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SENSOR WEB MODELLING FOR FLOOD APPLICATIONS

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В работе рассматриваются вопросы создания моделей в рамках технологии Sensor Web для задач мониторинга и прогнозирования наводнений.

Introduction.

The Sensor Web is an emerging paradigm and technology stack for integration of heterogeneous sensors into common informational infrastructure [1, 2]. The basic functionality required from such infrastructure is remote data access with filtering capabilities, sensors discovery and triggering of events by sensors conditions.

The Sensor Web is governed by a set of standards developed by the Open Geospatial Consortium [3]. At present, the following standards are available and approved by consortium:

— OGC Observations & Measurements (http://www.opengeospatial.org/standards/om) – Common terms and definition for Sensor Web domain;

— Sensor Model Language (http://www.opengeospatial.org/standards/sensorml) – XML-based language for describing different kinds of sensors;

— Transducer Model Language (http://www.opengeospatial.org/standards/tml) – XML-based language for describing the response characteristics of a transducer;

— Sensor Observations Service (http://www.opengeospatial.org/standards/sos) – an interface for providing remote access to sensors data;

— Sensor Planning Service (http://www.opengeospatial.org/standards/sps) – an interface for submitting tasks to sensors.

There are also standards drafts that are available from Sensor Web working group but not yet approved as official OpenGIS standards:

— Sensor Alert Service – service for triggering different kinds of events basing of sensors data;

— Web Notification Services – notification framework for sensor events.

Sensor Web paradigm assumes that sensors could belong to different organizations with different access policies or, in broader sense, to different administrative domains. However, existing standards stack does not provide any means for enforcing data access policies leaving it to underlying technologies. One possible way for handling informational security issues in Sensor Web is presented in the next sections.

Sensor Web Modelling within Flood Use Case

One of the most challenging problems for the Sensor Web technology implementation is a global ecological monitoring in the framework of the Global Earth Observation System of Systems (GEOSS). Decision makers in an emergency response situation (e.g. floods, droughts) need to have a rapid access to the existing data sets, the ability to request and process data including the specific of emergency, and tools to rapidly integrate the various information sources into a basis for decisions. In this paper we consider the problem of flood monitoring using satellite remote sensing data, in-situ data and results of simulations.

The flood monitoring and prediction scenario presented here is being implemented within the GEOSS AIP (Architecture Implementation Pilot, http://www.ogcnetwork.net/AIpilot). It uses precipitation data from the Global Forecasting System (GFS) model and NASA's Tropical Rainfall Measuring Mission (TRMM, http://trmm.gsfc.nasa.gov) to identify the potential flooded areas. Once the areas have been identified, we can request satellite data for the specific territory for flood assessment. These data can be both optical (like EO-1, MODIS, SPOT etc) and microwave (Envisat, ERS-2, ALOS, Radarsat-1 etc).

The problem of floods monitoring by itself consumes data from many heterogeneous data sources such as remote sensing satellites (we are using data of ASAR, MODIS and MERIS sensors), in-situ observations (water levels, temperature, humidity, etc). Floods prediction is adding the complexity of physical simulation to the task.

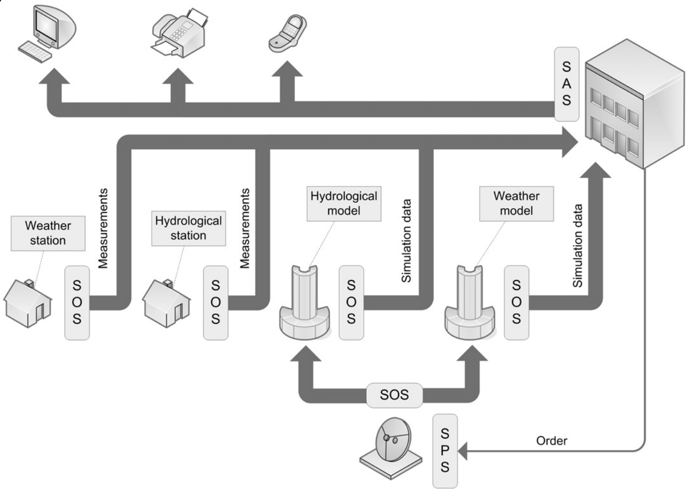

Figure 1. Sensor Web testbed for flood monitoring and prediction

The Sensor Web perspective of this test case is depicted in Fig. 11. It shows collaboration of different OpenGIS specifications of Sensor Web. The data from different sources (numerical models, remote sensing, in-situ observations) is accessed through Sensor Observation Service (SOS). Aggregator site is running Sensor Alert Service to notify interested organization of possible flood event using different communication mean. Aggregator site is also sending orders to satellite receiving facilities using Sensor Planning Service (SPS) to get satellite imagery only available by preliminary order.

SensorML Description of NWP Model

Sensor Modeling Language (SensorML) is the cornerstone of all Sensor Web services. It provides a comprehensive description of sensor parameters and capabilities as well as sensor calibration lineage, measure errors characteristics, response curves and other information about sensor. SensorML can be used for describing different kind of sensors:

— Stationary or dynamic;
— Remote or in-situ;
— Physical measurements or simulations.

Modelling and simulation are very important parts of environmental monitoring. The importance of different models in the process of solving of real-world tasks was demonstrated in the previous part of this paper. Sensor Web infrastructure should be able to integrate modelling data and provide remote data access for the as well as other Sensor Web features like discovery, sending orders, etc.

At the bare minimum, SensorML description should contain general information about sensor (time and geographical extents, contact persons, etc) and lists of inputs and outputs. SensorML input could be either physical phenomena or some external measured value. The first case applies to physical measuring devices and second – to models and simulations.

We have tried to describe weather modelling process using WRF [4] numerical model in terms of SensorML. There are nearly 50 inputs and 20 outputs for basic WRF configuration. It’s obvious that information density of inputs and outputs descriptions in SensorML is quite low and each of them requires quite significant amount of XML code to be properly described. The problem lies in very verbose description of multidimensional data. Three- and four- dimensional data arrays are very common in environmental modelling but SensorML provides poor experience regarding them.

Authors have raised this problem during thematic meeting and hope that next revision of SensorML will include some elements for simpler description of multidimensional data.

Sensor Observation Service Implementation

In order to provide access to hydrometeorological observations over the regions of interest we have deployed Sensor Observation Service implementation on the site of Space Research Institute of NASU-NSAU. We have studied two possible implementations of SOS for particular task of serving temperature sensors data. Implementations under study were UMN Mapserver v5 (http://mapserver.gis.umn.edu/) and 52North SOS (http://52north.org/).

The best experience received was with 52North SOS server. Its main disadvantage is complex relational database scheme. However it was possible to adapt existing database structure to the one, required by 52North using a number of SQL views and synthetic tables.

We have used 52North implementation for building a testbed SOS server providing data of temperature sensors over Ukraine and South Africa regions. The server is available by URL http://web.ikd.kiev.ua:8080/52nsos/sos. SOS output comes as XML document in special scheme, specified by SOS reference document. The standard is describing two possible forms of results, namely “Measurement” and “Observation”. The first form is more suitable to the situations when the service is returning small amounts of heterogeneous data. The second form is most suitable for long time series of homogeneous data.

Database Issues

The database of hydrometerological information of Space Research Institute of NASU-NSAU contains nearly 1.5 millions of records with observations started at year 2005 to the present moment. The data is stored in PostgreSQL database with PostGIS spatial extensions. Most of the data records are contained in single table ‘observations’ with indexes built over fields with observation time and station identifier. Tables of such volume requires some special handling so the index for time field was clusterized thus reordering data on the disks and reducing the need for I/O operations. Clusterization of time index reduced typical queries times from 8000 ms to 250 ms.

To adapt this database to the requirements of 52North we have created a number of auxiliary tables with reference values related to SOS (such as phenomena names, sensor names, regions parameters, etc) and a set of views that transforms underlying database structure into 52North scheme. 52North's database scheme uses string primary keys for auxiliary tables instead of synthetic numerical and is far from optimal in sense of performance. It doesn't have strong impact on performance with record counts in these tables less than one hundred but will surely cause problems in large-scale SOS-enabled data warehouses.

The typical SQL query from 52North service is quite complex (see listing below). An average response time for such query (assuming one month time period) is about 250 ms with PostgreSQL running in virtual environment on 4 CPUs server with 8GB of RAM and 5 SCSI 10k rpm disks in RAID5 array. The increase of query depth results in linear increasing of response time with estimate speed of 50 ms per month.

Conclusions

Despite of immaturity of Sensor Web technology stack it can provide good experience in serving for modelling in heterogeneous data in flood applications. SOS implementation for serving geospatial raster data that is important for remote sensing data are yet to be implemented. SensorML descriptions of complex environmental models are too verbose. To allow for a wide use of models in Sensor Web environment some changes should be made in SensorML to shorten descriptions of multidimensional inputs and outputs.

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