Concept for interoperable usage of multi-sensors within a landslide monitoring application scenario

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SUMMARY

This research paper focuses on handling or usage of different types of geodetic sensors like GPS, total stations, laser scanners, extensometers, etc., within a landslide monitoring application. Emphasis is given on interoperable working with these various instruments. In general, different sensors from different manufacturers provide different or proprietary data formats, communication protocols and interfaces making interoperability a very challenging task. However, some work around for these problems have been suggested. This paper addresses a concept in which SensorWeb is being investigated in its capability to support interoperable treatment of various sensors in a single monitoring system. Within the proposed concept, a description of an application scenario in which the sensors are manipulated is given. Also, a general framework in which the concept will be evaluated is described, in brief. In the conclusion, a summary of the current work and future outlook is given.

KEYWORDS: *Sensors, SensorWeb, SensorML, Interoperability, landslide monitoring*

INTRODUCTION

Monitoring of environmental hazards like landslides, floods, fires, disastrous weather events, etc., is a major issue of concern to the public, governments and responsible authorities. There are many efforts being carried out all over the world in order to mitigate the effects of such natural hazards (EEA, 2004; U.S. DOI; LGRB Baden-Württemberg report, 2002). Advances in information and communication technologies (ICT) like the Internet and wireless communication may be taken advantage of, in order to deal with such phenomenal problems. This paper mainly focuses on a concept, based on SensorWeb, for interoperable handling of multiple sensors within a landslide monitoring application. The various sensors should be accessed and controlled, as a single integrated sensor, using a sophisticated monitoring system. This paper restricts itself to terrestrial geodetic sensors like GPS, total stations, extensometers, laser scanners, cameras, etc., and their usage in a landslide monitoring application. However, treatment of multiple sensors in a common way within a single application imposes a number of challenges. In general, different sensors from different manufacturers provide different or proprietary data formats, communication protocols and interfaces. In order to work around this problem, a *sensor service* of the monitoring system should wrap these differences or simply hide them behind layers (e.g., sensor, communication, and information layers) and provide standard-based interfaces for the clients to collect and access sensor observations and manipulate them in different ways (Tao et.al., 2003). Tao and others also pointed out that accommodating various sensor types in a viewer and deliver valuable or meaningful information to the end user is a challenge. Because of the above discussed problems and needs, the research work investigates the Open Geospatial Consortium (OGC) SensorWeb concept capability to support interoperable usage of sensors in a single monitoring application. Investigations being carried out regarding the application of SensorWeb are the following:

- for the development of specific models for describing different geodetic sensors,
- for interoperable access and control of the various sensors, and
- for providing alert or alarm services.

Within a current bundle research project called "*Advancement of Geotechnology*" , being carried out by a consortium which comprises University of Osnabrueck (*Research Centre for Geoinformation and Remote Sensing*), University of Karlsruhe (*Institute for Photogrammetry and Remote Sensing*), EML (*European Media Laboratory*) Heidelberg and University of the Bundeswehr Munich (*AGIS GIS Lab*); AGIS and EML are working on a sub-project aiming at developing a sophisticated, standards-based mobile client for online geospatial data acquisition (Breunig et.al., 2003, Kandawasvika et.al., 2004). The mobile client employs sensors for the capturing of new geometries of features or for updating geometries of existing features. However, the software components of these sensors provide proprietary wrappers. This solution is not proper and only leads to the development of a new software module for each new sensor. As the number of sensors increases, this may lead to a complex and overwhelming monitoring system. This problem also has motivated the need for investigating SensorWeb for standard interfacing with the various sensors. This will be further discussed in the monitoring system concept section.

This paper is structured as follows: first a brief overview of the SensorWeb is given followed by a landslide monitoring system concept and proposed application of SensorWeb. Next is a description of a landslide monitoring scenario, in which the concept will be evaluated. Then a general framework is described, which comprise a simple architecture for the monitoring system and an example of a GPS model description done using SensorML.

OGC SensorWeb

Sensor Web Enablement activity (SWE) is the effort of Open Geospatial Consortium (OGC) [refer to http://www.opengis.org/functional/?page=swe], under which a number of SensorWeb specifications have been developed and are still undergoing refinement. A sensor web can be imagined or thought of as a "global sensor" that connects all web-resident sensors or sensor databases (Tao et.al., 2003). It can also be seen as a universal network of heterogeneous sensors. These sensors should be discovered, accessed, and tasked online using common interfaces. It is also interesting to note that the idea of sensor web can be referred back to the efforts of NASA Sensor Web Applied Research Planning Group. This group defined a Sensor Web as a "A system composed of multiple science instrument/processor platforms that are interconnected by means of a communications fabric for the purpose of collecting measurements and processing data for Earth or Space Science objectives." The NASA idea is focused more on advanced "smart "sensors and use own proprietary sensor web solution for networking the disparate sensors. However, what is substantial for this research work is the OGC SensorWeb concept. For this paper, the following specifications are of interest: SensorML (Botts, 2004), Sensor Collection/Observation Services (SCS) (McCarty, 2003), Observation and Measurements (O&M) (Cox, 2002), and Web Alert Services (WAS) (Simonis, et. al, 2003).

- *SensorML* provides information model and encodings for supporting the *discovery*, *querying*, *and controlling* of web-resident sensors. In essence, it provides a standard XML schema for describing a sensor, sensor platform, and sensor-tasking interfaces

- *SCS* is a service which provides standard interfaces to obtain observations from a sensor, a web of sensors, or an observation repository. Communication with these measurements data resources is via the web.

- *WAS* is a service which is being proposed for supporting alarm or alert service. For example, if a certain measurement threshold is exceeded, as reflected by the current measurements from a particular sensor, an alarm in form of an email, short message service, etc., should be send to responsible authorities.

For definitions of other specifications, refer to the OGC website. However, it is important to note that the SensorML has an extension specification which describes some models for remote sensors like frame cameras, scanner/profiler, rapid positioning coordinates (RPC) model, and a radiation response model (refer to OGC 04-068 or http://vast.uah.edu/SensorML). Each user community is expected to develop *specific models* for its applications. Hence, within the work for this paper, development of specific models for different types of geodetic sensors is done and evaluation of some SensorML elements in their applicability to fulfill the requirements of geodetic instruments descriptions. Regarding SCS, the following interfaces: *GetCapabilities*, *GetObservations*, *DescribePlatform* and *DescribeSensor* are being evaluated for interoperable communication with the instruments. The current SCS specification is based only on the pull model of service and for monitoring applications a push service is also needed. The following section discusses a concept for the landslide monitoring system and how the SensorWeb can be applied.

MONITORING SYSTEM CONCEPT

The concept involves three main roles: the end-user (i.e. geoscientist), the monitoring system (client/service), and the sensors. These three roles interact in a landslide monitoring application. For each role, specific requirements have been identified as well as the application of SensorWeb in order to fulfil the requirements.

End-user requirements

A geoscientist responsible for monitoring the debris avalanche might have the following requirements:

- Wants to task the sensors in the field in a common way. This means that requests to a sensors server should be similar regardless of the sensor type.
- Wants to know sensors which are still functional and well calibrated.
- Wants to know the properties and observables of a particular sensor.
- Be able to retrieve data in real-time from different sensors; process the data on-the-fly (i.e., integrate, filter,…) .
- From all the feeds from sensors, the user should be able to create new geographical features or update existing ones, display a map and perform situational analysis.
- The sensor feeds should enable the user to make timely decisions on the current landslide activity and this requires knowledge about the quality of the supplied data as well as knowledge of the consistency and reliability of the procedures used to process the data.
- If some critical thresholds of the features being observed are exceeded, the user should be alarmed.

Monitoring system requirements

- Each geodetic sensor should be able to describe itself (i.e. behaviour, characteristics,…) in a common way and also publishes it's capabilities. The SensorML is expected to satisfy this requirement. Also, ontology of different sensor types should be considered. This can be realised through use of dictionaries like sensor taxonomy dictionary, observables taxonomy dictionary,…
- Sensors are accessible via Web – *as suggested by the SensorWeb*.
- Wireless (e.g. Bluetooth, WLAN) and wired (e.g. serial cables) connections can be established for the purposes of communicating with the in-field sensor network.

- Access to different sensor types via standard interfaces – for the purposes of data retrieval as well as manipulation of these sensors. SCS will be evaluated for this point. This is a very challenging task and requires highly sophisticated services.
- Different data from different sensors can be processed on-the-fly and transformed into useful information.
- Sensors measurements data may be stored in databases using standard format (e.g., GML, O&M). Developing optimised databases for storing measurements is also a very challenging task. Some data compression and filtering mechanisms may also be necessary. This may be very important for data from laser scanners and digital cameras.
- Alert/ alarm should be generated if certain thresholds are reached or exceeded. Implementation of an alert service is challenging and may also need the development of intelligent, efficient agents for evaluating all the measurements from different sensors against predefined thresholds. Different protocols and technologies like OASIS Common Alert Protocol (CAP), Java Messaging Service may be integrated in to OGC Sensor Alert Service solution. Refence to related effort may be given to the OAK Ridge National Laboratory (ORNL).

Sensors requirements

The sensors used in this case study might supply the following data:

- *GPS* - positions, together with their timestamps, for determining displacement vectors of surface movements, etc.
- *Total stations* – positions plus other geodetic measurements (e.g., vertical and horizontal angles, distances,…), also for determining displacement vectors of surface movements, etc.
- *Digital cameras* - images showing changes in terrain appearance e.g., due to debris flow, vegetation collapse; new holes, ditches, or gaps on slopes or terrain
- *Laser scanners* – terrain points for reconstructing digital elevation models (DEM) ,…
- *Extensometers* – gaps expansions of the ditches in which they are installed.

The monitoring system should be able to handle the different data types provided by these sensors. However, it is very interesting to know how these data can be encoded and processed during real-time data acquisition.

Scenario use cases

Figure 1 shows an overview of the use cases defined for the monitoring system. These use cases should fulfill all the scenario requirements.

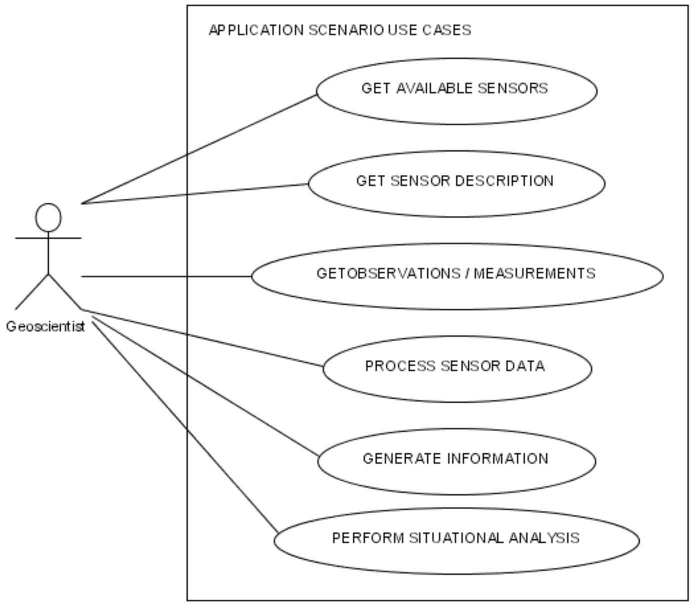

Figure 1. Application scenario use cases

i. Get Available Sensors requires that a sensors registry exists. An end-user can send a request asking for available sensors in the area of interest. The response from the sensors service should be a list of all sensors (i.e. sensorIDs and locations) that are installed on the site. Location information depends on where the sensor is installed. Sensors located within landslide active zones have variable positions. If possible, they should report their positions continuously.

ii. Get Sensor Description provides information about the sensor (i.e. sensor metadata). As proposed by SensorML, this information may include the following:

- Sensor type and identification
- Observables or *Measurands* – what the sensor can measure.
- Characteristics of the sensor relative to each of the observables (e.g., quality, sensitivity, range, environmental constraints,…)
- Functional model of the sensor – necessary for processing it's data.

iii. GetObservations/Measurements should support the use of low-level standard interfaces in fetching or retrieving measurements data from sensors. It should also be possible to use these same interfaces in tasking or making the sensors to "fire" or record measurements. The user should also be able to change data acquisition intervals and also change the quality thresholds for particular sensors depending on the current situation. For example, if the landslides are more active then the data intervals of sensors should be small. Also there is a need for push service, if the system detects some events to be reported, which the user is not aware of. It is not yet very clear whether the SCS specification can fulfill completely this requirement. This will be researched and evaluated prototypically.

iv Process Sensor Data may support on-the-fly or real-time processing of the data. This might include data filtering (e.g., in the case of laser scanners), compression, integration, etc.

v. G*enerate Information* - the results from processing are used to derive useful information for the user.

vi. Perform Situational Analysis – the generated information can help the user to make better situational analysis and informed decisions.

Following is the application scenario for the above concept.

APPLICATION SCENARIO

Within the current project a landslide application has been selected as a basis for evaluating the concepts of a sophisticated mobile data acquisition client (Plan et.al., 2004, Kandawasvika, et. al 2004). Two test areas have been selected for practical tests: Balingen and Rosenheim, Germany. These areas are very landslide active and it is being suspected that at any time rapid debris avalanches might occur, resulting in undesirable natural hazard. For this reason, continuous monitoring of these areas is vital. In order to achieve this, some sensors have been installed permanently in the field. Currently, there are a number of extensometers observing the inevitable seasonal expansions and contractions of the ditches (*ger.: Spalten*). Figure 2 shows an example of a geological object (i.e. ditch), in Balingen area, being monitored by an extensometer for any change in gap expansion. The extensometer's daily measurements are send regularly to a geological office for evaluation. As mentioned before, if a certain threshold is reached or exceeded, an alarm is generated, in this case, in form of a short messaging service (SMS) and the roads near-by landslide active area are closed. This avoids any danger to motorists or people on foot.

Figure 2. Extensometer monitoring ditch expansion

Also, some automatic total stations are observing fixed pegs or marks on the slopes or embankments (*ger.: Boeschung*) close to roads or rivers. For the purpose of this research, additional sensors like digital cameras, laser scanners, temperature and soil moisture recording sensors are envisaged for use. A monitoring system, used by the end user, would require to access in time and in a common way those heterogeneous sensors, during online data acquisition. These instruments acquire data or measurements of different types at different rates. The collected or measured data are send from these in-field sensors to a central office for processing, visualization and analysis. Following is a description of the framework for the concept.

FRAMEWORK FOR MULTI-SENSORS TREATMENT

Figure 3 shows a general architecture of the components which may be required in order to evaluate the proposed concept.

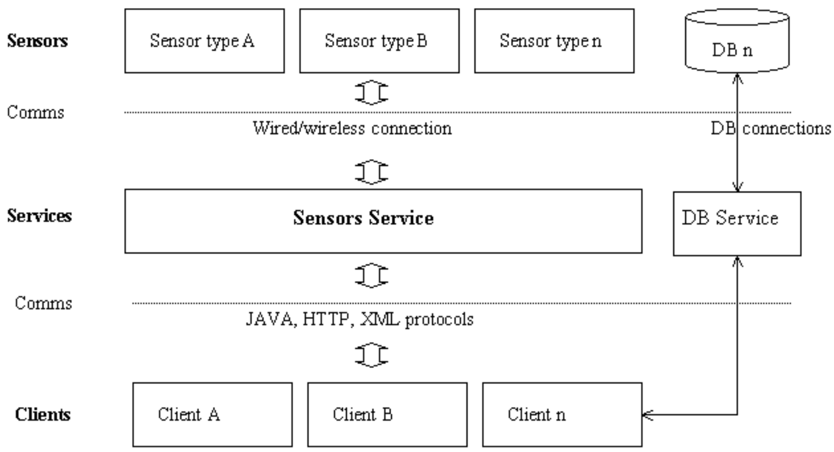

Figure 3. General, simple architecture components

From the above architecture, the following three levels can be identified: communication or access level, sensors level, and data processing level.

Sensors level

Each sensor type (e.g. GPS, total stations,...) should have a specific SensorML document which describes it. The document should include information like sensor identification, type, use, characteristics, behaviour, capabilities, etc. Such a model should facilitate common description of various sensors. This is analogy to GML (Cox et. al., 2004) descriptions of various geodata. The SensorML documents should enhance the end-user and the monitoring system to understand the sensors in use. Following is an example description of a GPS sensor used in the monitoring scenario.

The *identifier* element encodes the indentification data of the Anycom bluetooth GPS receiver.

```
<identifiedAs>
    <Identifier type="longName">AnyCom Blue GP-600 GPS Receiver</Identifier>
</identifiedAs>
<identifiedAs>
    <Identifier type="shortName">ANYCOM GP-600</Identifier>
</identifiedAs>
<classifiedAs>
    <Classifier type="sensorType" codeSpace="&SENSORS;">gpsSensor</Classifier>
</classifiedAs>
<hasCRS>
```

A position model for the GPS is used for locating the receiver. The position of the GPS is determined by its data and it may also be the position of a point feature being measured. A link to coordinate reference system like EPSG4329 is used as an example.

```
<locatedUsing>
        <GeoPositionModel id="gpsSensorPosition">
                <sourceCRS xlink:href="#sensorCRS"/>
                <referenceCRS xlink:href="&CRS;#EPSG4329"/>
                <usesParameters xlink:href="#gpsPosition"/>
```

```
            </GeoPositionModel>
    </locatedUsing>
```

The GPS can be used to measure the position of a Ditch feature within the landslide area. The observable here is the *ditchLocation*.

```
    <measures>
      <Product id="DITCHLocation">
        <observable>
          <Phenomenon id="ditchLocation">
              <name>Ditch Centre Position</name>
          </Phenomenon>
        </observable>
        …
    <measures>
```

To retrieve the location of the Ditch, the monitoring system has to parse the *values* element which accepts as input a *TupleData* or a reference to a *DataProvider* service. The “40000” represents a timestamp in seconds based on a certain time origin, “48.1340, 11.4385, 500.00000” stand for latitude, longitude, and height. The height is referred to the bottom of the ditch.

```
    <!--Position Data-->
      <values>
        <TupleData>
            40000,48.1340,11.4385,500.00000
        </TupleData>
      </values>
```

Additional information regarding the quality of the position can also be encoded. However, the SensorML is not suitable for encoding streams of positions like those of GPS. In this case, the TransducerML (TML) may be used. For other Sensors like total station, laser scanners, etc., the existing generic SensorML models have to be restricted and some extensions to the resulting models (i.e. from restriction) are necessary.

Communication level

The sensors *communication layer* should hide or wrap the proprietary communication protocols and interfaces from different manufacturers. The *sensors service* should be able to access different sensors using standard-based interfaces like the discussed SCS interfaces. It might also use different communication protocols like HTTP\XML or JAVA-based (i.e. RMI). The service is expected to fulfill the scenario requirements and match the use cases mentioned earlier. Also, tests will be made in order to evaluate how such a service satisfies the scenario requirements.

Data processing level

The application clients comprise the *data processing level*. The clients have to deal with data from different sensors like different data types, quality, etc. This may require the development of sophisticated clients that can manipulate and integrate heterogeneous data even on-the-fly. The clients may have also the possibility to store measurements using a database service. However, the data processing level is not within the scope of this paper.

CONCLUSION AND OUTLOOK

For this paper, the overall concept comprising different specific requirements and the proposed application of SensorWeb has been presented. From the discussion, in general, SensorWeb seems to be an appropriate solution for interoperable treatment or usage of disparate sensors within a landslide monitoring system. However, more detailed investigations have to be made. Also a simple example of SensorML application for describing a GPS sensor has been given. Detailed SensorML models or descriptions for the other types of sensors have to be developed and the capabilities of SensorML have to be proven in this respect. In a nutshell, the discussed concept is still under development and will further be refined as well as evaluated prototypically.

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OASIS: http://www.oasis-open.org/committees/tc_home.php?wg_abbrev=emergency