Sensors & Transducers, Vol. 194, Issue 11, November 2015, pp. 99-105

Sensors & Transducers

http://www.sensorsportal.com

Integrating Sensor Data Using Sensor Observation Service: Towards a Methodology for the O-Life Observatory

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Received: 31 August 2015 /Accepted: 15 October 2015 /Published: 30 November 2015

Abstract: This paper introduces an approach illustrating how the Open Geospatial Consortium (OGC) Sensor Web Enablement (SWE) framework can be used in order to build a franco-lebanese observatory. We present the practical application of SWE services as a source of real-time observation data and the associated technical architecture for making near real-time observations available to end users on the Web. We discuss the question of crossing sensor data with other data sources, e.g., data provided by human observations. We illustrate our approach by describing the methodology to integrate a first illustration case to monitor snow weather stations in the Lebanese Mountains. *Copyright © 2015 IFSA Publishing, S. L.*

Keywords: O-Life, Environmental observatory, Sensor web enablement, Lebanon, Snow monitoring, Sensor observation service.

1. Introduction

Lebanon is bordering the eastern Mediterranean Sea (see Fig. 1). The Mediterranean basin is a priority area and a leading area for the analysis of environmental data and for the extrapolation of trends that will allow a better management of the present and help envisage plausible scenarios for the future.

For this reason, actors of the French and Lebanese scientific research community are establishing a shared observatory between France and Lebanon named *"Observatoire Libano-Français de l'Environnement"* standing for "Lebanese-French Environmental Observatory", O-Life [6]. This observatory has the following objectives [6]:

a) Conduct simultaneously: Observation, Research, Training and Valorization;

b) Federate skills through common tools and objects;

c) Organize, share, sustain and enhance environmental data.

The observatory main activity is to study the critical zone around the Mediterranean Sea. As such, it addresses major environmental thematics such as water resources, biodiversity, natural hazards, environment management and ultimately land uses.

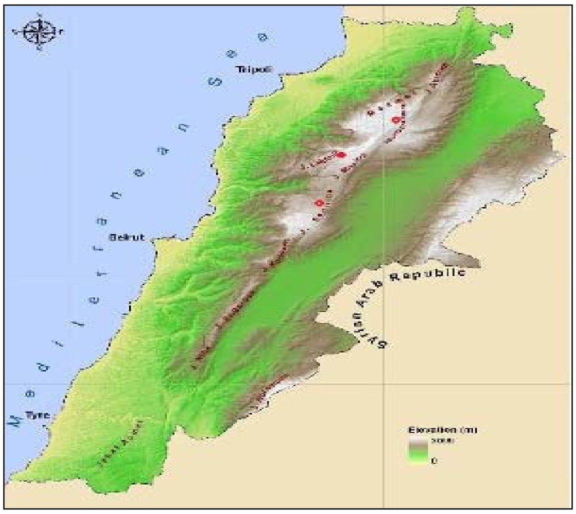

Fig. 1. Lebanon's map with snow stations locations (Study area).

To carry out its mission, O-Life observatory aims to construct environmental databases for the critical zone as well as to conduct monitoring services (Provide instruments, equipment, assist in operation and monitoring of sites), to create collaborative software tools, to exchange through innovative web services, to sustain and therefore enhance environmental data.

The main challenges are rooted on both heterogeneous and complex dimensions of data while treatments and end-users are not computer scientists and require information that may need multi-disciplinary approaches to cross several data sources. For this purpose, data must be fully integrated within a repository able to manage geospatial data and complex treatments (decision-making systems, visualization, data exchange, etc.).

This paper relies on O-Life Franco-Lebanese Environmental Observatory [5]. We discuss the main challenges from the data management point of view. We first introduce the Open Geospatial Consortium (OGC) Sensor Web Enablement (SWE) framework. OGC is the organization issuing geospatial data standards and references. We then present the architecture and implementation proposed within the framework of O-Life before detailing a case study dedicated to snow data management.

2. OGC Sensor Web Enablement

In this section, we present the main ideas leading the standard OGC, used in most environmental observatories and that enabling exchanges and uses of data from such observatories. OGC is an international, non-profit, voluntary consensus standards organization consisting of more than 500 companies, government agencies and universities [7]. The goal of OGC is the creation and establishment of standards that enable global infrastructures for delivery and integration of geospatial content and services and to ease adoption of open, spatially enabled reference architectures worldwide.

Within the last years, Sensor Web Enablement (SWE) architecture of Open Geospatial Consortium (OGC) has matured into its second generation [1]. The main goal of this standards framework is the integration of sensors and sensor data into Spatial Data Infrastructures (SDI) and thus makes it possible to use data measured by sensors in a broad range of applications. Thus, sensor data become an additional source for geospatial information besides conventional data types like maps. In addition, the availability of sensor data offers the possibility to integrate near real-time measurements with conventional geospatial data for visualization.

The SWE framework consists of a set of standards defining data formats for sensor data and its metadata, as well as service interfaces to access sensor data, task sensors or send and receive alerts based on sensor measurements [3].

In this article, a sensor is defined as a device whose purpose is to detect events or changes in its environment, and then provide a corresponding output.

3. Proposed Implementation

This section addresses similarities and specificities of O-Life Observatory and presents how OGC-SWE standards are integrated in O-Life infrastructure so that real-time data sources becomes available to end users.

3.1. Similarities and Specificities of O-Life Observatory

O-Life is built, as a first step, by combining and sharing data already collected and with direct access to in-situ sensors.

An extensive survey has been conducted for O-Life supported research projects. It illustrated that databases exist as well as data but mostly dispersed, diverse, not updated, unpublished, insecure, not shared, and not accessible to public. Furthermore, in many cases, data from many heterogeneous data sources might need to be combined and/or compared and different data sources have to be correlated. Moreover, there are different data sharing policy within the scientific community that prevents access to data. Sharing and leveraging data and research resources can avoid duplication of very expensive and time-consuming efforts, allowing scientists to spend more time in data analysis than in data collection and discovery, and enabling more people to benefit from environmental data. Advanced security concept is necessary so that only authorized users are able to insert/query data into O-Life infrastructure.

Hence, it is necessary to develop a standardized system for collecting data at national level and develop a data sharing policy resulting in sustainable databases, interoperable, shared, and regularly updated. This first step aims subsequently to create an ambitious Circum-Mediterranean observatory network.

3.2. Crossing Data

O-Life aims to collect and exchange data from various sources, including sensor and human observations. Any single problem requires many data sets and any single dataset serves many applications**.** As discussed in this paper, sensor data can easily be managed by the Sensor Web infrastructure. However, in some cases it may be difficult to manage human observations as such data do not always have compatible structures. For instance, way data are georeferenced, type of data (e.g., textual data) can make it difficult to integrate data directly as an input of Sensor Web. For this reason, we envision four possibilities for crossing data that will be explored in our work:

a) Transforming non sensor data so as to consider all data sources as inputs of Sensor Web;

b) Loading non sensor data directly in relational tables of the PostgreSQL database used to serialize Sensor Web data;

c) Crossing data thanks to an application within our infrastructure, thus relying on an application server to deliver the services;

d) Crossing data outside our platform, this option being taken by end-users after importing some data from O-Life database.

In the next section we present the architecture of O-Life infrastructure and explain how sensor data will be integrated within the infrastructure.

4. Proposed Architecture

Our implementation uses the 52 North (52N) German initiative for Geospatial Open Source software, 'Sensor Observation Service' (SOS) and 'Observations and Measurements' (O&M) and SensorML [8].

SOS is a web service to query real-time sensor data and sensor data time series and is part of the Sensor Web framework. 52N PostgreSQL database with a predefined schema for SOS will be used to store sensors data. PostGIS spatial extension will be included in the PostgreSQL database. Apache Tomcat will be used as Servlet container. The proposed architecture is shown in Fig. 2. SOS provides an interface for requesting sensor data sets based on temporal and spatial query parameters. The responses of SOS containing the requested data are then returned using O&M.

O&M framework defines a standard model and XML Schema for encoding observations and measurements from a sensor, both archived and real-time. This model defines how to link observed values with all relevant properties (i.e., location, time, observed parameter, unit of measurement) that are necessary to interpret them.

In the SOS interface, O&M is used in two operations:

- *GetObservation*: O&M is the default output
- *InsertObervation*: O&M is used for encoding all values that shall be inserted into a SOS server.

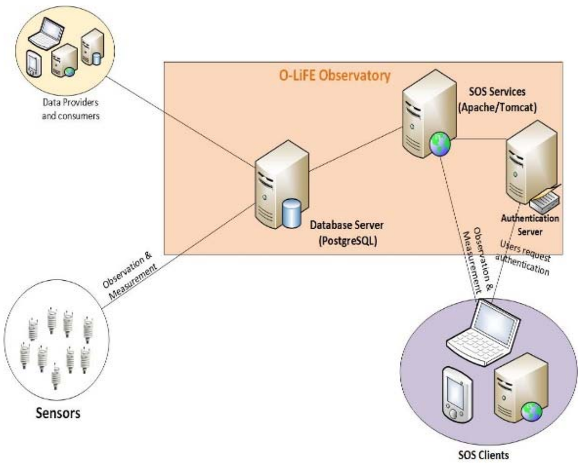

Fig. 2. Proposed architecture for integrating the SOS platform into the O-Life architecture.

SensorML offers a model and an XML encoding for sensor metadata. Information such as the sensor type, the owner of a sensor, identifiers of a sensor, inputs/outputs of a sensor, can be described in SensorML documents [2]. SensorML is used in two relevant SOS operations. *DescribeSensor* operation and *InsertSensor* operation for encoding the descriptions of sensors that shall be registered at SOS.

The existing PostgresSQL database server contains environmental data from different data providers for different thematics and structures. The SOS Server comes with its own database schema and store. The 52N SOS will maintain its own tables. Sensors data will be stored in the PostgresSQL database.

In the next sections, the snow weather monitoring case is explained in details to illustrate our proposed implementation.

5. Case Study: Snow Weather Stations

The observatory system is designed to support real-time monitoring that collect sensors data. This section introduces the use case of snow monitoring to apply our proposed implementation.

5.1. Presentation

In many Mediterranean and semi-arid regions, mountains are natural water tower for downstream plains, support for irrigated agriculture. For Lebanon, a significant part of the precipitation falls as snow that accumulates in winter to make an important contribution to the spring and summer flows. Yet, despite its significance for water surface and for groundwater recharge, this water layer is difficult to quantify. The study of snow and its cover dynamics is instructive for several reasons: trends, hazards and climate predictability, redistribution of melted water and impact on availability of downstream water.

Snow weather stations are installed in Lebanon as part of an agreement for scientific and technical cooperation for research on snow hydrology project and an observatory of joint project of the snow in the Mediterranean between CESBIO-IRD, the National Council for Scientific Research in Lebanon and the Saint Joseph University in Beirut [9].

A snow weather station consists of a central data logger (Campbell CR1000) receiving signals from various sensors connected to it. These sensors include:

a) A temperature and relative humidity probe;

b) A wind monitor sensors used to measure horizontal wind speed and direction;

c) A sonic ranging sensor, which is an acoustic sensor that provides a non-contact method for determining snow depth. The sensor determines depth by emitting an ultrasonic pulse and then measuring the elapsed time between the emission and return of the pulse;

d) Two pyranometers to measure incoming and reflected solar radiation;

e) A gyro sensor to measure rate of rotation around the station axis;

f) A barometer to measure the atmospheric pressure;

g) Battery level sensor to monitor the battery power level;

h) A digital camera to take real-time photos of the station surrounding.

Every 30 mn measurements from all sensors are aggregated and saved in a non-volatile storage on the station's data logger. It is a low power consumption device that autonomously operates for extended time periods on a battery recharged with a solar panel. When primary power drops below the threshold level, the data logger suspends execution reducing the possibility of inaccurate measurements.

In SensorML description, all sensors are described as separate entities and then assembled and connected to represent the whole snow station.

The three snow weather stations are located in three different regions in Lebanon (Mzaar, Cedars, Laqlouq) comprising sensors measuring temperature, snow height, relative humidity, precipitation, air pressure, wind speed and wind direction. The sensors are powered by solar cells as shown in Fig. 3. Sensor observations are sent remotely via a GPRS connection to a file server then to the database server hosted in the O-Life observatory datacenter using GPRS modem. Users will be able to query snow sensors data and access animated visualization of spatial-temporal data, including time series presentation.

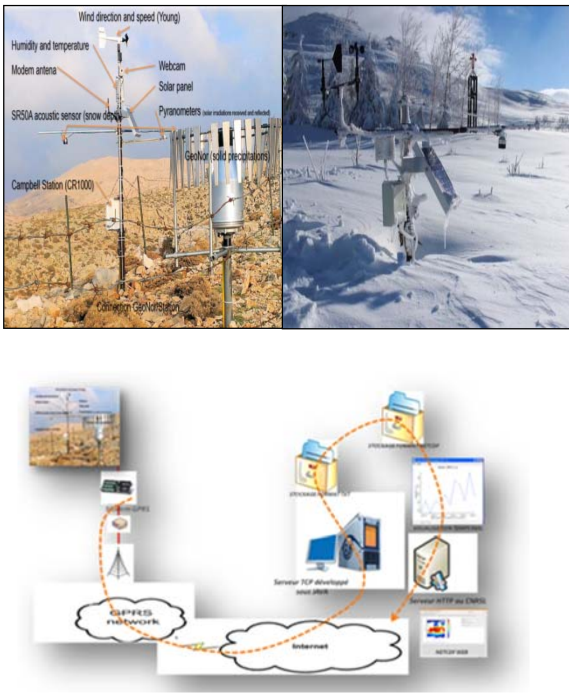

Fig 3. Snow weather stations in Laqlouq and Mzaar region, Lebanon.

Table 1 shows a snapshot of data generated by the snow weather stations.

The methodology applied to snow weather monitoring is detailed in the next section.

5.2. Methodology

In order to implement SWE system, we identify initial factors (feature of interest, procedure, phenomenon (observed property), time) and map the collected snow data in Table 1 to the UML diagram of O&M model shown in Fig. 4. Then the O&M data model that is designed as SOS database is filled with snow weather data.

Table 1 shows that the data are described by the following attributes:

- *TimeStamp* stands for the date and time of the measured values;
- *AirTemp* (C) is the Air temperature in Celsius;
- *vit_vent* (m/s) stands for Wind speed in m/s;
- *Direction vent* (degree) stands for Wind direction;
- *Std direction vent* (degree) measures the standard deviation of wind direction;
- *Pression* (mbar) is the Atmospheric pressure measured in mbar;
- *Geonor* (Hz) measures the frequency of vibrating wires in Geonor precipitation gauge;
- *Geonor* (mm) is the measurement of accumulation of precipitation in the bucket;
- *Wind max* (m/s) is the Maximum Wind speed.

Table 1. Example of part of the data generated by the snow weather stations.

TimeStamp	AirTemp (C)	vit_vent (m/s)	Direction vent (degree)	Std direction vent (degree)	Pressure (mbar)	Geonor (Hz)	Geonor (mm)	Wind max (m/s)
2015-04-09 08:00:00	8.06	13.49	190.8	12.5	764.1	2090	27.73	24.5
2015-04-09 07:30:00	8.34	13.34	187.1	10.66	764.3	2090	27.74	23.81
2015-04-09 07:00:00	8.97	14.77	189.8	10.99	764.2	2090	27.72	23.86
2015-04-09 06:30:00	9.19	14.24	186.1	11.49	764.2	2090	27.72	24.7
2015-04-09 06:00:00	8.67	11.11	187.2	13.52	765	2090	27.74	20.24
2015-04-09 05:30:00	9.49	11.18	185.6	10.64	764.9	2090	27.74	22.25
2015-04-09 05:00:00	10.21	13.12	183.3	11.19	764.5	2090	27.74	20.78
2015-04-09 04:30:00	10.63	13.9	183	11.6	764.5	2090	27.73	26.17
2015-04-09 04:00:00	11.36	16.05	188.9	12.64	764.4	2089	27.7	32.19

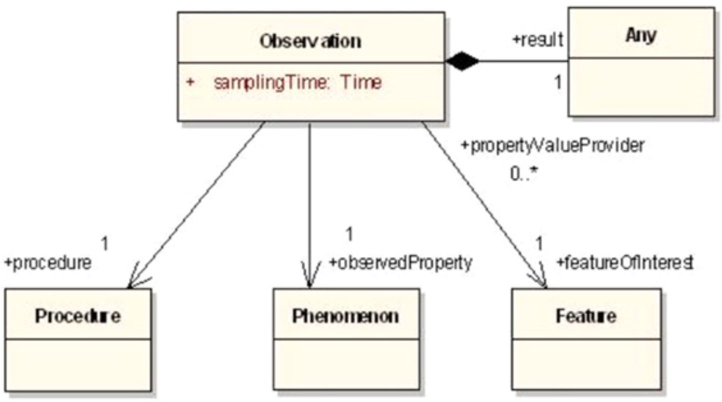

Fig. 4. UML diagram of basic observation model of O&M specification.

The *featureOfInterest* refers to the real world object from which the observation is collected. The model is voluntary very generic that it can encompass many systems. In our case snow is the central object of interest. However we are interested in comparing snow characteristics between three different regions. Consequently we must include the location in the concept of *featureOfInterest* which then becomes a snow station at a specific site.

In the O&M model the *procedures* are what produce the observations. In our case, this maps to the sensors. The snow station is an array of sensors that monitor the needed parameters like air temperature, wind speed, wind direction, etc.

The *observedProperty* is the *phenomenom* that was observed like *air temperature*, *wind speed*, *wind direction*, *air pressure*, *precipitation*, etc.

The location to which the observation belongs is indirectly referenced by the geolocation of the snow station.

The descriptions of sensors and observations are stored in a PostgreSQL/PostGIS database using standard metadata format (respectively SensorML and O&M). Since we do not need a particular database organization, we decided to store the data in a default database format using standard requests (*InsertSensor* and *InsertObservation*). Then, data can be obtained by request *GetObservation* and geolocated by *GetFeatureOfInterset*.

5.3. Results

Sensor observations are sent from the stations data logger through ftp to the database server at the O-Life datacenter and saved as CSV files. Then the SOS importer on the database server is used to import the files repeatedly every 30 minutes to the database server. The SOS Importer is a tool provided by 52N for importing observations from CSV files into a running SOS instance.

The workflow of the system is shown in Fig. 5. The users use the 52N Sensor Web Client which provides easy access to snow weather time series data stored within the SOS. The clients can send a request*GetObservation* to the SOS and receive the observation that is structured based on O&M. Through *GetObservation* operation, user can retrieve observations of interest for special features of interest, observed property and sensor. Furthermore, the result value for special observed property based on temporal filtering can be also retrieved. These parameters can be requested by making different queries. A station measuring air temperature can easily be selected interactively from a map, discovered by station's metadata. After a station has been selected, data can be loaded and displayed in the client as diagram for further investigation.

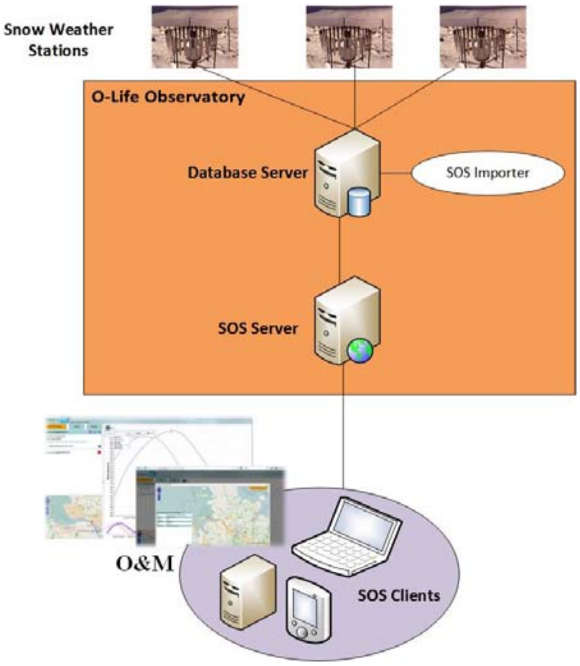

Fig. 5. Workflow of the snow monitoring system.

The proposed approach for in-situ sensor near real-time data acquisition is supposed to be a first step towards establishing the SWE framework within O-Life Observatory. The observatory aims to establish a National Spatial Data Infrastructure (NSDI) for Lebanon ensuring acquisition, archiving and management of multi-scale satellite imagery and in-situ datasets for the Lebanese territory and making it accessible by the scientific community and by various public actors involved in environment and management.

Data from in-situ or remote sensing devices form the basis for analyzing gradual processes, such as snow melting, water shortages, or increasing drought. 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. The near real time in-situ data could be used to calibrate and validate remote sensing data and models. Later, approaches to consolidate remote sensing data, and in-situ data will be considered to get more accurate results. This is highly prioritized by the O-LiFE observatory to make use and share all available source of data. Nevertheless, a special effort should be made to add additional in-situ sensors in different research areas and to include existing in-situ sensors in the country to the Observatory SDI. Besides, solutions to include mobile human sensors through mobile applications should be considered and developed to have vast amount of incoming georeferenced data and to allocate these data using the SWE standards.

6. Conclusions

In this paper, we investigate the possible ways for data management within O-Life observatory. We build an interoperable data model for environmental monitoring observation within O-Life observatory based on OGC-SWE standard formats. This has been followed by evaluating the Sensor Web architecture which is the set of data model definitions and web service specifications using the snow weather stations as a first use case. This work is being currently implemented in the framework of a collaboration between French and Lebanese organizations. Many perspectives are associated to this first approach. First, we aim at benchmarking our proposal with real data collected in the various data sources. Second, we aim at studying how our architecture can provide valuable services to scientists both for raw data crossing and exchanges and for analytical processing. Finally, we aim at studying how the O-Life data can be shared through Open Data for better enabling interoperability and linked to other open resources [4].

Acknowledgements

This work is part of a PhD thesis and is supported by the CNRS Lebanon PhD scholarship program. This is an O-Life contribution number SA 17-2015.

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