

# DESIGN AND IMPLEMENTATION OF SENSOR METADATA ON INTERNET

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**KEYWORDS:** METADATA, INTERNET, DISTRIBUTED, INTEROPERABILITY, WEB-BASED

## ABSTRACT

Recently, there is a large tendency toward using modern technologies specially those systems whose are intelligent and in hand, every where and every time. Sensor technology is one of the important technologies that were introduced in the recent years. In future, we may have a world wide network of sensing devices that collects all kinds of input from various environments, assesses that input, and then shares it with us humans over a worldwide computer grid. A network of sensors can perform as an extensive monitoring and sensing system that provides timely, comprehensive, continuous and multi-mode observations. This new earth observation system opens up a new avenue to fast assimilation of data from various sensors and to accurate analysis and informed decision makings.

One of the critical components in developing a sensor web is to build a geospatial information infrastructure, a backbone that connects the heterogeneous in-situ sensors over the wired or wireless networks. Although, with the rising trend to using of sensors, it is too important to have powerful and fast access to their collected data and themselves either, at any time and place.

For comply these needs, having standard metadata for sensors and their collected data is essential. In this way, by using metadata technology, sensors can be searched via their standard metadata. Moreover, for full access to wanted sensors and data, a web-based system would be the best alternative, in which accessing and sharing of data through the whole world, by using World Wide Web will be possible.

## 1. INTRODUCTION

From the technical view point, in the simplest form sensors are electric transducers that translate a physical property into an electrical signal. In the other hand, it can be known as a device for measurement of physical quantities. There are many kinds of sensors all over the world, from temperature sensor (visual thermometer) to position sensor (GPS). They can be used in air, land, sea and space.

In recent years, sensors could be integrated with Internet and related technologies. In this way its observed data can be captured in real-time, remotely control on them can be established, and at a glance the efficiency of the systems in the different parts of industry, agriculture, environment management and etc. will be improved.

Nowadays, Web comes to any activities, to business, education, communication and many other fields. Web can answer many of the needs; for example a person can easily book a seat on planes and room in hotel, in other country before he/she travel to that place. The possible use of Web seems endless, but there the technology is missing a crucial piece, that contains metadata which allows Web pages to be properly searched and processed in particular by computer. [1]

Metadata plays an important role in finding available services on the Web. Metadata is data about data and is necessary component for precise access to wanted services. In

fact, data without metadata is like a bottle of medicine without instruction, warning or an expiration date.

On the other hand, to make applications interoperable and sharing data on the Internet, the need for common formats and protocols make it possible heterogeneous systems and application to negotiate easily [1]. Today's, access to and integration of the basic data is very limited. For example, one Web site provides data maps, another gives data in static tables, another demonstrate data as text reports and etc. To obtain a complete illustration of desired data together, a user must access each of these data provider sites separately, take the data in a unique format, and then in some way reconcile the differences in the data and integrate them.

In general, this paper is going to study the formats/protocols that can be used for sensor collection services, metadata definition and sensor data encoding. The focus will be on Geography Markup Language (GML) as sensor measurements and observation application schema, Sensor Model Language (SensorML) as sensor description language and suitable for constructing observable dictionary and Scalable Vector Graphics (SVG) as a format for graphical rendering of the results.

## 2. SENSORS

*“In the next century, planet earth will don an electronic skin. It will use the Internet as a scaffold to support and transmit sensations. This skin is already being stitched together. It consists of millions of embedded electronic measuring devices: thermostats, pressure gauges, pollution detectors, cameras, microphones, glucose sensors, EKGs, electroencephalographs. These will probe and monitor cities and endangered species, the atmosphere, our ships, highways and fleets of trucks, our conversations, our bodies --even our dreams.” [3]*

One of the important activities in the GIS domain is data collection from the wanted area. Over the time many attempts by the scientists in the world have been accomplished to find the best way of data collection. One of these attempts result led to invention of the new technology which called sensor technology.

Using Sensors in many of the business have some favorites for users, such as:

- Real-time Data Capturing: Sensors give organizations the capability to receive real-time data and information about a situation or environment, wherever it is happening or located.
- Lead to Better Knowledge and Tracking throughout the Supply Chain: Sensors embedded in objects will enable manufacturers to increase their knowledge of products at all stages through the supply chain, from manufacturing to distribution to logistics.
- Lead to Consumer Trending: Wireless remote sensing combined with other data such as economic or market information can lead to useful trending of consumer tastes and preferences. This will deliver real-time customer insights while also providing valuable information on product life cycles.
- Provide Basis for Simulation: One of the key aspects of the Reality Online vision is a digital copy of an environment, object or person. Sensors will be one technology by which virtual doubles of environments will be created.
- Spur the New Applications

In general we have two types of sensors: remote sensors, which measure physical properties at some distance from the sensor and in-situ sensors, which measure a physical property within the area immediately surrounding the sensor [2].

Today, technological innovations have moved sensors well beyond their original capability as simple, standalone detection devices; they are now much more important than that. By continuously connecting a variety of sensors through wired/wireless connections, sensors are moving beyond individual smart objects to more complex networks that will enable people to "see" more of the physical world and act on it.

In fact, for some purposes, having a collection of sensors will be gratefully useful; a sensor collection can be in three following types:

- Sensor Package: Composed of multiple sensors that operate together to provide a collective observation or related group of observations. For example, a group of individual sensors that measure different chemical species can be grouped as one sensor that provides "water quality".
- Sensor array: A set of sensors of the same type at different locations.

- Sensor Web: Can be seen as 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 most unique feature of the sensor web is that information gathered by one pod is shared and used by other pods. While distributed sensors networks only gather data, communicate and uplink to a centre.

### 3. WEB SERVICE

A formal definition of a web service may be borrowed from IBM's tutorial:

*“Web services are a new breed of Web application. They are self-contained, self-describing, modular applications that can be published, located, and invoked across the Web. Web services perform functions, which can be anything from simple requests to complicated business processes...Once a Web service is deployed, other applications (and other Web services) can discover and invoke the deployed service.”*

It is obvious from this statement that the industry vision for Web Services perfectly correspond to the goal of designing an interoperable architecture for data fusion, data analysis or data sharing between different sensors/sensor webs. In such architecture, a web service is like a bridge for access to data or analysis tools of sensors/sensor webs which could be deployed for different purposes (Figure 1).

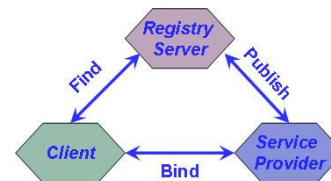


Figure 1: General web service architecture

### 4. SENSOR COLLECTION SERVICE (SCS)

With the rising trend in using Internet, accessing to environmental data via Internet has an important role in many of environmental projects. Sensor Collection Service (SCS) is introduced as a typical OpenGIS Consortium Geo Web Service that deals with sensors and provides the user facilities to access environmental sensor data through Internet. Clients implementing SCS can also obtain information that describes the associated sensors and platforms.

From viewpoint of implementation specification, SCS provides at least two operations as interfaces for client to interact with the service. The operations provide different facilities. Two available operations supported by SCS are GetCapabilities and GetObservation (Figure 2).

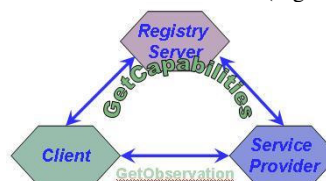


Figure 2: SCS as Service Provider, provides GetCapabilities and GetObservation interfaces

GetCapabilities operation makes it possible that SCS can provide general information about service itself and specific information about available sensors and observables. The whole provided information by this operation is called metadata. The result of invoking GetCapabilities operation is an XML encoded document called Capabilities XML

Using the GetObservation method, the SCS provides access to sensor observations and measurement data via a spatio-temporal query that can be filtered by observables. In addition, the SCS provides two other methods for retrieving detailed information about the sensors making those measurements and the platforms that carry the sensors. These are the Describe Sensor and Describe Platform operations.

## 5. METADATA

In the GIS world, information is used for research and manipulation everyday. This information comes from various sources from various times. Not all data that is in use is necessarily accurate, precise or up to date. But, how can one determine if it is of the accuracy, precision or as up to date as the project needs? This is determined simply through the use of metadata on the particular dataset in use.

Metadata is data about the data itself. This information helps the user of the data to determine whether the information contained within the dataset will be useful or in good condition to be used, by examining the quality, content and condition that the data is in. The location of where to find the information can also be a key factor in the use of the data. If it has to be sent away for, but the data is needed in an instant, then that data will not be of good use as access is poor to the user. This has the same purpose as in a library catalog system. When searching for a document one looks for the title, year it was published, author, description, location to find the document and many other attributes of the document to determine whether the document is of any use [5].

It is obvious that each web service needs to be described and published to one or more Internet registry service so that the users can locate and bind. In fact, published information is metadata about service (Figure 3). OGC has determined the following roles for metadata:

- Metadata specifies the characteristics of service provider. Service registry uses these characteristics to categorize service providers to support the find operation and Service requesters use them to match a service provider to their requirements.
- Metadata specifies non-functional characteristics. Non-functional characteristics may be used to help a service requester find a service provider.
- Metadata describes the interfaces used to access the service. The interface description includes its signature, allowed operations, data typing, and access protocols. Service requesters use this information to bind to the service provider and invoke its service using the published interfaces.

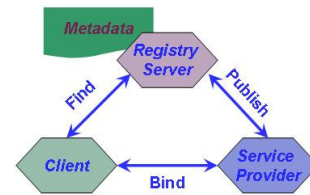


Figure 3: Metadata takes place in Registry Server

## 6. DATA FORMATS AND PROTOCOLS

The need for format/protocols comes from data heterogeneity between different programs and systems that are working on the Internet. To success in transferring and sharing data on the Internet it is necessary that component of the network use a common and standard vocabulary (formats/protocols) for their data encoding.

### 6.1. XML (eXtensible Markup Language)

*"The Extensible Markup Language (XML) is the universal format for structured documents and data on the Web."* [6].

The Extensible Markup Language (XML) is an extremely simple dialect (subset) of SGML the goal of which is to enable generic SGML to be served, received, and processed on the Web in the way that is now possible with HTML. XML has been designed for ease of implementation, and for interoperability with both SGML and HTML.

XML documents are made up of storage units called entities, which contain either parsed or unparsed data. Parsed data is made up of characters, some of which form the character data in the document, and some of which form markup. Markup encodes a description of the document's storage layout and logical structure. XML provides a mechanism to impose constraints on the storage layout and logical structure. A software module called an XML processor is used to read XML documents and provide access to their content and structure. It is assumed that an XML processor is doing its work on behalf of another module, called the application.

### 6.2. GML (Geographical Markup Language)

GML is one of the most important elements in interoperability Program managed by Open GIS. It provides standardized components to encode geographic information. Geography Markup Language (GML) is an XML grammar written in XML Schema for the modeling, transport, and storage of geographic information developed by Open GIS.

GML provides repository of schemas available on the Internet to support the encoding geographic information. Measurement.xsd and Value.xsd are the schemas, which supply the required elements to encode and describe sensor collection service observations and measurements.

The main idea about measurement model comes from OGC feature model. Based on the OGC definition feature is the basic item for geographic information. A feature has a number of properties, some of which may be geometric and spatial. Within measurement model a measurement is defined as a

specific feature type with particular properties to encoding in-situ sensors observations. Measurement model determines resultOf, MeasuredAt and timestamp properties to encode observed value, type of observer (sensor), location of measurement, and time of measurement respectively.

Value model provides elements required to encode observed value by the in-situ sensors. There are different kinds of classes for observed value.

At a glance, GML is an XML-based common encoding for spatial features which:

- Encodes geometry of geo-spatial features.
- Provides a schema language for geo-spatial features.
- Encodes non-geometric properties of spatial features.
- Encodes feature relationships and feature topology.
- Encodes temporal evolution of features and feature properties.
- Enables standard methods for separating geographic content from presentation
- Is foundation for Geo-Spatial Web (Its architecture is natively distributed and multi-server).

### 6.3. SVG (Scalable Vector Graphics)

SVG is a language for describing two-dimensional graphics in XML. SVG allows for three types of graphic objects: vector graphic shapes (e.g., paths consisting of straight lines and curves), images and text. Graphical objects can be grouped, styled, transformed and composited into previously rendered objects. The feature set includes nested transformations, clipping paths, alpha masks, filter effects and template objects.

SVG drawings can be interactive and dynamic. Animations can be defined and triggered either declaratively (i.e., by embedding SVG animation elements in SVG content) or via scripting.

Sophisticated applications of SVG are possible by use of a supplemental scripting language which accesses SVG Document Object Model (DOM), which provides complete access to all elements, attributes and properties. A rich set of event handlers such as onmouseover and onclick can be assigned to any SVG graphical object. Because of its compatibility and leveraging of other Web standards, features like scripting can be done on XHTML and SVG elements simultaneously within the same Web page.

SVG is a language for rich graphical content. For accessibility reasons, if there is an original source document containing higher-level structure and semantics, it is recommended that the higher-level information be made available somehow, either by making the original source document available, or making an alternative version available in an alternative format which conveys the higher-level information, or by using SVG's facilities to include the higher-level information within the SVG content. [4]

### 6.4. SensorML (Sensor Markup Language)

Sensor Model Language (SensorML) is an XML-based standard format that provides an XML schema for defining the geometric, dynamic, and observational characteristics of a

sensor. SensorML is suitable for both in-situ and remote sensor, whether mounted to static or mobile platform. The original SensorML, developed before any involvement of OGC, focused primarily on defining the geometric and dynamic properties of remote sensors. But the last release (published by OGC in 2002-08-16) refines and extends the previous schema and description to support dynamic, static, in-situ sensors and remote sensors.

To this end, the information provided by SensorML includes:

Observation characteristics:

- Physical properties measured (e.g. radiometry, temperature, concentration, etc.)
- Quality characteristics (e.g. accuracy, precision)
- Response characteristics (e.g. spectral curve, temporal response, etc.)

Geometry Characteristics:

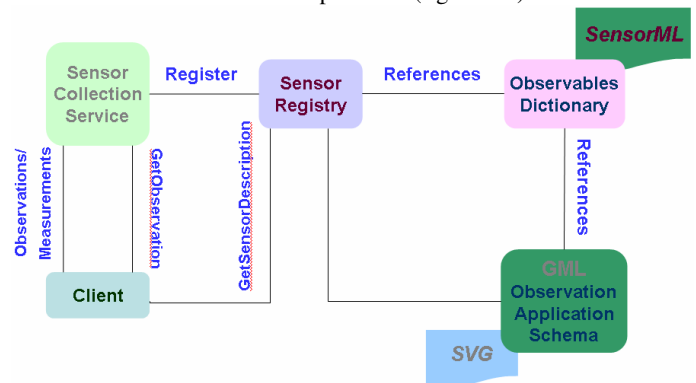
- Size, shape, spatial weight function (e.g. point spread function) of individual samples
- Geometric and temporal characteristics of sensor and sample collections (e.g. scans or arrays) that are required for metric exploitation

Description and Documentation:

- Overall information about the sensor
- History and reference information supporting the SensorML document

## 7. IMPLEMENTATION

In addition, through this study an architecture for Sensor Collection Service were preferred (figure 5-1).



Thanks to the evolvement of Internet, it creates a lot of new markets and business models. The sensor web concept builds a framework, which provides greater opportunities for public organizations and private sectors to open up new markets and services. The architecture proposed here creates a near real-time on-line transaction environment for sensor webs. Upon the open and scalable architecture, public organizations can publish interfaces and APIs to share the information collected by their sensors to the public. For private sectors, for example, a sensor provider could sell the information collected by the sensor to customers in the form of pay per use or pay by data volume.

The ability to locate, access, and use arbitrary sensors is one of the most challenging and practically relevant objectives in the design of open, distributed infrastructure for Sensors. And in dynamic, heterogeneous environments it is advantageous to allow late binding between sensors and clients; that is, a client will generally not know in advance where a

desired sensor is located. In this architecture, Sensor Registry is the component that supports the run-time discovery and evaluation of available sensors offers. It provides a common mechanism to classify, register, describe, search (by using the benefit of metadata), maintain and access information about Sensors and other Web Services.

Registry is a key component in such a service-oriented architecture that manages shared resources and facilitates service discovery. In fact, Registry allows:

- Sensor providers (Sensor Collection Service) to publish descriptions about sensors
- Clients to discover information about sensors which meet clients' interest.
- Clients to access (bind to) sensor providers.
- Clients in the other role can register a sensor in standard format in which Registry Defined.

The Sensor Registry defines a common information model and standard operations that allow clients to interact with registry instances, regardless of their role or content, in order to discover, access and manage sensor observation data, geospatial data and services.

Furthermore, the role of Sensor Collection Service as a service provider is to provide a web-enabled interface for sensor systems and other geo-spatial information as well. SCS acts like a wrapper which hides the different communication protocols, data formats and standards of sensor systems behind the server and provides a standard interface, based on the defined metadata, for clients to collect and access sensor observations and manipulate them in different ways. In order to accommodate various sensors in a sensor collection, the standard interfaces play a key role to keep the whole architecture efficient, extensible, and interoperable. Thanks to W3C and OpenGIS, they provide interoperability standards and interfaces, such as XML, SOAP, WSDL, UDDI and OGC Web Services Specifications.

In this architecture, Client has two roles, the one is Service Requestor. A service requestor first asks the Sensor Registry, where to find a suitable service provider by referencing to the Observables Dictionary which is based on SensorML and Observation Application schema which is based on GML, and then binds itself to the provider. After the service binding, Service Requestor sends requests to the Service Provider (SCS), and provider send responses back according to the requests (for client-side graphically displaying the requested data a conversion from GML to SVG in Service Provider will be done). After the responses are received, then client can perform the analysis and processing.

Client, in its other role, can register a sensor in Sensor Registry based on its rules which is standard metadata.

From the various issues considered in this seminar the following general conclusion can be drawn:

1. Data sharing is a serious problem for the development of distributed GIS applications. Developments of metadata and data exchange standards are solutions for this problem.
2. The most important criteria that must take into account to design and develop web based applications especially Internet GIS applications, are interoperability, openness, loose coupling, platform independency,

vendor neutral, and flexible data formats and protocols.

3. Basic technologies to describe and discover structured Geospatial information within the Internet are based on XML. XML is standardized, open, loosely coupled, platform independent, human and machine-readable technology. Flexibility of XML allows it to be customized to describe data for any application.
4. Geographic Markup Language (GML) is new standardized web data format for encoding and transferring Geospatial information using XML. Using GML, it is possible to encode a description of location or spatial extent of a building, sensor observations and measurements. The main advantage of using GML in today's Internet GIS applications is that GML is standardized, Open and no proprietary. GML offers an open approach to data sharing and interoperability. At present, the main problem regarding GML databases is size of GML files that are bigger than other formats (binary).
5. GML and Observations and Measurements Model can be used to describe web sensor data to development sensor-based applications. GML makes use of Observations and Measurements model to describe sensor observations and measurements in an interoperable way.
6. GML provides an interoperable way to package spatial data for Location-Based Services (LBSs) involving mobile Internet devices. However, use of GML in LBSs domain is in infancy and additional experiments are required to study effectiveness of GML in the mobile environment.
7. Sensor Model Language (SensorML) provides a standard XML schema for describing metadata for sensors, sensor platforms, and sensor tasking interfaces. Developing SensorML is one step toward preserving vital information required for geolocation and processing of sensor data for both

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