Linking Sensor Web Enablement and Web Processing Technology for Health-Environment Studies

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Abstract. This paper introduces an approach how the Sensor Web Enablement (SWE) framework of the Open Geospatial Consortium (OGC) can be coupled with geo-processing services (OGC Web Processing Service - WPS) in order to support health-environment studies. By presenting selected use cases of the EO2HEAVEN project it will be explained how SWE services can be used as a source of real-time observation data and how these data sets can be analysed in a process chain encapsulated by a WPS.

Keywords: Sensor Observation, Geo-Processing, Interpolation, Health-Environment, Air Quality.

1 Introduction

The Sensor Web Enablement (SWE) framework [1] - steered by the Open Geospatial Consortium (OGC) - facilitates the discovery, exchange and processing of sensor observations. SWE promises to make a multitude of sensors and their observations available on the Web. Together with distributed geo-processing services [2], SWE exploits distributed computing to fuse and integrate data through real-time service chain composition to generate up to date, dynamic and accurate information products that have been difficult, costly or impossible to access before.

The SWE framework defines a set of standards for data formats for sensor data and metadata as well as standards for service interfaces to access sensor data, task sensors or send and receive alerts based on sensor measurements. The SWE standards are intended to facilitate the integration of sensors and sensor data into spatial data infrastructures. Thus, sensor data becomes an additional source for geospatial information besides conventional data types like maps or geometries of geographic features. The SWE specifications can be divided into two classes: the information model comprises all specifications addressing data formats and encodings for sensor data and metadata whereas the service model defines the interface specifications for

Web Services providing sensor related functionality. For the applications described in this article, especially the specifications 'Sensor Observation Service' (SOS) [3] and 'Observations and Measurements' (O&M) [4], [5] are relevant. The SOS provides an interface for requesting sensor data sets based on temporal, spatial and thematic query parameters. The responses of the SOS containing the requested data are then returned using O&M. These standards can be used for coupling geo-processing services with sensors as data sources. Relying on such a standards based approach ensures that the developed geo-processing services can easily be coupled with other data sources, as long as these data sources support the SWE standards.

The OGC Web Processing Service (WPS) specification [6] provides a standardized technology for executing any (geo-)processes with various levels of complexity over the Web. The required data can be provided on external servers or can be delivered directly across a network by the client together with a processing request. Image data formats or data exchange standards such as Geography Markup Language (GML) [7] or O&M can be used to model and encode the required incoming data sets and final results. As the WPS specification does not specify which functionality geo-processes shall support, the service developers and providers are free to offer any functionality, ranging from individual self-developed processes to a wrapping of complete GIS libraries like GRASS GIS [8].

SWE and WPS technologies will be a core building block of the European Seventh Framework Programme (FP7) funded project EO2HEAVEN (Earth Observation and ENVironmental modelling for the mitigation of HEAlth risks, http://www.eo2heaven.org/). A core aim of this project is to build a Spatial Information Infrastructure (SII) for integrating in situ sensor data sets, Earth Observation (EO) data sets and health data sets to support environment related health risk prediction. All involved OGC specifications have proven themselves valuable in the past, although an integrated usage of SWE and WPS concepts is still missing. It is therefore highly beneficial not only to experiment with both concepts but also to integrate them into the stable EO2HEAVEN implementations.

2 Concept

One of the main objectives of the EO2HEAVEN project is to predict air quality levels in order to warn and protect people suffering from respiratory or cardiovascular diseases. An ad-hoc warning system is designed and implemented to create risk maps for the affected population. It integrates several Web Services for spatial data provision, processing and visualization. For the implementation and validation of an active warning system, two case studies dealing with air quality issues are developed: (1) Saxony (Germany) - mainly focusing on the creation of reliable models for predicting air pollution impacts on human health; (2) Durban (South Africa) - focusing on the implementation of an entirely service based warning system.

The service infrastructure of the project is based on common OGC standards, such as SOS for the provision of air quality measurements, Web Coverage Services (WCS) and SOS for the provision of remote sensing data, WPS for risk modelling and Web Map Service (WMS) for the visualization of the air quality and risk maps. Various remote sensing data sets are analyzed in terms of their usability for air quality prediction. In addition, approaches to consolidate remote sensing data, in situ data and health data are developed. The consolidation primarily focuses basic pollution dissemination models and correlation coefficients among different remote sensing and in situ sensor measurements.

As an intermediate result, a generic air pollution interpolation WPS has been developed to feed continuous air quality information to the EO2HEAVEN SII. The WPS accesses a SOS providing air quality measurements and calculates an interpolation (using GRASS GIS geo-processing modules) based on the requested sensor data. The workflow is initiated by a WMS which is capable to deal with a time dimension. A time enabled WMS client starts the service chain by providing the WMS with the requested air pollution parameter, the spatial extent, the spatial resolution for the result and the time frame. Based on these parameters the WMS initiates a request to the WPS including the required SOS request as reference (containing the air pollution parameter and the spatial and temporal extent) and the resolution/pixel size for the result. The WPS requests the SOS for the required O&M data set, extracts the required information, calculates the interpolation and returns the image to the WMS which itself provides the visualization for the air quality map back to the client.

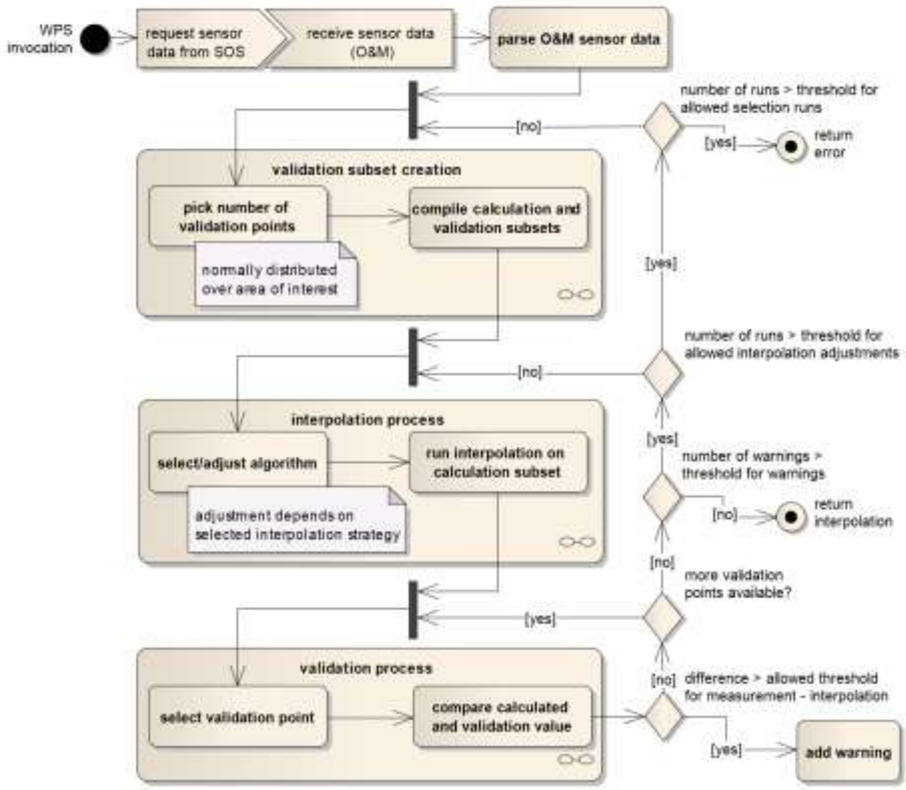

Fig. 1: Self-validation process of the WPS for sensor interpolation

The described approach is extended by a self-validation mechanism depicted in Fig. 1 to avoid inaccurate interpolations adopting the sensor validation process described by [9]. The in situ sensor observations are divided into a calculation set and a validation set. The calculation set is used as input for the interpolation process whereas the validation set only acts as a set of control points within the interpolated image. The validation points are compared to the values derived from the interpolated image. If the control point validation shows tolerable deviations, the interpolated image is returned to the system for direct visualization via WMS, direct storage in a WCS or further processing. If the deviation is outside the tolerable range, the interpolation process parameters have to be adjusted, e.g. by utilization of different interpolation algorithms or further validation loops with a different partition of the calculation and validation sets. In case of several successive failures, implying failures due to a lack of required measurements or measurement errors inside the situ data observations, an error will be returned to the client.

To identify a set of appropriate and sensible interpolation algorithms for the general area of interest, ‘historic’ interpolations can be compared with remote sensing data sets of the same spatial and temporal extent. A respective list of available earth observation products related to health-environmental studies can be found in [10]. The validation of in-situ and remote sensing data further reduces the number of unnecessary applications of inappropriate interpolation algorithms. Unfortunately, an on the fly validation is impossible as remote sensing data sets are usually not available ad hoc, but especially for the production of up to date maps for air quality prediction, highly topical data is essential. Moreover in-situ and satellite measurements are not directly comparable due to their basic configurations. In-situ sensors provide point based measurements at ground level whereas satellites observe the entire atmosphere. This aspect is already studied within the project but still needs further investigations.

The accuracy of the interpolation of air quality information strongly depends on the availability, reliability and distribution of the underlying in-situ sensors. Therefore the project also tackles problems with the uncertainty of measurements and the creation of continuous air quality information from widely distributed sensors networks by taking additional environmental characteristics (e.g. land use, elevation model, transportation network) into consideration. Subsequently health risk prediction models can be applied to the calculated air quality information to produce health risk maps as the final outcome of the system.

3 Conclusion

The presented approach for sensor validation is supposed to significantly enhance the reliability of the produced air quality maps and prevents false alarms of the warning system for the EO2HEAVEN Case Studies in Saxony and the Durban area. A detailed evaluation of the presented approach will be performed in conjunction with the validation of remote sensing data in the next step of the project. This is highly prioritized by the EO2HEAVEN project since derived health risk maps should be as trustworthy as possible for the end user. In addition, the presented approach shows that by combining and integrating the already matured SWE technology on the one hand and the WPS technology on the other, even more powerful solutions are possible and easy to implement. Nevertheless, one problem remains: Currently, the specifications of SOS and O&M provide a high degree of flexibility and can thus be applied to a broad range of applications. There is a broad diversity of O&M encoded data sets which makes it difficult to implement a generic parser for O&M data sets which is required on the WPS side. Thus, an important element of EO2HEAVEN is the definition of (domain-specific) SWE profiles to further increase interoperability.

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