Leveraging standardized near 'real-time' inSitu sensor measurements in nature conservation areas

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Abstract. This paper presents a standardized workflow from integrating, processing and presenting real-time in-situ sensor measurements in the Nature conservation application domain. Especially the integration of environmental phenomena like weather phenomena like, temperature, humidity, wind speed etc. into automated, SOA based distributed geographic information architecture allows for contextual provision of new domain specific 'spatial knowledge" in understanding ongoing changes in an protected area like the *National Park Berchtesgaden*. Therefore the local climate measurements from weather stations in the national park area have been integrated via geo- enabled sensor networks utilizing OGC Sensor Web Enablement interface standards. New dynamic geographic knowledge can be derived when integrating, combining and presenting this real-time data with existing geographical layers mainly from hydrosphere lithosphere and biosphere domain. To achieve and verify this goal, a framework has been developed which utilizes recent OGC standardization achievements for sensor measurement integration and distributed geographical processing, analysis and visualization methods. Measured data from various sensor sources (text, database) are transformed on-the-fly into OGC Observations- & Measurements XML-structured data, accessible via a custom OGC Sensor Observation (OGC SOS) service. We present a workflow, modules and components which permit the near-real-time integration into GI systems.

Keywords. OGC SWE; Sensor Obervation Service, Geographical analysis; real-time geographical analysis, spatial data infrastructures.

1. Introduction

Environmental data are traditionally maintained, processed, and archived by different national and international organizations. Increasingly, international environmental monitoring initiatives call for the integration of heterogeneous geographic data from local to global levels to assist in decision making and in achieving societal benefits [8]. By nature, in-Situ data are valid for points or very small test areas or, more rarely, for transects. Today, in-Situ data loggers – analogue or digital – are creating terabytes of data resulting in massive archives with enormous information potential. In many – if not most - cases, data access is very often constrained by organisatorical, technological and/or security barriers. Tools for spatially analyzing, comparing, visualizing and even sharing these data and their extracted information are still in their infancy. Furthermore, policy, legal and remuneration issues in regard to ownership and responsibility of value-added products or products that represent the culmination of different users input are yet to be stipulated but there is significant recent progress in spatial data infrastructure research (e.g., [6], [11], [5], [9]) and research on distributed geographic information processing [8] as well as new legal mandates like the European INSPIRE Directive [3] and their national deducted laws on National Spatial Data Infrastructures within the EU member states.

In this paper we briefly describe recent standardization efforts of OGC and other organizations and exploit them by dovetailing different types of 'real-time data' integration, information/processing services, visualization and knowledge provision. We describe 'Berchtesgaden live', a thematic service bus integrating 'real-time' location aware in-Situ sensor-data, enhance this structured data into thematic information layers, combine and analyze with legacy GI-layers and finally spatially valuate the results to extract new geographical knowledge being used in nature conservation domain.

2. Geo-sensor Network Data Integration approach

Future geo-sensor networks will be based on distributed ad-hoc wireless networks of sensor-enabled miniature platforms that monitor environmental phenomena in geographic space. Individual sensor communication nodes are low cost and low power, potentially allowing dense networks of nodes to be deployed to monitor environmental phenomena. Such geo-sensor networks provide the capability to monitor geographic phenomena in remote, sensitive, or hazardous environments at much higher spatial and temporal granularity than it is possible with well established monitoring systems.

Current research into geo-sensor networks is proceeding rapidly on several fronts. For example, special tasking services may ensure that not all sensors operate all the time. Some being in a sleeping mode may be activated based on threshold values of other sensors and, consequently, power consumption is minimized. However, apart from technical sensor network challenges, the real-time integration and usage of sensor data into expert and decision support systems is a vital part to evaluate and assess current environmental conditions. 'Timely' can differ and vary significantly depending on the specific application context. E.g. the update cycle for land slide monitoring can be around five seconds in some cases, whereas for tracking wild-life, half-our intervals may be sufficient for appropriate research. To guarantee maximum interoperability and wide applicability, the authors aim for a real-time sensor data integration – sensor fusion – into existing GIS systems using well-established geo-data provision standards such as OGC Web Feature Service (WFS), Web Map Service (WMS), and Web Coverage Service (WCS). This allows for an integration of real-time measurements by interfacing live data sources with a broad spectrum of geo-processing service infrastructures. Therefore for ESRI ArcGIS a plug-in data source and a datastore-extension for open source Geoserver 2 software components has been developed to allow the transparent usage of real-time sensor in abroad range of GIS.

3. Real-time data integration through Geo-Sensor Web standardization

Current approaches towards real-time data integration usually rely on the traditional request/response model in web service implementations [7]; [10]. Sarjakoski et al [18] establish a real-time spatial data infrastructure (SDI), which performs a few basic operations such as coordinate transformation, spatial data generalization, query processing or map rendering and adaptation. However, the implemented system does not consider the integration of real-time sensor data and event-based push technologies like XMPP which is e.g. widely used in various internet messaging clients (ICQ. Google Talk etc.).

Other approaches try to achieve real-time data integration via the creation of a temporary database. Oracle's system, presented by Rittman [17], is essentially a middleware between (web) services and a continuously updated database layer. The Oracle approach is able to detect database events in order to analyse heterogeneous data sources and to trigger actions accordingly. In Rahm et al. [16], a more dynamic way of data integration and fusion is presented using object matching and metadata repositories to create a flexible data integration environment.

However, all these approaches have their limitations. As data integration and fusion originated in the domain of computer science, very few approaches exist, which are dedicatedly designed for location aware data. Thus, integration of sensor data into GI systems currently mostly happens via the laborious interim step of a temporary physical database. This is not desirable in an automated GIS workflow chain as the database can easily become a bottleneck handling very large data volumes and spatial data sets. Moreover, such an indirect approach unnecessarily adds another component to the overall workflow, which can result in substantially lower performance. Thus, a need arises for an approach towards on-the-fly integration of sensor measurements and flexible adaptation of data containers.

Sensor Web Enablement (SWE) extends the OGC web services and encodings framework by providing additional models to enable the creation of web-accessible sensor assets through common interfaces and encodings. SWE services are designed to support the discovery of sensor assets and capabilities, access to those resources and data retrieval, subscription to alerts, and tasking of sensors to control observations (OGC 2008). SWE shall foster the interoperability between disparate sensors and optionally to simulation models and decision support systems. A number of authors have addressed the issue of service chaining in SDIs, and more particular, the use of distributed processing services that can be combined into value-added service chains to serve as specific GI applications (e.g., [6], [11], [5], [9]).

4. Leveraging *near-real-time* GI technologies for nature conservation areas and the INSPIRE ‚protected sites' domain

According to the International Union for the Conservation of Nature (IUCN) a Protected Site is "an area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means". The European Union Directive 2007/2/EC [3] aims at establishing an Infrastructure for Spatial Information in the European Community (INSPIRE) to support environmental policies. Therefore, harmonized datasets, services and structured information about the geographic resources are the main requirements for supporting decision-making processes at all levels. Domain experts in *protected areas* worldwide already generated a vast amount of environmental data in accordance with their immediate requirements and priorities. They organize specialized datasets including protected biotopes and habitats, flora and fauna species distribution and supporting datasets like geological data, soil data, forestry, hydrological data, climate data, elevation, administrative units etc.

Within the *nature conservation* domain representations of these various geospatial entities can differ in terms of data model, spatial, temporal and thematic scales, data generalization (the preserved information about real entities and/or phenomena), conceptual models, geographic projections etc. Therefore the integration of heterogeneous geospatial data needs a standardized conceptual model for capturing ‘spatial’ and temporal characteristics of environmental entities.

The OGC SOS provides an API for describing, accessing and managing deployed sensors and retrieving sensor data in a well structured standardized manner using XML technology. Such approaches for e.g. hydrosphere measurements via standardized interfaces allow for dramatically reducing time and efforts integrating this timely data into nature conservation SDIs.

Additional essential functionalities for embedding real-time sensor data analysis into application-specific workflows are *alerting* and *notification*. As there are a variety of real-time data sources available – with rising tendency – it is increasingly important to organize and filter these data according to pre-defined criteria and rules. For instance, when monitoring protected landscapes, temperature variations may mainly be of specific interest in connection with regard to other phenomena like precipitation and soil conditions in order to better and faster support landslide risk assessment. Only specific combinations of several of these parameters allow for the identification of so-called “events”, which can trigger appropriate ‘user’ actions. ‘Actions’ could be sending out automated information (e.g. SMS or emails) and/or to trigger further tasks.

OGC SWE therefore defines the Sensor Alert Service (SAS), which specifies interfaces (not a service in the traditional sense) enabling sensors to advertise and publish alerts including associated metadata. Clients may subscribe to sensor data alerts based on defined spatial and property based constraints. Also, sensors can be advertised to the SAS to allow clients to subscribe for the sensor data via the SAS, which is currently in its version 0.9.0, has not jet been released as an official OGC standard. There are still discussions on the common suitability of this standard and the standard document is currently under investigation especially in conjunction with OGC Sensor Event Service (SES).

SAS may use the Extensible Messaging and Presence Protocol (XMPP) a push protocol which has major technological advantages in terms of a very light-weight (low network payload) delivery of sensor notifications in comparison to HTTP. SAS notifications are provided via a Multi User Chatrooms (MUC) for each registered sensor and each predefined sensor alert definitions. To receive notifications, a client has to join the specific MUC. E.g.: There are chatrooms for different gauge-heights on a river-level. Values and alerts may be posted only into those chatrooms which height definitions have been exceeded. With this XMPP technology it’s possible for thousands of users to subscribe to OGC SAS and still the network-traffic stays low as the information alerts are casted just once.

5. GI analysis of 'real-time' environmental monitoring information: National Park Berchtesgaden

The geographic information infrastructure in the national Park Berchtesgaden is based on Service Oriented Architectures – SOA - to ensure flexibility, reusability and portability of the components and the overall infrastructure. The Berchtesgaden National Park in southeast Germany is one of the oldest protected areas in the Alps, established in 1978. It comprises 218 square kilometres, with altitudes ranging from 540 meter at lowland Königssee to the towering Watzmann Mountain (2670 m). It comprises one of the oldest GIS installations in Germany. Since 1984 enormous amount of data have been collected, analyzed and archived. The GI system is used as the main instrument for the long term "National Park Plan" which came into force in 2001. The original GIS data structure is currently being reorganized and restructured aiming to integrating also local weather-station measurements directly into the GI-environment for spatio-temporal analysis. The existing climate-station network consists of nine stations which send their measurements via GSM/GPRS to a hosted centralized server providing visual web-access (tables and graphs) for the different entities like temperature, humidity, snow cover etc in a proprietary manner.

To get spatial information on the actual climatologic situation within the National Park we implemented automated mechanisms (using python scripting language) to structure the proprietary measurements of the weather stations being accessible as OGC O&M on a 10 minutes basis. This enables the accessibility of the structured sensor datasets (temperature, humidity, barometric pressure, rain fall, snow depth etc.) via the well established OGC SOS interface. A special Web map solution (Fig. 1) has been developed (based on Microsoft Silverlight) to support 'real-time' areal snapshot analysis of the recent climatologic situation in the National Park. The measurements are directly integrated into ArcGIS Server (using a SOS custom plugin-datasource) as input for co-kriging and IDW interpolation processes integrating also differences in altitude (via DEM) of the weather stations.

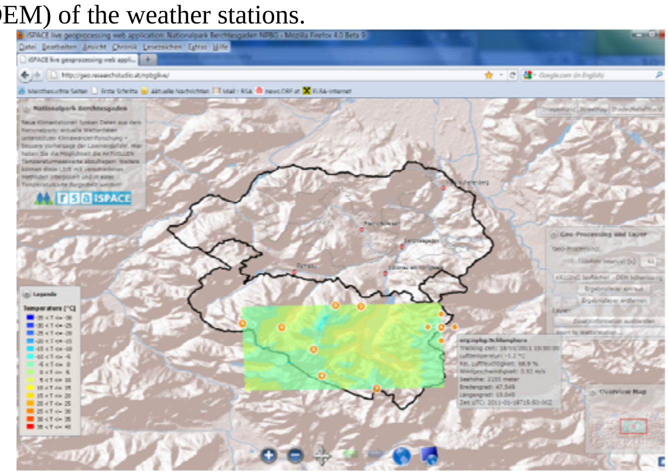

Fig 1 NP Berchtesgaden, Temperature Interpolation Application

This technological approach empowers the on-demand personalized web-based processing of 'near' real-time measurements for providing an interpolated map of the climatologic situation.

6. Conclusion

This new approach directly integrating ‘near-real-time’ environmental measurements into the nature conservation SDI in the National Park Berchtesgaden enables a faster and better understanding and assessment of environmental dynamics. The proposed and validated system is utilizing upcoming international standards like OGC SOS, interface and processing standards to shift possibilities in extracting new ‘spatial knowledge’ and enhance the support for National Park administration in their everyday’s work.

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