhang and Kerle, 2008). An example is the Yogyakarta earthquake aftermath where the Charter was triggered and Quickbird and Ikonos images were available, and a number of maps were produced by various entities. UNOSAT, DLR, IFRC, MapAction and OCHA produced their own maps that suit their needs, leading to duplication and waste of time and resources. The lack of both bottoms-up and top-down approach limits the local expertise involvement and inter-agency collaboration in times of disaster.

It is clear that satellite imagery information alone, without ground information, does not lead to a comprehensive analysis of a given disaster situation. It is fundamental to fuse the satellite based information with additional data to present it in a proper geospatial context (Kapucu, 2008). The most crucial problem is the availability and the access to accurate and upto date disaster maps, especially in remote regions. There is need for an interoperable Spatial Data Infrastructures (SDI) for data access and dissemination in the framework of disaster response. This promising approach implies that different organizations provide and integrate geospatial data via a common web service. Geo Web as a service is fundamental in data sharing and participatory post-disaster damage mapping.

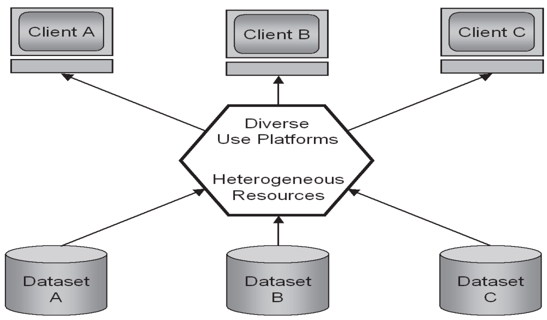


Figure 3. The two diversity challenges faced in the data distribution (Source: Lehto, 2007).

There is no standardized framework for Web-based Collaborative Decision Support Services (WCDSS) amongst stakeholders in the humanitarian continuum, to support information exchange and knowledge, software and model sharing from different organizations on the web (Wang and Cheng, 2006). Lack of sufficient infrastructural resources, technical capacity, Information and Communication Technologies (ICT) and especially internet connectivity in remote areas of developing countries are major stumbling blocks to effective geospatial data sharing and interoperability. Appropriate collaboration tools and products are necessary in realizing effective post-disaster damage mapping.

Today, many developing countries have established and operate a working SDI. However, some countries in Africa and the Asian-Pacific Countries are challenged by technical, financial and legal constraints. Appropriate geospatial data standards, frameworks and policies have not been fully realized especially in metadata, digital rights, and copyright. Hence, there is still a gap in the availability and access to local and regional scale geospatial data for disaster management.

2.2.6. Conflict of Interest

Depending on the stakeholder's perspective, disasters can represent a challenge or an opportunity, leading to a variety of possible competing or conflicting interests. On both the affected and the supporting side of the event there are entities that either have a humanitarian or a commercial motivation. For both fractions responding to an event may be the main mandate, or just one of several challenges requiring resources. Thus while originations such as MapAction may be able to focus their resources on aiding disaster response, for others, such as UNDP, disasters need to be dealt with as an additional challenge to meet development objectives. Also for UNOSAT, primarily associated with post-disaster damage mapping, disaster mapping competes for time needed for many other mapping activities. Disasters, however, can also constitute a source of prestige, be it for different disasters response websites vying to be the main platform, or different UN organizations. For example, within the UN body different entities, such as OOSA, OCHA or UNOSAT, have had disagreement on who should have the right to trigger the Charter.

Of greater concern from a practical disaster response perspective, however, are commercial interests. Disaster response has become an interesting business area where the lines of humanitarian support, research, and commercial interests blur. ImageCat, for example, has effectively partnered with humanitarian and research organizations (e.g. the Multidisciplinary Center for Earthquake Engineering Research, MCEER), and has developed tools that can greatly assist post-disaster damage mapping. However, it fundamentally remains a commercial company, and as such there are limitations in the use of their data or tools, and no permanence can be assumed for any currently available support. These private and commercial companies are also operating with commercial interest and hence we cannot expect effective emergency operations and services from them since they have their own agenda. Competition and funding levels towards data sharing and collaboration within these varying entities is still not feasible especially with stretched resources in parts of commercial entities. Limited resources for private companies make them unreliable when it comes to disasters of high magnitude that requires massive financial and logistical resources in emergency response and recovery operations.

We also see potentially competing interests on the side affected by the disaster. Such events can represent an opportunity to attract relief and reconstruction resources to the area, which are typically somewhat proportional to the scale of the damage. Disaster area feedback is unreliable where end-user and volunteer information from the field might be inaccurate and distorted. It would not be easy to rely on field reporting due to bias or misreporting especially with rival organisations and/or random user generated content. Hence a temptation exists to exaggerate the magnitude of the damage sustained during the event. Since we are proposing a system that integrates feedback and validation from the affected areas, a resulting unreliability must be considered in the setup.

2.3. Standards and Specifications

2.3.1. Product Development

The concept of disaster damage mapping and post disaster recovery is crucial in tackling natural and technological disasters. Despite massive investment, remote sensing provides only a partial solution to this problem, since many attributes, including place names, cannot be seen from space (Goodchild, 2007). Disaster experts, equipped with the means to upload their observations, could provide a very effective contribution to damage mapping. The willingness to do so is clearly there, only that the technology to integrate their inputs is still limited. Missing at this point are the collaborative mechanisms needed to ensure quality, to detect and remove errors, and to build the same level of standards, quality and assurance. Training and follow-up capacity building by provider organisations is important in end-user satisfaction and good use of the products. Expert interpretation and feedback data from the ground should meet the required standard and specifications, hence end-user expertise is mandatory for effective response. Mutual, bilateral and multilateral agreements between stakeholders organisations, the Charter and governments on collaboration issues and organisational provisions for space resource sharing and use of existing resources in important in product development. UNOSAT as the major player in the disaster arena has successfully implemented its training and awareness program resulting in record product visit, publicity and utilization.

2.3.2. ISO/OGC Open Standards

The process of data provision, integration and sharing should conform to International Standardization Organization (ISO) and the Open Geospatial Consortium (OGC) standards and specifications. OGC is an international consortium of more than 300 organizations, including large software companies, governmental bodies, research institutions and universities. OGC is a non-profit organization founded in 1994, an international voluntary consensus standards organization that develops Open Standards for geospatial and location based services. These standards form the base of established projects such as the United Nations Geospatial Information Working Group (UNGIWG) and the EU INSPIRE initiative. INSPIRE, Infrastructure for Spatial Information in Europe, was launched by the European Commission aiming at making available relevant, harmonized and quality geographic information to support formulation, implementation, monitoring and evaluation of community policies with a territorial dimension (Kohler and Wachter, 2006). OGC develops interoperability specifications for the management and processing of spatial data and information. Rapid dissemination and exchange of geo-information in emergency and disaster management for example is taken up in the Critical Infrastructure Protection Initiative (CIPI). Currently, the results of previous as well as present initiatives by OGC and ISO are evaluated and merged to reach added-values. The usage of Geographic Markup Language (GML) and OGC Web Services like Web Map Server and Web Feature Server are some examples (Kohler and Wachter, 2006).

2.3.3. Quality Control and Assurance (QA/QC)

Data quality and control especially in open platforms is a must. It is the prerogative of intermediary agencies and in particular the charter node to regulate the access, editing and integration of the dataset via a common protocol. Access logs for local and thematic experts are important in product monitoring and surveillance. Appropriate metadata catalogues should conform to International Standardization organisation/Open Geospatial Consortium (ISO/OGC) standards and specifications. A lot has been said regarding creation of global institutes of global geographical data quality control, and indeed Value Adding Resellers (VAR's) should play a leading role in data quality and accuracy assessments. Experts and non-expert stakeholders should have regulated access and editing so as to keep track and source of information especially to User Generated Content (UGC) of damage buildings and other features in the disaster region. UGC can have user centric metadata. Access control is important in disaster damage mapping by enforcing restricted access to data or to declare views on the relevant data for certain users (Herrmann, 2008). The intermediary regulatory agency should devise a mechanism to control the quality of its web service entries by sticking to OGC/ISO standards and end-user regulated access. An interoperable language is needed to declare policies for operations on Web Services used, containing rules that define which data can be accessed by a person through a given condition.

Geospatial Digital Rights Management (GeoDRM) should be part of the collaborative quality control mechanism in post disaster damage mapping. GeoDRM is a conceptual framework, an array of standards, and software tools for guarding the rights of both producers and consumers of geospatial data and services (Lieberman 2006). It addresses a variety of ad hoc approaches which currently exist for defining the exchange of value occurring between any users and providers of geospatial content and services, whether open or proprietary. One of the most important use cases involves assuring that free and open data in fact remain unencumbered. OGC GeoDRM initiatives have been working at an open standard framework and testing open-source tools for "DRM-enabling" Open Web Services (OWS). These initiatives should focus on protecting the rights of users and providers of disaster information and other service interactions.

2.4. The Need for a Real Time Collaborative System

2.4.1. Emerging Interoperable Geo Web Services

Geo Web Services are Web Services with a spatial component and with loosely-coupled functions that can be executed remotely via the internet. These services carry out geo-processing, acquisition, visualization and delivery tasks with seamless access and transfer of information via computer networks. It can be used to perform real-time geo-processing in several computers where GIS functionalities are located and feedback the results of applications to the client. Interoperability can be achieved by overcoming integrating, the syntactic, structural, and semantic levels

(Schmitz and Visser, 2002). Geo Web as a service has widespread distributed access, interoperability using standards and open Application Programming Interface (API) and has reliability and scalability through hosting on a strong IT platform (Maguire, 2006). In case of a disaster, the fast interoperable and secure exchange of spatial data is one of the key elements to quick disaster response. Geo Web presents a visual medium and geospatial platform for data self-organization, discovery and use. Capabilities that allow every Internet user to post to the flow of information and anyone to poll or pull the information It requires standardized data models, procedures for interoperability, standard and shared applications based on a spirit of collaboration.

Geo-information technologies are emerging as fundamental tools for post-disaster damage evaluation. The development from monolithic to distributed GIS architectures has revolutionalized seamless data access and transfer across networks. It is now possible to integrate spatial information from different geoprocessing systems and also integrate spatial information into non-spatial information systems. Such Service Oriented Architectures (SOA) have well defined interfaces that interact with other loosely-coupled network software applications. They fully encapsulate their own functionalities and makes it accessible only via well specified and standardized interfaces (Kobben, 2008). This is achieved by encoded data in a standardized, platform and application independent manner by use of encoding schemes and generic web service standards such as the eXtensible Markup Language (XML), Web Service Description Language (WSDL) and Simple Object Access Protocol (SOAP) utilized to deploy geographic web services.

There exist a range of proprietary Geo Web services in the market with interfaces open to the public. They include Google Earth/Maps, NASA Worldwind, Yahoo Maps and Microsoft Virtual Earth/MultiMap. Geobrowsers are both 3D and 2D, where 3D globes are a three dimensional interactive virtual globe that displays the Earth through a combination of different layers of information. Non-proprietary Open Standards have also been developed in an open and participatory process where interested persons influence the standards. These specifications are owned in common thus having open access to interface specifications. An example of Open Standards for Geo Web services is the Open Web Services (OWS) of the Open Geospatial Consortium (OGC).

2.4.1.1. Distributed Processing

Geo Web Services are web accessible applications and application components that exchange data, share tasks, and automate processes over the Internet. Because they are based on simple and non-proprietary standards, Web Services make it possible for distributed servers to communicate directly with one another and exchange data regardless of location, processing platforms, operating systems, or languages. Web Services lower the costs of software integration and data- sharing. The Web Services standards infrastructures greatly extend users' access to geoprocessing resources. Dangermond argues that evolution of technological paradigms has resulted in a vision for sharing and directly using distributed geographic information services (Dangermond, 2001). It is an open, collaborative, and multi-participant system that lets users publish, share, and use each other's services. Key distributed subsystems include a metadata catalogue service, distributed GIS data and application services, and GIS clients that directly use these services.

2.4.1.2. Interoperable Web Services

Geo Web offers an opportunity to overcome technical non-interoperability because it is an almost universal platform for distributed computing, with a web services architecture that is designed for integration of diverse information systems. The Web offers an opportunity to overcome semantic non-interoperability because it provides unique facilities for semantic processing of structured text (Doyle and Reed, 2007). By enabling interoperability, the web greatly increases access to spatial data and processing resources, and thus greatly increases the value of those resources.

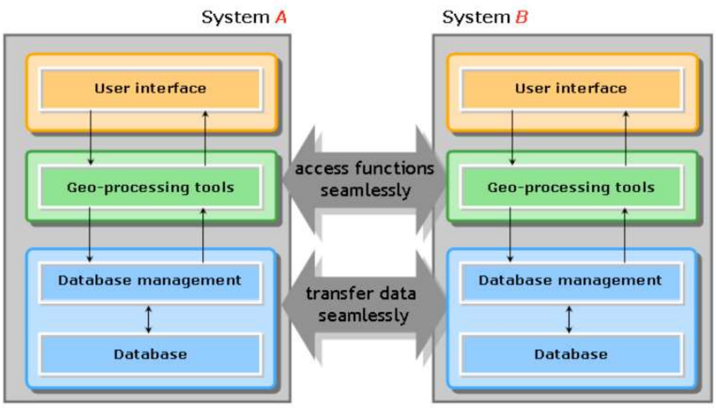


Figure 4. Interoperable Geographic Information Systems (Source: (Kobben, 2008)

Geo Web services are able to present disaster information in real time enhancing rapid decision process. Heterogeneous stakeholders should have authorised access to the datasets in order to expand the value of spatial data and processing resources. The Geo Web has become an important element of workflow in many geospatial applications which is fundamental for web-mediated disaster activities.

It is vital to tackle Ontologies in order to realise discovery and integration of disaster geo-information. Ontology is formal representation of a set of domain concepts, rules and their relationships, a prerequisite in disaster management (Xu and Zlatanova, 2007). On the other hand, interoperability can not be achieved without a well established Spatial Data Infrastructure (SDI).

2.4.1.3. Spatial Data Infrastructure (SDI)

Disaster management is one of the most important fields that depend on a working Spatial Data Infrastructure (SDI) as it constitutes a sustainable platform for the establishment of a comprehensive information infrastructure (Kohler and Wachter, 2006). The SDI denotes the relevant base collection of technologies, policies and institutional arrangements that facilitate the availability of and access to spatial data (Nebert, 2008). Development of a working SDI in the dissemination of rapid mapping products is critical where satellite based disaster relief efforts rely on inter-organizational collaboration. The European Initiative in GMES provides an important frame in this context.

There should be a clearinghouse that facilitates an ad hoc integration of diverse, available dataset after a disaster. Clearinghouse provides registry services with a description of each of the formally contributed components of the entire system, metadata about the various data and information holdings in each of the contributed components, technical specifications for using the services exposed by the contributed components, and descriptions of key interoperability standards in use across the contributed components of the architecture.

Developing an information infrastructure for disaster management in general contribute to, the implementation of a spatial data infrastructure. Context-aware SDI is technically feasible in the field of disaster management and beyond, with joint software architectures using standard elements with precisely specified interactions and interfaces on the technological level. The SDI provides a basis for spatial data access, discovery, evaluation, and application sharing for heterogeneous users and providers within all levels. The success of Charter activities will depend on the willingness to adopt a common SDI or data sharing policy.

Table 2. Requirements for a Spatial Data Infrastructure (SDI) in Disaster Management (DM) and its consequences (Source: Modified from Herrmann, 2008)

Requirements	**Consequences**
Up-to-date data	Decentralized data management
Location independent, reliable and fast accessibility of data and services	Geo Web Services have come into operation
Interoperability of data and services	Standards have to be used (e.g. OGC, ISO, W3C or OASIS)
Availability of Metadata (e.g. SRS date, QoS and ontology)	ISO/TC 211, OWL etc
Publish-find-bind paradigms for data and services	Catalogue services
Integration and linking-up of existing systems and infrastructure	Use of standards and deployment of a security framework
Secured Access Control (ACL) to data and services	Need for authentification, encryption, and authorisation

2.4.2. Collaborative Place Names and Description

Apart from image analysis, emerging web services for generation of comprehensive and easy-to-use map products can be used to display damaged infrastructures in the field by disaster experts and GI volunteers. Reference data sets such as place names, road network, rivers, critical infrastructure, and topographic information can be captured by use of these new interoperable web 2.0 User Generated Content (UGC) like geotags, Flickr, GeoRSS and GeoWIKI.

Geo-tagging is the process of adding geographical identification metadata to various open layers in a form of geospatial metadata. These data usually consists of latitude and longitude coordinates, though it can also include altitude, bearing, accuracy data, and place names. Geotagging can help users find a wide variety of location-specific information. With improvement in data sources integrity, it is now possible to log activities according to time and location on mapping applications with GPS coded phones and cameras via satcom and location-aware web links like Flickr. Geotagging-enabled information services can also potentially be used to find location-based disaster damaged infrastructure.

GeoRSS is an emerging standard for encoding location as part of an RSS feed. In GeoRSS, location content consists of geographical points, lines, and polygons of interest and related feature descriptions. GeoRSS feeds are designed to be consumed by geographic software such as map generators. By building these encodings on a common information model, the GeoRSS collaboration hopes to promote interoperability and compatibility web services across disaster domain.

Flickr organize images using tags (a form of metadata), which allow searchers to find images concerning a certain topic such as place name or subject matter. Flickr was also an early website to implement tag clouds, which provide access to images tagged with the most popular keywords. Flickr offers a fairly comprehensive web-service API that allows programmers to create applications that can perform almost any mapping function, and indeed disaster damage maps. Flickr registers photographs and links to source and person who provided the photograph. Humanitarian experts can take photographs of damaged infrastructure and tags it to the disaster mapping system.

GeoWIKI is essentially a means of many people contributing to the development of a large database (crowd-sourcing). A number of databases are being developed using a Google Earth based GeoWIKI and which, after quality control, will be used to answer some important environmental questions and will also be made available for download in common GIS formats. It is designed to enable anyone who accesses it to contribute or modify content, using a simplified mark-up language. Wikis are often used to create collaborative websites and to power community websites to which the proposed collaboration disaster mapping system should incorporate.

2.5. Concept of GeoWeb Services in Disaster Management

2.5.1. Geo Web Service Architectures

Information systems used in the field of disaster management are often not as open and extensive as needed to consolidate the complex data sets and the different systems for solving tasks and questions based on complex workflows and scenarios. There is currently no singly accepted architectural model for web services as a whole, a number of groups (W3C Architecture Working Group) have already begun work on defining how web services will be used with their products. Interoperability as well as application-oriented integration of methods, data and systems must be improved. This could be realized by designing distributed software architectures, which enable and support flexible and interoperable keeping, integration and networking (Kohler and Wachter, 2006).

The wide diversity and essential independence of component systems calls for a particular style of systems architecture, which is a style that emphasizes interoperability. Systems are interoperable when their differences are not a barrier to accomplishing a task that spans those systems. Interoperability allows systems to interoperate even though they are developed and operated independently (Christian, 2008). The success in disaster response will depend on data and information providers accepting and implementing a set of interoperability arrangements, including technical specifications for collecting, processing, storing, and disseminating shared data, metadata, and products.

2.5.2. Web Service Interoperability Stack

GIS has been recently influenced to a large extent by internet developments, resulting in an increasing availability of client/server applications using distributed Geo Web services. Web services are software systems that provide specific functionality to a group of clients over a computer network (Lemmens, 2008). Usually open Web Service standards and specifications are used to connect these products in an SOA stack. A methodology should be built to verify the interoperability of the various products in a SOA stack. The development of an Interoperability framework within the disaster domain will underpin the provision of integrated services by articulating a set of agreed policies and standards to allow electronic information and transactions to operate seamlessly across collaborating organizations.

2.6. Conclusion and Chapter Summary

In conclusion, networks and institutions such as the Charter, VAAs and humanitarian organizations lack collaboration. Geo Web Services provide the possibility to merge experts and users to handle and solve complex disaster challenges. The integration of users and organizations must be fostered by developing real time and collaborative methods, information products and applications for disaster management. This chapter looked into disaster response, standards and concept of Geo Web services in rapid mapping and response. The next chapter entails materials and methods employed in the research.

3. Materials and Methods

3.1. Scope

The project focuses on the major intermediary organisations, their operations and technological development. It narrows down to UNOSAT as an example of the intermediary organisations tasked with disaster damage map analysis, distribution and archival. The process involves assessing the various maps and image derived information format produced by UNOSAT and their limitations with respect to what current geoinformatics, and in particular web mapping, technologies can provide. The project evaluates if the infrastructural and technological capabilities are appropriate for a collaborative framework based on Geo Web services. A prove-of-concept running is set up as a demonstration using open source software and the Yogyakarta earthquake, Indonesia dataset of May 2006. ASTER pre-event imagery and post-event Quickbird and Ikonos images were available after the event and damage maps were produced.

3.2. Data Collection

The data was collected from the available literature sources of the Space Charter, UNOSAT, various intermediary agencies and OGC web service implementation and open standards specification documents. There was review of related work done by the JRC's GDACS on collaborative geo-information capturing for emergency response amongst others. More information and data was collected at UNOSAT in Geneva, a comprehensive field work plan involving interviews and use questionnaires.

3.2.1. Stakeholders

There exist a range of multinational and regional disaster response agencies from humanitarian community to the United Nations, private and NGO's working in joint disaster response projects. For example, UNOSAT works in partnership with relevant operational entities including United Nations Disaster Assessment and Coordination (UNDAC), Sertit, GDACS/Virtual OSSOC, Inter-Agency Standing Committee (IASC) members and NGOs such as CartONG, MapAction, Telecom Sans Frontiers, Space Charter and ESA's RESPOND initiative as summarised in Table 3.

Table 3. Major Stakeholders (UNOSAT, 2008)

Data Providers (VARs/VAAs) and Allied Agencies	**Collaboration and Project Partners**	**Humanitarian/Relief Organisations**
• RESPOND • UNOSAT • Sertit • JRC/SES • GMES-GDACS/ Virtual OSSOC • DLR-ZKI	• GIScorps • South West Response Team (SWRT) • UNJLC • CERN • UNDAC • CartONG • MapAction	• UN-OCHA Reliefweb • AlertNet • UNDP • UN-ISDR • Telecom Sans Frontiers • IASC Members

3.2.2. Data Dissemination

The data products are disseminated to end end-users in the following formats:

- ***Paper prints and posters:*** UNOSAT has a long history since its operation by sending paper prints and posters to the end-users using normal logistical shipping companies. A case in point is the delay of delivery of post-disaster damage maps which took more than seven days to reach Indonesia after the tsunami disaster in 2004. Logistic and shipping companies were affected to by the tragedy and hence its operations curtailed.
- ***Digital Distribution (ftp):*** With proper bandwidth and well endowed ICT infrastructure, end-users can get maps via File Transfer Protocol (ftp).
- ***RSS feeds (automatic ReliefWeb/AlertNet news alert):*** Web Syndication and the emergence of RSS/GeoRSS feeds is important in news alerts and dissemination of information over linked websites. It is a form of syndication in which a website recently added material is made available as a summary to other sites with links to the main material. Major information from AlertNet, IRIN and ReliefWeb humanitarian news and information is reflected in the UNOSAT website.
- ***Internet/Intranet sites (pdf):*** This is the most common mode of data transfer by UNOSAT and allied organisations like RESPOND. Analysed maps are posted to the UNOSAT website for end-users to view and download at their on volition.

- ***Vector- shared WFS/WMS***: This works well with collaborative projects, for example the Myanmar cyclone Nargis project with South West Response Team (SWRT). The project aimed to provide geospatial information to support relief and support of recovery operations within the Cyclone Nargis disaster areas of Myanmar Delta region by conducting pre-event land tenure mapping of rice paddy features throughout the disaster zone.
- ***UNOSAT Online*** (under construction): Plans are underway to set up OGC Web services using ESRI ArcIMS. The project in itself is in the take off stage and its future operation is still at stake.

3.2.3. Online Mapping Tools

The online mapping tool is under construction and will be built on ArcIMS and OGC WMS &WFS platform. Plans are underway to use Google map maker/Google earth in conjunction with GDACS whenever necessary. To be adopted soon is the use of a GPS coded camera that triggers a point in a disaster area and the point reflected on the central server via satcom.

3.3. Developing the Web Service Architecture

The Web Services Architecture describes the principles behind the proposed disaster management system. These are loosely connected information models based on the standard web architecture that enables geodata to be found and published and the servers that host data and process client requests. Web Services reflect a new Service Oriented Architectural (SOA) approach, based on the notion of building applications by discovering and orchestration of available network services. Web Services involve design of the capabilities of network services to perform a function and describe the orchestration of the collaborators. The architecture is tailored to meet eexpectations from disaster management communities that data can be accessed readily and incorporated into their applications with the minimum of fuss (ORCHESTRA, 2008).

3.3.1. Web Service Components

The main components of the web service architecture (Tartanoglu, 2007) are:

- ***Simple Object Access Protocol (SOAP)****:* Lightweight protocol for exchanging structured information in a decentralized, distributed environment. It is the software "envelope" to which messages are sent, defines a message structure, which determines the way requests and responses are encoded.

- ***Web Services Description Language (WSDL):*** A specification to create descriptions and capabilities of web services.
- ***Universal Description, Discovery and Integration (UDDI):*** Technical foundation for publication and discovery of web services implementations. It is a registry of services available.

These are XML-based specifications and are the building blocks for service trading. XML is encoding of data and descriptions of services which operate on the content.

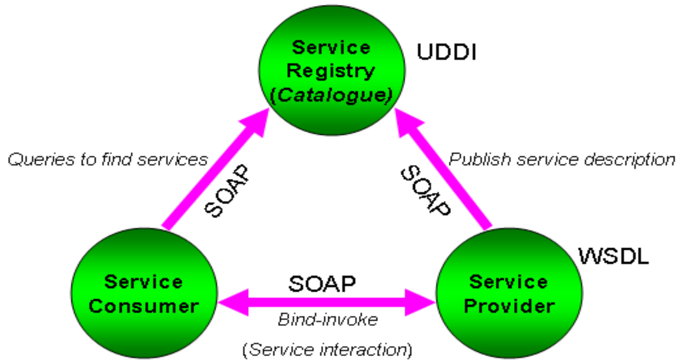


Figure 5. Web Service Components (Publish-find-bind paradigm)

3.3.2. Thin and Thick Client-Server Architectures

A thin client is a web based application where processing is done on the server. Thin client-server architecture gives the client limited applications by having processing capabilities residing in the server. The client can only access and view the data. Thick client is installed into the client side, connected to the server and most of the processing is done on client side. For the thick client architecture the client device is embedded with geo-processing applications for data processing.

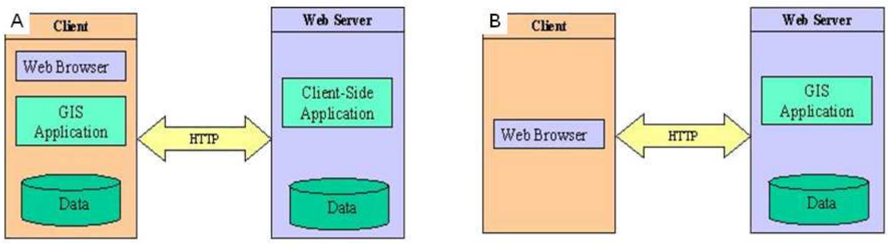


Figure 6 a) Thick client architecture, b) Thin client architecture

The proposed architecture will be of both thin and thick client-server where different end-users have varying privileges and access levels to the dataset. The advantages of thin client over thick client server is that less bandwidth is needed for data transfer and less processing power of client devices especially in disaster regions where internet connectivity is limited, hence no dedicated GIS software has to be bought.

3.4. OGC Web Services

3.4.1. Open Web Services (OWS)

The Open Geospatial Consortium (OGC) design, develop and maintain the technical architecture of Open Web Services (OWS). Web Services are self-contained, modular applications that can be described, published, located, and invoked over a web network environment. The Web Services architecture is the logical evolution of object-oriented analysis and design, and the logical evolution of components geared towards the architecture, design and implementation. Both approaches have been proven in dealing with the complexity of large systems. As in object-oriented systems, some of the fundamental concepts in Web Services are encapsulation, message passing, dynamic binding, and service description and querying.

3.4.2. OGC Specifications

Web Map Service (WMS): Interface that supports the creation and display of geo-referenced map-like views of data that come simultaneously from multiple remote and heterogeneous sources. It is cascadable and can act as a gateway to other WMS services. The WMS specification defines three operations: GetMap, GetCapabilities and GetFeatureInfo.

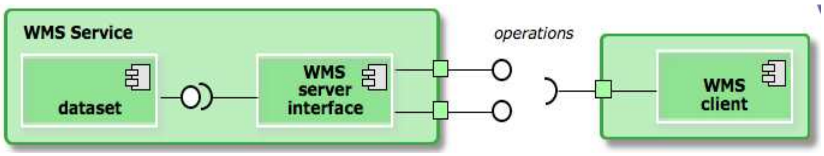


Figure 7. Web Map Service interface

Web Feature Service (WFS): Interface that supports query level access to vector data repositories.
Web Coverage Service (WCS): Supports networked interchange of geospatial coverages (raster) containing values and properties of location.

Styled Layer Descriptor (SLD): Extends the WMS specification to allow user-defined symbolization of feature data.
Catalog Web Services (CWS): Enables diverse but conformant applications to perform discovery, browse and query operations against distributed heterogeneous catalog services.
Simple Feature Specification (SFS): Provide for publishing, storage, access and simple operations on simple features.
Geography Markup Language (GML): Encoding for the transport and storage of spatial data (vector).
Web Processing Services (WPS): WPS makes it possible to publish, find, and bind to processes in a standardized and interoperable fashion.

3.5. Present Architecture

In the current architecture, each disaster map provider has setup a website in which end-users can view and download their data and information in pdf format, resulting in static redundant map copies that become quickly outdated. This shows that there is great demand for distributing real-time dynamic disaster information to heterogeneous end-users.

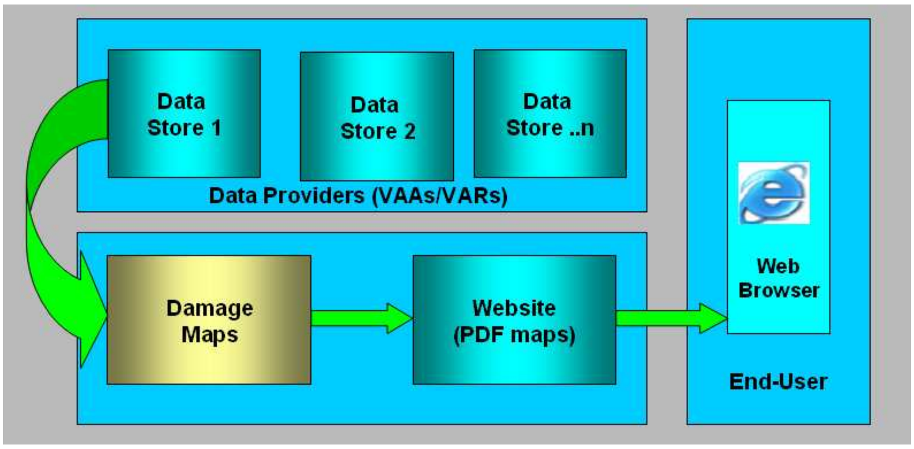


Figure 8. Present architecture where PDF maps are downloaded by end-users.

3.6. Extended Architectural Structure

For disaster geocollaboration, the architecture has to cope with web service specification, OGC specifications, and their dynamic integration. It serves as a collaborative Web-based Spatial Decision Support System (WebSDSS) architecture (Lei and Qiuming, 2006). The architecture involves decoupling the traditional architecture into three components: data layer, middleware and presentation layer. A presentation layer is responsible for the end-user interaction and the visualization within the thin-thick client (machine is embedded with geo-processing applications) environment (Beliën, 2005).

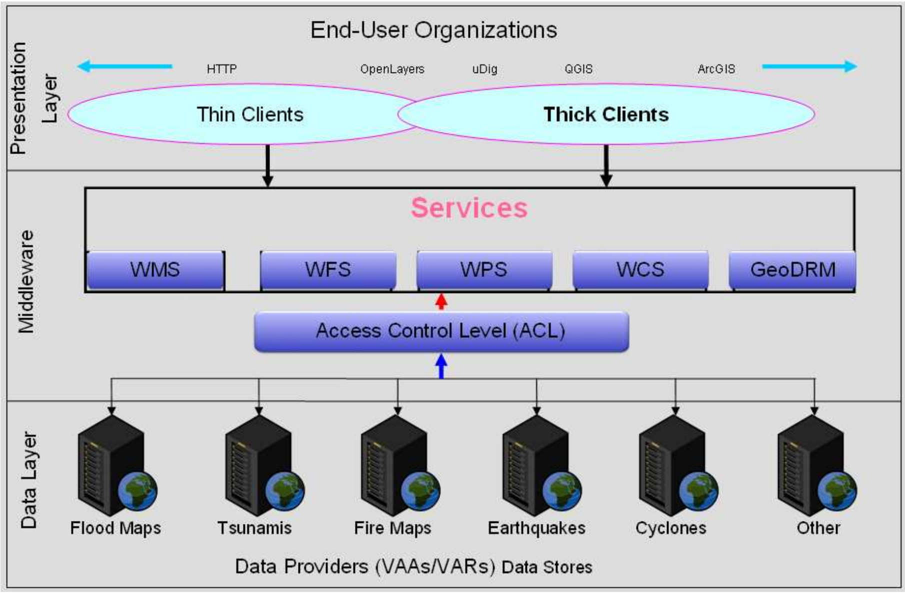


Figure 9. Generic schema of an extended geo web service architecture

From the 3-tier extended architecture shown in figure 9, a framework for a dynamic and adaptable extended architecture with manifold software infrastructure for disaster management agencies, stakeholders and distributed end-users is proposed. Such a framework will allow a flexible and problem-oriented integration of different services and applications supporting interoperability among them (Radetzki et al, 2002). Different user profiles should have appropriate access rights and privileges on the datasets.

3.6.1. Authorisation Service (Access Control Level)

An authorization service uses Access Control Levels (ACL) created in authentication services to manage permissions. Permissions are subject to the level of access rights and privileges of heterogeneous disaster damage mapping organizations and their relationship with the Charter and in particular the host organisation. Whether these permissions are directly bound to administrator or indirectly via additional associations like administrator-role and role-permission depends on the implementation of the authorisation service. Access control regulates conditions under which specific individual carry out the read, write and edit of the data (Herrmann, 2008). Independent from the way permissions and principals are related, an authorisation service is able to retrieve the permissions for a given end-user.

Data access and security is vital and reliable and secure Authentication Service should be established. The access levels will fall in 3 tiers conformal to ISO-3 tier model. A service will check whether some given session information is genuine and with limits. A trustworthy authentification mechanism should be put in place to curb data misuse. In the above architecture, security can be ensured between the services and the clients by establishing HTTPS and/or Secured Socket Layers (SSL). Thin clients access using web-browser while thick clients access via Simple Object Access Protocol (SOAP) over HTTP and/or a proprietary binary protocol over standard TCP/IP.

3.6.2. Service Tiers

The access levels are characterized as part of a service layer. The top tier is the one which users deal directly. It provides the interfaces to describe and use the services offered. The middle tier embodies all the geo-processing processes required to respond to requests issued by users. The services in general embody everything from authentication to complex geoprocessing on sets of data from various repositories and from generation of map views that the client gets back at the end of the process.
The lower tier provides read and write access to data, whether its geospatial data or catalogue entries stored in any of the different types of registries. The three layers are conceptual constructs that logically separate the functionality of the architecture; presentation, application logic and resource management layers.

3.7. Proof of Concept

The proliferation of location-aware end-user applications is increasing the demand for web service-based delivery of geospatial content (Lehto, 2007). The main goal of this prototype is to prove the technical concepts of a system that:

- Can provide on-line synchronized access to various map data and integrate heterogeneous disaster information sources,

- Contains customized map presentation forms and access options,
- Acts as a collaborative platform for post-disaster damage mapping,
- Uses open interfaces and standards that conform to OGC/ISO specifications.

3.7.1. Functional Requirements

User requirements are functions and capabilities that are available to end-users and the services the system is expected to provide and the constraints under which it must operate. Functional requirements capture the intended behaviour of the system, expressed as services, tasks or functions the system is required to perform. System requirements set out the systems functions, services and operational constraints in detail. System requirements are more detailed specification of the user requirements. The fundamental element of the architecture is the mapping component, which produces and delivers customized disaster maps. The mapping component has to be able to access different data services. Since disaster management if faced with geographical location, language and place names challenges, a multi-lingual option is appropriate. The system should be designed largely to accommodate diversity, end-user heterogeneity and language barriers.

3.7.2. System Requirements

a) A system running on a web server: There are many web servers available in the market, this project uses UMN Mapserver developed by University of Minnesota. MapServer is an Open Source (OS) platform for publishing spatial data and interactive mapping applications to the web (http://mapserver.org/). It is a development environment for building spatially enabled rich internet applications (RIAs). It acts as a map engine to serve maps and end-users can be able to explore geospatial data. It supports WMS, WFS and other OGC standards.
b) OpenLayers (OL): Open Source JavaScript map viewing library used to display map tiles and markers from any sources into web portal application (http://openlayers.org). It implements industry-standard methods for geospatial data access. It allows the use of many layers in the same client, coming from different sources such as WMS, NASA Worldwind and commercial API's like MultiMap, Google Maps and yahoo maps.
c) Firebug (for Firefox): Firebug integrates with Firefox as a web development tool to edit, debug, monitor and profile JavaScript in a webpage. It measures performance, finds errors and bottlenecks in a sluggish code.

d) ArcGIS: ESRI ArcMAP provides options to access WMS with clients which allow viewing and combining of WMS together with local data (Shapefiles) and related proprietary ArcIMS services.
e) uDig: Is an Open Source, java-based stand-alone GIS client. It is used to connect to file-based geodata and OS WMS/WFS-compliant server.

3.7.3. Materials

Feasibility analysis and project plan settled on the following materials from the Yogyakarta earthquake May 2006, Indonesia pre and post earthquake event:

- Pre-disaster ASTER imagery
- Post-disaster Quickbird imagery
- Post disaster IKONOS mosaic
- Damage areas vector (shapefiles from UNOSAT)
- Road layers (shapefiles)
- Background world map - www3.demis.nl is a publicly available global online map developed by DEMIS, a Dutch consortium organisation. Other global 2D maps are available both non-proprietary OCG compliant and proprietary such as google maps and yahoo maps.

3.7.4. Prototype Set-up

This prototype is built using the available Free and Open Source Solutions for Geospatial (or FOSS4G) software stack at ITC. The UMN Mapserver (http://mapserver.org) is used to create a WMS and WFS using OGC OWS standards and specifications to post geospatial data on the web and testing the relevant requests from the server and client sides. The client is developed using the OpenLayers (OL) API (http://openlayers.org). OpenLayers was used to build a simple mapping client in a web page to enable spatial querying and interrogation of Yogyakarta earthquake May 2006, Indonesia dataset with the web solution running on OpenLayers Java Script library. The server side scripting was done using Active Server Pages (ASP) for form querying and string requests.

The following factors where put into consideration before setting up the prototype:

- Identify the types of data and data products that must be ingested and accessed by the proposed system.
- Identify the types of data standards, format and information products to be supported and served by the proposed system.

- Identify the authorisation and access levels of the data and GeoDRM specifications that must be supported.

3.7.5. Use Cases

A series of use case scenarios are developed as part of the incubator test-bed project to test real scenarios of a collaborative disaster mapping system. Each use case focuses on describing how to achieve a task in the architecture to define the capabilities of the system. In order to demonstrate the feasibility of the proposed extended architecture, some use cases are developed during the incubation stage of the project. These use case scenarios outline possible applications that can be developed in order to achieve real time disaster map dissemination and feedback to and from heterogeneous end-users.

Scenario 1

In the first scenario, end-users of post-disaster maps from the disaster region have the possibility to spatially annotate these maps. Using a simple thin client (running a standard web browser), they can add notes or remarks that are geo-tagged, i.e. linked to a fixed point in the map. These spatial annotations are made available in the web portal (see the red arrows in figure 10), and therefore can be viewed by others users. They could also be used by the mapping agency to further approve their maps (see the blue arrows). Likewise, the agency can use these annotations to actively seek help, for instance by posing questions such as "„*is this building damaged?"* or *"„is this road/bridge passable?"*. The content of the spatial annotations is not limited to text, as we can employ links to existing photo-sharing services (such as Flickr or Panoramio) or even to other Geo Web Services (such as Google Maps).

Requirements:

- Use independent open application protocols and solutions.
- The users should be able to switch on and off unwanted layers of information.
- The user generated content should not clutter/populate the services

Scenario 2

For the second scenario, there is a limited user group, such as the major stakeholders and close collaborators that are asked to actively collaborate on the production of post-disaster damage maps. These users would have access the dataset via thick client, such as proprietary ArcGIS system and/or non-proprietary software like QGIS, uDig and would use that to help with data processing, for example delineation of damaged areas. The expert user in this case has full geoprocessing capabilities and can help with data processing, for example delineation of flooded areas, provide GCP's, digitize damaged features or even upload GPS data via a portable device like a PDA. These inputs are used to process the data for the final damage maps, hence a secure authentification, access and data validation mechanism should be available. At the same time, end-users should be able integrate and customize this dataset with their own dataset and produce their own custom maps.

Requirements:

- The existing heterogeneous systems should be interoperable.
- It should be bi-directional.
- End-user client machine should have geoprocessing capabilities

3.7.6. Proposed Prototype Architecture

The first step is developing a prototype that focuses on the concepts of distributed services. The main goal is to design and demonstrate an open service-oriented software architecture, which improves the interoperability among actors involved in post-disaster damage mapping. An interoperability arrangement includes technical specifications for collecting, processing, storing, and disseminating shared data and metadata products.

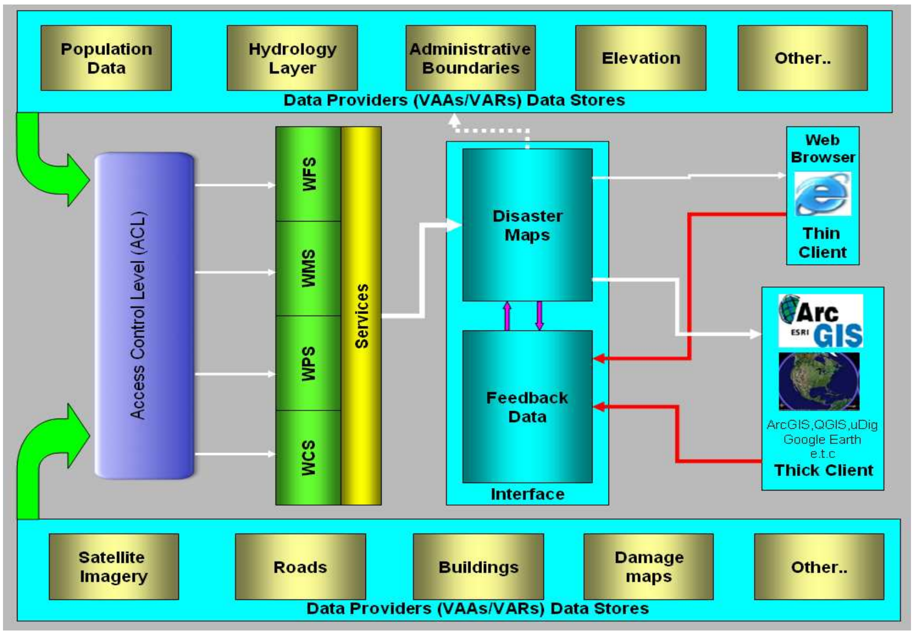


Figure 10: Example of the proposed prototype architecture where end users access the data as web services via thin and thick client.

A mechanism is needed that makes it possible to discover the available web services since the proposed architecture distributes components over heterogeneous locations. The architecture can be extended with a catalogue provider that registers all available data services using Universal Description, Discovery and Integration (UDDI). The catalogue provider tells service consumers that there is a map service available at a certain URL and that this service can process certain requests.

As a proof of concept for the use of open standards for end-user access to disaster maps, a prototype project based on appropriate service specifications is set up. The aim is to connect to different servers hosted by valued adding resellers and combine output of these servers in the distributed client machines via a browser or geo-processing software. For this reason, the proposal is to develop bi-directional web enabled services as seen in figure 10. An interface will be created to display the user profiles in order to be aware of the requirements of a remotely located end-user. The service has to be configured for any newly registered end-user. The architecture supports editing, customization and integration with thick client, a system embedded with geo-processing applications for data processing.

3.8. Conclusion and Chapter Summary

This chapter looked into the methodology for developing a web service architecture for disaster management and a proof-of-concept. A comprehensive analysis of information from the field (UNOSAT) and relevant material on web services, web service components, use case scenarios, functional requirements and the prototype of the proposed architecture. Major explanations and analysis of the various components and levels of the proposed architecture are reviewed: tiers, Access Control Levels (ACL), data access and security. The next chapter looks at the results from this developed prototype and the adopted methodology.

4. Results and Analysis

4.1. Introduction

The dramatic change in emerging web services has led to development of more flexible and adaptable geo-information architectures which cannot be fulfilled by monolithic and closed systems (Foerster et al, 2008). In the disaster management arena, new emergency strategies may be developed depending on the type of disaster and may result in changes in web service requirements. Thus, the architecture should always be flexible to accommodate new changes and also vary the interactions dynamically. This chapter looks into the results of the prototype, proof-of-concept output and an analysis of the proposed disaster management system. The product output is a bi-directional collaborative mapping system which can be tailored to support a specific disaster type at a time. The system is open and interoperable and any interested intermediary agency can customize it to suits its operations or use it the way it is. Therefore, once a disaster is triggered, the system has to be configured for any newly introduced user group who are going to participate in the mapping process.

4.2. Results and Findings

The results show the outcome of the two use case scenarios developed in chapter three and the proof-of-concept output. Below are working examples and snapshots of the tested and fully executed use cases. The designed prototype is deployed to a large extent on OpenLayers open source software and Geoserver running at ITC and results linked to external domains. From the results, MapServer provides a clear design by use of datastores to integrate existing Rich Internet Applications (RIAs) for disaster damage mapping. The date and time element has been incorporated in the system, showing exact date and time when information was captured at server and client sides to accommodate geographic location time differences of the end-users. The original architecture of having the PDF maps has not been shelved since they do target some end-users, therefore, the PDF option is still available.

4.2.1. Use Cases

Scenario 1: According to the functional requirements elicited in chapter three, the results show that end-users can access the dataset via a web interface (thin client) application and post comments on the situation of infrastructural features in the disaster region. Anybody can point on a collapsed feature and send comments or give a link to and uploaded image in Flickr, a Flickr API can be created (see pink arrow, figure 11) to enable feedback data be uploaded and seen by all users. The X and Y coordinates enable geotags of location specific image information where end-user tag location aware information. Use of location aware PDAs, iphones or digital cameras works best with this geotags option. These spatial annotations are made available in the web portal and therefore can be viewed by other users. They could also be used by the implementing agency to prove their maps, the agency can solicit response by posting a question seeking information on a particular disaster region. End-users can report an incident by filling a form, for instance is a road is passable or not, flooded or destroyed and the extent of the damage. The WMS handles the user-specific annotations and geotags for the damage information, thus increasing the degree of interoperability and make use of remote services.

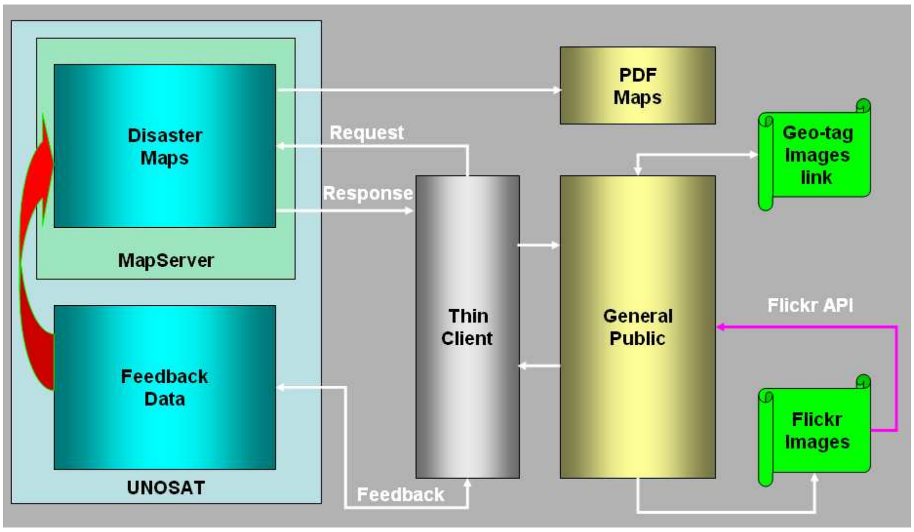


Figure 11: A diagram showing the general public accessing the dataset and provide feedback via a thin client.

From figure 11, the general public can be able to visualize the photographs, this is achieved by making use an API to provide a link to the photos available on the Flickr services. An input table was developed to link public tagged photos to Flickr site as part of end-user feedback of damaged infrastructure. The same application can be extended to include other publicly available sites such as Panoramio and also google earth and related independent geobrowsers.

Scenario 2: The major agencies involved in the project can have full access and geoprocessing privileges via interoperable WMS clients (thick client) such as proprietary ArcGIS desktop, or by consuming WMS/WFS in open source and interoperable clients such as Quantum GIS and uDig, where one can contribute in real-time input mapping. The disaster expert access data via an authentification mechanism and able to process and create damage features and feedback through a data upload web page to a database (DB) in the server as shown in figure 12. The secure access and upload is important for data security and quality control, only the required experts from the participating agencies should access full dataset and have full privileges to process the data for the final map and at the same time be able to integrate this dataset with their own to come create custom maps that suit their needs.

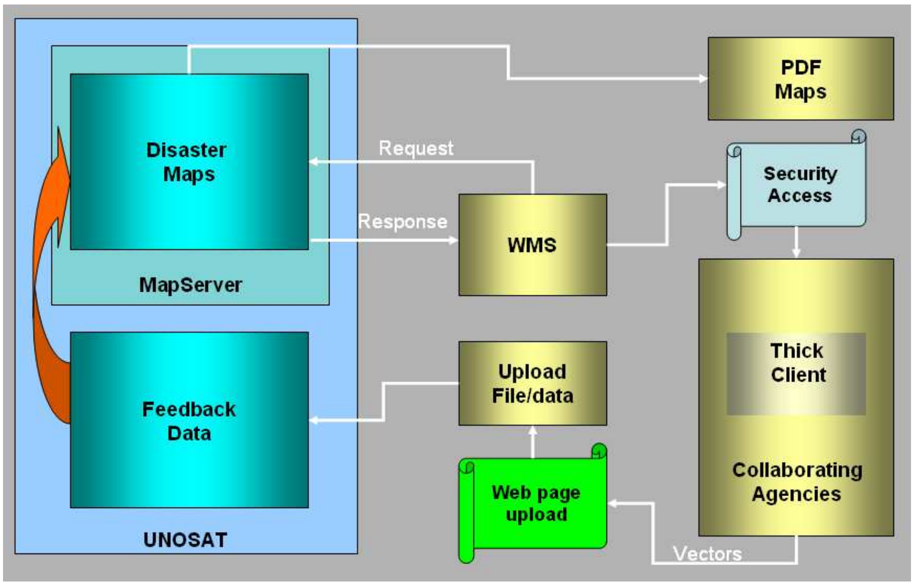


Figure 12: A diagram showing collaborating agencies accessing the map services via a thick client.

In this option, the mapping process is bi-directional and horizontal; both from the data providers and collaborators in the disaster region contribute to the final product. If possible, the data providers (UNOSAT, SERTIT, RESPOND, DLR) can have a horizontal linkage where they work together to produce a final map unlike parallel data provision. In the gap analysis (chapter two) the Indonesia earthquake was given as an example where many entities produced their own maps. The bi-directionality as summarized in figure 12 could have been a solution to the parallel mapping process. It also resolves the static map data that gets outdated immediately after the disaster, a dynamic architecture as demonstrated here is a solution for long term integration, publishing and temporal representation of the situation on the ground even during recovery and reconstruction phases. The services remain available and the users always see the data directly from the original source, any updates and changes are immediately available. The dataset can always be available incase of recurrent or future disasters, the frequency of tsunami, cyclones and earthquakes in Indonesia can be tackled easily with the presence of long term pre and post disaster information.

4.2.2. Prototype Output

The output proves that bi-directional collaboration amongst disaster experts and agencies can be achieved. The on-line form provided caters for a wide range of disaster options, it is upon the agency to decide on the disaster option. When a disaster occurs, the implementing agency sets up the system and connects the participating agencies, at the same time solicit for information from the ground. This real-time system allows feedback of disaster information with rapid and lossless heterogeneous distribution of disaster information and offers possibility for easy integration. The solution to real-time performance and speed of the system is enhanced by map optimization, indexing of data, tiling of images and caching of the web service.

As indicated earlier, the system is built on OpenLayers API and more tools and applications can be developed for an improved system. OpenLayers, a JavaScript Library based on AJAX (Asynchronous JavaScript and XML) principle, used to build general web mapping clients, making it easy to put dynamic maps in any web page. It utilises JavaScript APIs for building rich web-based geographic applications, similar to google maps and can be used to transform spatial mashups into advanced disaster mapping applications. This is just a proof-of-concept demonstration of a common application based on the methods and system components adopted in this project, it is upon the agency itself to build is further or select appropriate systems, either proprietary or non-proprietary to accommodate the many available applications and requirements.

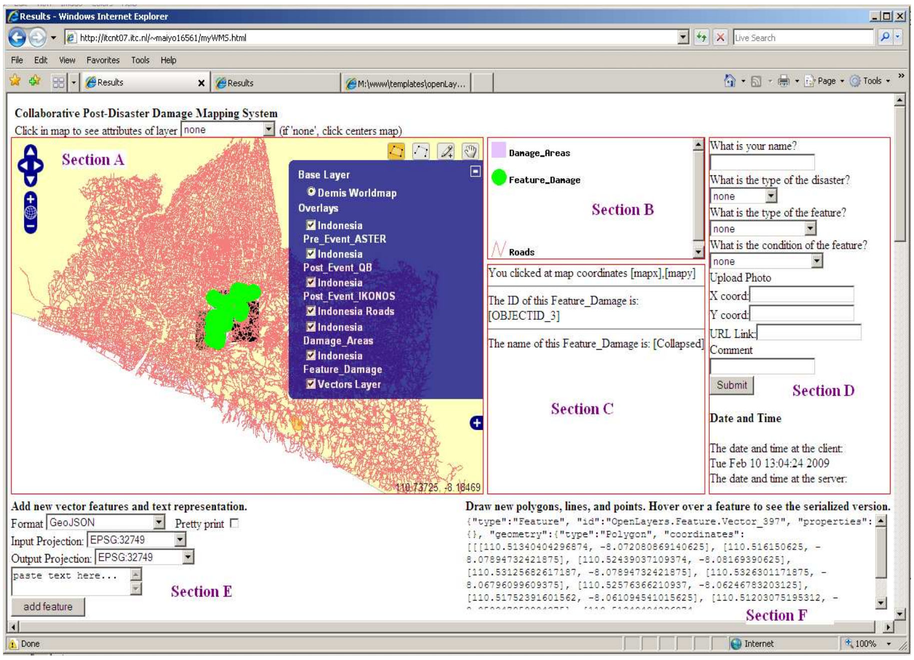


Figure 13: Overview of the system showing damage areas, roads and imagery of Yogyakarta earthquake, May 2006, Indonesia.

The Indonesia dataset acts as the overlays on top of the demis online base map where users can toggle, switch on and off layer using a checkbox list. The base layer sets the projection, extent and units of the map and the Indonesia data act as overlay layers that can be fitted on top of the base layer and on top of each other when rendered transparent. On-the-fly projection process is defined in the script since the system reprojects the added layers according to the projection of the base layer. The edit and capture tools (figure 13, section E - see appendix) accommodate various formats such as Shapefile, GeoJSON, GeoRSS, KML, GML (version 1&2), and Well Known Text (WKT). At the same time, the user can define the input and output projections and associated metadata and comments (see appendix). The tools to capture polygons, lines, and points (figure 13, section A) allows feedback where the end-user digitizes features of interests (damage features) and send back the data to the database where is becomes available to the users as an extra layer. An option for a serialized version (section F – see appendix) of the feature is available showing the feature type, date and time of creation, coordinates and feature description.

A form was done using Active Server Pages (ASP) with drop down options for features affected, location coordinates and the extent of the damage with possible

URL link to photos on other sites like Flickr or Panoramio as shown in figure 13 (section D). A database was created to receive the feedback data on the server side. The data will be uploaded or submitted through the form and will subsequently be stored in a database and will be available as an extra layer to the end-users as preliminary comments to damaged infrastructure or any other related user feedback.

Styled Layer Descriptor (SLD), a standardised map styling format was used to control the visual portrayal of the dataset by defining the styles and rules according to OGC standards. SLD allows user-defined symbolization of WMS, an SLD-enabled WMS retrieves unstyled features from its datasource(s) and applies explicit styling information provided by the user in order to render a map (Beaujardière, 2002). Other controls were added, for example, pan, zoom, zoom to full extent and coordinate readout. Section B is the legend, and more tools such as scale bar are available in figure 13, section A.

4.2.3. Analysis

OL allows use of many layers in the same client coming from different sources. These sources are WMS, WFS or other sources such as NASA Worldwind, marker-layers, text layers, and commercial APIs (google maps, yahoo maps, Microsoft and MultiMap). The WFS publishes feature-level geospatial data on the web, WMS returns an image while WFS delivers actual data; fine-grained information about specific features at geometry and attribute levels. It allows a client to receive and update geospatial data from multiple WFS and can also serve as the data source for WMS. WFS interface uses GML as its delivery mechanism. This gets us to the one of the objectives of the research, where the system should conform to standards and specifications for custom application and data integration. The request of maps by clients is conformal to OGC standards (Beaujardière, 2002). It defines the following three operations:

a) *GetCapabilities:* used to request that WMS generates an XML document with metadata of WMS information, describing the organization providing the service, the WFS operations that the service supports, a list of feature types that the service can operate on. This solves the problem of confusion and management of large online disaster information. The link to required dataset is faster and reduces redundancy in the system.
b) *GetMap:* return an image of a map according to the user's needs. It returns a map image with geospatial and dimensional parameters are well defined. This operation enables creation of a network of distributed map servers from which disaster experts

and clients can build customized disaster maps. This solves the problem of data becoming outdated within a short period like the current static pdf maps.
c) *GetFeatureInfo:* return information and retrieve attribute about feature as shown on the at mouse click/query. Figure 13 section A, is a good example of html query where end-users can get attribute information of a feature at a mouse click.

More tools and features to enhance the performance and versatility of the system can be added. For example, since there is variability in geographic location, language, culture and social differences across countries and regions where disasters occur, there is need for incorporating multi-lingual application in the system where collaborating agencies and experts overcome xenophobic language barriers. In cases of transboundary projects and regional projects where languages vary, the system should accommodate multiple language options. Volunteer content come from different locations and in some cases different languages, hence the multi-lingual tool will address discrepancies that arise due to place names and description.

4.3. Conclusion and Chapter Summary

This system addresses the collective mapping approach unlike the case of Indonesia disaster where many agencies produced their own maps, resulting in duplication and parallel resource allocation. The pre and post event comparison layers available can be overlaid with other global overview background maps, image-based maps, annotated auxiliary information, place names, and other stand-alone damage maps. This chapter dealt with analysis of results from the adopted methodology and prototype. The system outputs from the stated use cases demonstrate that there are many options for bi-directional feedback. The following chapter discusses in details the results and possible solutions for the adoption and implementation of the architecture.

5. Discussion

5.1. Introduction

The previous chapter outlined the results from the methodology and prototype output of the extended architecture as a solution to the current disaster management challenges especially on timely dissemination, collaborative mapping and information exchange, with bias to interoperability and heterogeneity. This system addresses access to segmented data sources, mash-up and integrate them to produce new products and applications. It tries to handle complicated heterogeneity issues by linking different systems, sensors and platforms. This chapter discusses the results and findings from chapter four based on the methodology employed in chapter three and give solutions for the adoption and implementation of the system.

5.2. Project Justification

Geo Web Services have been used in many fields including local disaster related probems, for example the cartesius (geoserver.itc.nl/cartesius) project done at ITC gives a perfect example how geo web was used to bring flood data to stakeholders (Kobben, 2008). Geo Web Services as demonstrated in this project allow extensive sharing of disaster maps and information by opening up easy access by all experts in disaster management. It mobilizes different people from different organisations, collects large amounts of heterogeneous data and integrates within the shortest time. According to Xu and Zlatanova (2007), that the "success in disaster management is getting the right resources to the right place at the right time; to provide the right information to the right people to make the right decisions at the right level at the right time". Hence, the system as shown in figure 13 is collaborative and dynamic while leveraging location and time.

The system itself can be utilised without restriction to scale and magnitude of the disaster or geographical coverage. It is adaptable to global scales as well as country level response. It can be implemented at local authority level, for example the current SDI structure for emergency response in the Netherlands that involved collective and harmonised structures from fire brigade, infrastructure location, police units and other stakeholders in emergency sector (Scholten et al, 2008). The gaps in collaboration highlighted in chapter three can be addressed with the adoption and implementation of working systems, an example of which is the architecture developed in this project. Disaster management is a spatiotemporal process (Dilo and Zlatanova, 2008) and therefore, spatiotemporal data can be used for analysis and decision making during disasters. Hence, the PDF maps as elaborated in chapter two get outdated so fast that they do not provide the best means to address spatiotemporal phenomena, the prototype output in chapter four is expected to address such shortcomings.

As indicated in the literature review and the results section, OGC standards and specifications, as proved by the dynamic access of the datasets served by MapServer in chapter four, are the most appropriate standards for collaborative mapping. One of the objectives of this project was to assess if there are appropriate standards and specifications for a collaborative disaster mapping system. The interfaces for data access enable integration of datasets from many sources and mashing them up to create new products and applications. The use of OGC compliant web services as demonstrated in the results section shows that geo web services are a very promising solution for post disaster damage mapping. It leverages resources at low costs and within reach of many small organisations operating on limited resources. An organisation in remote areas can utilize PDAs and cheap USB sticks with a stack of open source software that can meet their needs to tackle any disaster. These gadgets require less power and hence one can carry and plug in any desktop. At the same time, the ability to source and access the freely available data from other cooperating agencies will reduce time and cost of damage mapping. An advantage of getting the data directly from its source leads to no redundancy and the data is always upto date.

It is true, as seen in table 3, that there has been synergy and inter-agency collaboration on specific projects amongst few interest groups but not involving all the stakeholders in the region. Most of these shared projects are executed by intermediaries and interested partners. For example, UNOSAT worked with SWRT and GIScorps on rice paddy damage project after the Cyclone Nargis in Myanmar which did not involve other potential stakeholders on the ground. Intermediary agencies should not work in isolation, a geocollaboration mechanism, as envisaged in this project, should acts as a benchmark in realising mutual cooperation between the Charter, intermediary agencies, private and local organisations in tackling common disaster challenges that cannot be tackled by a single entity.

A lot is yet to be done on realising a stable and a working infrastructure within disaster management organisations and possibility of localizing the architecture to work at all levels. The proposed collaborative post-disaster damage mapping system is seen as a success and if fully developed and implemented, it is expected to surpass the capabilities of the present virtual disaster viewers. However, more effort for further development, sustainable adoption and implementation strategy is required.

5.3. Adoption and Implementation of the Architecture

The proposed architecture consists of several data services that can be adopted and implemented by several collaborating agencies willing to participate in mapping and contribute to the dissemination of timely disaster information. Cascading and semantic chaining of disaster information by collaborating agencies can be implemented to provide a unified access to all data sources (Schmitz et al, 2006). As indicated in chapter four, the original idea of having PDF maps online has not been phased out, the architecture itself has been tailored to accommodate the current situation. The yet to be adopted GeoPDF by OCG will be an added advantage to geospatial data distribution and collaboration format that connects disaster experts with robust mapping solutions.

This architecture uses remote user profiles and is able to disseminate post-disaster damage maps without any major constraints. The ability of experts to access the dataset via open standards, edit, annotate (as shown in figure 13) with the use of serialization format enables accurate mapping and feedback of local information within the shortest time possible. Some argue that collaboration gives emergency management organisations a pool of expertise far larger than the organisation itself can provide (Siegel et al, 2008). The system in itself can connect experts from any location with expertise in the disaster type, can be achieved by a link to social and professional network sites such as twitter (http://twitter.com/) where experts can actively participate. The Neogeography tools such as GeoRSS discussed in chapter two can be integrated where information from these sites can directly be summarised in the system. Relief agency news from ReliefWeb and AlertNet fit here. An expert roster and registration option can be introduced in the system where the database of all experts are kept and can be contacted and involved incase of a particular disaster type, this saves time and resources of sourcing for expertise after the disaster. A data bank of volunteer experts should be available and ready to contribute incase of an emergency.

The proposed architecture accommodates many standards and platforms as part of the "mass market" initiative where many neo-concepts for user generated content, crowd sourcing, volunteer geographic information and ubiquitous sensor networks converge. The concept of citizens as sensors (Goodchild, 2007), allows citizen observers and volunteers to upload their observations and contribute to disaster information reporting. This is demonstrated in the prototype where anybody can contribute by filling the form and uploading a photograph with location or URL link. As seen in the new emerging technologies it is evident that there is a drastic move from typing on keyboards to new collective intelligence applications driven by new kinds of ubiquitous sensors that comprise both human and portable gadgets. This system is open for such improvements and accommodates the heterogeneity and complexity of disaster information.

The implementation process should also incorporate the use of ontologies and service orchestration to enhance interoperability. Development of ontologies and ontology architectures for disaster response (Xu and Zlatanova, 2007), as part of an extended architecture is recommended in order to overcome semantic interoperability challenges, a step towards realising discovery and integration of disaster geo-information. Semantic interoperability is envisaged in the upcoming Web 3.0 platform to enable ubiquitous connectivity, semantics and transfer of geo-information via open standards and protocols. Ontologies are used to specify conceptualization in a domain of knowledge within different disaster risk domains (ORCHESTRA, 2008), and can be mapped to enhance interoperability between convergent heterogeneous information sources in many post-disaster response scenarios. On the other hand, service orchestration allows for composition of web services from multiple service providers and also ground segments which become available as web services. The EU OCHESTRA, WIN and OASIS projects have developed models and tests for overcoming ontology related issues in disaster management and are already reporting successful results.

5.3.1. Spatial Data Quality

As indicated chapter two, what is missing and required for the success of geocollaboration, and in particular crowd-sourcing is a mechanism to ensure quality, limit errors and to build trust and assurance on the sourced data. A range of tools and techniques are available to ensure data quality and integrity especially to user generated content is of good quality. It is possible to have user centric metadata to enable experts trace the source and quality of uploaded dataset. Geo-Digital Rights Management (GeoDRM) as one of the adopted OGC standard will handle and protect in spatial data and is included as one of the services in figure 9.

An OGC/ISO metadata catalog is necessary to ensure information available is upto standard, W3C, SOAP, and REST standards can be incorporated as well. The implementing agency at the same time can establish in-house QC/QA methods. Data security can be achieved by deploying SOAP over HTTP or TCP/IP (Herrmann, 2008), incases of joint mapping, authentification and regulated access can be achieved with the use of HTTPS or SSL as depicted in the second scenario. Other best practice guides and ethical documents can be developed to ensure prudent use of disaster information. Security and compliance should be enforced to conform to identity standards such as open access license generation and data file provenance tracking.

5.3.2. Establishment of Spatial Data Infrastructures

The success of the disaster management systems will require establishment of a working Spatial Information Infrastructure (SII) and SDIs. An SDI architecture incorporated in the service will facilitate access to various information, existing data and data coming from the field. There are generic services for SDI realization (Scholten et al, 2008) which enhances integration of information from different agencies with appropriate interfaces for different end-users. SDI's are mandatory in management of dynamic information where there are varying institutional and national data policies.

Introduction of common SDI architectures and standards will foster coordination among a confluence of participating agencies. Many SDI projects and initiatives have been successful and emergency response agencies will not be an exception. The UN-SDI by UNGWG has been successful, INSPIRE at the same time is almost getting there, an SDI for emergency response in Netherlands bringing several organisations together in sharing disaster information (Scholten et al, 2008) is already in place. One of the objectives of this research was to asses if SDI is a solution to collaborative disaster mapping, hence as evidenced by these examples, SDI is fundamental and an important tool in disaster management. A comprehensive research on SDI potential in disaster management was not fully done in this project, and this acts as a proposal for further research in chapter six.

5.4. Conclusion and Chapter Summary

Together with the growing availability of location-aware UGC and the ability to easily search, discover, leverage and mash-up web services, the system acts as an example in the development of new technologies for disaster management, a paradigm shift from the current online static pdf maps. It is true that the stated objectives of the research have been achieved, whereas the system in itself is interoperable, bi-directional, enables integration and its performance is real-time. This chapter looked critically at and analysed the results realised from the adopted methodology. The next section concludes and recommends on possible ways of realising geocollaboration and future work.

6. Conclusion and Recommendations

6.1. Conclusion

The Web 2.0 phenomenon has revolutionised Geo Web platform, spanning all connected heterogeneous systems. Web 2.0 applications deliver information, consuming and mashing-up data from multiple sources, including individual users, while providing their own data and services in a form that allows integration by others, creating network effects through an architecture of participation, to deliver rich user experiences. The web 2.0 environment has led to increasing interactions on the web, where technologies that run behind the web are becoming more convergent.

The best solution to meet current and future post-disaster damage mapping challenges is to employ off-the-shelf geo web tools and services. It enhances geocollaboration where data providers improve their data quality by receiving ground truth and local thematic information from end-users. The process of real time data sharing and transfer with distance reduces the cost of travel and shipping, and encourages a two way communication channel enhancing participatory approaches to common disaster challenges. The web service architecture, as demonstrated in this project, provides the ability for heterogeneous stakeholder's access their partner's disaster information in the same geographic context. Real-time damage mapping enables distributed disaster management experts to put damage evaluation into local context, aiding in response and recovery. Geo Web Services provides a means for analysis, augmenting both speed and precision of disaster situation evaluation.

Geo Web Services provide more possibilities for organisations to enhance the power of geo-information as a tool for solving disaster related problems. Dozens of data sources, many of them hosted by disaster management organizations, can be searchable and accessible through a portal. This enables users to drill through spatial data in all formats and track down the information needed about a specific disaster area. The data resources and data access provided by geospatial one-stop repositories will be critically important in all of these areas. This project demonstrate that Geo Web Services can fluidly supply up-to-the-minute the rapidly changing disaster thematic information. Disaster management agencies can now have additional capabilities in the areas of web-based online geo-processing and geo-fusion services, an infrastructure for spatial information.

6.2. Summary

In summary, the research questions are briefly answered:

a) *Are there any real time disaster management systems which allow collaboration within disaster management agencies?* There exist real-time systems that can be used in geocollaboration in disaster management and Geo Web Services as demonstrated in this project is a solution.

b) *Is the general humanitarian synergy and collaboration lacking? If yes, what is the way forward?* There exist a few interest groups collaboration, but the major stakeholders on the ground are not involved. The solution to this is implementing the proposed extended architecture to accommodate the existing organisations and end-users.

c) *Are there appropriate standards and specifications for a collaborative disaster mapping system?* Appropriate standards and specifications for a collaborative disaster mapping system do exist; OGC, ISO and W3C standards are available and can be utilized. This project employed OGC standards (GML, WMS, WFS, KML) in the prototype and has shown successful dynamic mapping results.

d) *Are Spatial Data Infrastructures (SDI) a solution to collaborative disaster management?* SDI is important and a solution to effective collaborative disaster management. A lot has to be done to enable access and sharing of disaster information between agencies.

e) *Are Geo Web Services a solution to collaborative post-disaster damage mapping?* Yes, Geo Web Services are a solution to collaborative post-disaster damage mapping as demonstrated in this projects.

6.3. Recommendations

From the foregoing discussion, sustainable collaboration amongst agencies in disaster management domain cannot be realised without a pool of resources, combined effort and policy implementation. The following proposals and recommendations will act as a guide to successful collaboration, adoption and implementation of the proposed system.

Data sharing and exploring SDI potentials: SDI is essential and a must in realising collaborative disaster management. Participating organisations at all levels should work out an appropriate SDI framework that breaks through institutional, policy and sectoral data sharing barriers by making use of organisational and semantic ontology concept. There should be optimisation of access to and usage as well as exchange of spatial data and information for operational disaster management. Clearinghouse concept for data mining and discovery should be introduced where necessary. Interoperability, on the other hand should span diverse networks and systems for data access. There should be full open exchange of data and information at all levels.

Outreach: The outreach objective is to promote and increase the general awareness of the benefits of Earth Observation and Charter space information, especially among present and future users, beneficiaries and sponsors of relevant systems. Further campaigns towards promoting participatory user involvement in collaborative disaster response is a must, hence, networking and bundling of actor's specific skills. Awareness will contribute to helping end-users engage in incorporating space-based information in disaster management. Communication and participatory end-user mobilization and empowerment can be achieved by integrating forum pages and GeoRSS feeds within the system. Everybody can post and reply threads on major issues of concern and also link to personalised disaster blogging. An account in social network sites such as Twitter enables colleagues and partners communicate and stay connected on some issues of particular interest.

Training and capacity building: Training and education programs are an integral part in the implementation of the architecture, where collaborating agencies are sufficed with information on the use and adoption of the proposed architectures plus joining the extended disaster response network. Training should be tailored to regional thematic groups and disaster types. Developing country organisations and professional outreach workshops, communication, education and training is vital for the success of geocollaboration. This will demystify the Geo Web paradigm as the so called "democratic digital '*lingua franca*'" by training relevant stakeholders in its importance in disaster response.

Research and development: There is need for establishing test-beds, development of models, review gaps and methodologies, data assimilation modules, improved new instrumentation e.g. location-aware GPS coded cameras and mobile phones as part of meeting future disaster response challenges. There is need of a swift and smooth transition from conceptual models and architecture systems to operational use.

Funding, shared cost and benefits: The regulatory agency and major inter-agency working groups should advocate pro-active financing of collaborative and shared projects to leverage the end-to-end value of EO, including the establishment of necessary infrastructure. There should be room for rules of engagement where participating agencies reap benefits from the technologies and development returns from their invested resources.

Resource and Development (R&D): According to Kohler and Wachter (2006), there should be design and validation of application-oriented prototypes and fostering the transfer from R&D to praxis. Appropriate collaborative disaster management technologies, in this case, Geo Web Services, Service oriented architectures and Location-Based Services should be implemented and put into action for effective disaster response. Practical use of existing and new technological resources should be workable and can be put into good use.

Shared Infrastructural Development: Efforts should be put towards funding and leveraging consumer internet services, bandwidth and connectivity augmented with mobile LBS in remote disaster locations. Capitalizing on the use of portable GIS on PDAs and high capacity USB sticks where data and open source software stacks are seamlessly carried in remote areas lacking better communication infrastructure, thus providing the right information at the right place, time and format.

Critical Infrastructure Protection and Link to Ubiquitous Sensors: The proposed system was initially developed for post-disaster damage mapping, assessment and possible reconstruction. Since VARs are mainly dealing with post-disaster damage mapping, the system can be extended to address Critical Infrastructure Protection (CIP) and Development. It can be extended to cover mobile telephony through the new Geo-micro blogging/feeds with Geo SMS chat services, used for example, by InSTEDD Golden Shadow Project in San Francisco by sending text messages to report fire spread in the neighbourhood by risk watchers to the rescue department aided by Google Earth.

The proposed open and interoperable architecture can be linked to other sensors to accumulate network-driven data and collective geointelligence as part of ambient computing network. Mobile phones, computers and other ubiquitous sensors have been incorporated as decentralised “network citizens” and part of the wider cloud computing technology. A good example is the Quake Catcher Network (http://qcn.stanford.edu/) developed by university of Stanford ad its partners. It is a collaborative initiative for developing the world's largest, low-cost strong-motion seismic network by utilizing sensors in and attached to internet-connected computers for early warning and emergency response systems.

Many laptops with Sudden Motion Sensors and/or Active Protection Systems inside them act as global seismic networks that can be used by disaster experts to detect earthquakes with respect to their magnitude, location and time of the event across the globe. QCN links participating laptops into a single coordinated network that can detect and analyze earthquakes faster and better, a successful example of a confluence of opportunity and technology in disaster management.

6.4. Limitation and Future Work

Unfortunately, time and scope limited the extensive coverage of many intriguing research objectives of this Thesis. From the major shortcomings and unaccomplished work, a roadmap for future research related to these objectives is presented here.

First, exploring institutional policies and set-ups limiting collaboration, especially on space law, funding, resources, Charter trigger privileges, data re-use and sharing. Further research should be done on agency operations and improvement of institutional operation, mandate and their inter-relationship towards effective disaster management and response.

Second, exploring possibility for Augmented Reality (AR) by blending computer graphic objects into disaster damage footage in real-time. Motion tracking data, fiducial markers recognition, use of GPS and orientation sensors as part of outdoor AR could be feasible and applied in disaster response. City GML as one of the recently adopted OGC standard has been incorporated with AR and can act as safety nets, evacuation guide and escape routes incase of high-rise built city disasters.

Third, competing and conflict of interests, as highlighted in chapter two may affect institutional stature when all services and mapping activities are "democratized". Distributing workflow chains even to small organisations might make the major stakeholders loose their power in disaster management. The development and expansion of web mapping and the birth of personalised UGC might degrade the power of major actors, or increase tension amongst competing agencies.

The fact that a larger group of experts can access and use disaster information or communicate in both directions (bottom-up, top-down) does not resolve fundamental inter-agency relationships. Democratization of information does not lead to greater concordance between agency policy and technical damage mapping assessments.

The internet beyond neo-modernism may lead to ordinary non-expert citizens to access, process and disseminate professionally grounded information leading to loss of data integrity. Further research on the social problems attached to geo web mash-up approach, its virtual "democratisation" effect and same level power geometries between participating agencies is vital.

7. References

Beaujardière, J., 2002, Web Map Service Implementation Specification, Report, OGC, Wayland, MA

Beliën, W., 2005, Distributed services architecture for geo-information architecture, Report, Cross-border Water Management Initiative, Utrecht

Bjorgo, E.,Pisano, F.,Lyons, J. and Heisig, H., 2008, Satellite imagery in use, Report, Geneva, Switzerland

Charter, 2008, Charter Members and Space Resources - http://www.disasterscharter.org/.

Christian, E.J., 2008, GEOS Architecture Principles and the GEOSS Clearinghouse. IEEE Systems Journal, Vol 2.

Dangermond, J., 2001, Mapping our World, Sandiego, California. USA.

Dilo, A. and Zlatanova, S., 2008, Spatiotemporal data modeling for disaster management in the Netherlands. In: Bartel van de Walle, Y.S., Siyka Zlatanova, and Jonathan Li (ed.), Information Systems for Crisis Response and Management, Harbin Engineering University, 517-528.

Doyle, A. and Reed, C., 2007, Introduction to OGC Web Services, Wayland MA, USA.

EU, 2004, Global Monitoring for Environment and Security (GMES): Establishing a GMES capacity by 2008 - (Action Plan (2004-2008)), Report, Brussels, Belgium

Foerster, T.,Stoter, J. and Lemmens, R., 2008, An interoperable Web Service Architecture to Provide Base Maps Empowered by Automated Generalisation. In: Ruas, A. and Gold, C. (eds.), Headway in Spatial Data Handling. Springer, Berlin, 255-276.

GEOSS, 2005, The Global Earth Observation System of Systems (GEOSS) 10-Year Implementation Plan, Report

Gitas, A.,Polychronaki, T.,Mallinis, G. and Katagis, 2007, Contribution of remote sensing to disaster management activities: A case study of the large fires in the Peloponnese, Greece. International Journal of Remote Sensing, Vol 29.

Goodchild, M., 2007, Citizens as Sensors: Web 2.0 and the Volunteering of Geographic Information, Santa Barbara.

Herrmann, J., 2008, Interoperable Access Control for Geo Web Services in Disaster Management. In: Nayak, S. and Zlatanova, S. (eds.), Remote Sensing and GIS Technologies for Monitoring and Prediction of Disasters. Springer, Berlin, 167-178.

Inglada, J. and Giros, A., 2004, On the real capabilities of remote sensing for disaster management - Feedback from real cases. IEEE Transactions on Geoscience and Remote Sensing, Vol 7803.

Ito, A., 2005, Issues in the Implementation of the International Charter on Space and Major Disasters. Science Direct, Vol 21.

Kapucu, N., 2008, Collaborative emergency management: better community organising, better public preparedness and response. Blackwell Publishing, Oxford, UK, Florida, USA.

Kerle, N., 2008, Satellite image-based response to the 2006 Indonesia earthquake – how accurate was it?, Pavia, Italy, 11-12 September 2008.

Kerle, N.,Heuel, S. and Pfeifer, N., 2008, Real-time data collection and information generation using airborne sensors. In: Zlatanova, S. and Li, J. (eds.), Geospatial Information Technology for Emergency Response. Springer, Berlin, 43-74.

Kerle, N. and Widartono, B., 2008, Geoinformation-Based Response to the 27 May Indonesia Earthquake - an Initial Assessment. In: Nayak, S. and Zlatanova, S. (eds.), Remote Sensing and GIS Technologies for Monitoring and Prediction of Disasters. Springer, Berlin, 11-23.

Kobben, B., 2008, A short introduction to Geo-WebServices - Unpublished Teaching material. International Institute for Geo-Information Science and Earth Observation (ITC), PO Box 6, 7500 AA Enschede, The Netherlands.

Kohler, P. and Wachter, J., 2006, Towards an Open Information Infrastructure for Disaster Research and Management: Data Management and Information Systems Inside DFNK. Springer 2006, Vol 38: pg 141-157.

Lehto, L., 2007, Real-Time Content Transformations in a Web Serice-Based Delivery Architecture for Geographic Information, Helsinki University of Technology, Helsinki, 65.

Lei, W. and Qiuming, C., 2006, Web-Based Collaborative Decision Support Services: Concept, Challenges and Application., Vienna.

Lemmens, R., 2008, Lost and Found, the Importance of Modelling Map Content Semantically. International perspectives on maps and the internet M.P.

Peterson, International Institute for Geo-Information Science and Earth Observation , Enschede, 377-396.

Lemoine, G., 2007, Collaborative Geo-information Capturing to Support Emergency Response, UN Campus Bonn, Germany.

Maguire, D., 2006, GeoWeb2.0: Implications for ESDI, Innsbruck Austria.

Mahmood, B., and Bequignon, 2004, Three typical examples of activation of the International Charter "Space and Major Disasters". Advances in Space Research, Vol 33: p 244-248.

Mahmood, C., Platzeck, and Bequignon, 2008, South American perspective of the International Charter "Space and Major Disasters". Advances in Geosciences, Vol 14: p 13–20.

Nebert, D., 2008, GEOS Architecture-GEOSS ADC Architecture Workshop, New York, USA.

ORCHESTRA, 2008, An Open Architecture for Risk Management, Report 978-3-00-024284-7, European Commission, Brussels.

Radetzki ,Alda, A.,Bode, T. and Cremers, B., 2002, First Steps in the Development of a Web Service Framework for Heterogeneous Environmental Information Systems, Bonn.

Schmitz, S. and Visser, U., Year, Interoperability in GIS-Enabling Technologies. Proceedings of 5th AGILE Conference on Geographic Information Science, Palma, Spain, 291-297.

Schmitz, S.,Glade, T.,Dellow, G.D. and Greve, K., 2006, Thinking OpenGIS WebServices (OWS) for the Dissemination of Natural Hazard Data, Belgium.

Scholten, H.,Fruijter, S.,Dilo, A. and Borkulo, E., 2008, Spatial Data Infrastructure for Emergency Response in Netherlands. In: Nayak, S. and Zlatanova, S. (eds.), Remote Sensing and GIS Technologies for Monitoring and Prediction of Disasters. Springer, Berlin, 179-195.

Siegel, C.,Fortin, D. and Gauthier, Y., 2008, Geocollaboration in Hazard, Risk and Response: Practical Experience with Real-Time Geocollaboration at Quebec Civil Security. In: Nayak, S. and Zlatanova, S. (eds.), Remote Sensing and GIS Technologies for Monitoring and Prediction of Disasters. Springer, Berlin, 199-215.

Stevens, D., 2008, Increasing the Use of Geospatial Technologies for Emergency Response and Disaster Rehabilitation in Developing Countries In: Nayak, S. and Zlatanova, S. (eds.), Remote Sensing and GIS Technologies for Monitoring and Prediction of Disasters. Springer, Berlin, 57-71.

Tartanoglu, V.I., Alexander Romanovsky and Nicole Levy, 2007, Dependability in the Web Services Architecture. Architecting Dependable Systems. Springer Berlin / Heidelberg, Berlin, 90-109.

UNOSAT, 2008, Space Charter and UNOSAT increase their collaboration - http://unosat.web.cern.ch/unosat/.

Voigt , T.K.,Riedlinger, T.,Kiefl, R.,Scholte, K. and Mehl, H., 2007, Satellite Image Analysis for Disaster and Crisis-Management Support. IEEE Transactions on Geoscience and Remote Sensing, Vol 45.

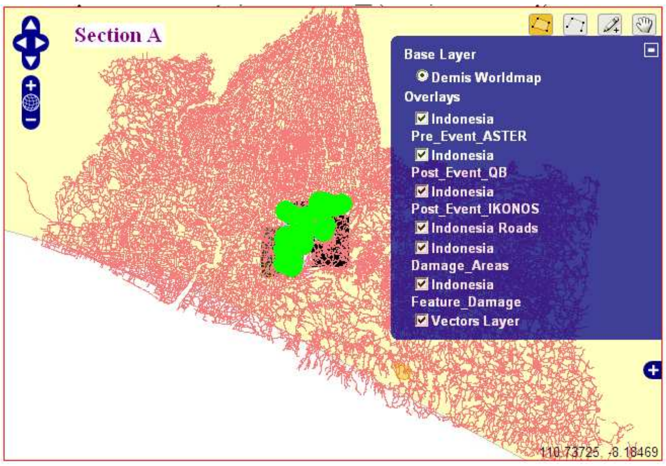
Wang, L. and Cheng, Q., 2006, Web-Based Collaborative Decision Support Services: Concept, Challenges and Application, Vienna.

Xu, W. and Zlatanova, S., 2007, Ontologies for Disaster Management Response. Geomatics Solutions for Disaster Management. Springer, Berlin, 185-200.

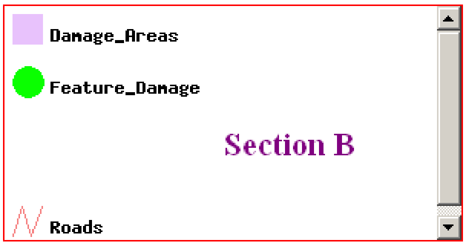
Zhang, Y. and Kerle, N., 2008, Satellite remote sensing for near-real time data collection. In: Zlatanova, S. and Li, J. (eds.), Geospatial Information Technology for Emergency Response. Springer, Berlin, 75-105.

8. Appendix

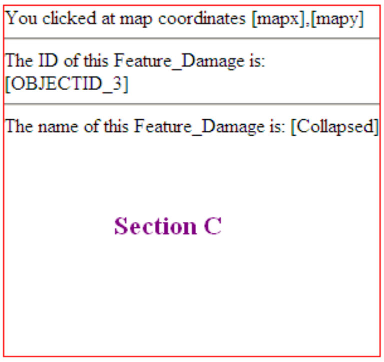
Section A: Main map window with basic tools



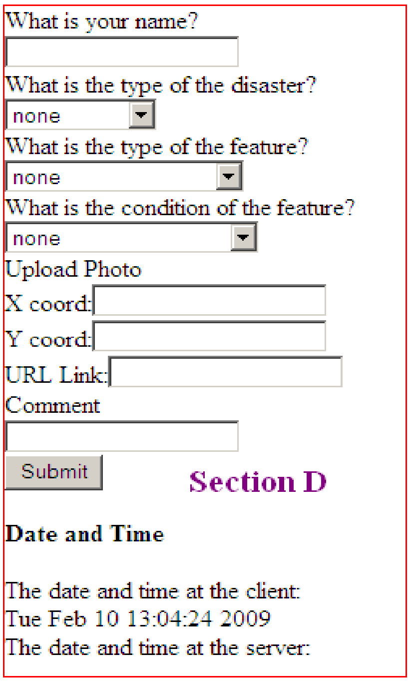
Section B: A legend



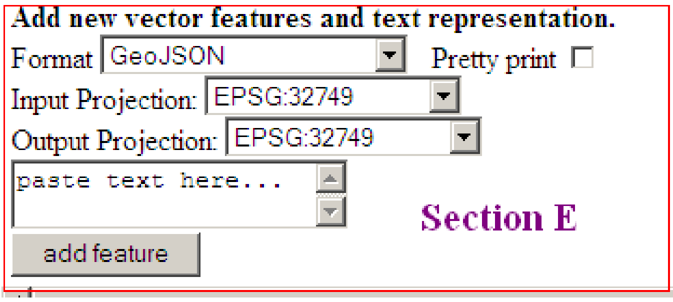
Section C. html text query results



Section D. ASP Form



Section E: Add vector feature and text representation



Section F: Serialization option