Collaborative Post-Disaster Damage Mapping via Geo Web Services

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Abstract

To mitigate the consequences of increasingly frequent disasters across the globe, better real-time collaborative post-disaster management tools are needed. The International Charter "Space and Major Disasters", in conjunction with intermediary agencies, provides for space resources to be available to support disaster response. It is widely seen as a successful example of international humanitarian assistance following disasters. However, the Charter is also facing challenges, with respect to accurate and timely data delivery and lack of validation, with information flow being largely mono-directional. It is, therefore, fundamental to move away from static map data provision to a more dynamic, distributed and collaborative environment. Geo Web Services can bring together vast stores of data from heterogeneous sources, along with geospatial services that can interact in a loosely coupled environment and be used to create more suitable information for different stakeholders. The aim of this paper is to evaluate the relevance and importance of Geo Web Services in the disaster management domain and present a suitable Geo Web Service architecture for a collaborative post-disaster damage mapping system. We focus particularly on satellite image-based post-disaster support situations, and present our ideas for a prototype based on this architecture with possibilities for User Generated Content.

The current state of post-disaster mapping

Disaster numbers and costs have been increasing worldwide in recent years, posing an increasingly global challenge that requires corresponding solutions. In conjunction with better understanding of disaster risk management (DRM) concept and theory, including better insight into links with socio-economic development, more global and collaborative information coordination platforms, such as Alert-

Net, Virtual OSSOC and ReliefWeb, some already using current geo-communication means such as news feeds and news alert.

An important information source for such networks is the International Charter "Space and Major Disasters" which has been a champion in space data acquisition and delivery of image based information to organisations involved in disaster response (Ito, 2005). It aims at providing a unified system of space data acquisition and delivery to those affected by natural or man- made disasters through Authorised Value Adding Resellers (VARs) and Value Adding Agencies (VAAs) (Mahmood, 2008). Since its inception in 1999, there has been an increasing number of activations, aided by a recent growth in Charter membership, now including DMCii, CONAE, ISRO, JAXA, USGC and NOAA, adding their space resources to those of CSA, CNES and ESA, a major improvement in space-based disaster response, and a success in meeting the modern challenges of varying disaster types. The bulk of the image processing has been carried out by UNOSAT, the German Space Agency's ZKI, and SERTIT.

Several other private companies and NGOs have recently become involved in post-disaster damage mapping, management, response and recovery. For example, ImageCat Inc., RapidEye, TerraSAR and MapAction focus on post disaster response, frequently linking disaster response and management efforts with the UN, the Charter and NGOs in the context of Public Private Partnerships (PPP). These PPPs are important in bringing in a pool of resources, technology, expertise and combined efforts towards rapid disaster response. ImageCat Inc., for example, has been developing tools for more efficient image based disaster response, most recently the Virtual Disaster Viewer (VDV) based on MS Virtual Earth, which offers an alternative method of rapid and robust damage assessment. The European Commission's Joint Research Centre (JRC) and ORCHESTRA project are also developing new disaster management tools and techniques (ORCHESTRA, 2008).

Challenges for post-disaster mapping

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 facing challenges in many areas of its operation, especially in accurate and timely information delivery. With the technology currently used, data flow is largely mono-directional, hence no participatory collaboration is possible, resulting in a situation where resources and knowledge outside the processing agency are insufficiently well integrated. The type and number of stakeholders has grown over the years, with increasing use of geodata, including satellite imagery and its derivatives, and better spatial data integration leading to more timely disaster response. The websites operated by the agencies processing Charter data, however, have been designed mainly to disseminate map products that end-users can view and download in print-optimised PDF format. This approach is poorly suited to meet the changing needs of increasingly specialized players in the disaster arena, and neither allows them to add local knowledge and additional information to the image-derived maps.

Thus an appropriate application framework has to be developed to enable multiple stakeholders in various locations to customize the post-disaster information, add value by providing feedback or access to their own information, and to collaborate with other agencies involved in the disaster aftermath. This requires *geospatial e-collaboration* in emergency response which is technically feasible with extensible elaborate spatial analysis and geo-processing tools. When considering these new ways of post-disaster mapping, however, we have to take into account that the Charter data use remains complicated, as original imagery is not free as such and also cannot be used freely after the use by the officially designated processing entity. Likewise, any information subsequently added by other stakeholders may also have access restrictions. Therefore, any distributed system architecture needs to deal with access conditions in a secure way.

Disasters can represent a challenge or an opportunity, leading to a variety of possible competing or conflicting interests since there are entities that either have a humanitarian or a commercial motivation. 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 different entities, such as OOSA, OCHA or UNOSAT, have had disagreement on who should have the right to trigger the Charter. Disaster response has become an interesting business area where humanitarian support, research, and commercial interests converge.

Towards collaborative disaster mapping using Geo Web Services

A number of non-standardized frameworks for Web-based Collaborative Decision Support Services (WCDSS) amongst stakeholders already exist (Wang and Cheng, 2006), but because such systems use proprietary interfaces, they are not useful for a larger user community. The solutions to collaborative environment require the use of Open Standards. Such standards have been developed and are increasingly used in Spatial Data Infrastructures (SDI), and our goal is to develop a generic architecture for such a collaborative system based on Geo Web Services. 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 make them accessible only via well specified and standardized interfaces (Köbben, 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 exists a range of proprietary Geo Web Services in the market. They include Google Earth/Maps, Yahoo Maps and Microsoft Virtual Earth/MultiMap. Free geo-browsers to view data through these services are available, both in 2D and 3D. Next to that, non-proprietary Open Standards have been developed in an open and participatory process, and are owned in common. Examples of Open Standards for Geo Web Services are the Open Web Services (OWS) specifications of the Open Geospatial Consortium (OGC). There are OWS specifications for most parts of the spatial data storage, analysis and delivery process: for geographic data encoding there is the Geographic Markup Language (GML), and for spatial data delivery the Web Coverage Service (WCS) and Web Feature Service (WFS), for querying and retrieving raster and vector data, respectively. For processing of spatial data the Web Processing Service (WPS) has been defined, and Web Map Service (WMS), for data visualization in the form of maps. An emerging specification is GeoDRM, specifying Digital Rights Management of geodata.

Importance of Geo Web Services as a tool for collaboration

Collaborative damage mapping requires situation assessment from existing and new datasets, impact assessment with post-disaster imagery and organisation of post-disaster work. Such diverse collaboration can only be supported 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. Geo Web Services can thus lead to a wide range of services for a long term, comprehensive and high quality EO system in support of critical disaster response. The main focus is to design a suitable framework of services and client solutions for a collaborative disaster mapping system.

A Geo Web Services approach can connect the various disaster management agencies, allowing more customized delivery of data and information, and allow users to add value by providing their own information, thus creating new synergies in a loosely coupled environment. Despite past achievements in providing image derived information, the Charter currently lacks a framework for collaboration, synergy and feedback from major stakeholders in disaster response.

User Generated Content (UGC) and Neogeography tools

Apart from image analysis, emerging web services can be used to display damaged infrastructure in the field by disaster experts and volunteers by employing new interoperable Web 2.0 tools such as geotags, Flickr, GeoRSS and GeoWIKI.

Geo-tagging is the process of tagging images to various open layers in the form of geospatial metadata, where users can find a wide variety of location-specific information. Geotagging-enabled information services can also be potentially used to find location-based disaster damaged infrastructure. Unlike Geo-tags, **Flickr** organize images as tag clouds, referenced by place names. It offers a comprehensive web-service Application Programming Interface (API) that allows humanitarian experts to tag photographs of damaged infrastructure. **GeoRSS** is a standard for encoding location as part of an RSS feed (http://en.wikipedia.org/wiki/RSS). GeoRSS collaboration can promote interoperable web services across the disaster domain. **GeoWIKI** is a means of many people contributing to the development of a large database (crowd-sourcing), using Google Earth based GeoWIKI, designed to enable anyone to contribute or modify its content (Goodchild, 2007).

Prototype

We develop different use case scenarios as part of a test-bed for a technically feasible collaborative disaster management system. The main goal of this prototype is to demonstrate the technical concepts of a collaborative mapping system. As a proof of concept for the use of open standards for end-user access to disaster maps, we are setting up a prototype project based on appropriate service specifications. The aim is to connect to different servers hosted by VAAs/VARs and combine output of these servers in the distributed client machines via a browser or geo-processing software as shown in Fig. 1. Data from intermediary agencies can be accessed by end-users via thin or thick client as map services through an interface, and through a regulatory Access Control Level (ACL) security mechanism.

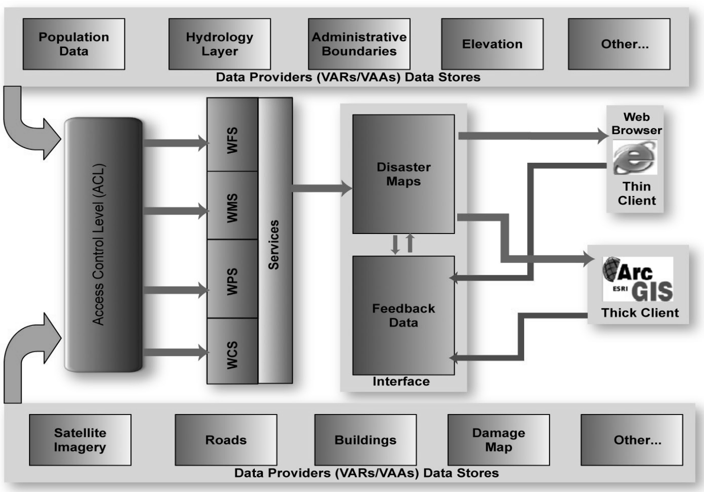

Fig. 1. The extended prototype architecture.

The prototype is developed based on the concepts of distributed services. End users might employ a range of applications, from simple so-called *thin clients*, with a limited functionality (e.g. a web browser for viewing maps from a WMS) to *thick clients*, e.g. a full blown GIS system that uses the architecture to access and process the base data. The prototype is built using already available Open Source components that we use in ITC education and research projects. The Geo Web Services layer is largely based on the UMN Mapserver (http://mapserver.org), while thin client is developed using the OpenLayers API (http://openlayers.org).

Use case scenarios are developed to demonstrate the feasibility of the proposed extended architecture. In the first scenario, end-users of post-disaster maps have the possibility to *spatially annote* these maps. Using a simple thin client (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 dark arrows in Fig. 1), and therefore can be viewed by others users. They could also be used by the mapping agency to further approve their maps. Likewise, the agency can use these annotations to actively seek help, for instance by posing questions such as „*does anybody know if this building is still standing?*" or „*is this road 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 (see Fig. 2a) or Panoramio) or other Geo Web Services (e.g. Google Maps).

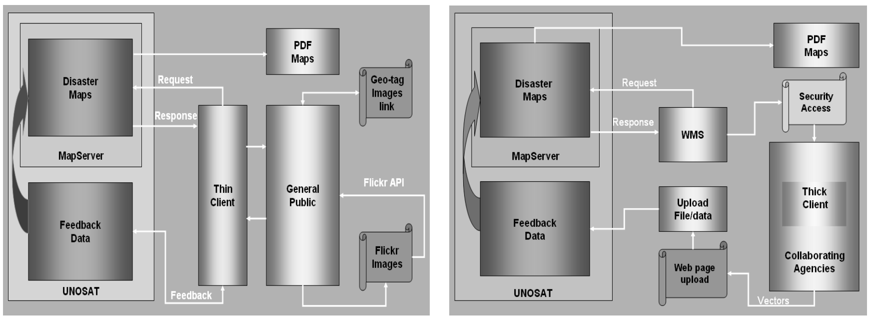

Fig. 2. Use case examples: (a) Scenario 1 architecture with thin client capabilities, (b) scenario 2 architecture with thick client full geo-processing capabilities.

For the second scenario, we envisage a more limited user group, such as stakeholders and collaborators that are asked to collaborate actively on the production of post-disaster maps. These users require a thick client, such as QGS, uDig and ESRI's ArcGIS system, and would use that to help with data processing, in our use case delineation of damaged areas and upload it via a secure web page. These inputs are used to process the data for the final damage maps, hence a secure access and validation mechanism needs to be in place (see Fig. 2b).

Results

The results are the outcome of the two use case scenarios developed and the proof-of-concept output with the Yogyakarta dataset, an aftermath of the may 2006 earthquake in Indonesia where post event ikonos and Quickbird images where available and several agencies produced their own maps. The designed prototype is deployed to a large extent on OpenLayers 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 is incorporated in the system, tracking data captured at server and client sides to accommodate location and time differences of the agency and end-users.

The form was developed using Active Server Pages (ASP) with drop down options for the features affected, location coordinates and the extent of the damage with possible URL link to photos on other sites such as Flickr or Panoramio as shown in Fig. 3 (section D). The form caters for a wide range of disaster options, providing flexibility to the agency in charge of processing the Charter data. When a disaster occurs, the implementing agency sets up the system and connects the participating agencies, at the same time soliciting information from the ground. A database was created to receive the feedback data on the server side. The data are uploaded through the form and are subsequently stored in a database, as well as available as an extra layer to the end-users. The performance and speed of the system is enhanced by map optimization, indexing of data, tiling of images and caching of the web service. The prototype can be found at http://geoserver.itc.nl/laban/

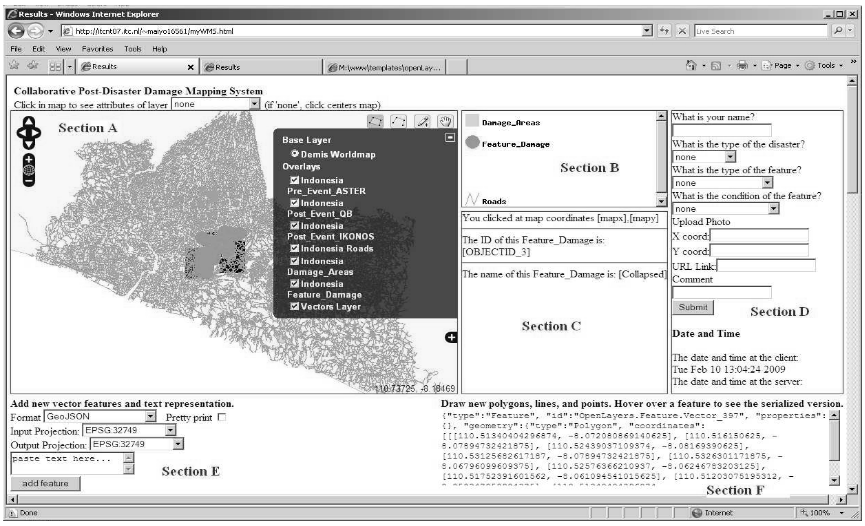

Fig. 3: Overview of the system showing damage areas, roads and imagery of Yogyakarta earthquake, May 2006, Indonesia.

The DEMIS online base map (www2.demis.nl) sets the projection, extent and units of the map and the disaster data act as overlay layers that can be fitted on top of the base layer and on top of each other when rendered transparent and end-users can toggle, switch on and off layers using a checkbox list. The edit and capture tools (Fig. 3, section E) accommodate formats such as GeoJSON, GeoRSS, KML, GML, and Well Known Text (WKT). At the same time, the user can define the input and output projections and associated metadata and comments. The tools to capture polygons, lines, and points (Fig. 3, section A) allow feedback where the end-user digitizes features of interests (damage features), and send back the data to the database. A serialized version of the feature (section F) is available showing the feature type, date and time of creation, coordinates and feature description.

Styled Layer Descriptor (SLD), a standardized map styling format is used to control the visual portrayal of the dataset by defining the styles and rules according to OGC standards. Other standard navigation tools were also added. Section B contains the legend, while other editing tools are location section A. More tools and features to enhance the performance and versatility of the system can be added as it is based on non-proprietary standards. 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 agencies and experts overcome language barriers.

Discussion and recommendations

Information systems used in the field of disaster management are often not as open and comprehensive as needed to integrate and accommodate the complex data sets and the different systems. There is currently no singly accepted architectural model for web services as a whole, although a number of groups (W3C Architecture Working Group) are working 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 by designing distributed software architectures (Kohler and Wachter, 2006). Our proposal is more of a working dynamic system as compared to ImageCat's VDV, which is more rigidly limited to real time post event damage assessment. The success of the system requires well established SDIs within disaster agencies. An SDI architecture incorporated in the service facilitates access to various information types, existing data and data coming from the field. There are generic services for SDI realization (Scholten et al, 2008) that enhance integration of information from different agencies with appropriate interfaces for different end-users. SDIs are mandatory in managing dynamic information with varying agency and national data policies.

The process of data provision, integration and sharing should conform to ISO and OGC standards and specifications. The utility of OGC Web Services has already been demonstrated (Kohler and Wachter, 2006). Data quality and control especially in open platforms is a must, a prerogative of intermediary agencies to regulate the access, editing and integration of the dataset via a common protocol. GeoDRM should be part of the collaborative quality control mechanism in post disaster damage mapping. It is a conceptual framework, and an array of standards and software tools for guarding the rights of both producers and consumers of geospatial data and services (Lieberman, 2006). Access Control Levels (ACL) are created in authentication services to manage permissions, subject to the level of access rights and privileges of heterogeneous users (Xu and Zlatanova, 2007). Security can be ensured between the services and the clients by establishing HTTPS and/or Secured Socket Layers (SSL).

The proposed architecture consists of several data services that can be adopted and implemented by VAAs/VARS for real time collaboration. 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). The proposed architecture uses remote user profiles and is able to disseminate post-disaster damage maps without any major constraints. Collaboration gives emergency management organisations a pool of expertise far larger than the organisation itself can provide (Siegel et al, 2008). The architecture is part of the “mass market” initiative where many neo-concepts for UGC, crowd-sourcing, VGI and ubiquitous sensor networks converge. The system itself can connect a roster of experts from any location with expertise in the disaster type, and can include a link to social and professional network sites such as twitter (http://twitter.com/), where experts can actively participate in an emergency. The concept of citizens as sensors (Goodchild, 2007) allows volunteers to contribute to disaster reporting.

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) is recommended in order to overcome semantic interoperability challenges. 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. The EC’s OCHESTRA, WIN and OASIS projects are developing models to overcome ontology issues in disaster management.

Conclusion

The Web 2.0 phenomenon has revolutionized Geo Web platforms, 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. The best solution to meet current post-disaster damage mapping challenges is to employ off-the-shelf geo web tools and services, in conjunction with non-proprietary tools and protocols. The process of real time data sharing and transfer 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 allows heterogeneous stakeholders to access all available 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 provide a means for analysis, augmenting both speed and precision of disaster situation evaluation. Dozens of data sources, many of them hosted by disaster management organizations, are now searchable and accessible through a portal. The data resources and data access provided by a geospatial one-stop repository 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.

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