GIS Web-based Platform for Experimentation Using Environmental Geosensors

http://dx.doi.org/10.3991/ijoe.v12i04.5261

A.M. Ribeiro[1,2], V. Sousa[1] and A. Cardoso[1]
[1] University of Coimbra, Coimbra, Portugal
[2] Coimbra Institute of Engineering, Coimbra, Portugal

***Abstract*—This work describes a GIS web-based open source platform for wireless *in situ* geosensor data visualization and distributed geoprocessing. Emphasis is put on: i) visualization of sensor measurements and sensor location on a map; ii) geoprocessing of these data; iii) and, visualization of geoprocessing results on a map. The platform combines the Open Geospatial Consortium (OGC) Sensor Web Enablement (SWE) standards, in particular the Sensor Observation Service (SOS), and the OGC Web Processing Service (WPS). Several results are presented using different methods of spatial interpolation of air temperature measurements as geoprocessing tasks.**

***Index Terms*—Environmental Geosensors, Sensor Web Enablement, Web-based Geographic Information Systems, Web Processing Service.**

I. INTRODUCTION

Geographic Information System (GIS) applications are currently developing on a distributed architecture comprised of independent and specialized geospatial web services, designed to offer distributed functionality over the Internet. The combination of Sensor Web Enablement (SWE) and Web Processing standards, specified by the Open Geospatial Consortium (OGC), opens up new possibilities by having near real-time data flows that can be linked on-demand to different processing services. It thereby offers a suitable mechanism, for instance, to adjust emergency support systems on-demand by integrating new resources via the Web.

In this work we present a GIS web-based open source platform for wireless *in situ* geosensor data visualization and distributed geoprocessing. Emphasis is put on: i) visualization of sensor measurements and sensor location on a map; ii) geoprocessing of these data; iii) and, visualization of geoprocessing results on a map. Currently, the platform prototype uses data remotely acquired from test bed sensors with artificially assigned geolocation. However, the requirements for being applied to real-world environmental conditions are already taken into account.

Most data for environmental variables (e.g., soil properties, weather) are collected from point sources. The spatial grid (or array) of these data may enable a more precise estimation of the value of properties at unsampled sites than simple averaging between sampled points. The value of a property between data points can be interpolated by fitting a suitable model to account for the expected variation. Obtaining this interpolated surface is very often the first step in a workflow (see [4] for a recent review on spatial interpolation methods applied in the environmental sciences). Currently, the architecture of the system allows only using the WPS for this purpose, in order to make the proof of concept. However, in the context of disaster management, environmental modelling and management, this and many other processes must be chained together in order to support complex decision-making.

II. OGC SENSOR WEB ENABLEMENT AND WEB PROCESSING SERVICE

The SWE architecture has been defined as a set of interfaces, data models, and data formats for the integration of sensors and sensor data into spatial data infrastructures. It comprises functionality for [1]: accessing sensor data; controlling measurement processes and sensors sampling rate; filtering sensor measurements according to user defined criteria; providing metadata about sensors and their measurements; and discovering sensors. In this work, the focus is on the SOS [2], since a pull-based approach is adopted. The SOS core profile contains three operations: *GetCapabilities* for requesting metadata of the SOS web service; *DescribeSensor* for acquiring the sensor description of a specific sensor; and *GetObservation* for requesting actual measurements in *Observations & Measurements* (O&M) format. Operations for writing new data into the SOS are contained in the optional transactional profile. Its *RegisterSensor* request sends a *SensorML* document to the SOS for publishing a new sensor and the *InsertObservation* operation allows sending new measurements in O&M format. The WPS interface specification defines a standardized way for publishing and executing web-based (geo)processes [3]. A process is defined as any calculation and/or computation model operating on spatially referenced data. The WPS interface specification describes three operations, which are all handled in a stateless manner: *GetCapabilities*, *DescribeProcess* and *Execute*. The communication with the WPS interface is based on HTTP-GET (using KVP encoding) and HTTP-POST (using XML or KVP encoding).

III. SYSTEM ARCHITECTURE AND IMPLEMENTATION

The application comprises a SOS Server (52º North SOS), a WPS Server (52º North WPS) and a Web Map Server (GeoServer). The SOS Server and the Web Map Server come with their own database schema and store (in this case, PostgreSQL/PostGIS). A "SOS injection" module was developed to publish both sensor and sensor observation data via SOS-Transactions to the SOS Server. This module runs regularly to deal with new incoming sensor observations. The 52º North WPS implementation offers a graphical configuration and administration interface. To access and visualize the information of the SOS and the WPS results, a JavaScript-based client application has been developed. Some ready-to-use widgets, capable of visualizing data series in charts and tables and show spatial information on a map, are utilized. The web client uses SOS *GetObservation* for requesting measurements. In the response, the location parameters (latitude, longitude, altitude) are treated as phenomena and listed together with the other sensor measurements. Temporal and spatial filters can be easily applied. In order to geoprocess the sensor measurements, the web client communicates with the WPS Server and queries the service metadata using a *GetCapabilities* request. The response provides a list of geoprocess models, including, hopefully, the desired one. The 52 North WPS offers several third-party processing back ends, such as SEXTANTE, GRASS, ArcGIS Server, or R. However, users are also allowed to upload their own processing algorithms. The *DescribeProcess* request queries the WPS instance for further metadata on the specific geoprocess model such as input and output parameters. This information is important to trigger the specific geoprocess model appropriately. For instance, the Inverse Distance Weighting (IDW) interpolation algorithm requires complex data for the geometries (sensor locations and property measurements) to be processed and literal data (e.g., distance power parameter, spatial resolution). Then, the client performs the *Execute* request. The complex data are included in the request as a reference to a SOS instance. The WPS has to retrieve the data from this location and process them accordingly. The WPS requesting is asynchronous and processed results are stored on the server side, i.e., on the Web Map Server, through HTTP REST API. After, they can be accessed and displayed on the fly in a map as OGC Web Map Service (WMS) instance.

IV. USE CASE

At this moment, the functionalities presented by the system are in accordance to the following use case:

a. A stationary *in situ* wireless geosensor network, spatially distributed over a geographic area, collects measurements, e.g. air temperature, humidity, precipitation, wind speed and direction.
b. Users that monitor the studied area need to visualize the sensors location on a map and to view the time-series data, graphically or in tabular form.
c. Users can select a subset of sensors on the map and visualize only the corresponding observations. For each selected sensor, the user can set the property(ies) to view (e.g., air temperature) and the time interval; alternatively, the user can choose all observations received during the last hour or the newest 100 observations.
d. For a given property, in this case the air temperature, the user chooses a spatial interpolation method (IDW, Ordinary Kriging or Spline) and defines the subset of the observations and the parameters required for the interpolation surface construction.
e. The output image of the interpolation surface is shown on the map. Successive results can be visually compared in order to detect changes between time frames or time-stamps, and between different spatial interpolation techniques.

V. RESULTS

The platform prototype geoprocessing tasks consist in an automated interpolation of air temperature measurements, using several spatial interpolation methods, to obtain a spatial distribution map (or grid surface) for different time-stamps or periods. Therefore, the user can compare the spatial-temporal results of each method for the same input data.

Results shown hereafter are outcomes of the prototype. Fig.1 depicts one of its graphical interface components: a map with the location of the sensors of a given region and the graphical representation of a time-series data collected by one of the selected sensors on the map.

IDW determines cell values using a linear-weighted combination set of sample points. The weight assigned is a function of the distance of an input point from the output cell location. The greater the distance, the less influence the cell has on the output value. The generated cell values do not exceed value range of samples, and the surface pass through samples. Fig. 2 shows the geoprocessing results for two different time-stamps. The displayed surfaces were obtained for the same spatial interpolation method – IDW.

Kriging considers that the distance or direction between sample points reflects a spatial correlation that can be used to explain variation in the surface. It fits a function to a specified radius to determine the output value for each location. Kriging is most appropriate when a spatially correlated distance or directional bias in the data is known. The predicted values are derived from the measure of relationship in samples using a sophisticated weighted average technique. The generated cell values can exceed value range of samples, and the surface does not pass through samples. Ordinary Kriging assumes that there is no constant mean for the data over an area (i.e., no trend).

Fig. 3 presents the interpolation surfaces obtained for the same time-stamps using the Ordinary Kriging method.

Spline estimates values using a mathematical function that minimizes overall surface curvature. This results in a smooth surface that passes exactly through the input points. It can predict ridges and valleys in the data and performs very well in representing the smoothly varying surfaces of phenomena such as temperature.

Fig. 4 presents the interpolation surfaces obtained for the same time-stamps using the Spline method.

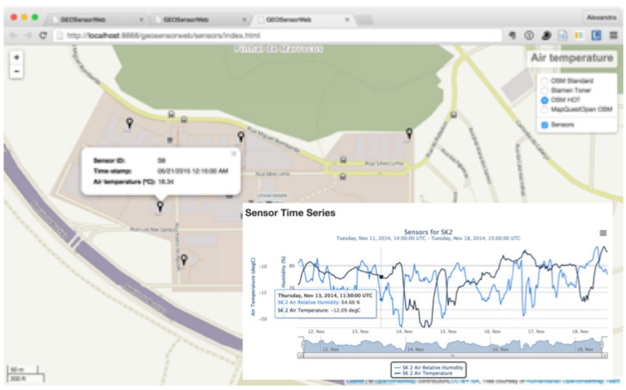

Figure 1. Sensors located on a map and time-series sensor data.

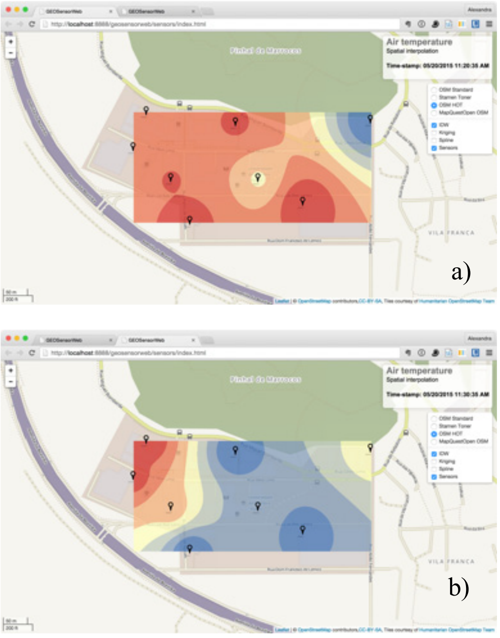

Figure 2. Interpolated air temperature surface using the IDW method for time-stamps: a) 05/20/2015 11:20:35 AM; b) 05/20/2015 11:30:35 AM. (Higher temperature values in dark red.)

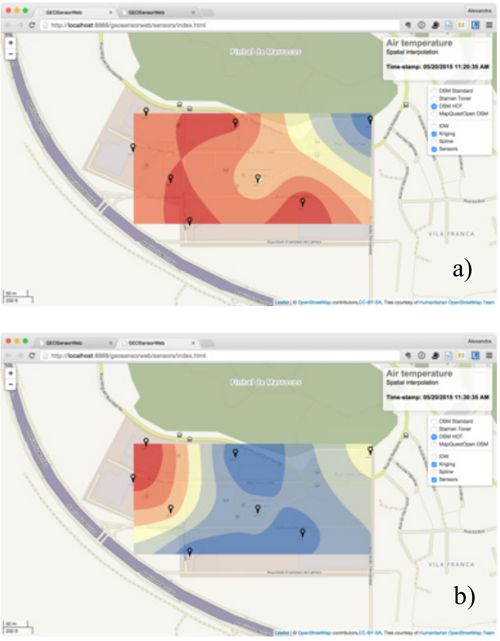

Figure 3. Interpolated air temperature surface using the Ordinary Kriging method for time-stamps: a) 05/20/2015 11:20:35 AM; b) 05/20/2015 11:30:35 AM. (Higher temperature values in dark red.)

VI. CONCLUSION

A GIS web-based platform for wireless *in situ* geosensor data visualization and distributed geoprocessing is presented. The system couples OGC standards for sensor data acquisition and access (SOS) and geoprocessing (WPS). For now, the data is remotely acquired from test bed sensors with artificially assigned geolocation. Moreover, the implemented geoprocessing tasks consist of spatial interpolation of air temperature measured values, using the methods IDW, Ordinary Kriging and Spline.

It is intended to enhance the system to support complex time-critical emergency activities, such as those carried out by the Civil Protection entities. Still, the platform can be used in an "offline mode", through substitution of real sensor data by generated ones. This way it becomes a learning tool not only for students of Geography and Engineering, but also for technicians, who wish to explore a possible cause-and-effect relationship between the conditions on the ground, represented by *in situ* measurements of environmental variables and additional spatial data, and the occurrence of phenomena such as floods, fires and landslides.

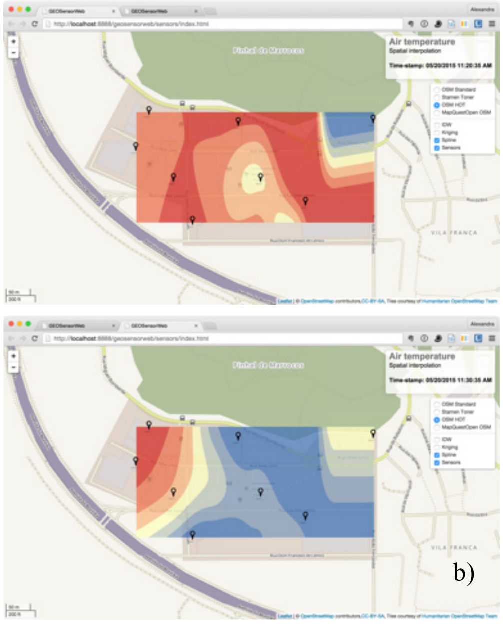

Figure 4. Interpolated air temperature surface using the Spline method for time-stamps: a) 05/20/2015 11:20:35 AM; b) 05/20/2015 11:30:35 AM. (Higher temperature values in dark red.)

REFERENCES

[1] A. Bröring, J. Echterhoff, S. Jirka, I. Simonis, T. Everding, C. Stasch, S. Liang, and R. Lemmens, "New generation sensor web enablement," Sensors, vol. 11, 2011, pp. 2652–2699. http://dx.doi.org/10.3390/s110302652

[2] A. Bröring, J. Echterhoff, and C. Stasch, "OGC Interface Standard 10-037: SOS 2.0 Interface Standard." *Open Geospatial Consortium*, Wayland, MA, USA, 2010.

[3] P. Schut and A. Whiteside, "OpenGIS web processing service," *OpenGIS Standard, Version 1.0. 0, OGC 05-007r7*, 2007.

[4] J. Li and A. D. Heap, 'Spatial interpolation methods applied in the environmental sciences: A review', *Environmental Modelling & Software*, vol. 53, pp. 173–189, 2014 http://dx.doi.org/10.1016/j.envsoft.2013.12.008

AUTHORS

A. M. Ribeiro is a PhD Student at the University of Coimbra and is with the Coimbra Institute of Engineering, 3030-199 Coimbra, Portugal (e-mail: alexr@isec.pt).

V. Sousa is researcher at CISUC, Dep. of Informatics Engineering, Polo II – UC, 3030-290 Coimbra, Portugal (email: vhsousa@student.dei.uc.pt).

A. Cardoso is with the Dep. of Informatics Engineering of the University of Coimbra, DEI, Polo II – UC, 3030-290 Coimbra, Portugal (email: alberto@dei.uc.pt).

The authors wish to thank FCT, CISUC and iCIS (CENTRO-07-0224-FEDER-002003) for supporting this work. Submitted 13 November 2015. Published as resubmitted 06 January 2016.