Distributed Web-processing for Ubiquitous Information Services – OGC WPS Critically Revisited

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1. Introduction

In analogy to the social and technological phenomena occurring in Web 2.0, solutions for online visualisation of environmental-human relationships and even analyses of those need to be developed to accomplish a more 'complete sensing'. Therefore, comparable to a social network, we may think of future 'ubiquitous sensing networks' based on locations and measurements connecting people and their surroundings. From an environmental urban systems viewpoint, ubiquitous monitoring and real-time data processing are also critical processes to ensure public safety including the state of the national infrastructure, to set up continuous information services, and to provide input for spatial decision support systems (Resch et al., 2009).

Thus, nations around the world are developing spatial data infrastructures (SDIs) facilitating the (re)use of GI through web services. The European INSPIRE Directive explicitly requires web services to be a central part of such infrastructures. Over the last decade, the Open Geospatial Consortium (OGC) has created a set of web service interface standards for publishing and accessing image maps, features, coverages and sensor data. These specifications are now quite mature and constitute the basis of most web-enabled geospatial systems that are currently being developed.

In this paper we briefly report on a complete standardised workflow for web-based geo-processing. We present some technical developments from the European Commission funded project GENESIS, which links different existing services for environmental management by providing users and governmental institutions with a way to connect a vast variety of resources available in Europe. Although GENESIS use cases address air and water quality the workflow and the developments described in this paper are generic in nature.

2. Technical Realisation and Preliminary Results

Following the recent service-oriented trend mentioned above, the OGC started an attempt to integrate web-processing functionality in a workflow-oriented infrastructure by creating the Web Processing Service (WPS) standard (Schut, 2007). WPS defines an open interface that enables publishing of geospatial processes and allows for the development of software clients that discover and bind to those processes. Figure 1 shows the WPS communication sequence of a geo-processing workflow between a client and a web-GIS engine integrating live measurement data.

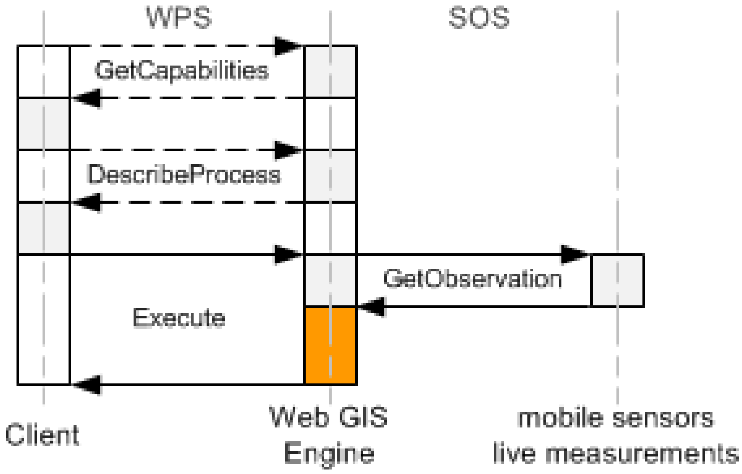

Figure 1. Geo-processing Workflow Based on OGC Web Services (OWS).

The engine can either be an open-source solution (e.g. GRASS) or a commercial product (e.g. ESRI ArcGIS Server), coupled with OGC compliant interfaces (e.g. PyWPS). In our workflow, the input data for the processing operation are live sensor data obtained from an OGC Sensor Observation Service (SOS) instance. A typical application of real-time geo-processing is for example the interpolation of up-to-date temperature values from weather stations based on validated models. The Inverse Distance Weighting (IDW) interpolation result in Figure 2 (right image) shows isotherms in user defined step sizes.

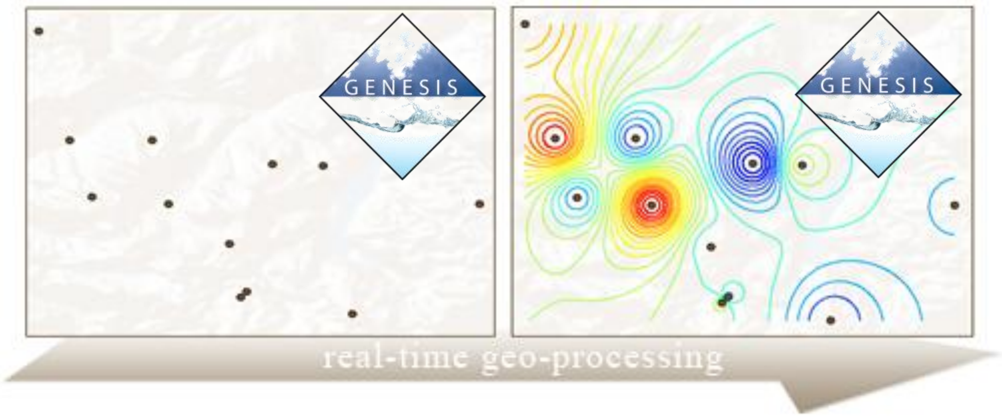

Figure 2. Live Interpolation Web Service: Air Temperature Values as Point Data (left) and Geo-processing Result as Isotherms (right).

3. A Critical Review of the OGC WPS Standard

Due to the exponential increase of available real-time data sources, comprehensive architectures in terms of distributed and cloud processing tasks will be required (Schaeffer et al. 2009, Friis-Christensen et al. 2007). WPS intends to provide a highly flexible service specification, which causes issues in terms of functional profiling, result provision, unambiguity of process descriptions, process interoperability, and client implementations.

3.1 WPS Profiles

According to the WPS specification, each process has to be specified in a separate document to achieve far-reaching interoperability. This can be considered WPS application profiling defining the following parameters.

- *URN*: unique process identification (mandatory)
- *Reference response*: reference to a DescribeProcess request (mandatory)
- *Description*: a human-readable document describing the process (optional, but recommended)
- *WSDL description*: a WSDL document describing the process (optional)

The creation of a WPS application profile is not trivial and straight-forward. Firstly, the definition of a unique URN (Uniform Resource Name) is problematic as the OGC has not defined consistent rules for specifying URNs. Secondly, there is no clear definition of how these profiles should be hierarchically structured. Nash (2008) presents an approach, in which a distinction is made between generic processes providing essential GIS functionality, and specialist processes. In a further step, the author suggests the differentiation between processes that operate on raster data from those working on vector data. This is due to the raster/vector dichotomy of data processing in today's GIS. In fact, even ISO 19129.2 recognises that existing content descriptions are not in conflict or incompatible, but reflect different real-world situations that require different treatments.

3.2 Asynchronous Processing

An essential aspect in web-based processing is that geo-computations involving large amounts of data in a complex algorithm may take longer than the typical Hypertext Transfer Protocol (HTTP) time-out duration. Thus, WPS also needs to support asynchronous processing (send the computation result outside the HTTP response), which can happen in two ways:

- the client regularly polls the server to check whether the process has finished
- the client gets notified by the server when the process has completed

The current WPS version (1.0.0) defines the polling approach for its asynchronous operations. A major disadvantage of this method is the significant overhead in exchanged messages, as the client continuously polls the server to find out whether a process has been completed. Thus, notifying the client when the process has finished seems to be a more suitable and optimised approach regarding message exchange between client and server. However, this method also requires a set of underlying messaging standards for notification etc. The World Wide Web Consortium (W3C) provides a number of relevant standards (WS-Notification, WS-Addressing etc.), but they are not fully acknowledged and integrated in current OGC specifications. Furthermore, they require the use of SOAP as a communication protocol, which is only one of several possibilities when using WPS.

3.3 Real-time Data Processing – the Bigger Picture

Generally speaking, the OGC Web Processing Service (WPS) is a promising move in the direction of service-oriented data analysis. However, it is not clear yet, which functionality it will contain, which data formats it will support, and what process descriptions will exactly look like. The rather slow and very broad development is partly due to different viewpoints within the geospatial community – often driven by individual application contexts. Hence, providing the possibility to integrate user-specific analysis models via the WPS interface will be a crucial point of discussion.

Figure 3 illustrates different approaches for standardised sensor fusion and data analysis in a service-oriented processing environment. This federated infrastructure concept serves the need for ready access to data for near real-time server-based geospatial analysis, web mapping and mobile GIS.

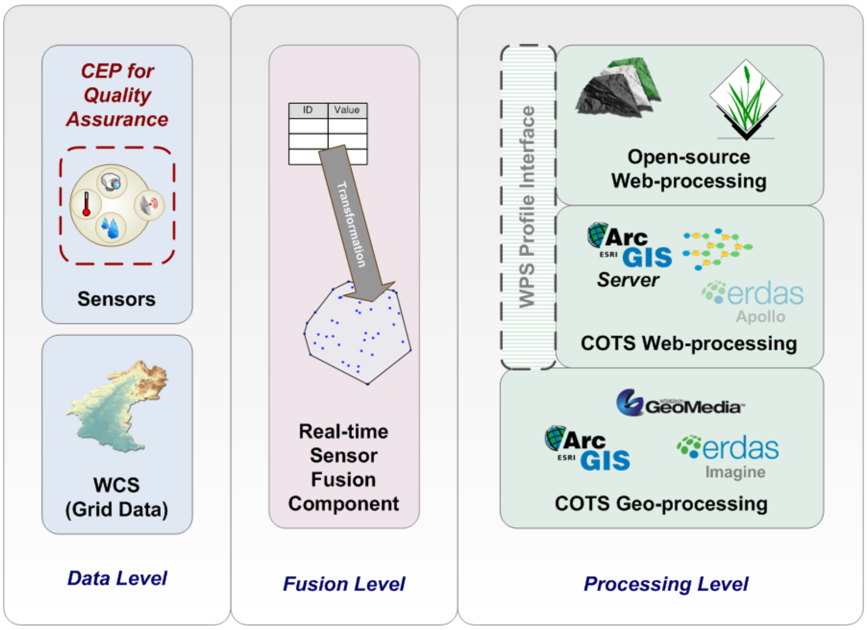

Figure 3. Web-based Analysis in a Real-time Geospatial Data Processing Workflow.

4. Discussion and Conclusion

Traditionally, Geographic Information processing has often been implemented in monolithic solutions with tight coupling of data, processing and visualisation in proprietary systems. Thus, a crucial advantage of the web-based processing approach is that GIS applications could be complemented (or replaced) by lightweight web-based analysis tools. This yields major benefits such as (a) users do not need expert knowledge to use GIS tools as only simple web interfaces are provided to the end user; (b) end users do not have to buy expensive and resource-consuming analysis software (naturally, this does not apply to not service providers); and (c) analysis models can be made accessible to a far broader spectrum of users by exposing them to the web, ranging from private persons who want to know about air quality in their neighbourhood in real-time, to urban planners, traffic management officers, and political decision makers.

In consequence, standardised web-processing can be considered a highly seminal research area, which is still in its infancy. Firstly, several technical challenges have to be tackled from a computer science and computer engineering viewpoint. These comprise efficient resource sharing, load balancing, cloud computing, and high-speed data transfer, particularly for GIS software. Furthermore, standardised processing service profiles, input and output descriptions, and data structures have to be defined to enable distributed web-based geospatial analysis.

In this context, GI-science has to provide the framework for spatially and temporally ‘continuous’ monitoring systems with web-based data analysis workflows.

The ‘Live Geography’ approach (Resch et al., 2009) has been proven to be applicable to a wide variety of cross-domain ubiquitous information services due to its high degree of interoperability, modularity and flexibility. The authors strongly believe that this standardised web-based geographic information processing framework will have broad impacts on society, but demands substantive research in GI-science both on comprehensive concepts as well as on the impacts of future technologies.

Acknowledgements

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