Sensor Web and Web Processing Standards for Crisis Management

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ABSTRACT

This paper introduces the latest state of the interoperable Sensor Web and Web Processing standards specified by the Open Geospatial Consortium. Based on these components it becomes possible to share, integrate and analyse observation data across political and administrative borders as well as across multiple thematic domains. We present the 52°North open source implementations of the OGC SWE and WPS standards and introduce an outlook how this technology could be applied in the field of crisis management. Thus, this paper aims at providing a perspective how currently existing technology can be combined and applied to solve problems in emergency management rather than describing an already finished product. Special consideration will be given to the combination of Sensor Web and Web Processing technology which opens up new possibilities by having near real-time data flows that can be linked on-demand to different processing services.

Keywords

Interoperability, Sensor Web, OGC Sensor Web Enablement, OGC Web Processing Service.

INTRODUCTION

In recent years the Sensor Web Enablement (SWE) architecture of the Open Geospatial Consortium (OGC) has matured into its second generation (Bröring et al., 2011). Similarly, the OGC Web Processing Service (WPS) (Schut, 2007) is now approaching its 2.0 specification version, as well. Several practical projects in domains such as hydrology (Spies and Heier, 2010) and air quality (Jirka et al., 2012) have shown the flexible use of this technology in different application contexts. Furthermore, the projects TRIDEC (Wächter et al., 2012), GITEWS (Raape et al., 2010), OSIRIS (Tacyniak et al., 2008), and SANY (Klopfer and Simonis, 2009) have shown the applicability and benefits of the SWE and WPS standards in the field of early warning systems and crisis management. Especially for the field of emergency management the use of standardized interfaces, data models, and encodings promises significant advantages. The high flexibility of such web-based interoperable architectures allows integrating new data sources and processing functionality. It thereby offers a good mechanism to adjust emergency support systems on-demand by integrating new resources via the Web. Depending on the situation at hand, a user is able to rely on additional data sources as well as functionality, as long as it is available through standardized interfaces. Client and server components from different vendors and across emergency response organizations can immediately be coupled.

OGC Sensor Web Enablement

A need for interoperably exchanging measurement data across organizational and political boundaries was a driving factor behind the development of the Sensor Web Enablement (SWE) framework of the Open Geospatial Consortium (OGC). The SWE architecture has been defined as a set of interfaces, data models, and data formats for the integration of sensors and sensor data into spatial data infrastructures. It comprises functionality for (Botts et al., 2007):

- accessing sensor data (Sensor Observation Service, SOS, Bröring et al., 2012),
- controlling measurement processes and sensors (e.g. setting sampling rates),

- filtering sensor measurements according to user defined criteria (e.g. exceeding a threshold) (Sensor Event Service, SES, Echterhoff and Everding, 2008),
- providing metadata about sensors and their measurements, and
- discovering sensors.

OGC Web Processing Service

Web processing is a well-known approach to share resources over the web and many different application scenarios have been described (Peisheng et al., 2012). To have a uniform way how such processing functionality can be discovered, described and executed, the OGC has developed a further standard covering exactly this aspect: The OGC Web Processing Service (WPS). Motivations behind web-based processing are collaboration, security concerns, as well as advantages through abstraction and reusability. Examples of successful application of these patterns are the INTAMAP (Pebesma et al., 2011) and SSE Grid (Goor et al., 2010) projects as well as the Spatio-temporal aggregation Service (STAS, Stasch et al., 2012). In INTAMAP a WPS is used to wrap the complexity of a data interpolation task done in the R environment for statistical computing. The system can provide advanced user control but also allows easy integration of sophisticated statistical interpolation into a wide range of applications without requiring specialized skills. This includes the request to provide the interpolation within a certain time frame for time-critical disaster use cases. In SSE Grid the WPS is used to provide access to a Grid-based on-demand processing for earth observation data while minimizing the transfer of data volumes and at the same time abstracting from the complex system underneath. Here the WPS is also extended to provide process control and monitoring features from a web-based frontend for a large computing facility. Instead of extending, the STAS is an example of a WPS profile. It provides on-demand spatio-temporal aggregation, utilizes the SOS for input data retrieval and relies on the transactional SOS interface (SOS-T) for output data storage for a specialized data model and a specific use case.

The aim of our work is to further facilitate the flexible integration of Sensor Web technology with the OGC WPS. As a result new tools for application domains such as emergency management will become available. Through the use of standardized interfaces it becomes possible to put together just the data sources that deliver a real-time view of the environment, potentially conventional geospatial data from spatial data infrastructures, and precisely the processing algorithms a user needs in a specific situation.

SENSOR WEB ENABLEMENT IMPLEMENTATIONS

The design of the 52°North Sensor Observation Service server implementation (http://52north.org/sos) is based on a flexible modular architecture. Special attention has been given to the design of a data access layer that facilitates the customization of the SOS server to different database types and models. In its latest version, the 52°North SOS relies on the Hibernate framework so that it is possible to configure the SOS to work with already existing databases[1]. For organizations that want to make their data accessible thorough the SOS interface this is a valuable feature as they do not need to change their existing database architecture. This is complemented by comfortable tools for installing and administrating SOS servers. The upcoming 4.0 release of the 52°North SOS will feature a full support of all operations specified in the OGC SOS 2.0 standard. Besides functionality for accessing sensor data it also comprises operations for publishing new sensor observations on a running SOS server.

For visualizing the observation data (i.e. time series data) accessible through SOS servers, several clients are available. An example for a web-based tool is the 52°North Sensor Web Client (http://52north.org/SensorWebClient). This application offers a comfortable graphical user interface for selecting time series and displaying according graph visualizations. An example of a client for advanced geospatial analysis is the one R environment for statistical computing and graphics (Nüst et al., 2011). An especially important aim during the design of the mentioned client was to hide the complexity and technical details of the SWE specifications from the user. Non-IT-experts that are not familiar with the SWE standards are able to use the Sensor Web Client for answering their questions. Also, a high degree of compatibility and platform-independency were driving factors during the client development. The client relies on the Google Web Toolkit (GWT). GWT translates the Java program code of the client automatically to different JavaScript variants. These are optimized to the individual capabilities of different browsers, which is especially useful to support older browsers often found in professional IT maintenance systems. Figure 1 provides an impression of the time series view. A user is able to display time series data (even multiple time series with different parameters from different stations) as a diagram. The user can discover correlations and compare values. A

[1] http://blog.52north.org/2012/12/21/new-52north-sos-4-0-0-beta1-released/

legend provides information about the different time series and a map helps the user to locate the position of the sensor stations.

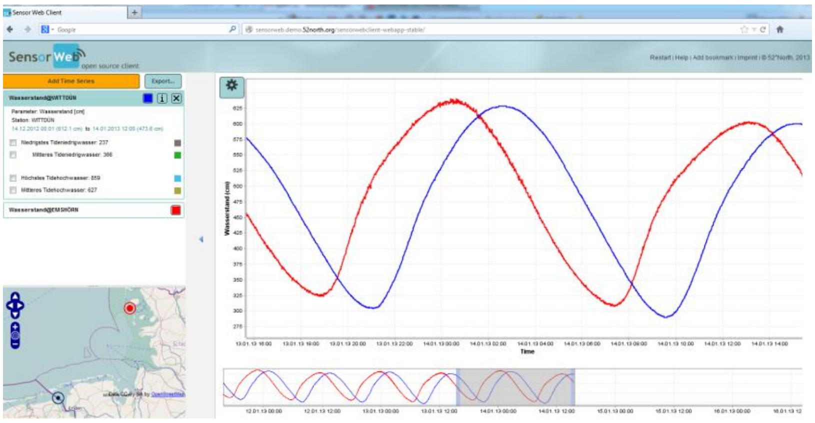

Figure 1. Sensor Web Client for Displaying Time Series Data

Risk monitoring use cases require to receive notifications as soon as a critical situation occurs (e.g. if the water level at a certain location rises beyond a threshold).

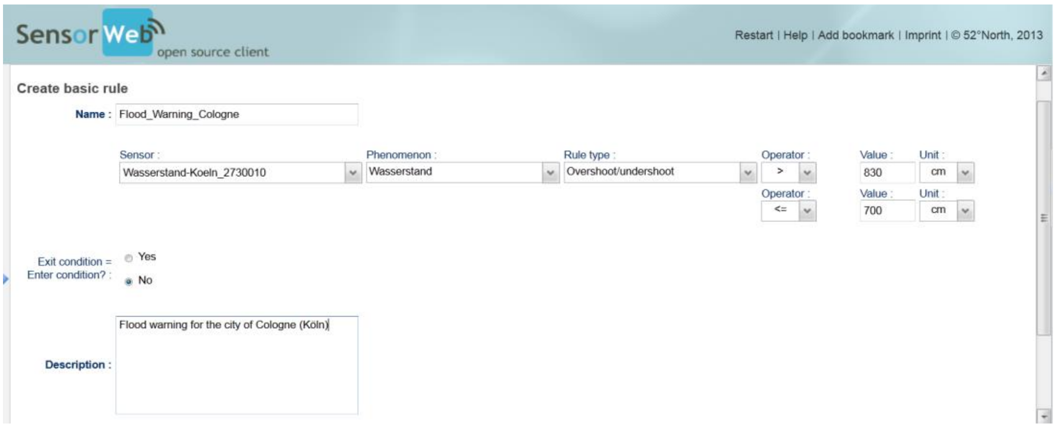

Figure 2. Sensor Web Client for Subscribing to Alert Notifications

For this purpose, the Sensor Web client offers a web form to define individual notification rules and to use the OGC SES to subscribe to these rules. Typical rules that need to be considered comprise: crossing of a threshold (e.g. water level above 830 cm), sum rules (e.g. the accumulated rain fall within the last hour exceeds 10 mm), and trend monitoring (e.g. the temperature has increased for more than 10°C within the last 10 minutes). In addition it is possible to combine multiple rules through logical operators so that complex notification conditions can be defined. Figure 2 shows an exemplary screenshot of the notification/eventing client. In this case a flood warning message based on a network of water level measurement stations along all German federal waterways is created.

WEB PROCESSING SERVICE IMPLEMENTATION

The 52°North WPS (http://52north.org/wps) is an example implementation of the WPS standard. It is a Java-based and fully OGC compliant. A plug-in architecture allows easily integrating new process types as well as data encodings. This leads to a very flexible framework which can be extended to the needs of a specific application scenario. In addition, this WPS implementation offers several features such as a graphical configuration and administration interface, support of synchronous and asynchronous processing tasks, and a transactional interface that allows users to upload their own processing algorithms into a running WPS server. By default, the 52°North WPS can use processing functionality that is provided in Java, through external third-party libraries, and full GIS computing environments. Thus, a WPS operator can easily rely on the full range of processing capabilities offered by processing backends[2] such as SEXTANTE, GRASS, ArcGIS Server, or R.

[2] http://52north.org/communities/geoprocessing/wps/backends.html

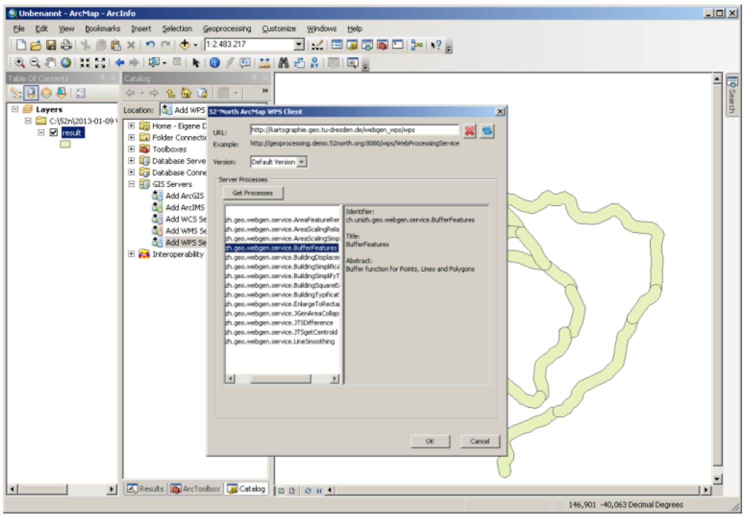

Figure 3. Example of WPS Client (within ArcMap)

Finally, besides the server-side implementation, there is also a set of client applications available that support the use of processing functionality provided through WPS servers. For the following GIS tools and frameworks, WPS support is already available[3]: uDig, Open Layers, Jump, ArcMap (see Figure 3), and Quantum GIS. Complementary to this, there is also a Java Client API for software developers who want to integrate connections to WPS servers into their own software.

COMBINING SENSOR WEB AND WPS TECHNOLOGY

After the SWE and WPS standards have been introduced, this section aims at discussing the combined use of these concepts. The main advantage is that information products can rely on live observation data as input for further processing. Examples for such processes could be the calculation of risk maps showing evacuation zones, the determination of areas that are affected by a disaster (e.g. like in the TRIDEC project), the prediction of the spreading of an air pollutant cloud, or simple data conflation and conversion. Recently projects such as EO2HEAVEN and TRIDEC have addressed the combination of the SWE and WPS technology. However, still relatively high efforts are necessary to combine SWE and WPS implementations in practice. To overcome this challenge, especially two aspects need to be addressed. On the one hand it is necessary to address this problem from an interoperability perspective. The SWE and WPS standards have intentionally been designed to accommodate a very broad range of use cases and requirements. Thus, they offer sometimes different ways to achieve the same functionality or to encode a certain data or metadata element. This can lead to reduced interoperability. To solve this issue, the development of according profiles of the standards is necessary (comparable to the development of WaterML 2.0 in the hydrology domain). This way, the requirements of crisis management can uniquely mapped on the according standards so that a common approach for using the SWE and WPS concepts across different implementations is ensured. On the other hand, software development aspects have to be considered. In the current situation SWE and WPS implementations are often developed in a rather isolated manner, while common libraries (e.g. common en-/decoders for SWE and WPS) are not used in many implementations. To facilitate the integration of SWE and WPS, especially for linking them to integrated clients, such libraries are needed.

CONCLUSION AND OUTLOOK

Within this paper we have presented an outlook how a closer integration of the OGC SWE and WPS standards will help to build powerful decision support applications for the field of emergency and crisis management. Through the SWE standards an improved situational awareness will be achieved as the integration of new data sources becomes easily possible. This can be complemented by the WPS standard so that users are able to access new algorithms on demand, specifically answering the questions they have in a certain situation. Even though first projects such as TRIDEC have shown the benefits of combining these technologies, the integration of SWE and WPS components is still an often cumbersome task. Besides aspects that are rather related to software development, it is also necessary to improve interoperability. The next steps will be to enhance

[3] http://52north.org/communities/geoprocessing/index.html

common libraries that facilitate the coupling of SWE and WPS servers (e.g. the 52°North OX-Framework). Actors in emergency management must provide requirements so that interoperability can be increased based on customized profiles of the introduced standards. As this work is still in progress, we intend to animate the discussion on these topics.

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