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OpenGIS® GML 3.2 image geopositioning metadata application schema

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i. Preface

This draft specifies a GML 3.2 Application Schema for image geopositioning metadata. This schema is also an Application Schema of ISO 19139. This geopositioning metadata schema is used by the separately specified Image Geopositioning Service (IGS) interface.

Suggested additions, changes, and comments on this draft are welcome and encouraged. Such suggestions may be submitted by email message or by making suggested changes in an edited copy of this document.

ii. Document terms and definitions

This document uses the specification terms defined in Subclause 5.3 of [OGC 05-008], which is based on the ISO/IEC Directives, Part 2. Rules for the structure and drafting of International Standards. In particular, the word “shall” (not “must”) is the verb form used to indicate a requirement to be strictly followed to conform to this specification.

iii. Submitting organizations

The following organizations submitted this document to the Open Geospatial Consortium Inc.

BAE Systems E&IS

iv. Document contributor contact points

All questions regarding this document should be directed to the editor or the contributors:

Name	Organization
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v. Revision history

Date	Release	Editor	Primary clauses modified	Description
2006-06-05	0.0.0	Arliss Whiteside	All	First draft
2006-07-03	0.0.0	Arliss Whiteside	vii, 7.2, 8.2, 9.2, 10.2, 11.2	Editorial improvements

vi. Changes to the OGC Abstract Specification

The OpenGIS® Abstract Specification Topic 11 "Metadata" (which includes ISO 19115) requires the following change to accommodate the technical contents of this document:

a) Change the "Maximum Occurrence" value from "1" to "N" of the valueUnit attribute of the DQ_QuantitativeResult class, in Figure A.4 of Subclause A.2.4.1 and in item 135 of Subclause B.2.4.4.4. (The corresponding change is also needed in ISO 19139.)

vii. Future work

Extensions of this Application Profile are desirable to:

a) Define specific image geometry (sensor) models. To allow useful implementation, at least one extension of this Application Profile is needed, that specifies at least one specific image geometry model. For each specific image geometry model added to this Application Schema, it is necessary to specify:

   1) A concrete subclass of one of the abstract classes GIG_MovingSensorParameters or GIG_StationarySensorParameters, which specifies the (exterior) orientation parameter values for that sensor
   2) A concrete subclass of the abstract class GSC_SensorParameterValues, which specifies the (interior) orientation parameter values for that sensor
   3) GML Application Schema for encoding two items listed above
   4) Specific parameters and sub-groups in a CC_OperationParametersGroup, which correspond to item 1)
   5) Specific parameters and sub-groups in a CC_OperationParametersGroup, which correspond to item 2)
   6) XML document(s) encoding two items listed above
   7) Specific "formula" referenced by the CC_OperationMethod that is referenced by GSM_ObjectImageTransformation, which uses the parameters and groups specified in items 3) and 4)

NOTE 1 More generally, several extensions of this Application Profile that each specifies one or more specific image geometry model seem desirable. As stated and explained in Section 2.10 of OGC Abstract Specification Topic 16 [OGC 00-116]: "A number of different image geometry models are needed, for exploiting different image types under different conditions. Multiple different image geometry models should thus be standardized by the OGC (in the long term). However, some proprietary image geometry models are expected to exist, and not be standardized."

NOTE 2 Where relevant, these specific image geometry models should build upon and adapt the Sensor Markup Language (SensorML), Transducer Markup Language (TML), and ISO 19130 (Sensor data model for imagery and gridded data).

b) Define image geometry (sensor) model components. For efficient extension of this Application Profile to more models, at least one extension of this Application Profile is needed, that specifies several components which are and/or can be used in multiple image geometry models.

EXAMPLES Possible components that could be used in multiple image geometry models would model lens distortion, atmospheric refraction, projection optics, correction functions, etc.

c) Stereoscopic pairs of images. An extension is desirable to more completely handle pairs of images that are expected to be exploited stereoscopically.

d) More covariance matrix types. Define additional subclasses of GCM_CovarianceMatrix for efficiently recording other covariance matrix types.

e) Triangulation results. An extension is desirable to more completely specify useful results from a triangulation

f) Image strip. Improvement is desirable to better handle strips of images.

g) Examples. An extension is desirable to include example XML documents.

h) Specify GML 3.2 and ISO 19139 profiles used. The profiles of GML 3.2 and ISO 19129 that are used by this Application Schema should be explicitly determined and documented, to simplify understanding those profiles.

Foreword

This document does not replace any previous OGC document, in whole or in part. This image geopositioning metadata application schema is used by the separately specified Image Geopositioning Service (IGS). That service is a specific Geodata Registration Service as described in Section 3.6 of OGC Abstract Specification Topic 15: Image Exploitation Services [OGC 00-115]. That service is designed to support the Register Images use case described in Section 2.1.2.5 of OGC Abstract Specification Topic 15: Image Exploitation Services [OGC 00-115].

This Application Schema uses small profiles (or subsets) of GML 3.2 (ISO 19136) and ISO 19139, although those profiles are not yet formally specified. For GML, the profile used is a subset of the GML grid CRSs and simple features profiles. For ISO 19139, the profile is a subset of the ISO 19139 profile that is used by GML 3.2 (ISO 19136).

This document includes three annexes; Annexes A and B are normative, and Annex C is informative.

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

Introduction

This document specifies a GML 3.2 Application Schema for image geopositioning metadata, which is also an Application Schema of ISO 19139. This geopositioning metadata schema is used by the separately specified Image Geopositioning Service (IGS) interface that adjusts the georeferencing coordinate transformations of images.

This XML schema encodes image georeferencing coordinate transformations with associated parameter error statistics. These georeferencing coordinate transformations can use many possible image geometry (or sensor) models that can be encoded using extensions of this Application Schema.

This application schema also encodes point positions measured in one of more images and optional object coordinates, with associated position error statistics. These object points can be tie points, control points, or check points. A control or check point has a measured position with position error statistics in one or more images, and a known position with error statistics in some geodetic Coordinate Reference System (CRS). A tie point has a measured position with error statistics in two or more images, but not a known position in any geodetic CRS.

Error statistics are represented as variance-covariance matrices, representing both absolute and relative accuracies. These covariance matrices are used to represent correlations between the accuracies of different coordinates, parameters, and positions.

OpenGIS® GML 3.2 image geopositioning metadata application schema

1 Scope

This document specifies a GML 3.2 Application Schema for image geopositioning metadata, which is also an Application Schema of ISO 19139. This geopositioning metadata is designed for use by a separately specified Image Geopositioning Service (IGS) that adjusts the georeferencing coordinate transformations of images.

This XML schema encodes image georeferencing coordinate transformations with associated parameter error statistics. These georeferencing coordinate transformations can use many possible image geometry (or sensor) models that can be encoded using extensions of this Application Schema.

This application schema also encodes object point positions measured in one of more images and optional object coordinates, with associated position error statistics. These object points can be tie points, control points, and check points.

Error statistics are represented as variance-covariance matrices, representing both absolute and relative accuracies. These covariance matrices are used to represent correlations between the accuracies of different coordinates, parameters, and positions.

2 Compliance

Compliance with this specification shall be checked using all the relevant tests specified in Annex A (normative).

3 Normative references

The following normative documents contain provisions that, through reference in this text, constitute provisions of this document. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the normative document referred to applies.

ISO 19105:2000, *Geographic information — Conformance and Testing*

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

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

ISO 19115:2003, *Geographic information — Metadata*

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

OGC 01-111, *OpenGIS® Metadata* (contains ISO/TC 211 DIS 19115)

OGC 05-010, *URNs of definitions in ogc namespace*

OGC 05-094r1, *GML 3.1.1 CRS support profile*

OGC 05-095r1, *GML 3.1.1 common CRSs profile*

OGC 05-096r1, *GML 3.1.1 grid CRSs profile*

OGC 05-103, *Geographic information — Spatial referencing by coordinates*

OGC 05-105, *Geographic information — Geography Markup Language (GML)* (version 3.2, ISO/DIS 19136)

OGC 06-054, *OpenGIS® Image Geopositioning Service Implementation Specification*

OGC 05-008, *Web Services Common Specification*, version 1.0

This OWS Common Specification contains a list of normative references that are also applicable to this Implementation Specification.

In addition to this document, this specification includes several normative XML Schema Document files as specified in Annex B.

4 Terms and definitions

For the purposes of this specification, the definitions specified in Clause 4 of the OpenGIS® Abstract Specification Topic 2 [OGC 05-103] and in OWS Common Implementation Specification [OGC 05-008] shall apply. In addition, the following terms and definitions apply.

4.1
absolute accuracy
absolute external accuracy
statistic which gives the uncertainty of a point with respect to the datum required by a product specification (adapted from USIGS Glossary)

NOTE This definition implies that the effects of all error sources, both random and systematic, are considered.

4.2
accuracy
degree to which information on a map or in a digital database matches true or accepted values (adapted from USIGS Glossary)

NOTE Accuracy pertains to the quality of data and the number of errors contained in a dataset or map. In discussing a GIS database, it is possible to consider horizontal and vertical accuracy with respect to geographic position, as well as attribute, conceptual, and logical accuracy. The effect of inaccuracy and error on a GIS solution is the subject of sensitivity analysis. Accuracy, or error, is distinguished from precision , which concerns the level of measurement or detail of data in a database

4.3

check point

point with known object (or ground) position used to check the geopositioning of one or more images

NOTE The known position of a check point is not used in the geopositioning. The position of a check point is measured in one or more of the images geopositioned.

4.4

control point

point with known object (or ground) position used to geoposition one or more images

NOTE The position of a control point is measured in one or more of the images being geopositioned.

4.5

covariance matrix

detailed form of position accuracy data, sometimes called a variance-covariance matrix (adapted from USIGS Glossary)

NOTE 1 For three object (or ground) coordinates, a covariance matrix is a 3 by 3 matrix, with the matrix rows and columns each corresponding to the three coordinates. For two horizontal coordinates, a covariance matrix is a 2 by 2 matrix, with the matrix rows and columns each corresponding to the two horizontal coordinates. Similarly, for two image coordinates, a covariance matrix is a 2 by 2 matrix, with the matrix rows and columns each corresponding to the two image coordinates.

NOTE 2 The covariance matrix cells contain the expected average values of the product of the error in the matrix row coordinate times the simultaneous error in the matrix column coordinate. For absolute accuracy, the diagonal matrix cells contain the error variances of the corresponding coordinates, or the squares of the standard deviations. The off-diagonal cells contain the covariances between the errors in the corresponding coordinates; these covariances will be zero when the errors in different coordinates are not statistically correlated. All covariance matrices are symmetrical, meaning that the same cell values appear on both sides of the diagonal cells.

NOTE 3 Covariance matrices can be used to record absolute and/or relative accuracies. A covariance matrix for relative accuracy uses the three (or two) coordinates of one point for matrix rows and the three (or two) coordinates of the second point for matrix columns. A complete covariance matrix for N specific points would contain 3N rows by 3N columns.

4.6

georeferencing transformation

coordinate transformation that can be used to convert grid coordinate values to values of coordinates referenced to a coordinate reference system that is related to the earth by a datum (adapted from ISO 19123)

4.7

image geopositioning

adjustment of the parameter values of image georeferencing coordinate transformations to produce correct coordinates in a coordinate reference system that is related to the earth or other imaged object

4.8
object point
ground point
point with position on the imaged object(s), often the earth

4.9
photogrammetry
science of mensuration and geometric adjustment of an aerial photograph or satellite image (adapted from USIGS Glossary)

NOTE 1 Photogrammetry requires: a mathematical model of the image formation process, computation of the internal geometry of an image, and subsequent correction of imagery based upon the ground relationship for every part of the image. Correction of imagery based on computational algorithms and measurement of geometrical position in an image.

NOTE 2 Effective photogrammetry makes use of ground control by which aerial photographs are carefully compared and registered to the locations and characteristics of features identified in ground-level surveys.

4.10
relative accuracy
relative internal accuracy
evaluation of random errors in determining the positional accuracy of one point feature with respect to another feature (adapted from USIGS Glossary)

4.11
tie point
point with measured position in one or more images, used to geoposition those images

NOTE The estimated object (or ground) position of a tie point is not known before the geopositioning.

4.12
transformation
approximate transformation of position coordinates from one Spatial Reference System (SRS) to another

NOTE For example, this term is used when the transformation coefficients are determined by least squares adjustment. This term is strictly used only when the transformation is known only approximately. This term is loosely used when the transformation is known either approximately or exactly.

5 Conventions

5.1 Abbreviated terms

CRS	Coordinate Reference System
GML	Geography Markup Language
IGS	Image Geopositioning Service
ISO	International Organization for Standardization
OGC	Open Geospatial Consortium
OWS	OGC Web Service, or Open Web Service

TBD	To Be Determined
TBR	To Be Reviewed
UML	Unified Modeling Language
URI	Universal Resource Identifier
URL	Uniform Resource Locator
URN	Universal Resource Name
XML	Extensible Markup Language
1D	One Dimensional
2D	Two Dimensional
3D	Three Dimensional

5.2 UML notation

Most diagrams that appear in this specification are presented using the Unified Modeling Language (UML) static structure diagram, as described in Subclause 5.2 of [OGC 05-008].

6 Image geopositioning metadata overview

6.1 Image geopositioning metadata

This GML Application Schema XML schema encodes parameter values for image georeferencing coordinate transformations with associated parameter error statistics. These georeferencing coordinate transformations can use many possible image geometry (or sensor) models that can be encoded using extensions of this Application Schema.

This application schema also encodes point positions measured in one of more images and optional object coordinates, with associated position error statistics. These object points can be tie points, control points, and check points. A control or check point has a measured position with position error statistics in one or more images, and a known position with error statistics in some geodetic Coordinate Reference System (CRS). A tie point has a measured position with error statistics in two or more images, but not a known position in any geodetic CRS

Error statistics are represented as variance-covariance matrices, representing both absolute and relative accuracies. These covariance matrices are used to represent correlations between the accuracies of different coordinates, parameters, and positions.

6.2 UML model packages

This GML image geopositioning metadata application schema is specified in five parts, corresponding to five UML packages with five corresponding XML Schema Documents. The five UML packages are listed and briefly described in Table 1. The dependencies

among these geopositioning metadata UML packages are shown in the Figure 1, together with the classes in each package.

Table 1 — Image geopositioning metadata UML model packages

Package Name	Description
GSM_SensorModel	Records multiple versions of object-to-image transformations and the sensor mathematical models used by these transformations
GIG_ImageGeometry	Records image orientation data, allowing multiple adjustments of orientation data and groups of images that are adjusted together
GSC_SensorCalibration	Records sensor calibration data, including multiple adjustments of interior orientation data
GOP_ObjectPoint	Records object point positions in one of more images with optional object coordinates, for control points, tie points, and other points
GCM_CovarianceMatrix	Records covariance matrices, for absolute and relative parameter and position error estimates

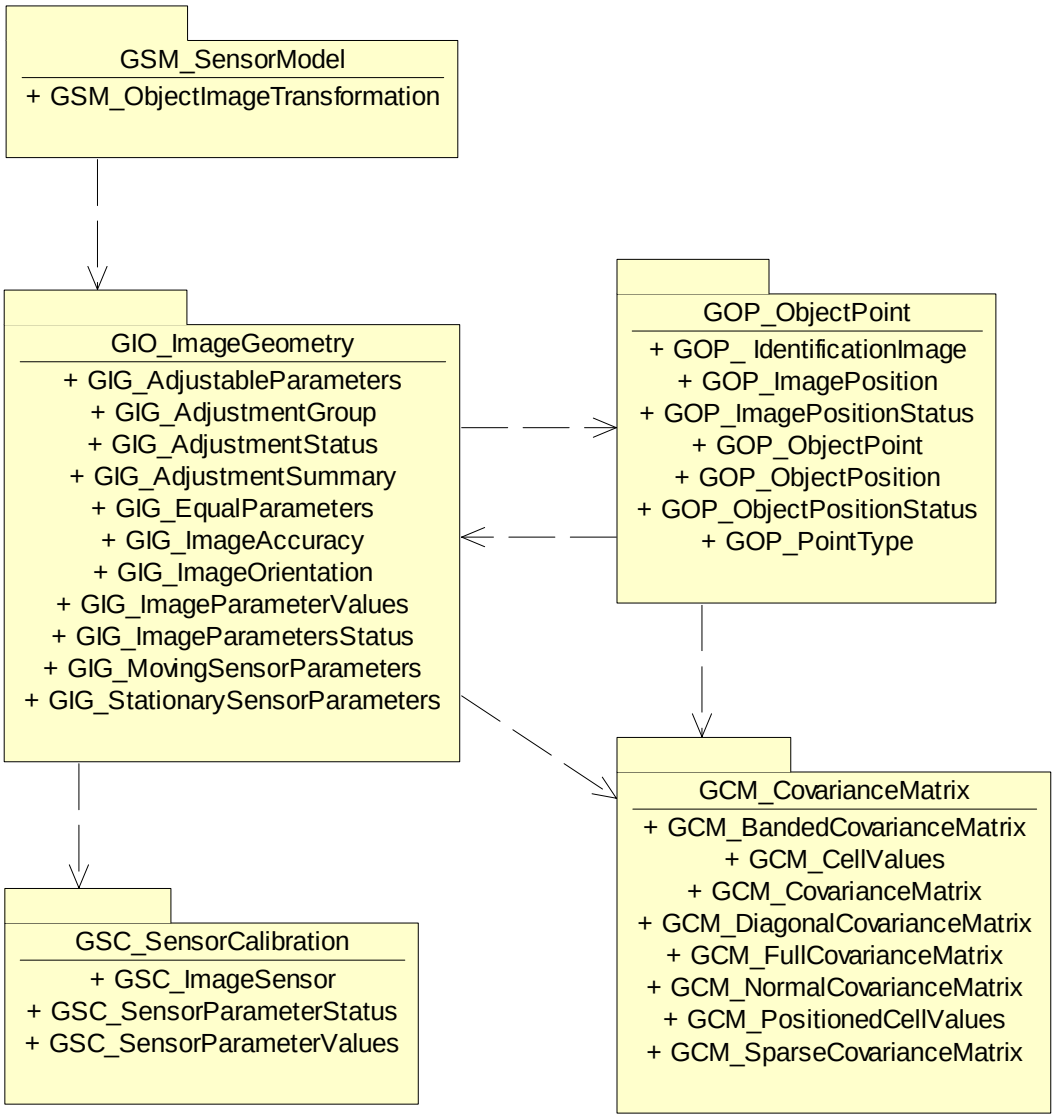

Figure 1 — Image geopositioning metadata UML packages with dependencies

This UML model is built upon the ISO/TC 211 UML model, contained in the ISO 191XX series of standards. The ISO/TC 211 UML model packages used, directly and indirectly, are listed in Table 2. The direct dependencies of the geopositioning metadata UML model packages on ISO/TC 211 UML model packages are shown in the Figure 2 (without the classes in each package).

Table 2 — ISO/TC 211 UML model packages used

ISO Standard	UML package name
19107 Geographic information — Spatial schema	GM_Geometry
19109 Geographic information — Rules for application schema	GF_GeneralFeature
19111 Geographic information — Spatial referencing by coordinates	CC_CoordinateOperation CD_Datum CS_CoordinateSystem IO_IdentifiedObject SC_CoordinateReferenceSystem
19115 Geographic information — Metadata	DQ_DataQuality EX_Extent

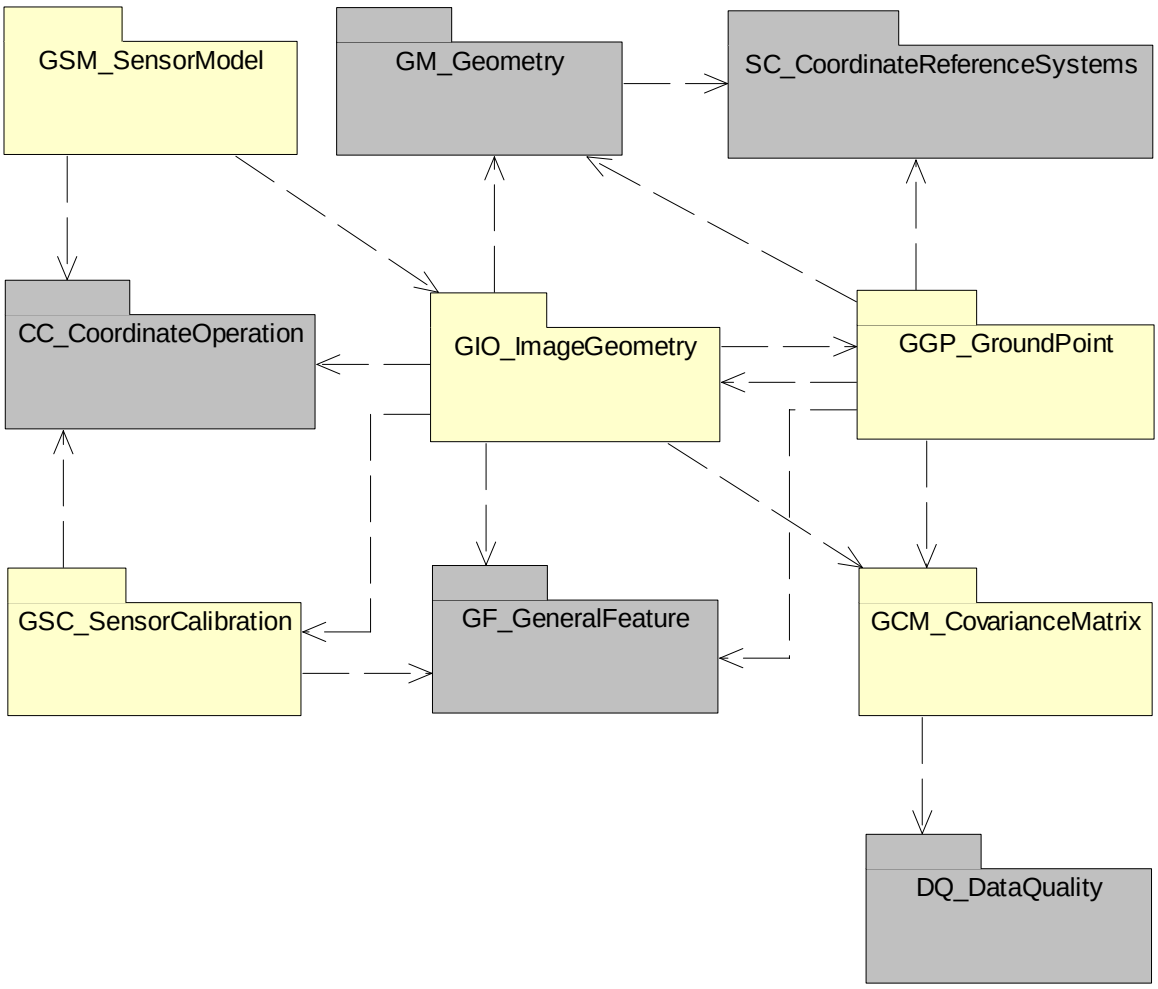

Figure 2 — Image geopositioning metadata and ISO/TC 211 packages

6.3 GML application schema

This GML 3.2 Application Schema for geopositioning metadata is also an Application Schema of ISO 19139. This Application Schema uses small profiles (or subsets) of GML

3.2 (ISO 19136) and ISO 19139, although those profiles are not yet formally specified. For GML, the profile used is essentially a subset of the GML grid CRSs and simple features profiles. For ISO 19139, the profile is a subset of the ISO 19139 profile that is used by GML 3.2 (ISO 19136).

Most of the ISO/TC 211 classes used in the UML model are encoded by GML 3.2 XML elements as listed in Table 3.

Table 3 — GML 3.2 elements encoding ISO classes

ISO package name (ISO number) UML class name	GML XML Schema Document XML element name
CC_CoordinateOperation (19111) CC_Transformation	coordinateOperations.xsd Transformation
CC_CoordinateOperation (19111) CC_OperationMethod	coordinateOperations.xsd OperationMethod
CC_CoordinateOperation (19111) CC_ParameterValueGroup	coordinateOperations.xsd ParameterValueGroup
CC_CoordinateOperation (19111) CC_OperationParameterGroup	coordinateOperations.xsd ParameterGroup
GF_GeneralFeature (19109) GF_FeatureType	feature.xsd AbstractFeature
GM_Geometry (19107) GM_Polygon	geometryBasic2d.xsd Polygon
GM_Geometry (19107) GM_Curve	geometryBasic0d1d.xsd AbstractCurve
GM_Geometry (19107) GM_Point	geometryBasic0d1d.xsd Point

Each of these geopositioning metadata UML packages and corresponding XML Schema Documents is defined in subsequent clauses.

7 Sensor model

7.1 Introduction

The sensor model part of the GML image geopositioning metadata application schema supports recording multiple versions of object-to-image transformations and the (image geometry) sensor mathematical models used by these transformations. These object-to-image transformations are used for georeferencing coordinate transformations. These coordinate transformations can use many possible image geometry (or sensor) models that can be encoded using extensions of this Application Schema. The parameter values used by these transformations are recorded in the image orientation and other parts of this application schema.

7.2 UML model

The UML class diagram for the GSM_SensorModel package is shown in Figure 3, together with the CC_CoordinateOperation classes that are directly inherited from. The new GSM_ObjectImageTransformation class defined in this GSM_SensorModel package is defined in Table 4. This diagram also shows two other classes added in this image geopositioning metadata application schema, namely GIG_ImageParameterValues and GSC_SensorParameterValues.

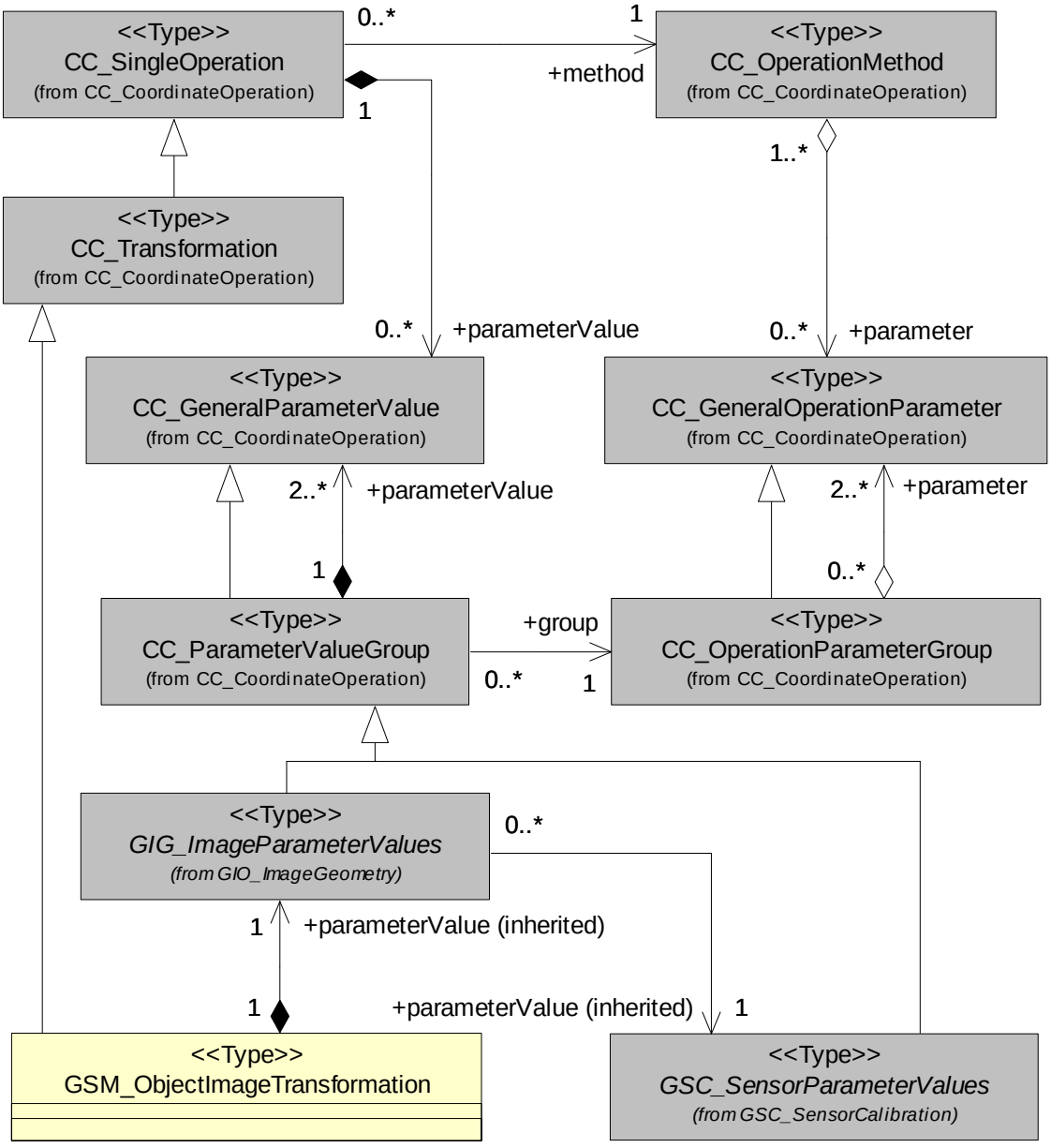

Figure 3 — GSM_SensorModel package UML class diagram

The GSM_SensorModel package for the GML image geopositioning metadata application schema specializes the CC_CoordinateOperation package in ISO 19111 (new

version), by defining more-specific subclasses. By specializing the CC_CoordinateOperation package, the GSM_SensorModel package uses the existing ISO 19111 concepts and terms, for coordinate Transformations, Operation Methods, Operation Parameter Groups, etc.

Specifically, the GSM_ObjectImageTransformation class specializes the CC_Transformation class for image georeferencing object-to-image coordinate transformations. That new class uses the GIG_ImageParameterValues and GSC_SensorParameterValues classes which specialize the CC_ParameterValueGroup class. The CC_OperationMethod and CC_OperationParameterGroup classes have instances that are specialized for this use (specialized classes are not used).

Table 4 — Defining elements of GSM_ObjectImageTransformation class

Description:	Definition of one object-to-image coordinate transformation for image georeferencing, using one group of (adjusted) image parameter values, which contains one group of (calibrated) sensor parameter values.
Stereotype:	Type
Class attribute:	Concrete
Inheritance from:	CC_Transformation
Association roles:	imageParameterValues to GIG_ImageParameterValues [1] [a] (Association to values of group of image parameters used by this transformation) method to CC_OperationMethod [1] [b] (Inherited association to method used by this transformation)
Public attributes:	11 attributes inherited from CC_Transformation and IO_IdentifiedObjectBase
a Association inherited through CC_Transformation, CC_SingleOperation, CC_GeneralPareameterValues, and CC_ParameterValueGroup.	
b Association inherited through CC_Transformation and CC_SingleOperation.	

NOTE These tables are using the table format used in ISO 19111 [OGC 05-103].

7.3 XML encoding

The GSM_SensorModel UML package is encoded in the igmSensorModel.xsd XML Schema Document, which imports the coordinateOperations.xsd XML Schema Document from GML 3.2. The ISO 19111 classes used in the UML model are encoded by the GML 3.2 XML elements as listed in Table 3. The contents of the igmSensorModel.xsd XML Schema Document shall be as specified in the attached file.

8 Image geometry

8.1 Introduction

The image geometry part of the GML image geopositioning metadata application schema supports recording image (exterior) orientation parameter values, including image sensor position and attitude. This package supports multiple adjustments of this image orientation data and groups of images that are adjusted together. Most of these orientation parameter values are specific to each image collected by one image sensor, and usually

must be adjusted for each image collected. These parameters can be for many possible image geometry (or sensor) models that can be encoded using extensions of this Application Schema.

8.2 UML model

The UML class diagram for the GIG_ImageGeometry package is shown in Figure 4 and Figure 5, together with the ISO 191XX UML classes that are directly inherited from. The new classes defined in this GIG_ImageGeometry package are described in Table 5 through Table 12.

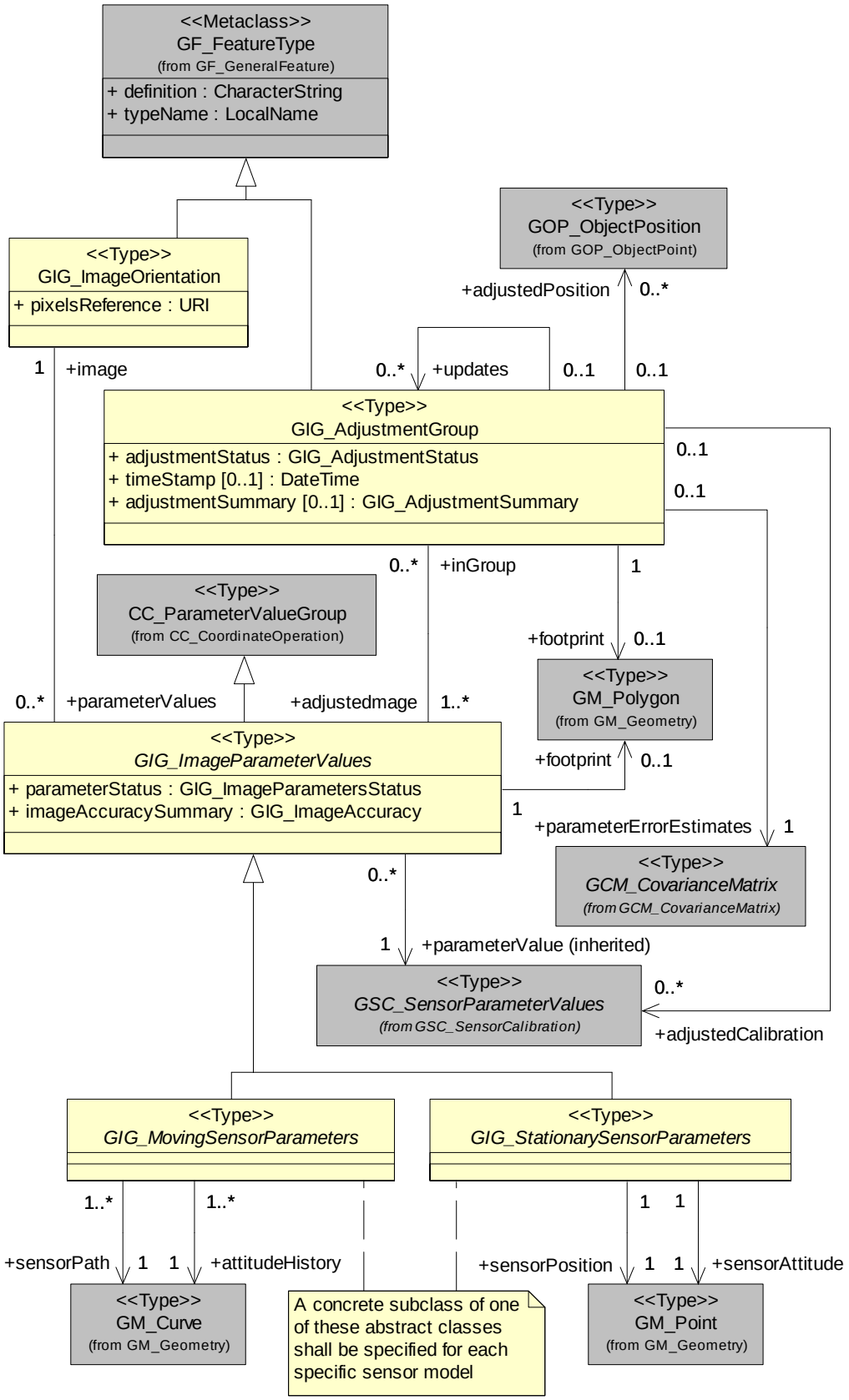

Figure 4 — GIG_ImageGeometry package UML class diagram, part 1

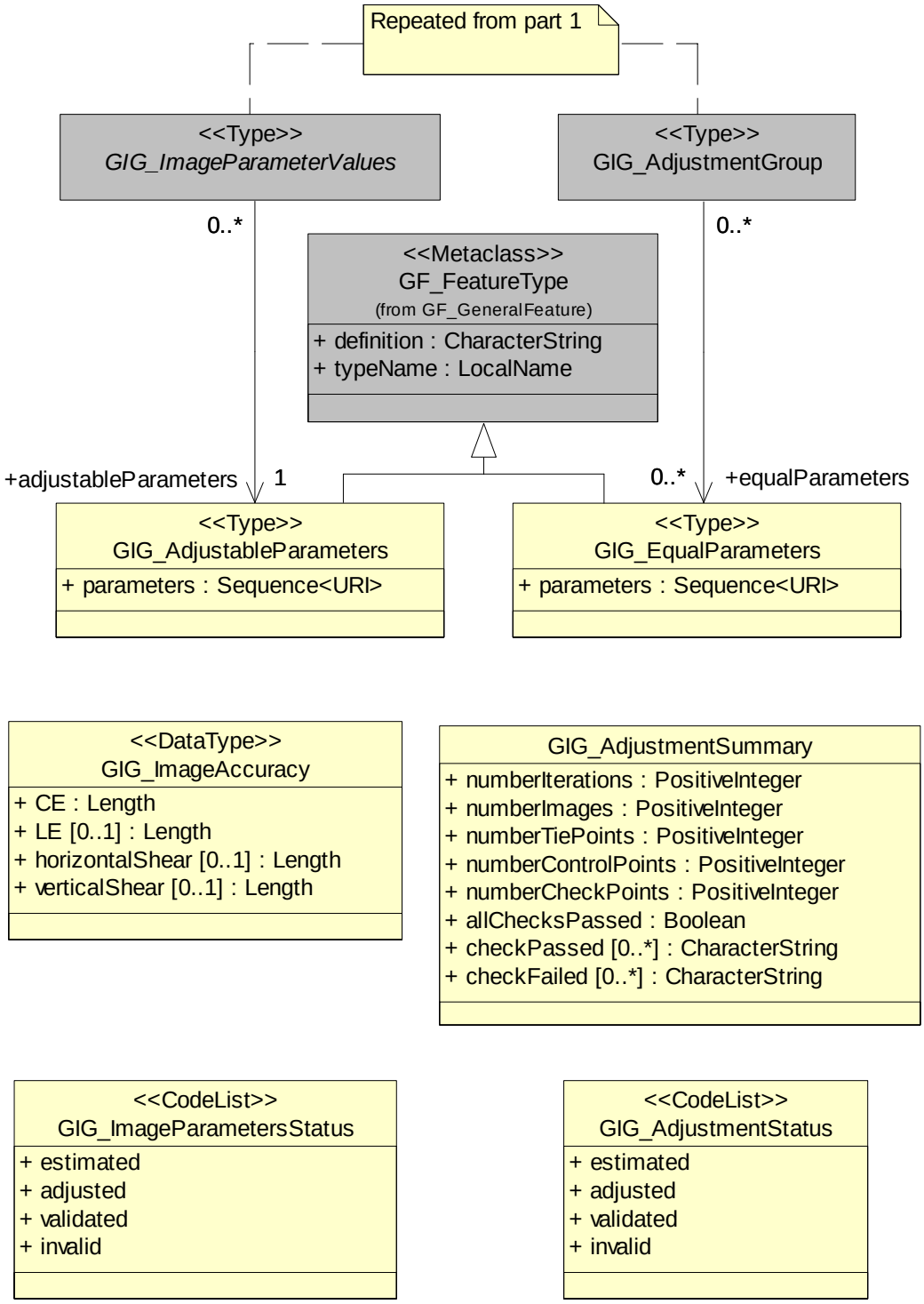

Figure 5 — GIG_ImageGeometry package UML class diagram, part 2

Part 1 of this UML class diagram shows how multiple groups of orientation parameter values can be recorded for each image, with each group associated with any one adjustment that produced it. That is, multiple ImageParameterValues objects can be associated with the ImageOrientation object for one image. Similarly, multiple

ImageParameterValues objects can be associated with an AdjustedGroup object for one adjustment (or triangulation).

As needed for different image types and purposes, different sensor models can be used by the multiple ImageParameterValues objects which are associated with the ImageOrientation for one image, or with the AdjustedGroup for one adjustment. Similarly, different image parameters can be adjusted in different ImageParameterValues objects. As indicated, the ImageOrientation class contains a pointer to the image pixels.

The AdjustedGroup concrete class records the status of that adjustment, and has an association to the CovarianceMatrix object that records all the parameter error estimates resulting from that adjustment. Each AdjustedGroup object is associated to the SensorParameterValues and ObjectPosition objects that were adjusted or computed by this adjustment. Each AdjustedGroup object also has an optional association to a Polygon giving the approximate footprint for that adjustment. Since the GM_Polygon is used, any holes in that polygon can be recorded.

The ImageParameterValues abstract class records the parameter values for any sensor model, including the status of that group of parameter values. Each ImageParameterValues object also has an optional association to a Polygon giving the (approximate) footprint for the image using those parameter values.

The StationarySensorParameters and MovingSensorParameters abstract subclasses of ImageParameterValues record the parameter values common to all stationary and moving sensors. For a stationary sensor, these parameters are the sensor position coordinates and the sensor attitude (rotation) parameters, each recorded using a GM_Point object. For a moving sensor, these parameters are the sensor path positions and the sensor attitude history, each recorded using a GM_Curve object. The sensor path and attitude history can be shared by multiple images collected in a strip, with each image specifying the collection time or range within this history.

The details specific to each specific sensor model are recorded as concrete subclasses of the StationarySensorParameters and MovingSensorParameters abstract classes, which shall be specified in extensions of this Application Schema. These classes should share more classes for common aspects (also not shown here). Wherever relevant, these specific image geometry models should build upon and adapt the Sensor Markup Language (SensorML), Transducer Markup Language (TML), and ISO 19130 (Sensor data model for imagery and gridded data).

Part 2 of this UML class diagram shows that each ImageParameterValues object also has an association to one AdjustableParameters object that identifies which of the image and sensor parameters could have been adjusted by the associated AdjustmentGroup. Each AdjustableParameters object can be associated from multiple ImageParameterValues objects which have the same set of adjustable parameters (as is common).

Also, each AdjustmentGroup object can have associations to zero or more EqualParameters objects, which each identify two or more otherwise adjustable parameters that were considered to have the same values during that adjustment. Each

EqualParameters object can be associated from multiple AdjustmentGroup objects which have the same set of equal parameters (as is common).

The ImageGeometry package for the GML image geopositioning metadata application schema specializes the GF_FeatureType package in ISO 19109, by defining more-specific subclasses. By defining the ImageOrientation and AdjustedGroup classes as feature collections, identification metadata is inherited and additional properties for recording needed metadata can be easily added. By defining the AdjustableParameters and EqualParameters as features, identification metadata is inherited and additional properties for recording needed metadata can be easily added.

This package also specializes the CC_CoordinateOperation package in ISO 19111, by defining more-specific subclasses of CC_ParameterValueGroup. By defining the ImageParameterValues class as a parameter value group, individual parameters and subsidiary parameter groups can be defined for different image geometry (or sensor) models. This package also uses parts of the GM_Geometry package from ISO 19107, avoiding new definitions of points, curves, and polygons.

Table 5 — Defining elements of GIG_ImageOrientation class

Description:	Orientation metadata for one image.
Stereotype:	Type
Class attribute:	Concrete
Inheritance from:	GF_FeatureType
Association roles:	parameterValues to GIG_ImageParameterValues [0..*] (Association to group of parameter values determined for this image) point to GOP_ObjectPoint [0..*] (Association to object point that falls within this image) image from GIG_ImageParameterValues [1] (Association from group of parameter values determined for this image) inImage from GOP_ImagePosition [1] (Association from position measured in this image)
Public attributes:	Two attributes inherited from GF_FeatureType, plus:

Attribute name	UML identifier	Data type	Obligation	Maximum occurrence	Attribute description
Pixels reference	pixelsReference	URI	M	1	Reference to pixels of this image.

Table 6 — Defining elements of GIG_AdjustedGroup class

Description:	Definition of a group of one or more images that were adjusted as a group. [a]
Stereotype:	Type
Class attribute:	Concrete
Inheritance from:	GF_FeatureType
Association roles:	adjustedImage to GIG_ImageParameterValues [1..*] (Association to image parameter values determined by this adjustment group) adjustedPosition to GOP_ObjectPosition [0..*] (Association to object positions determined by this adjustment group) adjustedCalibration to GSC_SensorParameterValues [0..*] (Association to group of sensor parameters determined by this adjustment group) parameterErrorEstimates to GCM_CovarianceMatrix [1] (Association to error estimates for all the image parameter values from this adjustment) footprint to GM_Polygon [0..1] (Association to approximate footprint of this adjustment group) equalParameters to GIG_EqualParameters [0..*] (Association to list of equal parameters for this adjusted group) updates to GIG_AdjustedGroup [0..*] (Association to previous group updated by this adjustment group) updates from GIG_AdjustedGroup [0..1] (Association from group that updated by this adjustment group) inGroup from GIG_ImageParameterValues [0..1] (Association from group of image parameter values adjusted by this group)
Public attributes:	Two attributes inherited from GF_FeatureType, plus:

Attribute name	UML identifier	Data type	Obligation	Maximum occurrence	Attribute description
Adjustment status	adjustmentStatus	GIG_AdjustmentStatus	M	1	Status of this adjustment of this group of images.
Time stamp	timeStamp	DateTime	C [b]	1	Time when this group adjustment was performed or last changed.
Adjustment Summary	adjustmentSummary	GIG_AdjustmentSummary	C [b]	1	Summary of results of this adjustment.

a A group of images can be either: 1) a strip of overlapping images collected in one pass, 2) a block of images covering a roughly rectangular area, 3) a group of blocks of images, or 4) a single image (for example, being adjusted to control points).

b Condition: Include after adjustment performed.

Table 7 — Defining elements of GIG_ImageParameterValues class

Description:	Group of parameter values for one adjustment of one image, including most exterior orientation parameters.
Stereotype:	Type
Class attribute:	Abstract
Inheritance from:	CC_ParameterValueGroup
Association roles:	image to GIG_ImageOrientation [1] (Association to the image orientation using this group of image parameter values) parameterValue to GSC_SensorParameterValues [1] a (Inherited association to calibrated sensor parameter values used by this image parameter adjustment) footprint to GM_Polygon [0..1] (Association to approximate footprint of this image using this group of image parameter values) adjustableParameters to GIG_AdjustableParameters [1} (Association to list of adjustable parameters in this group) group to CC_OperationParameterGroup [1] a (Inherited association to operation parameter group for this group of image parameter values) inGroup to GIG_AdjustedGroup [0..1] (Association to the adjustment group that produced this group of image parameter values) parameterValue from GSM_ObjectImageTransformation [1] (Association from object to image transformation that uses this set of parameter values)
Public attributes:	No attributes inherited from CC_ParameterValueGroup

Attribute name	UML identifier	Data type	Obligation	Maximum occurrence	Attribute description
Image parameter status	imageParameterStatus	GIG_ImageParametersStatus	M	1	Status of this group of image parameter values.
Image accuracy summary	imageAccuracySummary	GIG_ImageAccuracy	M	1	Summary of positional accuracy of this image using this group of parameter values.

a Association inherited from CC_ParameterValueGroup.

NOTE 1 All GM_Polygon objects reference the geodetic coordinate reference system of these polygons.

Table 8 — Defining elements of GIG_MovingSensorParameters class

Description:	Group of image parameter values for one image collected by a sensor which moved during image collection. A concrete subclass of this abstract class must be specified for each specific moving image geometry (sensor) mathematical model, in an extension of this GML image geopositioning metadata application schema.
Stereotype:	Type
Class attribute:	Abstract
Inheritance from:	GIG_ImageParameterValues
Association roles:	sensorPath to GM_Curve [1] (Association to sensor path position coordinates during the collection period of one or more images)
	sensorAttitudeHistory to GM_Curve [1] (Association to sensor attitude "history" during the collection period of one or more images)
	Plus associations inherited from GIG_ImageParameterValues class
Public attributes:	One attribute inherited from GIG_ImageParameterValues
a This geopositioning metadata structure assumes that GM_Curve is interpreted to allow recording of the four quantities used to specify the attitude of an imaging sensor, in place of the three coordinates of an imaging sensor position.	

Table 9 — Defining elements of GIG_StationarySensorParameters class

Description:	Group of image parameter values for one image collected by a sensor which was stationary during image collection. A concrete subclass of this abstract class must be specified for each specific stationary image geometry (sensor) mathematical model, in an extension of this GML image geopositioning metadata application schema.
Stereotype:	Type
Class attribute:	Abstract
Inheritance from:	GIG_ImageParameterValues
Association roles:	sensorPosition to GM_Point [1] (Association to sensor position coordinates at the collection time)
	sensorAttitude to GM_Point [1] (Association to sensor attitude at the collection time)
	Plus associations inherited from GIG_ImageParameterValues class
Public attributes:	One attribute inherited from GIG_ImageParameterValues
a This geopositioning metadata structure assumes that GM_Point is interpreted to allow recording of the four quantities used to specify the attitude of an imaging sensor, in place of the three coordinates of an imaging sensor position.	

NOTE 2 All GM_Curve and GM_Point objects reference the geodetic coordinate reference system for these positions and attitudes

Table 10 — Defining elements of GIG_ImageAccuracy class

Description:	Summary of the estimated positional accuracies of positions extracted using this image with this group of parameter values.
Stereotype:	DataType
Class attribute:	Concrete
Inheritance from:	(none)
Association roles:	(none)
Used by:	GIG_ImageParameterValues
Public attributes:	

Attribute name	UML identifier	Data type	Obligation	Maximum occurrence	Attribute description
Circular error (90%)	CE	Length	M	1	Estimated absolute (external) horizontal error in object positions extracted using this image.
Linear error (90%)	LE	Length	C [a]	1	Estimated absolute (external) elevation error in object positions extracted using this image with its stereo mate image in this adjusted group.
Horizontal shear	horizontal Shear	Length	C [b]	1	Estimated (relative internal) horizontal difference between object positions extracted using this image and overlapping image(s) in this adjusted group.
Vertical shear	verticalShear	Length	C [c]	1	Estimated (relative internal) elevation difference between object positions extracted using this image and overlapping image(s) in this adjusted group.

a Condition: At least one stereo mate image is included in this adjusted group.

b Condition: One or more overlapping images, excluding any stereo mate image(s), are included in this adjusted group.

c Condition: One or more overlapping stereo pairs of images are included in this adjusted group.

Table 11 — Defining elements of GIG_AdjustmentSummary class

Description:	Summary of results of this adjustment.
Stereotype:	DataType
Class attribute:	Concrete
Inheritance from:	(none)
Association roles:	(none)
Used by:	GIG_AdjustedGroup
Public attributes:	

Attribute name	UML identifier	Data type	Obligation	Maximum occurrence	Attribute description
Number of iterations	numberIterations	PositiveInteger	M	1	Number of adjustment computation iterations actually executed.
Number of images	numberImages	PositiveInteger	M	1	Number of images whose image parameters were adjusted.
Number of tie points	numberTiePoints	PositiveInteger	M	1	Number of tie points whose image position coordinates were used, and object positions estimated.
Number of control points	numberControlPoints	PositiveInteger	M	1	Number of control points whose object and image position coordinates were used, and object positions estimated.
Number of check points	numberCheckPoints	PositiveInteger	M	1	Number of check points whose object positions were estimated using image position coordinates with final image parameters (but were not used in adjustment).
All checks passed	allChecksPassed	Boolean	M	1	Adjustment results passed all required tests (or checks).
Check passed	checkPassed	Character String	C [a]	N	Adjustment results passed identified test.
Check failed	checkFailed	Character String	C [b]	N	Adjustment results failed identified test.

a Condition: At least one identified test was passed by adjustment results.

b Condition: At least one identified test was failed by adjustment results.

Table 12 — Defining elements of GIG_AdjustableParameters class

Description:	List of the adjustable parameters in a group of image parameter values, for the adjustment group that includes these parameter values.				
Stereotype:	Type				
Class attribute:	Concrete				
Inheritance from:	GF_FeatureType				
Association roles:	adjustableParameters from GIG_ImageParameterValues [0..*] (Association from list of adjustable parameters in this group)				
Public attributes:	Two attributes inherited from GF_FeatureType, plus:				
Attribute name	**UML identifier**	**Data type**	**Obligation**	**Maximum occurrence**	**Attribute description**
Name	name	CharacterString	M	N	Identifier of adjustable parameter.

Table 13 — Defining elements of GIG_EqualParameters class

Description:	List of adjustable parameters in an adjustment group that are constrained to have equal values.				
Stereotype:	Type				
Class attribute:	Concrete				
Inheritance from:	GF_FeatureType				
Association roles:	equalParameters from GIG_AdjustedGroup [0..*] (Association from adjusted group using this list of equal parameters)				
Public attributes:	Two attributes inherited from GF_FeatureType, plus:				
Attribute name	**UML identifier**	**Data type**	**Obligation**	**Maximum occurrence**	**Attribute description**
Name	name	CharacterString	M	N	Identifier of adjustable parameter constrained to have the same value as all others in this list.

Table 14 — Defining elements of GIG_ImageParametersStatus class

Description:	Status of this group of image parameter values.
Stereotype:	CodeList
Class attribute:	Concrete
Inheritance from:	(none)
Association roles:	(none)
Used by:	GIG_ImageParameterValues
Public attributes:	

Attribute name	UML identifier	Data type	Obligation	Maximum occurrence	Attribute description
Estimated	estimated	CharacterString	C	1	Contains initial estimated values.
Adjusted	adjusted	CharacterString	C	1	Contains computed adjusted values, not yet checked
Validated	validated	CharacterString	C	1	Contains validated (or checked) adjusted values.
Invalid	invalid	CharacterString	C	1	Contains values considered not valid for some reason (but object not yet deleted).

Condition: One and only one of the listed attributes shall be supplied.

Table 15 — Defining elements of GIG_AdjustmentStatus class

Description:	Status of this adjustment of this group of images.
Stereotype:	CodeList
Class attribute:	Concrete
Inheritance from:	(none)
Association roles:	(none)
Used by:	GIG_AdjustedGroup
Public attributes:	

Attribute name	UML identifier	Data type	Obligation	Maximum occurrence	Attribute description
Estimated	estimated	CharacterString	C	1	Contains initial estimated values.
Adjusted	adjusted	CharacterString	C	1	Contains computed adjusted values, not yet checked
Validated	validated	CharacterString	C	1	Contains validated (or checked) adjusted values.
Invalid	invalid	CharacterString	C	1	Contains values considered not valid for some reason (but object not yet deleted).

Condition: One and only one of the listed attributes shall be supplied.

8.3 XML encoding

The GIG_ImageGeometry UML package is encoded in the igmImageGeometry.xsd XML Schema Document, which imports the feature.xsd, coordinateOperations.xsd, and geometryBasic2d.xsd XML Schema Documents from GML 3.2. The ISO 19107, 19109, and 19111 classes used in the UML model are encoded by the GML 3.2 XML elements

as listed in Table 3. The contents of the igmImageGeometry.xsd XML Schema Document shall be as specified in the attached file.

9 Sensor calibration

9.1 Introduction

The sensor calibration part of the GML image geopositioning metadata application schema supports recording imaging sensor calibration parameter values, including multiple adjustments of interior orientation data. The sensor calibration parameter values are constant for many images collected by one image sensor, and are not frequently adjusted, so are recorded separate from the image parameter values specified above. This sensor calibration can be for many possible image geometry (or sensor) models that can be encoded using extensions of this Application Schema.

9.2 UML model

The UML class diagram for this package is shown in Figure 6, together with the classes that are inherited from. The four new classes defined in this GSC_SensorCalibration package are described in Table 16 through Table 16.

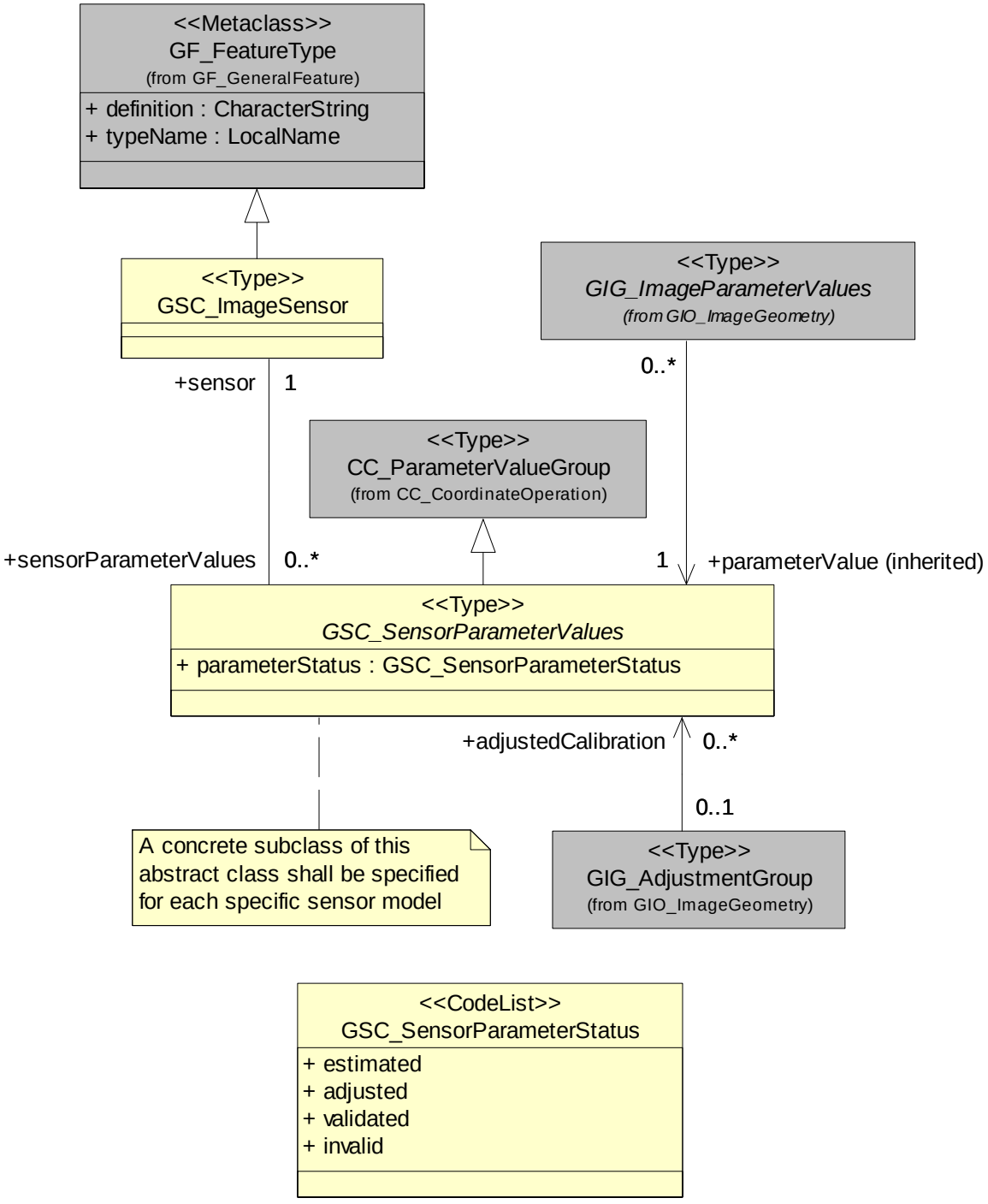

Figure 6 — GSC_SensorCalibration package UML class diagram

This UML class diagram shows how multiple groups of sensor calibration parameter values can be recorded for each image sensor, with each group associated with one AdjustedGroup that produced it. That is, multiple SensorParameterValues objects are associated with the ImageSensor object for one imaging sensor. The SensorParameterValues abstract class records the parameter values for any sensor model.

The details specific to each specific sensor model are recorded as concrete subclasses of the SensorParameterValues abstract class, which shall be specified in extensions of this Application Schema. These classes should share more classes for common aspects (also not shown here). Wherever relevant, these specific image geometry models should build upon and adapt the Sensor Markup Language (SensorML), Transducer Markup Language (TML), and ISO 19130 (Sensor data model for imagery and gridded data).

The GSC_SensorCalibration package for the GML image geopositioning metadata application schema specializes the GF_FeatureType package in ISO 19109, by defining more-specific subclasses. By defining the GSC_ImageSensor class as a feature, identification metadata is inherited and additional feature properties for recording needed metadata can be easily added.

This package also specializes the CC_CoordinateOperation package in ISO 19111, by defining more-specific subclasses of CC_ParameterValueGroup. By defining the GSC_SensorParameterValues class as a parameter value group, individual parameters and subsidiary parameter groups can be defined for different image geometry (or sensor) models.

Table 16 — Defining elements of GSC_ImageSensor class

Description:	Calibration (interior orientation) data for one imaging sensor.
Stereotype:	Type
Class attribute:	Concrete
Inheritance from:	GF_FeatureType
Association roles:	sensorParameterValues to GSC_SensorParameterValues [0..*] (Association to group of parameter values determined for this sensor) sensor from GSC_SensorParameterValues [1] (Association from group of parameter values determined for this sensor)
Public attributes:	Two attributes inherited from GF_FeatureType

Table 17 — Defining elements of GSC_SensorParameterValues class

Description:	Generic set of calibrated parameter values for one imaging sensor and sensor configuration, including most interior orientation parameters.
Stereotype:	Type
Class attribute:	Abstract
Inheritance from:	CC_ParameterValueGroup
Association roles:	sensor to GSC_ImageSensor [1] (Association to image sensor for this group of parameter values) group to CC_OperationParameterGroup [1] (Inherited association to operation parameter group for this group of sensor parameter values) sensorParameterValues from GIG_ImageParameterValues [1] (Association from image parameter adjustment to calibrated imaging sensor parameter used) adjustedCalibration from GIG_AdjustedGroup [0..1] (Association to group of sensor parameters determined by this adjustment group) sensorParameterValues from GSC_Sensor [0..*] (Association from sensor that uses this group of sensor parameter values)
Public attributes:	No attributes inherited from CC_ParameterValueGroup, plus:

Attribute name	UML identifier	Data type	Obligation	Maximum occurrence	Attribute description
Sensor parameter status	parameterStatus	GSC_SensorParameterStatus	M	1	Status of this group of sensor parameter values.

Table 18 — Defining elements of GSC_SensorParameterStatus class

Description:	Status of this group of sensor parameter values.
Stereotype:	CodeList
Class attribute:	Concrete
Inheritance from:	(none)
Association roles:	(none)
Used by:	GIG_SensorParameterValues
Public attributes:	

Attribute name	UML identifier	Data type	Obligation	Maximum occurrence	Attribute description
Estimated	estimated	CharacterString	C	1	Contains initial estimated values.
Adjusted	adjusted	CharacterString	C	1	Contains computed adjusted values, not yet checked
Validated	validated	CharacterString	C	1	Contains validated (or checked) adjusted values.
Invalid	invalid	CharacterString	C	1	Contains values considered not valid for some reason (but object not yet deleted).

Condition: One and only one of the listed attributes shall be supplied.

9.3 XML encoding

The GIG_SensorCalibration UML package is encoded in the igmSensorCalibration.xsd XML Schema Document, which imports the coordinateOperations.xsd XML Schema

Document from GML 3.2. The ISO 19107, 19109, and 19111 classes used in the UML model are encoded by the GML 3.2 XML elements as listed in Table 3. The contents of the igmSensorCalibration.xsd XML Schema Document shall be as specified in the attached file.

10 Object point

10.1 Introduction

The object point part of the GML image geopositioning metadata application schema records object point positions in one of more images and optional object (or ground) coordinates. These object points can be tie points, control points, or check points. A control point or check point has a measured position with position error statistics in one or more images, and a known position with error statistics in some geodetic Coordinate Reference System (CRS). A tie point has a measured position with error statistics in two or more images, but not a known position in any geodetic CRS. All types of points can have the estimated object position computed from the measured positions in two or more images.

10.2 UML model

The UML class diagram for this package is shown in Figure 7 and Figure 8, together with the classes that are inherited from. The new classes defined in this GOP_ObjectPoint package are described in Table 19 through Table 25.

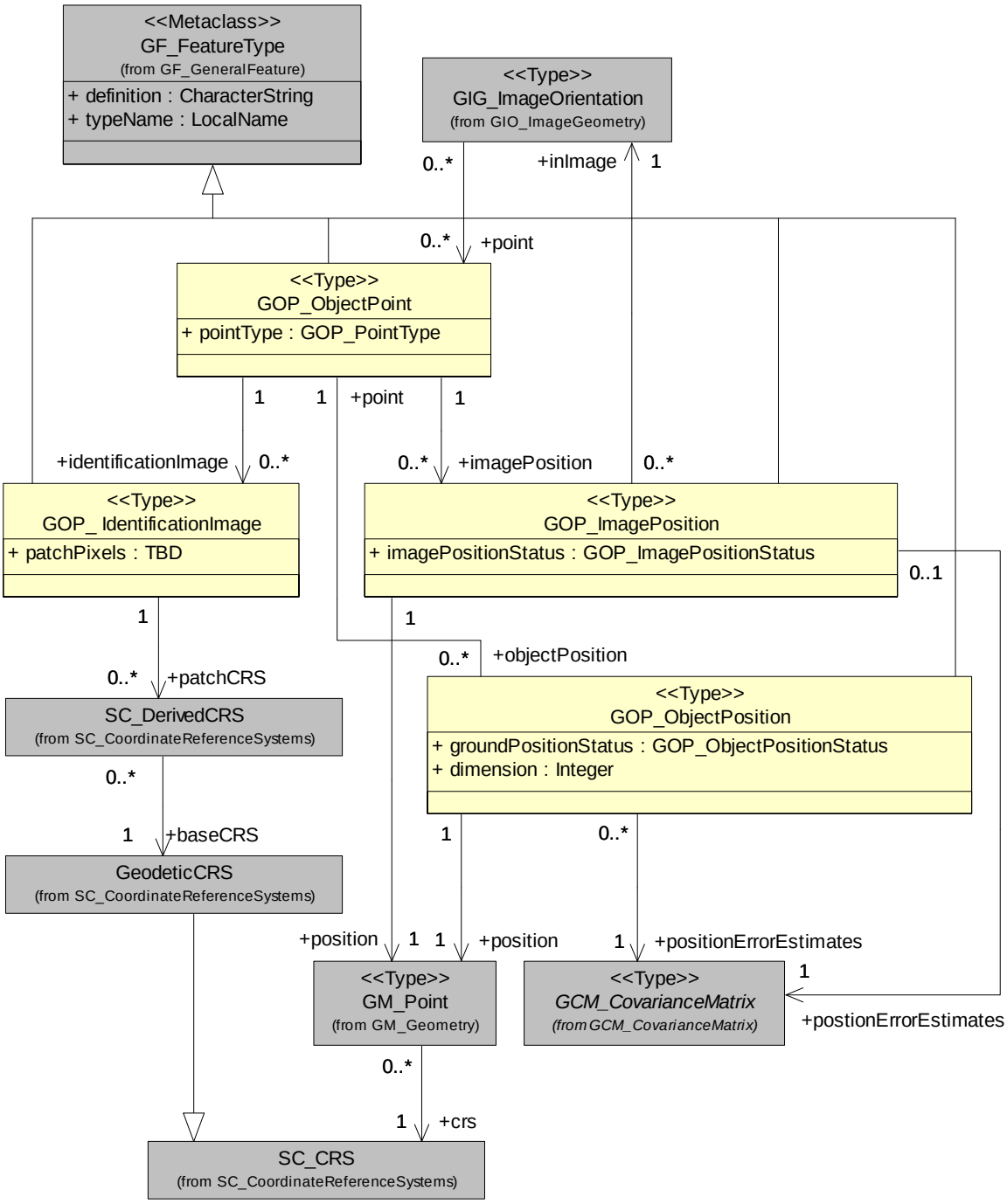

Figure 7 — GOP_ObjectPoint package UML class diagram, part 1

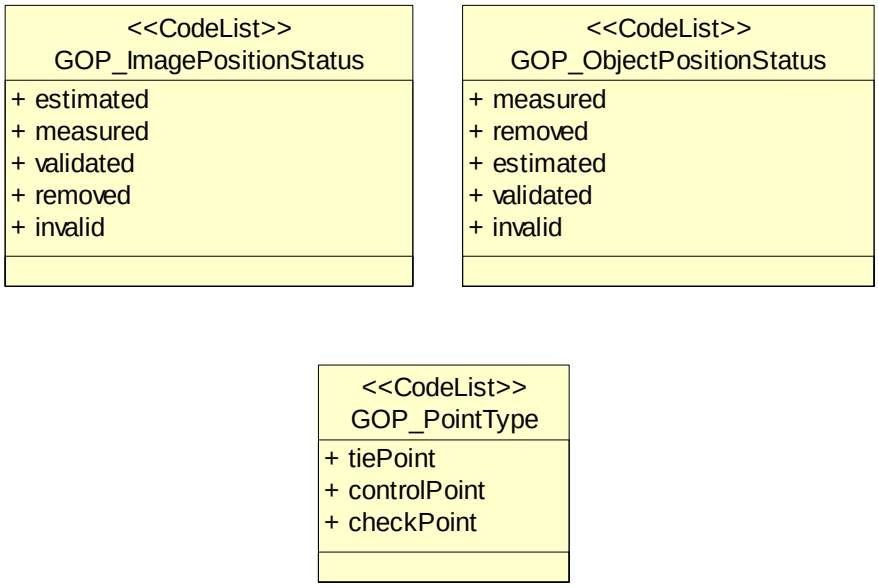

Figure 8 — GOP_ObjectPoint package UML class diagram, part 2

This UML class diagram shows how flexible object (or ground) point metadata is structured. A ObjectPoint object records the identification, type, and status of each recorded point. Each ObjectPoint object is associated to zero or more ObjectPosition objects that record object position coordinates for this point, using one GM_Point object. Similarly, each ObjectPoint object is associated to zero or more ImagePosition objects that record position coordinates of this point measured in different images, using one GM_Point. Also, each ObjectPoint is associated to zero or more IdentificationImage objects that record image patches for use in point identification within another image.

Both ObjectPosition and ImagePosition objects are associated with the CovarianceMatrix that records position error estimates. Each GM_Point references its Coordinate Reference System (SC_CRS), and each IdentificationImage references the image patch plus the SC_DerivedCRS for the image patch grid. That SC_DerivedCRS references its baseCRS, which is always a GeodeticCRS. More specifically, each GM_Point for a ObjectPosition references the GeodeticCRS for that point position, and each GM_Point for an ImagePosition references the ImageCRS for positions in that image.

The GOP_ObjectPoint package for the GML image geopositioning metadata application schema specializes the GF_FeatureType package in ISO 19109, by defining more-specific subclasses. The GOP_ObjectPoint class is a feature collection, and the GOP_ImagePosition, GOP_ObjectPosition, and GOP_IdentificationImage classes are considered features. By subclassing GF_FeatureType, identification metadata is inherited and additional feature properties for recording needed metadata can be easily added. This package also uses the GM_Point class from ISO 19107, avoiding new definitions of point positions.

Table 19 — Defining elements of GOP_ObjectPoint class

Description:	Description of one object (or ground) point, including its identification.
Stereotype:	Type
Class attribute:	Concrete
Inheritance from:	GF_FeatureType
Association roles:	objectPosition GOP_ObjectPosition [0..*] [a] (Association to object position for this point) imagePosition to GOP_ImagePosition [0..*] (association to image position for this point) identificationImage to GOP_IdentificationImage [0..*] [b] (Association to identification image for this object point) point from GIG_ImageOrientation [0..*] (Association from image containing this point)
Public attributes:	Two attributes inherited from GF_FeatureType, plus:

Attribute name	UML identifier	Data type	Obligation	Maximum occurrence	Attribute description
Object point type	pointType	GOP_ObjectPointType	M	1	Type of this object point.

a Multiple GOP_ObjectPosition objects can be associated to provide estimated positions from different adjustments.

b Multiple GOP_IdentificationImage objects can be associated to identify one object point when those image patches have significantly different object (or ground) resolutions or other image appearance differences.

Table 20 — Defining elements of GOP_ImagePosition class

Description:	Measured image position for a object point.
Stereotype:	Type
Class attribute:	Concrete
Inheritance from:	GF_FeatureType
Association roles:	inImage to GIG_ImageOrientation [1] (Association to image in which this image position was measured) position to GM_Point [1] (Association to measured image position coordinates) positionErrorEstimates to GCM_CovarianceMatrix [1] (Association to absolute position error estimates for this image position) imagePosition from GOP_ObjectPoint [0..*] (Association from object point that uses this image position)
Public attributes:	Two attributes inherited from GF_FeatureType, plus:

Attribute name	UML identifier	Data type	Obligation	Maximum occurrence	Attribute description
Image position status	imagePositionStatus	GSC_ImagePositionStatus	M	1	Status of this image position.

Table 21 — Defining elements of GOP_ObjectPosition class

Description:	Object (or ground) position for an object point.
Stereotype:	Type
Class attribute:	Concrete
Inheritance from:	GF_FeatureType
Association roles:	point to GOP_ObjectPoint [1] (Association to description of this object point) position to GM_Point [1] (Association to object position coordinates) positionErrorEstimates to GCM_CovarianceMatrix [1] (Association to position error estimates for this object position, including absolute errors of this object position and errors relative to other object positions) objectPosition from GOP_ObjectPoint [0..*] (Association from object point that uses this object position) adjustedPosition from GIG_AdjustedGroup [0..1] (Association from adjustment group that determined this object position)
Public attributes:	Two attributes inherited from GF_FeatureType, plus:

Attribute name	UML identifier	Data type	Obligation	Maximum occurrence	Attribute description
Object position status	ObjectPositionStatus	GSC_ObjectPositionStatus	M	1	Status of this object position.
Dimension	dimension	Integer	M	1	Number of object position coordinates that are known.

Table 22 — Defining elements of GOP_IdentificationImage class

Description:	Image patch identifying one object point, located at the center of this patch.
Stereotype:	Type
Class attribute:	Concrete
Inheritance from:	GF_FeatureType
Association roles:	patchCRS to SC_DerivedCRS [1] (Association to grid CRS for this image patch) [a] identification from GOP_ObjectPosition [0..*] (Association from object point that uses this image patch for identification)
Public attributes:	Two attributes inherited from GF_FeatureType, plus:

Attribute name	UML identifier	Data type	Obligation	Maximum occurrence	Attribute description
Patch pixels	patchPixels	TBD	M	1	Image pixels in identification image patch.

a This DerivedCRS is used for a pixel grid that is defined in a geodetic CRS that is the baseCRS of this DerivedCRS.

Table 23 — Defining elements of GOP_ObjectPointType class

Description:	Type of this object point.
Stereotype:	CodeList
Class attribute:	Concrete
Inheritance from:	(none)
Association roles:	(none)
Used by:	GOP_ObjectPoint
Public attributes:	

Attribute name	UML identifier	Data type	Obligation	Maximum occurrence	Attribute description
Tie point	tiePoint	CharacterString	C	1	Point with measured position in one or more images, used to geoposition those images.
Control point	controlPont	CharacterString	C	1	Point with known object position used to geoposition one or more images.
Check point	checkPoint	CharacterString	C	1	Point with known object position used to check the geopositioning of one or more images.

Condition: One and only one of the listed attributes shall be supplied.

Table 24 — Defining elements of GOP_ImagePositionStatus class

Description:	Status of this image position.
Stereotype:	CodeList
Class attribute:	Concrete
Inheritance from:	(none)
Association roles:	(none)
Used by:	GOP_ImagePosition
Public attributes:	

Attribute name	UML identifier	Data type	Obligation	Maximum occurrence	Attribute description
Estimated	estimated	CharacterString	C	1	Contains estimated position.
Measured	measured	CharacterString	C	1	Contains position measured in image, not yet checked.
Validated	validated	CharacterString	C	1	Contains validated (or checked) measured position.
Removed	removed	CharacterString	C	1	Contains position automatically detected as having a blunder, and removed from use in later triangulation computation iterations.
Invalid	invalid	CharacterString	C	1	Contains position considered not valid for some reason (but object not yet deleted).

Condition: One and only one of the listed attributes shall be supplied.

Table 25 — Defining elements of GOP_ObjectPositionStatus class

Description:	Status of this object position.				
Stereotype:	CodeList				
Class attribute:	Concrete				
Inheritance from:	(none)				
Association roles:	(none)				
Used by:	GOP_ObjectPosition				
Public attributes:					
Attribute name	**UML identifier**	**Data type**	**Obligation**	**Maximum occurrence**	**Attribute description**
Measured	measured	CharacterString	C	1	Contains measured and checked position.
Removed	removed	CharacterString	C	1	Contains position automatically detected as having a blunder, and removed from use in later triangulation computation iterations.
Estimated	estimated	CharacterString	C	1	Contains position estimated by computation.
Validated	validated	CharacterString	C	1	Contains validated (or checked) estimated position.
Invalid	invalid	CharacterString	C	1	Contains position considered not valid for some reason (but object not yet deleted).
Condition: One and only one of the listed attributes shall be supplied.					

10.3 XML encoding

The GOP_ObjectPoint UML package is encoded in the igmObjectPoint.xsd XML Schema Document, which imports the coordinateReferenceSystems.xsd XML Schema Documents from GML 3.2. The ISO 19107 and 19109 classes used in the UML model are encoded by the GML 3.2 XML elements as listed in Table 3. The contents of the igmObjectPoint.xsd XML Schema Document shall be as specified in the attached file.

11 Covariance matrix

11.1 Introduction

The covariance matrix part of the GML image geopositioning metadata application schema records combined absolute and relative position error estimates. The error statistics are in the form of covariance matrices, also called variance-covariance matrices, together with the (most-likely) values to which the covariance matrices apply. These covariance matrices normally represent correlations between the accuracies of different coordinates, parameters, and positions.

These covariance matrices contain the variance of each adjusted value estimated in the triangulation, and the covariances between these values. These estimated values include various parameters in georeferencing coordinate transformations, including the camera 3D position coordinates and 3D orientation angles. The estimated values also include point position coordinates in object CRSs.

NOTE Such covariance matrices for single point coordinates are described in Table D.33 of [ISO/TS 19138 draft n1934].

11.2 UML model

The UML class diagram for the GCM_CovarianceMatrix package is shown in Figure 9, together with the ISO 19115 classes that are inherited from. The new classes defined in this GCM_CovarianceMatrix package are described in through Table 26 through Table 33.

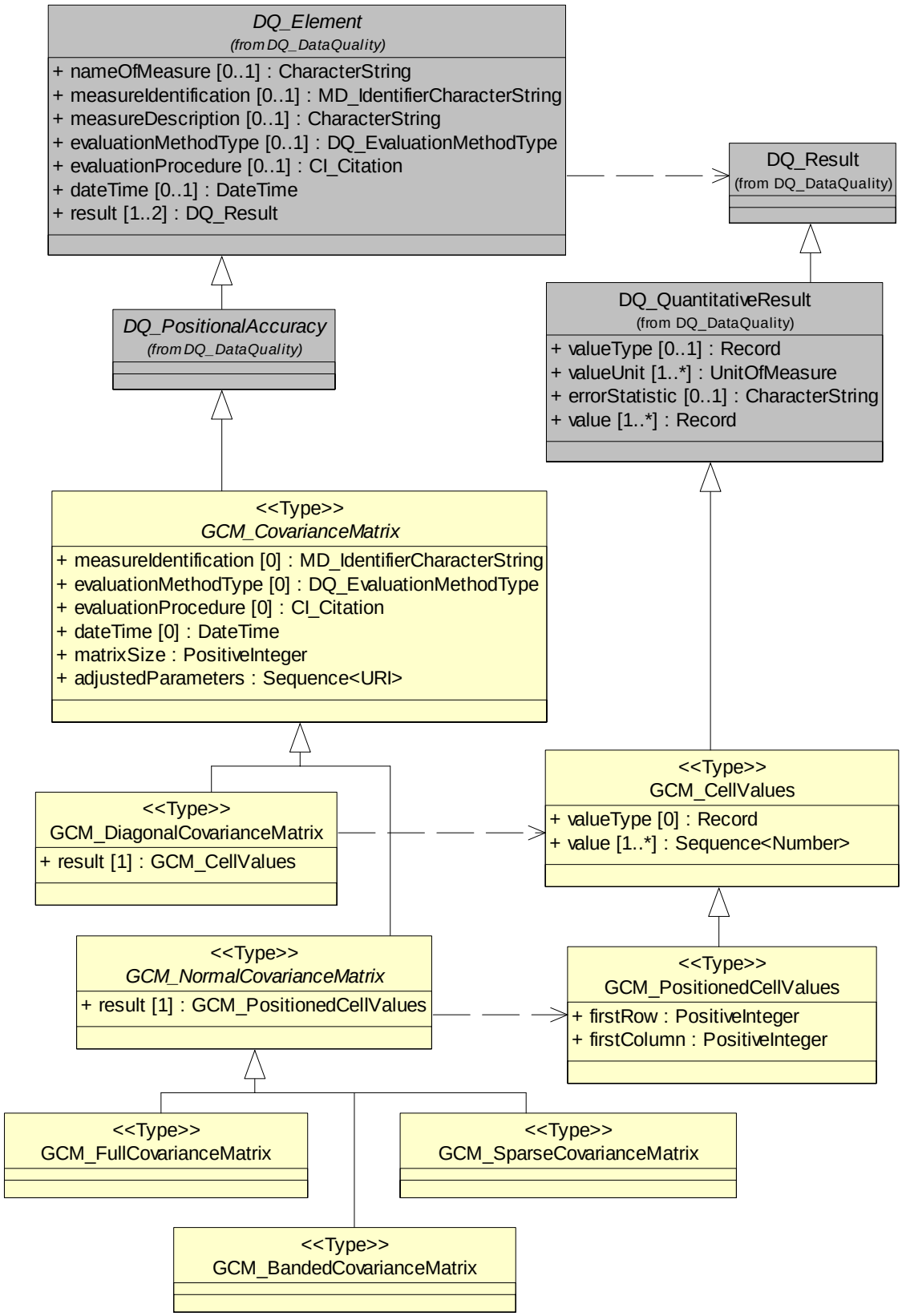

Figure 9 — GCM_CovarianceMatrix package UML class diagram

NOTE This GCM_CovarianceMatrix package class diagram shows all the attributes in the DQ_Element and DQ_QuantitativeResult classes. However, some of the optional attributes in each are not expected to be useful in this application, and are thus prohibited in the GCM_CovarianceMatrix and GCM_CellValues classes.

This UML class diagram shows how multiple types of covariance matrices can be efficiently recorded. The CovarianceMatrix package (for the GML image geopositioning metadata application schema) specializes the DQ_DataQuality package specified in ISO 19115, by defining more-specific subclasses of DQ_PositionalAccuracy and DQ_QuantitativeResult.

The CellValues concrete class restricts the DQ_QuantitativeResult concrete class for efficiently recording many ordered sequences of values for adjacent covariance matrix cells. Instead of a general record, each “value” attribute is an ordered sequence of values of adjacent covariance matrix cells. In the PositionedCellValues subclass of the Cell Values class, the cell position of the first value is specified by the firstRow and firstColumn indices for this covariance matrix.

The CovarianceMatrix abstract class restricts and extends the DQ_PositionalAccuracy abstract class for combined absolute external and relative internal positional accuracies. This class adds the size of this matrix and an ordered sequence of references to the parameters for this covariance matrix. The Diagonal-, Full-, Sparse-, and Banded-CovarianceMatrix concrete subclasses are designed to efficiently record different matrix types. The Full-, Sparse-, and Banded-CovarianceMatrix concrete subclasses are specialized subclasses of the NormalVovarianceMatrix abstract subclass of the CovarianceMatrix class, which contain the same contents but specify how multiple PositionedGridCells objects shall be used.

NOTE Additional concrete subclasses can be added to this Application Schema for more efficient encoding of covariance matrices with other properties.

Table 26 — Defining elements of GCM_CellValues class

Description:	Ordered sequence of values for adjacent covariance matrix cells.
Stereotype:	Type
Class attribute:	Concrete
Inheritance from:	DQ_QuantitativeResult
Association roles:	(none)
Public attributes:	(All four listed attributes are inherited from DQ_QuantitativeResult, with two attributes being restricted here.

Attribute name	UML identifier	Data type	Obligation	Maximum occurrence	Attribute description
valueType	valueType	RecordType	0	0 [a]	Value type for reporting a data quality result.
valueUnit	valueUnit	UnitOfMeasure	M	N [b]	Value unit for reporting a data quality result. [c]
errorStatistic	errorStatistic	CharacterString	0	1	Statistical method used to determine the value. [d]
value	value	Sequence of Number [e]	M	N	Ordered list of covariance matrix cell values.

a Inclusion of the valueType attribute is prohibited in this GCM_CellValues subclass of DQ_QuantitativeResult.

b In this GCM_CellValues subclass of DQ_QuantitativeResult, the valueUnit needs to be repeated, and that needed change in ISO 19115 is assumed here.

c In this GCM_CellValues class, these units shall be an ordered list of the units for each covariance matrix row, with the same units for each column, and with the unit for each matrix cell being the product of the corresponding row and column units.

d In this GCM_CellValues class, this attribute is allowed but is not expected to be included.

e Inherited from DQ_QuantitativeResult, but specialized from Record type to Sequence of Number type.

Table 27 — Defining elements of GCM_PositionedCellValues class

Description:	Ordered sequence of values for adjacent covariance matrix cells with starting cell position.
Stereotype:	Type
Class attribute:	Concrete
Inheritance from:	GCM_CellValues
Association roles:	(none)
Public attributes:	Four attributes inherited from GCM_CellValues, plus:

Attribute name	UML identifier	Data type	Obligation	Maximum occurrence	Attribute description
First row	firstRow	Positive Integer	M	1	Index of row in covariance matrix of first cell value included.
First column	firstColumn	Positive Integer	M	1	Index of column in covariance matrix of first cell value included.

Table 28 — Defining elements of GCM_CovarianceMatrix class

Description:	Generic covariance matrix error estimates, usually for statistically-correlated sets of parameters, containing ordered list of parameter names for matrix rows and columns.
Stereotype:	Type
Class attribute:	Abstract
Inheritance from:	DQ_PositionalAccuracy
Association roles:	parameterErrorEstimates from GIG_ImageParameterValues [1] (Association from set of image parameter values for these error estimates) positionErrorEstimates from GOP_ImagePosition [1] (Association from image position for these absolute and relative position error estimates) positionErrorEstimates from GOP_ObjectPosition [1] (Association to absolute and relative position error estimates for this object position)
Public attributes:	(The first eight optional attributes listed below are inherited from DQ_Element through DQ_PositionalAccuracy, with four of these attributes being prohibited here.)

Attribute name	UML identifier	Data type	Obligation	Maximum occurrence	Attribute description
nameOfMeasure	nameOfMeasure	CharacterString	O	N	Name of the test applied to the data. [b]
measureIdentification	measureIdentification	MD_Identifier	O	0 [a]	Code identifying a registered standard procedure.
measureDescription	measureDescription	CharacterString	O	1	Description of the measure. [b]
evaluationMethodType	evaluationMethodType	DQ_EvaluationMethodType	O	0 [a]	Type of method used to evaluate quality of the dataset.
evaluationMethodDescription	evaluationMethodDescription	CharacterString	O	1	Description of the evaluation method. [b]
evaluationProcedure	evaluationProcedure	CI_Citation	O	0 [a]	Reference to the procedure information.
dateTime	dateTime	DateTime	O	0 [a]	Date or range of dates on which a data quality measure was applied.
result	result	DQ_Result	M	1	Value (or set of values) obtained from applying a data quality measure.
Matrix size	matrixSize	PositiveInteger	M	1	Number or rows and columns in this covariance matrix.
Adjusted parameter	adjustedParameter	URI	M	N	Reference to adjusted parameter whose estimated error is represented by one row and one column in covariance matrix.

a Inclusion of this attribute is prohibited in this GCM_CovarianceMatrix class subclass of the DQ_PositionalAccuracy subclass of the DQ_Element class.

b In this GCM_CovarianceMatrix class, this attribute is allowed but is not expected to be included.

Table 29 — Defining elements of GCM_DiagonalCovarianceMatrix class

Description:	Covariance matrix containing non-zero values for only the matrix diagonal cells. (Such a matrix is for a statistically-uncorrelated set of parameters). For this Diagonal Covariance Matrix, there shall be one "value" attribute in the GCM_CellValues class, which shall contain an ordered list of the values of only the cells on the matrix diagonal.
Stereotype:	Type
Class attribute:	Concrete
Inheritance from:	GCM_CovarianceMatrix
Association roles:	(inherited from GCM_CovarianceMatrix)
Public attributes:	Ten attributes inherited from GCM_CovarianceMatrix, with one of these attributes being restricted as follows:

Attribute name	UML identifier	Data type	Obligation	Maximum occurrence	Attribute description
Result	result	GCM_CellValues [a]	M	1 [b]	Ordered sequence of values for adjacent covariance matrix cells.

a Restricted to GCM_CellValues subclass of the DQ_QuantitativeResult class.

b Restricted to one occurrence here.

Table 30 — Defining elements of GCM_NormalCovarianceMatrix class

Description:	Generic covariance matrix error estimates, for statistically-correlated sets of parameters.
Stereotype:	Type
Class attribute:	Abstract
Inheritance from:	GCM_CovarianceMatrix
Association roles:	(inherited from GCM_CovarianceMatrix)
Public attributes:	Ten attributes inherited from GCM_CovarianceMatrix, with one of these attributes being restricted as follows:

Attribute name	UML identifier	Data type	Obligation	Maximum occurrence	Attribute description
Result	result	GCM_PositionedCellValues [a]	M	1 [b]	Ordered sequence of values for adjacent covariance matrix cells, with position of first cell.

a Restricted to GCM_PositionedCellValues subclass of the GCM_CellValues subclass of the DQ_QuantitativeResult.

b Restricted to one occurrence here.

Table 31 — Defining elements of GCM_FullCovarianceMatrix class

Description:	Covariance matrix containing the values for all matrix cells, for a symmetric matrix. For this Full Covariance Matrix, one "result" attribute using the GCM_PositionedCellValues class shall be included for each matrix row. Each "result" attribute shall contain the value of one diagonal matrix cell, followed by the values of all other cells to the right in that matrix row (and down in that matrix column). Each sequence shall end when several sequential zero cell values are reached or the right edge of this matrix is reached.
Stereotype:	Type
Class attribute:	Concrete
Inheritance from:	GCM_NormalCovarianceMatrix
Association roles:	(inherited from GCM_CovarianceMatrix)
Public attributes:	Ten attributes inherited from GCM_NormalCovarianceMatrix

Table 32 — Defining elements of GCM_SparseCovarianceMatrix class

Description:	Covariance matrix containing only or mostly the values of non-zero matrix cells, for a symmetric matrix. For this Sparse Covariance Matrix, each "result" attribute shall contain the value of one non-zero matrix cell, followed by the values of other cells to the right in that matrix row. Each sequence shall end when several sequential zero cell values are reached or the right edge of this matrix is reached. The "result" attribute using the GCM_PositionedCellValues class shall contain a list of the values of this sequence of (mostly non-zero) matrix cells.
Stereotype:	Type
Class attribute:	Concrete
Inheritance from:	GCM_NormalCovarianceMatrix
Association roles:	(inherited from GCM_CovarianceMatrix)
Public attributes:	Ten attributes inherited from GCM_NormalCovarianceMatrix

Table 33 — Defining elements of GCM_BandedCovarianceMatrix class

Description:	Covariance matrix containing the values of all non-zero matrix cells, for a symmetric matrix with only zero values in the top-right and bottom-left corners. For this Banded Covariance Matrix, one "result" attribute using the GCM_PositionedCellValues class shall be included for each matrix row. Each "result" attribute shall contain the value of one diagonal matrix cell, followed by the values of other cells to the right in that matrix row (and down in that matrix column). Each sequence shall end when there are no more non-zero cell values in that row or the right edge of this matrix is reached.
Stereotype:	Type
Class attribute:	Concrete
Inheritance from:	GCM_NormalCovarianceMatrix
Association roles:	(inherited from GCM_CovarianceMatrix)
Public attributes:	Ten attributes inherited from GCM_NormalCovarianceMatrix

11.3 XML encoding

The GCM_CovarianceMatrix UML package is encoded in the igmCovarianceMatrix.xsd XML Schema Document, which imports the TBD XML Schema Document from ISO 19139. The ISO 19115 classes used in the UML model are encoded by the ISO 19139

XML elements as listed in Table 3. The contents of the igmCovarianceMatrix.xsd XML Schema Document shall be as specified in the attached file.

Annex A
(normative)

Abstract test suite

An abstract test suite is not provided in this draft version of this Implementation Specification, but should be included in version 1.0.0.

Annex B
(normative)

XML Schema Documents

In addition to this document, this specification includes several normative XML Schema Documents. These XML Schema Documents are bundled in a zip file with the present document. After OGC acceptance of a Version 1.0.0 of this specification, these XML Schema Documents will also be posted online at the URL http://schemas.opengeospatial.net/igs/1.0.0. In the event of a discrepancy between the bundled and online versions of the XML Schema Documents, the online files shall be considered authoritative.

The image geopositioning metadata application schema specified in this document use five specified XML Schema Documents included in the zip file with this document. These XML Schema Documents roughly match the five UML packages described in Clauses 7 through 11, and are named:

igmSensorModel.xsd

igmImageGeometry.xsd

igmSensorCalibration.xsd

igmObjectPoint.xsd

igmCovarianceMatrix.xsd

These XML Schema Documents import and build upon parts of many of the GML 3.2 XML Schema Documents specified in [OGC 05-105].

All these XML Schema Documents contain documentation of the meaning of each element and attribute, and this documentation shall be considered normative as specified in Subclause 11.6.3 of [OGC 05-008].

Bibliography

[1] ASPRS 2004, Manual of Photogrammetry, Fifth Edition, American Society for Photogrammetry and Remote Sensing, 2004

[2] ISO 19130 draft n1772, Geographic information - Sensor data model for imagery and gridded data

[3] ISO/TS 19138 draft n2027, Geographic information — Data quality measures

[4] OGC 00-115, OGC Abstract Specification Topic 15: Image Exploitation Services

[5] OGC 00-116, OGC Abstract Specification Topic 16: Image Coordinate Transformation Services

[6] OGC 05-095r1, GML 3.1.1 common CRSs profile

[7] OGC 05-096r1, GML 3.1.1 grid CRSs profile

[8] OGC 05-TBD, Transducer Markup Language (TML)

[9] OGC 05-TBD, Sensor Markup Language (SensorML)

[10] USIGS Glossary

