# Sensor Web Enablement – Standards and Open Source Implementations for Observation Data

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ABSTRACT: Sensor observation can be applied in the field of emergency management for predicting, monitoring and managing ecological risks locally and regionally. However, due to technical limitations, sensor observation marginally meets the challenges in this area. A standardized access to observation data would allow the reuse of data, as well as transnational and multidisciplinary usage. This paper introduces standards for sensor observation data, specified by the Open Geospatial Consortium. These standards comprise a definition of data models, xml-encodings and service interfaces, in order to make different types of sensor and sensor data accessible and useable via the internet.

Additionally, the paper elaborates on the application of these standards in the domain of avalanche prediction and snow risk monitoring. A free open source implementation of the standard by the 52North Initiative for Geospatial Open Source Software GmbH was chosen. A simple home weather station was deployed on our Departments rooftop to collect observation data for our experiments. We present the use of these standards on specific applications, such as observations made by a human, made by a meteorological weather station or the output of an algorithm for the correction of raw observation data values, and discuss the advantages and limitations experienced.

KEYWORDS: Weather Station, Sensor Web Enablement, Open Source, GIS, OGC, Standards

## 1 INTRODUCTION

Sensor observation can be applied in the field of emergency management for predicting, monitoring and managing ecological risks locally and regionally. However, due to technical limitations, sensor observation marginally meets the challenges in this area. A standardized access to observation data would allow the reuse of data, as well as transnational and multidisciplinary usage.

## 2 PROBLEM DEFINITION

Data collected by weather stations is crucial to nearly every application in the field of environmental monitoring. Gruber et al. (2009) aimed for an evaluation of actual avalanche danger and the identification of regional danger potentials. The discussed models are mainly based on weather data collected by such weather stations. This data serves as input for raster analysis operations that evaluate the danger potential of the actual weather condition for the region of Carinthia. A major problem in this approach was caused by the inhomogeneous data basis that obtains the data of various sources of departments in the Carinthian government. Although these departments all deal with similar types of weather stations, they do not share a common standard for data preparation, validation and transfer. A proprietary way to handle these problems concerning data was chosen in the thesis, but the potential for standards is obvious. Regarding the fact that avalanche formation is a phenomenon that does not care for administrative boundaries interoperability and a common knowledge for well defined problems is needed.

## 3 METHODS

In the last years a trend in software development from monolithic software systems to integrative service oriented approaches is noticed. Most sensor monitoring systems follow a centralized approach for data storage. They use proprietary or domain specific in-house developments that do not provide standardized interfaces for data sharing and integration.

The Open Geospatial Consortium (OGC) is a non-profit organization with the aim to establish interoperability in the domain of geospatial services. The OGC consists by the time of writing this paper of 384 members from the scientific and economic sector. In cooperation with these members abstract specifications of services and data encodings, as well as implementation specifications of their interfaces are de-

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veloped. These documents are available free of charge on the OGC homepage to enforce the development of geospatial standards.

### *3.1 Sensor Web Enablement*

The Sensor Web Enablement (SWE) is a working group within the OGC focusing on the recovery, retrieval and planning of sensors and their observations via the internet. Information models, to describe the sensors and their observations, and service models, that operate based on those information models, have been developed.

The information models comprise Observations & Measurements (O&M), to describe sensor observations and measurements themselves (Na and Priest, 2007), Sensor Model Language (SML), to describe sensor characteristics and Transducer Model Language (TML), describing conceptual models and encodings for tasking sensor systems.

The service models, based on the above mentioned information models, comprise the Sensor Observation Service (SOS), describing an interface for retrieval of sensor observation data and sensor description (Cox, 2007), the Sensor Planning Service (SPS), describing an interface that allows tasking of sensors to receive particular observations, the Sensor Alert Service (SAS) describing an interface that allows subscribing and publishing alerts from sensors and the Web Notification Service (WNS), describing an interface that allows asynchronous messaging between services. (Simonis, 2008)

### *3.2 Implementation*

For the experiments the SWE Service implementations of the 52°North Initiative for Geospatial Open Source Software GmbH were used. They are available for download on the homepage of the research institute (see Table 1).

Table 1: Software used in the experiments

| Name | Version | Source |
|---|---|---|
| SOS | 52N-SOS-3.0.1 | http://52north.org/ |
| SOS feeder | 52N-swe-sosfeeder-20071109. | http://52north.org/ |
| Rich OX Client | 52n-swe-oxf-client-20080922 | http://52north.org/ |
| Postgres | 8.3 | http://www.postgresql.org |
| Postgis | 1.3.5 | http://www.postgresql.org |
| Apache Tomcat | 6.0.18 | http://tomcat.apache.org |

## 4 EXPERIMENT – SWE FOR SNOW RISK MONITORING

Snow risk monitoring and avalanche prediction rely among others, on various sensor observations, such as precipitation, temperature, solar radiation, etc. Services and data models introduced by the SWE will be investigated and applied in an experiment on a simple weather station, a human observation and corrected raw observation data. The experiment should prove if the core functionalities expected from a sensor monitoring system for snow risk monitoring can be provided using SWE implementations:

- Storage of sensor observation data
- Retrieval of sensor observation data
- Spatial/Temporal visualization of sensor observation data
- Analysis of sensor observation data

### *4.1 Weather Station*

A simple home weather station comprising 5 sensors measuring temperature, air pressure, humidity, brightness, precipitation, wind speed and wind direction, was set up. The sensors were positioned on top of the University building. Considering an appropriate alignment, in order to insure meteorological recording the temperature sensor should be mounted on the north or west side and not exposed to direct sunshine, the wind sensor need to be positioned south and unshielded, etc. The outdoor sensors are powered by solar cells. The sensor system operates with radio data transfer (100m range). Sensor observations are sent continuously to an indoor base station that is connected to a PC via serial interface (RS 232).

A SOS with a Postgres database as central data storage was set up. The set up involves conceptual modelling of the application domain. In case of the home weather station we defined the surrounding of the University as feature of interest, georeferencing the related observations. The weather station itself was regarded as the procedure, including several sensors. They observe multiple phenomena, representing weather parameters like temperature, precipitation, wind speed etc., which are grouped as a offering named 'Weather_CUAS'. Using the 52°North SOS, this model is implemented in the PostgreSQL database and SML files. The sensor observation data is inserted in the database using a feeder service.

### *4.2 Human Sensor*

Beneath the usage of conventional weather stations almost always human observers are used to collect data as additional data provider. This might be the owner of a local mountain hut, a ski lift attendant or a member of an avalanche patrol. From a modeling point of view there is no difference between a conventional weather station and a human being. Both have capabilities to observe different phenomena with a specific quality and both can be located on a specific position on earth. The advantage of such a modeling approach is simple. It offers the possibility to handle both data sources in a common data basis side by side.

The human sensor has to be registered like a conventional weather station in the database including the SML conform sensor-description file. After registration the human sensor is available as procedure object beneath other procedures that may represent weather stations or even data correcting algorithms.

*4.3 Corrected Data Values*

Observation data, no matter if received by a technical or a human sensor, are provided as raw data that often need further processing. In the case of snow risk monitoring, reliable observation data is crucial. Therefore the raw data needs to be checked on plausibility. These or other post-processing activities generate new data.

The data model introduced in SWE comprises also processing of data by certain algorithms. SML allows describing such post-processing algorithms as procedures.

## 5 RESULTS

The storage of the sensor data is proposed in a Postgres database with a predefined schema by the 52North implementation of the SOS. Observation data of one ore more sensors can be stored in such a database. Already existing sources of observation data can be input to the database using a feeder, like it was realized in our experiment for the weather station, or using the DataAccessObjects (DAO) of the SOS. These DAO's can be implemented to integrate different data sources. The final realization of the integration of the observation data depends on the purpose and technologies used.

In order to collect observation data from a mobile human sensor, solutions from a simple website with login and input forms up to sophisticated mobile application, that allows immediate read-write access on the data, are possible.

The application of mobile sensors is one major topic in the OGC SWE working group. The challenge is to deal with the vast amount of incoming position data and an adequate handling and allocation of this data via the SOS. In the primary approach the geometry information is stored in the Feature of Interest (FOI) context. This leads to an overload when requesting FOI information, time outs are possible and the result can hardly be processed. A solution to this bottleneck is the introduction of a domain feature class that represents the original FOI and is linked to the 'mobile' FOI's by an 1:n relationship. Through this workaround the request is balanced. Nevertheless the topic of mobile sensors is on discussion right now in the OGC SWE and might end in a different approach for the next standard specification.

The observation data can be requested directly via the http protocol at the SOS address, (see Figure 1) using a GetObservation request. The request can be adopted to filter the data by attributive, spatial or temporal criteria. The response is delivered in O&M encoding.


Figure 1: GetObservation request

The responses, provided in O&M encoding, can be integrated in desktop or web-based client applications for visualization and further analysis. The 52North 'WeatherSweClient' (see Figure 2), demonstrates interoperability integrating various SOS instances in a Google Mash-Up.

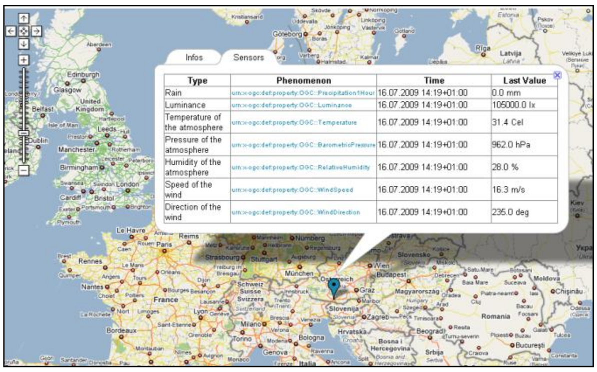

Figure 2: The weather station visualized in a web-based client application. Most recent sensor observation data is displayed.

The 'Rich OX-Client', a desktop application based on the 52North OX-Framework allows integrating various OGC Services, such as WMS, WCS, SOS as well as SPS, etc. . The observation data of the weather station experiment was visualized in a map window in combination with a background layer of country borders retrieved by a WMS. Time series charts can be rendered in both applications (see Figure 3).

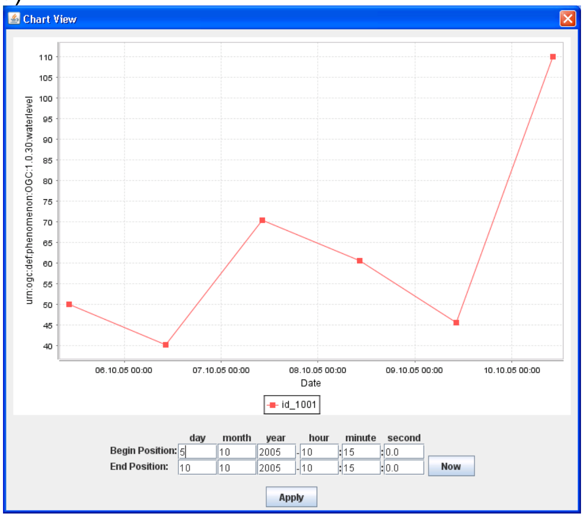


Figure 3: Time series of precipitation observations visualized in the 52North's OXClient-Framework

Further analysis, e.g. an interpolation of requested sensor observation data, is considered in the SWE standard, as well as in the 52North OX-Framework. However, performing an interpolation of the weather stations observation data our experiments did not result in the expected output.

## 6 CONCLUSION

Generally, standardized services and data encodings enable interoperability and cross-border exchange of data. Nevertheless the application of standards involves overhead during the modelling phase, as well as in the implementation and deployment phase. This additional work load is justified, if the resulting system is intended to be integrated in multiple heterogeneous applications.

In general we have to mention that the application of the service implementations and clients used in the experiment, claims for more advanced knowledge in computer science and demands advanced programming skills, when it comes to customization of data access classes. An additional challenge is the high frequency in the development circle of the 52North SWE implementations, resulting in many different versions for the services. It is not always the case that versions can be upgraded without causing problems at one or more positions.

However, rapid development and further evaluation in testbeds proves the rising interest in these services. Adaptors are in work, to integrate SOS and SWE Services in existing GI-Software. Awaiting further development, SWE should be considered when (re-)designing sensor monitoring systems.

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