Open Geospatial Consortium

Approval Date: 2011-12-12

Publication Date: 2013-09-17

External OGC identifier: http://www.opengis.net/doc/as/om/2.0

Reference number of this document: OGC 10-004r3

Version: 2.0

Category: OGC® Standard: Abstract Specification

Editors: Simon Cox

OGC Abstract Specification

Geographic information — Observations and measurements

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Document type: OGC® Abstract Specification
Document subtype: Encoding
Document stage: Approved for Public Release
Document language : English

ISO TC 211/SC

ISO 19156:2011(E)

Secretariat: SN

First edition
2011-12-15

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 19156 was prepared by Technical Committee ISO/TC 211, *Geographic information/Geomatics*, in collaboration with the Open Geospatial Consortium (OGC).

Introduction

This International Standard arises from work originally undertaken through the Open Geospatial Consortium's Sensor Web Enablement (SWE) activity. SWE is concerned with establishing interfaces and protocols that will enable a "Sensor Web" through which applications and services will be able to access sensors of all types, and observations generated by them, over the Web. SWE has defined, prototyped and tested several components needed for a Sensor Web, namely:

— Sensor Model Language (SensorML).

— Observations & Measurements (O&M).

— Sensor Observation Service (SOS).

— Sensor Planning Service (SPS).

— Sensor Alert Service (SAS).

This International Standard specifies the Observations and Measurements schema, including a schema for sampling features.

The content presented here derives from an earlier version published by Open Geospatial Consortium as OGC 07-022r1, *Observations and Measurements — Part 1 — Observation schema* and OGC 07-002r3, *Observations and Measurements — Part 2 — Sampling Features*. A technical note describing the changes from the earlier version is available from the Open Geospatial Consortium (see http://www.opengeospatial.org/standards/om).

Geographic information — Observations and measurements

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1 Scope

This International Standard defines a conceptual schema for observations, and for features involved in sampling when making observations. These provide models for the exchange of information describing observation acts and their results, both within and between different scientific and technical communities.

Observations commonly involve sampling of an ultimate feature-of-interest. This International Standard defines a common set of sampling feature types classified primarily by topological dimension, as well as samples for ex-situ observations. The schema includes relationships between sampling features (sub-sampling, derived samples).

This International Standard concerns only externally visible interfaces and places no restriction on the underlying implementations other than what is needed to satisfy the interface specifications in the actual situation.

2 Conformance

2.1 Overview

Clauses 7 to 11 of this International Standard use the Unified Modeling Language (UML) to present conceptual schemas for describing Observations. These schemas define conceptual classes that

a) may be considered to comprise a cross-domain application schema, or

b) may be used in application schemas, profiles and implementation specifications.

This flexibility is controlled by a set of UML types that can be implemented in a variety of manners. Use of alternative names that are more familiar in a particular application is acceptable, provided that there is a one-to-one mapping to classes and properties in this International Standard.

The UML model in this International Standard defines conceptual classes; various software systems define implementation classes or data structures. All of these reference the same information content. The same name may be used in implementations as in the model, so that types defined in the UML model may be used directly in application schemas.

Annex A defines a set of conformance tests that will support applications whose requirements range from the minimum necessary to define data structures to full object implementation.

2.2 Conformance classes related to Application Schemas including Observations and Measurements

The conformance rules for Application Schemas in general are described in ISO 19109:2005. Application Schemas also claiming conformance to this International Standard shall also conform to the rules specified in Clauses 7 to 11 and pass all relevant test cases of the Abstract Test Suite in Annex A.

Depending on the characteristics of an Application Schema, 18 conformance classes are distinguished. Table 1 lists these classes and the corresponding subclause of the Abstract Test Suite.

Table 1 — Conformance classes related to Application Schemas including Observations and Measurements

Conformance class	Subclause
Generic observation interchange	A.1.1
Measurement interchange	A.1.1, A.1.2
Category observation interchange	A.1.1, A.1.3
Count observation interchange	A.1.1, A.1.4
Truth observation interchange	A.1.1, A.1.5
Temporal observation interchange	A.1.1, A.1.6
Geometry observation interchange	A.1.1, A.1.7
Complex observation interchange	A.1.1, A.1.8
Discrete coverage observation interchange	A.1.1, A.1.9
Point coverage observation interchange	A.1.1, A.1.10
Time series observation interchange	A.1.1, A.1.11
Sampling feature interchange	A.2.1, A.2.2
Spatial sampling feature interchange	A.2.1 to A.2.3
Sampling point interchange	A.2.1 to A.2.4
Sampling curve interchange	A.2.1 to A.2.3, A.2.5
Sampling surface interchange	A.2.1 to A.2.3, A.2.6
Sampling solid interchange	A.2.1 to A.2.3, A.2.7
Specimen interchange	A.2.1 to A.2.3, A.2.8

3 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 19101:2002, *Geographic information — Reference model*

ISO/TS 19103:2005, *Geographic information — Conceptual schema language*

ISO 19107:2003, *Geographic information — Spatial schema*

ISO 19108:2002, *Geographic information — Temporal schema*

ISO 19109:2005, *Geographic information — Rules for application schema*

ISO 19111:2007, *Geographic information — Spatial referencing by coordinates*

ISO 19115:2003, *Geographic information — Metadata*

ISO 19115:2003/Cor.1:2006, *Geographic information — Metadata — Technical Corrigendum 1*

ISO 19123:2005, *Geographic information — Schema for coverage geometry and functions*

ISO 19136:2007, *Geographic information — Geography Markup Language (GML)*

ISO/IEC 19501:2005, *Information technology — Open Distributed Processing — Unified Modeling Language (UML) Version 1.4.2*

ISO 19157:—[1], *Geographic information — Data quality*

4 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

4.1
application schema
conceptual schema for data required by one or more applications

[ISO 19101:2002, definition 4.2]

4.2
coverage
feature that acts as a function to return **values** from its range for any direct position within its spatial, temporal or spatiotemporal domain

[ISO 19123:2005, definition 4.17]

4.3
data type
specification of a **value** domain with operations allowed on values in this domain

[ISO/TS 19103:2005, definition 4.1.5]

EXAMPLE Integer, Real, Boolean, String, Date (conversion of a date into a series of codes).

NOTE Data types include primitive predefined types and user-definable types. All instances of a data type lack identity.

4.4
domain feature
feature of a type defined within a particular application domain

NOTE This may be contrasted with **observations** and **sampling features**, which are features of types defined for cross-domain purposes.

4.5
ex-situ
referring to the study, maintenance or conservation of a specimen or population away from its natural surroundings

[1] To be published.

NOTE Opposite of *in-situ*.

4.6
feature
abstraction of real-world phenomena

[ISO 19101:2002, definition 4.11]

NOTE A feature may occur as a type or an instance. In this International Standard, feature instance is meant unless otherwise specified.

4.7
feature type
class of **features** having common characteristics

4.8
measurand
particular quantity subject to **measurement**

[ISO/TS 19138:2006, definition 4.5]

NOTE Specialization of observable **property type**.

4.9
measure
value described using a numeric amount with a scale or using a scalar reference system

[ISO 19136:2007, definition 4.1.41]

4.10
measurement
set of operations having the object of determining the **value** of a quantity

[ISO/TS 19101-2:2008, definition 4.20]

4.11
observation
act of measuring or otherwise determining the **value** of a **property**

4.12
observation procedure
method, algorithm or instrument, or system of these, which may be used in making an **observation**

4.13
observation protocol
combination of a sampling strategy and an **observation procedure** used in making an **observation**

4.14
observation result
estimate of the **value** of a **property** determined through a known observation procedure

4.15
property
facet or attribute of an object referenced by a name

[ISO 19143:2010, definition 4.21]

EXAMPLE Abby's car has the colour red, where "colour red" is a property of the car.

4.16
property type
characteristic of a **feature type**

EXAMPLE Cars (a feature type) all have a characteristic colour, where "colour" is a property type.

NOTE 1 The **value** for an instance of an observable property type can be estimated through an act of **observation**.

NOTE 2 In chemistry-related applications, the term "determinand" or "analyte" is often used.

NOTE 3 Adapted from ISO 19109:2005.

4.17
sampling feature
feature which is involved in making **observations** concerning a **domain feature**

EXAMPLE Station, transect, section or specimen.

NOTE A sampling feature is an artefact of the observational strategy, and has no significance independent of the observational campaign.

4.18
value
element of a type domain

[ISO/IEC 19501:2005]

NOTE 1 A value considers a possible state of an object within a class or type (domain).

NOTE 2 A data value is an instance of a **datatype**, a value without identity.

NOTE 3 A value can use one of a variety of scales including nominal, ordinal, ratio and interval, spatial and temporal. Primitive datatypes can be combined to form aggregate datatypes with aggregate values, including vectors, tensors and images.

5 Abbreviated terms and notation

5.1 Abbreviated terms

GFM General Feature Model

GML Geography Markup Language

O&M Observations and Measurements

OGC Open Geospatial Consortium

SensorML Sensor Model Language

SOS Sensor Observation Service

SWE Sensor Web Enablement

UML Unified Modeling Language

XML Extensible Markup Language

1-D One Dimensional

2-D Two Dimensional

3-D Three Dimensional

5.2 Schema language

The conceptual schema specified in this International Standard is in accordance with the Unified Modelling Language (UML) ISO/IEC 19501, following the guidance of ISO/TS 19103.

The UML is conformant with the profile described in ISO 19136:2007, Annex E. Use of this restricted idiom supports direct transformation into a GML Application Schema. ISO 19136 introduces some additional stereotypes. In particular «FeatureType» implies that a class is an instance of the «metaclass» GF_FeatureType (ISO 19109), and therefore represents a feature type.

The prose explanation of the model uses the term “property” to refer to both class attributes and association roles. This is consistent with the General Feature Model described in ISO 19109. In the context of properties, the term “value” refers to either a literal (for attributes whose type is simple), or to an instance of the class providing the type of the attribute or target of the association. Within the explanation, the property names (property types) are sometimes used as natural language words where this assists in constructing a readable text.

5.3 Model element names

This International Standard specifies a model for observations using terminology that is based on current practice in a variety of scientific and technical disciplines. It is designed to apply across disciplines, so the best or "most neutral" term has been used in naming the classes, attributes and associations provided. The terminology does not, however, correspond precisely with any single discipline. As an aid to implementors, a mapping from the element names specified in this International Standard to common terminology in some application domains is provided in Annex B.

6 Dependencies

Some model elements used in the schema described in Clauses 7 to 11 are defined in other International Standards. By convention within ISO/TC 211, names of UML classes, with the exception of basic data type classes, include a two or three letter prefix that identifies the International Standard and the UML package in which the class is defined. Table 2 lists the standards and packages in which UML classes used in this International Standard have been defined. UML classes defined in this International Standard have the prefix of CVT, GFI, OM and SF. The prefix GFI is used for classes defined in this International Standard, but which are associated with the GF package in ISO 19109. The prefix CVT is used for classes defined in this International Standard, but which are associated with the CV package in ISO 19123:2005.

Table 2 — Sources of UML classes

Prefix	International Standard	Package
CVT	This International Standard (Annex C)	Temporal coverage
CV	ISO 19123:2005	Coverage
GFI	This International Standard (Annex C)	General Feature Model general instance
DQ	ISO 19115:2003	Data Quality
GF	ISO 19109:2005	General Feature Model

Prefix	International Standard	Package
GM	ISO 19107:2003	Geometry
LI	ISO 19115:2003, ISO 19115:2003/Cor.1:2006	Data Quality
MD	ISO 19115:2003/Cor.1:2006	Metadata Entity
OM	This International Standard	Observations and Measurements
SC	ISO 19111:2007	Coordinate reference systems
SF	This International Standard	Sampling features
TM	ISO 19108:2002	Temporal Schema

7 Fundamental characteristics of observations

7.1 The context for observations

7.1.1 Property evaluation

Properties of a feature fall into two basic categories:

a) Value (e.g. name, price, legal boundary) assigned by some authority. These are exact.

b) Value (e.g. height, classification, colour) determined by application of an observation procedure. These are estimates, with a finite error associated with the value.

The observation error typically has a systematic component, which is similar for all estimates made using the same procedure, and a random component, associated with the particular application instance of the observation procedure. If potential errors in a property value are important in the context of a data analysis or processing application, then the details of the act of observation which provided the estimate of the value are required.

7.1.2 Observation

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 [2]. It involves application of a specified procedure, such as a sensor, instrument, algorithm or process chain. The procedure may be applied *in-situ*, remotely, or *ex-situ* with respect to the sampling location. The result of an observation is an estimate of the value of a property of some feature. Use of a common model allows observation data using different procedures to be combined unambiguously.

The observation itself is also a feature, since it has properties and identity.

Observation details are important for data discovery and for data quality estimation.

The observation could be considered to carry "property-level" instance metadata, which complements the dataset-level and feature-level metadata that have been conventionally considered (e.g. ISO 19115).

NOTE ISO 19115-2:2009 provides MI_Event, which plays a similar role to OM_Observation in the context of image capture.

7.1.3 Observation properties

An observation results in a value being assigned to a phenomenon. The phenomenon is a property of a feature, the latter being the feature-of-interest of the observation. The observation uses a procedure, which is often an instrument or sensor [1][2], 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.

The relationship between the properties of an observation and those of its feature-of-interest is key to the semantics of the model. This is further elaborated in D.3.

7.1.4 Observation location

The principal location of interest is usually associated with the ultimate feature-of-interest.

However, the location of the feature-of-interest may not be trivially available. For example: in remote sensing applications, a complex processing chain is required to geolocate the scene or swath; in feature-detection applications the initial observation may be made on a scene, but the entity to be detected, which is the ultimate feature-of-interest, occupies some location within it. The distinction between the proximate and ultimate feature-of-interest is a key consideration in these cases.

Other locations appear in various scenarios. Sub-sampling at locations within the feature-of-interest may occur. The procedure may involve a sensor located remotely from the ultimate feature-of-interest (e.g. remote sensing; or where specimens are removed from their sampling location and observations made *ex-situ*). Furthermore, the location of the feature-of-interest may be time-dependent.

The model is generic. The geospatial location of the feature-of-interest may be of little or no interest for some observations (e.g. live specimens, observations made on non-located things like chemical species).

For these reasons, a generic Observation class does not have an inherent location property. Relevant location information should be provided by the feature-of-interest, or by the observation procedure, according to the specific scenario.

NOTE In contrast to spatial properties, some temporal properties are associated directly with an observation (7.2.2.2; 7.2.2.3). This is a consequence of the fact that an observation is a kind of ‘event’ so its temporal characteristics are fundamental, rather than incidental.

7.1.5 Result types

Observation results may have many datatypes, including primitive types like category or measure, but also more complex types such as time, location and geometry. Complex results are obtained when the observed property requires multiple components for its encoding. Furthermore, if the property varies on the feature-of-interest, then the result is a coverage, whose domain extent is the extent of the feature. In a physical realization, the result will typically be sampled discretely on the domain, and may be represented as a discrete coverage.

The result type may be used as a basis for defining specialized observation types.

7.1.6 Measurements

In conventional measurement theory (e.g. [1][5][10][11][19]) the term “measurement” is used. However, a distinction between measurement and category-observation has been adopted in more recent work [2][12][21] so the term “observation” is used here for the general concept. “Measurement” may be reserved for cases where the result is a numerical quantity.

7.2 Observation schema

7.2.1 Packaging

The observation schema is organized in one package containing eleven leaf packages corresponding to the conformance classes defined in 2.2, with dependencies on several other packages from International

Standards covering geographic information, on the General Feature Instance package (C.2) and the Temporal Coverage package (C.3). The inter-package dependencies are shown in Figure 1. The core observation package is documented in this subclause. The specialized observations are documented in Clause 8.

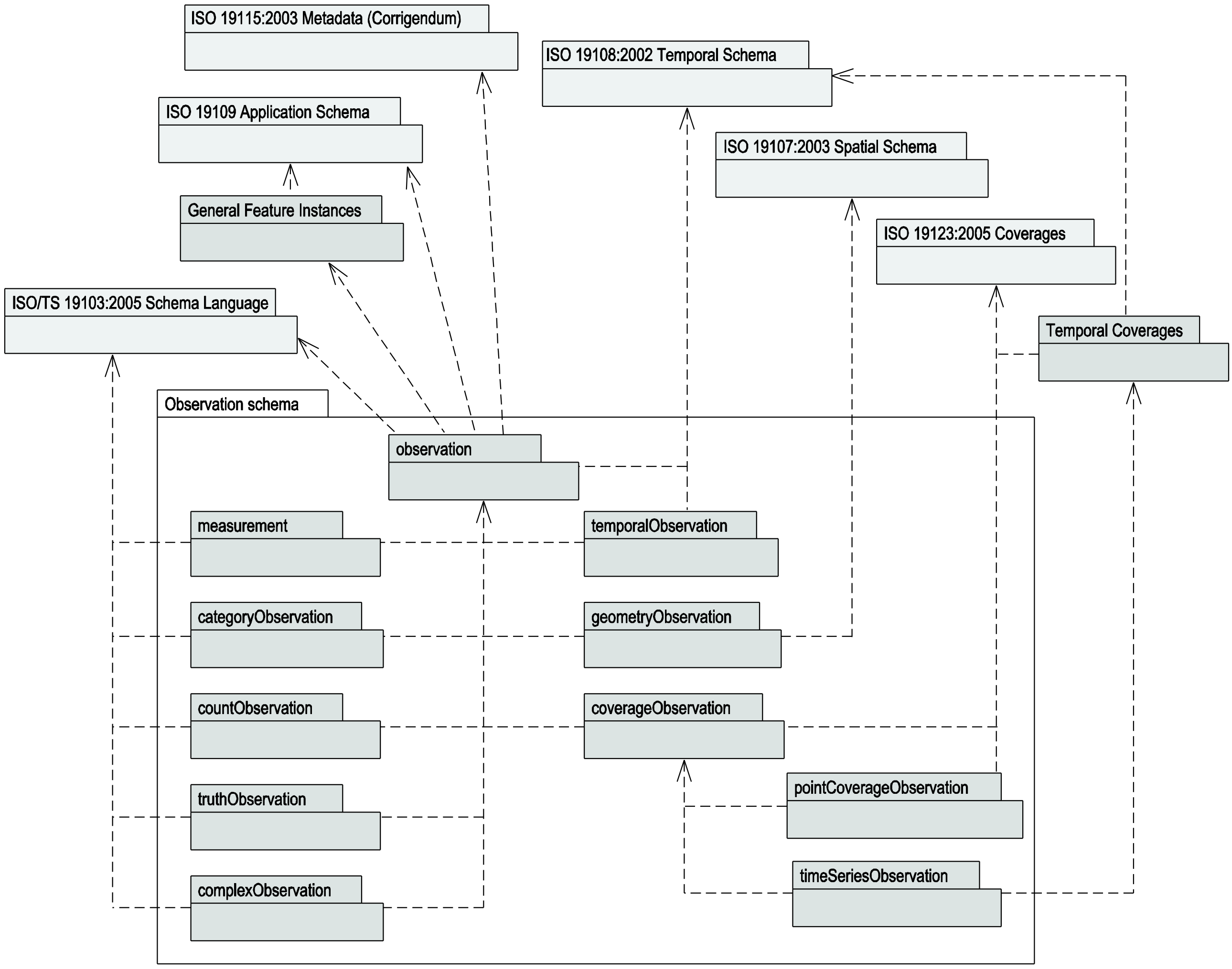

Figure 1 — Package dependencies of the observation schema

7.2.2 OM_Observation

7.2.2.1 General

The class *OM_Observation* (Figure 2) is an instance of the «metaclass» GF_FeatureType (ISO 19109), which therefore represents a feature type. OM_Observation shall support five attributes and six associations, and shall be subject to four constraints.

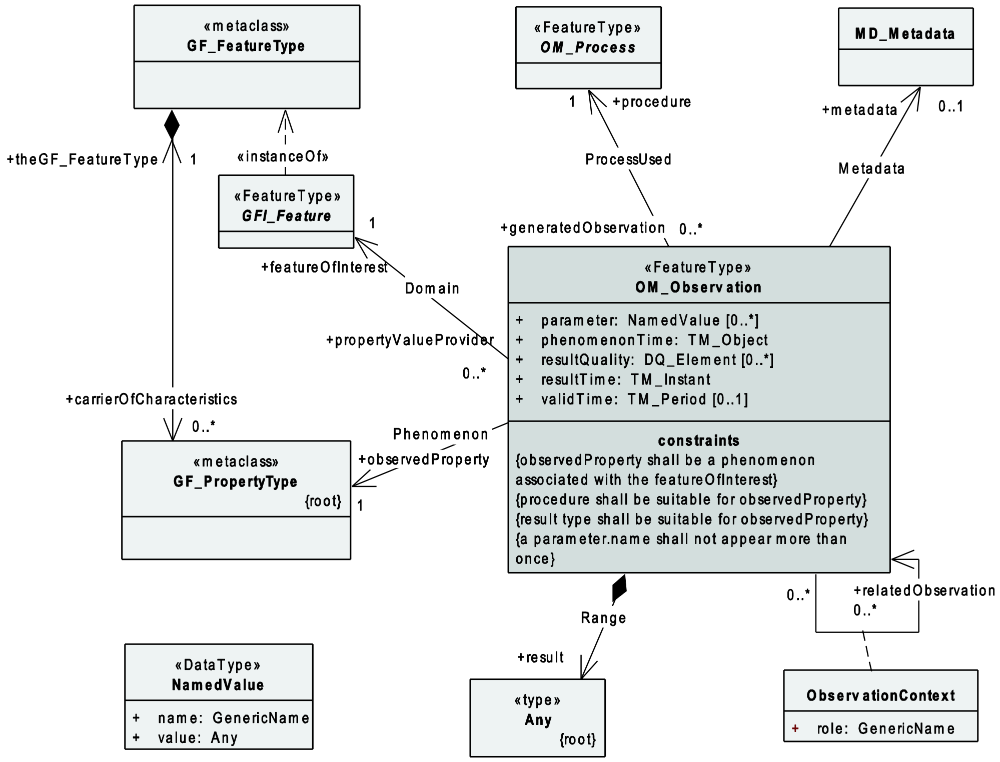

Figure 2 — The basic Observation type

7.2.2.2 phenomenonTime

The attribute *phenomenonTime:TM_Object* shall describe the time that the result (7.2.2.9) applies to the property of the feature-of-interest (7.2.2.7). This is often the time of interaction by a sampling procedure (9.1.3) or observation procedure (7.2.2.10) with a real-world feature.

NOTE The phenomenonTime is the temporal parameter normally used in geospatial analysis of the result.

If the observedProperty of an observation is ‘occurrence time’ then the result should be the same as the phenomenonTime.

7.2.2.3 resultTime

The attribute *resultTime:TM_Instant* shall describe the time when the result became available, typically when the procedure (7.2.2.10) associated with the observation was completed. For some observations, this is identical to the phenomenonTime. However, there are important cases where they differ.

EXAMPLE 1 Where a measurement is made on a specimen in a laboratory, the phenomenonTime is the time the specimen was retrieved from its host, while the resultTime is the time the laboratory procedure was applied.

EXAMPLE 2 The resultTime also supports disambiguation of repeat measurements made of the same property of a feature using the same procedure.

EXAMPLE 3 Where sensor observation results are post-processed, the resultTime is the post-processing time, while the phenomenonTime is the time of initial interaction with the world.

EXAMPLE 4 Simulations can estimate the values for phenomena in the future or past. The phenomenonTime is the time that the result applies to, while the resultTime is the time that the simulation was executed.

7.2.2.4 validTime

If present, the attribute *validTime:TM_Period* shall describe the time period during which the result is intended to be used.

NOTE This attribute is commonly required in forecasting applications.

7.2.2.5 parameter

If present, the attributes *parameter:NamedValue* shall describe an arbitrary event-specific parameter. This might be an environmental parameter, an instrument setting or input, or an event-specific sampling parameter that is not tightly bound to either the feature-of-interest (7.2.2.7) or to the observation procedure (7.2.2.10). To avoid ambiguity, there shall be no more than one parameter with the same name.

NOTE Parameters that are tightly bound to the procedure can be recorded as part of the procedure description.

In some contexts, the *Observation::procedure* (7.2.2.10) is a generic or standard procedure, rather than an event-specific process. In this context, parameters bound to the observation act, such as instrument settings, calibrations or inputs, local position, detection limits, asset identifier, operator, may augment the description of a standard procedure.

EXAMPLE A time sequence of observations of water quality in a well might be made at variable depths within the well. While these can be associated with specimens taken from the well at this depth as the features-of-interest, a more common approach is to identify the well itself as the feature-of-interest, and add a “samplingDepth” parameter to the observation (Figure 3). The sampling depth is of secondary interest compared to the temporal variation of water quality at the site.

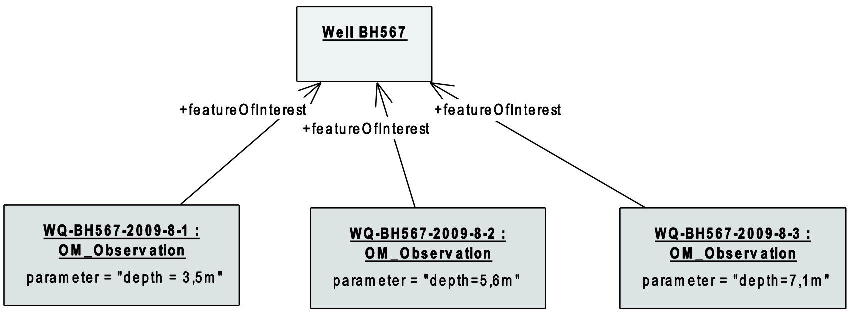

Figure 3 — (Example) Observation instances in the same well at different depths, described using the ‘parameter’ attribute

7.2.2.6 resultQuality

If present, the attributes *resultQuality:DQ_Element* shall describe the quality of the result (7.2.2.9). This instance-specific description complements the description of the observation procedure (7.2.2.10), which provides information concerning the quality of all observations using this procedure. The quality of a result may be assessed following the procedures in ISO 19157. Multiple measures may be provided.

7.2.2.7 Domain

The association *Domain* shall link the OM_Observation to the GFI_Feature (C.2.1) that is the subject of the observation and carries the observed property. This feature has the role *featureOfInterest* with respect to the observation. This feature is the real-world object whose properties are under observation, or is a feature intended to sample the real-world object, as described in Clause 9 of this International Standard. An observation instance serves as a *propertyValueProvider* for its feature-of-interest.

7.2.2.8 Phenomenon

The association *Phenomenon* shall link the OM_Observation to the GF_PropertyType for which the OM_Observation:result (7.2.2.9) provides an estimate of its value. The property type has the role *observedProperty* with respect to the observation.

The observed property shall be a phenomenon associated with the feature-of-interest.

An observed property may be, but need not be, modelled as a property (in the sense of the General Feature Model) in a formal application schema that defines the type of the feature-of-interest.

An instance of GF_PropertyType shall describe a property that is either assignable or observable (7.1.2), such as "temperature", "height", "colour", "material". A property type may be an operation or function such as a spatiotemporal coverage. Property-type definitions may be organized into a hierarchy or ontology and managed in a register and catalogued to support discovery functions. The observed property supports semantic or thematic classification of observations, which is useful for discovery and data fusion.

NOTE In general, the value of a specific observedProperty can be associated with different feature types in different observations, thus allowing the results of observations made in different projects or campaigns, and even from different disciplines, to be combined when required. A property-type register used in observations is most useful if each property type is not tied to a single feature type, or if equivalence relationships between similar property types from different feature types are provided.

7.2.2.9 Range

The association *Range* shall link the OM_Observation to the value generated by the procedure. The value has the role *result* with respect to the observation. The type of the result is shown as “Any”, since it may represent the value of any feature property.

NOTE 1 OGC SWE Common [20] provides a model suitable for describing many kinds of observation results.

The type of the observation result shall be consistent with the observed property, and the scale or scope for the value shall be consistent with the quantity or category type. If the observed property (7.2.2.8) is a spatial operation or function, the type of the result may be a coverage.

NOTE 2 In some contexts, particularly in earth and environmental sciences, the term “observation” is used to refer to the *result* itself.

7.2.2.10 ProcessUsed

The association *ProcessUsed* shall link the OM_Observation to the OM_Process (7.2.3) used to generate the result. The process has the role *procedure* with respect to the observation. A process might be responsible for more than one *generatedObservation*.

The OM_Process shall be suitable for the observed property. As a corollary, details of the observed property are constrained by the procedure used.

EXAMPLE Observed radiance wavelength is determined by the response characteristics of the sensor.

A description of the observation procedure provides or implies an indication of the reliability or quality of the observation result.

7.2.2.11 Metadata

If present, the association *Metadata* shall link the OM_Observation to descriptive metadata.

7.2.2.12 Constraints — Consistency with domain model

The type of the feature-of-interest is defined in an application schema (ISO 19109). This may be part of a domain model, or may be from a cross-domain model, such as Sampling Features (Clause 9). The feature type defines its set of properties. For consistency, the feature-of-interest shall carry the observed property as part of the definition of its type (e.g. Figure 4).

EXAMPLE A feature type "Pallet" might be defined as having the attribute "mass" of type "Measure". An observation providing the value of this property shall have observedProperty="mass", the result shall be of the type "Measure" and the scale (unit of measure) shall be suitable for mass measurements.

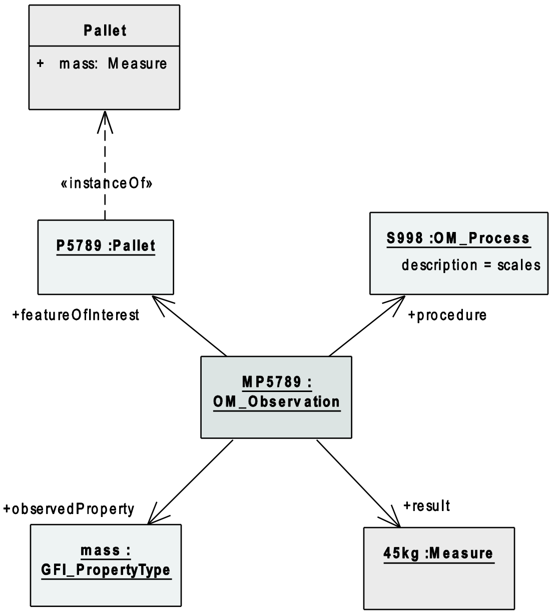

Figure 4 — (Example) An observation with consistent properties: the observed property (mass) is a phenomenon associated with the type of the feature-of-interest (Pallet) and the procedure and result type are also suitable

In the case of a feature property with internal structure (e.g. feature associations), the observed property may be of one component, or of a subset of elements, of the complete feature property. Hence, the observed property might not appear directly as a first-order property in the type definition for the feature-of-interest, but shall appear within the structure of the feature type definition at some level (e.g. Figure 5).

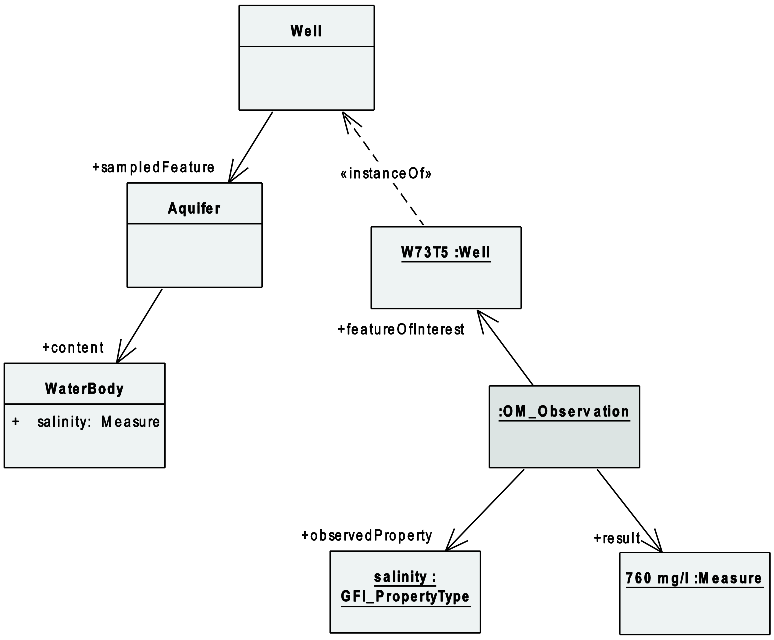

Figure 5 — (Example) An observation where the observed property is not a direct member of the type of the feature-of-interest

Other consistency constraints are that

— the procedure shall be suitable for the observed property, and

— the result type shall be consistent with the observed property (e.g. Figure 4).

7.2.3 OM_Process

The class OM_Process (Figure 2) is an instance of the «metaclass» GF_FeatureType (ISO 19109), which therefore represents a feature type. OM_Process is abstract, and has no attributes, operations or associations. It serves as the base class for observation processes. The purpose of an observation process is to generate an observation result. An instance of OM_Process is often an instrument or sensor, but may be a human observer, a simulator, or a process or algorithm applied to more primitive results used as inputs.

NOTE ISO 19115-2 provides MI_Instrument, LE_Processing and LE_Algorithm, which could all be modelled as specializations of OM_Process. OGC SensorML [16] provides a model which is suitable for many observation procedures.

7.2.4 ObservationContext

7.2.4.1 General

Some observations depend on other observations to provide a context which is important, sometimes essential, in understanding the result. These dependencies are stronger than mere spatiotemporal coincidences, requiring explicit representation. If present, the association class *ObservationContext* (Figure 2) shall link an OM_Observation to another OM_Observation, with the role name relatedObservation for the target. It shall support one attribute.

EXAMPLES Some examples include the conditions associated with experimental replicates (e.g. experimental plots and treatments used), biotic factors (e.g. ecological community), interactions among features (e.g. predator-prey), or other temporary relationships occurring at the time of observation that are not inherent to the observed features themselves (i.e. they change over time), or the related observation may provide input to a process that generates a new result.

This association complements the Intention association (9.2.2.1, 9.2.2.4) which describes relationships between a sampling feature and domain features.

7.2.4.2 role

The attribute *role:GenericName* shall describe the relationship of the target OM_Observation to the source OM_Observation.

7.2.5 NamedValue

7.2.5.1 General

The class *NamedValue* provides for a generic soft-typed parameter value. NamedValue shall support two attributes.

7.2.5.2 name

The attribute *name:GenericName* shall indicate the meaning of the named value. Its value should be taken from a well-governed source if possible.

EXAMPLE When used as the value of an Observation::;parameter, the name might take values like ‘procedureOperator’, ‘detectionLimit’, ‘amplifierGain’, ‘samplingDepth’.

7.2.5.3 value

The attribute *value:Any* shall provide the value. The type “Any” should be substituted by a suitable concrete type, such as CI_ResponsibleParty or Measure.

7.3 Use of the observation model

The Observation model takes a data-user-centric viewpoint, emphasizing the semantics of the feature-of-interest and its properties. This contrasts with Sensor-oriented models, which take a process- and thus provider-centric viewpoint.

An observation is a property-value-provider for a feature-of-interest. Aside from the result, the details of the observation event are primarily of interest in applications where an evaluation of errors in the estimate of the value of a property is of concern. The Observation could be considered to carry “property-level” instance metadata, complementing the dataset-level and feature-level metadata that have been conventionally considered (e.g. ISO 19115).

Additional discussion of the application of the observation and sampling models, and nuances within these, is provided in Annex D.

8 Specialized observations

8.1 Classification of observation by result type

The observation result type shall be suitable for the observed property. The observation type may be classified by the type of the result. Two groups of specialized observations may be distinguished:

a) Observations whose result is a constant or static value: observations for which the result of a single observation may be either single-valued or multi-valued, but, if there are multiple values, those values do not vary with either spatial position or time during the duration of the observation.

b) Observations whose result varies within the scope of the feature-of-interest: observations for which the result of a single observation contains multiple values that vary with either spatial position, time, or both, during the duration of the observation.

8.2 Observations whose result is constant

8.2.1 General

Where a property of the feature-of-interest is spatially and temporally invariant during the period of an observation, the corresponding observation result is a scalar (e.g. mass, length, temperature), or a record whose components correspond to a thematic decomposition of the observed property (e.g. bands of a spectrum, components of a wind-velocity vector, components of a stress tensor, elements of a geometry). Where a standard model for the observed property is available, this may be used for the result (e.g. observations of position, shape, or time should use GM_Object and TM_Object).

8.2.2 Taxonomy of observation types whose result is constant

Observation types with results that are internally invariant with respect to space or time are in the Specialized Observation package and are shown in Figure 6.

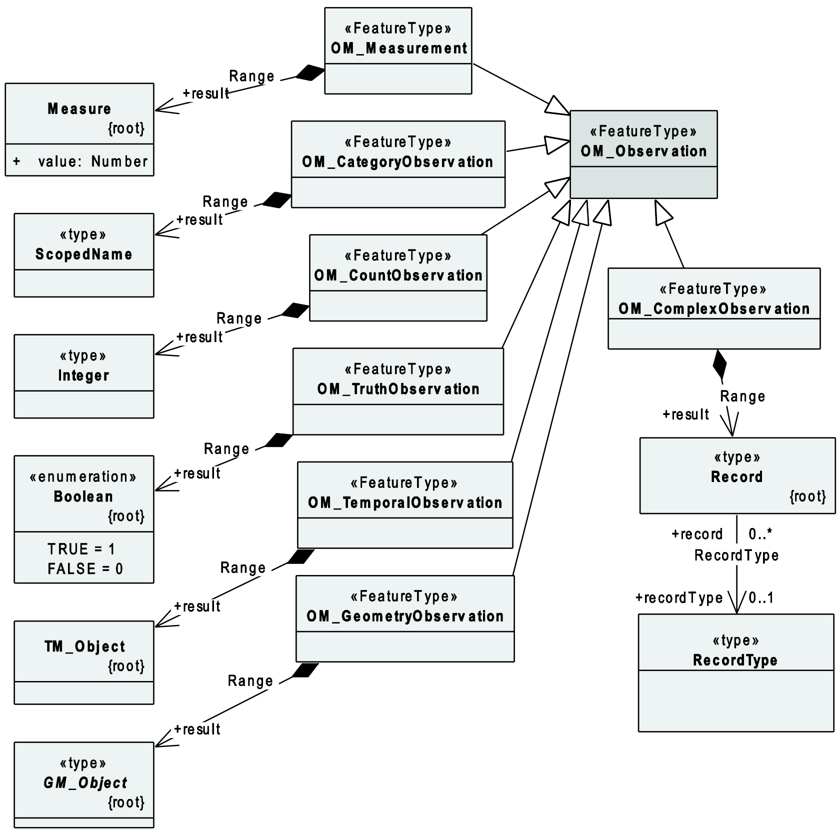

Figure 6 — Specializations of observation by result type

The classes Measure, ScopedName, Integer, Boolean, Record and RecordType are defined in ISO/TS 19103, TM_Object in ISO 19108 and GM_Object in ISO 19107.

For each specialized observation class, the target of the association named ‘Range’ with the role-name ‘result’ shall be redefined as indicated in Figure 6 and Table 3.

Table 3 — Result types for specialized observations

Specialized observation class	Result type	Example
OM_Measurement	Measure	A measurement of "mass" (property type) of "the seventh banana" (feature-of-interest) using the "kitchen scales" (procedure) had the result "150 g".
OM_CategoryObservation	ScopedName	A category observation of the "taxon" (property type) of "specimen 123" (feature-of-interest) by "Amy Bachrach" (procedure) had the result "Eucalyptus caesia" (from the Flora of Australia).
OM_CountObservation	Integer	A count observation of "the number of votes cast" (property type) at "the municipal election" (feature-of-interest) using the "electronic voting machine tally" (procedure) had the result "3542".
OM_TruthObservation	Boolean	A truth observation of "presence" (property type) of "intruder" (feature-of-interest) using the "CCTV" (procedure) had the result "false".
OM_TemporalObservation	TM_Object	A temporal observation of "duration" (property type) for "Usain Bolt 100m dash" (feature-of-interest) using the "stop watch" (procedure) had the result "9,6 s".[a]
OM_GeometryObservation	GM_Object	A geometry observation of "perimeter" (property type) for "plot 987" (feature-of-interest) using the "field survey GHJ" (procedure) had the result "(… description of polygon …)".
OM_ComplexObservation	Record (ISO/TS 19103:2005)	A complex observation of "major element composition" (property type) for "specimen h8j" (feature-of-interest) using the "ICPMS" (procedure) had the result "(… array of element proportions …)".

[a] If the observedProperty of a temporal observation is ‘occurrence time’ then the value of the result will generally be the same as the value of the phenomenonTime.

8.3 Observations whose result varies

8.3.1 General

Where the type of a feature allows for a property that is dependent on some parameter, then the value of the property is a *function* of this parameter.

EXAMPLE 1 The length of a rail varies with temperature.

If the variation is temporal or spatial, then the function is a *coverage* (CV_Coverage — ISO 19123:2005) whose domain extent is the spatiotemporal extent of the feature. The value of a corresponding observation result shall therefore be a function or coverage, respectively. In practice, the observation will *sample* the relevant axis of the target feature, so the observation result is usually represented as a *discrete* function or coverage (CV_DiscreteCoverage).

The target feature may have many observations made on it using different sampling regimes, so the sampling regime is associated with the act of observation, rather than being inherent in the feature-of-interest. This may be accommodated by the decomposition of the domain geometry (i.e. the CV_DomainObject elements) in the observation *result*. The decomposition of the domain geometry in the result provides an intrinsic element of the overall observation protocol.

NOTE The sampling regime may also be accommodated by multiple observations on a complex of sampling features (9.2.3).

EXAMPLE 2 The colour of a scene varies with position. The result of an observation of the property ”colour” of the scene is a coverage. Each domain element is a pixel whose index allows the spatial location within the scene to be obtained.

EXAMPLE 3 Many properties of an observation well vary along its length, including rock type, orientation, permeability, etc. These are conventionally encoded as “logs”, with different sampling regimes. Each well-log is a coverage whose domain is the curve describing the shape of the well. The domain is sampled with elements whose location is described in terms of 1-D position measured along the well axis.

A simple case concerns sampling a property at points on an extensive feature. The observation result is a set of point-value pairs (CV_PointValuePair — ISO 19123:2005).

EXAMPLE 4 Temperature might be sampled using an array of weather stations. The temperature field of the region covered by the array can be represented as a discrete point coverage, whose domain-elements correspond to the station locations.

An important case concerns monitoring a time-varying property of a persistent feature by sampling at discrete points in time. The observation result is a set of time-value pairs (either CV_PointValuePair, in which the point geometry uses a temporal reference system, or CVT_TimeInstantValuePair — C.3.2).

EXAMPLE 5 An air- or water-quality monitoring station observes properties such as ozone, turbidity, etc. The instantaneous value is a scalar concentration or index value. However, the value is time-dependent. The value can be expressed as a coverage whose domain is the period of interest. This is usually described as a time series, which is a discrete time coverage.

The feature-of-interest may be naturally structured into elements, such as a road network composed of road segments, or a state composed of administrative areas at a finer scale, or a farm composed of fields. Observation of a property of these features may capture its variation as a function of the sub-features. In these cases, the standard members of the target feature are responsible for decomposition of the domain geometry.

8.3.2 Taxonomy of coverage observation types

Observation types with variable results are shown in Figure 7.

For each specialized observation class whose result varies, the target of the association named ‘Range’ with the role-name ‘result’ shall be redefined as indicated in Figure 7 and Table 4.

Table 4 — Result types for specialized observations

Specialized observation class	Result type
OM_ DiscreteCoverageObservation	CV_DiscreteCoverage
OM_ DiscretePointCoverageObservation	CV_DiscretePointCoverage
OM_ DiscreteTimeSeriesObservation	CVT_DiscreteTimeInstantCoverage (C.3.1)

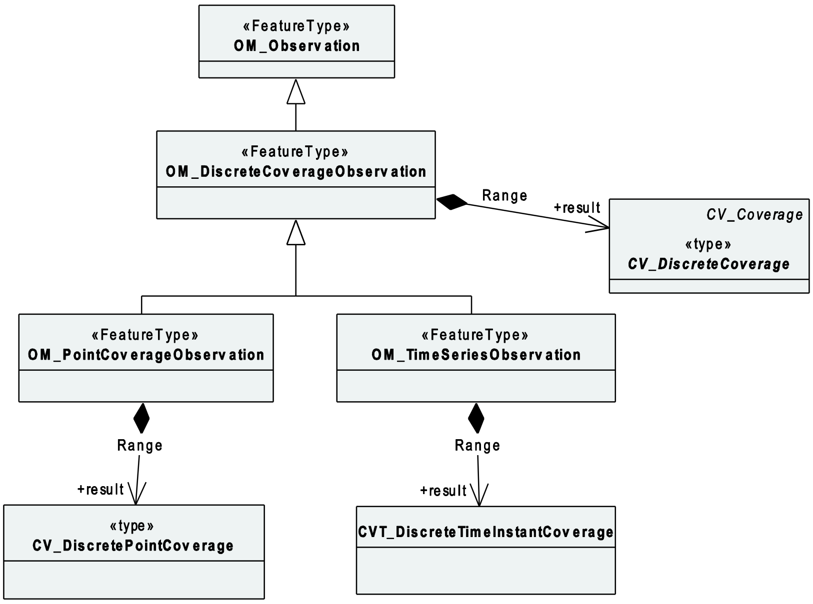

Figure 7 — Specialization of observations with coverage-valued results

9 Fundamental characteristics of sampling features

9.1 The context for sampling

9.1.1 Proximate vs. ultimate feature-of-interest

9.1.1.1 Introduction

The observation model maps the result of the application of a procedure to a subject, which plays the role of feature-of-interest of the observation (Clause 7). However, the proximate feature-of-interest of an observation may not be the ultimate domain-specific feature whose properties are of interest in the investigation of which the observation is a part. There are two circumstances that can lead to this:

a) the observation does not obtain values for the whole of a domain feature;

b) the observation procedure obtains values for properties that are not characteristic of the type of the ultimate feature.

Furthermore, in some practical situations, both differences apply.

9.1.1.2 Proximate feature-of-interest embodies a sample design

For various reasons, the domain feature may not be fully accessible. In such circumstances, the procedure for estimating the value of a property of the domain feature involves sampling in representative locations. Then the procedure for transforming a property value observed on the sample to an estimate of the property on the ultimate feature-of-interest depends on the sample design.

EXAMPLE 1 The chemistry of water in an underground aquifer is sampled at one or more positions in a well or bore.

EXAMPLE 2 The magnetic field of the earth is sampled at positions along a flight-line.

EXAMPLE 3 The structure of a rock mass is observed on a cross-section exposed in a river bank.

9.1.1.3 Observed property is a proxy

The procedure for obtaining values of the property of interest may be indirect, relying on direct observation of a more convenient parameter which is a proxy for the property of interest. Application of an algorithm or processing chain obtains an estimate of the ultimate property of interest.

The observation model requires that the feature-of-interest of the initial observation be of a type that carries the observed property within its properties. Thus, if the proxy property is not a member of the ultimate feature-of-interest, a proxy feature with a suitable model shall be involved.

EXAMPLE A remote sensing observation might obtain the reflectance colour, when the investigation is actually interested in vegetation type and quality. The feature which contains reflectance colour is a scene or swath, while the feature carrying vegetation properties is a parcel or tract.

9.1.1.4 Combination

These variations may be combined if exhaustive observation of the domain feature is impractical, and direct measurement is of a proxy property.

EXAMPLE For certain styles of mineralization, the gold concentration of rocks in a region might be estimated through measurement of a related element (e.g. copper), in a specimen of gravel collected from a stream that drains part of the region. The gravel samples the rocks in the catchment of the stream, i.e. in the stream bed and upslope.

9.1.2 Role of sampling features

Sampling features are artefacts of an observational strategy, and have no significant function outside of their role in the observation process. The physical characteristics of the features themselves are of little interest, except perhaps to the manager of a sampling campaign.

EXAMPLE A “station” is essentially an identifiable locality where a sensor system or procedure may be deployed and an observation made. In the context of the observation model, it connotes the “world in the vicinity of the station”, so the observed properties relate to the physical medium at the station, and not to any physical artefact such as a mooring, buoy, benchmark, monument, well, etc.

NOTE A transient sampling feature, such as a ships-track or flight-line, might be identified and described, but is unlikely to be revisited exactly.

A sampling feature is intended to sample some feature-of-interest in an application domain. However, in some cases the identity, and even the exact type, of the sampled feature may not be known when observations are made using the sampling features.

9.1.3 Classification of sampling features

A small number of sampling patterns are common across disciplines in observational science. These provide a basis for processing and portrayal tools which are similar across domains, and depend particularly on the geometry of the sample design. Common names for sampling features include specimen, station, profile, transect, path, swath and scene. Spatial sampling is classified primarily by the topological dimension. The generic characteristics of sampling features are defined in this clause; spatial samples of various dimensions are defined in Clause 10; and specimens in Clause 11.

9.2 Sampling Schema

9.2.1 Packaging

The sampling schema is organized in one package containing seven leaf packages corresponding to the conformance classes defined in 2.2, with dependencies on the observation schema (Clause 7), the general feature instance package (C.2), and on several other packages from International Standards covering geographic information. The inter-package dependencies are shown in Figure 8. The core sampling feature package is documented in this clause. The spatial sampling feature packages are documented in Clause 10 and the specimen package in Clause 11.

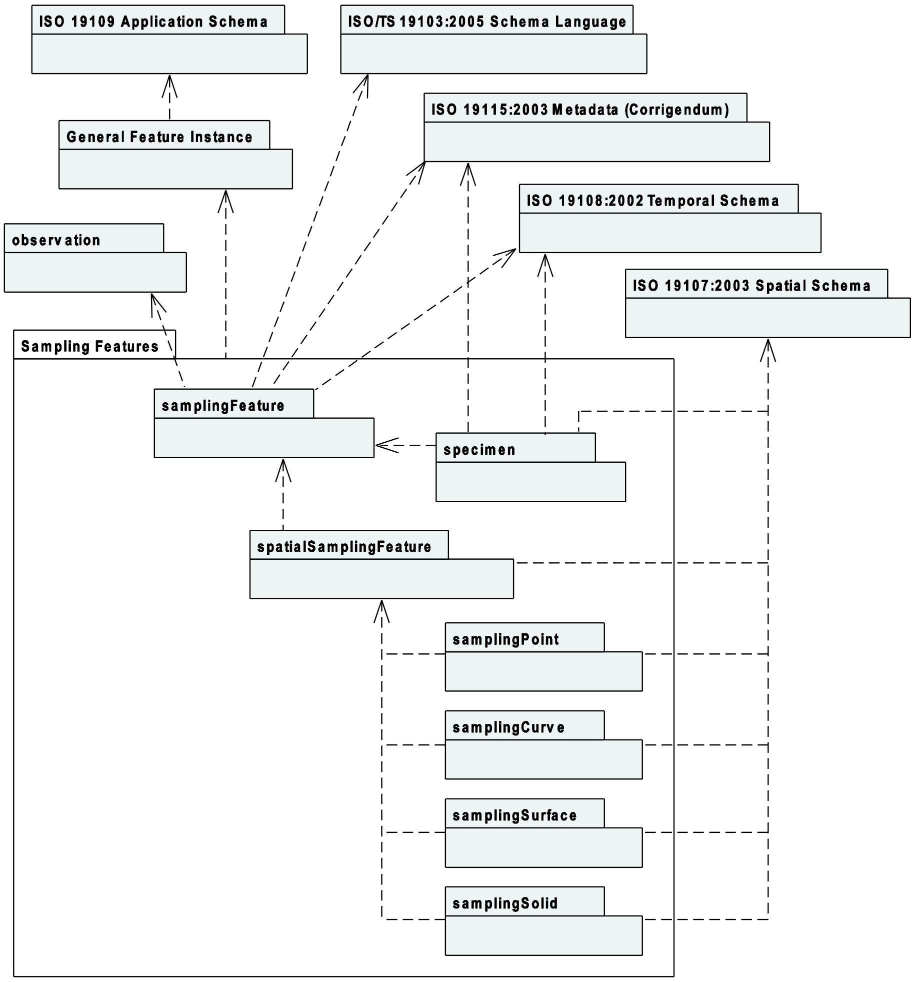

Figure 8 — Package dependencies of the sampling feature schema

9.2.2 SF_SamplingFeature

9.2.2.1 General

The abstract class *SF_SamplingFeature* (Figure 9) is an instance of the «metaclass» GF_FeatureType (ISO 19109), which therefore represents a feature type. SF_SamplingFeature shall support two attributes and three associations, and shall be subject to one constraint.

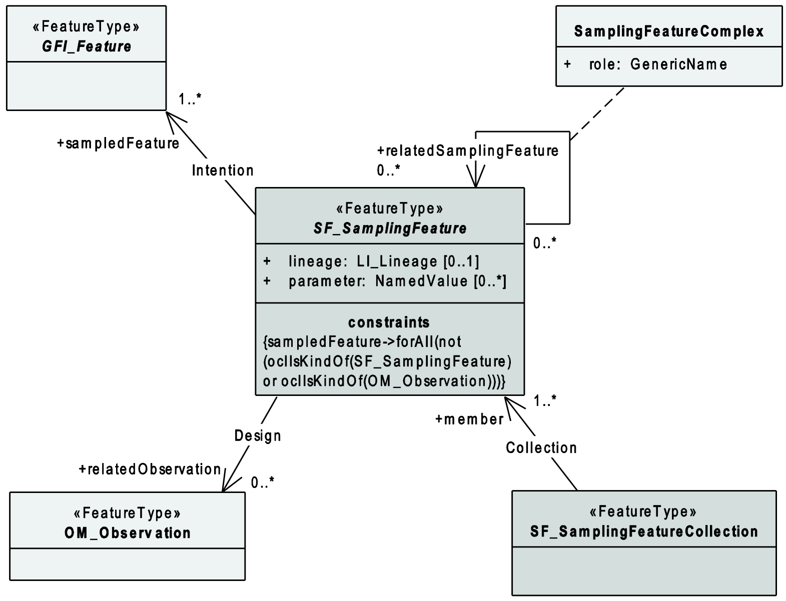

Figure 9 — Sampling feature core

9.2.2.2 parameter

If present, the attribute *parameter:NamedValue* shall describe an arbitrary parameter associated with the SF_SamplingFeature. This might be a parameter that qualifies the interaction with the sampled feature, or an environmental parameter associated with the sampling process.

9.2.2.3 lineage

If present, the attribute lineage:LI_Lineage shall describe the history and provenance of the SF_SamplingFeature. This might include information relating to the handling of the specimen, or details of the survey procedure of a spatial sampling feature.

9.2.2.4 Intention

A sampling feature is established in order to make observations concerning some domain feature. The association *Intention* shall link the SF_SamplingFeature to the feature which the sampling feature was designed to sample. The target of this association has the role *sampledFeature* with respect to the sampling feature, and shall not be a sampling feature or observation. It is usually a real-world feature from an application domain (Figures 5 and 10).

EXAMPLE A profile typically samples a water- or atmospheric-column; a well samples the water in an aquifer; a tissue specimen samples a part of an organism.

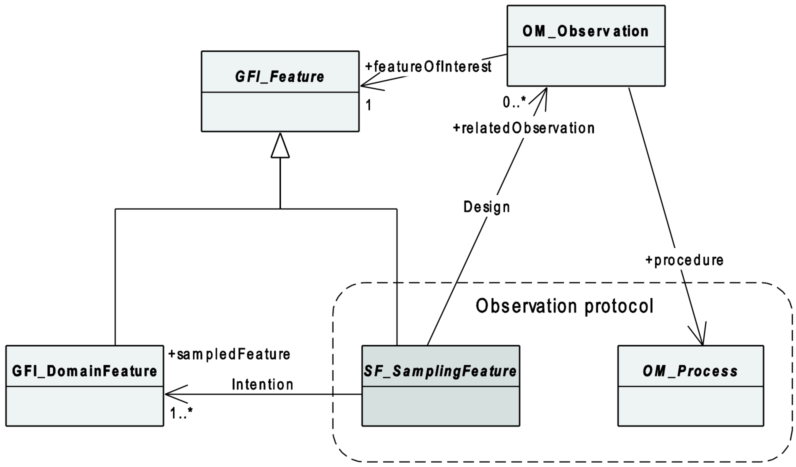

Figure 10 — (Informative) Relationship between sampling and domain features
(Each may appear as the feature-of-interest. If a sampling feature is involved, it samples a feature of a type defined in an application schema.)

NOTE 1 The sampling feature, together with the observation procedure, describes the observation protocol.

NOTE 2 GFI_DomainFeature is informative only. It stands for all feature types that are not observations or sampling features.

9.2.2.5 Design

Sampling features are distinctive compared with other features from application domains by having navigable associations to observations. If present, the association *Design* shall link the SF_SamplingFeature to an OM_Observation that was made utilizing the sampling feature, and the description of the sampling feature provides an intrinsic element of the observation protocol, along with the observation procedure (7.2.2) and the decomposition of the domain geometry in the case of a coverage-valued result (8.3). The OM_Observation has the role *relatedObservation* with respect to the sampling feature. Multiple observations may be made on a single sampling feature.

9.2.2.6 Constraint

A constraint on OM_Observation is that its observed property is a member property of the feature-of-interest either directly or transitively. Where the feature-of-interest of an observation is a sampling feature, the observed property shall be a member of the sampling feature or of the sampled feature.

Where the identity or type of the sampled feature is not known prior to processing the observation result, the constraint cannot be enforced immediately.

9.2.3 SamplingFeatureComplex

9.2.3.1 General

Sampling features are frequently related to each other, as parts of complexes, through sub-sampling, and in other ways. If present, the association class SamplingFeatureComplex (Figure 9) shall link an SF_SamplingFeature to another SF_SamplingFeature. It shall support one attribute.

EXAMPLE Sampling points are often located along a sampling curve; specimens are usually obtained from a sampling point; pixels are part of a scene; stations are often part of an array.

This association complements the Intention association which describes relationships between a sampling feature and domain features.

9.2.3.2 role

The attribute *role:GenericName* shall describe the relationship of the target SF_SamplingFeature to the source SF_SamplingFeature.

9.2.4 SF_SamplingFeatureCollection

9.2.4.1 General

The class *SF_SamplingFeatureCollection* (Figure 9) is an instance of the «metaclass» GF_FeatureType (ISO 19109), which therefore represents a feature type. SF_SamplingFeatureCollection shall support one association.

9.2.4.2 Collection

The association *Collection* shall link an SF_SamplingFeatureCollection to member SF_SamplingFeatures.

10 Spatial sampling features

10.1 The context for spatial sampling features

When observations are made to estimate properties of a geospatial feature, in particular where the value of a property varies within the scope of the feature, a spatial sampling feature is used. Depending on accessibility and on the nature of the expected property variation, the sampling feature may be extensive in one, two or three spatial dimensions. Processing and visualization methods are often dependent on the topological dimension of the sampling manifold, so this provides a natural classification system for sampling features.

This classification follows common practice in focussing on conventional spatial dimensions. Properties observed on sampling features may be time-dependent, but the temporal axis does not generally contribute to the classification of sampling feature classes. Sampling feature identity is usually less time-dependent than the property value.

10.2 Spatial sampling feature schema

10.2.1 SF_SpatialSamplingFeature

10.2.1.1 General

The class *SF_SpatialSamplingFeature* (Figure 11) is an instance of the «metaclass» GF_FeatureType (ISO 19109), which therefore represents a feature type. SF_SpatialSamplingFeature shall support one attribute and two associations.

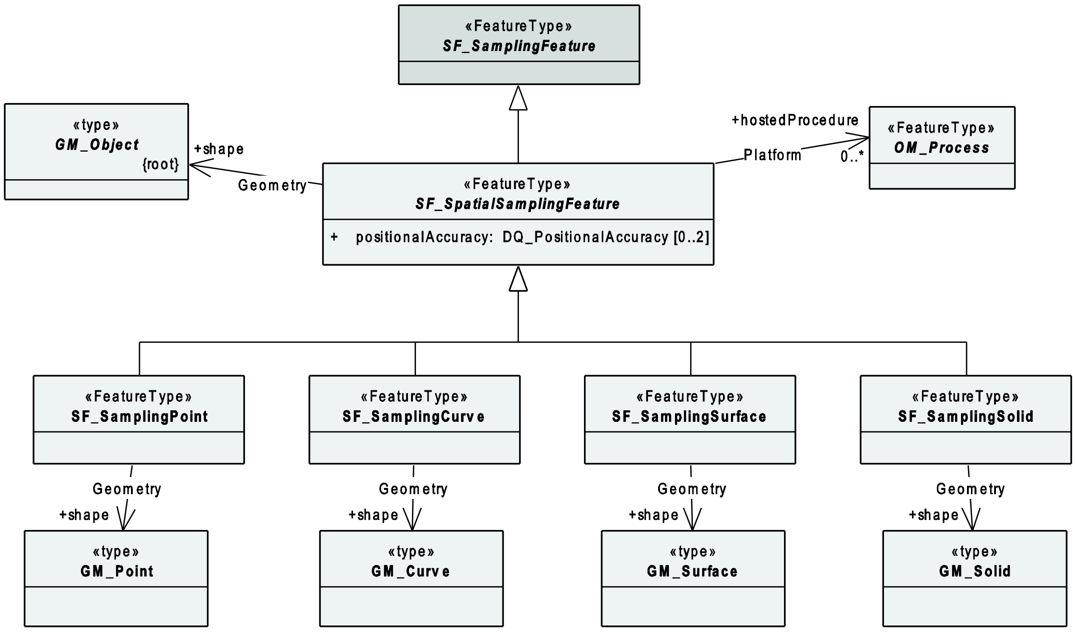

Figure 11 — Spatial sampling features

10.2.1.2 positionalAccuracy

Positioning metadata is commonly associated with sampling features defined in the context of field surveys. If present, *positionalAccuracy:DQ_PositionalAccuracy* shall describe the accuracy of the positioning of the sampling feature. Up to two instances of the attribute support the independent description of horizontal and vertical accuracy.

10.2.1.3 Geometry

The association *Geometry* shall link an SF_SpatialSamplingFeature to a GM_Object that describes its shape.

10.2.1.4 Platform

A common role for a spatial sampling feature is to host instruments or procedures deployed repetitively or permanently. If present, the association *Platform* shall link the SF_SpatialSamplingFeature to an OM_Process deployed at it. The OM_Process has the role *hostedProcedure* with respect to the sampling feature.

10.2.2 Taxonomy of spatial sampling features

Concrete spatial sampling feature classes shall be distinguished on the basis of the type of the shape property, as shown in Figure 11 and Table 5.

Table 5 — Shape types for specialized spatial sampling features

Specialized spatial sampling feature	Shape type
SF_SamplingPoint	GM_Point
SF_SamplingCurve	GM_Curve
SF_SamplingSurface	GM_Surface
SF_SamplingSolid	GM_Solid

The specialization of sampling features follows common practice in focussing on conventional spatial dimensions. Properties observed on sampling features may be time-dependent, but the temporal axis does not generally contribute to the classification of sampling feature classes. Sampling feature identity is usually less time-dependent than property value.

10.3 Decomposition of extensive sampling features for observations

The shape of a spatially extensive sampling feature (sampling-curve, -surface or -solid) defines a manifold within which a varying property may be characterized, and hence within which subsampling may be undertaken. The shape provides a complete sampling domain, but does not specify any particular decomposition. Sub-sampling may be described using related sampling features, or as domain elements (such as a segment in a 1-D curve; grid-cell, pixel or TIN triangle in 2-D; tetrahedron or block in 3-D) of a discrete coverage representation of the variation of a property within the sampling feature. The shape of the sampling feature is the context for domain decomposition. Where spatial sampling is involved, then both the sampling feature shape and its discretization as described in the domain of the coverage that comprises the observation result are required to describe the overall observation protocol.

EXAMPLE 1 Logs of different properties along a well or borehole might use different intervals, and sub-samples might be either spatially instantaneous, or averaged in some way over an interval. The position of the samples can be conveniently described in terms of offsets in a linear coordinate reference system that is defined by the shape of the well axis.

Time-dependent properties may be observed if a sampling feature is temporally persistent.

EXAMPLE 2 The temperature of the atmosphere at a weather station varies as a function of time.

Properties observed using a sampling feature may depend on non-spatiotemporal axes.

EXAMPLE 3 The density of a specimen varies as a function of temperature.

10.4 Common names for sampling features (informative)

Some common names for sampling features used in various application domains include Borehole, Flightline, Interval, Lidar Cloud, Map Horizon, Microscope Slide, Mine Level, Mine, Observation Well, Profile, Pulp, Quadrat, Scene, Section, ShipsTrack, Spot, Station, Swath, Trajectory, Traverse, etc. These are mapped to the standard sampling feature classes in Figure 12. Note that these mappings are informative, and may not match some applications.

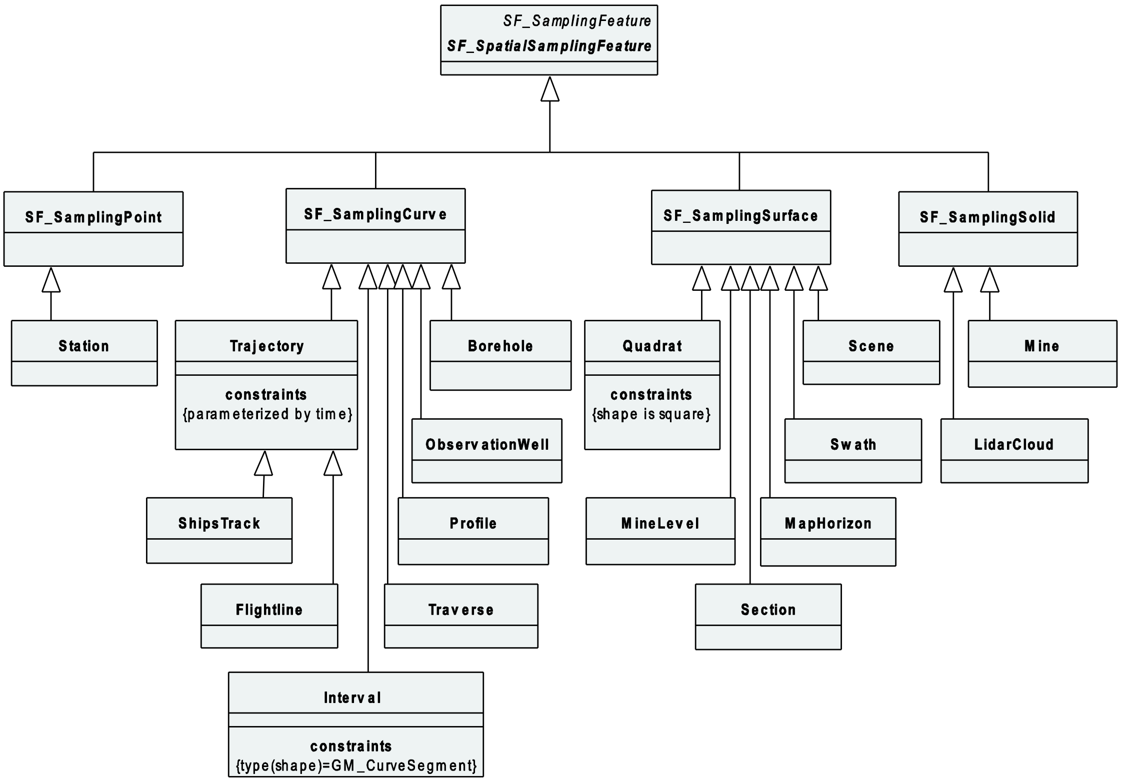

Figure 12 — (Informative) Common terms for spatially extensive sampling features (i.e. the classes whose names are unprefixed)

11 Specimens

11.1 The context for specimens

A Specimen is a physical sample, obtained for observation(s) normally carried out *ex-situ*, sometimes in a laboratory.

11.2 Specimen schema

11.2.1 SF_Specimen

11.2.1.1 General

The class *SF_Specimen* (Figure 13) is a specialized SF_SamplingFeature. The SF_Specimen shall support seven attributes and one association.

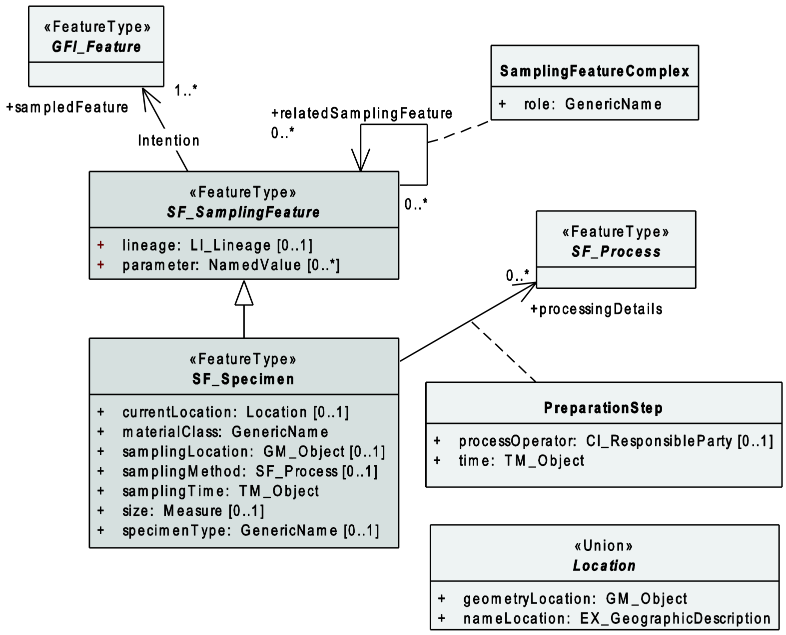

Figure 13 — Specimen model

11.2.1.2 materialClass

The attribute *materialClass:GenericName* shall provide a basic classification of the material type of the specimen.

EXAMPLE Soil, water, rock, aqueous, liquid, tissue, vegetation, food.

11.2.1.3 samplingTime

The attribute *samplingTime:TM_Object* shall record when the specimen was retrieved from the sampled feature.

11.2.1.4 samplingLocation

If present, the attribute *samplingLocation:GM_Object* shall describe the location from where the specimen was obtained.

NOTE Where a specimen has a relatedSamplingFeature whose location provides an unambiguous location then this attribute is not required. However, if the specific sampling location within the sampledFeature is important, then this attribute supports its description.

11.2.1.5 samplingMethod

If present, the attribute *samplingMethod:SF_Process* shall describe the method used to obtain the specimen from its sampledFeature.

11.2.1.6 currentLocation

If present, the attribute *currentLocation:Location* shall describe the location of a physical specimen. This may be a storage location, such as a shelf in a warehouse or a drawer in a museum.

NOTE If a specimen no longer exists, for example, it was destroyed in connection with an observation act, then the currentLocation should be omitted or carry a suitable null indicator.

11.2.1.7 specimenType

If present, the attribute *specimenType:GenericName* shall describe the basic form of the specimen.

EXAMPLE Polished section; core; pulp; solution.

11.2.1.8 size

If present, the attribute *size:Measure* shall describe a physical extent of the specimen. This may be length, mass, volume, etc., as appropriate for the specimen instance and its material class.

11.2.2 PreparationStep

11.2.2.1 General

In many applications, specimen preparation procedures are applied to the material prior to its use in an observation. The class *PreparationStep* (Figure 13) shall link an SF_Specimen to an SF_Process that describes a phase of the specimen preparation. It shall support two attributes.

11.2.2.2 time

The attribute *time:TM_Object* shall describe the time that the SF_Process was applied to the SF_Specimen. It supports ordering of preparation steps.

11.2.2.3 processOperator

If present, the attribute *processOperator:CI_ResponsibleParty* shall describe the operator of the process involved in the preparation step.

11.2.3 SF_Process

The class SF_Process (Figure 13) is an instance of the «metaclass» GF_FeatureType (ISO 19109), which therefore represents a feature type. The SF_Process is abstract, and has no attributes, operations or associations. It serves as the base class for processes associated with the design and preparation of sampling features. The purpose of a sampling process is to generate or transform a sampling feature.

11.2.4 Location

11.2.4.1 General

Location (Figure 13) is a union class (choice) that shall support two attributes.

11.2.4.2 geometryLocation

The attribute *geometryLocation:GM_Object* shall select a geometric representation of the location.

11.2.4.3 nameLocation

The attribute *nameLocation:EX_GeographicDescription* shall select a description of the location using text or an identifier.

Annex A
(normative)

Abstract Test Suite

A.1 Abstract tests for observation interchange

A.1.1 Observation interchange

The observation interchange test consists of the following:

a) Test Purpose: Verify that an interchange schema correctly implements the mandatory attributes, associations and constraints of OM_Observation.

b) Test Method: Inspect the documentation of the interchange schema.

c) Reference: ISO 19156, Clause 7.

d) Test Type: Capability.

A.1.2 Measurement interchange

The measurement interchange test consists of the following:

a) Test Purpose: Verify that an interchange schema correctly implements the mandatory attributes, associations and constraints of OM_Measurement.

b) Test Method: Inspect the documentation of the interchange schema.

c) Reference: ISO 19156, 8.2.2.

d) Test Type: Capability.

A.1.3 Category observation interchange

The category observation interchange test consists of the following:

a) Test Purpose: Verify that an interchange schema correctly implements the mandatory attributes, associations and constraints of OM_CategoryObservation.

b) Test Method: Inspect the documentation of the interchange schema.

c) Reference: ISO 19156, 8.2.2.

d) Test Type: Capability.

A.1.4 Count observation interchange

The count observation interchange test consists of the following:

a) Test Purpose: Verify that an interchange schema correctly implements the mandatory attributes, associations and constraints of OM_CountObservation.

b) Test Method: Inspect the documentation of the interchange schema.

c) Reference: ISO 19156, 8.2.2.

d) Test Type: Capability.

A.1.5 Truth observation interchange

The truth observation interchange test consists of the following:

a) Test Purpose: Verify that an interchange schema correctly implements the mandatory attributes, associations and constraints of OM_TruthObservation.

b) Test Method: Inspect the documentation of the interchange schema.

c) Reference: ISO 19156, 8.2.2.

d) Test Type: Capability.

A.1.6 Temporal observation interchange

The temporal observation interchange test consists of the following:

a) Test Purpose: Verify that an interchange schema correctly implements the mandatory attributes, associations and constraints of OM_TemporalObservation.

b) Test Method: Inspect the documentation of the interchange schema.

c) Reference: ISO 19156, 8.2.2.

d) Test Type: Capability.

A.1.7 Geometry observation interchange

The geometry observation interchange test consists of the following:

a) Test Purpose: Verify that an interchange schema correctly implements the mandatory attributes, associations and constraints of OM_GeometryObservation.

b) Test Method: Inspect the documentation of the interchange schema.

c) Reference: ISO 19156, 8.2.2.

d) Test Type: Capability.

A.1.8 Complex observation interchange

The complex observation interchange test consists of the following:

a) Test Purpose: Verify that an interchange schema correctly implements the mandatory attributes, associations and constraints of OM_ComplexObservation.

b) Test Method: Inspect the documentation of the interchange schema.

c) Reference: ISO 19156, 8.2.2.

d) Test Type: Capability.

A.1.9 Discrete coverage observation interchange

The discrete coverage observation interchange test consists of the following:

a) Test Purpose: Verify that an interchange schema correctly implements the mandatory attributes, associations and constraints of OM_DiscreteCoverageObservation.

b) Test Method: Inspect the documentation of the interchange schema.

c) Reference: ISO 19156, 8.3.2.

d) Test Type: Capability.

A.1.10 Point coverage observation interchange

The point coverage observation interchange test consists of the following:

a) Test Purpose: Verify that an interchange schema correctly implements the mandatory attributes, associations and constraints of OM_PointCoverageObservation.

b) Test Method: Inspect the documentation of the interchange schema.

c) Reference: ISO 19156, 8.3.2.

d) Test Type: Capability.

A.1.11 Time series observation interchange

The time series observation interchange test consists of the following:

a) Test Purpose: Verify that an interchange schema correctly implements the mandatory attributes, associations and constraints of OM_TimeSeriesObservation.

b) Test Method: Inspect the documentation of the interchange schema.

c) Reference: ISO 19156, 8.3.2.

d) Test Type: Capability.

A.2 Abstract tests for sampling feature interchange

A.2.1 Sampling feature interchange

The sampling feature interchange test consists of the following:

a) Test Purpose: Verify that an interchange schema correctly implements the mandatory attributes, associations and constraints of a concrete subclass of SF_SamplingFeature.

b) Test Method: Inspect the documentation of the interchange schema.

c) Reference: ISO 19156, Clauses 9, 10 and 11.

d) Test Type: Capability.

A.2.2 Sampling feature collection interchange

The sampling feature collection interchange test consists of the following:

a) Test Purpose: Verify that an interchange schema correctly implements the mandatory attributes, associations and constraints of SF_SamplingFeatureCollection.

b) Test Method: Inspect the documentation of the interchange schema.

c) Reference: ISO 19156, 9.2.4.

d) Test Type: Capability.

A.2.3 Spatial sampling feature interchange

The spatial sampling feature interchange test consists of the following:

a) Test Purpose: Verify that an interchange schema correctly implements the mandatory attributes, associations and constraints of a concrete subclass of SF_SpatialSamplingFeature.

b) Test Method: Inspect the documentation of the interchange schema.

c) Reference: ISO 19156, 10.2.

d) Test Type: Capability.

A.2.4 Sampling point interchange

The sampling point interchange test consists of the following:

a) Test Purpose: Verify that an interchange schema correctly implements the mandatory attributes, associations and constraints of SF_SamplingPoint.

b) Test Method: Inspect the documentation of the interchange schema.

c) Reference: ISO 19156, 10.2.2.

d) Test Type: Capability.

A.2.5 Sampling curve interchange

The sampling curve interchange test consists of the following:

a) Test Purpose: Verify that an interchange schema correctly implements the mandatory attributes, associations and constraints of SF_SamplingCurve.

b) Test Method: Inspect the documentation of the interchange schema.

c) Reference: ISO 19156, 10.2.2.

d) Test Type: Capability.

A.2.6 Sampling surface interchange

The sampling surface interchange test consists of the following:

a) Test Purpose: Verify that an interchange schema correctly implements the mandatory attributes, associations and constraints of SF_SamplingSurface.

b) Test Method: Inspect the documentation of the interchange schema.

c) Reference: ISO 19156, 10.2.2.

d) Test Type: Capability.

A.2.7 Sampling solid interchange

The sampling solid interchange test consists of the following:

a) Test Purpose: Verify that an interchange schema correctly implements the mandatory attributes, associations and constraints of SF_SamplingSolid.

b) Test Method: Inspect the documentation of the interchange schema.

c) Reference: ISO 19156, 10.2.2.

d) Test Type: Capability.

A.2.8 Specimen interchange

The specimen interchange test consists of the following:

a) Test Purpose: Verify that an interchange schema correctly implements the mandatory attributes, associations and constraints of SF_Specimen.

b) Test Method: Inspect the documentation of the interchange schema.

c) Reference: ISO 19156, 11.2.

d) Test Type: Capability.

Annex B
(informative)

Mapping O&M terminology to common usage

B.1 Introduction

This International Standard defines terminology in support of a generic, cross-domain model for observations and measurements. Terms are taken from a variety of disciplines. The terms are used within the model in a consistent manner, but in order to achieve internal consistency, this varies from how the same terms are used in some application domains. In order to assist in the correct application of the model across domains, this annex provides a mapping from observations and measurements (O&M) terminology to some domain vocabularies.

B.2 Mappings

B.2.1 Earth observations

Table B.1 — Earth Observations (EO)

O&M	EO	Example
Observation::result	Observation value, measurement value, observation	35 µg/m^3
Observation::procedure	Method, sensor	ASTER, U.S. EPA Federal Reference Method for PM $_{2.5}$
Observation::observedProperty	Parameter, variable	Reflectance, Particulate Matter 2.5
Observation::featureOfInterest:SamplingSurface	2-D swath or scene	Sampling grid
SamplingSurface:sampledFeature	Earth surface	—
Observation::featureOfInterest:SamplingSolid	3-D sampling space	Sampling grid
SamplingSolid::sampledFeature	Media (air, water, …), Global Change Master Directory "Topic"	Troposphere

B.2.2 Metrology

Table B.2 — Metrology

O&M	Metrology	Example: mass measurement
Observation::result	Value	35 mg
Observation::procedure	Instrument	Balance
Observation::observedProperty	Measurand	Mass

B.2.3 Earth science simulations

Table B.3 — Earth science simulations

O&M	Earth science
Observation::result	A model or field
Observation::observedProperty	Variable, parameter
Observation::featureofInterest:SamplingFeature	Section, swath, volume, grid
Observation::featureofInterest:SamplingFeature::sampledFeature (i.e. the ultimate or ‘domain’ feature-of-interest)	Atmosphere, ocean, solid earth
Observation::procedure	Earth process simulator
Observation::phenomenonTime	Future date (forecasts), past date (hindcasts)
Observation::resultTime	Simulator execution date
Observation::validTime	Period when result is intended to be used

B.2.4 Assay/Chemistry

Table B.4 — Assay/Chemistry

O&M	Geochemistry
Observation::featureOfInterest:Specimen	Sample
Specimen::sampledFeature:GeologicUnit	Ore body, Geologic Unit
Specimen::relatedSamplingFeature:Specimen	Pulp, separation
Specimen::materialClass	Whole-rock, mineral
Specimen::processingDetails	Sample preparation process
Specimen::samplingMethod	Sample collection process
Specimen::samplingLocation	Sample collection location
Specimen::size	Mass, length
Specimen::currentLocation	Store location
Specimen::samplingTime	Sample collection date
Observation::phenomenonTime	Sample collection date
Observation::resultTime	Analysis date
Observation::result	Analysis
Observation::observedProperty	Analyte
Observation::procedure	Instrument, analytical process

B.2.5 Field observations in geology

Table B.5 — Geology field observations

O&M	Geology
Observation::featureOfInterest:SamplingFeatureCollection	Outcrop
SamplingFeatureCollection::relatedSamplingFeature:SamplingPoint	Location of structure observation
SamplingPoint::sampledFeature:GeologicUnit	Geologic Unit
Observation::phenomenonTime	Outcrop visit date
Observation::observedProperty	Strike and dip, lithology, alteration state, etc.
SamplingFeatureCollection::relatedSamplingFeature:Specimen	Rock sample
Specimen::sampledFeature:GeologicUnit	Ore body, Geologic Unit

Annex C
(normative)

Utility classes

C.1 Introduction

The Observations and Measurements schema has dependencies on classes and packages from a number of other International Standards covering geographic information, as indicated in Figures 1 and 8. A small number of classes are required which are not provided by existing external standards, but which are also not purely within the scope of this International Standard. This annex describes those classes.

C.2 Extension to General Feature Model

C.2.1 GFI_Feature

The class *GFI_Feature* (Figure C.1) is an instance of the «metaclass» GF_FeatureType (ISO 19109). It represents the set of all feature instances.

NOTE GFI_Feature is implemented in GML (ISO 19136) by the element gml:AbstractFeature and type gml:AbstractFeatureType.

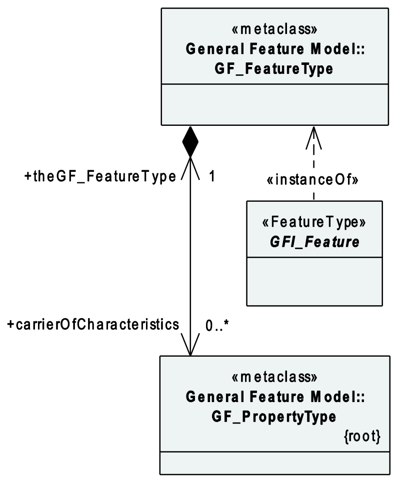

Figure C.1 — Feature Instance model

In an implementation, this abstract class shall be substituted by a concrete class representing a feature type from an application schema associated with a domain of discourse in accordance with ISO 19109:2005 and ISO 19101:2002. Sampling Features (Clause 9) are a class of feature types whose role is primarily associated with observations.

C.3 Extensions to Coverage schema

C.3.1 CVT_DiscreteTimeInstantCoverage

C.3.1.1 General

The class *CVT_DiscreteTimeInstantCoverage* (Figure C.2) is a specialization of CV_DiscreteCoverage as specified in ISO 19123. CVT_DiscreteTimeInstantCoverage shall support one association.

C.3.1.2 CoverageFunction

The association *CoverageFunction* shall link the CVT_DiscreteTimeInstantCoverage to an ordered set of CVT_TimeInstantValuePairs that are the elements of the time series.

C.3.2 CVT_TimeInstantValuePair

C.3.2.1 General

The class *CVT_TimeInstantValuePair* (Figure C.2) is a specialization of CV_GeometryValuePair (ISO 19123:2005). CVT_TimeInstantValuePair shall redefine one attribute inherited from CV_GeometryValuePair.

C.3.2.2 geometry

The attribute geometry:TM_Instant shall redefine the type of the geometry attribute inherited from CV_GeometryValuePair.

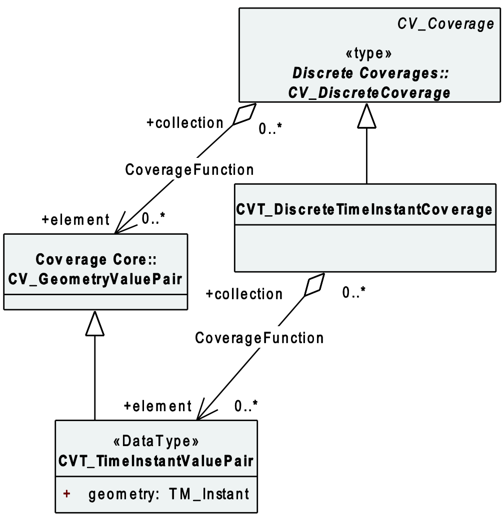

Figure C.2 — Specialized coverage type for time-series

Annex D
(informative)

Best practices in use of the observation and sampling models

D.1 Features, coverages and observations — Different views of information

ISO 19109 describes the *feature* as a “fundamental unit of geographic information”. The “General Feature Model” (GFM) presented in ISO 19101 and ISO 19109 defines a feature type in terms of its characteristic set of properties, including attributes, association roles, and behaviours, as well as generalization and specialization relationships, and constraints.

Typical concrete feature types have names like “road”, “watercourse”, “mine”, “atmosphere”, etc. For a road, the set of properties might include its name, its classification, the curve describing its centreline, the number of lanes, the surface material, etc. The complete description of a road instance, therefore, is the set of values for the set of properties that define a road type. This use of the feature model is object-centric, and supports a viewpoint of the world in terms of the set of discrete identifiable objects that occupy it.

The principal alternative model for geographic information is the coverage, described in ISO 19123. This viewpoint focuses on the variation of a property within the (spatiotemporal) domain of interest. The domain might be a scene, a grid, a transportation network, a volume, a set of sampling stations, etc. The range of the coverage can be any property, such as reflectance, material type, concentration of some pollutant, number of lanes, etc. But the key to the coverage viewpoint is that it is property-centric, concerning the distribution of the values of a property within its domain space.

These viewpoints are not exclusive, and both are used in analysis and modelling. For example, a feature might be detected from the analysis of variation of a property in a region of interest (e.g. an ore-body from a distribution of assay values). Also, for some feature types, the value of one or more properties might vary across the feature, in which case the shape of the feature provides the coverage domain (e.g. ore-grade within a mine).

Observations focus on the data collection event. An act of Observation serves to assign a value to a property of a feature. If the property is non-constant, the value is a function or coverage. The results of a set of observations of different properties on the same feature-of-interest can provide a complete description of the feature instance. Alternatively, the results of a set of observations of the same property on a set of different features provide a discrete coverage of that property over a domain composed of the geometry of the feature set. The other properties of the Observation are metadata concerning the estimation of the value(s) of a property on a feature-of-interest.

In particular, Observations concern properties (e.g. shape, colour) whose values are determined using an identifiable procedure, in which there is a finite uncertainty in the result. This can be contrasted with properties whose values are specified by assertion (e.g. name, owner) and are therefore exact. The observation instance provides “metadata” for the property value-estimation process.

An observation event is clearly a “feature” in its own right, according to the GFM definition. An observation instance is a useful unit of information, therefore observation is a feature type.

Transformation between viewpoints is frequently required. Some of the observation specializations provide an explicit demonstration of the transformation.

This is illustrated in Figure D.1, which schematically shows a dataset comprising values of a set of properties at a set of locations. A row of the table provides the complete description of the properties at a single location. This is a representation of a potential feature description. A column of the table describes the variation of a single property across the set of locations. This is a representation of a discrete coverage. A single cell in the table provides the value of a single property on a single feature. This might be the result of an observation.

Observations, Coverage and Feature representations might be associated with different phases of the data-processing cycle or value-chain:

— The observation view is associated with data collection, when an observation event causes values for a property of a feature to be determined, and during data entry when the data-store is updated by inserting values into fields in the datastore.

— A coverage view can be assembled from results of observations of a specific property, and represents data assembled for analysis, when the objective is to find signals in the variation of a property over a domain.

— A discrete feature description is a “summary” viewpoint, assembled from results of observation on the same target, or an “inferred” viewpoint, by extraction of a signal from a coverage.

	Location	Properties			
		Property 1	Property 2	...	Property m
	(x_1, y_2)	$Value_1^1$	$Value_1^2$	...	$Value_1^m$
	(x_2, y_2)	$Value_2^1$	$Value_2^2$	...	$Value_2^m$
Feature 3	(x_3, y_3)	$Value_3^1$	$Value_3^2$	...	$Value_3^m$
	(x_n, y_n)	$Value_n^1$	$Value_n^2$	...	$Value_n^m$
			Coverage 2		

Figure D.1 — Tabular representation of information associated with a set of locations

D.2 Observation concerns

D.2.1 Domain specialization

Specialization of the observation model for an application domain is accomplished primarily using a domain application schema and its feature-type catalogue. For example, an instance of a feature type in the domain feature-type catalogue will provide the ultimate feature-of-interest for the investigation of which the observation is a part, and the characteristic properties of the feature type provide potential observed properties. A description of a sensor or process familiar within the application domain is the value of the observation procedure.

The observation model encourages encapsulation of domain specialization in the associated classes, and the observation class itself rarely needs specialization.

Nevertheless, other choices could be made in partitioning information between the classes in the model. For some applications, it might be convenient for information that is strictly associated with a second-layer object (procedure, feature-of-interest) to be associated with a specialized observation type.

For example, when measuring chemistry or contamination, the process often involves retrieving *specimens* from a sampling station, which are then sent to a laboratory for analysis. The specimen is a very tangible feature instance, with an identity. For some applications, it might be important to recognize the existence of the specimen, and retain a separate description of it. However, in other applications, particularly when the focus is on monitoring the change in a property at a sampling station, the existence of a series of distinct specimens is of minor or no interest. In this case, creating a series of objects and identifiers is superfluous to the user's requirements.

Nevertheless, some properties that might be strictly associated with such a specimen must still be recorded, such as "sampling elevation" in a water or atmospheric column. A number of choices can be made. For example, the elevation could be

a) a property of each distinct specimen on which atomic observations are actually made,

b) a property of the sampling station (which would require distinct stations for all elevations at which observations are made),

c) a parameter of the observation procedure (which makes the procedure specific to this observation series only), or

d) a parameter of the observation event, either using the soft-typed procedureParameter, or through specialization of the observation type.

Any of these is a legitimate approach. The optimum one will be dependent on the application.

All of the classes in the models presented here for observations and procedures can be further specialized for domain-specific purposes. Additional attributes and associations can be added as necessary.

EXAMPLE "Assay" might be derived from Measurement, fixing the observedProperty to be "ChemicalConcentration" and adding an additional attribute "analyte".

D.2.2 Comparison with provider-oriented models

The O&M model is intended to provide a basic output- or user-oriented information model for sensor web and related applications. The goal is to provide a common language for discourse regarding sensor and observation systems.

In comparison, SensorML [16] has a process- or provider-oriented data model. These are usually used to describe data at an early stage in the data processing and value-adding chain. This might be prior to the details of the feature-of-interest and observed property being assembled and assigned to the result in a way that carries the key semantics to end-users of observation data. In particular, part of a SensorML datastream might include information that must be processed to determine the position of the target or feature-of-interest. At the early processing stage such positional and timing information might be embedded within the result.

Nevertheless, even within these low-level models the O&M formalization can be applied. The proximate feature-of-interest is the vicinity of the sensor. The observed property is a composite type including components representing observation timing, and position and attitude of a sensor, etc. This must be processed to obtain the details of the ultimate feature-of-interest. The procedure is a sensor package including elements that capture all of the elements of the composite phenomenon or property type, etc.

D.2.3 Observation discovery and use

The Observation and Measurements model presented here offers a user-oriented viewpoint. The information object is characterized by a small set of properties, which are likely to be of interest to a user for discovery and request of observation data. The user will typically be interested primarily in a feature-of-interest, or the variation of a phenomenon. The model provides these items as first-order elements. An interface to observation information should expose these properties explicitly.

SOS [17] leverages the O&M model directly, with *featureOfInterest* and *observedProperty* being (1) explicit classifiers for an observationOffering in the capabilities description, used for discovery, and (2) explicit parameters in the GetObservation request. From a user point of view, the sensor or procedure description is primarily *metadata*, which is only of interest to specialists during discovery, and then to assist evaluation or processing of individual results.

Each of these associated objects (sensor or procedure, target feature, phenomenon) might require a complex description. Hence they are modelled as distinct classes, which can be as simple or complex as necessary. In the XML serialized representation following the GML pattern, they might appear inline, perhaps described using one of the models presented here, or they can be indicated by reference using a URI [4]. The URI identifier might be a URL link or service call, which should resolve immediately to yield a complete resource. Or it might be a canonical identifier, such as a URN, which the user and provider are preconfigured to recognize and understand.

On the other hand, SensorML takes a process- or provider-oriented viewpoint. Discovery and request is based primarily on the user having knowledge of specific sensor systems and their application. While this is a reasonable assumption within technical communities, specialist knowledge of sensor systems would not be routinely available within a broader set of potential users of sensor data, particularly as this is made widely available through interfaces like SOS.

D.2.4 Observations vs. Interpretations

Some conceptual frameworks make a fundamental distinction between *observations* and *interpretations* as the basis for their information modelling approach. This supports a pattern in which observations are given precedence and archived, while interpretations are more transient, being the result of applying the current algorithms and paradigms to the currently available observations.

An alternative view is that the distinction is not absolute, but is one of degree. Even the most trivial "observations" are mediated by some theory or procedure. For example, the primary measurement when using a mercury-in-glass thermometer is the position of the meniscus relative to graduations. This allows the length of the column to be estimated. A theory of thermal expansion plus a calibration for the physical realization of the instrument allows conversion to an inferred temperature. Other observations and measurements all involve some kind of processing from the primary observable. For modern instruments, the primary observable is almost always voltage or resistance or frequency from some kind of sensing element, so the "procedure" typically involves calibrations, etc., built on a theory of operation for the sensor. However, the same high-level information model — that every "value" is an estimate of the value of a property, generated using a procedure and inputs — applies to both "observations" and "interpretations". It is just that the higher the semantic value of the estimate, the more theory and processing is involved.

In some cases, it might be useful to explicitly describe the processing chain instance that has taken a more primitive observation (e.g. an image) and retrieved a higher level observation (e.g. the presence of a certain type of feature instance) through the application of one or more processing steps.

D.3 Sampling concerns

D.3.1 Sampling feature acts as observation-collector

The sampling feature model satisfies the requirements described in 9.1. Sampling features provide

a) an intermediate feature type that allows the assignment of primitive and intermediate properties within a processing chain, and

b) a context for the description of sampling regimes.

In addition, sampling features provide a feature type for observation collections, which have the homogeneity constraint that they share a common feature-of-interest. This provides an access route to observation information that is convenient under some project scenarios, where the sampling strategy provides the logical organization of observations.

EXAMPLE An observational mission or campaign might organize its data according to flightlines, ship's tracks, outcrops, sampling-stations, quadrats, etc., or an observation archive or museum might organize observations by specimen.

D.3.2 Observation feature-of-interest

Application of the Observations and Measurements model requires careful attention to identify the feature-of-interest correctly. This can be straightforward if the observation is clearly concerned with an easily identified concrete feature type from a domain model. However, the ultimate feature-of-interest to the investigator might not be the proximate feature-of-interest for the observation. In some cases, a careful analysis reveals that the type of the feature-of-interest had not previously been identified in the application domain.

The key is that the proximate feature-of-interest must be capable of carrying this result as the value or component of the value of a relevant property. So a useful approach in analysis is to consider what the *result* of the observation is, and then the feature-of-interest can be deduced since it must have a property with this result as its value. If an observation produces a result with several elements, or if there are a series of related observations with different results, then this might help further refine the understanding the type of the true feature-of-interest.

EXAMPLE In monitoring situations, the feature-of-interest is often a typed event or “occurrence”. The observation procedure(s) provides an estimate of time, location, and type (e.g. species, identity) of the party involved.

D.3.3 Processing chains and intermediate features-of-interest

The Observation model implies a direct relationship between the observed property and the type of the feature-of-interest (e.g. a specimen type has a property ‘mass’ and observation observed property is ‘mass’). However, as discussed in 9.1.1.2 the relationship between the observed property and property(ies) of the ultimate feature-of-interest is often more complex.

The Sampling Feature model is a mechanism for preserving the strict association, by providing a specific intermediate feature type whose observable properties are unspecified in advance, but supplied through an unlimited set of related observations. The path from a sensed property obtained through observations related to the sampling feature, to the interesting property on the ultimate feature-of-interest, is modelled as a processing chain.

If intermediate values are explicit, then the processing chain can be modelled as a sequence of “observations”, with intermediate features of interest carrying intermediate property types. Each intermediate value must apply to a feature-of-interest that bears this property, or a sampling feature. Note that the types of these features might not be conventional or immediately recognisable, but the coherence of the Observations and Measurements model does imply their existence. Hence, if any intermediate result is made explicit, then a suitable intermediate feature must also be identified.

D.3.4 Consistency constraints for sampling coverage observations

An important class of observations are those made by sampling a property of a temporally persistent extensive feature, where the observation result is a discrete coverage over the sampling domain. Special cases include the OM_DiscreteCoverageObservation subclasses, but more generally the sampling geometry might be a compound structure in time and space.

EXAMPLE 1 Physical oceanographers deploy expendable bathythermographs to measure seawater temperature as a discrete coverage along the sampling curve traced by the instrument’s descent (regarded as instantaneous with respect to ocean dynamics).

EXAMPLE 2 Meteorologists use radar wind profilers to measure wind speed and direction as time-series of discrete coverages at fixed heights on a sampling curve extending vertically from the Earth's surface.

EXAMPLE 3 Mobile sensors are used experimentally for monitoring urban air quality, by measuring concentration of ambient pollutants as a coverage over the sensor's spatiotemporal trajectory along a sampling curve.

In many of these applications, there are consistency constraints that relate to the observation, a sampling feature and a coverage result (Figure D.2), which could be expressed formally (at least in part) as OCL constraints [13] on a specialized Observation class called 'SamplingCoverageObservation':

— the feature-of-interest of the sampling coverage observation is a sampling feature:

  — self.oclIsKindOf(SamplingCoverageObservation) and featureOfInterest.oclIsKindOf(SF_SpatialSamplingFeature)

— the observed property shall be consistent with the range type of the coverage result:

  — observedProperty.memberName = result.rangeType.name

— the shape of the sampling feature-of-interest shall contain the spatial elements of the domain of the coverage result:

  — result.domainElement >forAll(d : CV_DomainObject | featureOfInterest.shape::contains(d.spatialElement))

— the phenomenon time of the observation shall correspond to the temporal extent of the domain of the coverage result:

  — result.domainElement->forAll(d : CV_DomainObject | phenomenonTime::relativePosition(d.temporalElement) = TM_RelativePosition.Contains)

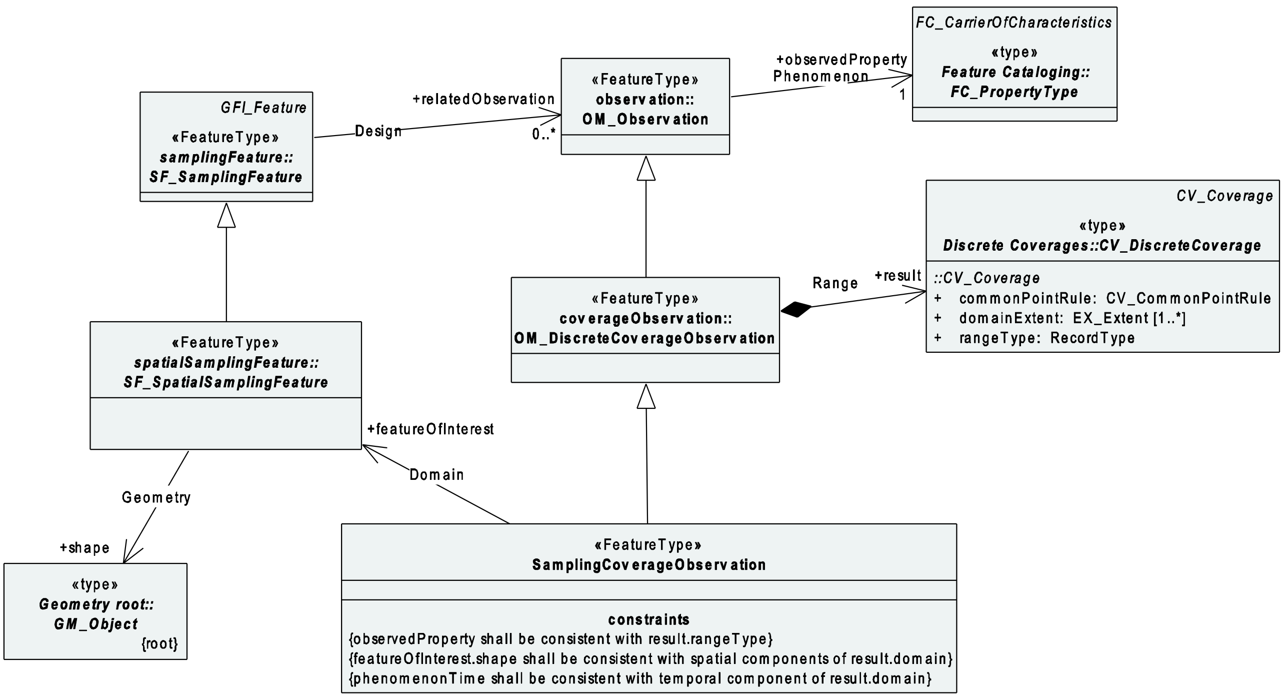

Figure D.2 — Consistency constraints for sampling coverage observations

NOTE Many such observation results can be accommodated by using appropriate application of a CV_DiscreteGridPointCoverage result, as shown in Table D.1.

Table D.1 — Examples of coverage results for different sampling regimes

Observation class	Example	Spatial sampling feature	Coverage result
Profile	Expendable bathythermograph observation of seawater temperature	SF_SamplingCurve	— one-dimensional grid at fixed (x,y,t) within four-dimensional (x-y-z-t) CRS — grid axis aligned with CRS z-axis
ProfileTimeSeries	Radar wind profiler measurement	SF_SamplingCurve	— two-dimensional grid at fixed (x,y) within four-dimensional (x,y,z,t) CRS — grid axes aligned with CRS z- and t-axes
Trajectory	Pollutant concentration from mobile air quality sensor	SF_SamplingCurve	— one-dimensional grid within four-dimensional (x-y-z-t) CRS
Section	Vertical profiles of water current measurements taken by an acoustic doppler current profiler towed along a ship’s track	SF_SamplingSurface	— two-dimensional grid within four-dimensional (x-y-z-t) CRS — one grid axis aligned with CRS z-axis
GridTimeSeries	Time-series of 3-D velocity field from a finite-difference seismic model	SF_SamplingSolid	— four-dimensional grid within four-dimensional (x-y-z-t) CRS

Bibliography

[1] CHRISMAN, N.R. *Exploring Geographical Information Systems*, 2nd Edition. Wiley. 2001

[2] FOWLER, M. *Analysis Patterns: reusable object models*. Addison Wesley Longman, Menlo Park, CA. 1998

[3] *GML Encoding of Discrete Coverages (interleaved pattern),* OpenGIS® Best Practice OGC document 06-188r1

[4] IETF RFC 2396, *Uniform Resource Identifiers (URI): Generic Syntax.* August 1998

[5] *International Vocabulary of Basic and General Terms in Metrology*. BIPM/ISO 1993

[6] ISO/TS 19101-2, 2008, *Geographic information — Reference model — Part 2: Imagery*

[7] ISO 19115-2:2009, *Geographic information — Metadata — Part 2: Extensions for imagery and gridded data*

[8] ISO/TS 19138:2006, *Geographic information — Data quality measures*

[9] ISO 19143:2010, *Geographic information — Filter encoding*

[10] KRANTZ, D.H., LUCE, R.D., SUPPES, P., TVERSKY, A. (1971), *Foundations of measurement, Vol. I: Additive and polynomial representations*, New York: Academic Press

[11] LUCE, R.D., KRANTZ, D.H., SUPPES, P., TVERSKY, A. (1990), *Foundations of measurement, Vol. III: Representation, axiomatization, and invariance*, New York: Academic Press

[12] NIEVA, T. *Remote data acquisition of embedded systems using internet technologies: a role-based generic system specification.* Thesis, Ecole Polytech. Fed. Lausanne 2001. Available (viewed 2011-10-14) at http://infoscience.epfl.ch/record/313/files/Nieva01.pdf

[13] *Object Constraint Language (OCL) v2.0*. OMG Available Specification formal/06-05-01. Object Management Group, Needham, Mass. USA

[14] SARLE, W.S., *Measurement theory: frequently asked questions*. Originally published in the Disseminations of the International Statistical Applications Institute, 4th edition, 1995, Wichita: ACG Press, pp. 61-66. Revised 1996, 1997. Available (viewed 2011-10-14) at ftp://ftp.sas.com/pub/neural/measurement.html

[15] SCHADOW, G., MCDONALD, C.J. (eds.), *UCUM, Unified Code for Units of Measure*. Available (viewed 2011-10-14) at http://aurora.rg.iupui.edu/UCUM

[16] *Sensor Model Language (SensorML)*, OpenGIS® Implementation Standard, OGC 07-000. Available (viewed 2011-10-14) at http://www.opengeospatial.org/standards/sensorml

[17] *Sensor Observation Service*, OpenGIS® Implementation Specification OGC document 06-009

[18] STEVENS, S.S. On the theory of scales of measurements. *Science* 1946, **103**, pp. 677-680

[19] SUPPES, P., KRANTZ, D.H., LUCE, R.D., TVERSKY, A. (1989), *Foundations of measurement, Vol. II: Geometrical, threshold, and probabilistic representations*, New York: Academic Press

[20] *SWE Common Data Model Implementation Standard,* OpenGIS® Implementation Standard OGC document 08-094r1

[21] *SWE Common Data Model*, OpenGIS® Implementation Standard. OGC document 08-094r1

[22] YODER, J.W., BALAGUER, F., JOHNSON, R. *From analysis to design of the observation pattern*. Available (viewed 2011-10-14) at citeseerx.ist.psu.edu

