INTERNATIONAL STANDARD

ISO 19116

First edition
2004-07-01

Geographic information — Positioning services

Information géographique — Services de positionnement

Reference number
ISO 19116:2004(E)

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

Contents

Page

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 19116 was prepared by Technical Committee ISO/TC 211, *Geographic information/Geomatics*.

Introduction

0.1 General

Positioning services are among the processing services identified in ISO 19119. Processing services include services that are computationally oriented and operate upon the elements from the model domain, rather than being directly integrated in the model domain itself. This International Standard defines and describes the positioning service. Other services in this domain are coordinate transformation, metric translation, format conversion, semantic translation, etc.

Positioning services employ a wide variety of technologies that provide position and related information to a similarly wide variety of applications, as depicted in Figure 1. Although these technologies differ in many respects, there are important items of information that are common among them and serve common needs of these application areas, such as the position data, time of observation and its accuracy. Also, there are items of information that apply only to specific technologies and are sometimes required in order to make correct use of the positioning results, such as signal strength, geometry factors, and raw measurements. Therefore, this International Standard includes both general data elements that are applicable to a wide variety of positioning services and technology specific elements that are relevant to particular technologies.

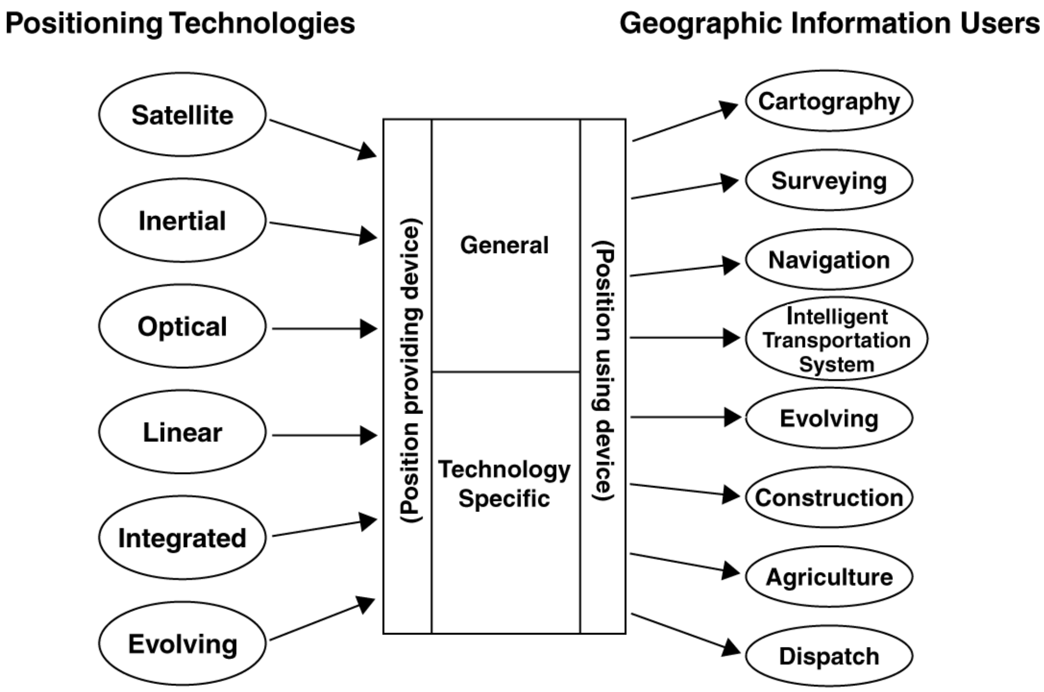

Figure 1 — Positioning services interface allows communication of position data for a wide variety of positioning technologies and users

Modern electronic positioning technology can measure the coordinates of a location on or near the Earth with great speed and accuracy, thereby allowing geographic information systems to be populated with any number of objects. However, the technologies for position determination have had neither a common structure for expression of position information, nor a common structure for expression of accuracy. The positioning-services interface specified in this International Standard provides data structures and operations that allow spatially oriented systems, such as GIS, to employ these technologies with greater efficiency by permitting interoperability among various implementations and various technologies.

This interface may be applied to communication among any of the components of systems that generate and use position information. Such systems may incorporate an instrument providing position updates to one or more position-using devices for data processing, storage, and display. For example, a navigation display system may include recording functions that store the history of a vehicle's movement, processing tools that compute guidance updates along a planned course relying on stored waypoints, and a display device that provides the navigator with current position, computed guidance information, and cartography from stored coordinate information. This International Standard specifies an interface that carries position and related information among any of these components, and should be sufficient for communication between the position providing device and any connected position using devices. Additional interfaces may also exist in such a system, for example providing for cartographic portrayal of stored coordinate information, which are outside the scope of this International Standard.

Standard positioning services provide client systems with operations that access positioning results and related information in a uniform manner, isolating the client from the multiplicity of protocols that may be employed to communicate with the positioning instruments. For example, a realized-positioning service could communicate with a GNSS receiver using the well-known NMEA 0183 protocol, translate the information, and provide the positioning results to a geographic information display client through the ISO 19116 standard interface specified in this document. Another realized-positioning service could communicate with a GNSS receiver using a manufacturer's proprietary binary protocol. Through the use of standardized positioning service interfaces, the hardware communication protocols become transparent to the client application.

Evolution of new communication protocols that closely follow the data structures described in this International Standard is also anticipated. Such communication standards will facilitate efficient fulfilment of the information requirements of the positioning services interface and facilitate modular interchangeability of the positioning technology components.

0.2 Potential use of the service

The application of this International Standard is illustrated in Figure 2 by a simplified case for a user obtaining coordinates from a GNSS receiver.

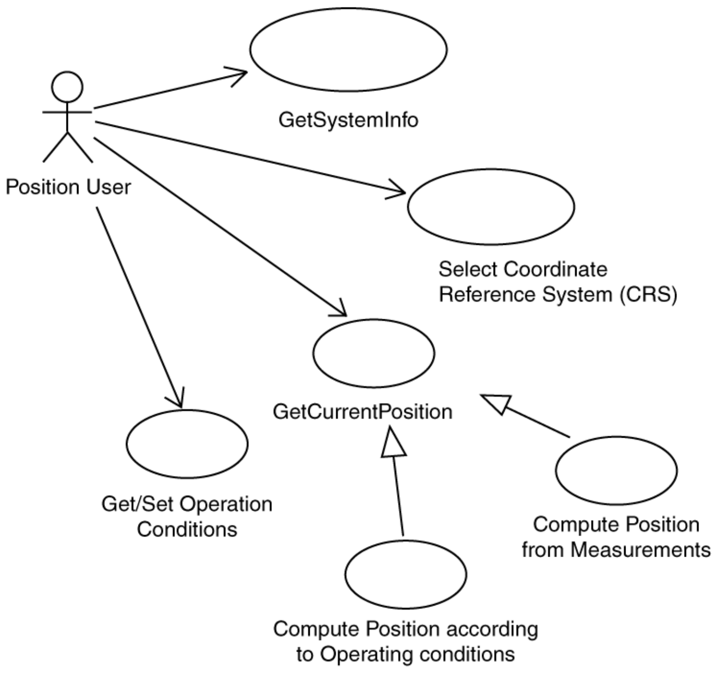

Figure 2 — Use case for getting coordinates from a positioning service

First, the positioning service device transmits system-identification data so that the user can determine the type of positioning system, in this case a GNSS receiver, and whether the system is operational.

Next, the user sets the GNSS receiver to provide coordinates in the desired Coordinate Reference System (CRS) through the interface by performing setMode operations. For instance, the coordinate reference system could be set to NAD27 Virginia State Plane, North Zone, US Survey feet. Note that by using well-recognized CRS names in accordance with the ISO 19111 structure, the user avoids some of the complexity of the definition of the coordinate reference system by using a named datum and mapping projection, and the system interprets these and loads predefined set of parameters.

By performing technology-specific setOperatingConditions operations, the user also sets certain operating conditions of the system so that the position determination will be performed in a desired manner. For example, the user sets the satellite-elevation mask of the GNSS receiver so that satellites that are at low angles in the sky, and consequently, more affected by signal passage through the atmosphere, are excluded from the computation. Certain other operating conditions, such as the current actual positions of available satellites, are not controllable by the user and are determined by the system.

The system then performs measurements according to the operating conditions of the signal from the GNSS satellites and uses these measurements to compute a position cast in the specified Coordinate Reference System.

Finally, the computed position is reported to the user through the PS_Observation data object.

The positioning system also reports on certain operating conditions to help the user decide whether to use the position value. For example, one of the indicators of solution quality is the dilution of precision (DOP) value, which is based on the geometry of the satellites observed to determine the position.

Communication of this information is performed through the standard data structures to the user’s display device, which portrays it to the user.

Geographic information — Positioning services

1 Scope

This International Standard specifies the data structure and content of an interface that permits communication between position-providing device(s) and position-using device(s) so that the position-using device(s) can obtain and unambiguously interpret position information and determine whether the results meet the requirements of the use. A standardized interface of geographic information with position allows the integration of positional information from a variety of positioning technologies into a variety of geographic information applications, such as surveying, navigation and intelligent transportation systems. This International Standard will benefit a wide range of applications for which positional information is important.

2 Conformance

This International Standard defines two levels of conformance: Basic (that all implementations shall meet) and Extended (for technology-specific data related to a positioning system). Any positioning services implementation or product claiming conformance with this part of the International Standard shall pass all the requirements described in the corresponding abstract test suite set forth in Annex A.

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 1000:1992, *SI units and recommendations for the use of their multiples and of certain other units*

ISO/TS 19103:—[1)], *Geographic information — Conceptual schema language*

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

ISO 19111:2003, *Geographic information — Spatial referencing by coordinates*

ISO 19113:2002, *Geographic information — Quality principles*

ISO 19114:2003, *Geographic information — Quality evaluation procedures*

ISO 19115:2003, *Geographic information — Metadata*

1) To be published.

4 Terms and definitions

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

4.1
accuracy
closeness of agreement between a test result and the accepted reference value

[ISO 3534-1]

NOTE For positioning services, the test result is a measured value or set of values.

4.2
attitude
orientation of a body, described by the angles between the axes of that body's **coordinate system** (4.5) and the axes of an external **coordinate system** (4.5)

NOTE In positioning services, this is usually the orientation of the user's platform, such as an aircraft, boat, or automobile.

4.3
coordinate
one of a sequence of n numbers designating the position of a point in n-dimensional space

[ISO 19111]

NOTE In a coordinate reference system, the numbers must be qualified by units.

4.4
coordinate reference system
coordinate system (4.5) that is related to the real world by a **datum** (4.6)

[ISO 19111]

NOTE For geodetic and vertical datums, it will be related to the Earth.

4.5
coordinate system
set of mathematical rules for specifying how **coordinates** (4.3) are to be assigned to points

[ISO 19111]

4.6
datum
parameter or set of parameters that serve as a reference or basis for the calculation of other parameters

[ISO 19111]

NOTE 1 A datum defines the position of the origin, the scale, and the orientation of the axes of a coordinate system.

NOTE 2 A datum may be a geodetic datum, a vertical datum or an engineering datum.

4.7
ellipsoidal height
geodetic height
h
distance of a point from the ellipsoid measured along the perpendicular from the ellipsoid to this point, positive if upwards or outside of the ellipsoid

[ISO 19111]

NOTE Only used as part of a three-dimensional geodetic coordinate system and never on its own.

4.8
geodetic datum
datum (4.6) describing the relationship of a **coordinate system** (4.5) to the Earth

[ISO 19111]

NOTE In most cases, the geodetic datum includes an ellipsoid definition.

4.9
gravity-related height
H
height (4.10) dependent on the Earth's gravity field

[ISO 19111]

NOTE In particular, orthometric height or normal height, which are both approximations of the distance of a point above the mean sea level.

4.10
height
altitude
h
H
distance of a point from a chosen reference surface along a line perpendicular to that surface

[ISO 19111]

NOTE 1 See ellipsoidal height and gravity-related height.

NOTE 2 Height of a point outside the surface treated as positive; negative height is designated as depth.

4.11
inertial positioning system
positioning system (4.21) employing accelerometers, gyroscopes, and computers as integral components to determine **coordinates** (4.3) of points or objects relative to an initial known reference point

4.12
integrated positioning system
positioning system (4.21) incorporating two or more positioning technologies

NOTE The measurements produced by each positioning technology in an integrated system may be of any position, motion, or attitude. There may be redundant measurements. When combined, a unified position, motion, or attitude is determined.

4.13
linear positioning system
positioning system (4.21) that measures distance from a reference point along a route

EXAMPLE An odometer used in conjunction with predefined mile or kilometre origin points along a route and provides a linear reference to a position.

4.14
linear reference system
reference system that identifies a location by reference to a segment of a linear geographic feature and distance along that segment from a given point

NOTE Linear reference systems are widely used in transportation, for example highway names and mile or kilometre markers.

4.15
map projection
coordinate (4.3) conversion from a geodetic **coordinate system** (4.5) to a plane

[ISO 19111]

4.16
motion
change in the position of an object over time, represented by change of **coordinate** (4.3) values with respect to a particular reference frame

EXAMPLE This may be motion of the position sensor mounted on a vehicle or other platform or motion of an object being tracked by a positioning system.

4.17
operating conditions
parameters influencing the determination of **coordinate** (4.3) values by a **positioning system** (4.21)

NOTE Measurements acquired in the field are affected by many instrumental and environmental factors, including meteorological conditions, computational methods and constraints, imperfect instrument construction, incomplete instrument adjustment or calibration, and, in the case of optical measuring systems, the personal bias of the observer. Solutions for positions may be affected by the geometric relationships of the observed data and/or mathematical model employed in the processing software.

4.18
optical positioning system
positioning system (4.21) that determines the position of an object by means of the properties of light

EXAMPLE Total Station: Commonly used term for an integrated optical positioning system incorporating an electronic theodolite and an electronic distance-measuring instrument into a single unit with an internal microprocessor for automatic computations.

4.19
performance indicator
internal parameters of **positioning systems** (4.21) indicative of the level of performance achieved

NOTE Performance indicators can be used as quality-control evidence of the positioning system and/or positioning solution. Internal quality control may include such factors as signal strength of received radio signals [signal-to-noise ratio (SNR)], figures indicating the dilution of precision (DOP) due to geometric constraints in radiolocation systems, and system-specific figure of merit (FOM).

4.20
positional accuracy
closeness of **coordinate** (4.3) value to the true or accepted value in a specified reference system

NOTE The phrase “absolute accuracy” is sometimes used for this concept to distinguish it from relative positional accuracy. Where the true coordinate value may not be perfectly known, accuracy is normally tested by comparison to available values that can best be accepted as true.

4.21
positioning system
system of instrumental and computational components for determining position

NOTE Examples include inertial, integrated, linear, optical and satellite positioning systems.

4.22
precision
measure of the repeatability of a set of measurements

NOTE Precision is usually expressed as a statistical value based upon a set of repeated measurements, such as the standard deviation from the sample mean.

4.23
relative position
position of a point with respect to the positions of other points

NOTE The spatial relationship of one point relative to another may be one-, two- or three-dimensional.

4.24
relative positional accuracy
closeness of **coordinate** (4.3) difference value to the true or accepted value in a specified reference system

NOTE Closely related terms such as local accuracy are employed in various countries, agencies and application groups. Where such terms are utilized, it is necessary to provide a description of the term.

4.25
satellite positioning system
positioning system (4.21) based upon receipt of signals broadcast from satellites

NOTE In this context, satellite positioning implies the use of radio signals transmitted from “active” artificial objects orbiting the Earth and received by “passive” instruments on or near the Earth’s surface to determine position, velocity, and/or attitude of an object. Examples are GPS and GLONASS.

4.26
uncertainty
parameter, associated with the result of measurement, that characterizes the dispersion of values that could reasonably be attributed to the measurand

[GUM]

NOTE When the quality of accuracy or precision of measured values, such as coordinates, is to be characterized quantitatively, the quality parameter is an estimate of the uncertainty of the measurement results. Because accuracy is a qualitative concept, one should not use it quantitatively, that is associate numbers with it; numbers should be associated with measures of uncertainty instead.

4.27
unit of measure
reference quantity chosen from a unit equivalence group

[adapted from ISO 31-0, 2.1]

NOTE In positioning services, the usual units of measurement are either angular units or linear units. Implementations of positioning services must clearly distinguish between SI units and non-SI units. When non-SI units are employed, it is required that their relation to SI units be specified.

4.28
vertical datum
datum (4.6) describing the relation of **gravity-related heights** (4.9) to the Earth

[ISO 19111]

NOTE In most cases, the vertical datum will be related to a defined mean sea level based on water level observations over a long time period. Ellipsoidal heights are treated as related to a three-dimensional ellipsoidal coordinate system referenced to a geodetic datum. Vertical datums include sounding datums (used for hydrographic purposes), in which case the heights may be negative heights or depths.

5 Symbols, abbreviations and UML notations

5.1 Symbols and abbreviated terms

C/A	Coarse / Acquisition code transmissions of the GPS and GLONASS
CRS	Coordinate Reference System
DOP	Dilution of Precision
DGPS	Differential GPS
FOM	Figure of Merit
GDOP	Geometric Dilution of Precision
GIS	Geographic Information System
GLONASS	GLObal NAvigation Satellite System (Russian Federation)
GNSS	Global Navigation Satellite System (generic)
GPS	Global Positioning System (USA)
HDOP	Horizontal Dilution of Precision
ITRF	International Terrestrial Reference Frame
L*n*	Signal transmission in a specified portion of the L band of the radio spectrum; suffix "*n*" indicates portion of the band for a defined frequency such as GPS L1 or GLONASS L1
LORAN-C	LOcation and RANging radiolocation system
NAD*yy*	North American Datum; suffix "" indicates last two digits of year
NMEA	National Marine Electronics Association
PDOP	Positional Dilution of Precision
PPS	Precise Positioning Service of a Global Navigation Satellite System
RAIM	Receiver Autonomous Integrity Monitoring
RINEX	Receiver INdependent EXchange Format
RMS	Root Mean Square
RMSE	Root Mean Square Error
SI	System of Units
SNR	Signal to Noise Ratio
SV	Space Vehicle
TDOP	Time Dilution of Precision
UML	Unified Modeling Language

UTM Universal Transverse Mercator

UTC Coordinated Universal Time

VDOP Vertical Dilution of Precision

WAAS Wide Area Augmentation System

5.2 UML Notations

The diagrams that appear in this International Standard are presented using the Unified Modeling Language (UML). Some important elements of UML notation are shown in Figure 3.

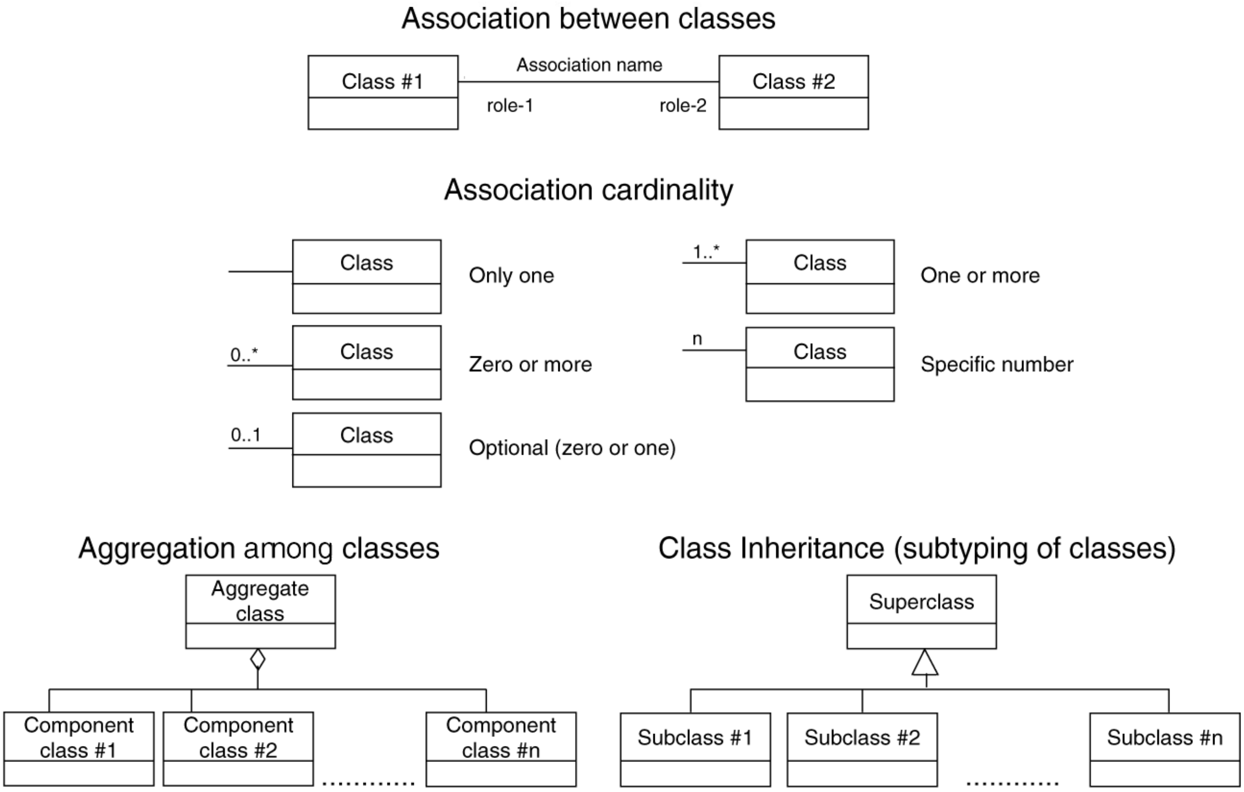

Figure 3 — UML Notation

5.3 UML model stereotypes

A UML stereotype is an extension mechanism for existing UML concepts. It is a model element that is used to classify (or mark) other UML elements so that they, in some respect, behave as if they were instances of new virtual or pseudo metamodel classes whose form is based on existing base metamodel classes. Stereotypes augment the classification mechanisms on the basis of the built-in UML metamodel class hierarchy. Below are brief descriptions of the stereotypes used in this International Standard. For more detailed descriptions, consult ISO/TS 19103.

In this International Standard the following stereotypes are used.

a) <<DataType>> descriptor of a set of values that lack identity (independent existence and the possibility of side effects). Data types include primitive predefined types and user-definable types. A DataType is thus a class with few or no operations, whose primary purpose is to hold the abstract state of another class.

b) <<CodeList>> used to describe an open list. <<CodeList>> is a flexible enumeration. Code lists are useful for expressing a long list of potential values. If the elements of the list are completely known, an enumeration should be used; if the only likely values of the elements are known, a code list should be used.

c) <<Abstract>> class (or other classifier) that cannot be directly instantiated. UML notation for this to show the name in italics.

d) <<Interface>> named set of operations that characterize the behaviour of an element.

e) <<Package>> cluster of logically related components, containing sub-packages.

5.4 Package abbreviations

Two letter abbreviations are used to denote the package that contains a class. These abbreviations precede class names, connected by a "_". A list of these abbreviations follows, together with a reference to the International Standard in which these classes are located.

CC	Changing coordinates	(ISO 19111)
CI	Citation	(ISO 19115)
DQ	Data quality	(ISO 19115)
EX	Extent	(ISO 19115)
MD	Metadata	(ISO 19115)
PS	Positioning services	(ISO 19116)
RS	Reference system	(ISO 19115)
SC	Spatial coordinates	(ISO 19111)
TM	Temporal	(ISO 19108)

6 Positioning services model

6.1 Introduction

Positioning services provide a means to obtain position information regarding a point or object. The data communication with a positioning service shall be structured in three classes:

a) System information — held in the PS_System class, identifying the system and its capabilities;

b) Session information — held in the PS_Session class, identifying a session of system operation;

c) Mode information — held in the PS_ObservationMode class, identifying the configuration used in each mode of operation, the positioning observations (results) and any associated quality information.

These classes apply elements defined in certain other ISO standards as shown in Figure 4, depicting the relationships among these elements as UML packages.

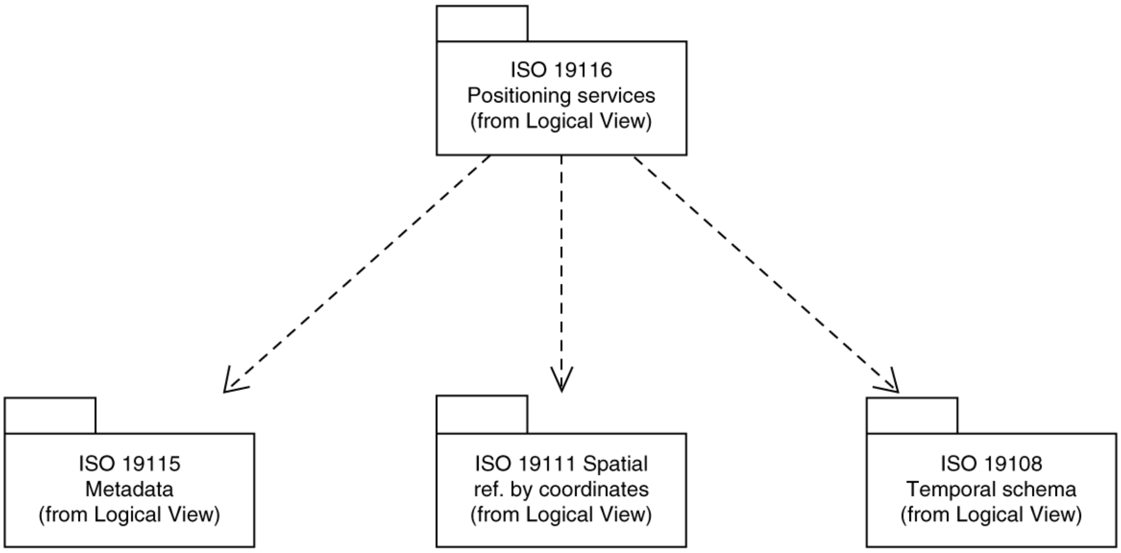

Figure 4 — Package diagram showing relationship with elements in other ISO standards

6.2 Static data structures of positioning services classes

The service is accessed through an interface that operates on these data classes, creating and destroying instances as necessary, and setting and getting information needed from the positioning service. This International Standard can be implemented as an interface between software modules within a system or as an interface between different systems. The relationships among these classes are depicted in Figure 5, and the details of these classes are discussed in Clause 7.

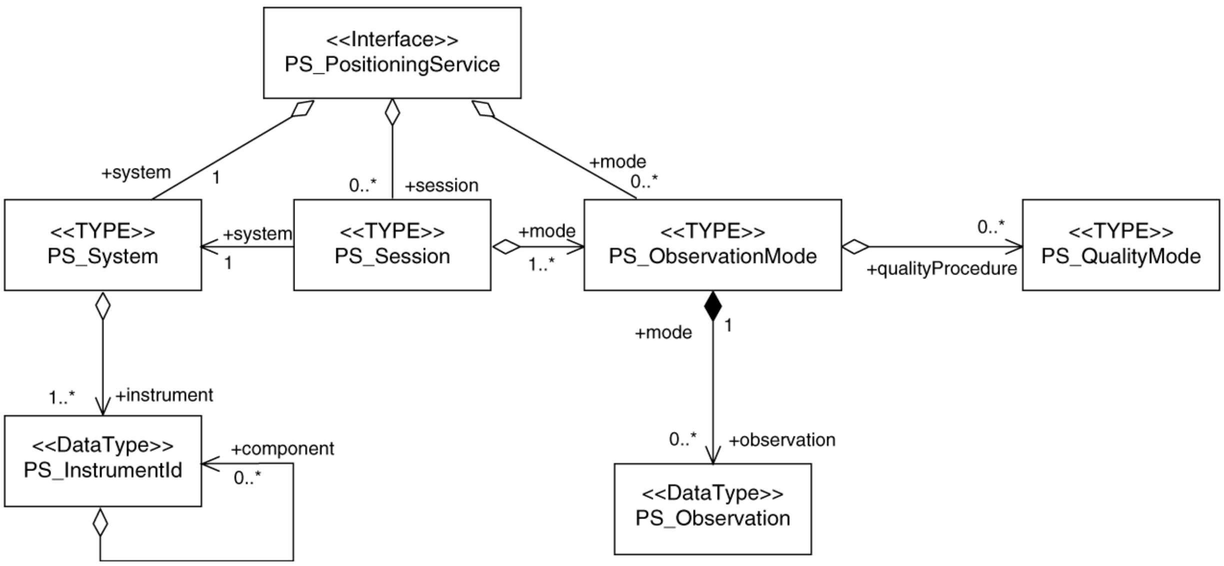

Figure 5 — UML depiction of the major data classes of positioning services

System information (PS_System) provides for identification and characterization of the positioning instrument(s) applied by the positioning service to make observations so that any necessary details can be obtained for operational purposes and for legacy metadata.

Observation mode information (PS_ObservationMode) encompasses all configuration and set-up parameters, including the spatial and temporal reference systems on which the observation results are cast. Associated with the mode may be data-quality configuration information, held in the PS_QualityElement class, that characterizes how quality results will be evaluated and expressed.

Positioning services can produce several types of observation: position, orientation (attitude), motion and rotation (angular motion). Because each type of observation shall be cast in its own type of reference system, a separate instance of the PS_ObservationMode class is created for each type of observation and the type is an attribute of the mode.

Observations are aggregated to each mode so that the information needed for interpretation is associated with each observation. A positioning service can create as many mode instances as needed for its various observation types and reference systems. Numerous observation results can belong to each mode.

Observations aggregated to modes of operation (PS_ObservationMode) can be further aggregated in sessions (PS_Session). The concept of observation sessions is widely employed when positioning observations are recorded for land survey or GIS applications. Sessions associate the observations with system information, attributes of the session, and all the modes of operation employed in making a discrete group of positioning observations and any associated quality information. Positioning services that do not provide for the recording of observation results, such as certain navigation systems, may omit implementation of the PS_Session class.

Positioning-result information is segregated from configuration information in order to avoid excessive repetition of the configuration when the positioning service reports numerous observations. Similarly, quality-result information is segregated at the same level as positioning results, so that numerous quality reports of the same type, evaluated by the same procedure, can be reported without repetition of the element identification and evaluation procedure citation.

Quality results are associated directly with positioning observation results, and are held in the PS_ObservationQuality class, which is a subtype of the DQ_QualityMeasure class.

6.3 Positioning services operations

6.3.1 Definition of positioning services operations

The operations of the positioning service interface create, set, get and end (destroy) instances of these classes as needed to convey the configuration and observation information, and are listed in Figure 6.

<<Interface>>
PS_PositioningService

+ setSystemInfo(initialization : PS_System) : PS_System
+ getSystemInfo() : PS_System
+ getInstrumentID() : PS_InstrumentIDInfo : PS_Session
+ newSession(sessionID : CharacterString)
+ setSessionInfo(sessionID : CharacterString, sessionInfo : PS_Session)
+ getSessionInfo(sessionID : CharacterString) : PS_Session
+ endSession(sessionID : CharacterString)
+ newObservationMode(name : CharacterString)
+ setObservationMode(name : CharacterString, desiredMode : PS_ObservationMode)
+ getObservationMode(name : CharacterString) : PS_ObservationMode
+ endObservationMode(name : CharacterString)
+ getObservation(PS_ObservationMode.name : CharacterString) : PS_Observation
+ setQualityElement(PS_ObservationMode.name : CharacterString, desiredQualityElement : MD_QualityElement)
+ getQualityElement(PS_ObservationMode.name : CharacterString) : MD_QualityElement
+ getPositionQuality(PS_ObservationMode.name : CharacterString) : record
+ setOperatingConditions(instrument.Name, desiredOperatingConditions)
+ getOperatingConditions(instrument.Name)
+ getPerformanceIndicators(instrument.Name)
+ getMeasurementConditions(instrument.Name)

Figure 6 — Operations of positioning services

These positioning service operations are described below.

— getSystemInfo() shall cause the positioning service to return a result object of the PS_System class with attribute values reflecting current information regarding the description of the positioning service itself.

— setSystemInfo(initialization) shall cause the positioning service to set current information regarding the description of the positioning service itself to values held in an argument 'initialization' that is of the PS_System class.

— getInstrumentID() shall cause the positioning service to return a result object of the PS_InstrumentID class with attribute values reflecting current information regarding the identification of the instrumentation employed by the positioning service for the determination of positioning observations. Because the identification of instrumentation is often used for traceability and authentication of results, setting of identification parameters such as model and serial number is performed by the manufacturer or by authorized operators using means outside the scope of the ISO positioning-services interface.

— newSession(sessionID) shall cause the positioning service to create one instance of a data object of the PS_Session class populated with current values of parameters identifying an operating session of the service and set the current value of its sessionID attribute to the value contained in the argument 'sessionID', which is of the CharacterString type. The PS_Session object so created shall be enabled to aggregate one or more instances of objects of the PS_Operating mode class within it, and thereby aggregate one or more positioning observations and quality measures within each PS_OperatingMode object.

— setSessionInfo(sessionID, sessionInfo) shall cause the positioning service to set current information describing an object of the PS_Session class, of which the sessionID attribute value matches the sessionID argument value, to the values contained in the sessionInfo argument, which is of the PS_Session class.

— getSessionInfo(sessionID : CharacterString) shall cause the positioning service to get current information describing an object of the PS_Session class.

— endSession(sessionID) shall cause the positioning service to disable aggregation of operating mode class objects to the instance of a PS_Session class object that has a sessionID attribute value matching the sessionID argument value of the operation and cause all instances of PS_ObservationMode objects within it to cease aggregating positioning observations and quality measures.

— newMode(name) shall cause the positioning service to create an instance of the PS_ObservationMode class and assign to its 'name' attribute the value of the 'name' argument of the operation, associate it with the currently active instance of the PS_Session class if such exists, and enable it to aggregate one or more PS_Observation objects and associate with zero or more PS_QualityElement objects with their aggregation of PS_QualityResult objects that associate with PS_Observation objects as their resultQuality.

— setObservationMode(name, desiredObservationMode) shall cause the positioning service to set operating mode parameters of the positioning instruments employed to the values contained in the desiredObservationMode argument so far as possible, and to set the values of the PS_ObservationMode attributes to reflect the operating mode actually achieved.

— getObservationMode(name) shall cause the positioning service to return a result object of the PS_ObservationMode class with attributes holding the current values of the instance of PS_ObservationMode with a name attribute matching the value of the name argument.

— endObservationMode(name) shall cause the positioning service to disable the instance of PS_ObservationMode with name attribute matching the value of the name argument from aggregating PS_Observation objects, from associating with PS_QualityElement objects and any aggregated PS_QualityResult objects, and destroy that instance of PS_ObservationMode.

— getObservation(PS_ObservationMode.name) shall cause the positioning service to return a result object of the PS_Observation type with attributes reflecting the current position values including the dateTime of observation and the result vector. The observation may optionally be associated with PS_QualityResult(s) obtained by use of the getPositionQuality operation.

— setQualityElement(PS_ObservationMode.Name, desiredQualityElement) shall cause the Positioning service to create an instance of the PS_QualityElement class having attributes with the values contained in the desiredQualityElement argument and associate it with the PS_ObservationMode instance with a name attribute matching the PS_ObservationMode.name argument and to act upon the instruments and computational components of the positioning service to effect the performance of quality evaluations of the positioning observations in accordance with the desiredQualityElement argument.

— getQualityElement(PS_ObservationMode.name) shall cause the positioning service to return a result object of the PS_QualityElement class with attributes reflecting the currently selected quality evaluation parameters associated with the PS_ObservationMode instance with a name attribute matching the value of the PS_ObservationMode.name argument.

— getPositionQuality shall cause the positioning service to return a result object of the PS_QualityResult type with attributes reflecting the results of quality evaluation performed upon the currently associated PS_Observation by the procedures specified in the PS_QualityElement instance associated with this PS_ObservationMode instance.

— setOperatingConditions(instrumentName, desiredOperatingConditions) shall cause the positioning service to set user adjustable parameters of the instrument with a name matching the instrumentName argument to the values contained in the desiredOperatingCondtitions. Note that technological and manufacturing considerations are outside the scope of this standard and therefore not all technology-specific operating conditions are required to be adjustable by the user through the use of the setOperatingConditions operation.

— getOperatingConditions(instrumentName) shall cause the positioning service to return a result object of the PS_OperatingConditions class with attributes reflecting the current operating conditions of the instrument with a name matching the instrumentName argument.

— getPerformanceIndicators(instrumentName) shall cause the positioning service to return a result object of the PS_PerformanceIndicators class with attributes reflecting the current performance indicators of the instrument with a name matching the instrumentName argument.

— getMeasurementConditions(instrumentName) shall cause the positioning service to return a result object of the PS_MeasurementConditions class with attributes reflecting the current measurement conditions of the instrument with a name matching the instrumentName argument.

6.3.2 Applying the positioning services operations

Naturally, one of the primary operations of a positioning service is getObservation, which returns an instance of the PS_Observation. Among the attributes of the PS_Observation class are the positioning result values, offsets and object identification. The PS_Observation class may also be associated with one or more PS_ObservationQuality classes containing quality results. Technology-specific data are reported in the operatingConditions attribute of the observation. This International Standard does not require that operations be performed in any specific sequence, because it is recognized that various implementations will perform these operations in sequences appropriate to various uses of the systems. If operations are requested in a sequence that is illogical or not supported by an implementation of a positioning service, the service shall respond with a null result without disruption of operation.

Positioning services do not directly provide the metadata structures specified in ISO 19115, but provide data classes from which such standard metadata can readily be derived when needed. Metadata supporting the interpretation of the position values are provided by the getSystemInfo operation and the getMode operation, which return the PS_System and PS_ObservationMode classes, respectively. In the PS_System class are values that indicate the type of technology employed in the positioning instrumentation, how it represents position, and identifies the specific instruments employed. In the PS_ObservationMode class are the configuration parameters pertaining to the generation of particular types of positioning results, such as the temporal and spatial reference systems. Associated with the PS_ObservationMode may be PS_QualityElement instances holding quality evaluation and reporting configuration information.

Additional metadata supporting the citation of the source of position values are handled by the setSessionInfo and getSessionInfo operations, which employ the PS_Session class. In the PS_Session class are values that identify the agency, mission, and observers for which the position information is being obtained.

6.4 Basic and Extended Information

As listed in Table 1, Basic Information from a positioning service includes system information (PS_System), session information (PS_Session), mode of operation (PS_ObservationMode), observation information (PS_Observation) and observation quality information (PS_ObservationQuality). A dataset that conforms to this International Standard shall include sufficient information for a recipient to know how these relate to a common frame of reference specified by the PS_ReferencingMethod and PS_ReferenceSystem data elements. For example, the statement of the coordinate reference system shall include the frame of reference, the units of measure, projection information, and so forth.

Table 1 — Positioning service information structure

Basic information (all technologies, see Clause 7)	System information (PS_System)	System type System capabilities Referencing method Instrument identification
	Session identification (PS_Session)	Session identification Dataset initiative Observer identification
	Mode of operation (PS_ObservationMode) (PS_QualityElement)	Positioning reference system Link to reference system Coordinate transformations applied Quality element and subelement
	Observation (PS_Observation) (PS_ObservationQuality)	Observation date time Result Object ID Offset Quality result
Extended information (technology specific, see Clause 8)	GNSS technology (PS_Observation)	Operating conditions MeasurementConditions Performance indicators Solution vector Raw measurement

To maintain generality of the data structures, technology-specific information like DOP, SV selection, signal strength, etc., is classified as Extended Information and separated from the Basic Information for Conformance testing. This allows this International Standard to be used for a wide variety of position source devices from GNSS to Total Stations.

Positioning services can employ various technologies; so when the getObservation operation returns the PS_Observation class, it can contain technology-specific information in the operatingConditions attribute. For example, when GNSS is used for positioning, information like the dilution of precision (DOP) values, satellite selection, and performance indicators is provided.

7 Basic information definition and description

7.1 Introduction

Basic information provided by positioning services is structured into three main elements:

a) system information – identifying the system's type and capabilities;

b) session information – identifying the specific instrument, mission and session;

c) positioning-mode information – containing configuration and result values.

The location of an object at an instant of time is completely specified by two groups of dimensions: a three-dimensional position vector and a three-dimensional orientation (attitude) vector. Similarly, the rate of change in location of that object over time is specified by a three-dimensional motion (velocity) vector and a three-dimensional rotation (angular velocity) vector. A positioning service may provide values for all or a subset of these four groups of dimensions as four types of observations.

The positioning-observation information element provides structures for positioning results in these four types of observations and the associated ancillary information needed by a user to interpret them unambiguously. This associated information includes the reference system, link to reference frame, and observation quality element report of quality parameters.

7.2 System Information

7.2.1 Introduction

The system information data element (PS_System) identifies the positioningdata source, the type of technology applied, and its capabilities.

The capability attribute (PS_System.capability) may be queried to determine what data types are available according to the System Capability codes. This allows a user to request and interpret position observations of the appropriate types.

The positioning-technology attribute (PS_System.positioningTechonology) may be queried so that the user can apply interpretive techniques appropriate to that technology. For example, the accuracy of GNSS receivers is affected by reflected radio signals (multipath), whereas inertial systems are unaffected because they do not employ radio reception. However, the accuracy of inertial systems degrades over time after initialization due to gyroscope drift, whereas GNSS systems are not subject to this type of drift. Therefore, a user might need to know which type of technology is employed in order to know what kinds of error to expect.

The referencing method attribute (PS_System.referencingMethod) identifies the generalized method by which the positioning service represents a position, which shall be known by the user so that the results can be interpreted. For example, the location of a road intersection may be specified by a pair of coordinates in a coordinate reference system, or by a route number and distance in a linear referencing system. Though these refer to the same place by means of a pair of numbers, the means of interpretation of these numbers is fundamentally different.

The instrument-identification class (PS_InstrumentID) provides details about the equipment employed by the positioning service to obtain positioning results, and may be used to create metadata regarding the origin of a dataset or be used by software to adjust model and version specific details of operation. The instrument-identification data may be iterated to identify as many components of the system as needed.

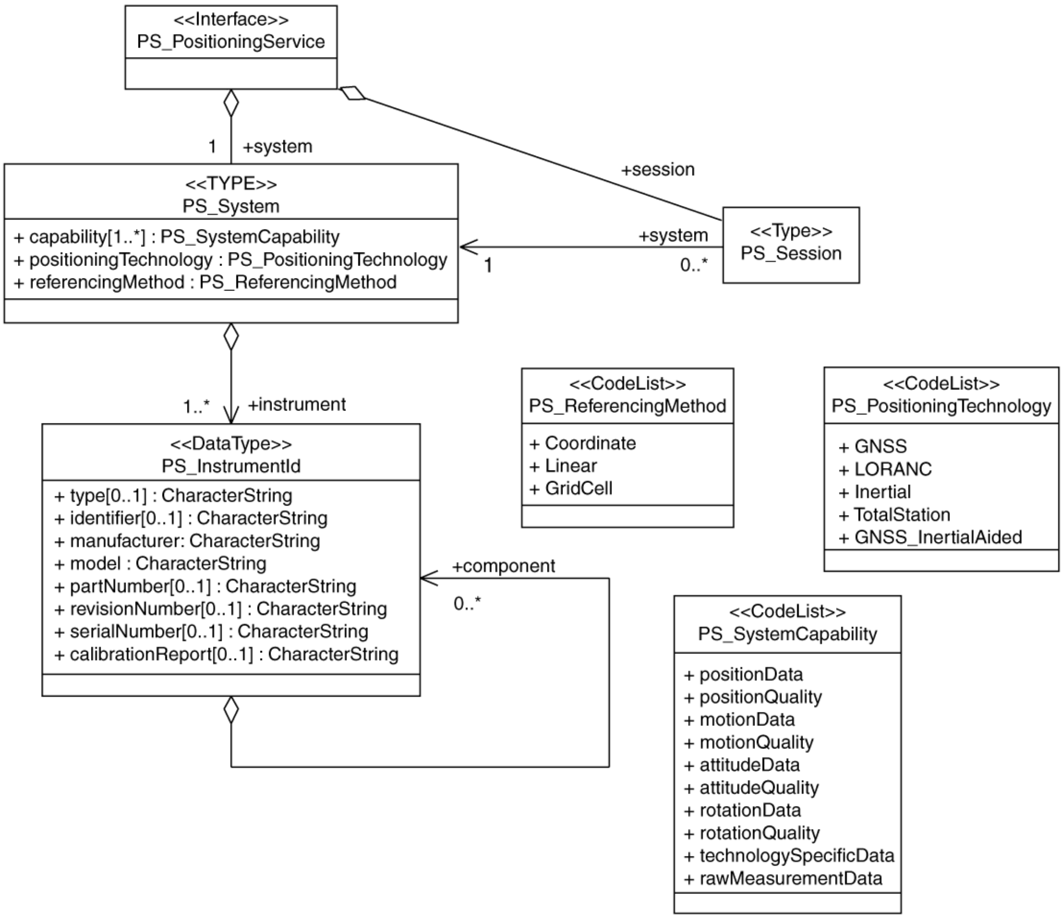

Figure 7 — UML depiction of the PS_System and PS_InstrumentID classes and their attributes

7.2.2 PS_system

7.2.2.1 Introduction

— Class Name: PS_System;

— Attributes and descriptions:

  — capability[1..*] PS_SystemCapability – code(s) identifying capabilities,

  — positioningTechnology PS_PositioningTechnology – code identifying technology type,

  — referencingMethod PS_ReferencingMethod – code identifying referencing method;

— Associations:

  — instrument to make positioning observations, a positioning system employs an instrument that is characterized by information in the PS_InstrumentID class.

7.2.2.2 System capability

System capacity indicates whether particular data elements are provided by the realized-positioning service. Each code specifies the availability of a data element or subelement. As many instances of system capability codes may be present as are required to represent all the capabilities of the realized system.

— Class Name: <<CodeList>> PS_SystemCapability;

  PS_System capability is a list of codes by which capabilities of a positioning service are identified;

— Attributes and descriptions:

  — positionData this service is capable of providing position data,

  — positionQuality this service is capable of providing position-quality data,

  — motionData this service is capable of providing motion data,

  — motionQuality this service is capable of providing motion-quality data,

  — attitudeData this service is capable of providing attitude data,

  — attitudeQuality this service is capable of providing attitude-quality data,

  — rotationData this service is capable of providing rotation data,

  — rotationQuality this service is capable of providing rotation-quality data,

  — technologySpecificData this service is capable of providing technology-specific data,

  — rawMeasurementData this service is capable of providing raw-measurement data;

— Associations: none.

7.2.2.3 Positioning technology

Because the various positioning technologies have characteristics of capabilities and behaviour that differ from each other, users of positioning results require knowledge of the technology employed. For example, GNSS reception is degraded or blocked when the system is operated inside buildings or tunnels, but inertial systems can operate continuously in such environments, yet inertial systems require initialization at known points whereas GNSS does not. Similarly, the accuracy characteristics of GNSS positioning instruments depend upon factors different from those of inertial systems, and from those of hyperbolic radio location systems, such as LORAN-C.

Where positioning technologies that are not identified in the PS_PositioningTechnology code list are used, additional codes may be defined by the user, provided that they shall not conflict with the codes defined in this International Standard. Such codes may later be standardized by Technical Amendment to this International Standard.

— Class Name: <<CodeList>> PS_PositioningTechnology:

  Codelist used to identify the positioning technology employed by a positioning service;

— Attributes and descriptions:

  — GNSS Global Navigation Satellite System,

  — LORANC LORAN-C hyperbolic radiolocation system,

— Inertial Inertial navigation system,

— TotalStation Electronic theodolite, tacheometer,

— GNSS_InertialAided GNSS system with inertial aiding;

— Associations: none.

7.2.2.4 Referencing method

Knowledge of the referencing method employed by a positioning system is essential to interpretation of the positioning results. Though many practical positioning systems employ spatial referencing by coordinates, other referencing methods are also available. For example, linear referencing is widely applied in transportation as route - distance (milepost or kilometre post) pairs. The linear reference to a point in a transportation network is as unambiguous as a coordinate, and might be more appropriate for particular uses. In such cases, positioning systems operating with a linear referencing method might be employed. As technology evolves, additional referencing methods may be implemented, for example, those reporting street name, cross street and offset could be provided by systems using automotive sensors and map matching. For these, new referencing method codes will be needed.

Where positioning technologies that are not identified in the PS_PositioningTechnology code list are used, additional codes may be defined by the user, provided that they shall not conflict with the codes defined in this International Standard. Such codes may later be standardized by Technical Amendment to this International Standard.

— Class Name: <<CodeList>> PS_ReferencingMethod:

  PS_Referencing is a list of codes by which the referencing method used by a positioning service is identified;

— Attributes and descriptions:

— Coordinate Coordinate Referencing,

— Linear Linear Referencing,

— LocatorGrid Alphanumeric Locator Grid;

— Associations: none.

7.2.3 Instrument identification

Identification of the specific positioning-service instrument in use is required so that the measurements can be traced to their origin, and that information related to the characteristics of the device (or version of device) can be applied by the position-using system. Many positioning systems employ a receptive device such as a GNSS antenna for which the particular type is important in attaining accurate calibration of the system; therefore, the instrument identification may be repeated as necessary to identify the components.

— Class Name: PS_InstrumentID:

  To make positioning observations, a positioning system employs an instrument that is characterized by information in the PS_InstrumentID class. If the instrument has components requiring identification, this class may be repeated.

— Attributes and descriptions:

  — type[0..1] CharacterString – Identifies the instrument type,

  — identifier[0..1] CharacterString – Label or number assigned to the specific instrument,

  — manufacturer CharacterString – Identifies the instrument manufacturer,

  — model CharacterString – Model name, number, or product type identifier,

  — partNumber[0..1] CharacterString – Manufacturer’s part number identifying the production version,

  — revisionNumber[0..1] CharacterString – Instrument version or revision identifier,

  — serialNumber[0..1] CharacterString – Instrument serial number,

  — calibrationReport[0..1] Citation – Identifies calibration report regarding the instrument;

— Associations:

  — component identifies the instrumentation employed. PS_InstrumentID may be repeated to describe additional components.

7.3 Session

7.3.1 Introduction

Observations made by a positioning service may be aggregated into sessions, which may correspond to any time period of significance to the user, such as a data collection session to populate GIS themes, a navigation session between an origin and destination, or hourly, daily, or other observation files recorded as units of information. The session information includes an identifier, the starting and ending times, identification of the mission or task, identification of the observer or other responsible party, and is depicted in Figure 8. This information may be applied in populating metadata items regarding data source and legacy. Implementation of these data element is optional.

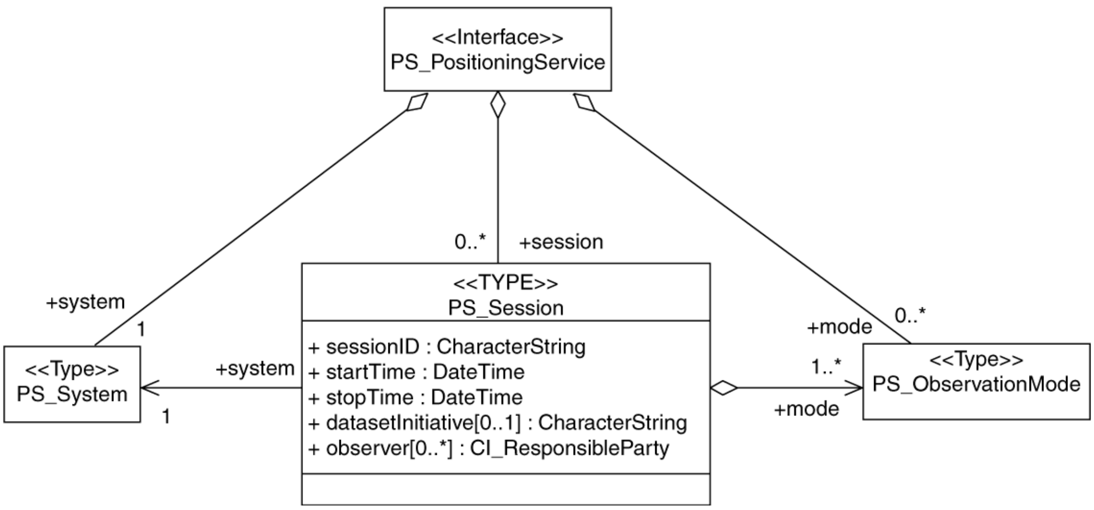

Figure 8 — UML depiction of PS_Session class attributes and associations

7.3.2 PS_Session

- Class Name: PS_Session:

  Identifies an observation session and aggregates observations made within that session with their associated system information and mode(s) of operation;

- Attributes and descriptions:

  - sessionID — CharacterString – Identifies the session by number, name, or other identifier,
  - startTime — DateTime – Date and time session was initiated,
  - stopTime — DateTime – Date and time session terminated.
  - datasetInitiative[0..1] — CharacterString – Identifies the agency and task or mission,
  - observer[0..1] — CI_ResponsibleParty – Identifies observer, operator, manager or similar party responsible for session;

- Associations:

  - system — Holds the characteristics of the positioning system employed to conduct that session;
  - mode — Holds the characteristics of the mode(s) of operation applied to conduct that session and aggregates to each mode the corresponding observations.

7.4 Mode of operation

7.4.1 Introduction

Positioning observations can be expressed in numerous ways: using various datums, projections, units of measure, and so forth. The mode-of-operation class specifies the way in which a particular set of observations is being expressed, and the information about the mode of operation shall include all pertinent details about the representation of results so that they can be interpreted without ambiguity. This information includes

- name of mode;
- type of measurement;
- positional reference system;
- temporal reference system;
- links through which the positioning service accesses the reference system(s);
- coordinate transformation and conversion operations applied to the measurements.

For example, if an observation result presented the numbers 45,75 and −108,5 without explanation, the user doesn't know whether they were coordinates in degrees of latitude and longitude, meters on a local coordinate grid, or speed and heading in meters/second and degrees from true north. If they were coordinates, the geodetic datum upon which they were cast would have to be known. Information contained in the PS_ObservationMode class specifies all this, so that a recipient is not faced with ambiguity in the interpretation of positioning results. Information in the PS_ObservationMode class may be used both in real-time applications and as the basis for metadata to be stored with datasets acquired by use of the positioning service.

Although this International Standard does not specify how often a system should supply the positioning service data elements, it is likely that many systems will transmit Mode data early in a session to establish metadata for the session to prepare the recipient to interpret the positioning data stream. Numerous transactions of positioning observations and (optional) quality results then may proceed as needed for the application.

Each mode of operation may optionally be given a name to facilitate reference to the entire set of configuration values.

Some positioning instrumentation measures not only the location of a point, but also the orientation of an object and its motion; therefore, the measurement type, e. g. position, orientation (attitude), motion (velocity) or rotation (angular velocity), of each operating mode shall be identified. As mentioned above, observation results cannot be interpreted without knowledge of their respective reference system(s), therefore identification of the temporal reference system and the spatial reference system are mandatory.

Information detailing the links through which the positioning service accesses its reference systems may optionally be provided. Such information is often needed when high accuracy is sought or when a user requires traceability of the measurement's results or accuracy report.

Identification of the (concatenated) coordinate transformation and conversion operations applied in producing the positioning results may optionally also be provided. This information is often required in geodetic measurements when high accuracy is sought.

Positioning services capable of reporting several types of measurement simultaneously, for example both position and motion, shall instantiate a mode of operation for each. The axes and units of measure for the various measurement types may differ from each other; for example, position may be reported in degrees of latitude and longitude while motion is reported as speed in meters per second on a heading expressed in degrees from north.

7.4.2 PS_ObservationMode

7.4.2.1 Introduction

— Class Name: PS_ObservationMode:

  The PS_ObservationMode class holds information about the configuration of a positioning service to provide a particular type of positioning result. The positioning service may create as many PS_ObservationMode instances as needed to provide the various types of results requested by its user. One PS_ObservationMode instance shall hold each set of configuration information, whether several types of results (e.g. position, motion and orientation) are presented simultaneously or one type of results is presented in several different reference systems (e.g. position reported in geodetic latitude and longitude and also in the UTM projection); see Figure 9.

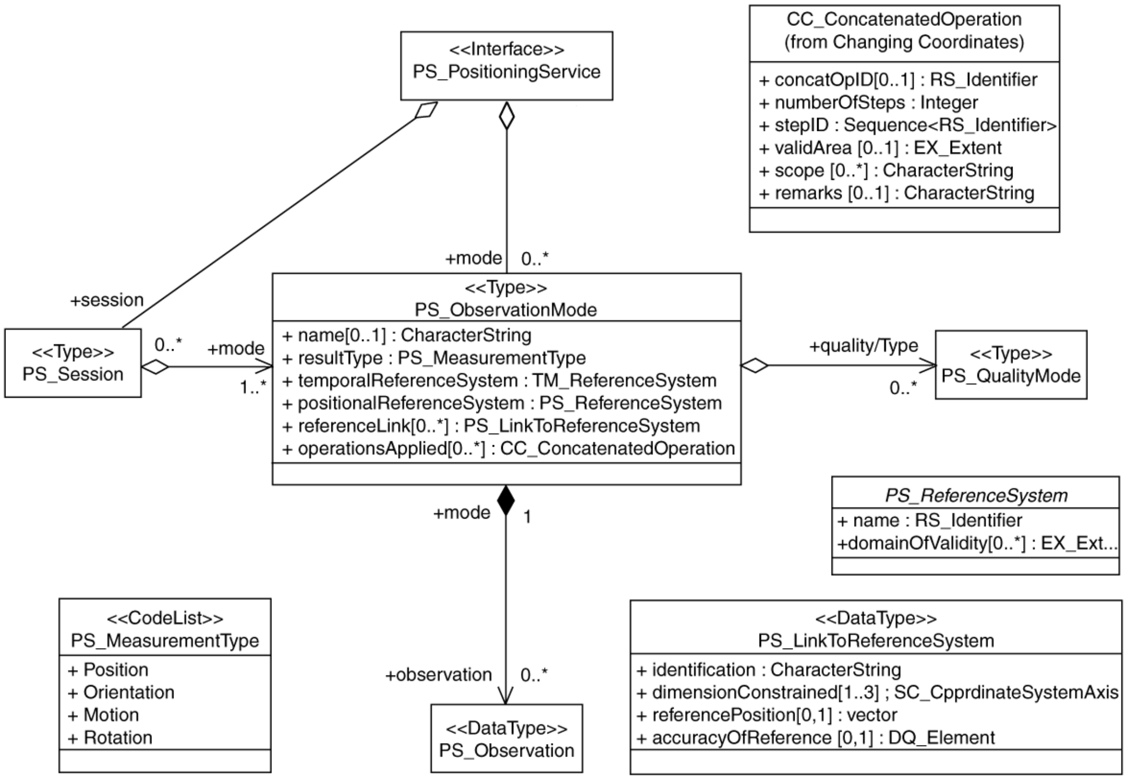

Figure 9 — UML depiction of the PS_ObservationMode class attributes, associations and related data types

— Attributes and descriptions:

— name[0..1] CharacterString – Word or phrase identifying the mode of operation:

The service may optionally provide a name for the mode of operation in order to refer to the entire set of configuration values.

— resultType PS_MeasurementType – Code identifying the type of measurement made in this mode:

Measurement types are position, motion, orientation and rotation.

— temporalReferenceSystem TM_ReferenceSystem – Temporal reference system in use:

The temporal reference system shall be defined in accordance with the specifications of ISO 19108.

— positionalReferenceSystem PS_ReferenceSystem – Spatial, motion, orientation or rotation reference system on which positioning results are cast:

The positioning reference system is described according to the type of positioning measurement. If it is a position measurement, it shall be described in accordance with ISO 19111; otherwise, it shall be described according to the classes defined in this International Standard.

— referenceLink[0..*] PS_LinkToReferenceSystem – Identifies links through which a positioning service accesses the reference system(s) (positional or temporal):

In any realization of a positioning service, there are one or more links through which the positioning service accesses the coordinate reference system and the temporal reference system. These may be survey-control monuments, a set of GNSS ground stations from which a predicted ephemeris is derived, a differential-correction beacon, or the initialization point of an inertial navigation system. Temporal reference systems are accessed through some reference clock which can be well coordinated, such as that of the GNSS satellites or of the UTC broadcasting beacons, or only approximate, such as a PC's system clock. The accuracy of the results depends upon this linkage. When traceability or high accuracy of the result is sought, the user may require recording of the link(s) to the reference system.

— operationsApplied[0..*] CS_ConcatenatedOperation – Coordinate transformations and conversions applied.

Often, a positioning service is required to present results in a reference system different from its internal computational reference system, and so coordinate transformation and conversion operations are applied. For example coordinate transformations are commonly applied in order to express geodetic coordinates in relation to a desired datum. These coordinate transformations may have inherent inaccuracies, and so when traceability or high accuracy is required, a record of the operations applied may be needed. The ConcatenatedOperation class defined in ISO 19111 specifies the identification of these operations.

— Associations:

— mode:

A positioning service has one or more modes of operation, therefore the PS_PositioningService class aggregates one or more PS_ObservationMode instances.

— qualityType:

If quality information is reported by the positioning service regarding its positioning results, the DQ_Element shall be associated with the PS_ObservationMode, so that quality results associated with positioning results are properly characterized as to the quality element type, sub-element type and evaluation descriptor.

— observation:

Zero to many instances of PS_Observation aggregate to each PS_ObservationMode. A PS_ObservationMode shall be instantiated prior to making observations; therefore, a PS_ObservationMode can exist with no observations. Any number of observations may be made in a particular mode of operation, but a PS_Observation will be ambiguous unless associated with a PS_ObservationMode.

7.4.2.2 PS_MeasurementType

— Class Name <<code list>> PS_MeasurementType:

PS_MeasurementType is a list of codes by which types of measurements provided by a positioning service are identified.

— Attributes and operations:

— position this mode of operation reports position,

— orientation this mode of operation reports orientation,

— motion this mode of operation reports motion,

— rotation this mode of operation reports rotation;

— Associations: none

7.4.2.3 PS_ReferenceSystem

7.4.2.3.1 Introduction

Figure 10 depicts the PS_Reference system, which is a supertype of four subtypes.

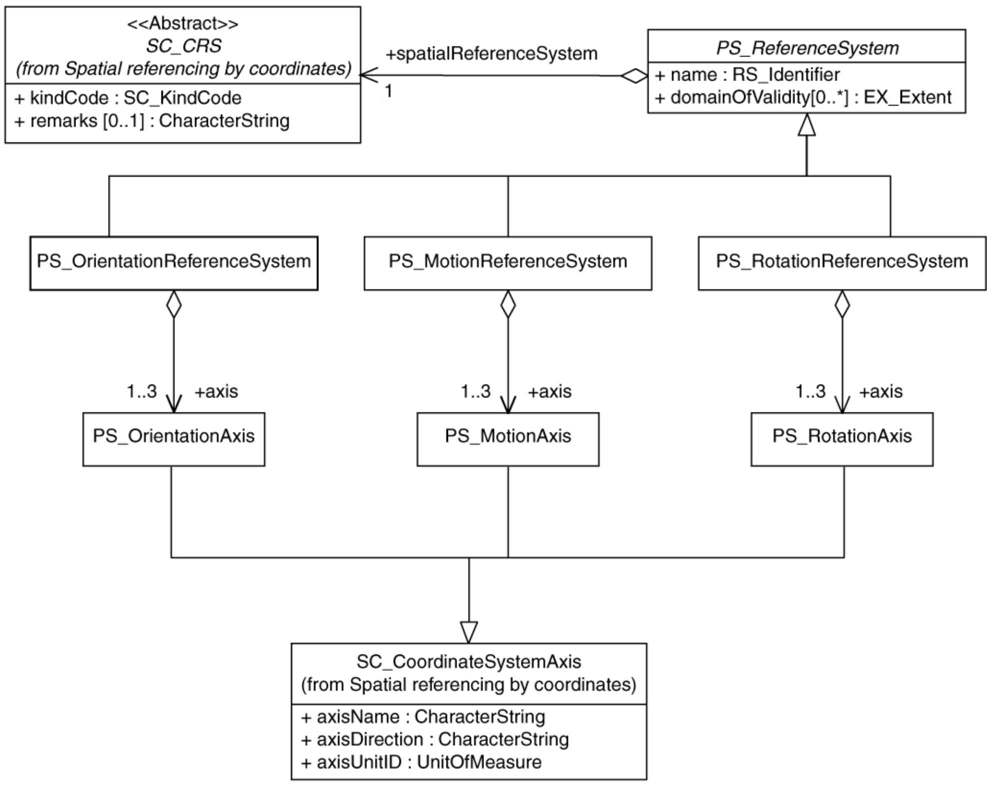

Figure 10 — UML depiction of the PS_ReferenceMode

— Class Name: PS_ReferenceSystem:

The PS_ReferenceSystem is a generalization of the four types of reference systems applicable to the various types of measurements:

— SC_CRS (coordinate reference system); for more information, see ISO 19111;

— PS_MotionReferenceSystem;

— PS_OrientationReferenceSystem;

— PS_RotationReferenceSystem.

When position measurements are made, they generalize the CS_CRS coordinate reference system, and when other types of measurements are made they generalize the corresponding type of reference system.

— Attributes and operations:

— name RS_Identifier – Identifies the reference system;

— domainOfValidity[0..1] EX_Extent – Domain over which the reference system is valid.

The domain of validity of a reference system may be global (as in the case of geocentric geodetic datums), regional (as in the case of certain national geodetic datums and certain mapping projections) or local (as in the case of grids on mobile platforms such as ships). When the domain of validity is not global, specification of its extent is recommended.

— Associations:

— spatialReferenceSystem The PS_ReferenceSystem is identified by the kindCode in the abstract class SC_CRS from Spatial Referencing by Coordinates.

7.4.2.3.2 Coordinate Reference System (SC_CRS)

The coordinate reference system used within a positioning service session shall be structured in a manner consistent with ISO 19111 and shall be identified by an RS_Identifier consistent with the requirements of ISO 19115. If that RS_Identifier does not uniquely and unambiguously define the identity of the elements within the coordinate reference system such as the datum and projection information, units of measure and so forth, then the datum and projection information shall be identified in accordance with the requirements of ISO 19115 to state the identifiers or actual values employed within the ISO 19111 structure.

7.4.2.3.3 Orientation Reference

7.4.2.3.3.1 Introduction

The PS_OrientationReferenceSystem class presents the identification and characteristics of the reference system on which orientation results are cast, and is depicted in Figure 11.

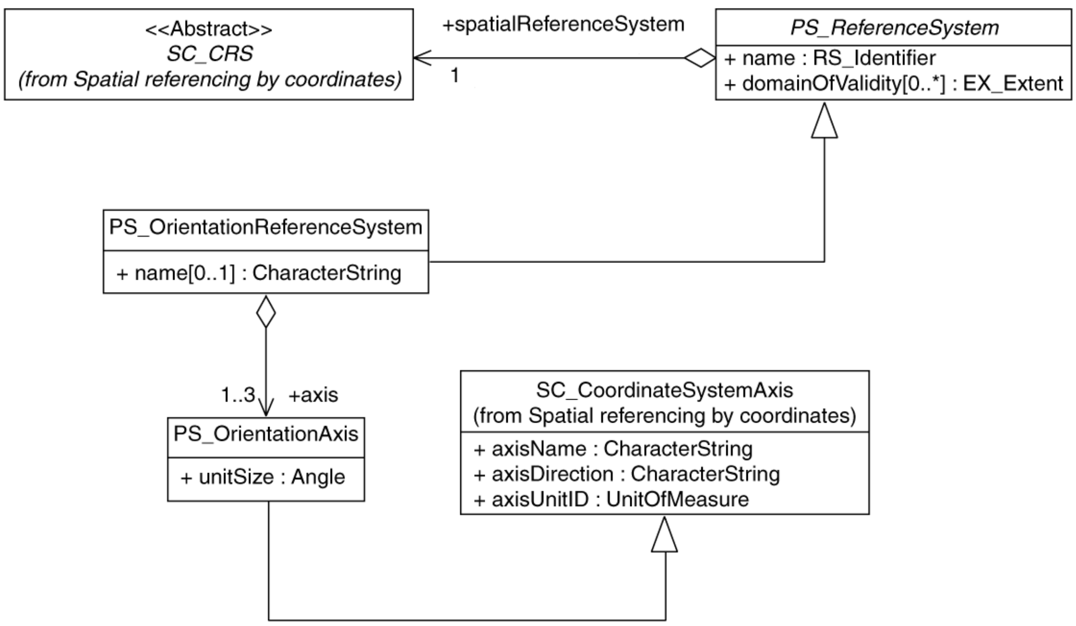

Figure 11 — UML depiction of PS_OrientationReferenceSystem with its attributes and associations

7.4.2.3.3.2 OrientationReferenceSystem

Orientation is the angular relationship between two spatial reference systems: one associated with the object of interest such as a vehicle, and one associated with a reference body such as the Earth. In this class, the spatial reference system specified by an SC_CRS is associated with the reference body and the set of axis descriptions specified as PS_OrientationAxis are associated with the object of interest.

- Class Name: PS_OrientationReferenceSystem:

  The PS_OrientationReferenceSystem class is an aggregate of a (spatial) coordinate reference system and one to three axis descriptions, which are subclasses of SC_CoordinateSystemAxis constrained to unit sizes that are angles.

- Attributes and descriptions:
  - name[0..1] CharacterString – Identifier of orientation reference system.
- Associations:
  - axis The PS_OrientationReference system aggregates one to three PS_OrientationAxis instances;
  - spatialReferenceSystem the system for describing a position.

7.4.2.3.3.3 Orientation Axis

As depicted in Figure 12, PS_OrientationAxis is a subtype of SC_CoordinateSystemAxis, and inherits its attributes.

One to three orientation axes are specified as instances of coordinate system axes (defined in ISO 19111) with the constraint that the unit size must be an angle.

- Class Name: PS_OrientationAxis
- Attributes and descriptions:
  - axisName CharacterString – Identifies the axis, for example ‘heading’;
  - axisDirection CharacterString – Identifies the orientation (direction or heading) of the axis for example ‘clockwise from true north’;
  - unitID UnitOfMeasure – Identifies the unit of measure on the axis, for example ‘degree’;
  - unitSize Angle – Size of the angular unit employed on the axis relative to that defined in ISO 1000.

7.4.2.3.4 Motion reference system

7.4.2.3.4.1 Introduction

The PS_MotionReferenceSystem class with its attributes and associations is shown in Figure 12.

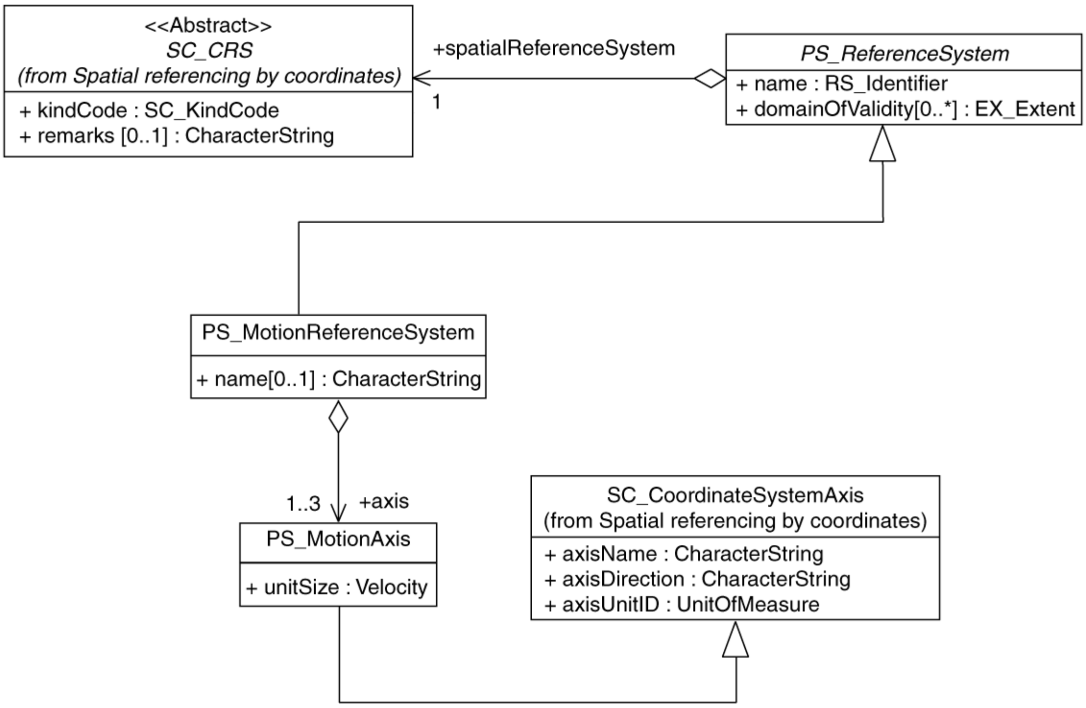

Figure 12 — UML depiction of PS_MotionReferenceSystem class with its attributes and associations

7.4.2.3.4.2 PS_MotionReferenceSystem

Motion is the rate of change in positional relationship (translation) between two spatial reference systems: one associated with the object of interest such as a vehicle, and one associated with a reference body such as the Earth. In this class, the spatial reference system specified by an SC_CRS is associated with the reference body and the set of axis descriptions specified as PS_MotionAxis are associated with the object of interest. This class is depicted in Figure 13.

— Class Name: PS_MotionReferenceSystem:

  The PS_MotionReferenceSystem class is an aggregate of a (spatial) coordinate reference system and one to three axis descriptions, which are subclasses of SC_CoordinateSystemAxis constrained to unit sizes that are velocities.

— Attributes and descriptions:

  name[0..1] CharacterString – Identifier of motion reference system.

— Associations:

  — Axis:

    The PS_MotionReferenceSystem aggregates one to three motion-axis specifications that identify the axes upon which motion is reported. The PS_MotionAxis is a subclass of SC_CoordinateSystemAxis with the constraint that the unitSize is a Velocity.

  — spatialReferenceSystem

    Motion is observable only relative to some spatial reference system. Conventionally, motion on Earth is reported relative to a terrestrial reference system, and so the coordinate reference system employed for position observation might often be the basis for motion observation as well. But, consider the distinction between the air speed and ground speed of an aircraft. Each is useful, but these shall not be confused or piloting errors could occur. Therefore identification of the spatial reference system to which motion is related is required.

7.4.2.3.4.3 Motion axis

One to three motion axes are specified as instances of coordinate system axes (defined in ISO 19111) with the constraint that the unit size shall be velocity.

PS_OrientationAxis is a subtype of SC_CoordinateSystemAxis, and inherits its attributes.

— Class Name: PS_MotionAxis;

— Attributes and descriptions:

  — axisName CharacterString – Identifies the axis;

  — axisDirection CharacterString – Identifies the motion;

  — axisUnitID UnitOfMeasure – Identifies the unit of measure on the motion axis;

  — unitSize Velocity – Measure of velocity.

7.4.2.3.5 Rotation reference system

7.4.2.3.5.1 Introduction

Rotation is observable only relative to some spatial reference system. Conventionally, rotation on or near Earth is reported relative to a terrestrial reference system, and so the coordinate reference system employed for position observation might often be the basis for motion observation as well. But, rotation can also be observed relative to another platform that is not fixed to the Earth, for example between a crane and a ship's deck. Therefore, the spatial reference system to which rotation is related shall be identified, as it is mandatory. This class is depicted in Figure 13.

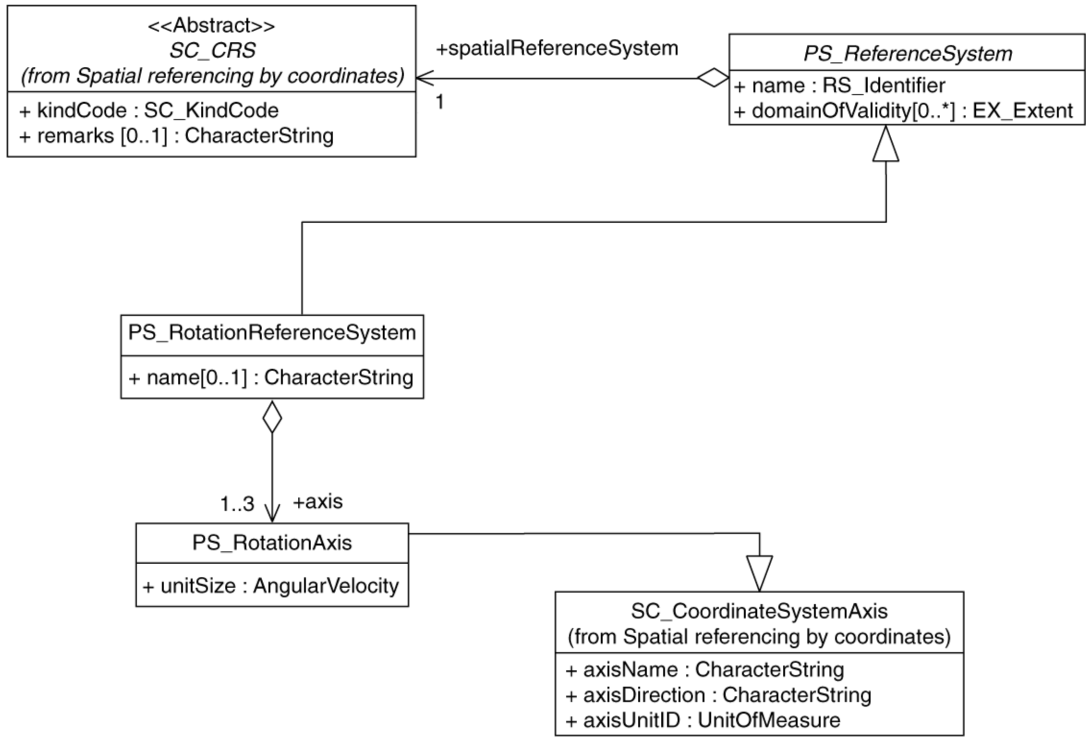

Figure 13 — UML depiction of PS_RotationReferenceSystem class with its attributes and associations

7.4.2.3.5.2 PS_RotationReferenceSystem

— Class Name: PS_RotationReferenceSystem;

— Attributes and descriptions:

  — name[0..1] CharacterString – Identifier of rotation reference system;

— Associations:

  — axis:

  The PS_RotationReferenceSystem aggregates one to three rotation axis specifications that identify the axes upon which rotation is reported. The PS_RotationAxis is a subclass of PS_CoordinateSystemAxis with the constraint that the unitSize is an AngularVelocity.

  — spatialReferenceSystem:

  identifies the spatial reference system within which rotation is reported.

7.4.2.3.5.3 Rotation axis

Rotation axes are specified as instances of coordinate system axes (defined in ISO 19111) with the constraint that the unit size shall be angular velocity.

PS_RotationAxis is a subtype of SC_CoordinateSystemAxis, and inherits its attributes.

— Class Name: PS_RotationAxis:

- Attributes and descriptions:
  - unitSize — Measure of velocity employed in the Rotation Axis;
  - axisName — String identifying the conventional name of the Coordinate System Axis;
  - axisDirection — String identifying the orientation (direction or heading) of the Coordinate System Axis;
  - axisUnitID — Identifies the unit of measure of the Coordinate System Axis.

7.4.2.4 Link to spatial reference system

Measurements made by a positioning system generally are related to the desired coordinate reference frame by some linkage within the positioning system. For example, this linkage may be established by a control point occupied by an optical instrument, a differential GPS reference station, or the initialization point of a linear measuring system. Information regarding this linkage shall be stored in zero to many instances of the PS_referenceLink class, which is an attribute of the PS_ObservationMode, as depicted in Figure 9.

To properly estimate the accuracy of a position value, knowledge of the accuracy of that link may be needed. To verify proper application of that link or detect and correct errors of application, the identity and actual linkage values shall be specified. This data structure provides for that information. When a network or other wide-scale reference method is applied rather than a single point, the name or identifier of that method should be provided.

This data structure is expected to be employed to contribute information to the legacy-data element of the quality metadata. The data structure may be repeated as required by the application. For example, a GNSS receiver implementation of a positioning service may report the link-point identification, reference coordinates and an estimate of their accuracy whenever the DGPS reference beacon station is changed. Similarly, a survey conducted with a total station through a positioning service should report one link record for each known control point occupied in the survey.

- Class Name: PS_LinkToReferenceSystem;
- Attributes and descriptions:
  - identification — CharacterString – Identifies reference link point, such as a reference station of a differential GNSS broadcast service;
  - dimensionsConstrained[1..3] — SC_CoordinateSystemAxis – Identifies axes, (e.g. latitude, longitude, and height) for which values are held as good;
  - referencePosition — vector – Coordinates of the point that accesses the reference system;
  - accuracyOfReference — DQ_QualityElement – Accuracy of the reference coordinates in their specified reference system.
- Associations: none.

7.4.2.5 Concatenated operation

Positioning systems may apply concatenated operations that change coordinate values from one coordinate reference system to another. The concatenated operation data element identifies the operations that have been applied in obtaining the observation result so that a recipient can know how transformation and conversion of coordinates was performed and the estimated accuracy of these operations.

Some operations that change coordinate values from one coordinate reference system to another are defined by analytic mathematical functions. For example, some national systems are defined with respect to the

International Terrestrial Reference Frame (ITRF) realization of a particular epoch. Other geodetic datums are related only by a statistically optimized fit based on observations at fixed points, so coordinate transformations between them employ these fitted parameters. Therefore, it is important that the users of transformed coordinates be able to identify how the coordinate transformation was performed and the estimated accuracy of the transformation. Only with this information can certain kinds of positional discrepancies between datasets be resolved.

A positioning service that applies a coordinate transformation to the position data may report the identification and accuracy of the operations applied. The operations applied are assigned identifying labels for reporting and are identified explicitly by reference to geodetic literature in documentation of the implemented system.

If an operation has been modified from the method described in a citation, for example by truncation of series computations or other approximations, that modification shall be explicitly identified.

For a more precise description of the Class CC_ConcatenatedOperation, see ISO 19111.

7.4.3 Observation

7.4.3.1 Introduction

Results of positioning observations are reported in the PS_Observation class, of which, as shown in Figure 14, instances are aggregated under instances of PS_ObservationMode that hold descriptors of the mode of operation that are common to all the observations in that set. The PS_Observation attributes includes the date and time of the positioning observation and the result vector in accordance with the reference system specified in the related PS_ObservationMode. Additional information about the observation is held in this class, including the identification of an object to which it applies, any offset between the positioning sensor and an object of interest, and any pertaining technology-specific operating information. Quality information associated with each observation can be reported using the PS_ObservationQuality class, which is described in 7.5.

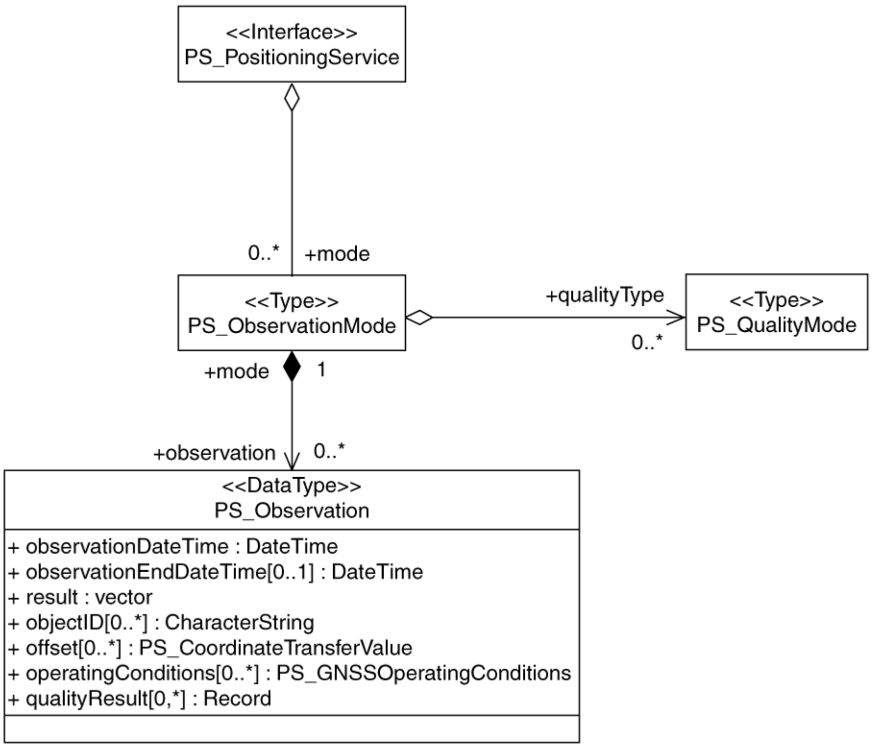

Figure 14 — UML depiction of the PS_Observation class

The objectID identifier provides a means to link the position data to other geographic object attributes, such as a navigational waypoint, a geographic feature, a control point, or an aerial photographic exposure station. The presence of this identifier is optional because many positioning instruments in current use, including many GNSS receivers, do not provide an identifier for each position fix for navigation purposes. However, one or more such identifiers may be employed in surveying and GIS development. Implementations may employ a single objectID that serves as an index or key that relates to a table of other descriptors, or multiple objectIDs may be employed as indices or keys that relate to multiple tables of descriptors. For example, the first objectID instance could be used to enumerate the observed locations, and a second objectID instance could be used to identify sequences or groups of observations, such as groups of points that collectively represent the centerlines of segments of roadway.

When the positioning service reports results as a relative positioning vector, such as in GNSS static, kinematic, or real-time kinematic relative positioning, the objectID shall identify the vector's endpoint, and the PS_ObservationMode linkToReferenceSystem shall identify the vector's origin point.

When the positioning service reports results that are computed over an observation interval rather than estimating an instantaneous position, the observationDateTime shall state the date and time at which observations used in this result were commenced and the observationEndDateTime shall state the date and time at which observations included in this result were terminated.

- Class Name: PS_Observation;
- Attributes and descriptions:
  - observationDateTime — DateTime – Date and time the observation(s) were made (or commenced),
  - observationEndDateTime[0..1] — DateTime – Date and time measurements were concluded (if not instantaneous),
  - result — vector – Vector containing the result values,
  - objectID[0..*] — CharacterString – Identifying an associated object or event,
  - offset[0..*] — PS_CoordinateTransferValue – Values relating the result to an associated object,
  - operatingConditions[0..*] — PS_GNSSOperatingConditions – Technology specific operating conditions data,
  - + qualityResult [0..*] — Record – A container for the quality result, described in PS_QualityMode;
- Associations:
  - mode:

    Each instance of a PS_Observation belongs to an instance of PS_ObservationMode so that the time and positioning values are properly associated with their respective reference systems.
  - observationQuality:

    If quality information is reported by the positioning service, each quality result is associated with an observation result.

7.4.3.2 Coordinate transfer (offset) values

7.4.3.2.1 Introduction

Position measurement can be made to a location that is offset from the actual point or object of interest, as illustrated in Figure 15, due to requirements of the positioning-service sensor equipment or for convenience of operation. In such cases, provision is made for transfer of coordinates from the measured point to the desired point through the PS_CoordinateTransferValues class, depicted in Figure 16. This offset may be the difference in location between the GPS L1 phase center of the antenna and a mounting reference point used in high accuracy geodetic measurements.

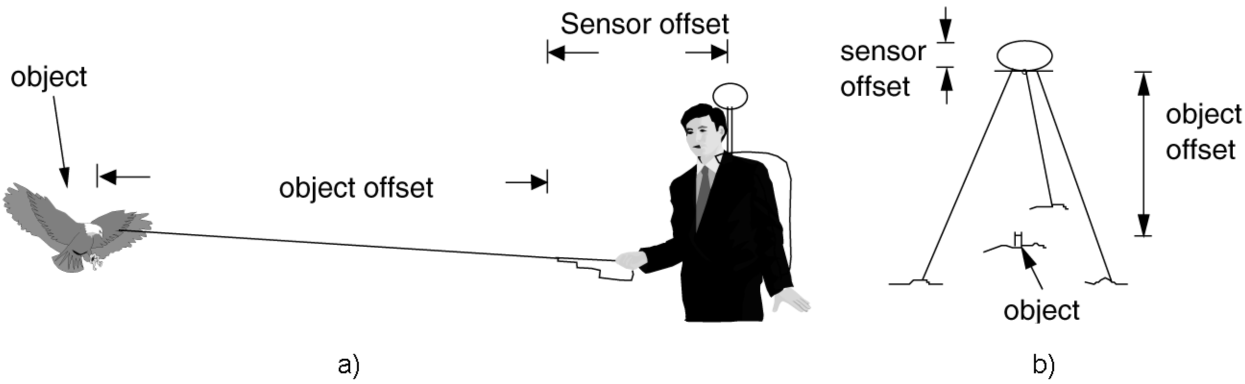

Figure 15 — Sensor offsets (a) and object offsets (b)

When the offset between the sensor position and the point of interest is important, the user needs to acquire and store the values involved. These values consist of the sensor offset and the object offset. The sensor offset values are used to store any offset between the actual point of measurement, such as the phase centre of a GNSS antenna, and a reference point representing the measurement system or platform. For example, several bodies publish antenna-offset values for many manufacturers' GNSS antenna models. The object-offset values then are used to store any offset between that reference point and the object of interest (i.e., a geographic feature). For example, object offsets might be the antenna height above a mark or might be the offset to a distant object measured by a laser rangefinder and compass.

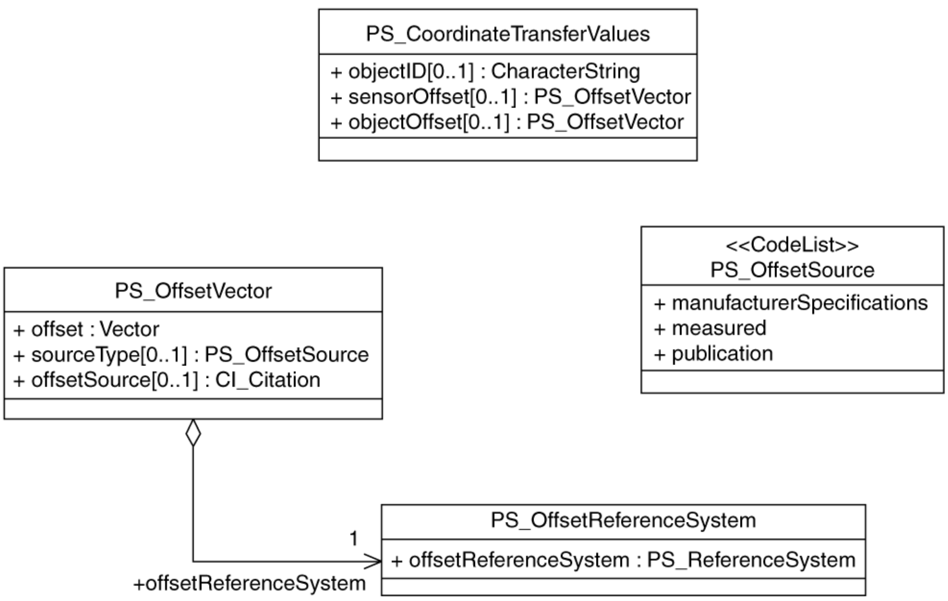

Figure 16 — UML depiction of PS_CoordinateTransferValues class with its attributes and associations

- Class Name: PS_CoordinateTransferValues:

  Values that specify the spatial relationships by which coordinates are transferred from the sensor location to the location of the point or object of interest are conveyed by the PS_CoordinateTransferValues class. This consists of offset between the sensing element and a fiducial point on the instrumentation, and from that fiducial point to an object of interest.

- Attributes and descriptions:
  - objectID[0..1] CharacterString – Identifier of the object of interest;
  - sensorOffset[0..1] PS_Offset vector – Offset from a fiducial point to the sensing point of the instrument;
  - objectOffset[0..1] PS_Offset vector – Offset from a fiducial point on the instrument to a point or object of interest.

7.4.3.2.2 Offset vector

- Class Name: PS_OffsetVector:

  Holds offset value(s) and identifies their source.

- Attributes and descriptions:
  - offset vector – Vector holding the offset value(s);
  - sourceType[0..1] PS_OffsetSourceType – Type of source from which the offset vector was obtained;
  - offsetSource[0..1] CI_Citation – Citation of source of the offset vector.
- Associations:
  - offsetReferenceSystem:

    Spatial reference system in which the offset vector is cast.

7.4.3.2.3 Offset reference system

The PS_OffsetReferenceSystem class specifies the reference system in which the offset vector is cast. This might or might not be identical to the reference system in which positioning results are cast due to the fact that some offset measurements are made separately from the primary positioning measurements. For example, a positioning service using a GNSS sensor might have an offset between the phase centre of the receiving antenna and a fiducial mark by which the antenna is aligned. The service might be reporting coordinates in degrees of latitude and longitude, though the offset is measured in millimetres above/below the fiducial mark and its axis is aligned to the local vertical. Further, if a theodolite or laser range finder is employed to measure the offset to an object of interest, that instrument might report its measurement of distance in meters on an azimuth from true or magnetic north and an elevation angle from the local horizontal, leaving application of the offset in a geodetic forward calculation to the system.

- Class Name: PS_OffsetReferenceSystem
- Attributes and descriptions:
  - offsetReferenceSystem PS_ReferenceSystem – Specifies the reference system in which the offset vector is cast.
- Associations: none.

7.4.3.2.4 PS_OffsetSourceType

— Class Name: <<CodeList>>PS_OffsetSourceType:

PS_OffsetSourceType is a list of codes by which the type of source from which an offset vector has been obtained are identified.

— Attributes and descriptions:

— manufacturerSpecifications – The values have been obtained from manufacturer's specifications.

— measured – The values have been measured.

— publication – The values have been obtained from a publication other than the manufacturer's specifications.

— Associations: none.

7.5 Quality information

7.5.1 Introduction

A positioning service may (optionally) provide quality information regarding its positioning observations, as illustrated in Figure 17. That quality information can be used to decide upon the fitness of the observation result for certain uses, for example, observations would only be used in land surveying or in populating a GIS with geographic features if their accuracy meets the specifications of the project. Observation-quality information can also be carried with the data to use in quality evaluations of larger datasets.

Positioning services generally report positioning observations in or near real time, therefore quality evaluation differs somewhat from that pertaining to GIS themes or similar spatial datasets. Quality evaluation may be performed on each observation, or on observations in small reporting groups acquired over brief intervals. Therefore, many quality measures may be computed using the same evaluation procedure and reported during a session.

Measured values are considered to have some amount of uncertainty contained in them, and, therefore, repetitions of the measurement will yield values dispersed over some range. A statement of uncertainty asserts that the value provided is not exact, and attempts to express that inexactness quantitatively. The magnitude of the uncertainty of a result is one of the most important aspects of its quality.

Generally, uncertainty cannot be determined directly, but must be estimated by appropriate quality evaluation procedures. Estimates of uncertainty can be based on statistical methods, previous experience with the system or professional judgement considering knowledge of measuring methods, field conditions, equipment capabilities, computational methods and geometric characteristics among others. The means used for quality evaluation shall be characterized in accordance with the specifications of ISO 19114 when quality measures are associated with positioning results.

When uncertainty estimation is made with respect to values that can best be accepted as approximating truth, the uncertainty expression is termed "accuracy" or "absolute accuracy".

When uncertainty estimation is made with respect to values best approximating the true values of differences within a dataset or within a positioning system implementation, the uncertainty expression is termed "relative accuracy".

When uncertainty estimation is made with respect to the consistency of repeated measurements, made under similar conditions, with each other but without comparison to independent values acceptable as approximations of truth, the uncertainty expression is termed "precision".

Ideally, the accuracy of positioning observations would be reported by stating an estimated value for the residual uncertainty, but this is not always feasible within the positioning service itself. Often there is no real-time access to an independent source of higher accuracy values for comparison.

In such cases, though, it might be possible to estimate observation precision, e.g. the repeatability of measurements, rather than to estimate the actual accuracy. For this reason, an additional quality sub-element, precision, is defined for positioning services. Additional quality sub-elements may also be user-defined in accordance with ISO 19113 for use in positioning services implementations.

To avoid repetition of information, the PS_QualityElement class is associated with the PS_ObservationMode so that when the configuration information for a mode of operation is specified, the corresponding quality reporting configuration can be associated with it. This allows the positioning observations made in a particular mode of operation to be associated with quality measures made by a particular evaluation procedure without ambiguity.

The evaluation descriptor may be held either in the PS_QualityElement class or the DQ_QualityMeasure class, but in positioning services it will normally be held in the PS_QualityElement class because it is associated with a mode of operation.

Data-quality results can be quantitative results or conformance results, and both kinds are applicable to positioning observations. For example, accuracy and precision values are quantitative results, but coded performance indicators and system integrity monitors are conformance results.

Because of the complexity of positioning calculations, it is particularly important in positioning services to clearly specify the evaluation procedure by which quality results are obtained. This includes specifying whether the quality pertains to horizontal, vertical or three-dimensional errors. When three-dimensional values are reported, distinguish whether each of the three dimensions has a separate quality value or a single value reports a spherical quality estimator. It is necessary to state the nature of the statistical quantity utilized, such as mean error, probable (median) error, or standard (RMS) error, and whether the statistic itself is based upon a one-, two- or three-dimensional distribution function. It is also essential to clearly identify the source of comparison values in making accuracy or precision evaluations.

Positioning services may make quality evaluations based on internal evidence, such as comparison of closely spaced repeat measurements, signal characteristics and geometric factors, or computations involving overdetermined observables. In such cases, precision, or some user-defined sub-elements, will be more appropriate quality measures than accuracy.

When neither independent sources of comparison nor internal evidence is available, positioning services may report quality information based upon typical performance under similar circumstances. In such cases, the basis of such reporting and the nature of validation testing should be explicitly stated.

Implementations of positioning services may provide substantial portions of the evaluation procedure information in the product documentation accompanying the system and convey the reference to that documentation in the quality data structures by citation.

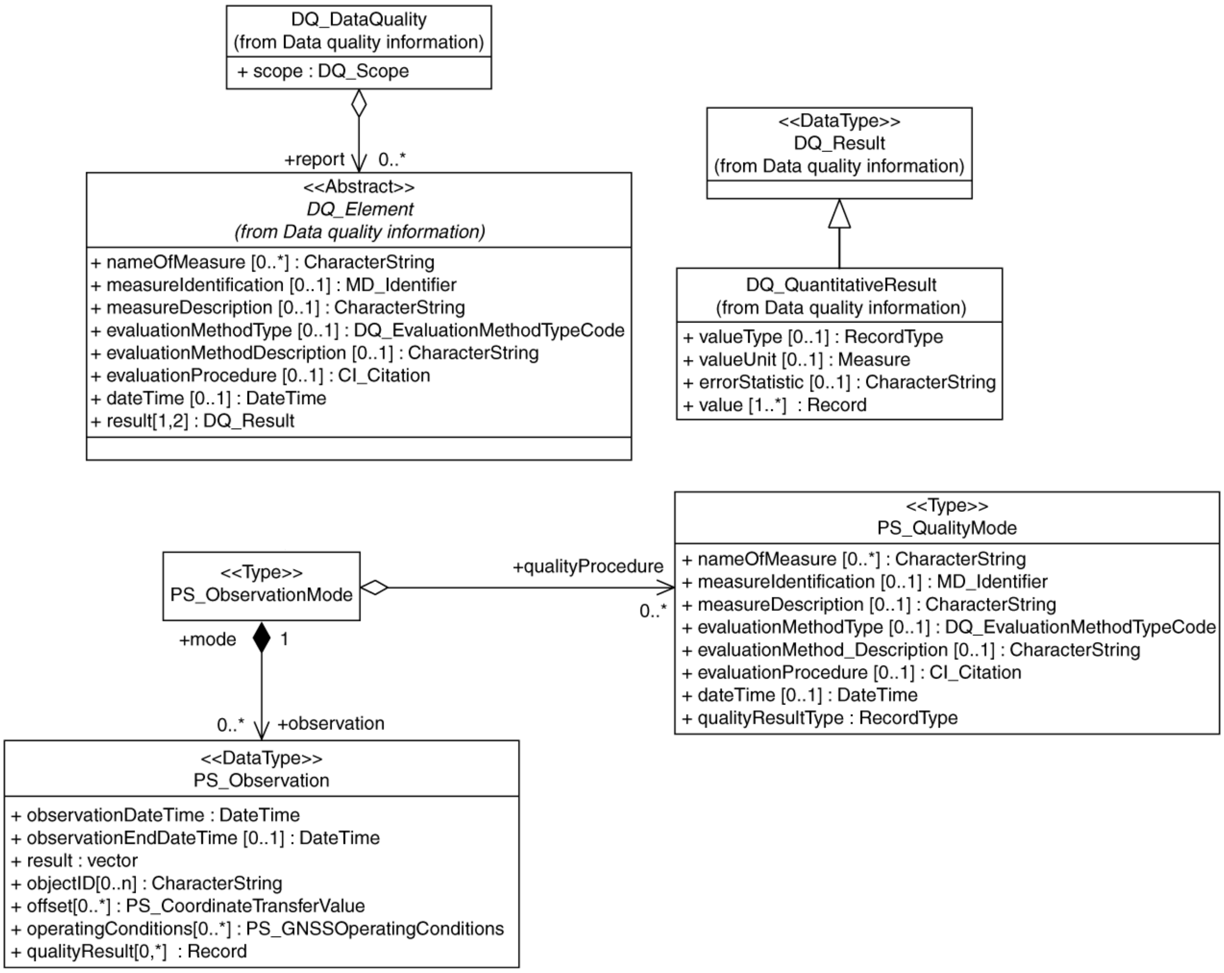

Figure 17 — UML depiction of positioning services quality reporting classes

7.5.2 PS_QualityMode

— Class Name: PS_QualityMode:

PS_QualityElement holds attributes that are similar to those of DQ_Element described in ISO 19115, and identifies the data-quality element to be reported and the evaluation procedure by which it is evaluated. This information is expected to be employed in generation of the DQ_Element metadata or similar reports or for automated decision processes requiring quality information about the observation results.

— Attributes and descriptions:

- — nameOfMeasure[0..*] — CharacterString – name of the test applied to the data;
- — measureIdentification[0..1] — MD_Identifier – code identifying a registered standard procedure;
- — measureDescription[0..1] — CharacterString – description of the measure being determined;
- — evaluationMethodType — DQ_EvaluationMethodTypeCode – type of method used to evaluate quality of the dataset;

- evaluationMethodDescription [0..1] — CharacterString – description of the evaluation method;
- evaluationProcedure[0..1] — CI_Citation – reference to the procedure information;
- dateTime[0..1] — DateTime – date or range of dates on which a data quality measure was applied;
- qualityResultType — RecordType – identifies elements in the corresponding quality result record(s).

— Associations:

PS_QualityMode instances are aggregated by PS_ObservationMode.

8 Technology-specific information

8.1 Introduction

Technology-specific information classes permit a positioning service to obtain and convey information that is not applicable to all technologies but may be needed in application of specific technologies. The specifications of technology-specific classes may vary from one technology to another. In general, technology-specific information can be categorized into two groups:

a) Operating Conditions – Information pertaining to the operation and performance of the system;

b) Raw Measurement Data – Values of the observables from which the technology derives positioning results.

This International Standard provides classes and definitions for the GNSS technology only, though their structure can be used as a basis for extension of this International Standard to other technologies.

8.2 GNSS Operating Conditions

8.2.1 Introduction

To use data application or archival metadata, the communication of details of operating conditions is often required. These details can be grouped into those which indicate the mode of position or related computation (the mathematical model applied to derive the result), those which indicate the measurement conditions (the qualities of the raw data from which a result is derived) and those coded performance indicators which summarize these into a simpler indicator which can guide an operator's decision as to the use of that result. These same values are applied in estimation of accuracy and precision by some implementations, but do not necessarily represent accuracy.

Figure 18 illustrates the operating conditions for GNSS.

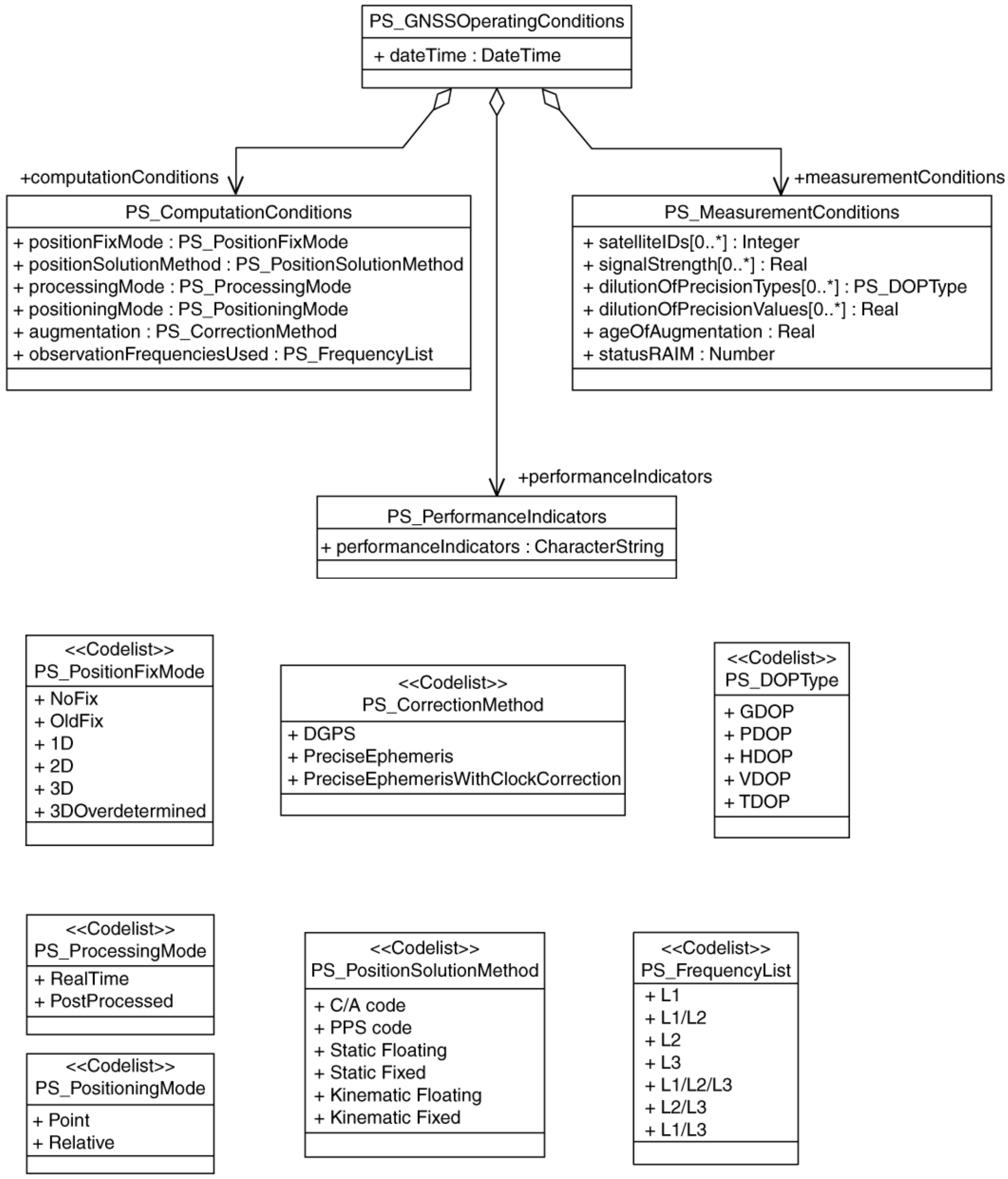

Figure 18 — UML depiction of the PS_GNSSOperatingConditions class with its attributes

8.2.2 PS_GNSSOperatingConditions

- Class Name: PS_GNSSOperatingConditions;
- Attributes and descriptions:
  - dateTime: -Date and time the measurements of the Operating Conditions are valid;
- Associations:
  - computationConditions – Provides parameters that indicate method of position computation;
  - performanceIndicators – Provides parameters that indicate level or quality of system performance;
  - measurementConditions – Provides parameters that indicate conditions under which measurements have been made.

8.2.3 PS_ComputationalConditions

8.2.3.1 Introduction

Computational Conditions data provides those parameters of the positioning-service device that indicate its mode of position computation for interpretation by the user or application. An example is indication of whether a three-dimensional position has been obtained so that the height value in the position data can be applied.

- Class Name: PS_ComputationalConditions;
- Attributes and descriptions:
  - positionFixMode — PS_PositionFixMode – Type of positioning solution obtained;
  - positionSolutionMethod — PS_PositionSolutionMethod – Type of algorithm applied for positioning;
  - processingMode — PS_ProcessingMode – Indicates whether real-time or post-processed solution;
  - positioningMode — PS_PositioningMode – Basis of positioning model;
  - augmentation — PS_Augmentation – Type of augmentation system being applied;
  - observationFrequenciesUsed — PS_FrequencyList – Frequency(ies) observed for positioning.
- Associations: none.

8.2.3.2 Position-fix mode

- Class Name: <<CodeList>> PS_PositionFixMode;

  Designations of the positioning solution types according to the number spatial dimensions that can be determined from the set independent observables available at the time of computation.

- Attributes and descriptions:
  - No fix — Insufficient observables are available to compute a position fix;
  - Old fix — Only available position fix information is stale;
  - 1D — Only enough observables are available for time observation;
  - 2D — Enough observables are available for a two-dimensional fix;
  - 3D — Enough observables are available for a three-dimensional fix;
  - 3D overdetermined — Enough observables are available for a three-dimensional fix with additional degrees of freedom for statistical computations;
- Associations: none.

8.2.3.3 Position solution method

— Class Name: PS_PositionSolutionMethod;

— Attributes and descriptions:

- — C/A code – GNSS Coarse/Acquisition code;
- — PPS code – GNSS Precise Positioning Service P or Y code;
- — Static Floating – Double difference vector with floating integer part and antennas stationary during observation;
- — Static Fixed – Double difference vector with fixed integer part and antennas stationary during observation;
- — Kinematic Floating – Double difference vector with floating integer part and antenna mobile during observation;
- — Kinematic Fixed – Double difference vector with fixed integer part and antenna mobile during observation;

— Associations: none.

8.2.3.4 Positioning mode

— Class Name: <<CodeList>> PS_PositioningMode;

Codes to designate the nature of the positioning system's connection to its reference system;

— Attributes and descriptions:

- — Point:

  Point positioning – position determined directly in the reference system by known parameters of the system, for example autonomous GNSS positioning and positioning from astronomical observations.

- — Relative:

  Relative positioning – position determined relative to another point used by the positioning system, for example inertial positioning, double difference GNSS vector positioning (static or kinematic), and positioning with theodolite or total station.

— Associations: none.

8.2.3.5 CorrectionMethod

— Class Name: <<CodeList>>PS_CorrectionMethod;

— Attributes and descriptions:

- — DGPS   Differential GPS correction,
- — PreciseEphemeries   Precise ephemeries,
- — PreciseEphemeriesWithClockCorrection   Precise ephemeries with clock correction;

— Associations: none.

8.2.3.6 Frequency list

- Class Name: <<CodeList>> PS_FrequencyList;

  Identifiers of the frequency band designations employed in GNSS positioning systems and their combinations that may be observed to obtain positioning results.

- Attributes and descriptions:
  - L1 Positioning solution employed solely L-band frequency 1;
  - L2 Positioning solution employed solely L-band frequency 2 observables;
  - L3 Positioning solution employed solely L-band frequency 3 observables;
  - L1/L2 Positioning solution employed observables from L-band frequencies 1 and 2;
  - L2/L3 Positioning solution employed observables from L-band frequencies 2 and 3;
  - L1/L3 Positioning solution employed observables from L-band frequencies 1 and 3;
  - L1/L2/L3 Positioning solution employed observables from L-band frequencies 1, 2 and 3;
- Associations: none.

8.2.4 Performance indicators

Some systems provide performance-indicator information coded by some indicator (usually numeric) which incorporates system-operating conditions and measurement conditions into a single performance indicator. Consequently, the operator's decisions as to suitability for use can be guided with less complexity than is required to interpret the many operating and measurement-condition values. Since these indicators are both technology- and implementation-specific, their meaning and interpretation is not standardized, but reserved for negotiation between the manufacturer and the user. Instead, provision for their communication is standardized.

- Class Name: PS_PerformanceIndicators;
- Attributes and descriptions:
  - performanceIndicator CharacterString – Values of the system's performance indicators;
- Associations: none.

8.2.5 Measurement conditions

8.2.5.1 Introduction

The conditions under which a particular position or related measurement has been made are useful for judging the quality of the result, for diagnosis of problems and/or for archival documentation of how a particular result was derived. Therefore, these conditions are transmitted in a standardized manner. Because significant measurement conditions vary between technologies, these sub-elements are specified as technology-specific items.

In the case of GPS positioning services, the satellites received, the strength of their signals and their geometric parameters are among the most important conditions affecting the quality of the position result. In addition, the selection and age of augmentation data, such as differential correction, indicate the quality of the position result. Certain implementations include capability for Receiver Autonomous Integrity Monitoring (RAIM), which identifies for the operator any failure of the integrity of the GPS as a positioning service.

8.2.5.2 Positioning-measurement conditions

8.2.5.2.1 Introduction

- Class Name: PS_MeasurementConditions;
- Attributes and descriptions:
  - satelliteIDs — sequence<integer> – Sequence of space vehicle identification numbers;
  - signalStrengths — sequence<real> – Number identifying the strengths of the signal;
  - dilutionOfPrecisionTypes — sequence<PS_DOPType> – Identification of dilution of precision parameters;
  - dilutionOfPrecisionValues — sequence<real> – Values of dilution of precision parameters;
  - ageOfAugmentation — real – Interval in seconds since most recent update of augmentation values;
  - statusRAIM — Number – Receiver autonomous integrity monitoring result;
- Associations: none.

8.2.5.2.2 Dilution of precision type

- Class Name: <<CodeList>>PS_DOPType;
- Attributes and descriptions:
  - GDOP Geometric dilution of precision,
  - PDOP Positional dilution of precision,
  - HDOP Horizontal dilution of precision,
  - VDOP Vertical dilution of precision,
  - TDOP Time dilution of precision;
- Associations: none.

8.3 Raw measurement data

Raw measurement data are transmitted by the positioning system instrument to a data-recording instrument for subsequent processing into position solution data. This processing may occur in real time or post mission. In either case, the data recording instrument is responsible for the proper storage of the data structures. Raw measurement data structures are positioning-system dependent. GPS raw measurement data consist of the GPS observables, time, orbital parameters and optional meteorological data, tide gauge or tilt sensor data for example. This procedure currently is available through either proprietary defined specifications or through industry-adopted specifications, for example RINEX. This procedure is outside the scope of this International Standard.

Annex A
(normative)

Conformance

A.1 Conformance

Table A.1 — Levels of conformance for positioning services data elements

Basic data								**Extended data**		
System information		Session info	Positioning observation information					Technology specific		
System Type	Ref Info	Session ID	Value Info	Ref System	Quant Element Report	Link to Ref System	Coord Transfer Info	Operating Conditions	Perform Indicators	Raw Values
M[a]	M[a]	O[c]	M_1[b]	M_1[b]	O[c]	O[c]	O[c]	O[c]	O[c]	O[c]

[a] M Mandatory.

[b] M_1 At least one of the measurement types: Position, Attitude, Motion, or Rotation shall be implemented.

[c] O Optional.

The requirement for the presence of mandatory elements makes no statement regarding access to the information content of these elements. Public access to some mandatory elements might be provided or restricted by procedural rules outside the scope of this International Standard. Where access to detailed values of parameters may be limited, reference by name or other identifier is supported by this International Standard.

This International Standard defines two conformance classes: Basic (that any implementation shall meet) and Extended (for technology-specific data related to positioning system), see Table A.1. Any positioning services implementation or product that claims conformance with this International Standard shall pass all the requirements described in the following corresponding abstract test suite.

A.2 Abstract test suite for basic conformance

A.2.1 Positioning services device

a) Test Purpose: Check conformance of positioning services device to this International Standard;

b) Test Method: Verify existence (presence) of positioning services;

c) Reference: this International Standard, Clause 6;

d) Test Type: Basic;

e) Test Verdict: Pass/Fail.

A.2.2 System information (mandatory)

a) Test Purpose: Check conformance of system information to this International Standard;

b) Test Method:

1) Verify existence (presence) of system information,

2) If system information exists, verify that positioningTechnology (mandatory) and reference method (mandatory) are present and structured as specified in this International Standard,

3) For each content item, verify that content values are present and consistent with definitions provided by this International Standard;

c) Reference: this International Standard, 7.2;

d) Test Type: Basic;

e) Test Verdict: Pass/Fail.

A.2.3 Session identification (optional)

a) Test Purpose: Check conformance of session information to this International Standard;

b) Test Method:

1) Verify existence (presence) of session information,

2) If Session Information exists, verify that SessionID (mandatory) and startTime (mandatory) Information (optional) are present and structured as specified in this International Standard,

3) For Session Information, verify that the content value is present and consistent with definitions provided by this International Standard;

c) Reference: this International Standard, 7.3;

d) Test Type: Basic;

e) Test Verdict: Pass/Fail.

A.2.4 Mode information (mandatory)

a) Test Purpose: Check conformance of mode information to this International Standard;

b) Test Method:

1) Verify existence (presence) of mode information,

2) Identify the existence of the data sub-elements resultType, TemporalReferenceSystem and positionalReferenceSystem implemented in the PS_ObservationMode class (shall implement at least one instance of PS_ObservationMode), and observationDateTime and result from the associated PS_Observation class,

3) For each sub-element implemented, verify that content items are present and structured, as specified in this International Standard,

4) For each content item, verify that content values are present and consistent with definitions provided by this International Standard,

5) Determine which optional data sub-elements, as identified in this International Standard, are implemented. If these data subelements are not present, conformance is not invalidated;

c) Reference: this International Standard, 7.4;

d) Test Type: Basic;

e) Test Verdict: Pass/Fail.

A.3 Abstract test suite for extended conformance

A.3.1 Technology-specific operating conditions (optional)

a) Test Purpose: Check conformance of technology-specific operating conditions to this International Standard;

b) Test Method:

1) Verify existence (presence) of technology-specific operating conditions (PS_OperatingConditions),

2) If technology-specific operating conditions exist, verify that the operating conditions are present and structured as specified in this International Standard,

3) For each content item, verify that the operating conditions are present and consistent with definitions provided by this International Standard;

c) Reference: this International Standard, 8.2;

d) Test Type: Basic;

e) Test Verdict: Pass/Fail.

A.3.2 Technology-specific performance indicators (optional)

a) Test Purpose: Check conformance of technology-specific performance Indicators to this International Standard;

b) Test Method:

1) Verify existence (presence) of technology-specific performance indicators,

2) If technology-specific performance indicators exist, verify that the performance indicators are present and ordered as specified in this International Standard,

3) For each content item, verify that the performance indicators are present and consistent with definitions provided by this International Standard;

c) Reference: this International Standard, 8.2.4;

d) Test Type: Basic;

e) Test Verdict: Pass/Fail.

Annex B
(informative)

Implementing accuracy reports for positioning services

B.1 Introduction

A positioning service may report the quality of positioning results so that the devices using this information can potentially screen information for usability, and store sufficient information for generation of quality reporting metadata. The following structure is suggested for positioning-services specific reporting tasks, showing how the positioning-services-specific detailed items can be aggregated for reporting as data quality metadata.

B.2 Structure of descriptors for data quality sub-elements identified as applicable for positioning services

The positional accuracy sub-element is described by the following:

- Data-quality measure, consisting of
  - statistic or indicator, such as standard deviation, RMSE, % confidence interval, probable error;
  - conformance with associated dimension, which may be one-dimensional, two-dimensional, three-dimensional;
  - associated quality measure component terms, such as
    - base part (constant error term),
    - higher order error terms (seldom used, but allowable).
- Data-quality value type, consisting of
  - characteristic, such as Boolean, distance, angle, ratio, change in position over time;
  - associated unit of measure, if dimensional, such as feet, centimetres, meters;
  - associated orientation, such as vertical, horizontal, spherical, specified single-axis.
- Data-quality evaluation procedure, consisting of
  - evaluation method, such as statistical calculating procedure;
  - with associated basis of comparison, such as short phrase designating the basis to which accuracy is referenced.
- Data-quality result: the resultant value(s).
- Data-quality scope: identification of the scope to which a data quality measure has been applied.
- Data-quality date: one data quality date for each data quality measure.

Table B.1 shows the possible data-quality sub-elements, quality measures and value domain.

Table B.1 — Possible data quality sub-elements, including quality measure and value domain

Data quality sub-element	Data-quality measure	Data-quality value domain	Types of data-quality scopes to which a data quality measure may be applied
Absolute or external accuracy – closeness of reported coordinate values to values accepted as being true	pass-fail	Boolean variable	dataset series dataset reporting group – features
	error statistic: - standard deviation, RMSE - % confidence level error statistic dimension: - one-dimensional - two-dimensional - three-dimensional measure components: - base error - proportional error	Boolean variable angle change in position over time distance number ratio (See notes 1 and 2.)	reporting group – feature attributes: applicable only to feature attributes that supply coordinate values
Relative or internal accuracy – closeness of the positional relationships of features in a dataset to the relationships accepted as being true	pass-fail	Boolean variable	dataset series dataset reporting group – features
	error statistic: - standard deviation, RMSE - % confidence level error statistic dimension: - one-dimensional - two-dimensional - three-dimensional measure components: - base error (See note 3.)	Boolean variable angle change in position over time distance number ratio (See notes 1 and 2.)	reporting group – feature attributes: applicable only to feature attributes that supply coordinate values

NOTE 1 These data-quality value domains require a statement of the orientation of the domain such as vertical, horizontal, spherical, specific axis, etc.

NOTE 2 Dimensional data-quality value domains such as distance require a statement of the unit of measure, such as feet or meters.

NOTE 3 Data-quality measures must be consistent with the coordinate reference system identified in the product specification. For example, a dataset in a compound coordinate system may be tested by both horizontal data quality measures and vertical data quality measures.

B.3 Generalize to dataset accuracy

B.3.1 Example 1 — Accuracy of a map

For a 1:25 000 map meeting national map-accuracy standards, the quality element for positional accuracy may be reported in the following way:

— Data-quality measure:

Result reported in terms of conformance with the positional requirements of national map-accuracy standards.

— Data-quality value domain:

The value domain is Boolean (true or false).

— Data-quality procedure:

Positions on the map are compared with positions of corresponding features obtained by or from an independent source of higher accuracy, for example, a ground survey of positions determined for identifiable points independent of the control points used to produce the map. If the position differences between the map-derived position and ground survey position for the test points fall with allowable limits for distance and percentage of points that must pass the test as specified by national map accuracy standards, the map is in compliance, otherwise it fails the accuracy test.

— Data-quality result:

Meets or fails positional requirements for national map accuracy standards.

— Data-quality date:

Date of map publication.

— Data-quality scope

Quality is reported at the dataset level, where the dataset is the map. Only positions of “well-defined” points are evaluated to produce the data quality result.

B.3.2 Example 2 — Positional stability of survey marks

The position of a survey mark may change over time due to

— plate-tectonic movement;

— local or regional subsidence;

— changes to moisture content in reactive soils;

— other factors.

The movement may cause the published accuracies (determined at the time of computation) to become seriously misleading.

A set of Positional Stability parameters has been devised to address this situation. The parameters indicate the rate at which positional accuracy is expected to degrade due to mark movement. A separate parameter is available for each coordinate axis. Note the following.

— The parameters are based on local knowledge of ground conditions.

— The parameters indicate degradation relative to the coordinate system in use. Thus, if a national coordinate system is fixed to a tectonic plate, movement of the plate will not result in positional degradation.

— The parameters do not indicate the actual change in coordinate values. Rather, they indicate the rate at which the published coordinate accuracy is degrading.

B.3.3 Example 3 — Positional accuracy of the horizontal network

— Data-quality measure:

Result reported in terms of conformance with the horizontal confidence-interval requirements as specified in national coordinate reference-system accuracy standards.

— Data-quality value domain:

The value domain for the coordinates at the time of measurement is Boolean. This is qualified by the change in position over time.

— Data-quality procedure:

The coordinate accuracy as derived from the measurements is based on the specified confidence level, e.g. 95 %, relative-error ellipses generated by a statistically valid least squares adjustment. The semi-major axes of the error ellipses are compared against criteria included in national coordinate reference-system accuracy standards.

— Data-quality result:

Meets or fails criteria specified in the national coordinate-reference system accuracy standards.

— Data-quality date:

Date of coordinate computation.

— Data-quality scope:

Quality is reported at the network level.

B.3.4 Example 4 — Accuracy of position data subjected to coordinate transformation between datums

When a positioning service delivers data in a coordinate reference system different from the system in which its native measurements and calculations are performed, the coordinates are commonly converted and transformed from the system's native coordinate reference system to the coordinate reference system desired by the user of the position data. Most coordinate transformations between geodetic datums degrade the accuracy of the result. The magnitude of this degradation is sometimes greater than the error inherent in the original observations, so the resultant accuracy must be reported as the applicable quality values.

For example, when position results achieved at some level of accuracy are transformed to a different datum, the accuracy of the transformed coordinates may not be maintained if the accuracy of the parameters used in the coordinate transformation are less accurate than the accuracy for the original position results.

For some countries, several coordinate transformation formulae have been published, including three-parameter and seven-parameter similarity transformations (often known as Molodensky and Bursa-Wolf transformations, respectively). When coordinate transformation is performed between an older or historical datum and a new or modern datum through the three-parameter transformation, distortions in the old or new datum may cause the transformed coordinates to be less accurate.

In the case where the coordinate transformation process is consistent over small areas, substantial random errors are not introduced. Consequently, the accuracy of the spatial relationship to nearby features may be largely preserved, but the accuracy of the transformed coordinates relative to a national datum might be substantially degraded.

Alternatively, a seven-parameter transformation between an old and a new datum, if available, might provide superior accuracy to the three-parameter version of that transformation.

Bibliography

Selected works potentially of interest to users of this International Standard.

[1] *Datums, Ellipsoids, Grids and Grid Reference Systems*, NIMA TM8358.1, National Imagery and Mapping Agency Technical Report, September 1990. Available at <http://164.214.2.59/GandG/puborder.html>

[2] *Geodesy Parameters*, EPSG, July 1999. Available at <http://www.epsg.org/>

[3] *Geodetic Codes and Parameters*, The Digital Geographic Information Exchange Standard (DIGEST), June 1997, draft 3.0, edition 2.0, part 3, chapter 6. Available at <http://www.digest.org/html/gp36.htm>

[4] Glossary of the Mapping Sciences, American Society for Photogrammetry and Remote Sensing, American Congress on Surveying and Mapping, and American Society of Civil Engineers, 1994. Available at <http://www.asprs.org/publications.html>

[5] *Guide to the expression of uncertainty in measurement* (*GUM*), published jointly by BIPM/IEC/IFCC/ISO/IUPAC/IUPAP/OIML, *1993 (Corrected and reprinted, 1995)*

[6] TAYLOR, B. N., and KUYALL, C. E., *Guidelines for Evaluating and Expressing Uncertainty in NIST Measurement Results,* National Institute of Standards and Technology NIST Technical Report 1297, 1994

[7] ISO 6709:1983, *Standard representation of latitude, longitude and altitude for geographic point locations*

[8] ISO 8601:2000, *Data elements and interchange formats — Information interchange — Representation of dates and times*

[9] ISO 19101:2002, *Geographic information — Reference model*

[10] ISO 19107:2003, *Geographic information — Spatial schema*

[11] ISO 19119:—[1]), *Geographic information — Services*

[12] *Recommended Standards for Differential NAVSTAR GPS Service*, Version 2.1, RTCM Paper 194-93/SC 104-STD, RTCM (Radio Technical Commission for Maritime Services), January 1994. Available at <http://www.navcen.uscg.gov/pubs/dgps/rctm104/Default.htm>

[13] GURTNER, Werner, *RINEX: The Receiver Independent Exchange Format*, Version 2, Astronomical Institute, University of Berne, September 1998. Available at: <ftp://igscb.jpl.nasa.gov/igscb/data/format/rinex2.txt>

[14] NMEA 0183, *Standard for Interfacing Marine Electronic Devices*, Version 2.30, National Marine Electronic Association, March 1, 1998. Available at <http://www.nmea.org/pub/0183/index.html>

[15] NIMA TR8350.2, *DoD World Geodetic System 1984 — Its Definition and Relationships with Local Geodetic Systems*, Third Edition, National Imagery and Mapping Agency Technical Report, July 1997. Available at <http://164.214.2.59/GandG/puborder.html>

ICS 35.240.70

Price based on 51 pages