Boosting the OGC Sensor Web Enablement Initiative by Open Source Web Services – The Case of 52°North

Adam SLIWINSKI, Ingo SIMONIS, Albert REMKE, Ulrich STREIT and Andreas WYTZISK

Abstract
The contemporary efforts regarding Sensor Web Enablement (SWE) pave the way towards an interoperable integration of real-time geosensor data into Geospatial Data Infrastructures (GDIs). Web services establish a key technology within this context. In this paper, we draw a line from simple models of stationary and mobile geosensor networks through the specification and standardization of SWE services to the engineering of appropriate software implementations. All these are at the heart of the recently established free and open source initiative called 52°North.

1 Introduction
As far as geospatial information science is concerned, Sensor Web can be viewed as a new breed of distributed systems for monitoring geospatio-temporal phenomena (objects and processes) appearing in the physical environment. Unattended and untethered geosensors either remain at fixed locations (e.g. as part of weather stations) or move autonomously or are carried by agents in physical space (e.g. on board of vehicles measuring the diffusion of pollutants). Once deployed, each geosensor associates the phenomenon it senses with the location it currently populates and stores the respective data. The retrieval and processing of geosensor data, but also the management of sensor devices (i.a. tasking), will soon be carried out by means of distributed software entities that interoperate via the Internet.

Interoperability has been a major concern within the user and vendor communities of geospatial information technologies for years. In general terms, interoperability is the ability of distinct software entities to communicate with each other, i.e. mutually invoke operations and exchange messages. The web service architecture presently gains momentum as one possible approach to achieve interoperability across system boundaries. Numerous publications explain the nature of web services and the technological benefits that accompany them (see e.g. GOTTSCALK et al. 2002, KOSSMANN & LEYMANN 2004). In this paper, a web service is defined as a distributed software entity which provides access to its functionality via an interface, and which is described, published, discovered, and invoked over the web.
Syntactic interoperability between different web services is to a great degree assured by an array of existing industrial standards (e.g. HTTP, SOAP, WSDL, UDDI, XML). The Open Geospatial Consortium (OGC) complements these (partly ongoing) efforts by issuing implementation specification for web services (e.g. WMS, WFS, CS-W, GML). These specifications particularly support users from the geospatial information domain. In this paper, the main focus is on OGC’s work on Sensor Web Enablement (SWE) and how it may propel the establishment of interoperable geosensor networks. We also seize the opportunity to introduce the recently founded free and open source software initiative 52°North which, inter alia, tackles the research and engineering tasks being related to SWE.

2 Geosensor Networks

2.1 Stationary and Mobile Networks

At present, research on geosensor networks gains increasing attention in geospatial information science (see e.g. NITTEL et al. 2004). Such networks may be deployed to monitor and capture the geospatio-temporal variance of phenomena appearing in physical space. The application domains for geosensor networks are manifold. The microclimate monitoring in a particular habitat patch or an urban area is just one candidate. Thereby, each node in the geosensor network continuously measures (possibly in different frequencies) one observable or a set of distinct observables at the location it resides. The observables may comprise sunlight, temperature, humidity, air pressure, precipitation, or wind speed at ground, depending on the geosensor hardware capability. The resulting fine-grained (in terms of their spatial and temporal resolution) data enable the scientists to obtain unprecedented models and predictions of objects and processes in the physical environment.

Here is an abstract example: let \( S \) denote a finite set of stationary geosensors and let \( M \) denote a finite set of mobile geosensors that are either self-propelled or carried in space by agents. These two geosensor networks monitor an environmental phenomenon that retains
its extent but changes its location as time elapses. Figure 1 depicts the spatial distribution of elements of $S$ and $M$ in planar space. While each element of $S$ retains its location in $t=0$ through $t=i$ to $t=n$, elements of $M$ proceed from one location to another as time goes by. Thereby, mobile geosensors may adapt their mobility to the exposure of the phenomenon in order to improve the geospatial representation of the phenomenon being captured over a finite time period (SLIWINSKI & SIMONIS 2005).

2.2 From Geosensors Networks to Distributed Computing Systems

It is highly likely that operational geosensors will be designed to immediately transmit their data in order to avoid any data loss resulting from power outages or hardware damages. Let us assume that the data acquired by $S$ is stored at a location different from the location of data acquired by $M$. Furthermore, let us assume that these two geospatial datasets are encapsulated by two different GI service instances that make the data available to client applications upon a request. We may take for granted that scientific, governmental, or commercial inquiries may require an integrative processing of complementary geosensor datasets that come from different sources and which possibly exhibit nonconforming data encodings, adhere to different data models, or expose different semantics.

Rapid advances in software and hardware technology in the last two decades make it possible to establish distributed computing systems from multiple machines located at distinct physical locations. The main benefit of such a system, as far as the geospatial information domain is concerned, is to allow any user to seamlessly access different geospatial datasets and geoprocessing functionality from remote locations and concurrently share own ones with other users to allow for unprecedented computational collaboration.

GI services constitute a recent technological innovation. They begin to cater to such a computational collaboration. The capability associated with a GI service can vary. While one GI service may specialize in data retrieval, others may support the processing, manipulation, integration, analysis, or visualization of geospatial data from multiple sources. A single GI service itself can possess a considerable capability, but it also constitutes a part of a greater whole. This is often the case if more sophisticated tasks need to be accomplished. The contemporary state of the art of technology enables several instances of different GI services to be loosely or tightly aggregated to form service chains that may support such tasks (ALAMEH 2003).

2.3 On the Need for Interoperability of GI Services

Any distributed computing system is by virtue of its network structure a highly dynamic system. Geospatial Data Infrastructures (GDIs) follow this approach. With regard to the architecture underlying the majority of GDIs, additional GI services may join after the infrastructure has been launched. Others may increase their capability. Some will be replaced by better ones. For simplicity reasons, let us assume three different GI services: $A$, $B$, and $C$ within an exemplary GDI. If a client aims at establishing a transparent service chain that has the sequence $ABC$, bilateral interface agreements between the providers of
A and B as well as B and C must be implemented in order to assure interoperability. Other clients may eventually require the same services, but chained within another sequence, for instance CAB. Thus, the service providers are urged to maintain interoperability by signing and implementing an additional bilateral interface agreement in order to enable A to interoperate with C.

It is not beneficial to establish interoperability by means of bilateral interface agreements in such a distributed system environment. With \( n \) distinct GI services, this would end up in \( 0.5n(n-1) \) proprietary solutions to achieve global interoperability. With every new service joining the system, additional \( n-1 \) interface agreements would have to follow. A tedious implementation work is the consequence for all GI service providers. The approach usually taken to avoid such complexity is to agree upon standards and specifications that declare the interoperability rules for all parts of a distributed computing system. This is precisely the approach the Open Geospatial Consortium follows in order to assure that GI services of various types become interoperable within GDIs.

3 OGC Sensor Web Enablement

3.1 The Vision

The Sensor Web Enablement Working Group at OGC puts its focus on standard interface specifications and data encodings for GI services that enable the interoperable integration of geosensor data into GDIs. This group must tackle problems that still hinder the harvesting and integrative processing of real-time data from such geosensor types like flood gauges and air pollution monitors, as well as space and airborne earth imaging devices. They have, however, made a lot of progress.

SWE’s vision is to enable a distributed computation of geosensor data by means of web services. In this context, the trading function (aka publish-find-bind pattern) plays an important role (ISO/IEC 1998). This function facilitates the publishing and finding of web services that relate to SWE. While the geosensor data provider publishes its service by storing a service description (metadata) within a registry run by a service broker, the service requestor browses the metadata available in the registry to decide on a suitable service. Once the requestor identifies a particular service for use, he can bind his client or another service to it as specified in the technical part of the respective metadata record.

3.2 Web Service Implementation Specifications

Although the SWE working group at OGC has already issued a stack of implementation specifications as discussion papers (Botts & Rechardt 2003), the following chapter gives a brief description of three of them, i.e. Sensor Observation Service (SOS), Sensor Planning Service (SPS), and Web Alert Service (WAS).

The Sensor Observation Service (SOS) specification, which overrides the Sensor Collection Service (SCS) specification, describes a web service interface for the retrieval of data acquired by one or a community of geosensors via the Internet. This service type
A. Sliwinski, I. Simonis, A. Remke, U. Streit and A. Wytzisk

establishes an intermediary entity between the client and a geosensor data repository or a gateway to near real-time geosensors. If required, client applications that interact with SOS instances can also request metadata that describe the geosensor(s) behind an SOS.

The Sensor Planning Service (SPS) offers an interface for requesting metadata about its capabilities, for determining the feasibility of an intended sensor planning request, for delivering the request parameterization template, for submitting such a request, for inquiring about the request’s status, and for updating or canceling the request. The SPS is particularly beneficial if a geosensor or other data generator cannot immediately provide data for a certain location and/or point in time. For instance, an SPS may encapsulate a simulation model that needs a while to answer a request. After a request has been parameterized and submitted to the SPS, the requesting user/service in turn receives a process identifier. This must be used after a notification about the availability of simulation results has taken place in order to retrieve the respective result.

The Web Alert Service (WAS) plays a crucial role when it comes to the dynamic composition of service chains. Since domain experts are not involved in the web service business, a service is needed to provide an interface to register a set of observation and processing rules. The WAS processes the rule set while gathering the necessary geosensor data by making use of dynamic GI service chain composition (Simonis & Wytzisk 2004). Automatic GI service chain composition, however, is still a complex task. The next section demonstrates an alternative approach that requires a previously defined chain description.

3.3 Translucent Service Chaining

Interoperability is a precondition for building GI service chains. Such chains may encapsulate compound functionality that can be used by a client by transferring a valid request. Figure 2 illustrates an exemplary translucent GI service chain. Translucent chaining addresses an automated execution of GI service chains by means of a workflow enactment service (ISO/TC 211 2002). This chaining type, however, requires an existing formal description of a service chain that matches the user requirements (eventually with minor modifications) and thus can be reused by the client application. If no formal description exists, the user himself must formally define a new service chain that fits his task.

The GI service chain illustrated in Figure 2 returns an image rendered by a Web Mapping Service. It portrays a surface representation of the geospatio-temporal phenomenon in scope which is interpolated from a point pattern of geosensor measurements for the same observable, where the point pattern is provided by different geosensors networks encapsulated by different SOSs. Once the respective service chain definition is at hand, the client requests a workflow enactment service to execute it as depicted at (1). The workflow enactment service determines the GI services in the chain and invokes the sequence step by step. As depicted, SOS 1 constitutes the initial service (2a). Upon notification of completion of the first service, the workflow enactment service determines the subsequent GI service in the chain and invokes it (2b). This pattern repeats until the last SOS is invoked (2c). In the meantime, the workflow enactment service collects the intermediary responses conveying geosensor data. It passes them to the processing service for geospatial
interpolation at (3). Upon notification of completion of the second last service, the workflow enactment service receives the response encoding and forwards it to the Web Mapping Services for rendering (4). The resulting image is forwarded by the workflow enactment service to the client applications for display to the user as the output of the chain execution (5).

Fig. 2: Translucent GI service chain

4 The Free and Open Source Software Initiative 52°North

4.1 Background and Mission

Modern geospatial information and communication technology shall foster human decision making by ensuring a seamless access to usable geospatial data and geoprocessing functionality. Today, one of the challenges in the international geospatial information community is the development and deployment of distributed technology arrangements that provide means for accessing, exploring, and utilizing the aforementioned resources over a pervasive communication network like the Internet – anywhere, anytime, and with any device. A purposeful step in this direction is the establishment of Geospatial Data Infrastructures (GDI). This is a process currently gaining respectable momentum worldwide.

Concurrently, research bodies and the software industry explore a new software business model that proves beneficial for both the software user and the respective provider. Free and open source software development can no longer be exclusively associated with non-commercial, independent developer communities. It also represents an economically viable model for the software industry. These two orthogonal trends establish a tremendous challenge in geoinformatics. This new business model still remains unexplored with regard to its technological and commercial potential.

The Institute for Geoinformatics at the University of Münster and con terra GmbH rose to this challenge in late 2004 and founded the free and open source software initiative

1 http://www.52north.org.
52°North. As of February 2005, the International Institute for Geo-Information Science and Earth Observation (ITC) in Enschede (The Netherlands) joined 52°North as a principal partner. 52°North’s mission is to advance the design, development and use of open source software in geoinformatics research, training and application. It is also about bridging the gap between open source and proprietary solutions. Not limited to, but of a key interest to this conjoint initiative is the development of software for the acquisition, analysis and visualization of geospatial data within open GDIs. Sensor Web Enablement (SWE) constitutes one of the focal areas of 52°North’s activities. The widest possible dissemination and popularization of the already developed SWE software in the market for geospatial information technologies (public and private users, research and education bodies, developer communities, commercial entities etc.) is assured by publishing it under the GNU General Public License.

Moreover, the research and software development activities will be tailored to accompany technical innovations and user oriented software releases. Quality management is of paramount importance as it helps to keep track of software usability and continuity. At the same time, the initiative fuels national and international standardization efforts relevant for the software in scope. The Web Notification Service (WNS) specification for instance, as a key element of the existing SWE specifications of OGC, has its roots in 52°North. Based on the already existing network of excellence for geospatial information technologies, which spans across science and industry, 52°North shall empower the development of free and open source software, its deployment, and use.

4.2 Exploring New Technological Horizons in SWE

The contemporary advancements in the field of SWE are propelled by alterations in user requirements, novel methodological and theoretical approaches in geospatial information science, as well as by the rapid technological progress in general. These advancements share a common trend: proprietary and monolithic software solutions begin to vanish while open, distributed, and interoperable systems come into being.

52°North’s SWE Working Group reflects current trends and requirements specified by users by making real-time geosensor data available by means of web service technology. Its current software portfolio consists of a Sensor Observation Service (SOS), a Sensor Planning Service (SPS), a Web Alert Service (WAS) and a Web Notification Service. Additional components also play an important role in bringing SWE to life. These are, inter alia, services that govern access to raster data (Web Coverage Service, WCS), but include also geosensor registries. Hypothesizing that the success of any new SWE software strongly depends on its user-orientation, a multi-functional client, which is intended to interact with any SWE related service, and an WCS coverage import tool are under development.

To ensure a sustainable and successful development of GI services over the next years, technological needs will have to be anticipated. Direct sensor-sensor communication, continuous data streaming that cannot be put on top of HTTP, or new interaction patterns between components for publishing or subscribing geosensor based events will have to be addressed respectively.
Although of paramount importance, the short-term software engineering objectives introduced in the previous paragraphs do not put an end to long-term academic research objectives. One such long-term research topic is the development of distributed simulation architectures in which SOSs play a crucial role (Simonis et al. 2003). To give an example, damage amounting to almost three billion Euros was caused by the Elbe river floods in 2002. It was almost impossible to quickly compute any reliable forecast about the time and location of possible bursting dams at that time. No doubt, it would have been very helpful if the emergency management units had accurate knowledge about the affected areas in order to prepare and execute evacuations in time. This knowledge can be accumulated to some extent from simulations. It is absolutely necessary to provide simulation capabilities that are available instantaneously to each decision maker and instantly provide information about geospatial conditions at a future point in time (Simonis & Cox 2003). Appropriate ideas and methodological approaches materialize and shed light upon ubiquitous web based simulation technology that soon will enable the responsible bodies to answer the important question: What would be here and there if…? OGC’s work on Sensor Web Enablement establishes a starting point en route to the integration of GI services and simulation models within GDI.

4.3 Flood Alerting Demonstrator

A project at 52°North has recently been set up to assemble the prototypical SWE components2 developed by this initiative and to provide a demonstrator for a realistic flooding alert scenario (Walkowski 2005). The system notifies the user whenever flooding is expected for a (user) registered location in the proximity of a river. Its architecture is depicted in figure 3.

The following paragraph briefly describes the demonstrator’s3 functionality. At (1), the user invokes an WAS by means of a client application (see figure 4) and registers a set of locations for which he or she wishes to receive alerts whenever a critical water level is forecasted to put these locations at risk. The user specifies the target threshold and the preferred communication channel (e.g. WWW, e-mail, SMS or phone call). Subsequently, the WAS subscribes to an appropriate SOS (2) with the goal to continuously receive real-time and archived data from relevant water gauges along the river (3). The WAS uses this geosensor data to parameterize a simulation model by means of an SPS (4). In turn (5), the WAS receives an identifier to be retained for later use. The planning service encapsulates the simulation model which, upon execution, computes a water level forecast for user locations based on data from the nearby water gauges (6). After the simulation terminates, the results are made accessible by another SOS (7). The WAS then receives notification that the simulation data can be retrieved from the SOS (not illustrated in the figure). Using the identifier from (5), the WAS invokes the SOS (8) and retrieves this simulation data (9). If the simulation results for the user location(s) exceed the custom threshold value, the WAS dispatches an alert message to the WNS (10). The notification services

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2 By the opening of AGIT 2005 the 52°North’s SWE services, at least the SOS implementation, will be issued as stable releases.
3 The demonstrator is accessible via the 52°North web page http://www.52north.org. Please navigate to: Development → Projects → Flooding Scenario.
then notifies the user about impending flooding via the user’s preferred communication channel (11).

Fig. 3: GI service architecture to support a flooding alert scenario

Fig. 4: Screenshot of the demonstrator’s web client application

5 Conclusion

This paper has introduced a world of stationary and mobile geosensors and the related research and software development efforts undertaken at 52°North. The Sensor Web Enablement working group at OGC can be seen as an ‘early bird’ in this field. This group issues standard interface specifications and data encodings for GI services that enable the
interoperable integration of geosensor data into Geospatial Data Infrastructures. The importance of this new breed of technologies is unquestionable. Many decision makers are likely to benefit from the knowledge gained from geosensor data. Moreover, the Internet technologies revealing the power of geosensor networks represent innovative technology in which many developments are in their infancy and which leads to more questions than answers. But we are convinced that free and open source software development will gather the necessary resources to proceed toward mature technologies. What proved an appropriate approach to engineer implementations of the OGC Web Map Service (e.g. UMN Map Server), the OGC Web Feature Service (e.g. GeoServer) and Co. can be assumed to fuel the engineering of Sensor Web Enablement software in a similar manner. 52°North is one of the candidate organizations to walk in these shoes.

Bibliography