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Visualization of Sensor Data in Virtual Globes

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Abstract

Virtual Globes have become a common platform for visualizing geographical data. The capability for customization, extensibility and the support of interaction with the visualized elements are some of the aspects to consider when selecting a Virtual Globe for visualization. For visualizing sensor data, aspects such as cardinality, the nature of the data and its temporal and spatial dimensions have to be considered. In this paper we present a prototype application to visualize sensor data retrieved from SOS servers over the NASA World Wind virtual Globe. For implementing the prototype application we relied on a categorization of the sensor data that provides possible visualization methods. The prototype has integrated the SEXTANTE library to enable data analysis over sensor data and include the results as part of the visualizations.
Keywords: Virtual Globes; Sensor Web; Data Visualization; Sensor Observation Service.

1 Introduction

In recent years, virtual globes play an important role in daily life. They provide geographical information in a way that is possible to perceive the 3D aspects of the geographical features. Images, videos, points, 2D and 3D shapes, and live or dynamic content are just some of the visual tools supported for visualizing location-aware data. However a further integration of these elements with existing visualization techniques and analysis tools is needed [1].

Sensors are one of the sources of data that can be leveraged for representing in virtual globes. The recent improvements in terms of standardization and accessibility in this field [15] widen the possibilities for consuming and visualizing such data.

In this paper we describe a prototype tool for visualizing sensor data retrieved through Sensor Observation Services (SOS) [14] integrated with the spatial analysis library SEXTANTE[1]. The tool relies on a sensor data classification also included in this document.

The remainder of this paper is structured as follows. The next section presents a background of the relevant technologies related to this work and other efforts on the subject of sensor data visualization. In Section 3 we present a classification of sensor data used as a base for selecting the visualization methods that can be applied. Section 4 describes a prototype tool to visualize sensor data. Finally, in Section 5 we present our conclusions and future work.

2 Background

In this section we briefly introduce relevant technologies and efforts related to our work.

[1] http://www.sextantegis.com

2.1 Virtual Globes

The increasingly important role of Virtual globes in society and geosciences has been widely recognized in [3, 4, 5, 6]. Currently, several implementations are available, some examples are NASA World Wind Java (WWJ)[2], Google Earth[3] and Bing Maps 3D[4]. These products support different features and very often use different data sources for imagery [2], which implies more or less temporal accuracy and visual quality of represented geographical features. Aspects such as supported formats for representing features, visual elements that can be used (objects, shapes, geometries, textual content), and extensibility capabilities are crucial for choosing the appropriate virtual globe for visualizing a particular kind of data.

2.2 Sensor Web Enablement

The Open Geospatial Consortium (OGC) under the Sensor Web Enablement (SWE) initiative has developed a set of standards and protocols for accessing, publishing, and describing sensors and sensor data [15]. The main standards relevant to this work are the following:

- *Observations & Measurements (O&M)*: Contains the data models and XML encodings for sensor data, grouped as observations and measurements [12].
- *Sensor Model Language (SensorML)*: Includes the standard model and XML schemas for describing processes and sensor systems [13].
- *Sensor Observation Service (SOS)*: Describes the protocol and web service interface for accessing sensor data [14].

The SOS specification includes three profiles: core, transactional, and enhanced. The core profile (mandatory) contains the

[2] http://worldwind.arc.nasa.gov/features.html
[3] http://earth.google.com
[4] http://maps.bing.com

operation *GetCapabilities* that is the entry point to the service and provides information about available observations, the operation *DescribeSensor* that enables obtaining detailed metadata information about a specific sensor, and *GetObservation* that provides access to the observations kept in the SOS server. The responses of the last two operations are encoded in SensorML and O&M, respectively. The rest of the profiles are not supported by most of available SOS servers [9].

2.3 Related work

A work for visualizing sensor data availability is presented in [11]. It proposes different visualization methods for showing the presence of data for different time periods accessible in a SOS server. Other works such as [8] and [10], present the integration of the sensor web with virtual globes and its potential applications, but neither the scope of the data that can be represented is explained, nor the supported visualization methods.

A tool for visualizing sensor data acquired throughout OGC standards is presented in [7], however, it is not specified if this tool could be generalized for visualizing sensor information outside the scope of the project.

3 Sensor Data classification for visualization

To visualize sensor data, certain data taxonomy is needed to analyze the most suitable visualization methods in each case. This taxonomy should capture elements such as cardinality, nature and dimensions of the data to describe its temporal and spatial behavior. To start with we use the classification of observation by result type presented in [16]:

I. Observations for which the result of a single observation may be either single-valued or multi-valued, but, if there are multiple values, those values do not vary with either spatial position or time during the duration of the observation.
II. Observations for which the result of a single observation contains multiple values that varies with spatial position, time, or both, during the duration of the observation.

This initial classification allows us to split the observations that exhibit a static behavior regarding its temporal and spatial components, from those whose values vary in time and spatial position during an observation.

Besides this classification, at a lower level, the data can be classified by its type. In O&M this is addressed by providing specialized types of observations. Some of the types included in the specification are: category, count, truth, geometry, complex, discrete coverage, and point coverage observations [16]. The type of observation can impose limits in the visualization method to be used.

In the following subsections we analyze some possible visualization methods for each case.

3.1 Data in category I

In this category the sensor data may be coming from one or multiple sensors, resulting in different visualization possibilities.

3.1.1 One sensor

If the data is coming from a single source, its visualization could include metadata obtained from a *DescribeSensor* operation. Regarding the number of observations to be visualized, the following cases exist:

1. *One observation* (data for a particular observation): Visualization methods in this case could be based on just representing the observed value as text or linked to some visual property of the representation. Examples of such properties could be the size or the color. If appropriate, some categorization of the data could be done, so that the category of the value is represented in the visualization.
2. *Multiple observations* (sequence of observed values gathered in various observations): In this case different kind of chart visualizations such as bar charts, time series, or difference charts[5] can be used.

3.1.2 Multiple sensors

For multiple sensors data, following the same classification as in the previous subsection we have the following possibilities:

1. *One observation*: The visualization could be done in the same way as for a single sensor and, if appropriate, use the same representation for data from similar observed properties, in order to ease the comparison between the data. For example, temperature sensor data gathered from two different locations could have the same representation.
2. *Multiple observations*: In the presence of multiple sensor data series it is possible to create visualizations that allow for analyzing potential correlations. Possible visualizations could use scatter plots, line charts, and time series. It is necessary to consider that there is no guarantee of having values from different sensors in a common time range, and this could limit the possibility of having meaningful visualization charts. Moreover, an animation can be shown where the animated visual properties are linked to the values of the data.

3.2 Data in category II

Under this category we can classify the data depending on its spatial and temporal variability.

3.2.1 Data that varies its spatial position

In this case the data would have to be visualized by using some method that shows the values distributed in the space. Some possible visualization methods could be contour lines, paths, dot distribution[6] maps-like representation, and analytic surfaces.

Contour lines[7] would be useful to compare the different values belonging to the observation. Paths having some of the visualizations listed in 3.1 as vertices would help recognize similar values of the observation at different positions. Although it is a valid representation, it might not be appropriate in some cases,

[5] Chart types: http://en.wikipedia.org/wiki/Chart
[6] http://en.wikipedia.org/wiki/Dot_distribution_map
[7] http://en.wikipedia.org/wiki/Contour_line

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as paths could give the idea of an order in between the different values that might not exist. Additionally, a dot distribution map could be used, possibly showing the values using categories, linked to different colors. The analytic surfaces, surfaces where the height at a given point depends on the value observed in this position, could also be effective for visualizing this type of data.

3.2.2 Data that varies with time

This case could include an animation that shows the values during the observation. A time series chart could be also appropriate, showing the values during the observation.

3.2.3 Data that varies in space and time

This case is the conjunction of the previous two cases. A possible visualization method to use could be the dynamic analytic surfaces (analytic surfaces animated).

3.3 Other types

Besides the previous two categories, it would be necessary to introduce a further generalization. This would be the case in which the position of the observed value (or values) varies from one observation to another, despite of the spatio-temporal behavior of them during the observation. The visualization methods in this case could include paths, for visualizing the spatial distributions of the different observations. It should show the order in which the observations are performed in time, and each observation could, in general, use the previously mentioned methods - as suggested in Sections 3.1 and 3.2.

4 Prototype description

To visualize sensor data, we have implemented a prototype application using WWJ. WWJ offers an application programming interface (API) that allows the creation of several types of annotation, shapes, solid shapes, lines, custom rendered elements, and also allows a fine level of interaction with the different visual elements included in the globe.

One of the goals of our application is to provide functionalities for sensor data access, selection and manipulation in a user friendly way. We also aimed to include a set of visualizations methods and data analysis capabilities to facilitate sensor data exploration.

In the prototype we mainly address the data and the visualization methods listed in 3.1, however our aim is to include support for sensor data belonging to 3.2 and 3.3 categories.

4.1 Sensor data access and handling

To access sensor data we have reused a data access layer implemented in previous projects [17]. Regarding the access to observations, only the ones encoded using the *ObservationType* as specified in O&M are supported. Other types, such as *MeasurementType* are not supported because they occupy more space to encode the same data. Known SOS servers such as 52 North Server[8], Deegree[9] and Mapserver[10] encode the data retrieved from a sensor as an array containing the observations data, and usually support both types.

At a higher level, the tool offers a set of wizards to assist in the process of connecting to SOS servers and accessing the sensor data. The data selection process is supported by offering wizards to filter the data using temporal, spatial, and property-based filters.

As the data retrieved from *GetObservation* requests can contain information from different sensor systems, with measurements performed at different times, we represented the data retrieved from each sensor in our object model as a different dataset. Each dataset contains a set of measurements with the time associated to each measurement and the feature of interest.

For including data analysis capabilities to our prototype we have integrated the library SEXTANTE, which comprises a vast collection of algorithms and allows the inclusion of customized functionality. To achieve this integration, we have written the bindings necessary to provide SEXTANTE with the sensor data as input for the algorithms. We considered each dataset as a table or vector data layer that contains the position of the feature of interest as a point. The results of analysis performed with this library can be then visualized in WWJ.

4.2 Data Visualization

The visualization process is assisted by offering various types of visualizations with the possibility of configuring how different visual aspects of the visualization are related to the data. For example, it is possible to categorize the data of the observations according to a certain criteria and then use those categories for controlling aspects such as the size, shape or the color of the presented elements in the virtual globe.

We provided different mechanisms for supporting data comparability. For example, important values (such as the mean of the observations) can be displayed as part of the visualization of a given measurement. Time series charts can also be visualized, enabling the user to see the behavior of the observed property and its relationship with other observations.

The basic types of visualizations included in the prototype are: line and time series charts, scatter plot charts , and in general any chart produced by using the SEXTANTE library. Figure 1 shows a time series chart representing the behavior of the temperatures in a given period.

We included an observation based visualization that allows the representation of the values of the observed properties retrieved from a sensor. In this type of visualization it is possible to animate the visualized elements of the selected data based on the time of different measurements (Figure 2). The location of the feature of interest is used for placing the visualized elements in the globe.

The tool also allows the visualization of results of analysis using SEXTANTE library. The different types of output generated with SEXTANTE are visualized in the tool in a different way. Textual content and charts are shown in balloons while the resulting geometries are represented in the surface of the globe.

[8] http://52north.org/downloads/sensor-web/sos
[9] http://deegree.org
[10] http://mapserver.org

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Figure 1: Multi-axis time series chart showing levels of CO (Carbon Monoxide) and NO (Nitrogen Monoxide).

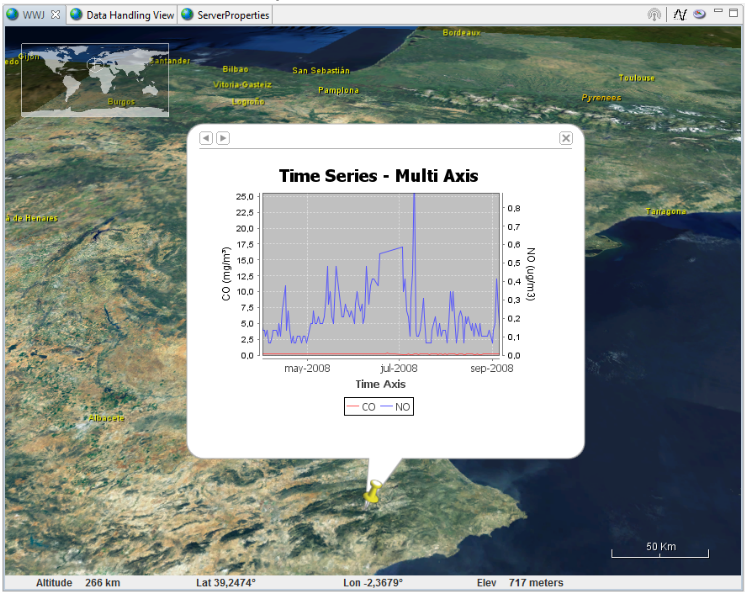
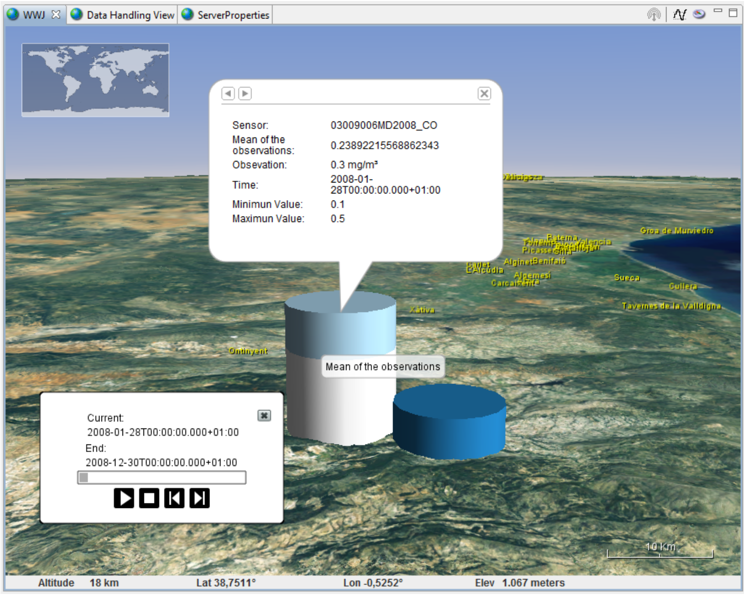


Figure 2: Observations animation for two observed properties (highlighted CO, Carbon Monoxide).



In Figure 3, the sizes of the buffers are linked to the values of the observations. This is one possible application but many others can be derived from the implementation and use of SEXTANTE's geo-algorithms.

5 Conclusion and future work

This work has presented a prototype for visualizing sensor data based on a classification used to identify possible visualization methods. Data access and handling capabilities have been incorporated to the prototype to ease data selection and retrieval from the SOS servers. Functionality has also been included for performing data analysis and integrating the results in the visualization. The further extensibility of SEXTANTE widen the possibilities for visualizing results of customized, context-specific analysis. The data types addressed for visualizing include some of the commonly supported by SOS servers. As future work we plan to extend the tool to support the representation of more data types widely used in the sensor web and to incorporate more visualization methods.

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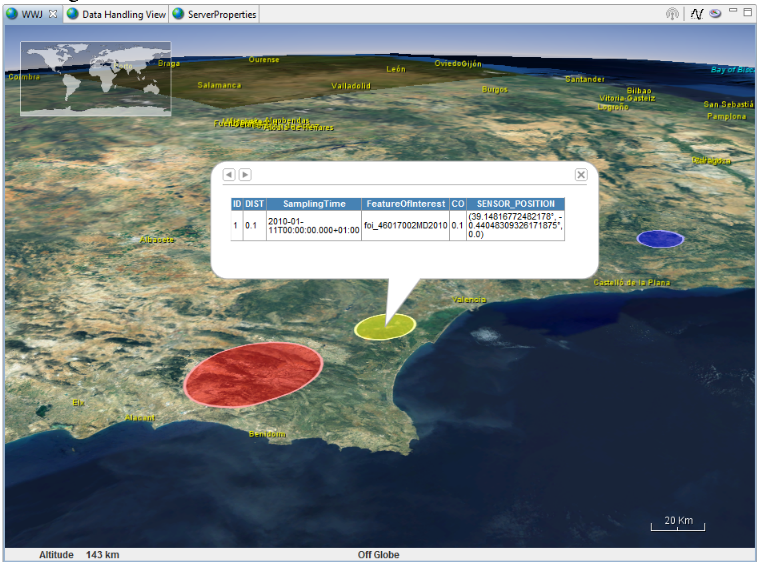
Figure 3: Buffers generated with SEXTANTE for three observations obtained from different sensors.



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