INTEGRATION OF DISASTER EVENT DATA INTO SPATIAL DATA INFRASTRUCTURES

B. Stollberg [a, *], T. De Groeve [a], A. Hirner [a], L. Vernaccini [a], S. Paris [a]

[a] Joint Research Centre of the European Commission, Institute for the Protection and Security of the Citizen, 21027 Ispra, Italy - (beate.stollberg, tom.de-groeve, andreas.hirner, luca.vernaccini, stefano.paris)@jrc.ec.europa.eu

Commission VI, WG VI/4

KEY WORDS: Spatial Infrastructures, Integration, Hazards, Interoperability, Disaster, Sensor, Real-time

ABSTRACT:

The Global Disaster Alert and Coordination System (GDACS) collects near real-time hazard information about earthquakes, tsunamis, tropical cyclones, floods and volcanoes. Although all the collected disaster event data has a geographic reference it was up to now not integrated into a Spatial Data Infrastructure (SDI). For a more efficient use of the data and to create interoperability we started this integration and make all resources available as independent services. In the beginning of this work it was clear that we will expose our data by the well-known Web Map Service (WMS) standard for the dynamic creation of maps. Less clear was the use of the Web Feature Service (WFS) and/or Sensor Observation Service (SOS) standard which offer both the possibility to retrieve data in a standardized XML format which can be further processed. We will show why up to now we do not see the necessity of offering our data through a SOS as all our use cases are covered by the WMS and WFS standards. Furthermore we will point out why adequate data filter mechanisms are important and present a Filter Service we developed for this purpose.

1. INTRODUCTION

The Global Disaster Alert and Coordination System (GDACS) provides global multi-hazard disaster monitoring and alerting for earthquakes, tsunamis, tropical cyclones, floods and volcanoes. The system was established to reduce the need to monitor several web sites for several disaster types and is based on the request for a single portal to access information on any natural disaster. The observed hazards have very different physics and are studied in disconnected scientific communities. Through partnerships with scientific organisations and other hazard monitoring institutions, GDACS collects near real-time hazard information. As all events are collected from various sources the further processing and storage of the different data types are varying and have faced a diverse development since GDACS started in 2004.

Although all the collected GDACS data has a geographic reference it was up to now not integrated into a Spatial Data Infrastructure (SDI) but stored in various databases without spatial extensions or in simple file structures. For the usage in geographic applications different workarounds were developed, according to the use case and the data type. For a more efficient use of the data and to create interoperability we started to integrate the various disaster event data into an SDI where all resources are made available as independent services.

In this paper we will present how we integrated different types of disaster events into our SDI, based on current standards. We will answer the question which standards in the geospatial domain suit best the offering of disaster event data and we will show how the data is now used for different purposes.

2. DISASTER EVENT DATA

2.1 Earthquakes

GDACS earthquake event data is scraped from two sources: the United States Geological Survey's (USGS) Earthquake Hazards Program and the European-Mediterranean Seismological Centre (EMSC). After the data scraping we perform a risk analysis: the magnitude of an earthquake is combined with an element at risk (such as the amount of people in the affected area) and a vulnerability factor accounting for physical and socio-economic resilience of the affected area. According to the result an alert level is assigned to the earthquake event. Finally the processed event data has been stored in a non-spatial database up to now.

2.2 Tsunamis

GDACS tsunami alert calculations are triggered by strong earthquakes that occur in or near water. The logic for the tsunami alert is based on the magnitude of the earthquake, the depth of the earthquake and the maximum wave height at any coast reached by the tsunami. This wave height as a third parameter is looked up in our tsunami model database which contains more than 132.000 pre-calculated scenarios. The database is queried for the closest matching scenario and the maximum wave height is extracted from it. According to this height an alert level is assigned.

The disaster event types 'earthquake' and 'tsunami' are stored in the same database. More precisely all earthquake datasets contain an attribute expressing if a tsunami was initiated by it or not, as well as another attribute 'wave height'. This means there are no separate databases for these both disaster event types.

---

* Corresponding author. This is useful to know for communication with the appropriate person in cases with more than one author.

2.3 Tropical Cyclones

Based on tropical cyclone track information provided by the Pacific Disaster Center, we calculate areas around the track affected by high winds. Depending on the wind speed and the population in the area, alert levels are assigned. The tropical cyclone data is the first event data that has been stored in a spatial database. In particular three layers were defined and are continually updated. The first layer contains the points of the cyclone track including various attributes. The second layer contains the lines of the cyclone connecting the track points. The third layer contains calculated polygons representing wind fields along the storm track.

2.4 Floods and Volcanoes

Besides the earthquake/tsunami and tropical cyclones data GDACS offers also a repository of flood and volcano data. The integration of this data into the SDI will take place in the future and is not content of this paper.

3. RELEVANT OGC STANDARDS

As mentioned above all collected event data has a geographic reference but until now it was stored in various databases and file systems without integration into an SDI. Only the cyclone data has already been kept in a spatial database but not exposed via common standards and interfaces for the interoperable use of the data. Our goal is now to create this interoperability and make all resources available as web services. The Open Geospatial Consortium (OGC) offers standardized OGC Web Services (OWS) such as Web Map Service (WMS), Web Feature Service (WFS) and Web Coverage Service (WCS). In the recent past the growing number and availability of sensor data made it furthermore necessary to develop new standards and technologies for the integration of dynamic data (e.g. temperatures, water levels etc.) within SDIs. This need was addressed within OGC by the development of several standards within the Sensor Web Enablement (SWE) initiative. The goal of SWE is to enable all possible types of sensors to be detectable, accessible and controllable via the Web in a standardized and open way.

This paper will present which OGC standards we have chosen for the provision of the GDACS earthquake/tsunami and tropical cyclone data. We started with these two types of disaster event data and will begin with the SDI integration of the flood and volcano data in the near future. In the following chapter we will describe for which purposes the disaster event data is used and the application of which standards is derived from this.

3.1 Data Use

The first type of use of the disaster event data is the creation of images for presentation and visualization. The data is for example visualized in the GDACS website (www.gdacs.org), integrated in GDACS reports and used for the production of (paper) maps in crisis situations. All these cases are covered by the well-known WMS standard which offers the dynamic generation of maps out of spatially referenced vector or raster data. These maps can be visualized in common web browsers, integrated into mashups or used in reports.

The second type of use is the further analyzing or processing of the disaster event data. For this purpose it is useful to offer the data in a standardized encoding. Here two standards could potentially be used: either the Geographic Markup Language (GML) or the Observation and Measurement (O&M) encoding. GML is provided as output by the well-known WFS while O&M is provided as output by the less common Sensor Observation Service (SOS) which is one service recently developed within the OGC SWE initiative.

In the beginning of our work it was clear that we will expose our data by the WMS standard for the dynamic creation of maps. Less clear was the use of the WFS and/or SOS standard. Both offer the possibility to retrieve data in a standardized XML format which can be further processed. So we decided to expose the earthquake data experimentally as WFS and SOS for a comparison. The results of this comparison are presented in chapter 6.

3.2 Description of used OGC Standards

WMS provides an interface for the dynamic generation of maps (Beaujardiere, 2006). The two mandatory operations defined for a WMS are *GetCapabilities* and *GetMap*. The purpose of the *GetCapabilities* operation is to obtain service metadata. The *GetMap* operation returns a map.

WFS provides an interface to query, as well as to perform transactions of features (Vretanos, 2002). The *GetCapabilities* operation responds with the capabilities of the service, meaning the operations that are available. The *DescribeFeatureType* operation responds with the schema of a feature type. The *GetFeature* request contains one or more query elements. A query element contains a *featureType*, and one or more property names related to the *featureType*. The *GetFeature* response provides a feature that contains properties in GML encoding.

GML is one standardized encoding mechanism for geographic information developed by the OGC (Portele, 2007). A widespread modelling concept for geographic data which is used in GML and other exchange formats is the so-called feature. "A feature is an abstraction of a real world phenomenon. A geographic feature is a feature associated with a location relative to the Earth." (OGC, 2008). Thus, features may have geometric or non-geometric properties.

SOS provides a standardized web service interface which allows a client to access descriptions of associated sensors and their collected observations (Na and Priest, 2007). The SOS core profile includes the three mandatory operations *GetCapabilities* for requesting a description of the service and the offered sensor data, *DescribeSensor* for retrieving the metadata documents of the sensors and *GetObservation* for querying observations of certain sensors or phenomena. The response to a *GetObservation* request is encoded in O&M.

O&M specifies basic models and encodings for observations and measurements made by sensors (Cox, 2007). An observation could be defined as an act of observing a phenomenon. A measurement is a specialized observation, whose result is a numerical value. The basic observation model contains five components: The *procedure* element should point to the procedure (usually a sensor), which produced the value for the observation. The *observedProperty* element references the phenomenon. The *featureOfInterest* refers to the real world object to which the observation belongs. The *samplingTime*

attribute indicates the time, when the observation was made. The observation value is contained in the *result* element. It acts as a *property value provider* for a feature as it gives a value (e.g. 6.0) for a property (e.g. magnitude) of the *featureOfInterest* at a certain timestamp (Stasch et al., 2008). The location to which the observation belongs is indirectly referenced by the geometry of the *featureOfInterest*.

3.3 Filtering

The GDACS data archive runs from about 2002. We provide more than 30.000 earthquake events from the last decade and more than 400 tropical cyclones of the last three years. In order to find specific data it is important to provide filter functionally. A typical request would be: the user is interested in all earthquakes with a magnitude greater than 6.0 which took place in Indonesia in 2009. This section describes how our chosen standards WMS, WFS and SOS support such filtering of the data.

OGC defines a general XML encoding for filter expression: the Filter Encoding Standard (FES) (Vretanos, 2004). Such a filter expression logically combines constraints on the properties of a feature in order to identify a particular subset of features to be operated upon. Constraints can be specified on values of spatial (e.g. in Indonesia), temporal (e.g. in 2009) and scalar properties (magnitude greater than 6.0). FES defines spatial operators, comparison operators, logical operators and arithmetic operators.

The WMS standard and the *GetMap* request respectively do not offer a direct capability of filtering. But the Styled Layer Descriptor (SLD) language defines an encoding that extends the WMS standard to allow user-defined symbolization and colouring of geographic features (Lalonde, 2002). Furthermore SLD offers the possibility to define a *FeatureTypeStyle* with so-called *Rules*. These *Rules* can contain filters according to the FES. For this reason it is possible to filter the output of a WMS through the indirect way of using SLDs.

The *GetFeature* request of the WFS standard offers the possibility to use filters to define a set of feature instances. The operating set can be comprised of one or more enumerated features or a set of features defined by specifying spatial and non-spatial constraints on the geometric and scalar properties of a feature type. According to the WFS specification such filter specifications shall be encoded as described in the FES.

The SOS *GetObservation* operation includes a query capability that allows a client to filter observations by time, space, sensor, and phenomena. This leverages FES. The capabilities document for SOS includes a *FilterCapabilities* section that is used to indicate the query parameters supported by the service. The filter capabilities element has been broken up into spatial capabilities, scalar capabilities, ID capabilities, and temporal capabilities.

4. SETTING UP WMS, WFS AND SOS

Setting up WMS and WFS for the earthquake and cyclone event data was quite straightforward. The first step was the transfer of the earthquake data into a spatial database. We used in this case Microsoft SQL Server which supports a *Spatial* system data type since release 2008. Afterwards we exposed the earthquake data as well as the cyclone data (which was already stored in a spatial database before) as WMS and WFS, both through ESRI ArcGIS Server.

Setting up a SOS for the earthquake data was more complex. We chose the existing implementation of the SOS framework of the 52° North Open Source Initiative where all sensor data is stored in a PostGIS database (Broering et al., 2009). The framework defines 14 different database tables for representing *featureOfInterests*, *procedures*, *observations*, *offerings*, *phenomena* and the relations between them. So we started to map our data structure into a proper SOS data structure.

Our first approach was to formally define our whole earthquake event database as one virtual sensor. Our *procedure* is earthquake. Then we have x events (each dataset in the database) which we defined as *FeatureOfInterest*. Each *FeatureOfInterest* has four *offerings*: depth, magnitude, affected population and alert level. But during this mapping process we realized that our whole dataset is not really the kind of sensor data the SOS was specified for. We do not have fixed sensors which are continuously providing observations. Each earthquake takes places in a different location, so the *FeatureOfInterest* is different for each event. The idea behind the SOS specification is to access sensors and their collected observations. So a typical SOS request would be: get observations from date A to date B of sensor X. In contrast we only provide one sensor (of the whole world) where this kind of request is not useful. Sensors and *FeatureOfInterests* in the sense of SOS and respectively O&M are endurants, meaning wholly present at any time (Babitski et al., 2009), whereas our data is more corresponding to perdurants as each event occurs at a certain time.

According to this our second approach was to define only one sensor and one *FeatureOfInterst* (the whole world). For presenting the location of an earthquake we defined 'position' as an additional offering for the *FeatureOfInterest*. This approach is more consistent with the SOS and O&M model. So we decided to transfer all our data from the existing database schema to the given schema of the 52° North SOS PostGIS tables using the described mapping approach. After this data transfer we successfully initialized the SOS.

5. IMPLEMENTAION OF A FILTER SERVICE

As described in chapter 3.3 it is important for us to filter the disaster event data. Normally we only need a subset of the data for the visualisation or the further processing. The WMS interface offers the possibility to send a SLD within the *GetMap* request for retrieving a map containing only such a desired subset. Within these SLDs it is possible to define filters using FES expressions. These FES expressions can also be used within the WFS *GetFeature* request for retrieving filtered features encoded as GML. The underlying data structure for the WMS and the WFS interfaces is the same. According to this the filter expressions for both services are exactly the same.

The underlying data model of the SOS is different compared to the WMS/WFS data structure. This means that in this case the before mentioned filter expressions cannot be transferred one-to-one as they are different.

We realized such filter functionality through the implementation of a Filter Service, modelled in the style of an OGC Web Service. Our service offers five operations: *GetCapabilities*, *GetFilter*, *GetFeature, GetSLD* and *GetMap* which are all

executable via HTTP GET requests. The *GetCapabilities* operation responds with the capabilities of the service, meaning the operations that are available and a description of possible parameters. These parameters are described in Table 1.

Parameter	Description	Remark
DISASTER	Type of disaster; values "EQ" (earthquake) or "TC" (tropical cyclone)	
START	Time span; both expressed as YYYYMMDD	
END		
STORE	Result shall be stored on server (URL to result is responded) or not; true or false (default)	
AFFECTEDPOP	Affected population more than requested numerical value	In case of DISASTER=EQ
MAGNITUDE	Magnitude larger than requested numerical value	
DEPTH	Depth smaller than requested numerical value	
RED	Red Alert Level; true (default) or false	
ORANGE	Orange Alert Level; true (default) or false	
GREEN	Green Alert Level; true (default) or false	
CYCLONENAME	Name of requested cyclone	In case of DISASTER=TC

Table 1 – Parameters of the implemented Filter Service

If a user sends a *GetFilter*, *GetFeature, GetSLD* or *GetMap* request to the Filter Service, it creates a filter by means of the given parameters and according to the FES. In case of a *GetFilter* request this produced filter is directly sent back to the user who can use it for further purposes. In case of a *GetFeature* request the Filter Service includes the produced filter into a WFS *GetFeature* request and forwards it to the disaster event WFS. The GML encoded features returned by the WFS are then sent back to the user as a response.

In case of a *GetSLD* request the produced filter is integrated into a SLD which is sent back to the user as the response to the request. In case of a *GetMap* request to the Filter Service the filter is also integrated into a SLD which is then integrated into a WMS *GetMap* request and forwarded to the disaster event WMS. The map returned by the WMS is then sent back to the user of the Filter Service as a response. All operations offer the alternative possibility to receive the result not directly as a response but to store it on a server (parameter STORE=true). In

this case the response is the URL to the stored result. This is useful if the result shall be used repeatedly and not only once.

One example where we use the Filter Service is the integration of the disaster event data into our Web Map Viewer (http://dma.jrc.it/map) which is based on the JavaScript *OpenLayers* library. The user can choose his filter criteria in a web form (Figure 1). The viewer builds a *GetSLD* request according to the given criteria and sends it to the Filter Service. As the parameter STORE is set to 'true' the SLD is stored on a server and the Filter Service returns the URL to the SLD as response. The viewer requests the map from the WMS via the OpenLayers API which offers the possibility to include an URL to a SLD as an optional parameter.

Figure 1 - Web form for setting filter criteria

Another example where we use the Filter Service is the integration of the disaster event data into the GDACS website (www.gdacs.org). Also here the user can choose filter criteria in a web form and a *GetFeature* request is created and sent to the Filter Service. As the parameter STORE is set to 'false' the Filter Service produces the filter according to the criteria of the user, includes it into a WFS *GetFeature* request and sends it to the disaster event WFS. The GML encoded features returned by the WFS are then transformed by an XSLT document into a simple listing which is included into the website (Figure 2).

Figure 2 - Filtered results included in a website

The Filter Service is extendable with regard to other disaster types or in general to other feature types available as WMS/WFS. We originally planned to offer and implement also a *GetObservation* request for returning filtered observations from the SOS providing the earthquake data. But during the work we realized that through the WFS and the corresponding filtering all our use cases are already covered.

6. DISCUSSION AND CONCLUSION

We successfully integrated earthquake and tropical cyclone data into an SDI and offer them now through the well-known WMS and WFS standards. To allow a reasonable use of the data we implemented in addition a Filter Service for offering the possibility to easily retrieve only a subset of the data the user is interested in. The setup of WMS and WFS was quite straightforward without occurring hassle.

As our data is quite dynamic we also had a look at the recently developed standards of the SWE initiative, especially the SOS and the O&M encoding. Thereby we realized that our data model is not really compatible with these specifications and we could only "forcibly press" it into these interfaces. The basic concept behind WFS/GML is the *Feature* which is very general. Therefore a *GetFeature* response does not contain explicit semantics. In contrast to this the basic concept behind SOS/O&M is the *Observation*. Therefore a *GetObservation* response is semantically well defined. It contains an event whose result is a value of some property of a *FeatureOfInterest*, obtained using a specific procedure. For our purposes the *Feature* concept is perfectly sufficient and we do not see the need to model and offer the data also according to the *Observation* concept.

The main point here is that our data is indeed derived from sensors but it is already processed and aggregated while SOS/O&M were developed for "real" sensor data, meaning to give the possibility to access sensors and their observations directly. Up to now we do not see the necessity of offering our data also through a SOS as all our use cases are covered by the WMS and WFS standard and the adequate filter mechanisms. But in the future we will also integrate our flood data repository into the SDI which consists of time series. For this purpose the SOS standard seems to be more appropriate (Bermudez et al., 2009).

Another advantage of WFS/GML is that both are established standards and well accepted in the geospatial domain. Therefore many applications support these interfaces and allow the easy integration. This includes for example also the OGC Web Processing Service (WPS) interface which allows GML encoded data directly as input for subsequent processing. SOS/O&M on the other hand are still quite new standards and not yet as well supported in common geospatial applications as WFS/GML.

In conclusion we provide now more than 30.000 earthquake events of the last ten years and more than 400 tropical cyclones of the last three years through standardized and well-known OGC Web Services, namely WMS and WFS. Furthermore we offer the easy filtering of this data through the implementation of a Filter Service.

7. REFERENCES

Babitski, G., Bergweiler, S., Hoffmann, J., Schoen, D., Stasch, C. and Walkowski, A., 2009. Ontology-based Integration of Sensor Web Services in Disaster Management. Proceedings of the 3rd International Conference on GeoSpatial Semantics, Mexico City, Mexico.

Beaujardiere, J. de la, 2006. OpenGIS Web Map Server Implementation Specification. Version 1.3.0. OGC 06-042.

Bermudez, L., Bogden, P., Bridger, E., Cook, T., Galvarino, C., Creager, G., Forrest, D. and Graybeal, J., 2009. Web Feature Service (WFS) and Sensor Observation Service (SOS) Comparison to Publish Time Series Data. International Symposium on Collaborative Technologies and Systems, pp. 36-43, International Symposium on Collaborative Technologies and Systems 2009, Baltimore, Maryland, USA.

Broering, A., Juerrens, E. H., Jirka, S. and Stasch, C., 2009. Development of Sensor Web Applications with Open Source Software. Proceedings of the 1st Open Source GIS UK Conference, Nottingham, UK.

Cox, S., 2007. Observations and Measurements – Part 1 – Observation schema. Version 1.0.0. OGC 07-022r1.

Lalonde, W., 2002. Styled Layer Descriptor Implementation Specification. Version 1.0.0. OGC 02-070.

Na, A. and Priest, M., 2007. Sensor Observation Service. Version 1.0.0. OGC 06-009r6.

OGC, 2008. OGC Reference Model. Version 2.0.0. OGC 08-062r4.

Portele, C., 2007. OpenGIS Geography Markup Language (GML) Encoding Standard. Version 3.2.1. OGC 07-036.

Stasch, C., Bröring, A. and Walkowski, A. C., 2008. Providing Mobile Sensor Data in a Standardized Way - The SOSmobile Web Service Interface. Proceedings of the 10th AGILE Conference, Girona, Spain.

Vretanos, P., 2002. Web Feature Service Implementation Specification. Version 1.0.0. OGC 02-058.

Vretanos, P., 2004. OpenGIS Filter Encoding Implementation Specification. Version 1.1.0. OGC 04-095.