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GVSOS: A NEW CLIENT FOR OGC® SOS INTERFACE STANDARD

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GVSOS: A NEW CLIENT FOR OGC® SOS INTERFACE STANDARD

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ABSTRACT

The popularity of sensor networks has increased very fast recently. A major problem with these networks is achieving interoperability between different networks which are potentially built using different platforms. OGC's specifications allow clients to access geospatial data without knowing the details about how this data is gathered or stored. Currently OGC is working on an initiative called Sensor Web Enablement (SWE), for specifying interoperability interfaces and metadata encodings that enable real-time integration of heterogeneous sensor webs into the information infrastructure. In this work we present the implementation of gvSOS, a new module for the GIS gvSIG to connect to Sensor Observation Services (SOS). The SOS client module allows gvSIG users to interact with SOS servers, displaying the information gathered by sensors in a layer composed by features. We present the detailed software engineering development process followed to build the module. For each step of the process we specify the main obstacles found during the development such as, restrictions of the gvSIG architecture, inaccuracies in the OGC's specifications, and a set of common problems found in current SOS servers implementations available on the Internet.

KEYWORDS

GIS Applications

Sensor Web Enablement

OGC SOS specification

gvSIG extensions

Software Engineering

ACRONYMS

OGC – Open Geospatial Consortium

SOA - Service-Oriented Architecture

GIS – Geographic Information System

WMS - Web Map Service

WCS - Web Coverage Service

WFS - Web Feature Service

SWE - Sensor Web Enablement

O&M - Observation & Measurement

SOS - Sensor Observations Service

SPS - Sensor Planning Service

SAS - Sensor Alert Service

WNS - Web Notification Service

ADC - Analog to Digital Converter

SIVAM - System for the Vigilance of the Amazon

XML - Extensible Markup Language

GML – Geography Markup Language

GPL - GNU General Public License

MDI - Multiple Documents Interface

JTS – Java Topology Suite

OWS – OGC Web Services

UML- Unified Modelling Language

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1

INTRODUCTION

The popularity of sensor networks has increased very quickly. The production of sensors that become cheaper every day is possible due to continuous advances in semiconductor technology. At present, a low-cost processor, a group of sensors and a radio transmitter, can be easily combined in a single and inexpensive unit. These devices, although useful individually, offer maximum effectiveness when used together for sensing complex physical phenomena. Sensor nodes can be distributed inside a particular phenomenon or in its neighbourhood to measure its main properties. Sensor networks can be used in a wide variety of applications. Examples include environmental monitoring (Martinez et al., 2004), habitat monitoring (Mainwaring et al., 2002)(Szewczyk et al., 2004), structural health monitoring (Paek et al.,2005)(Chintalapudi et al., 2006), seismic detection (Werner-Allen et al., 2005) (Werner-Allen et al., 2006) and military surveillance.

Sensor networks can be implemented using a large range of technologies regarding sensors and communication devices. Many design aspects must be considered such as fault tolerance, scalability, production costs, operating environment, network topology, hardware constraints, transmission media and power consumption (Akyildiz et al., 2002). For these reasons, building such networks is not a trivial task. Apart from dealing with the inherent complexity of a single network, another problem is achieving interoperability between different networks that are potentially built using different software and hardware technologies. Consider the problem of different government agencies trying to integrate their data sources to build a unified model of the environment. Each agency might gather their data using sensors that cannot interoperate with devices from other agencies because they were deployed by different companies using their own communication protocols. The gathered data might also be stored using different formats because interoperability was not a primary goal when the system was built.

Over the last few years, a lot of work has been devoted to standardise the components and interfaces, including hardware and software interfaces, composing sensor networks. This standardisation simplifies the interoperability between the components inside a specific network, which we call internal interoperability, and the interoperability of different clients with different networks, which we call external interoperability. The latter is frequently achieved using a Service-Oriented Architecture (SOA). This architecture presents an approach for building distributed systems that deliver application functionality as services to either end-user applications or other services (Endrei et al, 2004). Some of the benefits of SOS are the reuse of existing software assets just by wrapping them up as services, the minimization of the impact of future changes because they focus on an interface and not in the implementation, and the possibility of composing existing services to build new ones (Endrei et al, 2004).

This architecture is widely used in the GIS field to access geospatial data through implementation specifications like: Web Map Service Implementation Specification (WMS) (OGC, 2006a), Web Coverage Service Interface Implementation Specification (WCS) (OGC, 2006) and Web Feature Service Implementation Specification (WFS) (OGC, 2005). These specifications maintained by the Open Geospatial Consortium (OGC) allow GIS clients to access geospatial data without knowing details about how this data is gathered or stored. The use of standard specifications addresses the following needs of the GIS community (OGC, 2005b):

- To share and reuse data in order to decrease costs (avoid redundant data collection), get more or better information, and increase the value of data holdings.
- To choose the best tool for the job, and the related need of reducing technology and procurement risk (i.e., the need to avoid being locked-in to one vendor).
- To allow people with less training to benefit from using geospatial data in more applications: That is, the need to leverage investments in software and data.

At present, OGC is working on an initiative called Sensor Web Enablement (SWE), for "specifying interoperability interfaces and metadata encodings that enable real time integration of heterogeneous sensor webs into the information infrastructure. Developers will use these specifications to create applications, platforms, and products involving Web-connected devices such as flood gauges, air pollution monitors, stress gauges on bridges, mobile heart monitors, Webcams, and robots as well as space and airborne earth imaging devices" (OGC, 2008b). This framework should allow sensor nodes and their corresponding sensor networks to be monitored and controlled through web interfaces using GIS clients.

SWE includes several implementation specifications and best practices papers. Each one of them addresses a specific area within the topic. They can be divided in two groups: specifications dealing with schemata of data and processes, and specifications of services. In the first category we can find the following specifications (OGC, 2008): Observation & Measurement (O&M) Schema (OGC, 2007), Sensor Model Language (SensorML) (OGC, 2007b) and Transducer Markup Language (TransducerML or TML) (OGC, 2007d). In the second category we can find four different services: Sensor Observations Service (SOS) (OGC, 2007g), Sensor Planning Service (SPS) (OGC, 2007c), Sensor Alert Service (SAS) (OGC, 2007a) and Web Notification Services (WNS) (OGC, 2007e).

The goal of this project is to implement an extension for the GIS client gvSIG (gvSIG, 2008) to connect to Sensor Observation Services providers. gvSIG is an open source GIS designed for managing geographic information. This tool provides support for common data formats, including vector and raster spatial data, remote spatial databases, and standard OGC web services. gvSIG allows the combination in a single view of geospatial data with different formats and coming from different sources. Its name is an abbreviation of "Generalitat Valenciana, Sistema d'Informació Geográfica".

A gvSIG extension is a software component that can be installed to a client to add new functionality. In this case, the SOS client extension allows gvSIG users to interact with SOS servers displaying the information gathered by sensors in a layer composed by features. With this extension, the community of gvSIG users is able to access these networks without depending on any proprietary software or any specific internal protocols used by the underlying networks. The project is a joint effort between the University Jaume I, the software company Prodevelop, and independent developers. Our role in the project is implementing the communication and user interface layers, although the whole extension architecture is presented here.

The rest of this document is structured as follows: Chapter 2 presents an introduction to the sensor networks topic. The chapter presents basic concepts and some general information about these networks, but it focuses mainly in the current OGC standards related with SWE. Chapter 3 introduces gvSIG, presenting its architecture and extension mechanisms. Chapters 4 and 5, present the analysis, design and implementation of the SOS client. Finally, Chapter 6 presents conclusions of our work.

2

STATE OF THE ART

In this chapter, we present a general introduction to the topic of sensor networks. First, the main concepts of the subject are presented. After that, a set of applications examples is shown. Last, an extensive introduction to the SWE framework is presented, especially to the Sensor Observation Service implementation specification.

2.1 Sensor Networks

Sensors are devices for the measurement of physical quantities (OGC, 2007b). A *sensor network* can be described as a collection of sensor nodes that coordinate to perform some specific action. The sensors nodes form a computer accessible network of many, spatially distributed, devices to monitor conditions at different locations (OGC, 2007g). Figure 1 shows a generic architecture of such networks taken from (Akyildiz et al., 2002).

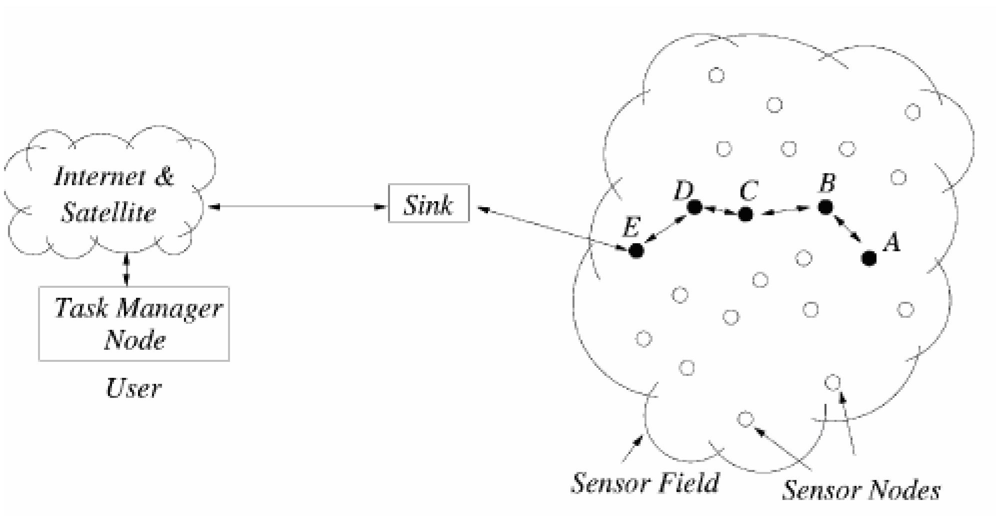


Fig. 1: Generic architecture of sensor networks

Sensor nodes are located in the *sensor field*. These nodes collect and route data about the field to the *sink*, which make the data available to the end user over the communication network (e.g. Internet).

Sensor networks provide several advantages when compared with traditional sensor platforms (Akyildiz et al., 2002) (Rentala et al, 2001):

- Sensors can be easily deployed "within" the actual phenomenon in an ad-hoc manner.
- Sensors have (limited) processing capabilities to pre-process the gathered data. Traditional models usually performed all the processing on central nodes in charge of gathering the raw data from the sensors.
- Greater fault tolerance is provided through redundancy.
- Coverage of large areas is provided through the union of individual nodes coverage area
- Sensors can be deployed in areas without energy infrastructure.

Sensor networks present different operational and technical characteristics than ad-hoc and cellular networks, in which the main goal is to optimize Quality of Service (QoS) and high bandwidth efficiency. On the other hand, the main goal in a sensor network is to maximize the network lifetime focusing mostly on power conservation. Next, we mention some of the differences between these networks (Akyildiz et al., 2002)(Rentala et al, 2001):

- The network is composed by hundreds to thousands of nodes that are densely deployed.
- The position of sensor nodes need not be engineered or pre-determined implying that the network must present self-organizing capabilities.
- The network topology may change frequently because of mobile nodes, defective nodes, new added nodes, or changes in the environment.
- Designed for unattended operation; the network must work without human intervention maybe because it might be located in inaccessible or hostile areas.
- The sensor nodes are not usually connected to an energy source, so energy must be used optimally.

- Sensors are prone to failure. The network must be fault tolerant; its overall functioning should not be compromised by the failure of individual nodes.
- Sensor nodes use mainly broadcast communication
- Sensors have limited computational capacities and memory. However, they partially process raw data to minimize communication which is the most energy consuming operation (Culler et al, 2004).

2.1.1 Sensor Nodes

A sensor node must satisfy the following requirements (Vieira et al., 2003):

- ***Energy-efficiency***: Energy is the major resource. It determines the node lifetime.
- ***Low-cost***: A node must be low-cost to keep a network with hundreds or thousand cost-effective.
- ***Wireless***: usually an installed communication infrastructure is not available.

It is composed of the following main components (Akyildiz et al., 2002) (Vieira et al., 2003):

- ***Sensing unit***: usually formed by sensors and analog to digital converters (ADC). Sensors estimate the values of observed properties and produce analog signals. These analog signals are converted to a digital one by the ADCs and sent to the processing unit.
- ***Processing Unit***: it is composed of a microcontroller and memory to store data and applications programs. The processing unit executes procedures for gathering the data read by sensors and in some cases it pre-processes the data before sending it to the sink.
- ***Transceiver unit***: connects the node to the network. Possible choices of transmission technologies are optical, infrared and radio frequency communication. Most of the platforms use short-range radio.
- ***Power unit***: usually rechargeable or non-rechargeable batteries.

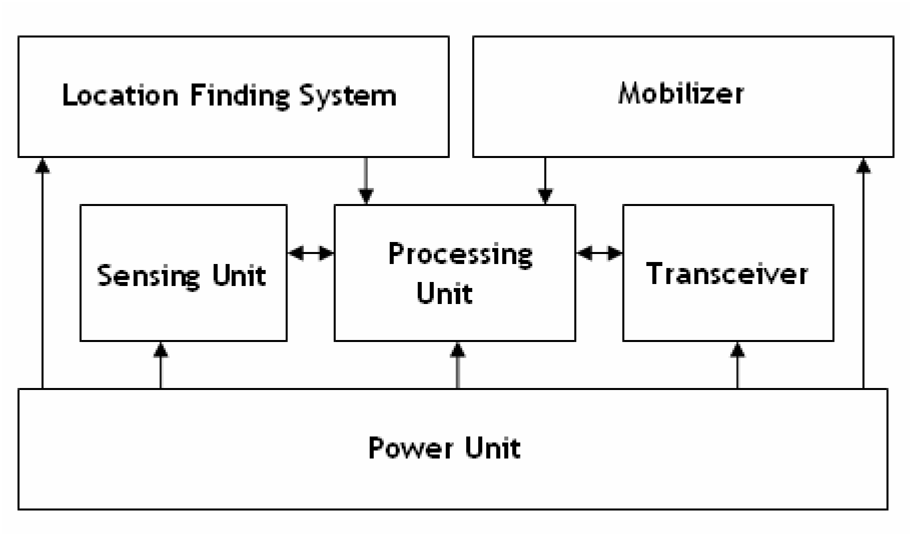


Fig. 2: Components of a sensor node

Apart from the basic components two others are commonly found on sensor nodes (Akyildiz et al., 2002):

- ***Location finding system***: frequently the location of the must be known with high accuracy.
- ***Mobilizer***: Useful to change the position of nodes

Typically, sensors (and therefore sensor nodes) can be classified in two basic categories: *In-situ sensors* measuring a physical property of the phenomenon surrounding the sensor, and *remote sensors* measuring physical properties associated with features at some distance from the sensor (OGC, 2007b).

2.1.2 Applications

In this section we present examples of how sensor networks have been applied in different fields. Specifically, we selected examples from environmental monitoring, habitat monitoring, structural health monitoring and seismic detection.

Environmental monitoring

Monitoring the environment has been one of the main applications of sensor networks since their inception. Several research projects using sensor networks at a small or large scale have been developed. In (Martinez et al., 2004) a system for monitoring a glacial environment is presented. The system's aim was to record the behaviour of ice caps and glaciers over a reasonable geographic area and over a relatively long time in an autonomous way. (Tolle et al.,2005) presents a study of complex spatial variations and temporal dynamics of the microclimate surrounding a coastal redwood tree. A sensor network was deployed where each sensor was able to measure air temperature, relative humidity, and photosynthetically active solar radiation.

The FLOODNET project (Envisense, 2008) uses sensor network for flood warning. The network nodes adapts dynamically in presence of environmental or infrastructural circumstances. The SECOAS project uses smart sensors to measure sea bed movement. The sensors are capable of dynamic self-configuration and use decentralized algorithms that enable automated adaptation to failures, upgrades and requirement changes (Envisense, 2008b).

As an example of a large scale network for environmental monitoring we can mention the System for the Vigilance of the Amazon (SIVAM). SIVAM is a project including a network of surveillance radars, environmental sensors, communications systems, an air traffic control centre, and coordination centres scattered throughout a the Brazilian Amazon region (Jensen, 2002).

Habitat Monitoring

Another field with many sensor networks applications is habitat monitoring. The characteristics of sensor networks make them specially well-suited for this kind of application. They can be inserted into the observed habitat without altering the parameters to be measured. Thanks to the wireless technology used commonly in these networks the behaviour of subjects can be studied without intrusions by observers. Last, the health and status of the instrumentation can be monitored remotely (Szewczyk et al., 2004). Maybe the best known example in this field is the study of sea birds at Great Duck Island, Maine (Szewczyk et al., 2004)(Mainwaring et al., 2002)(Szewczyk et al., 2004a). In this project, the occupancy of small, underground nesting burrows and the role of micro-climatic factors in their habitat selection were measured. Another example in this field is presented in (Zhang et al., 2004) where a wireless sensor network is used for studying how the number of location of microorganisms is correlated with chemical and physical parameters in the marine environment.

Seismic detection

Volcanoes are studied for predicting possible eruptions, measuring the level of volcano unrest or just to understand physical processes occurring inside the volcano (Werner-Allen et al., 2006a). The seismometer is the most commonly used instrument when studying volcanoes. It measures round-propagating elastic radiation from both sources internal to the volcano (e.g., fracture induced by pressurization) and on the surface (e.g., expansion of gases during an eruption) (McNutt, 1996).

In (Werner-Allen et al., 2006) a wireless network for monitoring volcanic eruptions at the Tungurahua volcano in Ecuador is presented. This network was built using low frequency acoustic sensor for collecting infrasonic signal that were transmitted to a remote base station. In (Werner-Allen et al., 2006a) a sensor network was deployed at the Reventador volcano in Ecuador. Network nodes used an event-detection algorithm to trigger on interesting volcanic activity and initiate reliable data transfer to the base station.

A large scale project in this field is being carried out by Jet Propulsion Laboratory, California Institute of Technology. The Sensor Web Project uses a network of sensors linked by software and the internet to an autonomous satellite observation response facility. This system has been used to implement a global surveillance program to study volcanoes. Tests to study flooding, cryosphere events, and atmospheric phenomena have been also executed (NASA, 2008) (Chien at al., 2007) (Sherwood&Chien, 2007).

Structure Health Monitoring

Structure Health monitoring (SHM) is focused in assessing integrity in a variety of structure such as buildings or bridges. Different techniques are used to detect and locate damages in the structures. These techniques rely on measuring structural response to ambient vibrations or forced excitation. Ambient vibrations can be caused by earthquakes, wind, or passing vehicles, and forced vibrations can be delivered by hydraulic or piezoelectric shakers. The existence and location of damage can be inferred by detecting differences in local or global structural response before and after damage (Chintalapudi et al., 2006). According to (Paek et al.,2005) most existing implementations use wired data acquisition systems to collect structural vibration data from various locations in the structure. The installation of a large scale system of this kind can be a very time consuming and expensive task. For these reasons, the use of sensor networks is considered a more appropriate solution.

In (Chintalapudi et al., 2006) the design of NETSHM is described. NETSHM is a programmable, re-usable and evolvable sensor network system that can be used to implement a variety of structural monitoring techniques. The system implements programming abstractions that allow structural engineers to use it without knowing low level details about the network details. (Paek et al.,2005) presents Wisdem, a system consisting of wireless nodes, placed at various locations on a large structure, to collect and transmit time-synchronized structural vibration data to a base-station. Each Wisden node measures structural vibrations with the help of a vibration card specifically designed for high quality low-power vibration sensing

2.2 Sensor Web Enablement

Despite the large number of existing sensor networks deployed, most of them remained traditionally close to certain sensor communities offering limited mechanisms for interoperability. Sensors within these communities are not easily discovered, accessed or tasked. Each type of sensor usually uses its own metadata, its own data format and its own software. Hence, the extension and modification of networks containing them is restricted at a serious degree (OGC, 2008). The OGC's[1] Sensor Web Enablement (SWE) initiative is a framework that specifies interfaces and metadata encodings to enable real time integration

[1] The Open Geospatial Consortium, Inc (OGC) is an international industry consortium of **368** companies, government agencies and universities participating in a consensus process to develop publicly available interface specifications (OGC, 2009).

of heterogeneous sensor webs into the information infrastructure. It provides services and encodings to enable the creation of web-accessible sensor assets (OGC, 2008b). According to (OGC, 2007g) the models, encodings, and services of the SWE architecture enable implementation of interoperable and scalable service-oriented networks of heterogeneous sensor systems and client applications. The functionality implemented in SWE must allow the implementation of solutions capable of:

- Discovery of sensor systems, observations, and observation processes that meet an application's or user's immediate needs;
- Determination of a sensor's capabilities and quality of measurements;
- Access to sensor parameters that automatically allow software to process and geo-locate observations;
- Retrieval of real-time or time-series observations and coverages in standard encodings
- Tasking of sensors to acquire observations of interest;
- Subscription to and publishing of alerts to be issued by sensors or sensor services based upon certain criteria.

Figure 3 shows the role of SWE in an information infrastructure. SWE acts like a middleware between the physical sensor networks and the software clients operated by final users. It can also be seen in this figure that the term "sensor" is not only applied to physical sensors but can be also applied to observation archives, simulations, and observation processing algorithms (OGC, 2008).

2.2.1 Services and Encodings

SWE includes several implementation specifications and best practices papers defining services and encodings. Implementation specifications for encodings are (OGC, 2007g):

- ***Observation & Measurement Schema (O&M)***: It defines standard models and XML schemata for encoding observations and measurements from a sensor, both archived and real-time. (OGC, 2007).

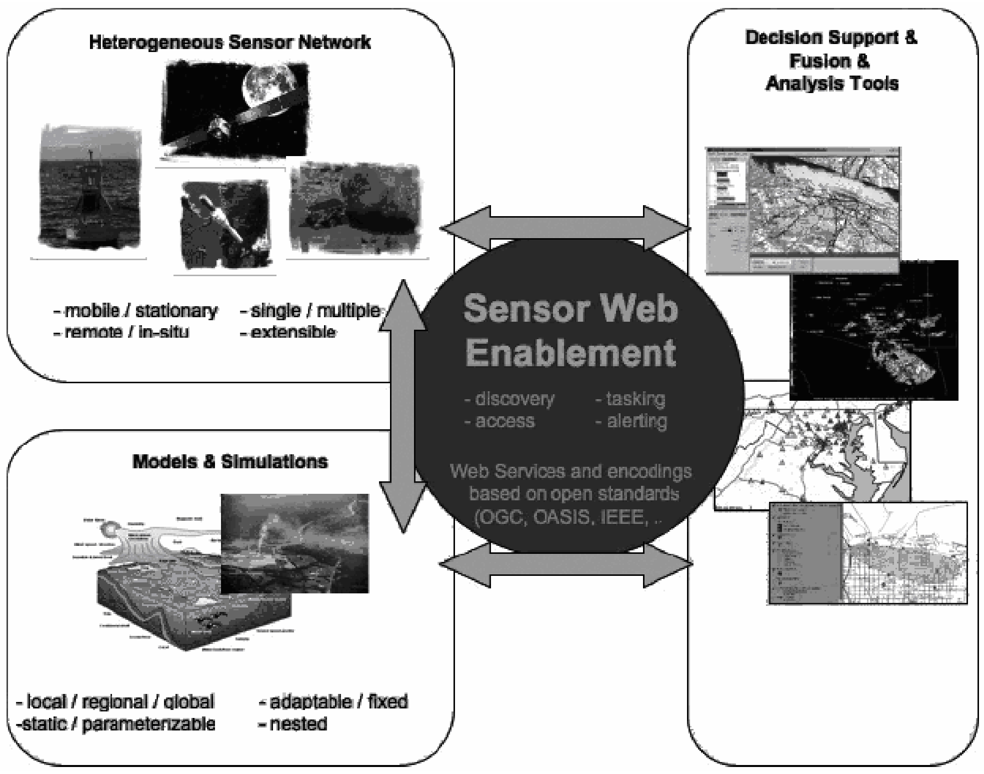

Heterogeneous Sensor Network
- mobile / stationary
- remote / in-situ
- single / multiple
- extensible
Models & Simulations
- local / regional / global
-static / parameterizable
- adaptable / fixed
- nested
Sensor Web Enablement
- discovery
- access
- tasking
- alerting
Web Services and encodings based on open standards (OGC, OASIS, IEEE, ..
Decision Support & Fusion & Analysis Tools

Fig. 3: SWE framework context (OGC, 2008)

- *Sensor Model Language (SensorML):* It defines standard models and XML schemata for describing sensors systems and processes; provides information needed for discovery of sensors, location of sensor observations, processing of low-level sensor observations, and listing of taskable properties (OGC, 2007b).
- *Transducer Markup Language (TransducerML or TML):* It defines the conceptual model and XML schemata for describing transducers and supporting real-time streaming of data to and from sensor systems (OGC, 2007d).

Implementation specifications for services are (OGC, 2007g):

- *Sensor Observations Service (SOS):* Standard web service interface for requesting, filtering, and retrieving observations and sensor system information. This is the intermediary between a client and an observation repository or near real-time sensor channel. (OGC, 2007g).

- ***Sensor Planning Service (SPS):*** Standard web service interface for requesting user-driven acquisitions and observations. This is the intermediary between a client and a sensor collection management environment (OGC, 2007c).

Best practices papers specifying services are (OGC, 2007g):

- ***Sensor Alert Service (SAS)*****:** Standard web service interface for publishing and subscribing to alerts from sensors (OGC, 2007a).
- ***Web Notification Services (WNS):*** Standard web service interface for asynchronous delivery of messages or alerts from SAS and SPS web services and other elements of service workflows (OGC, 2007e).

All these services and encodings working together enable Internet-accessible sensors to be accessed and possibly controlled via Web. The vision is the construction of the "Sensor Web", a collaborative, coherent, consistent, and consolidated sensor data collection, fusion, and distribution system for monitoring spatio-temporal phenomena appearing in the physical environment in real time (OGC, 2008). XML encodings provides standard formats for exchanging information regarding sensors. This information can be interpreted and used by any client implementing the specification without knowing low-level details of the actual sensor network. The service specifications provide standard interfaces for exchanging the aforementioned information, giving the users a broad set of tools for building sophisticated systems.

From all the specifications only O&M, SensorML, and SOS are relevant for the work we are presenting here. In subsequent sections they are explained in further detail.

2.2.2 Typical workflows

In this section we present some of the SWE typical workflows. A subset of the workflows introduced in (OGC, 2008) is discussed below to illustrate the general functioning of the SWE building blocks relevant to our work.

Request of discrete observation data

Requesting discrete observation data is one of the most used functionalities provided by SWE framework. Data about sensor observations is published by some data producer in a SOS server. Then, SOS client connects to the server and reads some of this data. Figure 4 shows a sequence diagram illustrating this workflow. First, the client must send a *GetCapabilities* request to the server to know for sure which data is published on it. After that, the client sends a *GetObservation* request specifying the specific information to be retrieved. The response to this request is a XML file in O&M format.

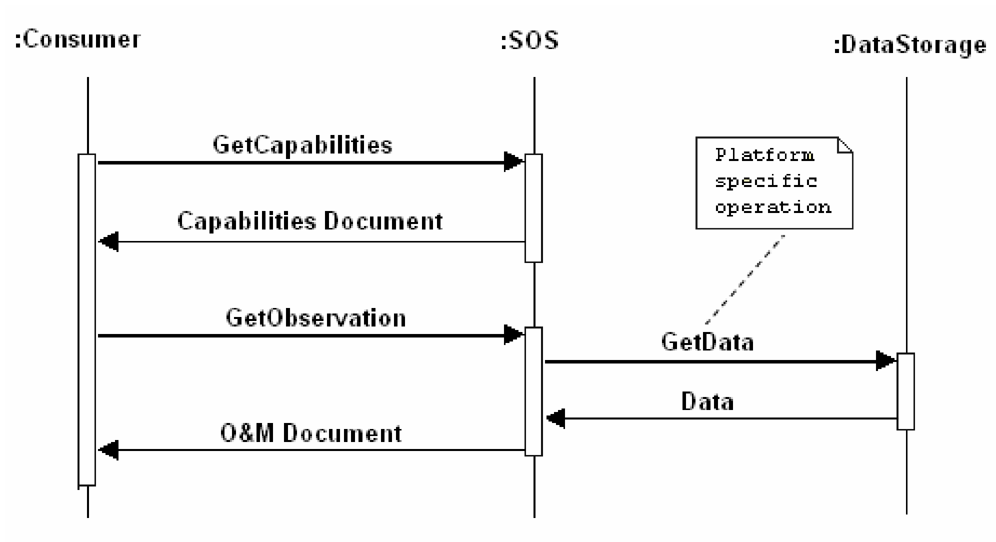


Fig. 4: SOS client requesting observation's data from a server (OGC, 2008)

Request of streaming (out of band) observation data

Streaming data can be accessed through an SOS server in two ways: using the *GetResult* SOS operation or by connecting directly to the real source using a hyperlink returned from the server. In neither case the observation data is returned inline within the *GetObservation* operation's response. Figure 5 shows how this works when the information is read from the source. First, the client must send a *GetCapabilities* request to the server. Next, the client sends a *GetObservation* request specifying the specific information to be retrieved. The response to this request includes a hyperlink to the data source, which is then accessed directly from the client. In the other case for this scenario, after performing the *GetCapabilities* request, the client reads the information from the SOS server sending *GetResult* request in a continuous way until all the data has been read.

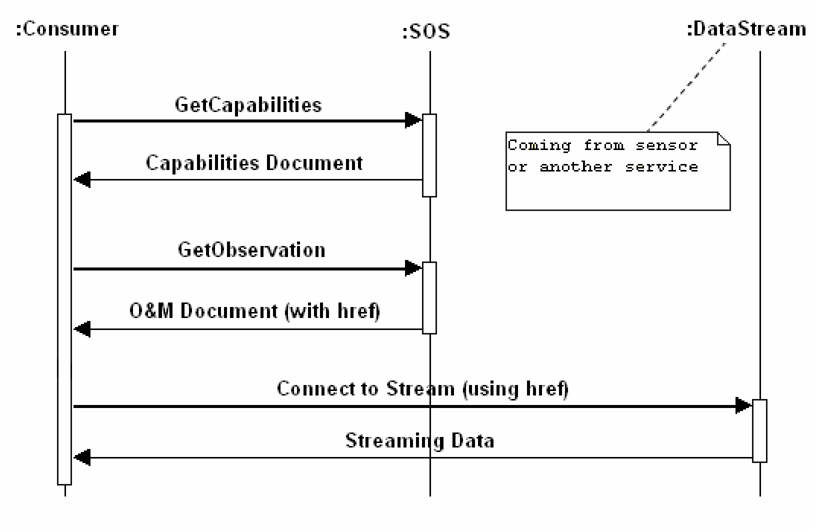


Fig. 5: SOS client accessing streaming data from the source (OGC, 2008)

Access to Sensor Descriptions

Sensor descriptions in SensorML format can be accessed from the client in a similar way as the observations (Figure 6). After doing the GetCapabilities request, a *DescribeSensor* request is sent to the server specifying an identifier for the sensor we want information about. The SensorML descriptions of every sensor were previously stored in some kind of data storage associated to the SOS server.

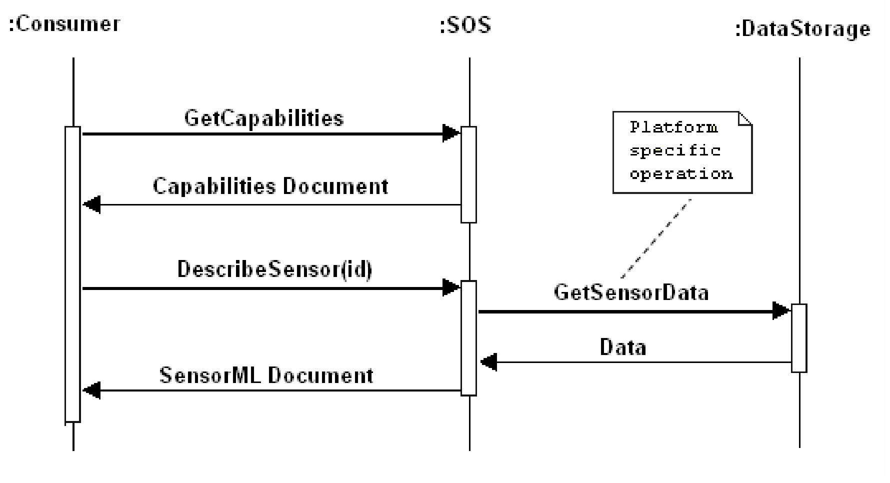


Fig. 6: SOS client accessing sensor's data from a server (OGC, 2008)

2.2.2 SWE Common

All SWE schemata and services share common data types and data encodings defined in a single namespace are called SWE Common. SWE Common provides data types and related components that fall in the following categories (OGC, 2007b):

- Primitive data types, complementing those implemented in GML
- General purpose aggregate data types, including records, arrays, vectors and matrices
- Aggregate data types with specialized semantics, including position, curve, and time-aggregates
- Standard encodings to add semantics, quality indication and constraints to both primitive and aggregate types
- Specialized components to support semantic definitions, as required above
- A notation for the description of XML and non-XML array encodings.

2.2.3 O&M implementation specification

As mentioned before O&M defines standard models and XML schemata for encoding observations and measurements from a sensor, both archived and real-time. Most of the concepts included in this specification are defined in the following paragraph taken from (OGC, 2007):

"An *observation* is an act associated with a discrete time instant or period through which a number, term or other symbol is assigned to a phenomenon [FOW1998]. The phenomenon is a *property* of an identifiable object, which is the *feature of interest* of the observation. The observation uses a *procedure*, which is often an instrument or sensor [NRC1995] but may be a process chain, human observer, an algorithm, a computation or simulator. The key idea is that the observation *result* is an estimate of the value of some property of the feature of interest, and the other observation properties provide context or metadata to support evaluation, interpretation and use of the result."[2]

[2] The references included in the paragraph are the ones included in the original document.

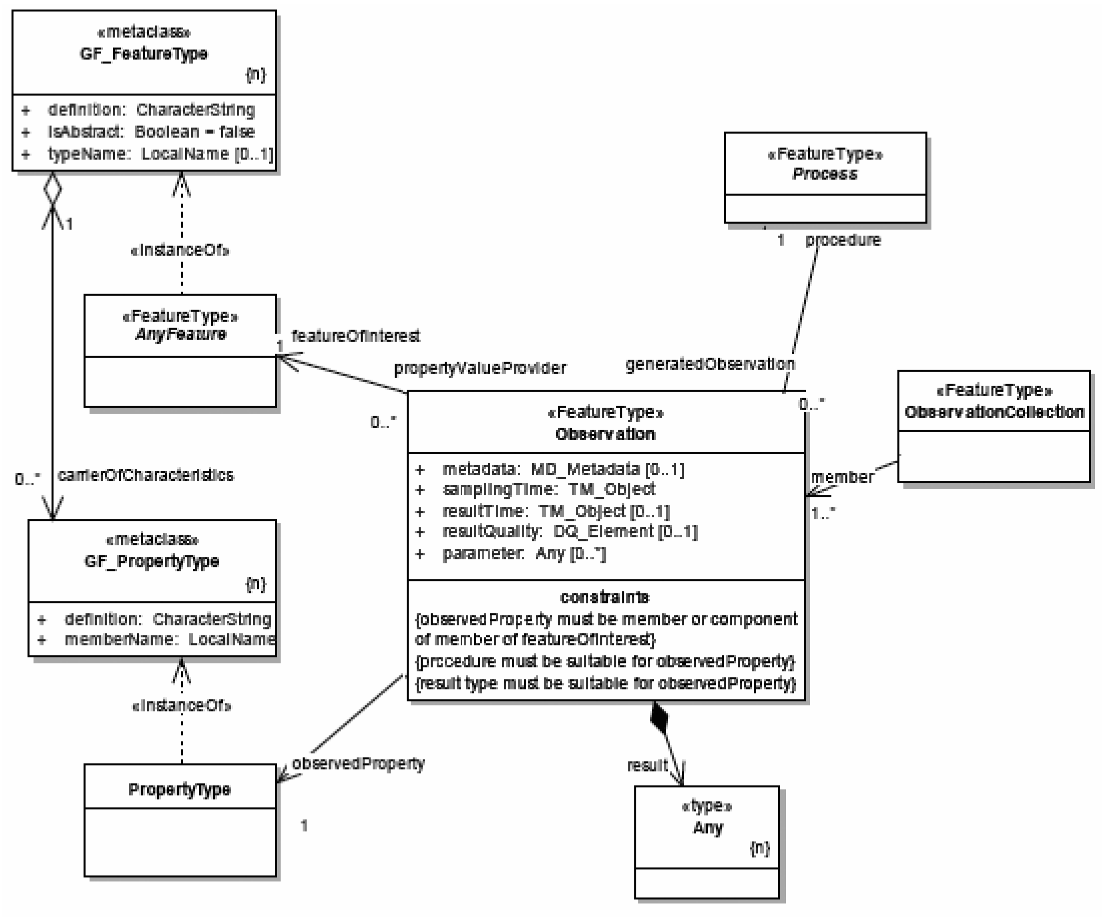

«metaclass»
GF_FeatureType
{n}
+ definition: CharacterString
+ isAbstract: Boolean = false
+ typeName: LocalName [0..1]
«instanceOf»
«FeatureType»
AnyFeature
1
featureOfInterest
propertyValueProvider
generatedObservation
0..*
1
procedure
«FeatureType»
Process
«FeatureType»
Observation
+ metadata: MD_Metadata [0..1]
+ samplingTime: TM_Object
+ resultTime: TM_Object [0..1]
+ resultQuality: DQ_Element [0..1]
+ parameter: Any [0..*]
constraints
{observedProperty must be member or component of member of featureOfInterest}
{procedure must be suitable for observedProperty}
{result type must be suitable for observedProperty}
«FeatureType»
ObservationCollection
member
1..*
0..*
0..*
carrierOfCharacteristics
«metaclass»
GF_PropertyType
{n}
+ definition: CharacterString
+ memberName: LocalName
«instanceOf»
PropertyType
observedProperty
1
result
«type»
Any
{n}

Fig. 7: Basic Observation Model (OGC, 2007)

In this paragraph the definitions for *observation*, *property*, *feature of interest*, *procedure* and *result* in which the Observation Model is based are clearly stated. These definitions and their relationships are shown in an UML diagram in Figure 7. As can be seen in the figure, an Observation is related with:

- ***A feature of interest***: feature of any type representing the real world object which is the observation target. Note that as an Observation object can be related with a single feature of interest, a feature of interest can be related to, or be the real world object associated with, several Observation objects (OGC, 2007).
- ***An Observed property***: identifies or describes the phenomenon for which a value is measured or estimated. It must be a property associated with the type of the feature of interest (OGC, 2007).

- ***A procedure***: description of a process used to generate the result. It must be suitable for the observed property (OGC, 2007).
- ***A result***: contains the value generated by the procedure. The type of the observation result must be consistent with the observed property, and the scale or scope for the value must be consistent with the quantity or category type (OGC, 2007).

O&M defines several specializations of the generic observation. For single-value properties, the corresponding observation result is a scalar, or a record whose components correspond to a thematic decomposition of the observed property. These properties ca be modelled as (OGC, 2008) (OGC, 2007):

- ***CountObservation***, if the result is an integer representing the count of the observed property
- ***CategoryObservation***, if the result is a textual value from a controlled vocabulary
- ***TruthObservation***, if the result is a boolean value representing the truth value (usually existence) of the observed property
- ***GeometryObservation***, if the result is a geometry
- ***TemporalObservation***, if the result is a temporal object
- ***ComplexObservation***, if the result is a record representing a multi-component phenomenon
- ***Measurement***, if the result is a Measure, i.e. the result is a value described using a numeric amount with a scale or using a scalar reference system

If the values of the property vary over time and/or space, then the observation-type is modeled as discrete coverages of the following types (OGC, 2008) (OGC, 2007):

- ***PointCoverageObservation***, if the result is a point coverage which samples properties at points in the feature of interest,
- ***DiscreteCoverageObservation***, if the result is a generalized discrete coverage
- ***TimeSeriesObservation***, if the result is a time-instant coverage which samples a property of the feature of interest at different times

- ***ElementCoverageObservation***, if the result is a coverage whose domain elements contain references to objects encoded elsewhere, which provide the sampling geometry of the feature of interest

Finally, observations can be aggregated into Observation collections when certain conditions of homogeneity for a group of observations exist, such as: having the same feature of interest, the same sampling time and different observed properties; or having the same feature of interest, the same observed property and different sampling time.

2.2.4 SensorML implementation Specification

SensorML defines standard models and XML schemata for describing sensors systems and processes; provides information needed for discovery of sensors, location of sensor observations, processing of low-level sensor observations, and listing of taskable properties (OGC, 2007b). This language, although an important component of SWE can be used independently to describe any sensor system, as well as the processes that might be associated with it. According to (OGC, 2007b), the purposes of SensorML are to:

- Provide descriptions of sensors and sensor systems for inventory management
- Provide sensor and process information in support of resource and observation discovery
- Support the processing and analysis of the sensor observations
- Support the geolocation of observed values (measured data)
- Provide performance characteristics (e.g., accuracy, threshold, etc.)
- Provide an explicit description of the process by which an observation was obtained (i.e., it's lineage)
- Provide an executable process chain for deriving new data products on demand (i.e., derivable observation)
- Archive fundamental properties and assumptions regarding sensor systems

One of the main concepts in SensorML is process, which defines inputs, outputs, parameters, and a method for that process, as well as a collection of metadata useful for discovery and user assistance. In SensorML, all elements are modelled as processes. This includes components normally viewed as hardware such as transducers, actuators, processors, sensors and sensor platforms (OGC, 2007b). Sensor systems are modelled as a collection of physical and non-physical processes. The first category applied to physical processes such as detectors, actuators and sensor systems. These processes have some relationship with space and time. The second category includes processes that can be modelled by mathematical operations.

Figure 8 is a class diagram showing the main type relationships between the main SensorML concepts. All processes are derived from the *AbstractProcess* class which have among its fields the input and output "ports" for exchanging data with exterior entities. The subclasses of *AbstractProcess* are (OGC, 2007b):

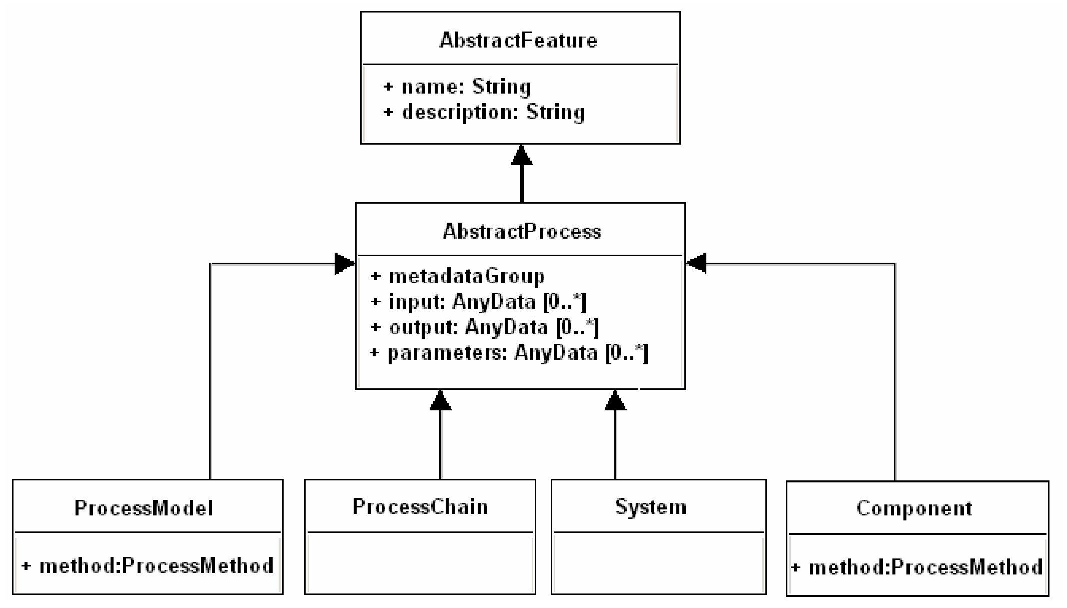


Fig. 8: Conceptual model for Processes (OGC, 2007b)

- ***ProcessModel***: it defines non-physical processes used to build more complex processes.
- ***ProcessChain***: a collection of processes that executed sequentially produce a result. A process chain may contain zero or more physical of non-physical processes. It is built using the Composite design pattern (Gamma et al., 1995); therefore it can be included inside other process chains.
- ***Component***: Physical process that cannot be subdivided into smaller sub-processes or that wants to be treated as such.

- ***System***: physical equivalent of a *ProcessChain*. It is also implemented using the Composite design pattern.

The metadata describing processes includes identifiers, classifiers, constraints (time, legal, and security), capabilities, characteristics, contacts, and references, in addition to inputs, outputs, parameters, and system location (OGC, 2008) (OGC, 2007b).

2.2.5 SOS implementation Specification

The SOS specification provide access to observations from sensors and sensor systems in a standard way that is consistent for all sensor systems, including remote, in-situ, fixed and mobile sensors (OGC, 2007g). The information exchanged between SOS clients and servers follows the O&M specification for observations and the SensorML specification for sensors or system of sensors descriptions.

The main goal of SOS is to provide access to observations, which are grouped into Observation offerings. An observation offering is a set of related observations that follow some criteria. Unfortunately, the specification does not provide a more precise definition or any clear guidance on this grouping. The only clue provided is that classifiers must be factored into offerings in such a way that in response to a *GetObservation* request the likelihood of getting an empty response for a valid query should be minimized (OGC, 2007g).

The offerings are constrained by the following parameters (OGC, 2007g):

- Specific sensor systems that report the observations,
- Time period(s) for which observations may be requested (supports historical data),
- Phenomena that are being sensed,
- Geographical region that contains the sensors, and
- Geographical region that contains the features that are the subject of the sensor observations (may differ from the sensor region for remote sensors)

The SOS implementation specification defines three operation profiles: core profile (mandatory), transactional profile (optional) and enhanced profile. The core profile contains three operations: *GetCapabilities*, *DescribeSensor*, and *GetObservation*. These are the basic operations needed for any data consumer to access sensor observations stored in an SOS server. *GetCapabilities* is an operation that is common for all the OGC's web services, and as such is defined in (OGC, 2007f). The operation allows clients to access metadata about the capabilities provided by the server. The *DescribeSensor* operation allows SOS clients to retrieve SensorML or TML description of a given sensor specified as parameter of the operation. The *GetObservation* operation is used to retrieve observation data from the server. Several parameters for filtering the observations must be supplied.

The transactional profile offers support for data producer. Using the supplied operations *RegisterSensor* and *InsertObservation*, a data producer can register its sensor systems and insert the observations produced by them into the server. Later, clients can read this information using the core profile operations.

The third and last profile is the enhanced profile, which provides clients with a richer interface for interacting with the server. The operations are *GetResult*, and allows clients to obtain sensor data repeatedly without having to send and receive requests and responses that largely contain the same data except for a new timestamp; *GetFeatureOfInterest* returns a *featureOfInterest* that was advertised in one of the observation offerings of the SOS capabilities document; *GetFeatureOfInterestTime* returns the time periods for which the SOS will return data for a given advertised feature of interest; *DescribeFeatureOfInterest* returns the XML schema for a given feature; *DescribeObservationType* returns the XML schema that describes the Observation type that is returned for a particular phenomenon; and *DescribeResultModel* returns the schema for the result element that will be returned when the client asks for the given result model by the given *ResultName*.

2.3 Known SWE implementations

The fact that SWE specifications are so recent is reflected in the relatively few known implementations of the framework. OGC keeps a list of products compliant or implementing its specifications (OGC, 2009a). In this list only a handful of products are listed that implement any of the SWE specifications, in either client or server versions of them. The most prominent implementations listed are the ones from: 52°North/University of Muenster

(52North, 2009) and University of Alabama in Huntsville (UAH VAST, 2009). More details about these implementations are provided in the following sections. Another popular server implementation of the SOS 1.0.0 specification is included in MapServer (Mapserver, 2008), a very popular open source platform for publishing spatial data and interactive mapping applications to the web.

2.3.1 52° North's SWE implementation

52°North Initiative is an international research and development company for developing open source geo-software for research, education, training and practical use (52North, 2009). One of its core communities is the Sensor Web Community. This community is focused on development of SWE services and encodings. They have developed implementations of all the services and encodings specifications within SWE. In addition to this, they have developed the OX-Framework, providing a client architecture where the information of all kind of OGC Services can be accessed, visualized and integrated.

2.3.2 UAH VAST's SWE implementation

The VisAnalysis Systems Technologies (VAST) Team, from The University of Alabama in Huntsville (UAH), works on research and development on visualization and analysis, as well as standard web-based technologies (UAH VAST, 2009). This team has developed multiple tools related with SWE specifications, most of them specialized in working with SensorML. In our opinion the most relevant ones are the SensorML Processing Engine, which allows for the execution of process chains obtained from SensorML documents; and the Space Time Toolkit (STT), which provides capabilities for integrating spatially and temporally-disparate data in a highly interactive 3D display environment (UAH VAST, 2009a). Data retrieved from different OGC services including SOS can be handled and visualized using this tool.

2.4 Some projects using SWE

At present, several projects using SWE related technologies exist in different parts of the world. Some of these projects are listed below:

- ***Marine Metadata Interoperability (MMI) project and OOSTethys:*** The MMI is a project for promoting the exchange, integration and use of marine data through enhanced data publishing, discovery, documentation and accessibility (Marine Metadata Interoperability, 2009). Within this project OOSTethys (OOSThetys, 2008) is a provider-to-user data system framework, using interoperable standards, enabling discovery and use of data. OOSTethys allows a data provider to setup an OGC Sensor Observation Service with minimal effort.
- ***OSIRIS (Open architecture for Smart and Interoperable networks in Risk management based on In-situ Sensors)***: is one of the GMES' supporting projects. GMES (Global Monitoring for Environment and Security) is a European initiative which will provide us with the tools to improve our environment and will help us keep our planet safe and healthy (GMES, 2008). OSIRIS provides a Service Oriented Architecture based on standards and delivers functions ranging from in-situ earth observation to user services (OSIRIS, 2009).
- ***SANY IP (Sensors Anywhere Integrated Project)***: This project focuses on interoperability of in-situ sensors and sensor networks. The project's aim is to deliver a standard SOA for environmental sensor networks, reference implementations of re-usable sensor- and domain-agnostic services, and three risk management applications covering the areas of air pollution, marine risks and geo hazards (SANY, 2009).
- ***Advanced Fire Information Service:*** is a near real-time operational satellite fire monitoring system. Its main goal is assisting in the prediction, detection and assessment of fires using Remote Sensing and GIS technology. It is part of the Wide Area Monitoring Information Service (WAMIS) which delivers relevant sensor based information for supporting decision-making in the monitoring of the Southern African environment (CSIR, 2008) .

2.5 Summary

In this chapter, we presented a general introduction to the topic of sensor networks. We introduced the main concepts such as sensors networks and their advantages over traditional sensor platforms; sensor nodes and their components; and examples of fields where these networks have been applied. We also introduced the Sensor Web Enablement initiative and presented an introduction to the specifications that are relevant to our work. Finally, we mentioned some known implementations and projects applying SWE.

3

GVSIG

gvSIG[3] is an open source tool designed for managing geographic information. This tool provides support for common data formats, including vector and raster spatial data, remote spatial databases, and standard OGC web services. gvSIG allows for the combination of geospatial data with different formats and from different sources in a single view. gvSIG is developed using Java under the GNU General Public License (GPL). In this chapter we present a general description of the gvSIG architecture and the plug-in model used to add new functionality in the form of extensions. Its name is an abbreviation of "*Generalitat Valenciana, Sistema d'Informació Geográfica*" (gvSIG, 2008).

3.1. Architecture

gvSIG is built using a plug-in model where functionality can be added to a generic framework called ANDAMI. ANDAMI is an extensible framework for building Multiple Documents Interface (MDI) applications, which can be customized for different kinds of applications. ANDAMI starts the application and then loads a group of previously registered plug-ins, which provides the domain-specific behaviour. ANDAMI also assists plug-ins with a set of services such as user interface initialization, windows management and internalization support.

The GIS-specific behaviour is added to the application by the three main subsystems (gvSIG, 2008a):

[3] All the information presented here is related to the last stable version of gvSIG: 1.1.2

- *gvSIG*: The gvSIG subsystem is the equivalent of the Presentation layer in an enterprise layered architecture (Fowler, 2002). It handles, with the help of ANDAMI, the interaction between the system and the user. It provides the user with the graphic representation of geographical data and the tools to interact with this data. It takes the form of a plug-in, which is loaded by ANDAMI when execution starts.
- *FMAP*: This library includes all that is needed to handle GIS objects. It includes classes that can draw layers, assign legends, execute queries, make spatial analysis, etc. It is the equivalent of the Domain Layer in an enteprise layered architecture.
- *SubDriver*: Contains classes to access the different data formats. It handles the communication with real data sources isolating other layers from the specific details of this interaction. It is the equivalent of a Data Source Layer in an enterprise layered architecture.

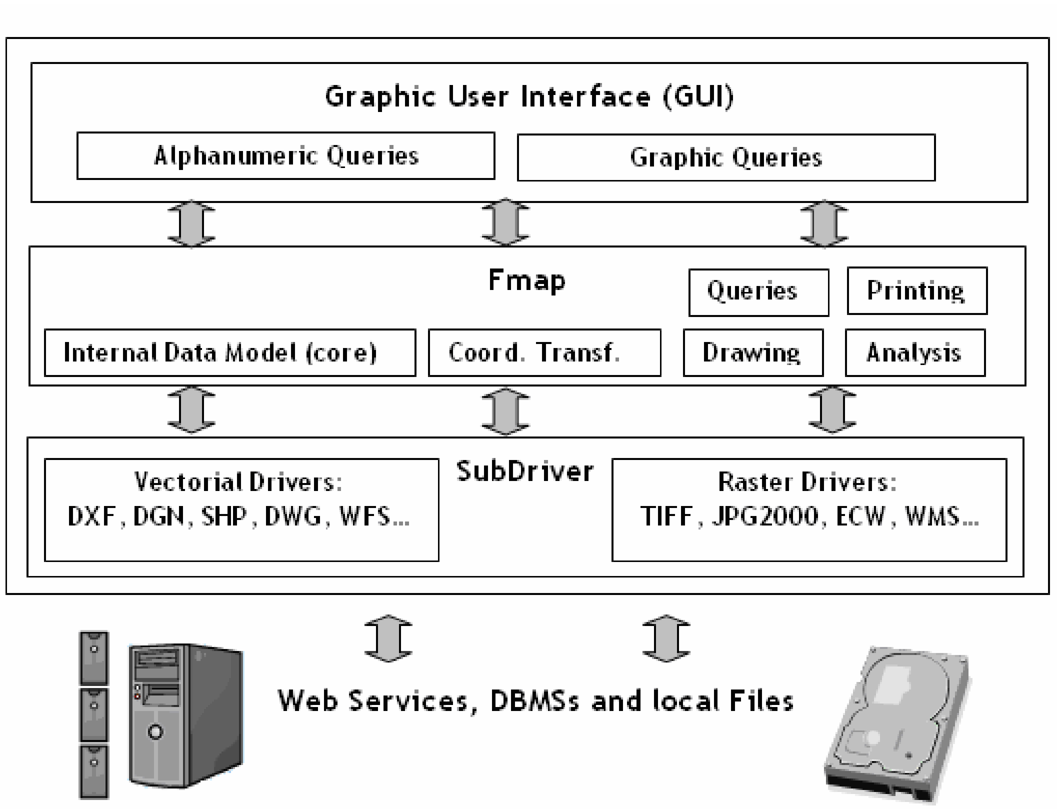

Graphic User Interface (GUI)
Alphanumeric Queries
Graphic Queries
Fmap
Queries
Printing
Internal Data Model (core)
Coord. Transf.
Drawing
Analysis
SubDriver
Vectorial Drivers:
DXF, DGN, SHP, DWG, WFS...
Raster Drivers:
TIFF, JPG2000, ECW, WMS...
Web Services, DBMSs and local Files

Fig. 9: Functional components of gvSIG.

Figure 9 shows all these components and their interconnections. The general functioning of the system can be explained in a few words: the drivers are responsible for accessing the data sources, reading and/or writing spatial data stored in different formats. Vectorial drivers transforms GIS entities retrieved from the data source to objects of the internal data model. The FMAP module performs operations using this data such as: drawing layers, executing alphanumeric and graphic queries, making spatial analysis or transforming coordinates between the different reference systems. Finally, the GUI module handles the user interaction through user interface elements. (gvSIG, 2008a)

In the following sections we provide a more detailed explanation of the four main components of gvSIG: the gvSIG subsystem[4], FMAP, SubDriver and ANDAMI.

3.1.1 The gvSIG Subsystem

As mentioned before, the gvSIG subsystem handles the interaction between the system and the user. It provides the user with the graphic representation of geographical data and the tools to interact with this data.

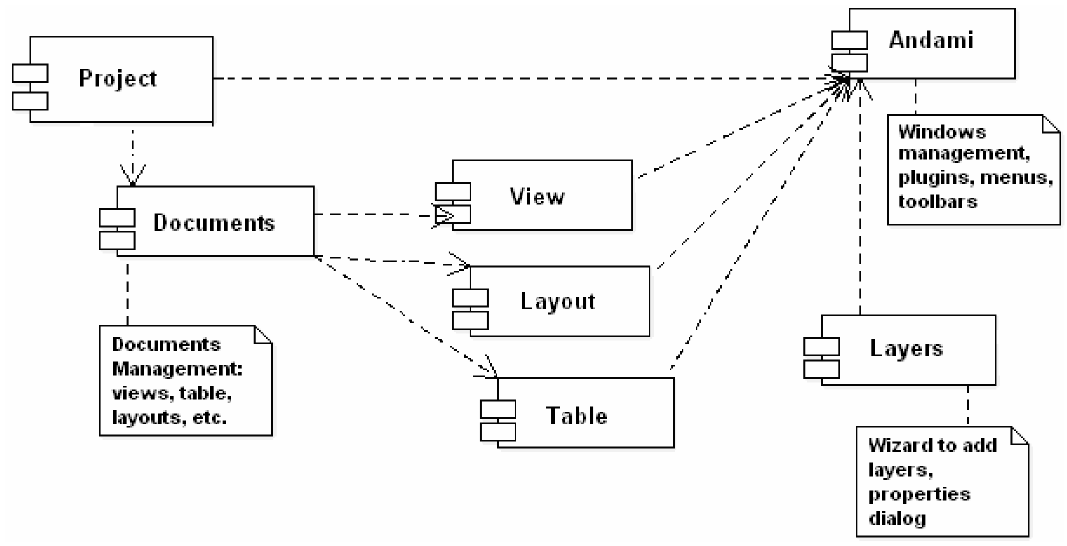

Project
Andami
Windows management, plugins, menus, toolbars
Documents
View
Layout
Table
Layers
Documents Management: views, table, layouts, etc.
Wizard to add layers, properties dialog

Fig. 10: Component diagram of the gvSIG subsystem (gvSIG, 2008a)

[4] Note that the main subsystem has the same name as the application; this may sometimes cause some confusion.

Figure 10 shows the main components of this subsystem, which we explain next: (gvSIG, 2008a):

- *Project*: Container of the document structure opened at a given time. It may contain several documents of different types in addition to general information such as project name, location or date.
- *Documents*: Different document types supported by the application. Current supported document types are: Views, Tables and Layouts. It also provides extension points for new document types.
- *Views*: Contains the graphical representation of geospatial information and its corresponding legend (TOC[5]).
- *Tables*: Tabulated representation of alphanumeric data related with the geospatial information contained on the project
- *Layouts*: Representation of a view in a printer friendly format.
- *Layers*: User interface elements utilized to add a new layer to the current view.

Although we do not consider ANDAMI as part of this subsystem, it is shown in the figure to illustrate its relationships with the rest of the components.

3.1.2 The Fmap Subsystem

Fmap is the GIS engine of the gvSIG application. It provides the internal model used to represent geospatial data and it provides the main operations to process and display such data. It is implemented as an independent library that can be reused in other projects. The main component in this library is *MapControl*, in charge of storing, handling and displaying the geospatial information.

Figure 11 shows the main components contained in Fmap. A short description of the components is provided next (gvSIG, 2008a):

[5] TOC: Table of Contents.

- *MapControl*: It is a user interface Java component used by views to draw and handle the geospatial information distributed between several layers.
- *MapContext*: It contains all the information needed by *MapControl* to display graphical information, including references to the layers contained in a single view.

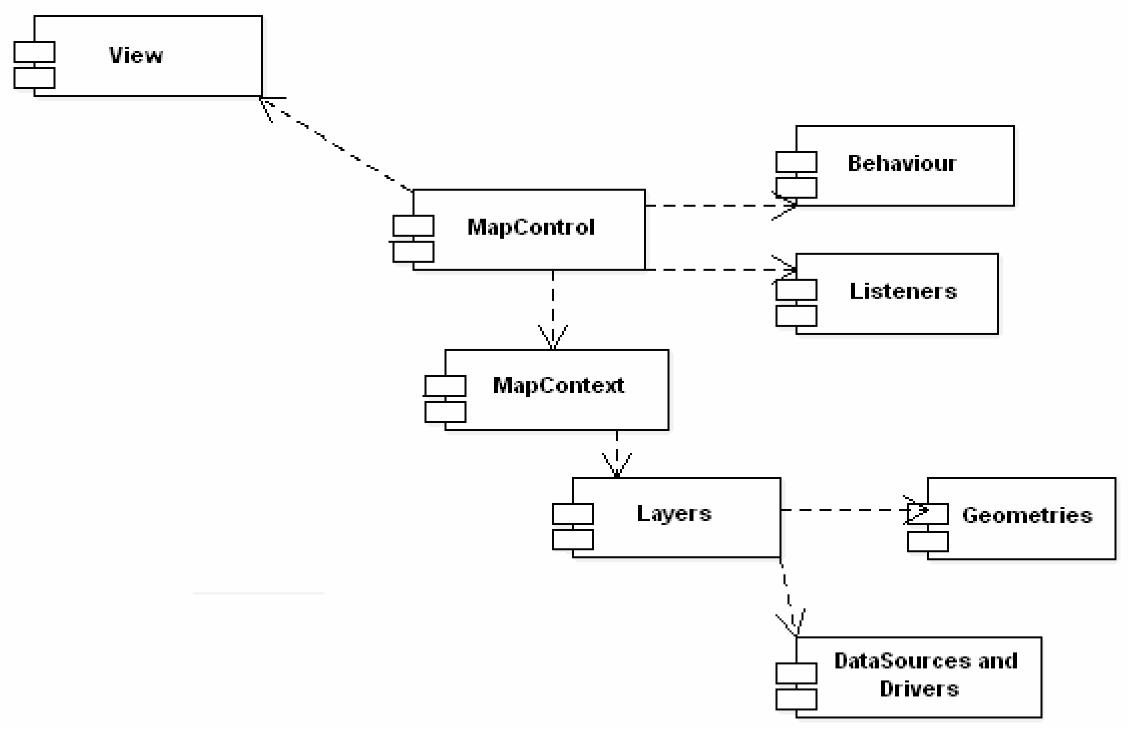


Fig. 11: Component diagram of the Fmap subsystem (gvSIG, 2008a)

- *Behaviours*: Represent the behaviour of different tools associated with *MapControl* objects. It controls how this tool is displayed and how it fires events. It allows the implementation of complex behaviours such as the selection of rectangular, circular or polygonal areas with the mouse.
- *Listeners*: Represent the entities in charge of processing the events generated by behaviours. This means that, for each behaviour supported in a layer, a corresponding listener must be specified to respond to the event generated by it and update the state of the *MapControl* object. An ample set of behaviour and listeners is supported by default in gvSIG.

- *Layers*: Set of layers contained within a view each one containing the representation of some geospatial information.
- *Geometries*: all the types of graphic elements that can be represented within a layer.
- *DataSources* and Drivers: It contains the necessary logic to access and manage graphical and alphanumeric data. They do not interact directly with the final data source, but use the SubDriver subsystem to access the data.

3.1.3 The Subdriver Subsystem

SubDriver handles the communication with real data sources isolating other layers from the specific details of this interaction. It contains the classes for accessing data stored using data format on the file systems, databases or remote servers.

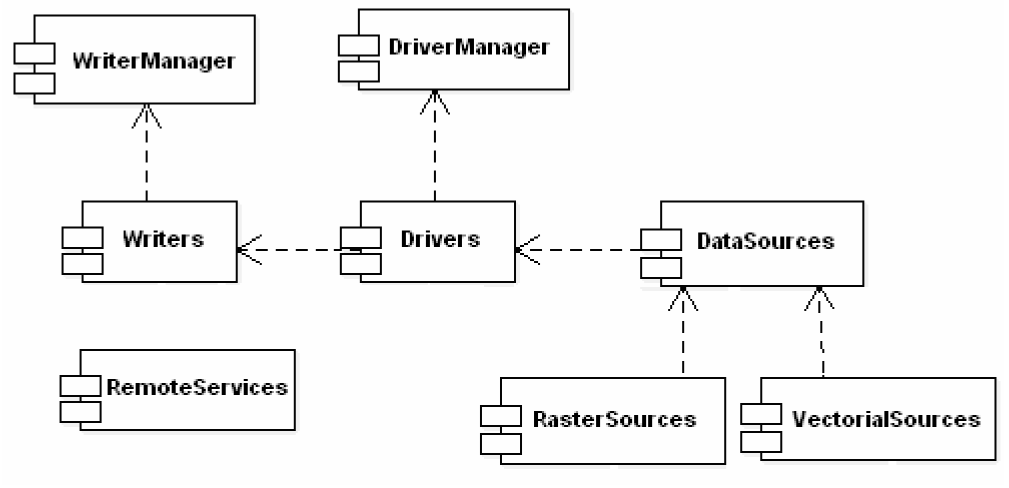


Fig. 12: Component diagram of the SubDriver subsystem (gvSIG, 2008a)

Figure 12 shows the components of the SubDriver subsystem. Next, we present a short description of each component (gvSIG, 2008a):

- *DriverManager*: It provides driver loading and access support to the drivers available in the application.
- *Drivers*: Manage the different data formats supported by gvSIG.
- *WriteManager*: It provides loading and access support to the writers available in the application.

- *Writers:* It allows writing operations to different data formats.
- *Vectorial Sources*: It provides access to vectorial data.
- *RasterSources*: It provides access to raster data.
- *DataSources*: It provides access to alphanumeric data.
- *Remote Services*: This component contains the logic to communicate with remote data sources such as WFS, WMS, or WCS.

3.1.4 Andami

ANDAMI is a framework which can be extended adding plug-ins. Apart from managing plug-ins; it provides the basic functionality to implement the user interface such as window and event management. The gvSIG subsystem itself is a plug-in which adds GIS-specific behaviour to the Andami framework. Figure 13 shows the functional block composing Andami. A more detailed description of these components and their functionality is provided next (gvSIG, 2008a):

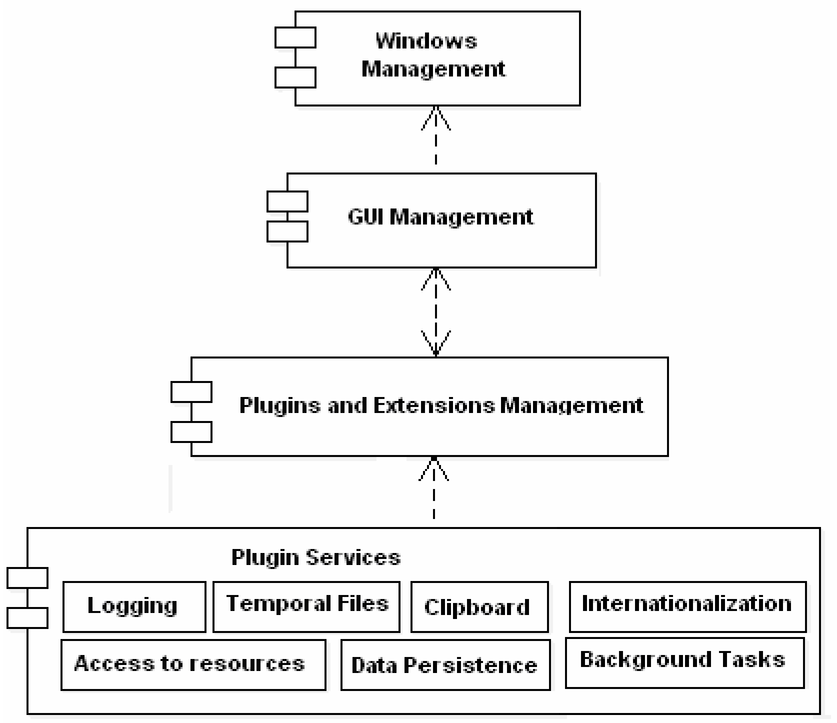


Fig. 13: ANDAMI functional blocks (gvSIG, 2008a)

- *Windows management*: It provides support for creating windows, modifying its properties, etc. When a plug-in wants to show a window it must only supply a panel with the window content. The window frame, the Window menu, and the window's basic operations (minimize, maximize, etc.) are handled by Andami.
- *User interface* initialization from XML files: It provides support for using toolbars, menus and the status bar whose properties and initial state are stored in a XML file. It also provides the basic tools for handling events generated by these user interface elements.
- *Plug-in Management*: At start-up, Andami loads and initializes the plug-ins registered with the system. Every plug-in specifies a set of user interface elements associated to it and the extension that should handle the events generated by them.
- *Plug-in Services*: Apart from the general services mentioned there are a set of services that plug-ins can use programmatically:
    - *Data persistence*: It allows data to be stored at the local file system between different executions of the application. The information persisted by a plug-in cannot be accessed by any other plug-in. The use of this service is only recommended for small-sized data.
    - *Internationalization support*: Every plug-in defines different files containing translation keys and a translation associated with it in different languages. Then a plug-in can ask for strings from these files and the one matching the language selected by the user in the language configuration settings, is returned.
    - *Background task execution*: it allows the creation and handling of background tasks.
    - *Logging support*: It provides a log to keep a history of significant errors or events. The events may belong to different categories: Info, Warning, Error or Debug.
    - *Clipboard support*: Andami provides support for copying to or retrieving information from the clipboard. Only information in text format is supported so far.

- *Temporal files*: Temporal files that last only until the current session is closed can be created.
- *Access* to *plug-in resources*: It allows plug-ins resources such as images or XML files to be accessed using paths which are relative to the plug-in directory. This eases source code portability.

3.2. Plug-in and Extensions

A gvSIG plug-in is a module containing a set of extensions to add new functionality. An extension is a Java class implementing the *IExtension* interface that bridges new functionality with the existing one (gvSIG, 2008a). An extension receives notifications of user actions related with it, and responds accordingly. All of the installed plug-ins are located in a single directory called *gvSIG\extensions* and they are loaded by Andami while starting execution. A plug-in must contain a configuration file named config.xml. This file contains information about the plug-in such as name, library path, dependencies, translation files, and extensions contained in the plug-in and user interface components configuration.

3.2.1 Extensions

As mentioned before, an extension must implement the *IEXtension* interface, which contains the following methods (gvSIG, 2008a):

- *public void initialize():* This method is called to initialize the extension at loading time.
- *public void postInitialize():* This methods is called for every extension after all of them have been initialized.
- *public void terminate():* Called for every extension when the application ends. They are invoked in reverse order than they were called at loading time.
- *public void execute(String actionCommand):* This method is executed to respond to user interface generated events. The parameter can be used to identify the source of the event.

- *public Boolean isEnabled():* This method is used to determine if the user interface elements associated to the extension are enabled or not.
- *public boolean isVisible():* Determines if the user interface elements associated with the extension are visible or not.

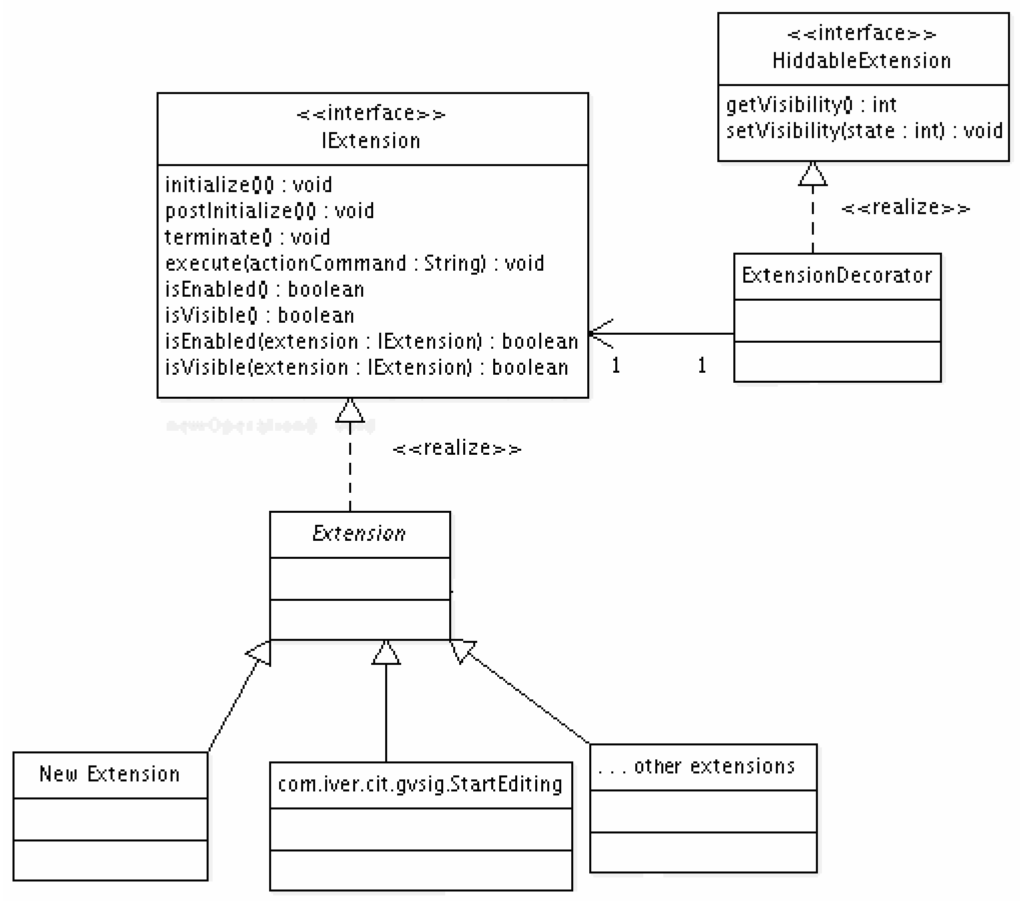


Fig. 14: IExtension relationships (gvSIG, 2008a)

In Figure 14 we can see a class diagram showing how *IExtension* is related with other classes and interfaces. Every extension is related to an *ExtensionDecorator* object implementing the *HiddableExtension* interface. An *ExtensionDecorator* allows the visibility of an extension to be modified by others extensions at execution time. The *Extension* abstract class provides default implementations for the *IExtension* interface methods, easing the job of extension developers.

3.3. gvSIG Mobile

gvSIG Mobile is a version of gvSIG that can be executed in mobile devices with Windows Mobile 5.0 and 6.0 platforms (gvSIG, 2008b). As gvSIG, the mobile version is a GIS that can also act as a Spatial Data Infrastructure (SDI) client, supporting communication with providers of some OGC's compliant services. According to the gvSIG Portal, it is the first registered free software system with such attributes.

This software provides support for (gvSIG, 2008b):

- Several vectors and raster formats such as SHP, ECW, JPEG, PNG, GIF, KML, GML, etc.
- Connection to WMS Services.
- Layer manipulation with operations like adding vector, raster or WMS layer, exporting layer content, etc.
- Map navigation (zoom in, zoom out, pan, etc.)
- Operations for measuring distances and areas, selecting features, querying attributes properties.
- GPS Support: Real-time navigation, and waypoints and tracklogs captures are supported.

3.4. Supporting Libraries

gvSIG is not implemented from scratch. It uses a set of existing libraries to provide some of the supported functionality. Some of these libraries, followed by a brief description are listed next:

- ***Geotools2*** (GeoTools, 2008): GeoTools is an open source library, which provides standard compliant methods to manipulate geospatial data. GeoTools provides support for several vectorial and raster data formats such as Shapefiles, GML, WFS, PostGIS, Oracle Spatial, ArcSDE, MapInfo, ArcGrid, Image, GeoTIFF and WMS. It represents basic geographic elements in a vector system, using Java Topology Suite (JTS) as the current geometry model. It implements grid coverages providing support for data management, presentation, image data format access, tiling support, and a framework for raster data processing. It implements a subset of the OGC's Coordinate Transformation Services specification providing an implementation for general positioning, coordinate reference systems, and coordinate transformations.

- ***JTS (Java Topology Suite)*** (Vivid Solutions Inc., 2008): The JTS Topology Suite is a Java API that implements a core set of spatial data operations using an explicit precision model and robust geometric algorithms. It provides a complete model for specifying 2-D linear Geometry. JTS is intended to be used in the development of applications that support the validation, cleaning, integration and querying of spatial datasets (Vivid Solutions Inc., 2008a). JTS attempts to implement the OpenGIS Simple Features Specification (SFS) as accurately as possible.
- ***Batik***: Batik (Batik, 2008) is a Java-based toolkit for applications or applets that want to use images in the Scalable Vector Graphics (SVG). The Batik modules can be used to generate, manipulate and transcode SVG images in your applications or applets. Using Batik a Java application or applet can very easily export graphics into the SVG format. SVG viewing and interaction capabilities can be easily added using the SVG viewing component. Conversion of SVG images to other formats such as JPGE, PNG, TIFF, EPS or PDF is also supported.
- ***Castor*** (Castor Project, 2005): Castor is an Open Source data binding framework for Java. It provides Java-to-XML binding, Java-to-SQL persistence, and more. The main components of the Castor framework are Castor XML and Castor JDO. Castor XML is an XML data-binding framework. Castor enables access to data defined in an XML document through an object model representing that data. Castor XML can marshall almost any "bean-like" Java Object to and from XML. Castor JDO is an Object-Relational Mapping and Data-Binding Framework which frees the programmer from dealing directly with databases. Castor supports the following relational databases: DB2, Derby, Generic DBMS, Hypersonic SQL, Informix, InstantDB, Interbase, MySQL, Oracle, PostgreSQL, Progress, SAP DB / MaxDB, SQLServer and Sysbase.

- ***Ermapper*** (ERDAS, 2008): Library to work with free ECW. Only available for Windows-based systems. ERMapper Image Compression SDK provides support for JPEG 2000 and ECW image formats. Some of the features supported in this SDK are lossless and lossy compression, 64 bit file support handles TB+ size images, fast viewing at any resolution for any region, 64 bit OS support, low memory footprint even on TB size images, geolocation data preserved as embedded metadata, etc.
- ***GDAL*** (OSGEO, 2008): GDAL is a translator library for raster geospatial data formats. It presents a single abstract data model to the calling application for all supported formats. It also comes with a variety of useful command-line utilities for data translation and processing. The GDAL data model contains the types of information that a GDAL data store can contain, and their semantics. The main types of the model are Datasets, Raster Bands and Overviews.
- ***Lizardtech GeoSDK*** (Lizardtech, 2008): The GeoExpress SDK provides a framework for creating image pipelines that enable developers to efficiently read, write and manipulate data in a variety of formats, including MrSID, JPEG 2000, and other common geospatial formats.

3.5. Summary

gvSIG is an open source GIS structured in three layers: gvSIG, handling the interaction between the system and the user; FMAP with the business logic to handle GIS objects; and SubDriver, containing classes to access different data formats. gvSIG is built using a plug-in model where functionality is added to a generic framework in charge of managing the basic interaction with the user interface. A gvSIG plug-in is a module containing a set of extensions to add new functionality. A version of gvSIG called gvSIG Mobile also exists. gvSIG Mobile provides support for several data and raster formats, WMS services, real-time navigation with a GPS, etc.

4

ANALYSIS

In this chapter we present the analysis phase of the SOS client plug-in for gvSIG, which is called gvSOS. The plug-in requirements, the use case model, and the high-level architecture are exposed.

4.1 Plug-in Requirements

The SOS plug-in must satisfy a set of requirements listed and explained next:

- It must implement the Core profile of the SOS 1.0.0 specification including the operations: *GetCapabilities*, *DescribeSensor* and *GetObservation*.
- Other supporting specifications used by SOS 1.0.0 must be also implemented. In this case, SensorML 1.0.1 and O&M 1.0.0 are implemented to represent sensors and observations descriptions.
- A user interface must be provided to connect to the server and select the information to be displayed. At this step the user must be able to select an observation offering and set filters that will be used to retrieve information about sensor observations.
- Only one observation offering must be visualized in a layer, although this restriction can be modified in the near future. Each sensor contained in the selected offering must be displayed as a point in a layer. Here, we are assuming that all sensors are geolocated.
- Users must be able to interact with the sensors, so that they can request information about one or more sensors previously selected. In a similar way, observations gathered by the selected sensors can be requested. This information must be displayed graphically and a tabular representation must also be available.

- The SOS plug-in must follow an internal (architecture) and external (GUI) design similar to other OGC Web Services (OWS) plug-ins (WMS, WFS, etc.) already implemented in gvSIG.
- Complete redesign and reimplementation should be avoided. The maximum amount of design and source code must be reused to speed up development.
- High standards of code organization must be followed, including Javadoc comments in every class and every public method, comments in the source code to help understand its purpose and the use of gvSIG naming conventions when applicable.

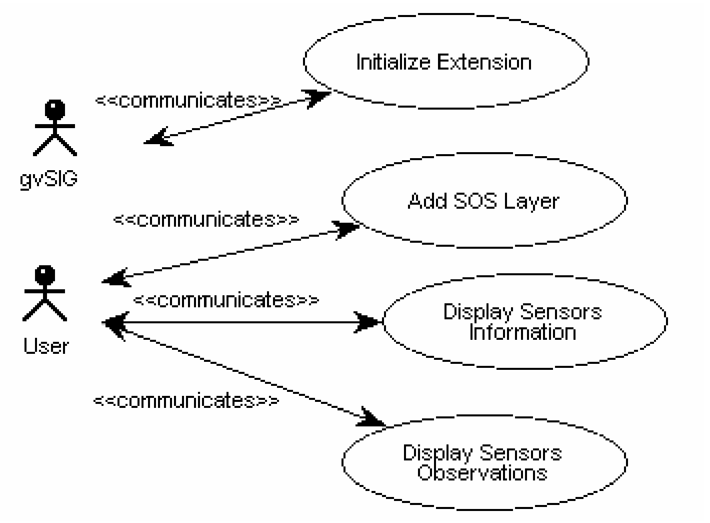


Fig. 15: Use case diagram for gvSOS.

4.1 Use case model

The use case model for gvSOS is very simple containing only four use cases and two actors (Figure 15). The use cases are:

- *Initialize Extension*: This includes the initialization of the extension carried out at start-up. *Andami* is in charge of loading and initializing all the plug-ins. At this point user interface elements related with the extension are registered (toolbar buttons, menu items, connection wizards, etc.)
- *Add SOS Layer*: In this use case the user adds a new SOS layer to a gvSIG view. This process includes the connection to the SOS server, the selection of the

offering whose information will be displayed in the layer and the addition of filters that will be used to request observations.

- *Display Sensors Information*: Once displayed in a view, sensors can be selected by the user to ask for further details about them. This information will be displayed in a table inserted in a different window.
- *Display Sensors Observations*: The sensors can also be selected to request observations gathered by them. This information can be filtered using temporal or spatial filters, depending on the server's capabilities.

The actors are:

- *gvSIG*: This actor is used to represent the special case when execution of some functionality is started automatically. In this case, plug-in initialization is executed at start-up.
- *User*: End users of gvSIG using gvSOS. This actor fires the main use cases of the plug-in related with retrieving and displaying information about sensors and their observations.

4.2 High Level Architecture

The plug-in architecture derives from the gvSIG architecture. It is arranged as a variation of the layer pattern (Buschman et al., 1996), containing the same main gvSIG layers as can be seen in Figure 16[6]:

- *gvSIG-SOS*: It contains the user interface of the plug-in, providing the wizard utilized by the user to connect to the SOS server and dialog boxes to request information about sensors and observations. This package is an extension of the gvSIG layer.
- *FMap-SOS*: This package contains the code for integrating the information received from the server with the rest of the information in the system. It contains the code to

[6] In this figure packages refers to analysis packages, do not confuse with Java packages.

create and draw layers, drivers for interacting with the remote clients, etc. It is an extension of the FMap layer.

- *RemoteServices-SOS*: It implements the low-level communication with the remote SOS web service, isolating the rest of the system from the details of this interaction. This package is an extension of the SubDriver layer.

It also relies on Andami for initialization and internationalization issues, use of temporal files, etc.

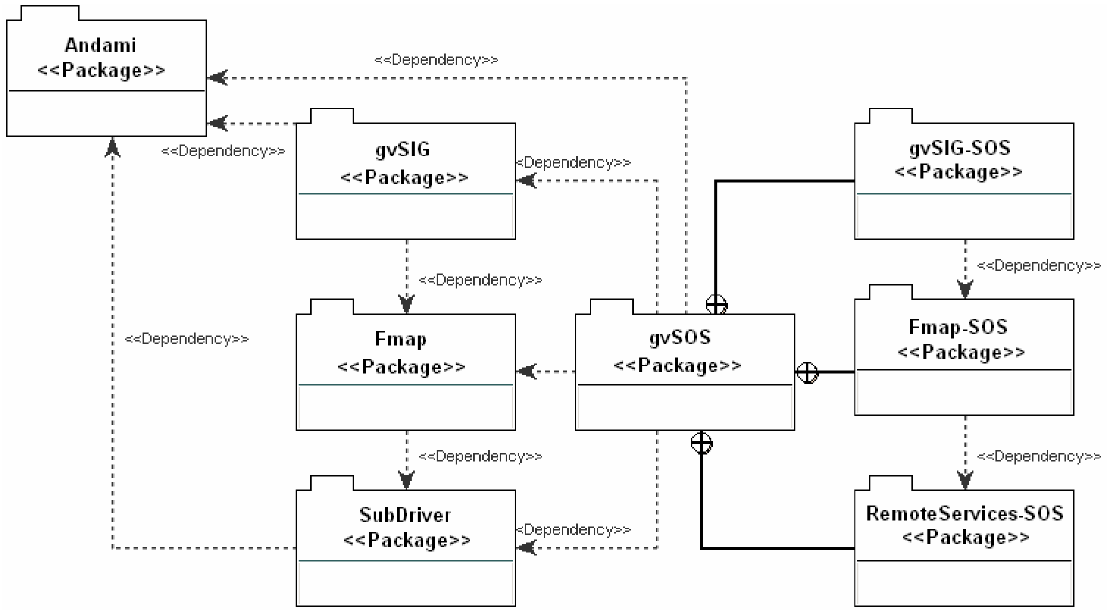


Fig. 16: Package diagram showing the gvSOS architecture.

4.3 Summary

gvSOS must implement the Core profile of the SOS 1.0.0 specification and other related encodings. It must also provide users with tools to connect to the servers and select the information to be displayed. This information must be displayed graphically and through tables. gvSOS architecture is arranged in three layers: *gvSIG-SOS*, containing user interface elements; *FMap-SOS*, containing the code to integrate the sensor and observation data into gvSIG; and *RemoteServices-SOS*, implementing the communication with the servers.

5

DESIGN AND IMPLEMENTATION

This chapter provides details about the design and implementation phases of gvSOS. For every layer mentioned in the analysis phase we provide a design and implementation oriented view including class diagrams and a detailed explanation of how they implement the functionality of every use case.

5.1 gvSIG layer

The gvSIG layer is divided in a set of implementation packages listed next: (Figure 17):

- *com.iver.cit.gvsig.sos*: It contains the *SOSClientExtesion* class, which is the entry point for our extension functionality.
- *com.iver.cit.gvsig.gui.wizards*: This package contains the implementation of the Connection Wizard used to establish connection with the server and to select the observation offering to be displayed (*SOSWizard*).
- *com.iver.cit.gvsig.gui.dialogs*: The package contains the implementation of all the dialog boxes used by the plug-in.
- *com.iver.cit.gvsig.gui.panels*:It contains the panels used to implement the user interface of the wizard and the dialog boxes.
- *com.iver.cit.gvsig.gui.toc*: This package contains the implementation of the behaviour of the popup menu entry added to the TOC (*SOSPropsTocMenuEntry*).

As can be seen, the content of all packages is related with user interface elements. The initialize method of the *SOSClientExtension* class is executed at start-up to initialize the extension. *SOSWizard* is executed when an SOS layer wants to be added to the current view. Different dialog boxes are invoked to show and to modify layer properties, to request information about sensors and to request information about observation. *SOSPropsTocMenuEntry* is used to add and manage menu items to the view's TOC.

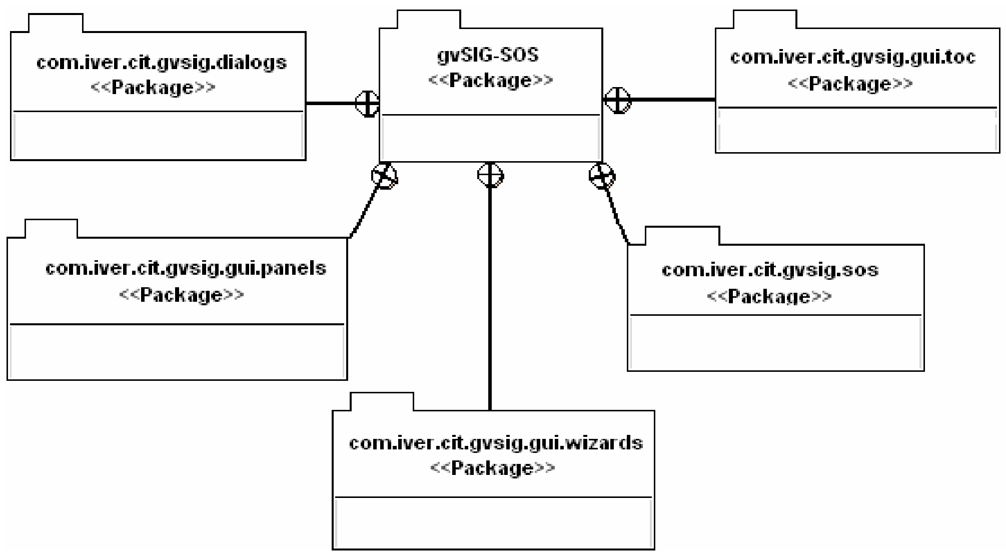

com.iver.cit.gvsig.dialogs
<<Package>>
gvSIG-SOS
<<Package>>
com.iver.cit.gvsig.gui.toc
<<Package>>
com.iver.cit.gvsig.gui.panels
<<Package>>
com.iver.cit.gvsig.sos
<<Package>>
com.iver.cit.gvsig.gui.wizards
<<Package>>

Fig. 17: gvSIG-SOS package diagram.

Figure 18 shows a simplified class diagrams representing the main classes and relationships within the gvSIG layer. The centre of our diagram is the *SOSWizard* class which:

- inherits from the *WizardPanel* class, the base class for all the wizards used to add layers.
- contains *SOSWizardData,* which acts as data source for the wizard and the panels contained in it. *SOSWizardData* pre-process data obtained using a driver implemented in lower layers (see next section)
- contains several Swing components to implement the connection page of the wizard.
- contains the *SOSParamsPanel* class, encapsulating the rest of the pages of the wizard to show information about the server and the selected offering (*InfoPanel*), to select the offering (*SOSSelectOfferingPanel*), and to specify filters (*SOSFilterPanel*).

To simplify the diagram, classes representing individual Java Swing components are not shown and for each class only the main methods are listed.

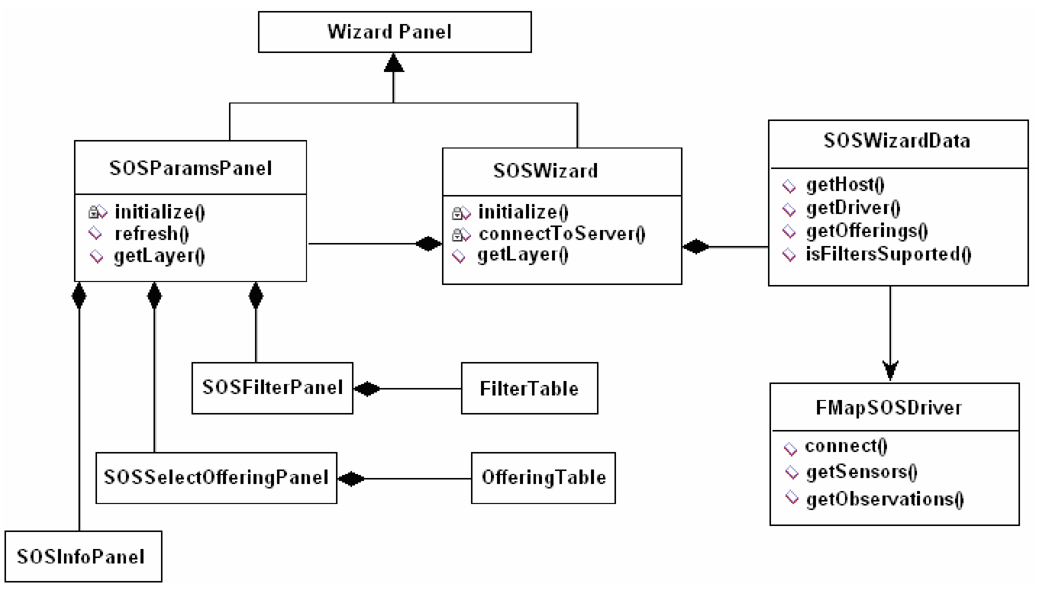


Fig. 18: Class diagram showing *SOSWizard* and its relationships

5.2 Fmap layer

The Fmap layer contains the following packages (Figure 19):

- *com.iver.cit.fmap.core*: This package contains the feature types used by layers composed of sensor and sensor observations.
- *com.iver.cit.fmap.drivers*: It contains the declaration of the interface of the driver that must be implemented by the plug-in. It also includes the definition of the exceptions that can be thrown by this driver.
- *com.iver.cit.fmap.drivers.sos*: The package contains the implementation of the driver used to access information located in an SOS server.
- *com.iver.cit.fmap.layers*: It contains the implementation of the layer contained the information retrieved from an SOS server.

The internal functioning of the Fmap package is a rather complex one. In order to simplify things a bit, we can say that *SOSFeature* represents the features that are represented in a layer of type *FLyrSOS*. *FlyrSOS* inherits from class *FLyrVect*, a base class used to implement layers composed of vector data. *FlyrSOS* uses an instance of

FMapSOSDriver to recover all the data from the server. Once the data is retrieved, *SOSAdapter* processes this information. It uses an object implementing the *GPEParser* interface to parse the XML files. Depending if the XML file is an O&M document or a SensorML document it creates a *GPEOMv10Parser* or a *GPESensorMLv101Parser* object. These classes are implemented in a different project called *libGPE-Sensor*[7].

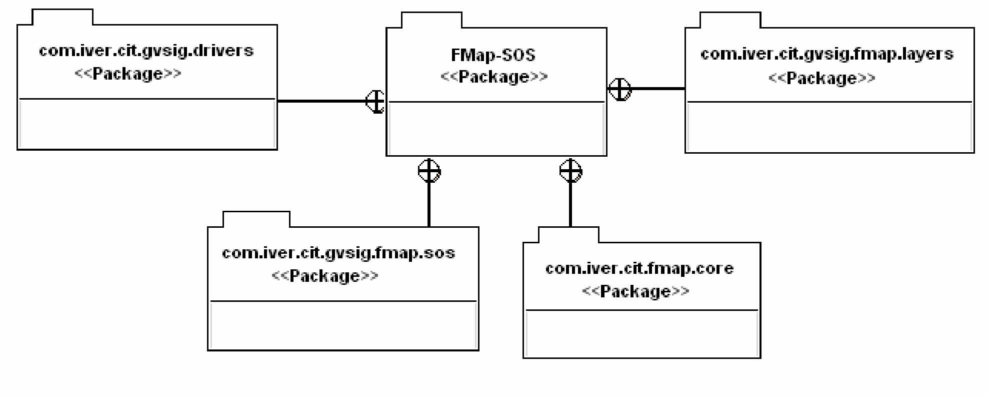

com.iver.cit.gvsig.drivers <<Package>>
FMap-SOS <<Package>>
com.iver.cit.gvsig.fmap.layers <<Package>>
com.iver.cit.gvsig.fmap.sos <<Package>>
com.iver.cit.fmap.core <<Package>>

Fig. 19: Fmap-SOS package diagram.

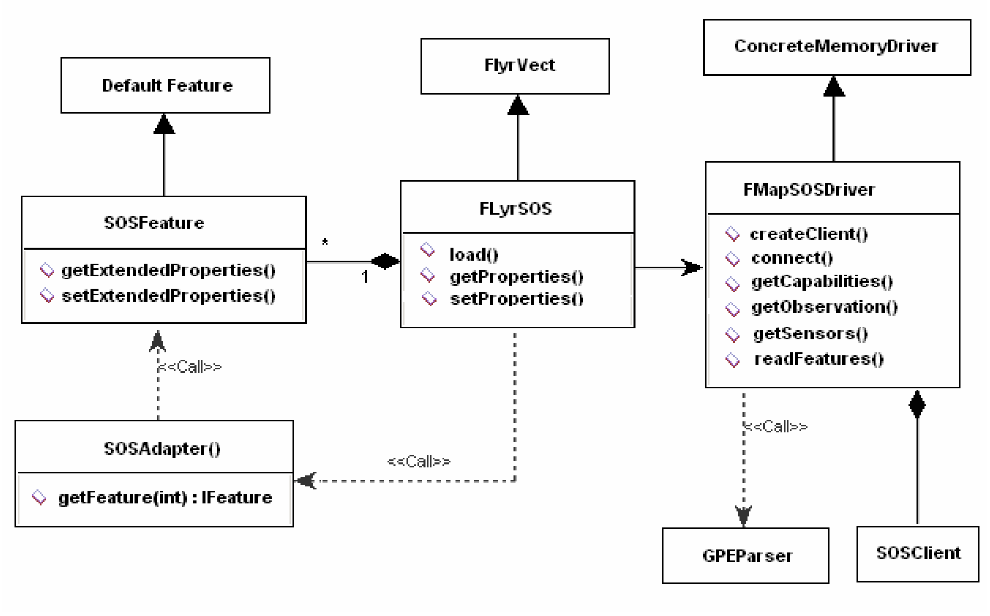


Fig. 20: Fmap-SOS class diagram.

[7] This library was implemented by the Prodevelop staff; in this document we do not provide too many details about how it works.

FMapSOSDriver inherits from *ConcreteMemoryDriver*, which allows data to be kept in memory and also provides cache capabilities. *FMapSOSDriver* recovers data from the SOS server using functionalities provided by lower layers. A class diagram showing these relationships is presented in Figure 20.

At this point a major design challenge was found: the gvSIG architecture provides support for adding and caching features in *ConcreteMemoryDriver*, but only information about geometries and simple attributes values can be included in such features. There is no support for complex data structures like sensors containing information about observations, with the added complexity that observations intrinsically hold a temporal component. To solve this problem the sensors descriptions are kept as features following the gvSIG model, but observations are stored in two nested hash tables. The first table uses the sensor identifier as a key to link the sensor with an internal table containing the observation data. This data uses the observed property as a key to access pair values including the time instant and the measured value for an observation.

5.3 SubDriver layer

In this layer, the analysis package RemoteClient-SOS is implemented. The RemoteServices-SOS package implements the communication with the SOS Server and it resembles most of the structure of the rest of the OWS extensions already included in gvSIG.

The package is composed of 8 sub-packages within the *org.gvsig.remoteClient* namespace (Figure 21):

- *ows.capabilities*: This package implements objects representing the information contained in the server capabilities document.
- *sos*: It contains the *SOSClient* class and a group of classes to support its behaviour. This class provides the main functionality offered to upper layer, which is connecting and retrieving data from servers implementing the SOS specification. The classes included in this layer are version-independent; this means that some of them must be specialized to work with specific versions of the specification.

- *sos.exceptions*: The package includes one class representing the exception that can be thrown from this layer.
- *sos.filters*: It implements classes representing filters that can be applied to *GetObservation* requests. It initially includes only some temporal and spatial filters.
- *sos.requests*: This package includes the common mechanism used to send different request types to the server.
- *sos.sos1_0_0*: It contains the specialization of the class *SOSProtocolHandler,* included in the *sos* package, for version 1.0.0.
- *sos.sos1_0_0.requests*: It contains specializations of classes contained in the *sos.request* package for version 1.0.0

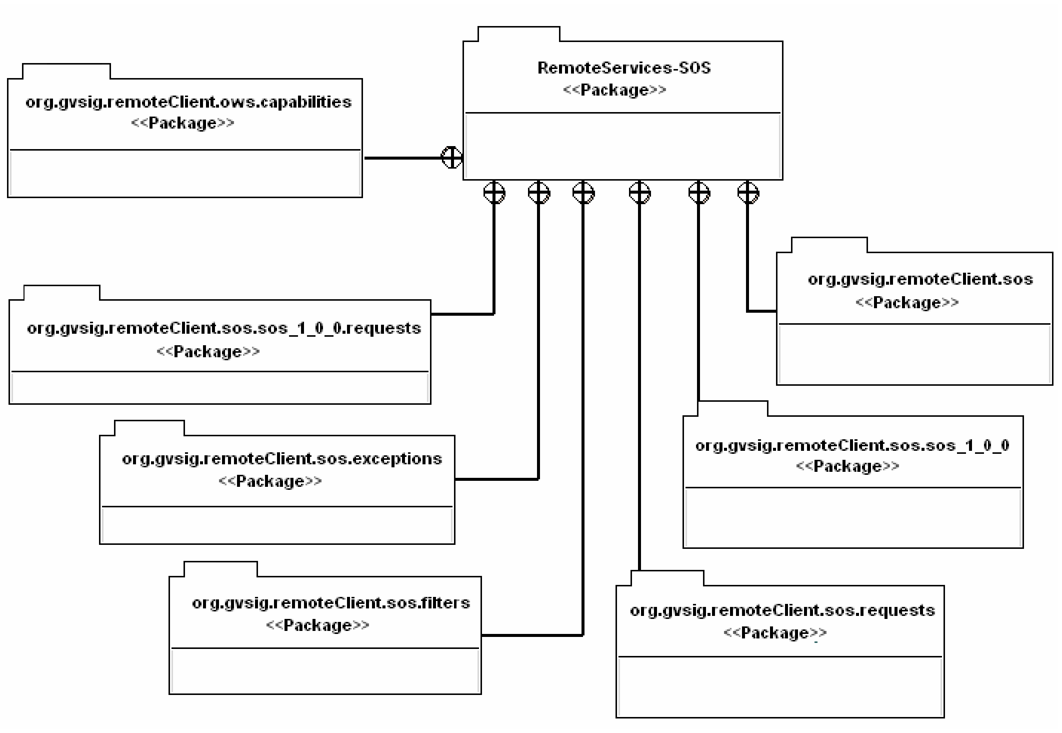

RemoteServices-SOS
<<Package>>
org.gvsig.remoteClient.ows.capabilities
<<Package>>
org.gvsig.remoteClient.sos.sos_1_0_0.requests
<<Package>>
org.gvsig.remoteClient.sos.exceptions
<<Package>>
org.gvsig.remoteClient.sos.filters
<<Package>>
org.gvsig.remoteClient.sos
<<Package>>
org.gvsig.remoteClient.sos.sos_1_0_0
<<Package>>
org.gvsig.remoteClient.sos.requests
<<Package>>

Fig. 21: Remote Services package diagram.

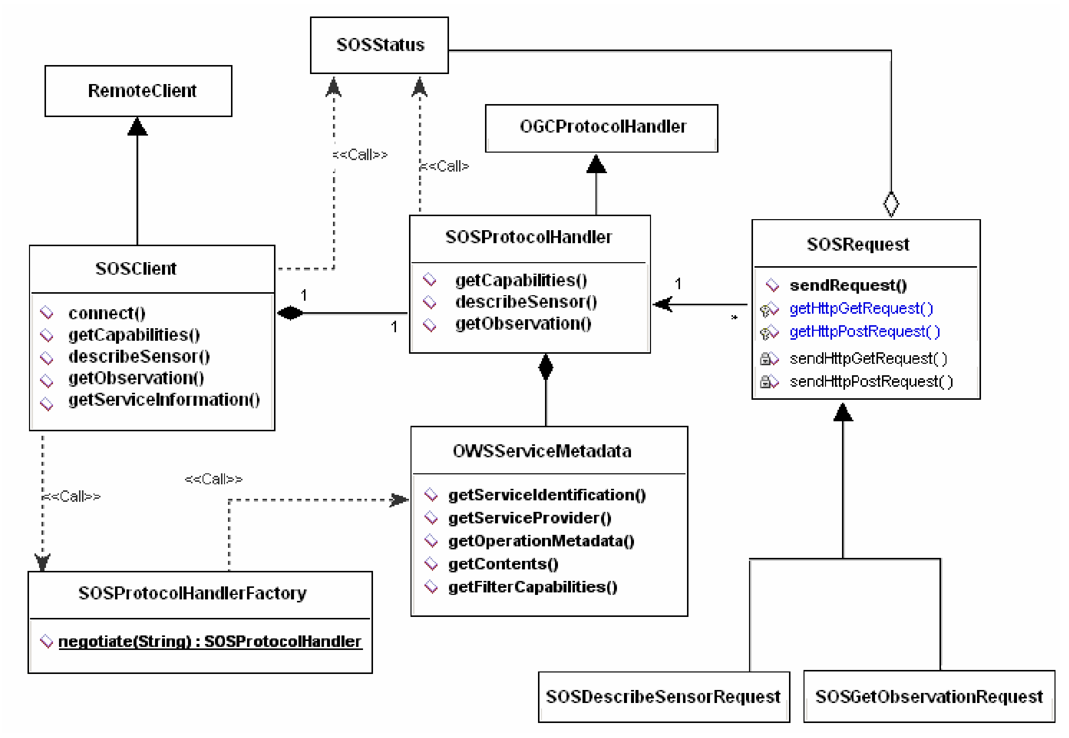


Fig. 22: Class diagram of the RemoteServices-SOS package.

The main classes in this package are *SOSClient* and *SOSProtocolHandler* (Figure 22). *SOSClient* represents the SOS client end-point, encapsulating the logic for connecting to and requesting operations from the SOS server. The class is a subclass of *org.gvsig.remoteClient.RemoteClient*. *SOSProtocolHandler* is in charge of sending the requests from a SOS client to the corresponding server. Only the SOS specification *core profile* is supported so far. *SOSProtocolHandler* is a subclass of the abstract class *org.gvsig.remoteClient.OGCProtocolHandler,* which implements the common behaviour for all OGC services. *SOSProtocolHandler* is also abstract and it must be specialized for every version of the SOS specification. Other important classes in this package are:

- *OWSMetadata*: It contains all the information returned by the server in its capabilities document.
- *SOSRequest:* This class encapsulates the common structure and behavior of an SOS client request. It must be specialized for specific requests. In this case, one child class for the *DescribeSensor* operation and another for the *GetObservation* operation are added.

- *SOSStatus:* This class contains the parameters passed to an SOS request operations.
- *SOSFilterOperation:* It encapsulates a filter operation used for filtering the output from a SOS server. It is meant to be specialized by subsequent classes. At present, specialization for several temporal filters and spatial filters exists.
- *SOSException:* This class represents any exception generated during the SOS request execution cycle. It may represent a SOS server-side exception or another exception generated during the client-side processing.

To implement the 1.0.0 version of the SOS specification at least three more classes must be added. The first one is *SOSProtocolHandler1_0_0* inheriting from *SOSProtocolHandler* and including all the version-specific logic. The two others are *SOSDescribeSensorRequest1_0_0* and *SOSGetObservationRequest1_0_0*, specializing the corresponding requests classes.

5.4 Initialize extension

Starting from this section we proceed to explain in further detail each one of the use cases. We start with the extension initialization use case, which is executed at start-up. At this time, basic user interface elements and extension classes are loaded using the information contained in the configuration file (Figure 23). In our case we register the extension class *com.iver.cit.gvsig.sos.SOSClientExtension* containing gvSOS. We also specify the dependencies of the gvSIG and GPE plug-ins, and the toolbar buttons used to query sensors and observations information.

```
<?xml version="1.0" encoding="UTF-8"?>
<plugin-config>
    <depends plugin-name="com.iver.cit.gvsig" />
    <depends plugin-name="org.gvsig.gpe" />
    <libraries library-dir="./lib"/>
    <resourceBundle name="text"/>
    <extensions>
        <extension class-name="com.iver.cit.gvsig.sos.SOSClientExtension"
                   description="Support to access SOS"
                   active="true"
                   priority="1">
        </extension>
        <extension class-name="org.gvsig.sos.SingleObservationExtension"
               description="My first extension."
               active="true">
               <tool-bar name="SOS" position="1">
                  <selectable-tool icon="images/information.png"
                        tooltip="getObservation"
                        action-command="GET_OBSERVATION" position="1"/>
              </tool-bar>
        </extension>
    </extensions>
</plugin-config>
```

Fig. 23: gvSOS configuration file (config.xml).

Once these elements are loaded, a method of our extension class is executed. This method is very simple; it must only add some other user interface elements such as the wizard used to connect to the SOS servers and a menu entry to the popup menu associated to the TOC. The wizard class *SOSWizard* is added to the class *AddLayer* from the gvSIG layer. This class handles the dialog box shown to the users when they request a new layer. The dialog box contains wizards for all possible formats supported by the system. A popup menu entry for requesting and modifying the properties of an SOS layer is added to class *FPopMenu,* which is in charge of displaying the popup menu associated with the TOC corresponding to the selected view.

5.5 Add SOS Layer

The use case *Add SOS Layer* is much more complex than the previous one. The use case is started by the users when after creating a view they want to add a new layer. By selecting the option *Layer\Add Layer* from the menu or pressing the *"Add Layer"* toolbar button the Add Layer dialog box is shown. Within this dialog box we select the "SOS" tab to specify the parameters to connect to the SOS server and retrieve the data describing a given observation offering. In the following sections we explain how this behaviour is implemented layer by layer.

5.5.1 gvSIG layer

The gvSIG layer contains the classes handling the interaction with the user to establish the connection with the server and to select the observation offering to be displayed. It also allows the specification of filters that will be used for retrieving observations. The class implementing this user interface is *SOSWizard*. After establishing connection with the server and setting the required parameters *SOSWizard* must return the layer that contains all the sensors within the selected offering represented as points. This layer is used by gvSIG to create the view that shows the selected information to the user.

Figure 24 contains a sequence diagram illustrating the flow of messages to connect to the server. The diagram below shows how the *SOSWizard* obtains its data from *SOSWizardData,* which in turn get it from *FMapSOSDriver*. After establishing connection and retrieving the service capabilities the information displayed in the rest of the panels is updated. Internal details about how *FMapSOSDriver* obtains the data is provided in the following section.

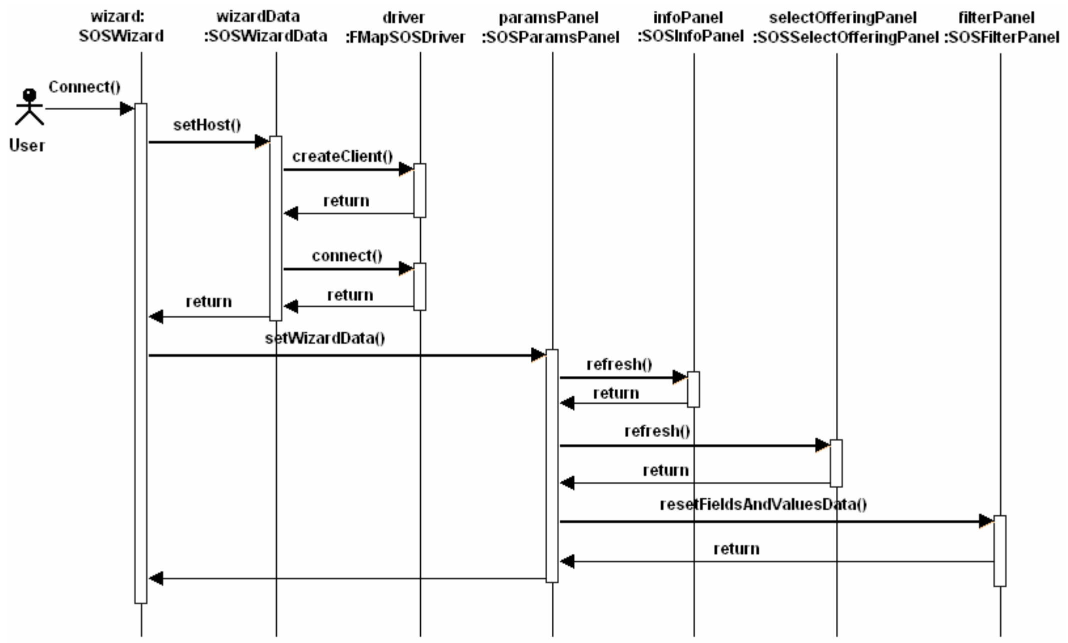


Fig. 24: Diagram showing how connection is established at the user interface level.

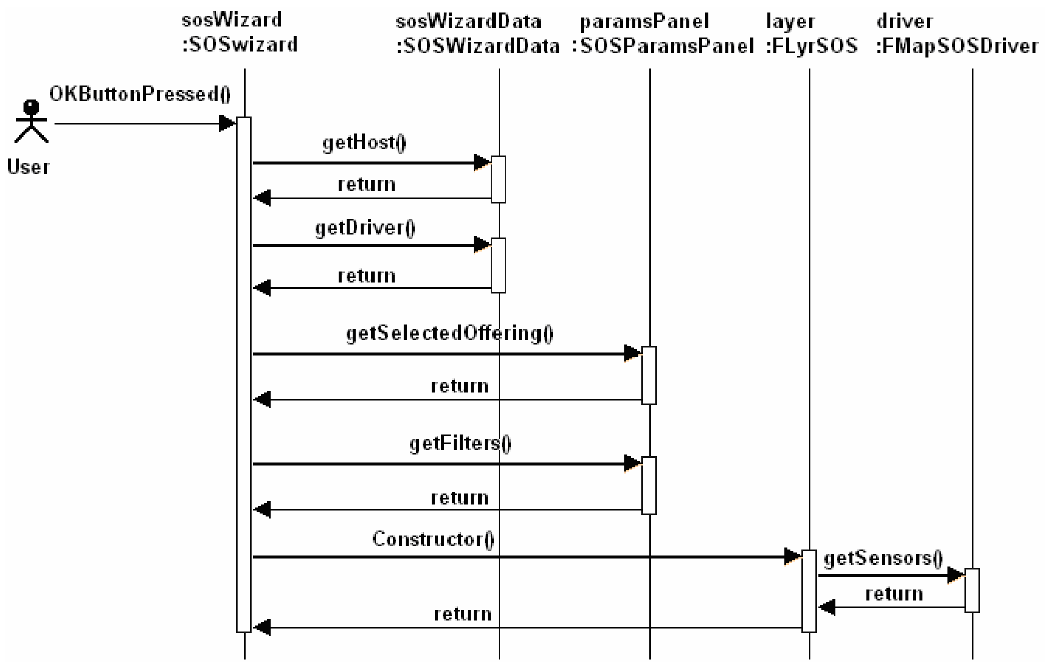


Fig. 25: Sequence diagram showing the layer creation process

In Figure 25 we present a sequence diagram showing the layer creation process. After selecting the required parameters all the necessary data to create the layer is retrieved by *SOSWizard* from *SOSWizardData* and *SOSParamsPanel.* This data is passed to the layer constructor which read the features using the *FMapSOSDriver* class.

5.5.2 Fmap and Remote Services layers

In the *Fmap* layer the main class to explain is *FMapSOSDriver* which intermediates between the classes in the *FMap* and *gvSIG* layers and the classes in the *RemoteServices* layer. We also include in this section the inner workings of the *RemoteServices* layer. The main scenarios at this point are how *FMapSOSDriver* implements the connection with the SOS server and how it implements the reading of features composing a layer.

To connect to the server, *FMapSOSDriver* issues a request to *SOSClient*, which uses *SOSProtocolHandler* to connect to the SOS Server (Figure 26). In this case, the version-specific specialization of *SOSProtocolHandler* is not used because *getCapabilities* requests are implemented in *gvSIG* in a unique way. Direct communication with the server is accomplished through the static method *downloadFile* included in the Utilities class.

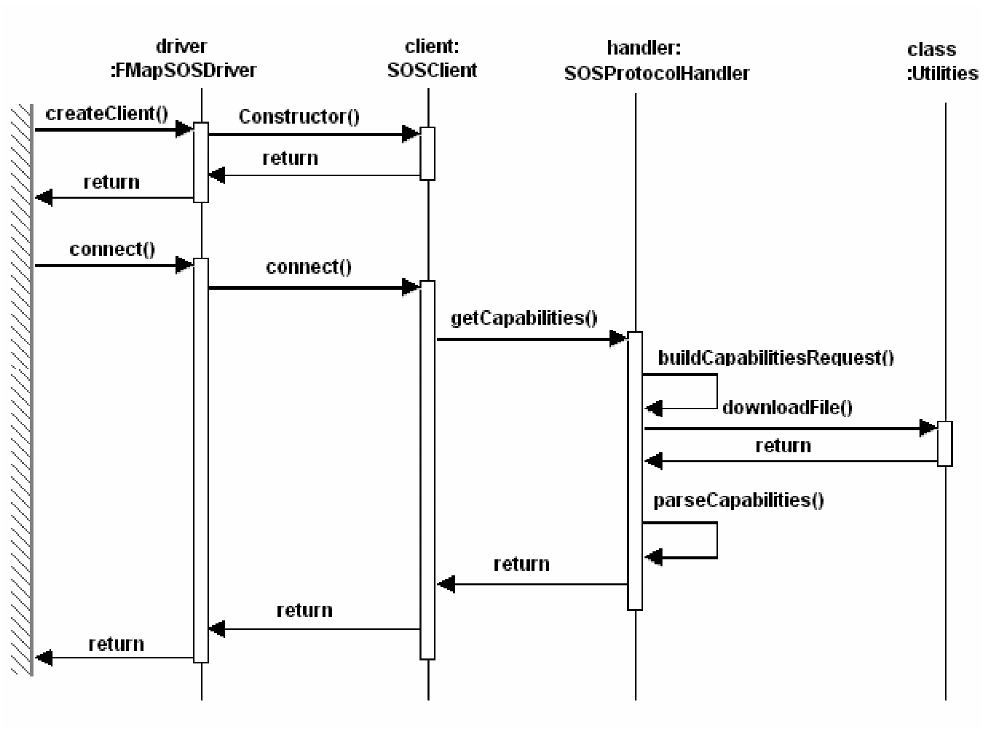


Fig. 26: Sequence diagram showing how connection is established at the driver level.

To read the features composing a layer, a call to *setOffering* must be executed upon the *FMapSOSDriver* class to set the offering selected by the user. This call must be followed by a call to *readFeatures* which read from the SOS server the information of every procedure associated with the previously selected offering using a *SOSClient* class instance. *SOSClient* use the *SOSProtocolHandler1_0_0* class to accomplish its task (Figure 27). The information from the procedures is retrieved from the server in SensorML format. These files are processed using a *GPESensorMLv101Parser* instance not included in Figure 27 to keep it as simple as possible. The parser converts the information contained in the files to *SOSFeature* objects whose content is added to the internal gvSIG data model using the *addGeometries* method. *addGeometries* is declared in the *ConcreteMemoryDriver* class, which keeps the features information in both spatial and tabular format.

An example of the final result of these operations is shown in Figure 28. In the view four layers are included; the first one starting from the bottom contains an ECW image of the Iberian Peninsula. The second and third layers contain boundaries from Spanish autonomous communities and provinces respectively. The layer at the top contains sensor systems located in harbours of four Spanish cities retrieved from a local files used for testing purposes. Sensors systems are represented as yellow points.

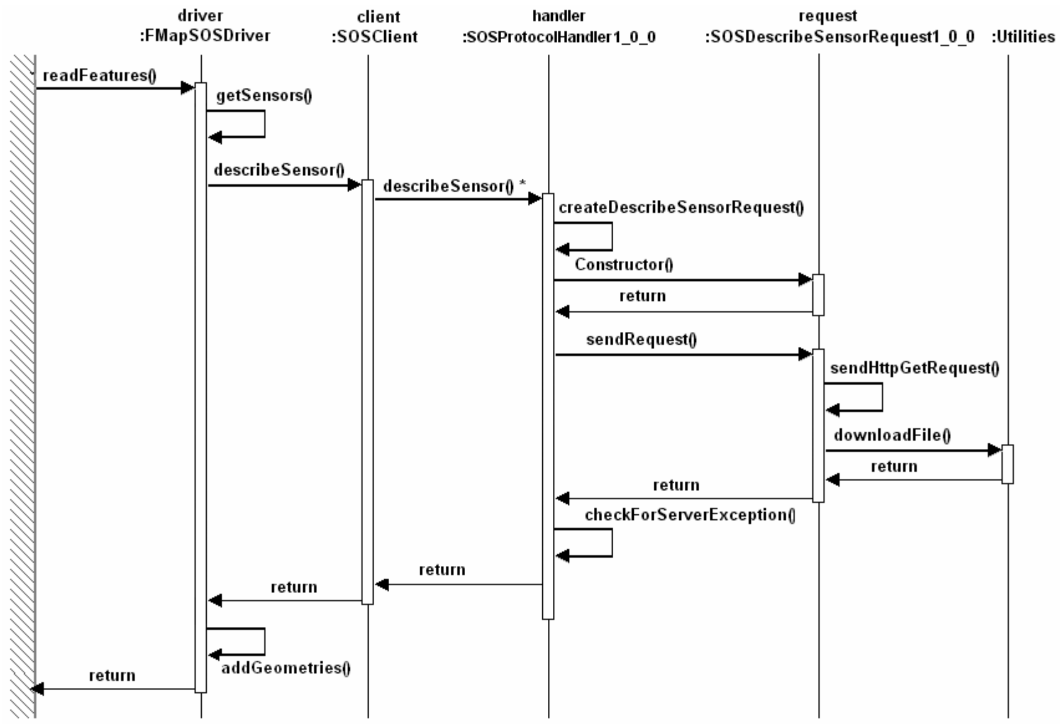


Fig. 27: Sequence diagram showing how information regarding procedures is read

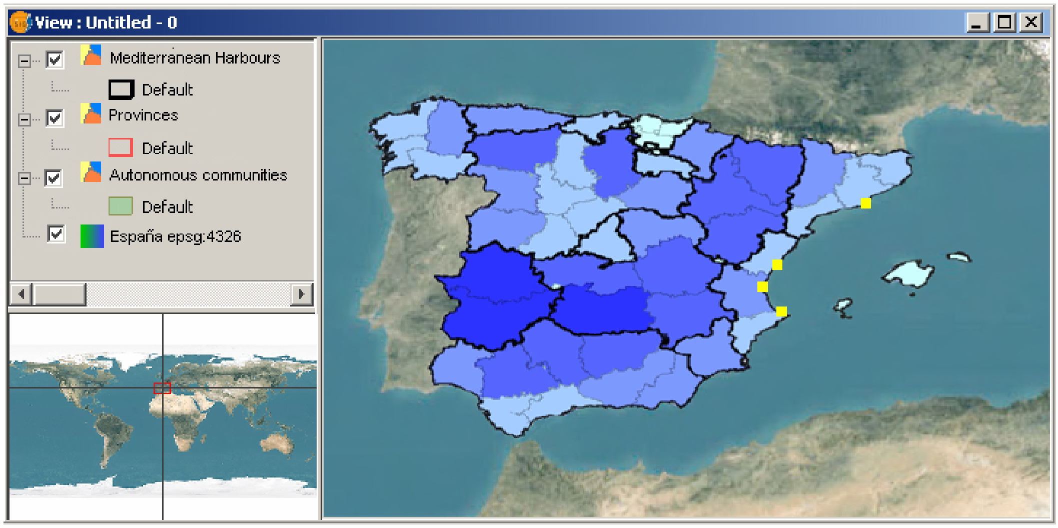
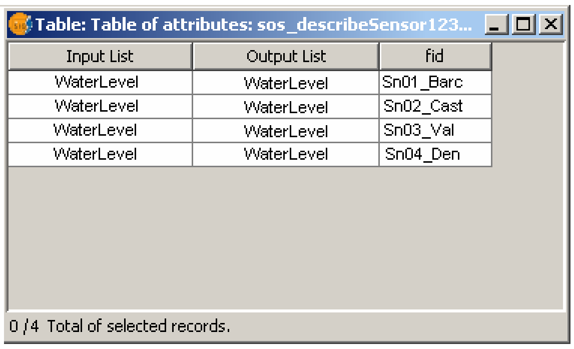


Fig. 28: Sensor systems located in four Mediterranean harbours.

5.6 Showing sensors and observations data

Once the layer with sensors is displayed in a view, the user may issue requests for information about sensors and observations. The information about sensors can be requested easily by clicking the "See table attributes" button. The table containing the sensors descriptions looks like the one in Figure 29. It includes the input list, output list and identifier for every sensor included in the layer. To implement this behaviour, interaction with the remote server is not necessary because metadata about sensors was already read when the layer was loaded. At this point, we only have to show this information in a tabulated form. The Fmap subsystem implements this behaviour in class *FlyrVect*, the direct ancestor of *FlyrSOS*. *FlyrVect* keeps an internal table model, updated every time the layer content changes, which is used by gvSIG to create a table at the user's request.



Input List	Output List	fid
WaterLevel	WaterLevel	Sn01_Barc
WaterLevel	WaterLevel	Sn02_Cast
WaterLevel	WaterLevel	Sn03_Val
WaterLevel	WaterLevel	Sn04_Den

0 /4 Total of selected records.

Fig. 29: Table containing the information about the sensors included in the view.

To display information about observations gathered by sensors the user must select them first and then press the *GetObservation* toolbar button. This action displays a dialog box, implemented by the *DlgGetObservation* class. This class allows the user to specify the parameters for a *GetObservation* request. Some of the parameters are already set, such as the offering which was set when the layer was created, and others, like filters, may be modified by the user at this step. Using the data entered in this dialog box, *GetObservation* requests are generated and sent to the server. This process is similar to the above mentioned process for reading sensors information. Now, instead of executing *getSensors* in *FMapSOSDriver*, *getObservations* is executed. *getObservations* delegates the processing of this call to the *SOSClient* object (Figure 30).

After the observations are read from the server a dialog box showing them in a table is presented to the users (Figure 31). This dialog box is implemented in the class *DlgObservations*. In the left side of the dialog box the user has a list with the requested sensors. Depending on the selected sensor, a table containing observations related with this sensor is displayed on the right side. This table includes the time in which every observation was made (if available) and the value of the observation. The example used shows the value of the WaterLevel property in a four days period, sampling the property every twelve hours. The test was accomplished using a local server filled with test data.

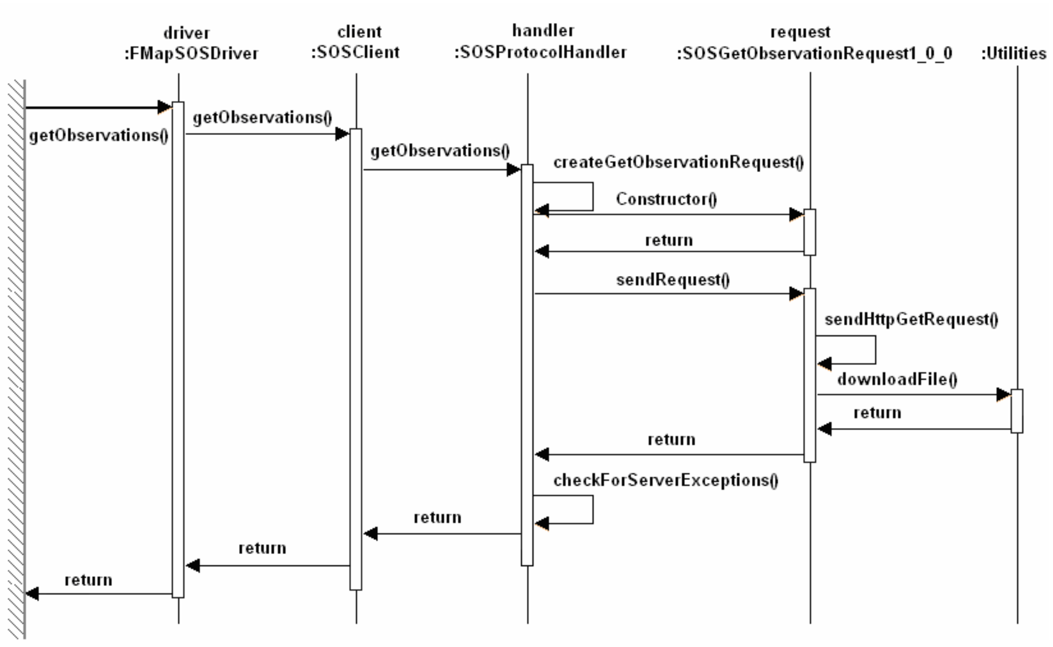
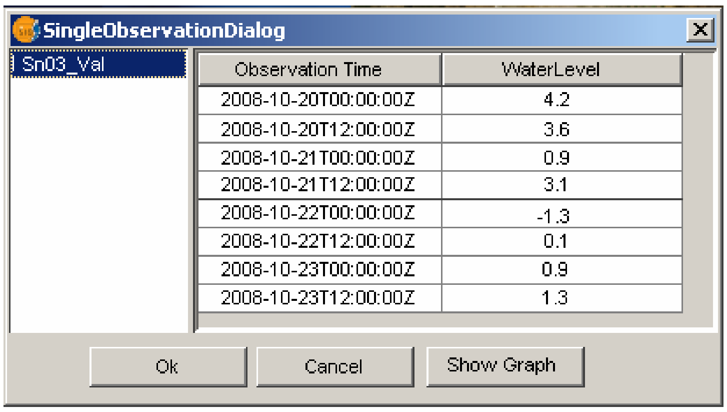


Fig. 30: Sequence diagram showing how observations are read from the server.



Observation Time	WaterLevel
2008-10-20T00:00:00Z	4.2
2008-10-20T12:00:00Z	3.6
2008-10-21T00:00:00Z	0.9
2008-10-21T12:00:00Z	3.1
2008-10-22T00:00:00Z	-1.3
2008-10-22T12:00:00Z	0.1
2008-10-23T00:00:00Z	0.9
2008-10-23T12:00:00Z	1.3

Fig. 31: Table showing observation times and values.

The user can also display this information as a graph, being this in most of the cases a more convenient solution than just looking into the bare numbers. A graph displaying the values shown in Figure 31 is shown in Figure 32. Graphs are implemented using the JFreeChart library (JFreeChart, 2009).

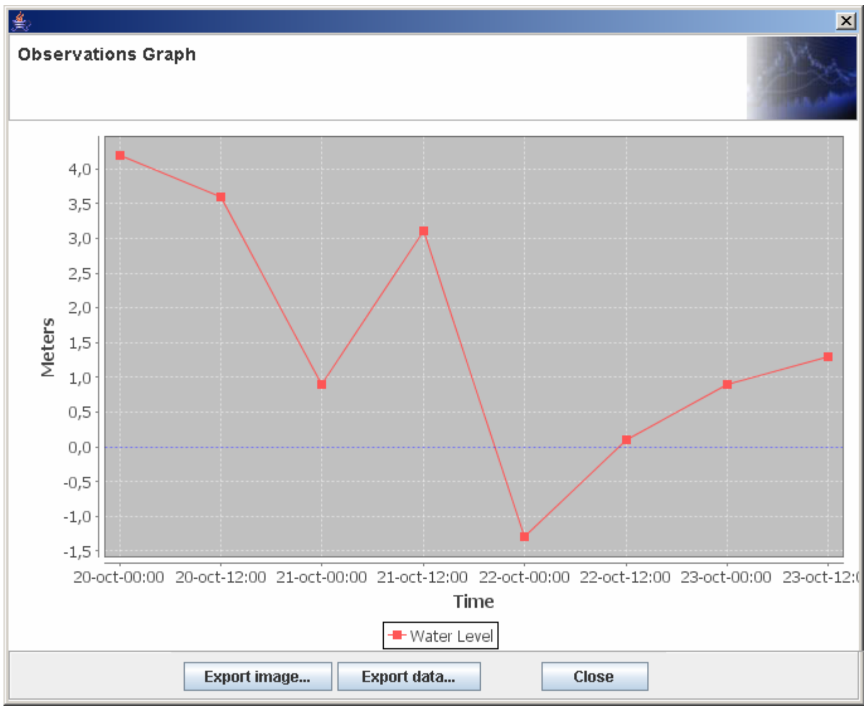


Fig. 32: Displaying observations on a graph.

5.7 Tests and Preliminary Results

Although the module implementation is not complete yet, tests have been executed to validate the functioning of some of its components. These tests have revealed some details in the SOS specification that complicates the implementation of clients and servers:

- In the server capabilities document there is no information about how procedures and observed properties of an offering are related. The only way to know which observed property is related with a given sensor is by executing a DescribeSensor operation.
- The time attribute for offerings permits specifying a temporal reference system through the frame attribute. Default ISO 8601 and the Gregorian calendar with UTC

are used. Having only this information does not seem to be enough. ISO 8601 allows several variations in the dates and times representation with basic and extended formats. After running some tests with SOS servers available on the Internet, we have observed that they do not support all possible variations in the data and time formats. Usually only one or a few variations are supported. This situation can provoke that a client sending valid ISO 8601 time values to the server may receive "Invalid Time Format" responses. To solve this problem gvSOS remembers how servers represent time values and convert any time value sent to it to this format. This problem could be avoided if the capabilities document included more detailed information about the time format supported by the server.

- Some examined server implementations do not use the parameter name sensorId to identify the sensor or sensor systems to be described using the DescribeSensor operation. Instead the parameter named procedure is used. This implies that a client issuing a correct request to a server may receive an error message.
- Practically no information about temporal filters is included in any of the OGC specifications. Maybe this is the reason why usually service implementations omit the FilterCapabilities section from the capabilities document. To complicate matters, filters specified in a GetObservation request are scattered all around since request temporal filters are included in the sos:eventTime tag, Id and spatial filters are included in the sos:featureOfInterest tag, and scalar filters are included in the sos:result tag.
- The SOS specification states that zero or many temporal filters (eventTime tags) may be specified in a GetObservation request. There is no mechanism for a SOS client to know the number of filters supported for a specific server. As a result a client might send a correct request containing more filters than the supported by the server, without any warranties about what the server will response.

5.8 Summary

In this chapter we presented the gvSOS design and implementation phases. For every layer in the module, the main packages and classes have been explained. We also provided details about how each one of the use cases were implemented, including sequence diagrams and screenshots. Finally, some preliminary results have been exposed.

6

CONCLUSIONS

We presented details of the development process for a new module for gvSIG to connect to Sensor Observation Services. The SOS client module allows gvSIG users to interact with SOS servers, displaying information about sensors and observations in a set of layers composed by features. Sensors are shown as features in the map and their information can be inspected also in tabular form. Observations can be inspected through tables or graphs, being the latter a more convenient choice for users.

For each step of the development process we specify the main obstacles found during the development such as, restrictions of the gvSIG architecture, inaccuracies in the OGC's specifications, and a set of common problems found in current SOS servers implementations available on the Internet. However, the OGC SWE specifications are a first attempt to make sensor resources broadly available to isolated communities to foster the integration of sensor data in Spatial Data Infrastructures.

Finally, future research should try to align with ongoing sensor experiments as in the context of GEOSS and the interoperability experiments within the OWS phase-6, which pursue among others, open issues to create geospatial processing workflows combining sensor data with mainstream GI data.

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