

Open Geospatial Consortium Inc.

Date: 2005-04-14

Reference number of this OGC™ document: OGC 05-027r1

Version: 1.1.0

Category: OGC™ Recommendation Paper

Editor: Arliss Whiteside

Recommended XML/GML 3.1.1 encoding of image CRS definitions

Copyright © Open Geospatial Consortium (2005)

Recipients of this document are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

Document type:	OGC™ Recommendation Paper
Document subtype:	(none)
Document stage:	Expanded Recommendation Paper
Document language:	English

Contents	Page
i. Preface.....	v
ii. Document contributor contact points.....	v
iii. Revision history	vi
iv. Changes to the OGC Abstract Specification.....	vi
v. Future work.....	vi
Foreword.....	vii
Introduction.....	viii
1 Scope.....	1
2 Conformance.....	1
3 Normative references	1
4 Terms and definitions	3
5 Conventions	3
5.1 Symbols (and abbreviated terms).....	3
5.2 UML Notation.....	4
5.3 Document terms and definitions	4
6 Unrectified image coordinate reference systems	4
6.1 Overview.....	4
6.2 Simple UML model	5
6.3 Full XML document template.....	6
6.4 Recommended simple XML document template	8
6.5 Full UML model	9
7 Georectified image coordinate reference systems	10
7.1 Overview.....	10
7.2 Simple UML model	11
7.3 Full XML document template.....	12
7.4 Recommended simple XML document template	17
7.5 Full UML model	20
8 Coordinate transformations.....	22
8.1 Introduction.....	22
8.2 Simple UML model	22
8.3 XML document example templates	23
8.3.1 Image georeferencing Transformation full template	23
8.3.2 Image georeferencing Transformation recommended simple template.....	24
8.3.3 Grid elevation model Transformation full template	25

8.3.4	Grid elevation model Transformation recommended simple template.....	26
8.3.5	Concatenated operation full template	27
8.3.6	Concatenated operation recommended simple template.....	27
8.3.7	XML schema fragment	30
8.4	Full UML model	30
9	Standard URNs and XML definitions.....	32
9.1	Overview	32
9.2	Image CRSs with origin in centre of first pixel	32
9.3	Image CRSs with origin in corner of first pixel.....	34
9.4	Grid 2D square coordinate system.....	35
9.5	Row coordinate axis.....	36
9.6	Column coordinate axis	37
9.7	Image datum at pixel center.....	37
9.8	Image datum at pixel corner	38
9.9	Grid spacing unit of measure	39
10	Supporting information.....	39
Annex A (informative)	Application schema examples.....	40
A.1	Introduction.....	40
A.2	Extended operation parameter definition.....	40
A.2.1	Introduction.....	40
A.2.2	UML package.....	40
A.2.3	Application schema.....	41
A.2.4	Standard contents of parameterType	43
A.2.5	Example XML document.....	48
A.3	Universal image geometry model transformation.....	49
A.3.1	Introduction.....	49
A.3.2	UML package.....	50
A.3.3	Application schemas	56
A.3.4	Example XML documents	71
Annex B (informative)	Image coordinate operation methods	75
B.1	Introduction.....	84
B.2	Ground-to-image transformations.....	84
B.3	Elevation coverage for 2D to 3D coordinate transformation.....	84
B.4	Single-image-to-ground transformations	84
B.5	Elevation coverage with single-image-to-ground transformation	85
Bibliography	86

Figures

Page

Figure 1— ImageCRS simple UML class diagram.....	5
Figure 2 — ImageCRS full UML class diagram.....	10
Figure 3 — DerivedCRS simple UML class diagram.....	12
Figure 4 — DerivedCRS full UML class diagram.....	21
Figure 5 — Transformation and ConcatenatedOperation simple class diagram.....	22
Figure 6 — Transformation and ConcatenatedOperation full UML class diagram	31
Figure A.1 — UML package for Extended Operation Method.....	41
Figure A.3 — UML package for UIGM transformation, page 1.....	51
Figure A.3 — UML package for UIGM transformation, page 2.....	52
Figure A.5 — UML package for UIGM transformation, page 3.....	53
Figure A.6 — UML package for UIGM transformation, page 4.....	54
Figure A.7 — UML package for UIGM transformation, page 5.....	55

Tables

Page

Table 1 — Standard URNs for unrectified images CRSs	32
---	----

i. Preface

This expanded OGC™ Recommendation Paper specifies XML encoding of data defining image coordinate reference systems and coordinate operations. The previous version was limited to CRSs for individual (monoscopic) unrectified images. This extension also covers georectified images. This paper might be expanded in the future to also cover stereoscopic images.

This expanded paper adapts more the parts of [OGC 05-014], titled Image CRSs for IH4DS.

Many key contents of this paper are provided in the attached set of files, in the same zip file. These files include the:

- a) Example XML documents included and XML Schemas referenced in Clause 6 “Unrectified image coordinate reference systems”, Clause 7 “Georectified image coordinate reference systems”, and Clause 8 “Coordinate transformations”
- b) Standard definitions encoded in XML in Clause 9 “Standard URNs and XML definitions”
- c) Example Application Schemas and XML documents in Annex A "Application schema examples".

The changes made in this document version, relative to the previous version, are tracked by Microsoft Word, and can be viewed if desired. If you choose to submit suggested changes by editing this document, please first accept all the current changes, and then make your suggested changes with change tracking on.

ii. Document contributor contact points

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

Person	Company	Address	Phone	Email
Arliss Whiteside	BAE SYSTEMS National Security Solutions	10920 Technology Dr. San Diego, CA 92127-1874 USA	+1 858-592-1608	Arliss.Whiteside@bae systems.com

iii. Revision history

Date	Release	Editor	Primary clauses modified	Description
2004-12-09	0.0.0	Arliss Whiteside	All	Initial version
2005-01-28	1.0.0	Arliss Whiteside	Cover, i	Edited as approved Recommendation Paper
2005-03-08	1.0.1	Arliss Whiteside	7, 8	Added new Clauses 7 and 8
2005-04-14	1.1.0	Arliss Whiteside	Cover, i, 7.2, 8.3	Edited as approved Recommendation Paper

iv. Changes to the OGC Abstract Specification

The OGC™ Abstract Specification does not require changes to accommodate the technical contents of this document.

v. Future work

Improvements of this document are needed to:

- a) Modify XML schemas to reflect recent changes in the Topic 2 UML model [OGC 04-046r3]
- b) Specify standard XML encodings of some well-known operation methods, coordinate operations, CRSs, units, etc., and specify URNs to reference them

Foreword

This OGC™ Recommendation Paper expands and supersedes previous OGC Recommendation Paper numbered 05-012, also titled "Recommended XML/GML3.1.1 encoding of image CRS definitions". This document is based on the GML 3.1.1 OGC Recommendation Paper [04-092r4]. This document uses XML Schemas as specified by the W3C.

This document contains two informative annexes.

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

Introduction

This document recommends standard XML encodings of data defining monoscopic image coordinate reference systems. The scope of this encoding now includes unrectified and georectified images. The recommended CRSs for georectified images are recommended for multiple georectified images that are ready to be mosaicked together.

These recommended encodings are based on GML 3.1.1 and use XML Schemas. These image CRS definitions will often be referenced in data transferred between client and server software that implements various standardised interfaces. This specified definition data encoding is expected to be used by multiple OGC Implementation Specifications. That is, each of these specifications is expected to use a subset and/or superset of this recommended definition data.

The position or location of a point can be described using coordinates. Such coordinates are unambiguous only when the coordinate reference system on which those coordinates are based is fully defined. Each position is described by a set of coordinates based on a specified coordinate reference system. Coordinates are often used in datasets in which all coordinates belong to the same coordinate reference system. This paper specifies XML encoding of data defining image coordinate reference systems.

Recommended XML/GML 3.1.1 encoding of image CRS definitions

1 Scope

This OGC™ Recommendation Paper specifies standard XML encodings of definition data for monoscopic image coordinate reference systems and coordinate operations. These recommended encodings are based on GML 3.1.1 and use XML Schemas. This encoding is intended for use when referencing or transferring such definition data between client and server software that uses OGC standard interfaces, as specified in other documents. The expected uses of this definition data transfer include those described in Annex B of document [OGC 05-011].

The scope of this encoding now includes unrectified and georectified images. The recommended CRSs for georectified images are recommended for multiple georectified images that are ready to be mosaicked together. The current scope of this encoding does not include stereoscopic (multiple) images exploited together.

This Recommendation Paper specifies standard XML encodings of image CRS definition data applicable to multiple separate OGC interface Implementation Specifications. Each such Implementation Specification should specify one or more subsets and/or supersets of the definition data specified herein, each to be used for one or more purposes. That is, for each operation specified, the Implementation Specification should specify which specific image CRSs should be supported.

This document also defines a Profile of GML 3.1.1 for unrectified image CRSs. That profile includes all the elements and types in all the XML Schema fragments listed herein. That profile omits essentially all the CRS-related GML 3.1.1 elements and types not discussed in this document.

2 Conformance

Conformance with this specification shall be checked using all the relevant tests specified in each separate specification that normatively references this specification, and specifically references the applicable parts of this specification.

3 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this specification. 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.

IETF RFC 2141 (May 1997), *URN Syntax*, R. Moats
<<http://www.ietf.org/rfc/rfc2141.txt>>

IETF RFC 2396 (August 1998), *Uniform Resource Identifiers (URI): Generic Syntax*, Berners-Lee, T., Fielding, N., and Masinter, L., eds.,
<<http://www.ietf.org/rfc/rfc2396.txt>>

ISO 8601, *Data elements and interchange formats - Information interchange Representation of dates and times*

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

ISO 19109:2004, *Geographic Information – Rules for Application Schemas*

ISO 19115:2003, *Geographic information — Metadata*

OGC 99-107, *OGC Abstract Specification Topic 7: The Earth Imagery Case*, old version

OGC 04-046r3, *The OpenGIS Abstract Specification, Topic 2: Spatial referencing by coordinates*

OGC 04-092r4, *Geography Markup Language (GML) version 3.1.1 schemas* (draft)

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

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

OGC 05-011, *Recommended XML/GML 3.1.1 encoding of common CRS definitions*

W3C Recommendation 6 October 2000, *Extensible Markup Language (XML) 1.0* (Second Edition), <http://www.w3.org/TR/REC-xml>

W3C Recommendation 2 May 2001: *XML Schema Part 0: Primer*,
<http://www.w3.org/TR/2001/REC-xmlschema-0-20010502/>

W3C Recommendation 2 May 2001: *XML Schema Part 1: Structures*,
<http://www.w3.org/TR/2001/REC-xmlschema-1-20010502/>

W3C Recommendation 2 May 2001: *XML Schema Part 2: Datatypes*,
<http://www.w3.org/TR/2001/REC-xmlschema-2-20010502/>

In addition to this document, this Recommendation Paper includes several normative XML Schema files and XML documents. After this document is approved, these files will be posted online at the URL <http://schemas.opengespatial.net/ImageCRSs/1.1.0>. These XML Schema files are also bundled with the present document. In the event of a

discrepancy between the bundled and online versions of the XML Schema files, the online files shall be considered authoritative.

4 Terms and definitions

For the purposes of this specification, many of the definitions specified in Clauses 4 of the OGC Abstract Specification Topic 2 [04-046r3] and OWS Common Specification [OGC 05-008] shall apply. In addition, the following terms and definitions apply.

4.1

Application Schema

conceptual schema for data required by one or more applications [ISO 19101]

4.2

GML Application Schema

an XML Schema written according to the GML 3 rules for Application Schemas, which defines a vocabulary of geographic objects for a particular domain of discourse [GML 3.0]

4.3

object

an XML document element of a type derived from AbstractGMLType [GML 3.0]

4.4

profile

specified logical subset of XML Schema specified elements and types, defined to enhance interoperability and to curtail ambiguity [adapted from GML 3.0]

4.5

sequence

finite, ordered collection of related items (objects or values) that may be repeated [ISO 19107]

4.6

set

unordered collection of related items (**objects** or values) with no repetition [ISO 19107]

4.7

Uniform Resource Identifier (URI)

simple and extensible means for identifying a resource; a short string or address; classified as a name, a locator, or both [RFC 2396]

5 Conventions

5.1 Symbols (and abbreviated terms)

CRS Coordinate Reference System

GML	Geography Markup Language
IETF	Internet Engineering Task Force
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

All diagrams in this document are Unified Modeling Language (UML) class diagrams, as described in Subclause 5.2 of [OGC 05-008].

5.3 Document terms and definitions

This document uses the specification terms defined in Subclause 5.3 of [OGC 05-008].

6 Unrectified image coordinate reference systems

6.1 Overview

The definition of the CRS of each unrectified image shall be represented by the SC_ImageCRS class in the UML model in Topic 2. (This SC_ImageCRS class is clearly the best alternative for modelling the CRS of each unrectified image.) The definition of this class shall be XML encoded using the CRS portion of GML 3.1.1.

This CRS of each unrectified image shall be identified as the CRS of feature geometries measured or computed in that unrectified image. This CRS will also be used for identification of the georeferencing coordinate transformations discussed in Subclause 7.2.2.1 of the “WCTS profile for unrectified images” [draft].

NOTE An unrectified image is usually georeferenced to a 3D CRS that represents positions relative to the earth (or other planet or moon). That 3D CRS can be represented by a 3D GeographicCRS, GeocentricCRS, or CompoundCRS in the UML model in Topic 2. Such a CompoundCRS combines a (2D) ProjectedCRS with a (1D) VerticalCRS.

This clause specifies how to define the CRS-related objects for unrectified images. These definitions are usually not required to be transferred between servers and clients. However, these definitions shall be used in defining georeferencing coordinate transformations, and shall be referenced by those coordinate transformation definitions.

References to these CRSs shall be in the form of the anyURI type specified by XML Schema. As specified in Subclause 10.3 of [05-008], such an anyURI value can be either a URL with standard form or a URN in the “ogc” URN namespace.

6.2 Simple UML model

Figure 1 is a simplified UML class diagram extracted from Topic 2 that shows all the concrete (non-abstract) object classes and associations related to the SC_ImageCRS class. To keep this diagram simple, none of the class attributes are displayed. This diagram shows that the SC_ImageCRS class can use either a CS_CartesianCS or CS_AffineCS, but a CS_AffineCS is rarely used and is not required by this WCTS profile.

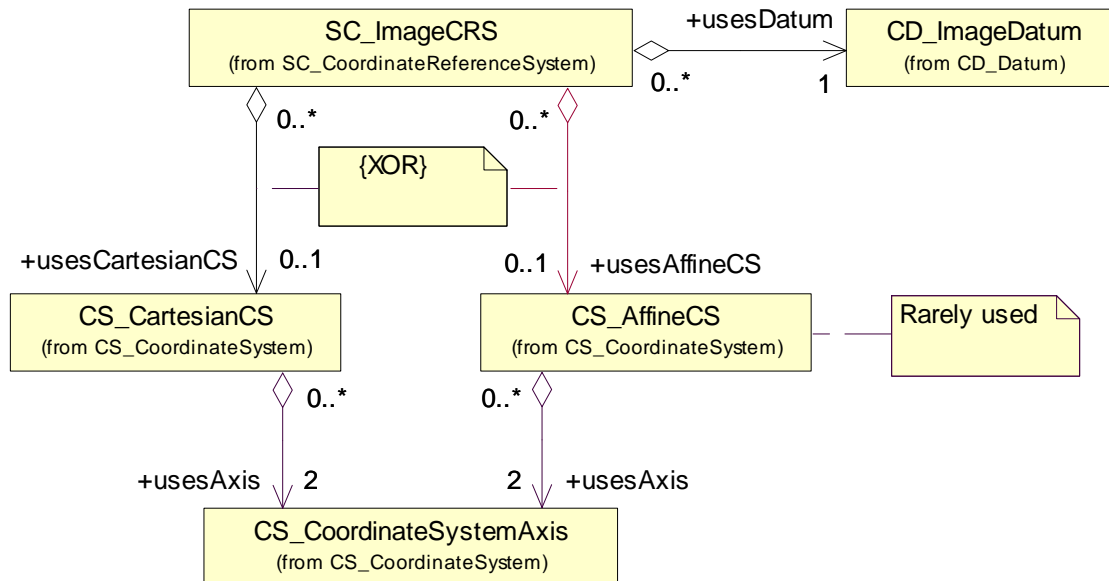


Figure 1— ImageCRS simple UML class diagram

Notice that the ImageCRS class does NOT include or reference any coordinate Transformations or operations which can be used to georeference this image. However, the coordinate Transformations or operations available to georeference an unrectified image can be saved with that image. These transformations must reference or include the SC_ImageCRS used for that unrectified image.

6.3 Full XML document template

An example template XML document completely defining an ImageCRS is:

```
<?xml version="1.0" encoding="UTF-8"?>
<ImageCRS xmlns="http://www.opengis.net/gml"
xmlns:gml="http://www.opengis.net/gml"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.opengis.net/gml fragmentImageCRSs.xsd"
gml:id="ImageTBDCRSpixelCenter">
  <!-- Primary editor: Arliss Whiteside. Last updated 2005-01-28-->
  <srsName>Image TBD CRS pixel centers</srsName>
  <!-- Specific image or group shall be identified by "TBD" in this
srsName. -->
  <srsID>
    <name
codeSpace="urn:ogc:def:crs:OGC:1.0:ImageCRSpixelCenter:">ImageTBDCRSpix
elCenter</name>
    <!-- Specifies the URN that can be used to reference this image
CRS. This URN includes the image name as a parameter. The specific
image or group shall be identified by the "TBD" in the "name" value. --
>
  </srsID>
  <remarks>Parameterized definition of 2D image coordinate reference
systems with the origin at the center of the first pixel in the image
file. This CRS definition can be used for any size image, since no
image size is specified.

This CRS definition is designed to be used for ungeorectified images,
and is not expected to be used for a georectified image. This
definition can be used for a georeferenced or ungeoreferenced image,
where a georeferenced image CRS is associated with the coordinate
Transformation(s) that georeference it. </remarks>
  <usesCartesianCS>
    <CartesianCS gml:id="Grid2dSquareCS">
      <csName>2D square-cell grid based coordinate system</csName>
      <csID>
        <name
codeSpace="urn:ogc:def:cs:OGC:1.0:">Grid2dSquareCS</name>
      </csID>
      <remarks>A 2D grid-based coordinate system for use by an image
or other continuous grid coverage. It can be used for a grid of any
size, since no grid size is defined. This coordinate system specifies
that each row coordinate value shall be listed before the column
coordinate value. The grid cells are assumed to be square, with the
same grid spacing or pixel spacing in each direction.
```

In a grid coverage file, the "row" axis shall be the first axis by which grid points are sequenced, and the "column" axis shall be the second axis, as could be specified by the "scanDirection : Sequence(CharacterString)" attribute of the CV_SequenceRule class in Clause 8 of ISO 19123. With linear sequencing, the grid points in the first row shall be listed first, followed by other rows, with the grid points in each row listed in column number order. This relationship between the "row" and "column" names and the first grid points shall

apply whether this Grid2dSquareCS is associated with a grid file before or after that file is recorded.

The "row" and "column" axis names are used here although the "scanDirection : Sequence(CharacterString)" attribute may provide other axis names. Use of other axis names would require defining different CartesianCSs for other names, or adding other names as additional axisID values. The following XML includes the axis names "line" and "sample" as additional axisID values.

If not otherwise identified in an image file, the "row" axis shall be the first axis whose number of pixels is identified, and the "column" axis shall be the second axis, as could be specified by the "extent[0..1] : CV_GridEnvelope" attribute of the CV_Grid class in Clause 8 of ISO 19123. In either case, the first point in the grid coverage file is assumed to be numbered (1, 1), meaning row 1, column 1.

The first row in a grid is sometimes called the "top" row, the first column is sometimes called the "left" column, and the first grid point is then called the "upperLeft" point. If desired, those names can be used with this Grid2dSquareCS. However other names can also be used, since this Grid2dSquareCS has been defined so that it does not depend on such left/right, top/bottom, and up/down names. </remarks>

```

    <usesAxis>
      <CoordinateSystemAxis gml:id="Row"
gml:uom="urn:ogc:def:uom:OGC:1.0:GridSpacing">
        <name>Grid row axis</name>
        <axisID>
          <name
codeSpace="urn:ogc:def:axis:OGC:1.0:">Row</name>
        </axisID>
        <remarks>For this grid axis, row coordinate values match
grid row numbers, but allow fractional coordinate values between grid
points. The first row in a grid is sometimes called the "top" row, so
the direction of this axis is "down", but these terms are not required.
</remarks>
        <axisAbbrev>R</axisAbbrev>

      <axisDirection>urn:ogc:def:axisDirection:OGC:1.0:rowPositive</axisDi
rection>
    </CoordinateSystemAxis>
  </usesAxis>
  <usesAxis>
    <CoordinateSystemAxis gml:id="Column"
gml:uom="urn:ogc:def:uom:OGC:1.0:GridSpacing">
      <name>Grid column axis</name>
      <axisID>
        <name
codeSpace="urn:ogc:def:axis:OGC:1.0:">Column</name>
      </axisID>
      <remarks>For this grid axis, column coordinate values
match grid column numbers, but allow fractional coordinate values
between grid points. The first column is sometimes called the "left"
column, so the direction of this axis is "right", but these terms are
not required. </remarks>
      <axisAbbrev>C</axisAbbrev>

```

```

    <axisDirection>urn:ogc:def:axisDirection:OGC:1.0:columnPositive</axisDirection>
    </CoordinateSystemAxis>
  </usesAxis>
</CartesianCS>
</usesCartesianCS>
<usesImageDatum>
  <ImageDatum gml:id="ImageDatumPixelCenter">
    <datumName>Origin at center of first pixel</datumName>
    <datumID>
      <name
codeSpace="urn:ogc:def:datum:OGC:1.0:">ImageDatumPixelCenter</name>
    </datumID>
    <remarks>A 2D image datum with the origin at the center of the
first pixel in the image file. In an image file, the pixels in the
first row are assumed to be listed first, followed by other rows, with
pixels in each row listed (and collected) in column number order.
</remarks>
    <anchorPoint>center of first pixel</anchorPoint>
    <pixelInCell
codeSpace="urn:ogc:def:pixelInCell:OGC:1.0:">cellCenter</pixelInCell>
    </ImageDatum>
  </usesImageDatum>
</ImageCRS>

```

6.4 Recommended simple XML document template

The above template XML document can be simplified by referencing the standard XML documents specified in Clause 8, becoming:

```

<?xml version="1.0" encoding="UTF-8"?>
<ImageCRS xmlns="http://www.opengis.net/gml"
xmlns:gml="http://www.opengis.net/gml"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.opengis.net/gml fragmentImageCRSs.xsd"
gml:id="ImageTBDCRSPixelCenter">
  <!-- Primary editor: Arliss Whiteside. Last updated 2005-01-28 -->
  <srsName>Image TBD CRS pixel centers</srsName>
  <!-- Specific image or group shall be identified by "TBD" in this
srsName. -->
  <srsID>
    <name
codeSpace="urn:ogc:def:crs:OGC:1.0:ImageCRSPixelCenter:">ImageTBDCRSPixelCenter</name>
    <!-- Specifies the URN that can be used to reference this image
CRS. This URN includes the image name as a parameter. The specific
image or group shall be identified by the "TBD" in the "name" value. --
>
  </srsID>
  <remarks>Parameterized definition of 2D image coordinate reference
systems with the origin at the center of the first pixel in the image
file. This CRS definition can be used for any size image, since no
image size is specified.

```

This CRS definition is designed to be used for ungeorectified images, and is not expected to be used for a georectified image. This definition can be used for a georeferenced or ungeoreferenced image, where a georeferenced image CRS is associated with the coordinate Transformation(s) that georeference it. </remarks>

```
<usesCartesianCS
xlink:href="urn:ogc:def:cs:OGC:1.0:Grid2dSquareCS"/>
<usesImageDatum
xlink:href="urn:ogc:def:datum:OGC:1.0:ImageDatumPixelCenter"/>
</ImageCRS>
```

This simplified template XML document is recommended for use in defining the CRSs of unrectified images. Of course, the included XML comments and <remarks> elements can be removed or edited.

The corresponding GML 3.1.1 XML Schema fragment for defining an ImageCRS is attached in the file fragmentImageCRSs.xsd.

6.5 Full UML model

Figure 2 is a more complete UML class diagram extracted from Topic 2 that shows essentially all the classes and associations related to the SC_ImageCRS class.

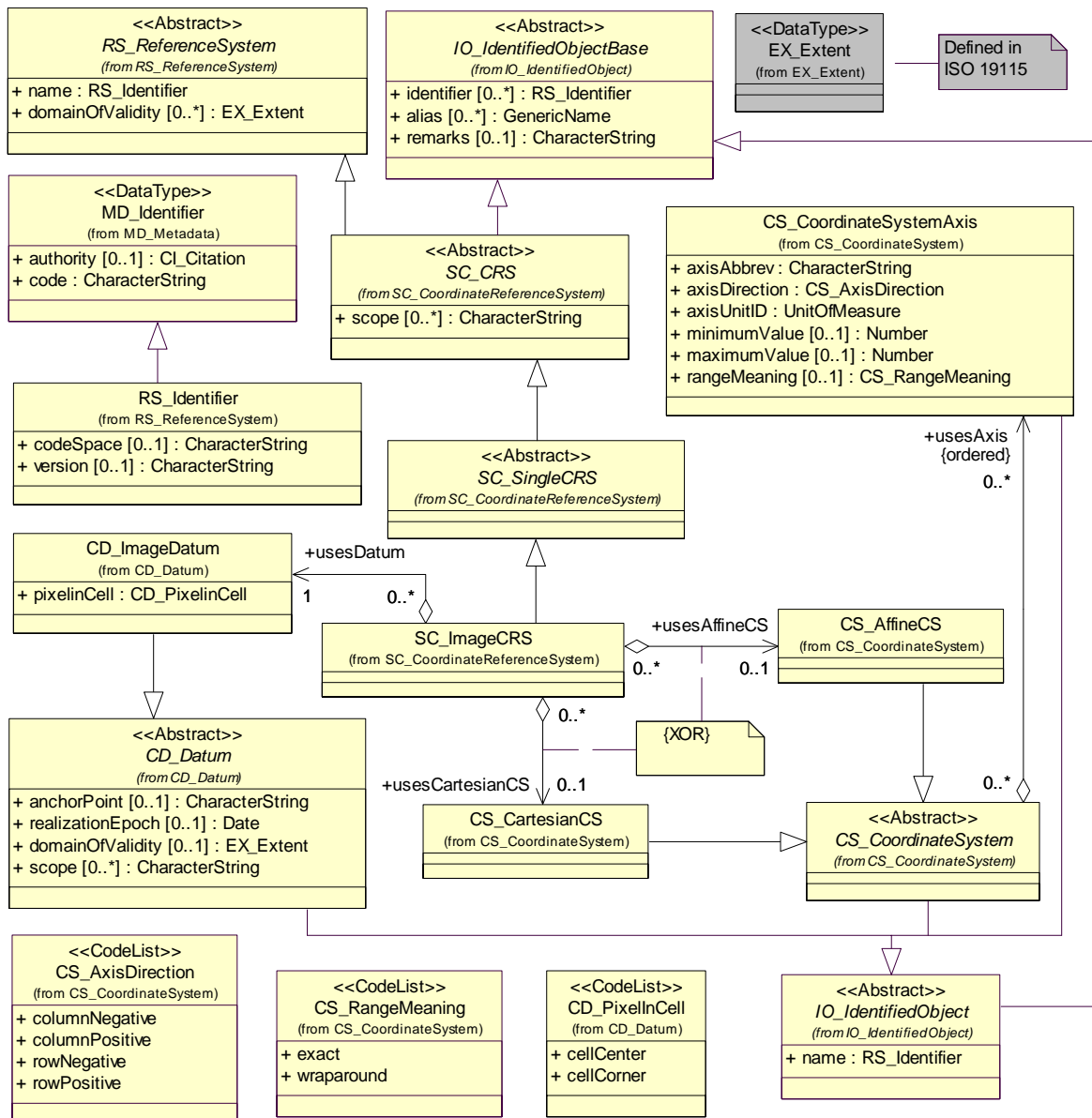


Figure 2 — ImageCRS full UML class diagram

7 Georectified image coordinate reference systems

7.1 Overview

The definition of the CRSs used for multiple georectified images should be represented by the SC_DerivedCRS class in the UML model in Topic 2. This SC_DerivedCRS class is not the only alternative for representing the definition of the CRS of a georectified image, but is recommended when multiple georectified images do or should use the same image CRS. Multiple georectified images must use the same CRS, or closely related CRSs, when those georectified images are directly ready for image mosaicking.

To support image mosaicking, these georectified images must use exactly the same pixel positions wherever they (do or might) overlap. This means that the grids must have the same baseCRSs, grid point spacings in that CRS, and grid rotation in that CRS. When different origins are used, these origins must be grid points in the same SC_DerivedCRS.

This CRS for a georectified image should be identified as the CRS of feature geometries measured or computed in that georectified image. This CRS should also be used for identification of the georeferencing coordinate transformations discussed in Subclause 7.2.2.1 of the “WCTS profile for unrectified images” [draft].

NOTE 1 The gml:RectifiedGrid element in grids.xsd specifies the locations of a grid of points in a base or external coordinate reference system (CRS). The relationship between those grid points and the image pixels is largely defined by gml:coverageFunction. However, a gml: _Coverage is not a CRS, so does not define a CRS suitable for positions that are measured or computed in that georectified image. Also, it does not define a CRS that can be used as the sourceCRS or TargetCRS of a coordinate Transformation.

The definition of this class shall be XML encoded using the CRS portion of GML 3.1.1. The baseCRS of a georectified image SC_DerivedCRS is 2D and is usually either a GeographicCRS or a ProjectedCRS. The usesCS Coordinate System of a georectified image SC_DerivedCRS specifies a 2D grid of positions, with integer coordinate values designating grid point indices. The definedByConversion of a georectified image SC_DerivedCRS specifies the grid origin, grid spacing, and any rotation in the base CRS.

NOTE 2 Non-integer values of coordinates in the usesCS Coordinate System specify positions between the grid points.

This clause specifies how to define these CRS objects for georectified images. These definitions are usually not required to be transferred between servers and clients. However, these definitions shall be used in defining the definedByConversion and georeferencing coordinate transformations, and shall be referenced by those coordinate transformation definitions.

References to these CRSs shall be in the form of the anyURI type specified by XML Schema. As specified in Subclause 10.3 of [05-008], such an anyURI value can be either a URL with standard form or a URN in the “ogc” URN namespace.

7.2 Simple UML model

Figure 3 is a simplified UML class diagram extracted from Topic 2 that shows all the concrete (non-abstract) object classes and associations related to the SC_DerivedCRS class when used for a georectified image. To keep this diagram simple, none of the class attributes are displayed. This diagram shows that the SC_DerivedCRS class can use as its baseCRS either a SC_GeographicCRS or SC_ProjectedCRS. The CC_Conversion class is detailed in Subclause 6.4, the SC_GeographicCRS class is detailed in Subclause 6.2, and the SC_ProjectedCRS class is detailed in Subclause 6.3, all in [OGC 05-011].

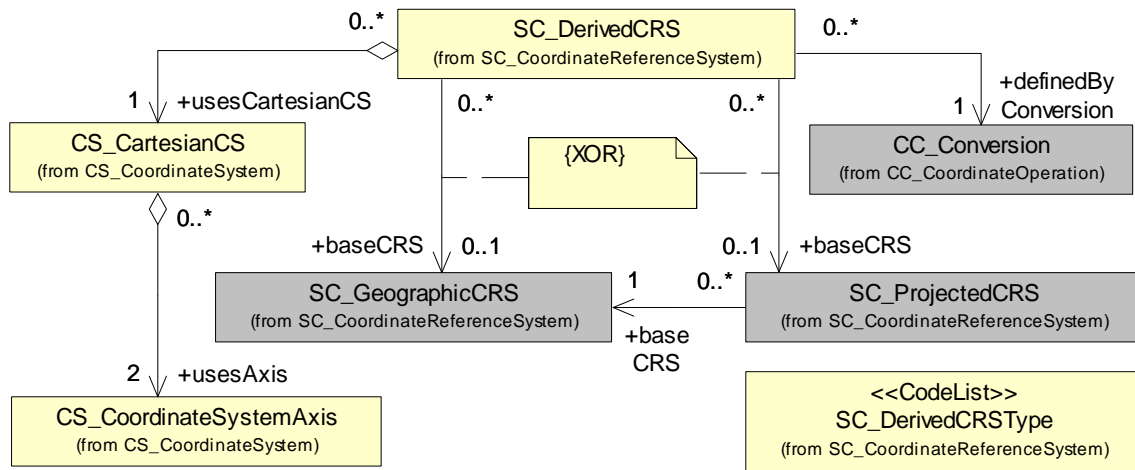


Figure 3 — DerivedCRS simple UML class diagram

Notice that this **SC_DerivedCRS** class does NOT include or reference any coordinate Transformations or operations which could be used to georeference the original image that was georectified. However, the coordinate Transformations and operations used to georeference and georectify the original image should be saved with the georectified image. One of these transformations must reference or include the **SC_DerivedCRS** used for that georectified image.

NOTE The image georectification process must use a georeferencing coordinate Transformation (or ConcatenatedOperation). That georeferencing Transformation must have the unrectified image CRS (ImageCRS) as its source (or target) CRS. That georeferencing Transformation could have the georectified image CRS (DerivedCRS) as its target (or source) CRS; in this case, the **definedByConversion** is not used to perform the georectification. Alternately, that georeferencing Transformation could have the (GeographicCRS or ProjectedCRS) baseCRS of the georectified image CRS (DerivedCRS) as its target (or source) CRS; in this case (discussed in Clause 8), the **definedByConversion** must also be used to perform the georectification. There are probably other useful alternatives.

7.3 Full XML document template

An example template XML document completely defining a DerivedCRS for a georectified image is:

```

<?xml version="1.0" encoding="UTF-8"?>
<DerivedCRS xmlns="http://www.opengis.net/gml"
xmlns:gml="http://www.opengis.net/gml"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.opengis.net/gml
fragmentGeorectifiedGridCRSs.xsd" gml:id="GeorectifiedImageXXXXCRS">
  <!-- Specific georectified image or grid must be identified in this
gml:id. -->
  <!-- Last updated 2005-03-08 -->
  <!-- ===== -->
  <srsName>Georectified Image XXXX CRS</srsName>
  <!-- Specific georectified image or grid must be identified in
srsName. -->
  <srsID>

```

```

    <name
codeSpace="urn:opengis:def:crs:OGC:0.20:GeorectifiedImageXXXXCRS">Geore
ctifiedImageXXXXCRS</name>
    <!-- Specific image must be identified in "name" value. -->
    </srsID>
    <remarks>Template for georectified 2D image coordinate reference
system definition. In this CRS, the origin is at the center of the
first pixel in the georectified image file. This CRS template can be
used for any size georectified image, since no image size is specified.
A CRS definition using this template is expected to be needed and thus
created before the georectified image pixels are produced. The
coordinate Conversion used by this CRS definition is expected to NOT
closely approximate the reverse of the coordinate Transformation used
to georectify this image. This CRS template is not expected to be
useful for an ungeorectified image. </remarks>
    <baseCRS xlink:href="urn:opengis:def:crs:EPSG:6.3:YYYY"/>
    <!-- Specific 2D CRS that was georectified into must be identified
in baseCRS, usually a ProjectedCRS or GeographicCRS -->
    <!-- ===== -->
    <definedByConversion>
        <Conversion gml:id="GeorectifiedImageXXXXConversion">
            <!-- Specific georectified image or grid must be identified in
this gml:id. -->
            <coordinateOperationName>Georectified image XXXX
conversion</coordinateOperationName>
            <!-- Specific image must be identified in this
coordinateOperationName. -->
            <usesMethod>
                <OperationMethod gml:id="EPSG9624">
                    <methodName>Affine general parametric
transformation</methodName>
                    <methodID>
                        <name
codeSpace="urn:opengis:method:EPSG:6.3:">9624</name>
                        </methodID>
                        <methodFormula>
XT    =  A0  +  A1.XS  +  A2.YS;
YT    =  B0  +  B1.XS  +  B2.YS;
where XT , YT  are the coordinates of a point P in the target
coordinate system;
        XS , YS  are the coordinates of P in the source coordinate
system.

Reversibility: The parameter values for an affine transformation cannot
be used for the reverse transformation. However, the reverse
transformation is another affine transformation using the same formulas
but with different parameter values. The reverse parameter values,
indicated by a prime ('), can be calculated from those of the forward
transformation as follows:
D      =  A1 . B2      -  A2 . B1;
A0'    =  (A2 . B0      -  B2 . A0) / D;
B0'    =  (B1 . A0      -  A1 . B0) / D;
A1'    =  +B2 / D;
A2'    =  - A2 / D;
B1'    =  - B1 / D;
B2'    =  +A1 / D.

See Section 2.4.2.1 of EPSG Guidance Note 7. </methodFormula>

```

```

<sourceDimensions>2</sourceDimensions>
<targetDimensions>2</targetDimensions>
<!-- ===== -->
<usesParameter>
  <OperationParameter gml:id="EPSG8623">
    <parameterName>A0</parameterName>
    <parameterID>
      <name
codeSpace="urn:ogc:def:parameter:EPSG:6.3:">8623</name>
    </parameterID>
  </OperationParameter>
</usesParameter>
<!-- ===== -->
<usesParameter>
  <OperationParameter gml:id="EPSG8624">
    <parameterName>A1</parameterName>
    <parameterID>
      <name
codeSpace="urn:ogc:def:parameter:EPSG:6.3:">8624</name>
    </parameterID>
  </OperationParameter>
</usesParameter>
<!-- ===== -->
<usesParameter>
  <OperationParameter gml:id="EPSG8625">
    <parameterName>A2</parameterName>
    <parameterID>
      <name
codeSpace="urn:ogc:def:parameter:EPSG:6.3:">8625</name>
    </parameterID>
  </OperationParameter>
</usesParameter>
<!-- ===== -->
<usesParameter>
  <OperationParameter gml:id="EPSG8639">
    <parameterName>B0</parameterName>
    <parameterID>
      <name
codeSpace="urn:ogc:def:parameter:EPSG:6.3:">8639</name>
    </parameterID>
  </OperationParameter>
</usesParameter>
<!-- ===== -->
<usesParameter>
  <OperationParameter gml:id="EPSG8640">
    <parameterName>B1</parameterName>
    <parameterID>
      <name
codeSpace="urn:ogc:def:parameter:EPSG:6.3:">8640</name>
    </parameterID>
  </OperationParameter>
</usesParameter>
<!-- ===== -->
<usesParameter>
  <OperationParameter gml:id="EPSG8641">
    <parameterName>B2</parameterName>
    <parameterID>

```

```

        <name
codeSpace="urn:ogc:def:parameter:EPSG:6.3:">8641</name>
        </parameterID>
    </OperationParameter>
</usesParameter>
</OperationMethod>
</usesMethod>
<!-- ===== -->
<usesValue>
    <value uom="urn:opengis:def:uom:EPSG:6.3:ZZZZ">9999</value>
    <!-- Specific uom code and parameter value must be inserted
-->
        <valueOfParameter
xlink:href="urn:opengis:def:parameter:EPSG:6.3:8623"/>
    </usesValue>
    <!-- ===== -->
    <usesValue>
        <value uom="urn:opengis:def:uom:EPSG:6.3:ZZZZ">9999</value>
        <!-- Specific uom code and parameter value must be inserted
-->
        <valueOfParameter
xlink:href="urn:opengis:def:parameter:EPSG:6.3:8624"/>
    </usesValue>
    <!-- ===== -->
    <usesValue>
        <value uom="urn:opengis:def:uom:EPSG:6.3:ZZZZ">9999</value>
        <!-- Specific uom code and parameter value must be
inserted.
            The value of this parameter is often 0.0. -->
        <valueOfParameter
xlink:href="urn:opengis:def:parameter:EPSG:6.3:8625"/>
    </usesValue>
    <!-- ===== -->
    <usesValue>
        <value uom="urn:opengis:def:uom:EPSG:6.3:ZZZZ">9999</value>
        <!-- Specific uom code and parameter value must be inserted
-->
        <valueOfParameter
xlink:href="urn:opengis:def:parameter:EPSG:6.3:8639"/>
    </usesValue>
    <!-- ===== -->
    <usesValue>
        <value uom="urn:opengis:def:uom:EPSG:6.3:ZZZZ">9999</value>
        <!-- Specific uom code and parameter value must be
inserted.
            The value of this parameter is often 0.0. -->
        <valueOfParameter
xlink:href="urn:opengis:def:parameter:EPSG:6.3:8640"/>
    </usesValue>
    <!-- ===== -->
    <usesValue>
        <value uom="urn:opengis:def:uom:EPSG:6.3:ZZZZ">9999</value>
        <!-- Specific uom code and parameter value must be inserted
-->
        <valueOfParameter
xlink:href="urn:opengis:def:parameter:EPSG:6.3:8641"/>
    </usesValue>
</Conversion>

```

```

</definedByConversion>
<!-- ===== -->
<derivedCRSType
codeSpace="#DerivedCRSTypeValues">#image</derivedCRSType>
<!-- ===== -->
<usesCS>
  <CartesianCS gml:id="Grid2dSquareCS">
    <csName>2D square-cell grid based coordinate system</csName>
    <csID>
      <name
codeSpace="urn:ogc:def:cs:OGC:1.0:">Grid2dSquareCS</name>
      </csID>
      <remarks>A 2D grid-based coordinate system for use by an image
or other continuous grid coverage. It can be used for a grid of any
size, since no grid size is defined. This coordinate system specifies
that each row coordinate value shall be listed before the column
coordinate value. The grid cells are assumed to be square, with the
same grid spacing or pixel spacing in each direction.

```

In a grid coverage file, the "row" axis shall be the first axis by which grid points are sequenced, and the "column" axis shall be the second axis, as could be specified by the "scanDirection : Sequence(CharacterString)" attribute of the CV_SequenceRule class in Clause 8 of ISO 19123. With linear sequencing, the grid points in the first row shall be listed first, followed by other rows, with the grid points in each row listed in column number order. This relationship between the "row" and "column" names and the first grid points shall apply whether this Grid2dSquareCS is associated with a grid file before or after that file is recorded.

The "row" and "column" axis names are used here although the "scanDirection : Sequence(CharacterString)" attribute may provide other axis names. Use of other axis names would require defining different CartesianCSs for other names, or adding other names as additional axisID values. The following XML includes the axis names "line" and "sample" as additional axisID values.

If not otherwise identified in an image file, the "row" axis shall be the first axis whose number of pixels is identified, and the "column" axis shall be the second axis, as could be specified by the "extent[0..1] : CV_GridEnvelope" attribute of the CV_Grid class in Clause 8 of ISO 19123. In either case, the first point in the grid coverage file is assumed to be numbered (1, 1), meaning row 1, column 1.

The first row in a grid is sometimes called the "top" row, the first column is sometimes called the "left" column, and the first grid point is then called the "upperLeft" point. If desired, those names can be used with this Grid2dSquareCS. However other names can also be used, since this Grid2dSquareCS has been defined so that it does not depend on such left/right, top/bottom, and up/down names. </remarks>

```

  <usesAxis>
    <CoordinateSystemAxis gml:id="Row"
gml:uom="urn:ogc:def:uom:OGC:1.0:GridSpacing">
      <name>Grid row axis</name>
      <axisID>

```

```

        <name
codeSpace="urn:ogc:def:axis:OGC:1.0:">Row</name>
        </axisID>
        <remarks>For this grid axis, row coordinate values match
grid row numbers, but allow fractional coordinate values between grid
points. The first row in a grid is sometimes called the "top" row, so
the direction of this axis is "down", but these terms are not required.
</remarks>
        <axisAbbrev>R</axisAbbrev>

        <axisDirection>urn:ogc:def:axisDirection:OGC:1.0:rowPositive</axisDi
rection>
        </CoordinateSystemAxis>
        </usesAxis>
        <usesAxis>
        <CoordinateSystemAxis gml:id="Column"
gml:uom="urn:ogc:def:uom:OGC:1.0:GridSpacing">
        <name>Grid column axis</name>
        <axisID>
        <name
codeSpace="urn:ogc:def:axis:OGC:1.0:">Column</name>
        </axisID>
        <remarks>For this grid axis, column coordinate values
match grid column numbers, but allow fractional coordinate values
between grid points. The first column is sometimes called the "left"
column, so the direction of this axis is "right", but these terms are
not required. </remarks>
        <axisAbbrev>C</axisAbbrev>

        <axisDirection>urn:ogc:def:axisDirection:OGC:1.0:columnPositive</axi
sDirection>
        </CoordinateSystemAxis>
        </usesAxis>
        </CartesianCS>
        </usesCS>
</DerivedCRS>

```

The above template XML document uses the operation Method catalogued by EPSG using code 9624, because that EPSG method seems closest to the desired Method. However, various other operation Methods could be used, including Methods specified by the OGC. For example, one or more operation Methods could be defined that use parts of the gml:RectifiedGrid element as operation Parameters.

7.4 Recommended simple XML document template

The above example template XML document can be simplified by referencing the standard XML documents specified in Clause 9, and referencing the EPSG 9624 Operation Method, becoming:

```

<?xml version="1.0" encoding="UTF-8"?>
<DerivedCRS xmlns="http://www.opengis.net/gml"
xmlns:gml="http://www.opengis.net/gml"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.opengis.net/gml
fragmentGeorectifiedGridCRSS.xsd" gml:id="GeorectifiedImageXXXXCRS">
  <!-- Specific georectified image or grid must be identified in this
gml:id. -->
  <!-- Last updated 2005-03-08 -->
  <!-- ===== -->
  <srsName>Georectified Image XXXX CRS</srsName>
  <!-- Specific georectified image or grid must be identified in
srsName. -->
  <srsID>
    <name
codeSpace="urn:opengis:def:crs:OGC:0.:GeorectifiedImageCRS">Georectifie
dImageXXXXCRS</name>
    <!-- Specific image must be identified in "name" value. -->
  </srsID>
  <remarks>Template for georectified 2D image coordinate reference
system definition. In this CRS, the origin is at the center of the
first pixel in the georectified image file. This CRS template can be
used for any size georectified image, since no image size is specified.
A CRS definition using this template is expected to be needed and thus
created before the georectified image pixels are produced. The
coordinate Conversion used by this CRS definition is expected to NOT
closely approximate the reverse of the coordinate Transformation used
to georectify this image. This CRS template is not expected to be
useful for an ungeorectified image. </remarks>
  <baseCRS xlink:href="urn:opengis:def:crs:EPSG:6.3:YYYY"/>
  <!-- Specific 2D CRS that was georectified into must be identified
in baseCRS, usually a ProjectedCRS or GeographicCRS -->
  <!-- ===== -->
  <definedByConversion>
    <Conversion gml:id="GeorectifiedImageXXXXConversion">
      <!-- Specific georectified image or grid must be identified in
this gml:id. -->
      <coordinateOperationName>Georectified image XXXX
conversion</coordinateOperationName>
      <!-- Specific image must be identified in this
coordinateOperationName. -->
      <usesMethod xlink:href="urn:opengis:method:EPSG:6.3:9624"/>
      <!-- ===== -->
      <usesValue>
        <value uom="urn:opengis:def:uom:EPSG:6.3:ZZZZ">9999</value>
        <!-- Specific uom code and parameter value must be inserted
-->
        <valueOfParameter
xlink:href="urn:opengis:def:parameter:EPSG:6.3:8623"/>
      </usesValue>
      <!-- ===== -->
      <usesValue>
        <value uom="urn:opengis:def:uom:EPSG:6.3:ZZZZ">9999</value>
        <!-- Specific uom code and parameter value must be inserted
-->

```

```

        <valueOfParameter
xlink:href="urn:opengis:def:parameter:EPSG:6.3:8624"/>
        </usesValue>
        <!-- ===== -->
        <usesValue>
            <value uom="urn:opengis:def:uom:EPSG:6.3:ZZZZ">9999</value>
            <!-- Specific uom code and parameter value must be
inserted. The value of this parameter is often 0.0. -->
            <valueOfParameter
xlink:href="urn:opengis:def:parameter:EPSG:6.3:8625"/>
            </usesValue>
            <!-- ===== -->
            <usesValue>
                <value uom="urn:opengis:def:uom:EPSG:6.3:ZZZZ">9999</value>
                <!-- Specific uom code and parameter value must be inserted
-->
                <valueOfParameter
xlink:href="urn:opengis:def:parameter:EPSG:6.3:8639"/>
                </usesValue>
                <!-- ===== -->
                <usesValue>
                    <value uom="urn:opengis:def:uom:EPSG:6.3:ZZZZ">9999</value>
                    <!-- Specific uom code and parameter value must be
inserted.
                        The value of this parameter is often 0.0. -->
                    <valueOfParameter
xlink:href="urn:opengis:def:parameter:EPSG:6.3:8640"/>
                    </usesValue>
                    <!-- ===== -->
                    <usesValue>
                        <value uom="urn:opengis:def:uom:EPSG:6.3:ZZZZ">9999</value>
                        <!-- Specific uom code and parameter value must be inserted
-->
                        <valueOfParameter
xlink:href="urn:opengis:def:parameter:EPSG:6.3:8641"/>
                        </usesValue>
                    </Conversion>
                </definedByConversion>
                <!-- ===== -->
                <derivedCRSType
codeSpace="#DerivedCRSTypeValues">#image</derivedCRSType>
                <usesCS xlink:href="urn:ogc:def:cs:OGC:1.0:Grid2dSquareCS"/>
            </DerivedCRS>

```

This simplified template XML document is recommended for use in defining the CRSs of georectified images. Of course, the OperationMethod can be changed, and the included XML comments and <remarks> elements can be removed or edited.

The corresponding GML 3.1.1 XML Schema fragment for defining a DerivedCRS for a georectified image is attached in the file fragmentGeorectifiedImageCRSs.xsd. An example XML document defining the EPSG 9624 Operation Method is also attached.

7.5 Full UML model

Figure 4 is a more complete UML class diagram extracted from Topic 2 that shows essentially all the classes and associations related to the SC_DerivedCRS class. Again, the CC_Conversion class is detailed in Subclause 6.4, the SC_GeographicCRS class is detailed in Subclause 6.2, and the SC_ProjectedCRS class is detailed in Subclause 6.3, all in [OGC 05-011]

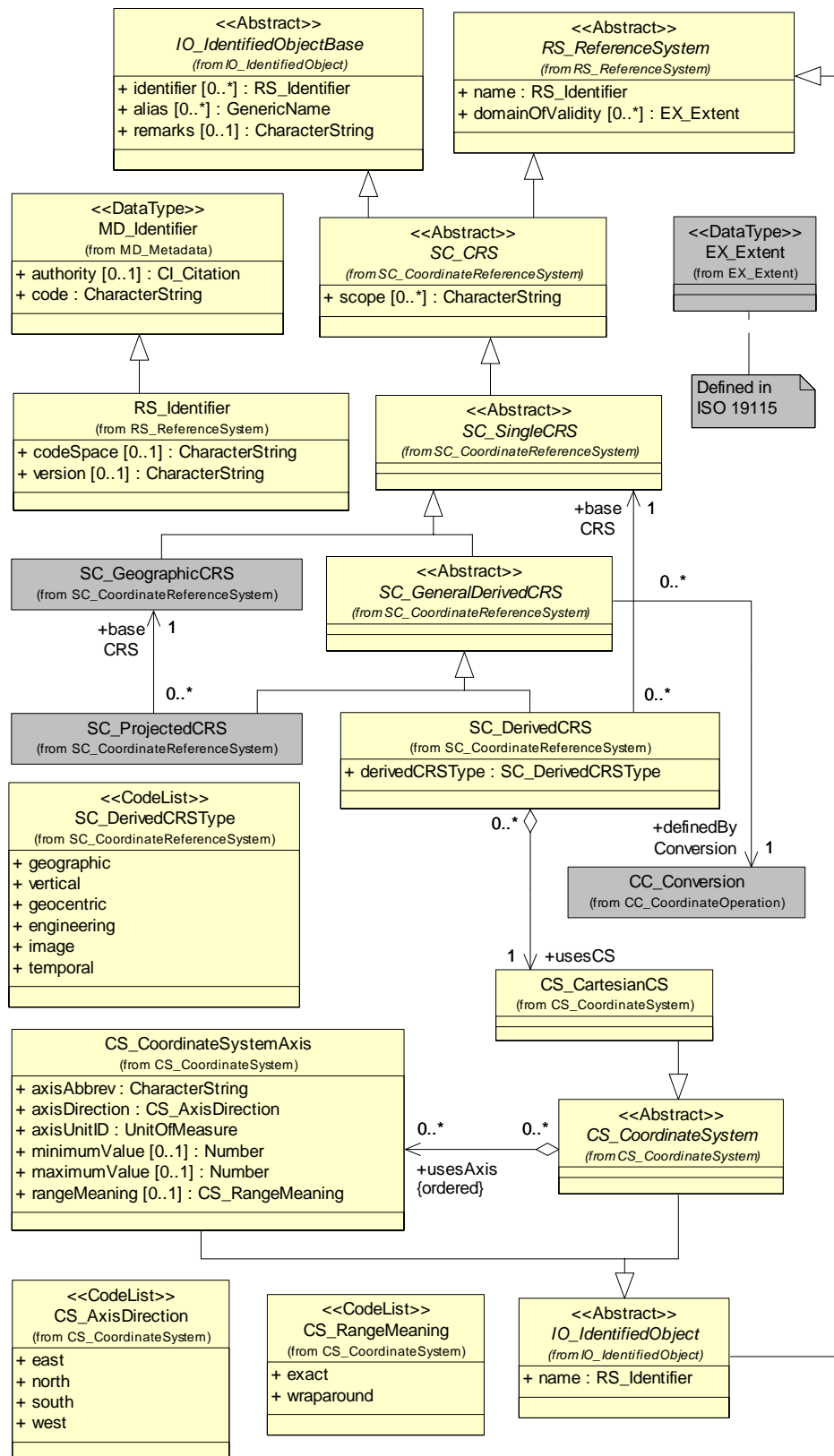


Figure 4 — DerivedCRS full UML class diagram

8 Coordinate transformations

8.1 Introduction

An unrectified image can be georeferenced by at least one coordinate transformation, between the CRS of the unrectified image and a reference CRS for positions relative to the earth (or other planet or moon). This georeferencing coordinate transformation can be represented by a coordinate Transformation in the UML model in Topic 2. A frequent alternative to using one Transformation is using a ConcatenatedOperation that sequentially combines two or more Transformations.

The reference CRS is usually 3D, while the unrectified image is only 2D. The georeferencing coordinate transformation is thus assumed to be from the reference 3D CRS to the 2D image CRS. If the reference CRS is 2D, that would be equivalent to combining the georeferencing coordinate transformation with the elevation model coordinate transformation discussed later in this clause.

8.2 Simple UML model

Figure 5 is a simplified UML class diagram extracted from Topic 2 for a CC_Transformation and CC_ConcatenatedOperation. This diagram shows most of the concrete (non-abstract) classes and associations related to the CC_Transformation and CC_ConcatenatedOperation classes, except for the CC_ParameterValueGroup and CC_OperationParameterGroup classes. The CC_ParameterValueGroup and CC_OperationParameterGroup classes are not always useful, but are useful for some operation methods used for image geometry models.

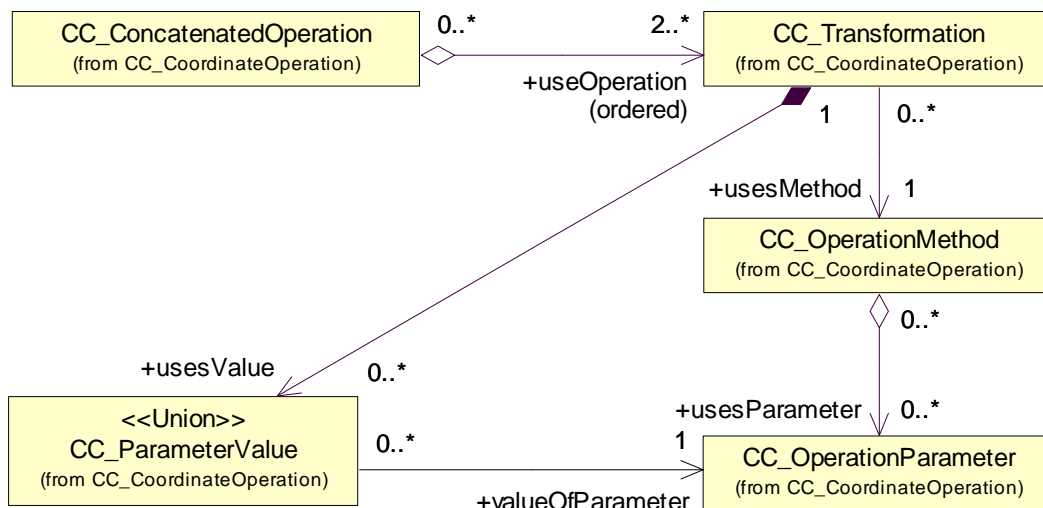


Figure 5 — Transformation and ConcatenatedOperation simple class diagram

To keep this diagram simple, none of the class attributes are displayed. The CC_ConcatenatedOperation class can also have usesOperation associations to the

CC_Conversion class, with each associated object of CC_Conversion class substituting for an object of CC_Transformation class in this UML model.

This simplified UML diagram does not include the two associations with the role names sourceCRS and targetCRS, required to the abstract SC_CRS class from both the CC_Transformation and CC_ConcatenatedOperation classes. For a georeferencing Transformation, the targetCRS will be a SC_ImageCRS and the sourceCRS will be the reference CRS used in that georeferencing, both being non-abstract subclasses of the SC_CRS class.

8.3 XML document example templates

8.3.1 Image georeferencing Transformation full template

An example template XML document defining a CC_Transformation for image georeferencing is:

```
<?xml version="1.0" encoding="UTF-8"?>
<Transformation xmlns="http://www.opengis.net/gml"
xmlns:gml="http://www.opengis.net/gml"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.opengis.net/gml
fragmentTransformations.xsd"
gml:id="TemplateGeoreferencingTransformation">
  <!-- Primary editor: Arliss Whiteside. Last updated 2005-03-08 -->
  <coordinateOperationName>Example template for image georeferencing
coordinate Transformations</coordinateOperationName>
  <operationVersion>1.0</operationVersion>
  <sourceCRS xlink:href="urn:ogc:def:crs:EPSG:6.3:TBD">
    <!-- This sourceCRS must be 3D. -->
  </sourceCRS>
  <targetCRS
xlink:href="urn:ogc:def:crs:OGC:0.0:ImageCRSPixelCenter:TBD"/>
  <usesMethod>
    <OperationMethod gml:id="ReplacementSensorModel">
      <methodName>Replacement Sensor Model (RSM) coordinate
Transformation</methodName>
      <methodID>
        <name
codeSpace="urn:ogc:def:method:OGC:0.0:">ReplacementSensorModel</name>
      </methodID>
      <remarks>This operation method is for a coordinate
Transformation that georeferences an unrectified image using the
Replacement Sensor Model (RSM). </remarks>

      <methodFormula>urn:ogc:def:method:OGC:0.0:ReplacementSensorModel.
</methodFormula>
      <sourceDimensions>3</sourceDimensions>
      <targetDimensions>2</targetDimensions>
      <usesParameter>
        <OperationParameter gml:id="RSMPParameters">
          <parameterName>Parameters for Replacement Sensor Model
(RSM). </parameterName>
          <parameterID>
```

```

        <name
codeSpace="http://baesystems.com/rsm/rsmParameters"/>
        </parameterID>
        <remarks>The value of this operation parameter is the
URL of a file containing all the parameters for the Replacement Sensor
Model (RSM) for the specific image. </remarks>
        </OperationParameter>
    </usesParameter>
</OperationMethod>
</usesMethod>
<usesValue>

    <valueFile>http://baesystems.com/rsm/rsmParameterValues/TBD.xml</val
ueFile>
    <valueOfParameter
xlink:href="http://baesystems.com/rsm/rsmParameters"/>
    </usesValue>
</Transformation>

```

This example template uses the “Replacement Sensor Model (RSM)” Operation Method for georeferencing Transformations. That example method uses one parameter named “RSMParameters” that contains the URL of a file containing all the RSM parameters for a specific image. That RSM Operation Method is an extension of the “Universal image geometry model transformation” discussed in Subclause A.3.

8.3.2 Image georeferencing Transformation recommended simple template

That Operation Method could be specified elsewhere and referenced by this georeferencing Transformations template, instead of being included in-line. Doing this produces the simplified template XML document:

```

<?xml version="1.0" encoding="UTF-8"?>
<Transformation xmlns="http://www.opengis.net/gml"
xmlns:gml="http://www.opengis.net/gml"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.opengis.net/gml
fragmentTransformations.xsd"
gml:id="TemplateGeoreferencingTransformation">
    <!-- Primary editor: Arliss Whiteside. Last updated 2005-03-08 -->
    <coordinateOperationName>Example template for image georeferencing
coordinate Transformations</coordinateOperationName>
    <operationVersion>1.0</operationVersion>
    <sourceCRS xlink:href="urn:ogc:def:crs:EPSG:6.3:TBD">
        <!-- This sourceCRS must be 3D. -->
    </sourceCRS>
    <targetCRS
xlink:href="urn:ogc:def:crs:OGC:0.0:ImageCRSPixelCenter:TBD"/>
    <usesMethod
xlink:href="urn:ogc:def:method:OGC:0.0:ReplacementSensorModel"/>
    <usesValue>

    <valueFile>http://baesystems.com/rsm/rsmParameterValues/TBD.xml</val
ueFile>

```

```

        <valueOfParameter
xlink:href="http://baesystems.com/rsm/rsmParameters"/>
        </usesValue>
</Transformation>

```

This simplified template XML document is recommended for use in defining the image georeferencing coordinate Transformations. Of course, the OperationMethod can be changed, and the included XML comments and <remarks> elements can be removed or edited.

8.3.3 Grid elevation model Transformation full template

A template XML document defining a CC_Transformation for a grid elevation model is:

```

<?xml version="1.0" encoding="UTF-8"?>
<Transformation xmlns="http://www.opengis.net/gml"
xmlns:gml="http://www.opengis.net/gml"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.opengis.net/gml
fragmentTransformations.xsd"
gml:id="TemplateGridElevationModelTransformation">
  <!-- Primary editor: Arliss Whiteside. Last updated 2005-03-08 -->
  <coordinateOperationName>Template for grid elevation model
coordinate Transformations</coordinateOperationName>
  <operationVersion>1.0</operationVersion>
  <sourceCRS xlink:href="urn:ogc:def:crs:EPSG:6.3:TBD">
    <!-- This sourceCRS must be 2D. -->
  </sourceCRS>
  <targetCRS xlink:href="urn:ogc:def:crs:EPSG:6.3:TBD">
    <!-- This targetCRS must be 3D. -->
  </targetCRS>
  <usesMethod>
    <OperationMethod gml:id="GridElevationModel">
      <methodName>Grid elevation model</methodName>
      <methodID>
        <name
codeSpace="urn:ogc:def:method:OGC:0.0:">GridElevationModel</name>
      </methodID>
      <remarks>This operation method is for a coordinate
Transformation that implements an elevation model using grid elevation
data. </remarks>
      <methodFormula>The elevation value for the input horizontal
position shall be bilinear interpolated between the surrounding four
grid points, and added to the input horizontal coordinates.
</methodFormula>
      <sourceDimensions>2</sourceDimensions>
      <targetDimensions>3</targetDimensions>
      <usesParameter>
        <OperationParameter gml:id="GridElevationData">
          <parameterName>Grid Elevation Data</parameterName>
          <parameterID>
            <name
codeSpace="urn:ogc:def:parameter:OGC:0.0:">GridElevationData</name>
          </parameterID>

```

```

        <remarks>The value of this operation parameter is the
        URL of a source of grid elevation data, in the 3D targetCRS of the
        coordinate Transformation that contains the value of this operation
        parameter. </remarks>
    </OperationParameter>
</usesParameter>
</OperationMethod>
</usesMethod>
<usesValue>
    <valueFile>http://baesystems.com/DEM/TBD</valueFile>
    <valueOfParameter
xlink:href="urn:ogc:def:parameter:OGC:0.0:GridElevationData"/>
    </usesValue>
</Transformation>

```

This example template uses the “GridElevationModel” Operation Method. That example method uses one parameter named “GridElevationData” that contains the URL of a file containing the grid elevation data.

8.3.4 Grid elevation model Transformation recommended simple template

That Operation Method could be specified elsewhere and referenced by this GridElevationModel Transformations template, instead of being included in-line. Doing this produces the simplified template XML document:

```

<?xml version="1.0" encoding="UTF-8"?>
<Transformation xmlns="http://www.opengis.net/gml"
xmlns:gml="http://www.opengis.net/gml"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.opengis.net/gml
fragmentTransformations.xsd"
gml:id="TemplateGridElevationModelTransformation">
    <!-- Primary editor: Arliss Whiteside. Last updated 2005-03-08 -->
    <coordinateOperationName>Template for grid elevation model
coordinate Transformations</coordinateOperationName>
    <operationVersion>1.0</operationVersion>
    <sourceCRS xlink:href="urn:ogc:def:crs:EPSG:6.3:TBD">
        <!-- This sourceCRS must be 2D. -->
    </sourceCRS>
    <targetCRS xlink:href="urn:ogc:def:crs:EPSG:6.3:TBD">
        <!-- This targetCRS must be 3D. -->
    </targetCRS>
    <usesMethod
xlink:href="urn:ogc:def:method:OGC:0.0:GridElevationModel"/>
    <usesValue>
        <valueFile>http://baesystems.com/DEM/TBD</valueFile>
        <valueOfParameter
xlink:href="urn:ogc:def:parameter:OGC:0.0:GridElevationData"/>
        </usesValue>
    </Transformation>

```

This simplified template XML document is recommended for use in defining grid elevation model coordinate Transformations. Of course, the OperationMethod can be

changed, and the included XML comments and <remarks> elements can be removed or edited.

8.3.5 Concatenated operation full template

A template XML document defining a CC_ConcatenatedOperation that combines the two full transformation templates above is:

```
<?xml version="1.0" encoding="UTF-8"?>
<ConcatenatedOperation xmlns="http://www.opengis.net/gml"
xmlns:gml="http://www.opengis.net/gml"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.opengis.net/gml
fragmentTransformations.xsd" gml:id="TemplateConcatenatedOperation">
  <!-- Primary editor: Arliss Whiteside. Last updated 2005-04-13 -->
  <coordinateOperationName>Template for
ConcatenatedOperation</coordinateOperationName>
  <remarks>Template for coordinate ConcatenatedOperation to
unrectified image coordinates from ground CRS coordinates. </remarks>
  <sourceCRS xlink:href="urn:ogc:def:crs:EPSG:6.3:TBD">
    <!-- This sourceCRS must be 2D. -->
  </sourceCRS>
  <targetCRS
xlink:href="urn:ogc:def:crs:OGC:0.0:ImageCRSpixelCenter:TBD"/>
  <usesSingleOperation>
    <Transformation
gml:id="TemplateGridElevationModelTransformation">
      <coordinateOperationName>Template for grid elevation model
coordinate Transformations</coordinateOperationName>
      <operationVersion>1.0</operationVersion>
      <sourceCRS xlink:href="urn:ogc:def:crs:EPSG:6.3:TBD">
        <!-- This sourceCRS must be the same as the sourceCRS
above. -->
      </sourceCRS>
      <targetCRS xlink:href="urn:ogc:def:crs:EPSG:6.3:TBD">
        <!-- This targetCRS must be 3D. -->
      </targetCRS>
      <usesMethod>
        <OperationMethod gml:id="GridElevationModel">
          <methodName>Grid elevation model</methodName>
          <methodID>
            <name
codeSpace="urn:ogc:def:method:OGC:0.0:">GridElevationModel</name>
          </methodID>
          <remarks>This operation method is for a coordinate
Transformation that implements an elevation model using grid elevation
data. </remarks>
          <methodFormula>The elevation value for the input
horizontal position shall be bilinear interpolated between the
surrounding four grid points, and added to the input horizontal
coordinates. </methodFormula>
          <sourceDimensions>2</sourceDimensions>
          <targetDimensions>3</targetDimensions>
          <usesParameter>
            <OperationParameter gml:id="GridElevationData">
              <parameterName>Grid Elevation Data</parameterName>
```

```

        <parameterID>
          <name
codeSpace="urn:ogc:def:parameter:OGC:0.0:">GridElevationData</name>
        </parameterID>
        <remarks>The value of this operation parameter is
the URL of a source of grid elevation data, in the 3D targetCRS of the
coordinate Transformation that contains the value of this operation
parameter. </remarks>
      </OperationParameter>
    </usesParameter>
  </OperationMethod>
</usesMethod>
<usesValue>
  <valueFile>http://baesystems.com/DEM/TBD</valueFile>
  <valueOfParameter
xlink:href="urn:ogc:def:parameter:OGC:0.0:GridElevationData"/>
  </usesValue>
</Transformation>
</usesSingleOperation>
<usesSingleOperation>
  <Transformation gml:id="TemplateGeoreferencingTransformation">
    <coordinateOperationName>Template for image georeferencing
coordinate Transformation</coordinateOperationName>
    <operationVersion>1.0</operationVersion>
    <sourceCRS xlink:href="urn:ogc:def:crs:EPSG:6.3:TBD">
      <!-- This sourceCRS must be the same as the targetCRS
above. -->
    </sourceCRS>
    <targetCRS
xlink:href="urn:ogc:def:crs:OGC:0.0:ImageCRSPixelCenter:TBD"/>
    </usesMethod>
    <OperationMethod gml:id="ReplacementSensorModel">
      <methodName>Replacement Sensor Model (RSM) coordinate
Transformation</methodName>
      <methodID>
        <name
codeSpace="urn:ogc:def:method:OGC:0.0:">ReplacementSensorModel</name>
      </methodID>
      <remarks>This operation method is for a coordinate
Transformation that georeferences an unrectified image using the
Replacement Sensor Model (RSM). </remarks>

      <methodFormula>urn:ogc:def:method:OGC:0.0:ReplacementSensorModel.
</methodFormula>
      <sourceDimensions>3</sourceDimensions>
      <targetDimensions>2</targetDimensions>
      <usesParameter>
        <OperationParameter gml:id="RSMPParameters">
          <parameterName>Parameters for Replacement Sensor
Model (RSM). </parameterName>
          <parameterID>
            <name
codeSpace="http://baesystems.com/rsm/rsmParameters"/>
          </parameterID>
          <remarks>The value of this operation parameter is
the URL of a file containing all the parameters for the Replacement
Sensor Model (RSM) for the specific image. </remarks>

```

```

        </OperationParameter>
      </usesParameter>
    </OperationMethod>
  </usesMethod>
</usesValue>

  <valueFile>http://baesystems.com/rsm/rsmParameterValues/TBD.xml</valueFile>
    <valueOfParameter
xlink:href="http://baesystems.com/rsm/rsmParameters"/>
    </usesValue>
  </Transformation>
</usesSingleOperation>
</ConcatenatedOperation>

```

8.3.6 Concatenated operation recommended simple template

The above template uses the “Replacement Sensor Model (RSM)” and “GridElevationModel” Operation Methods. Those Operation Methods could be specified elsewhere and referenced by this template, instead of being included in-line. Doing this produces the simplified template XML document:

```

<?xml version="1.0" encoding="UTF-8"?>
<ConcatenatedOperation xmlns="http://www.opengis.net/gml"
xmlns:gml="http://www.opengis.net/gml"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.opengis.net/gml
fragmentTransformations.xsd" gml:id="TemplateConcatenatedOperation">
  <!-- Primary editor: Arliss Whiteside. Last updated 2005-04-13 -->
  <coordinateOperationName>Template for
ConcatenatedOperation</coordinateOperationName>
  <remarks>Template for coordinate ConcatenatedOperation to
unrectified image coordinates from ground CRS coordinates. </remarks>
  <sourceCRS xlink:href="urn:ogc:def:crs:EPSG:6.3:TBD">
    <!-- This sourceCRS must be 2D. -->
  </sourceCRS>
  <targetCRS
xlink:href="urn:ogc:def:crs:OGC:0.0:ImageCRSPixelCenter:TBD"/>
  <usesSingleOperation>
    <Transformation
gml:id="TemplateGridElevationModelTransformation">
      <coordinateOperationName>Template for grid elevation model
coordinate Transformations</coordinateOperationName>
      <operationVersion>1.0</operationVersion>
      <sourceCRS xlink:href="urn:ogc:def:crs:EPSG:6.3:TBD">
        <!-- This sourceCRS must be the same as the sourceCRS
above. -->
      </sourceCRS>
      <targetCRS xlink:href="urn:ogc:def:crs:EPSG:6.3:TBD">
        <!-- This targetCRS must be 3D. -->
      </targetCRS>
      <usesMethod
xlink:href="urn:ogc:def:method:OGC:0.0:GridElevationModel"/>
      <usesValue>
        <valueFile>http://baesystems.com/DEM/TBD</valueFile>

```

```

        <valueOfParameter
xlink:href="urn:ogc:def:parameter:OGC:0.0:GridElevationData"/>
        </usesValue>
    </Transformation>
</usesSingleOperation>
<usesSingleOperation>
    <Transformation gml:id="TemplateGeoreferencingTransformation">
        <coordinateOperationName>Template for image georeferencing
coordinate Transformation</coordinateOperationName>
        <operationVersion>1.0</operationVersion>
        <sourceCRS xlink:href="urn:ogc:def:crs:EPSG:6.3:TBD">
            <!-- This sourceCRS must be the same as the targetCRS
above. -->
        </sourceCRS>
        <targetCRS
xlink:href="urn:ogc:def:crs:OGC:0.0:ImageCRSPixelCenter:TBD"/>
        <usesMethod
xlink:href="urn:ogc:def:method:OGC:0.0:ReplacementSensorModel"/>
        <usesValue>

        <valueFile>http://baesystems.com/rsm/rsmParameterValues/TBD.xml</valueFile>
        <valueOfParameter
xlink:href="http://baesystems.com/rsm/rsmParameters"/>
        </usesValue>
    </Transformation>
</usesSingleOperation>
</ConcatenatedOperation>

```

This simplified template XML document is recommended for use in defining such concatenated Transformations. Of course, the OperationMethods can be changed, and the included XML comments and <remarks> elements can be removed or edited.

8.3.7 XML schema fragment

The corresponding GML 3.1.1 XML Schema fragment for defining a CC_Transformation or CC_ConcatenatedOperation is attached in file fragmentTransformations.xsd. That XML Schema fragment omits the encoding of the validArea and positionalAccuracy attributes in the UML model. Example XML documents defining the Operation Methods that might be defined elsewhere are also attached

8.4 Full UML model

Figure 6 is a more complete UML class diagram extracted from Topic 2 for a coordinate CC_Transformation and CC_ConcatenatedOperation. This diagram shows essentially all the classes and associations related to the CC_Transformation and CC_ConcatenatedOperation classes, except for the:

- Contents of the DQ_PositionalAccuracy and EX_Extent classes, defined in ISO 19115
- Contents of the SC_CRS class, such as defined in Clauses 6 and 7

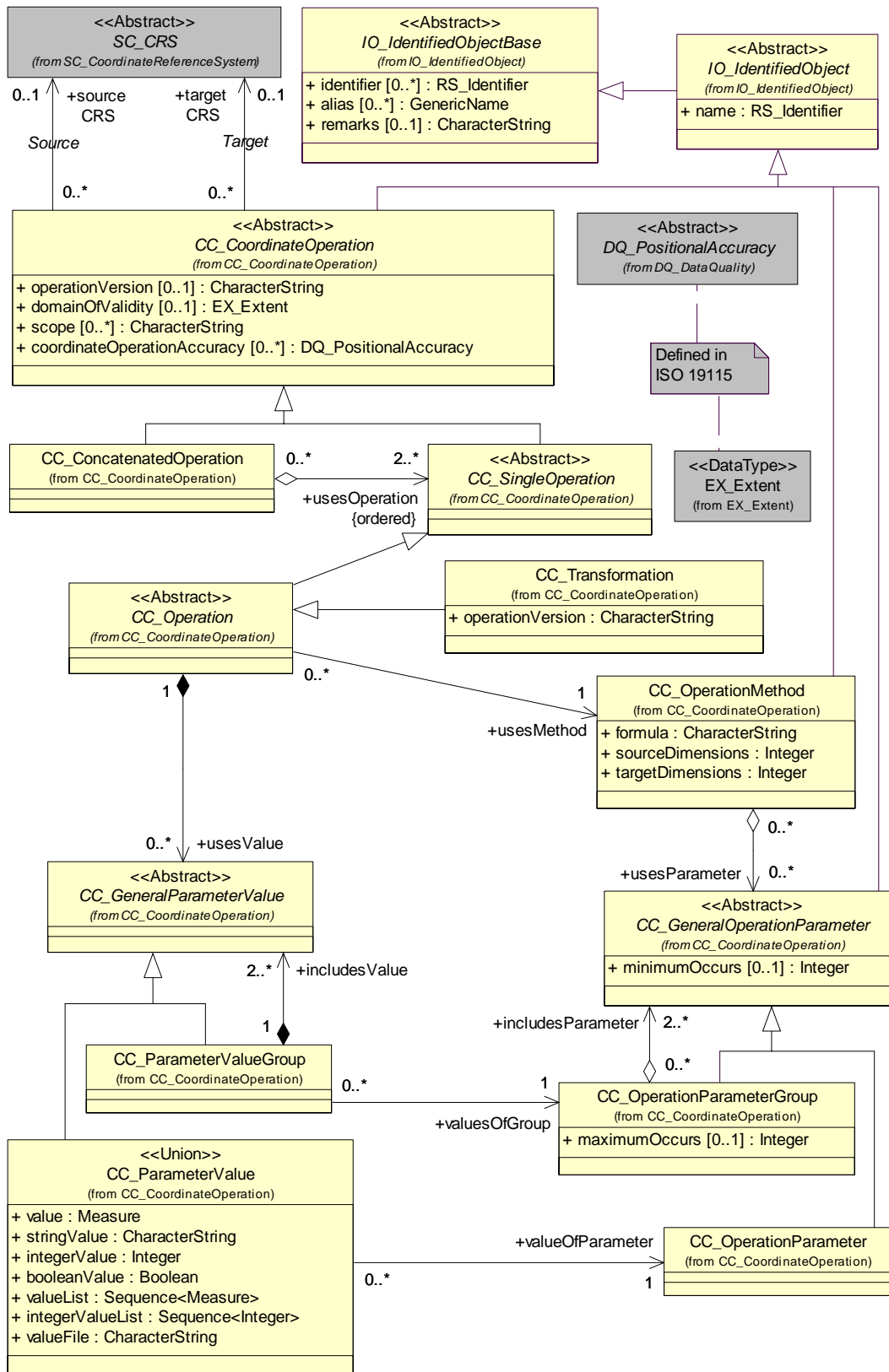


Figure 6 — Transformation and ConcatenatedOperation full UML class diagram

Notice that each Transformation and ConcatenatedOperation inherits two associations with the role names sourceCRS and targetCRS, required to the abstract SC_CRS class from both the CC_Transformation and CC_ConcatenatedOperation classes. For a georeferencing Transformation, the targetCRS will be a SC_ImageCRS and the sourceCRS will be the reference CRS used in that georeferencing, both being non-abstract subclasses of the SC_CRS class.

9 Standard URNs and XML definitions

9.1 Overview

This clause specifies a standard set of definitions and corresponding URNs that shall be used whenever applicable for unrectified and georectified images. These definitions are encoded in GML 3.1.1 [OGC 04-092r4].

Whenever applicable, CRS definitions for images shall use the eight URNs in the “ogc” URN namespace that are specified in Table 1. The first two these URNs use the format for not-completely-specified objects specified in Subclause 7.2 of “URNs of definitions in ogc namespace” [OGC 05-010]. The remaining six of these URNs use the format for single objects specified in Subclause 7.1.

Table 1 — Standard URNs for unrectified images CRSs

URN	Object name & gml:id	Definition specified in
urn:ogc:def:crs:OGC:0.0:ImageCRSPixelCenter:TBD ^a	ImageTBDCRSPixelCenter	Subclause 7.2
urn:ogc:def:crs:OGC:0.0:ImageCRSPixelCorner:TBD ^a	ImageTBDCRSPixelCorner	Subclause 7.3
urn:ogc:def:cs:OGC:0.0:Grid2dSquareCS	Grid2dSquareCS	Subclause 7.4
urn:ogc:def:axis:OGC:0.0:Row	Row	Subclause 7.5
urn:ogc:def:axis:OGC:0.0:Column	Column	Subclause 7.6
urn:ogc:def:datum:OGC:0.0:ImageDatumPixelCenter	ImageDatumPixelCenter	Subclause 7.7
urn:ogc:def:datum:OGC:0.0:ImageDatumPixelCorner	ImageDatumPixelCorner	Subclause 7.8
urn:ogc:def:uom:OGC:0.0:GridSpacing	GridSpacing	Subclause 7.9
^a This “TBD” shall be replaced by the image identifier alphanumeric character string.		

NOTE These image CRSa and components were defined and used in the XML document attached to Discussion Paper “Image CRSs for IH4DS” [OGC 05-014]. The definitions of these components have now been updated to use a later version of the CRS Schemas, in [OGC 04-092r4].

9.2 Image CRSs with origin in centre of first pixel

The URN value “urn:ogc:def:crs:OGC:0.0:ImageCRSPixelCenter:TBD” shall reference the definition of an (unrectified) image CRS with its origin in the centre of the first pixel in the image file. This image CRS shall be for the image, or image group, whose alphanumeric character string identifier is substituted for the “TBD” in this URN.

NOTE 1 This document does not specify any format for an image alphanumeric identifier, since many different formats are used for such identifiers. One such format could concatenate a camera identifier with the image collection date and time.

The definitions of these image CRSs shall be the same as can be XML encoded using GML 3.1.1 as:

```
<?xml version="1.0" encoding="UTF-8"?>
<ImageCRS xmlns="http://www.opengis.net/gml"
xmlns:gml="http://www.opengis.net/gml"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.opengis.net/gml
../gml/3.1.1/base/coordinateReferenceSystems.xsd"
gml:id="ImageTBDCRSpixelCenter">
  <!-- Specific image or group shall be identified by "TBD" in this
gml:id. -->
  <!-- Primary editor: Arliss Whiteside. Last updated 2005-01-28-->
  <!-- ===== -->
  <srsName>Image TBD CRS pixel centers</srsName>
  <!-- Specific image or group shall be identified by "TBD" in this
srsName. -->
  <srsID>
    <name
codeSpace="urn:ogc:def:crs:OGC:1.0:ImageCRSpixelCenter:">TBD</name>
    <!-- Specifies the URN that can be used to reference this image
CRS. This URN includes the image name as a parameter. The specific
image or group shall be identified by the "TBD" in the "name" value. --
>
  </srsID>
  <remarks>Parameterized definition of 2D image coordinate reference
systems with the origin at the center of the first pixel in the image
file. This CRS definition can be used for any size image, since no
image size is specified.

This CRS definition is designed to be used for ungeorectified images,
and is not expected to be used for a georectified image. This
definition can be used for a georeferenced or ungeoreferenced image,
where a georeferenced image CRS is associated with the coordinate
Transformation(s) that georeference it. </remarks>
  <usesCartesianCS
xlink:href="urn:ogc:def:cs:OGC:1.0:Grid2dSquareCS"/>
  <usesImageDatum
xlink:href="urn:ogc:def:datum:OGC:1.0:ImageDatumPixelCenter"/>
</ImageCRS>
```

NOTE 2 It is not expected to be necessary in most cases to produce an XML document that specifies the image CRS for a specific image identifier, since this CRS definition can be referenced using the specified URN value with the "TBD" replaced by the specific image identifier. However, it is possible to do this, as shown in the following example.

EXAMPLE If this XML document were modified to specify the image CRS with its origin in the centre of first pixel for an image with the identifier "C543D041201T084027", this XML document could be:

```
<?xml version="1.0" encoding="UTF-8"?>
<ImageCRS xmlns="http://www.opengis.net/gml"
xmlns:gml="http://www.opengis.net/gml"
xmlns:xlink="http://www.w3.org/1999/xlink"
```

```

xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.opengis.net/gml
../gml/3.1.1/base/coordinateReferenceSystems.xsd"
gml:id="ImageC543D041201T084027CRSPixelCenter">
  <!-- Primary editor: Arliss Whiteside. Last updated 2005-01-28-->
  <srsName>Image C543D041201T084027 CRS pixel centers</srsName>
  <srsID>
    <name
codeSpace="urn:ogc:def:crs:OGC:1.0:ImageCRSPixelCenter:">C543D041201T084027</na
me>
    <!-- This name specifies the URN by which this CRS can be referenced. -->
  </srsID>
  <usesCartesianCS xlink:href="urn:ogc:def:cs:OGC:1.0:Grid2dSquareCS"/>
  <usesImageDatum
xlink:href="urn:ogc:def:datum:OGC:1.0:ImageDatumPixelCenter"/>
</ImageCRS>

```

9.3 Image CRSs with origin in corner of first pixel

The URN value “urn:ogc:def:crs:OGC:0.0:ImageCRSPixelCorner:TBD” shall reference the definition of an (unrectified) image CRS with its origin in the outside corner of the first pixel in the image file. This image CRS shall be for the image, or image group, whose identifier is substituted for the “TBD” in this URN.

The definitions of these image CRSs shall be the same as can be XML encoded using GML 3.1.1 as:

```

<?xml version="1.0" encoding="UTF-8"?>
<ImageCRS xmlns="http://www.opengis.net/gml"
xmlns:gml="http://www.opengis.net/gml"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.opengis.net/gml
../gml/3.1.1/base/coordinateReferenceSystems.xsd"
gml:id="ImageTBDCRSPixelCorner">
  <!-- Specific image or group shall be identified by "TBD" in this
gml:id. -->
  <!-- Primary editor: Arliss Whiteside. Last updated 2005-01-28 -->
  <!-- ===== -->
  <srsName>Image TBD CRS pixel corner</srsName>
  <!-- Specific image or group shall be identified by "TBD" in this
srsName. -->
  <srsID>
    <name
codeSpace="urn:ogc:def:crs:OGC:1.0:ImageCRSPixelCorner:">TBD</name>
    <!-- Specifies the URN that can be used to reference this image
CRS. This URN includes the image name as a parameter. The specific
image or group shall be identified by the "TBD" in the "name" value. --
>
    </srsID>
    <remarks>Parameterized definition of 2D image coordinate reference
systems with the origin at the outside corner of the first pixel in the
image file. This CRS definition can be used for any size image, since
no image size is specified.

```

This CRS definition is designed to be used for ungeorectified images, and is not expected to be used for a georectified image. This definition can be used for a georeferenced or ungeoreferenced image, where a georeferenced image CRS is associated with the coordinate Transformation(s) that georeference it. </remarks>

```
<usesCartesianCS
xlink:href="urn:ogc:def:cs:OGC:1.0:Grid2dSquareCS"/>
<usesImageDatum
xlink:href="urn:ogc:def:datum:OGC:1.0:ImageDatumPixelCorner"/>
</ImageCRS>
```

EXAMPLE If this XML document were modified to specify the image CRS with its origin in the outside corner of first pixel for an image with the identifier “C543D041201T084027”, this XML document could be:

```
<?xml version="1.0" encoding="UTF-8"?>
<ImageCRS xmlns="http://www.opengis.net/gml"
xmlns:gml="http://www.opengis.net/gml"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.opengis.net/gml
../gml/3.1.1/base/coordinateReferenceSystems.xsd"
gml:id="ImageC543D041201T084027CRSpixelCorner">
  <!-- Primary editor: Arliss Whiteside. Last updated 2005-01-28-->
  <srsName>Image C543D041201T084027 CRS pixel corners</srsName>
  <srsID>
    <name
codeSpace="urn:ogc:def:crs:OGC:1.0:ImageCRSpixelCorner:">C543D041201T084027</na
me>
    <!-- This name specifies the URN by which this CRS can be referenced. -->
  </srsID>
  <usesCartesianCS xlink:href="urn:ogc:def:cs:OGC:1.0:Grid2dSquareCS"/>
  <usesImageDatum
xlink:href="urn:ogc:def:datum:OGC:1.0:ImageDatumPixelCorner"/>
</ImageCRS>
```

9.4 Grid 2D square coordinate system

The URN “urn:ogc:def:cs:OGC:0.0:Grid2dSquareCS” shall reference the definition of a Coordinate System for a 2D grid with square grid cells. The definition of this grid shall be the same as can be XML encoded using GML 3.1.1 as:

```
<?xml version="1.0" encoding="UTF-8"?>
<CartesianCS xmlns="http://www.opengis.net/gml"
xmlns:gml="http://www.opengis.net/gml"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.opengis.net/gml
../gml/3.1.1/base/coordinateSystems.xsd" gml:id="Grid2dSquareCS">
  <!-- Primary editor: Arliss Whiteside. Last updated 2005-01-28-->
  <csName>2D square-cell grid based coordinate system</csName>
  <csID>
    <name codeSpace="urn:ogc:def:cs:OGC:1.0:">Grid2dSquareCS</name>
  </csID>
  <remarks>2D grid-based coordinate system for use by an image or
other continuous grid coverage. It can be used for a grid of any size,
since no grid size is defined. This coordinate system specifies that
each row coordinate value will be listed before the column coordinate
```

value. The grid cells are assumed to be square, with the same grid spacing or pixel spacing in each direction.

In a grid coverage file, the "row" axis shall be the first axis by which grid points are sequenced, and the "column" axis shall be the second axis, as could be specified by the "scanDirection : Sequence(CharacterString)" attribute of the CV_SequenceRule class in Clause 8 of ISO 19123. With linear sequencing, the grid points in the first row shall be listed first, followed by other rows, with the grid points in each row listed in column number order. This relationship between the "row" and "column" names and the first grid points shall apply whether this Grid2dSquareCS is associated with a grid file before or after that file is recorded.

The "row" and "column" axis names are used here although the "scanDirection : Sequence(CharacterString)" attribute may provide other axis names. Use of other axis names would require defining different CartesianCSs for other names, or adding other names as additional axisID values. The following XML includes the axis names "line" and "sample" as additional axisID values.

If not otherwise identified in an image file, the "row" axis shall be the first axis whose number of pixels is identified, and the "column" axis shall be the second axis, as could be specified by the "extent[0..1] : CV_GridEnvelope" attribute of the CV_Grid class in Clause 8 of ISO 19123. In either case, the first point in the grid coverage file is assumed to be numbered (1, 1), meaning row 1, column 1.

The first row in a grid is sometimes called the "top" row, the first column is sometimes called the "left" column, and the first grid point is then called the "upperLeft" point. If desired, those names can be used with this Grid2dSquareCS. However other names can also be used, since this Grid2dSquareCS has been defined so that it does not depend on such left/right, top/bottom, and up/down names. </remarks>

```
<usesAxis xlink:href="urn:ogc:def:axis:OGC:1.0:Row"/>
<usesAxis xlink:href="urn:ogc:def:axis:OGC:1.0:Column"/>
</CartesianCS>
```

This xml document references the two standard grid axes specified below.

9.5 Row coordinate axis

The URN "urn:ogc:def:axis:OGC:0.0:Row" shall reference the definition of the row coordinate axis for a 2D square grid coordinate system. The definition of this row axis shall be the same as can be XML encoded using GML 3.1.1 as:

```
<?xml version="1.0" encoding="UTF-8"?>
<CoordinateSystemAxis xmlns="http://www.opengis.net/gml"
xmlns:gml="http://www.opengis.net/gml"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.opengis.net/gml
../gml/3.1.1/base/coordinateSystems.xsd" gml:id="Row"
gml:uom="urn:ogc:def:uom:OGC:1.0:GridSpacing">
```

```

<!-- Primary editor: Arliss Whiteside. Last updated 2005-01-28 -->
<name>Grid row axis</name>
<axisID>
  <name codeSpace="urn:ogc:def:axis:OGC:1.0:">Row</name>
</axisID>
<axisID>
  <name codeSpace="urn:ogc:def:axis:OGC:1.0:">Line</name>
</axisID>
<remarks>For this first grid axis, row coordinate values match grid
row numbers, but allow fractional coordinate values between grid
points. The first row in a grid is sometimes called the "top" row, so
the direction of this axis is "down", but these terms are not required.
</remarks>
<axisAbbrev>R</axisAbbrev>
<axisDirection>urn:ogc:def:axisDirection:OGC:1.0:rowPositive</axisDi
rection>
</CoordinateSystemAxis>

```

9.6 Column coordinate axis

The URN “urn:ogc:def:axis:OGC:0.0:Column” shall reference the definition of the column coordinate axis for a 2D square grid coordinate system. The definition of this column axis shall be the same as can be XML encoded using GML 3.1.1 as:

```

<?xml version="1.0" encoding="UTF-8"?>
<CoordinateSystemAxis xmlns="http://www.opengis.net/gml"
xmlns:gml="http://www.opengis.net/gml"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.opengis.net/gml
../gml/3.1.1/base/coordinateSystems.xsd" gml:id="Column"
gml:uom="urn:ogc:def:uom:OGC:1.0:GridSpacing">
  <!-- Primary editor: Arliss Whiteside. Last updated 2005-01-28 -->
  <name>Grid column axis</name>
  <axisID>
    <name codeSpace="urn:ogc:def:axis:OGC:1.0:">Column</name>
  </axisID>
  <axisID>
    <name codeSpace="urn:ogc:def:axis:OGC:1.0:">Sample</name>
  </axisID>
  <remarks>For this second grid axis, column coordinate values match
grid column numbers, but allow fractional coordinate values between
grid points. The first column is sometimes called the "left" column, so
the direction of this axis is "right", but these terms are not
required. </remarks>
  <axisAbbrev>C</axisAbbrev>
  <axisDirection>urn:ogc:def:axisDirection:OGC:1.0:columnPositive</axis
sDirection>
</CoordinateSystemAxis>

```

9.7 Image datum at pixel center

The URN “urn:ogc:def:datum:OGC:0.0:ImageDatumPixelCenter” shall reference the definition of an image datum with the origin at the centre of the first pixel. The definition of this image datum shall be the same as can be XML encoded using GML 3.1.1 as:

```

<?xml version="1.0" encoding="UTF-8"?>
<ImageDatum xmlns="http://www.opengis.net/gml"
xmlns:gml="http://www.opengis.net/gml"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.opengis.net/gml
../gml/3.1.1/base/datums.xsd" gml:id="ImageDatumPixelCenter">
  <!-- Primary editor: Arliss Whiteside. Last updated 2005-01-28-->
  <datumName>Origin at center of first pixel</datumName>
  <datumID>
    <name
codeSpace="urn:ogc:def:datum:OGC:1.0:">ImageDatumPixelCenter</name>
  </datumID>
  <remarks>2D image datum with the origin at the center of the first
pixel in the image file, usually the first pixel collected by the image
sensor. In an image file, the pixels in the first row are assumed to be
listed first, followed by other rows, with pixels in each row listed
(and collected) in column number order. </remarks>
  <anchorPoint>center of first pixel</anchorPoint>
  <pixelInCell
codeSpace="urn:ogc:def:pixelInCell:OGC:1.0:">cellCenter</pixelInCell>
</ImageDatum>

```

9.8 Image datum at pixel corner

The URN “urn:ogc:def:datum:OGC:0.0:ImageDatumPixelCorner” shall reference the definition of an image datum with the origin at the outside corner of the first pixel. The definition of this image datum shall be the same as can be XML encoded using GML 3.1.1 as:

```

<?xml version="1.0" encoding="UTF-8"?>
<ImageDatum xmlns="http://www.opengis.net/gml"
xmlns:gml="http://www.opengis.net/gml"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.opengis.net/gml
../gml/3.1.1/base/datums.xsd" gml:id="ImageDatumPixelCorner">
  <!-- Primary editor: Arliss Whiteside. Last updated 2005-01-28-->
  <datumName>Origin at outside corner of first pixel</datumName>
  <datumID>
    <name
codeSpace="urn:ogc:def:datum:OGC:1.0:">ImageDatumPixelCorner</name>
  </datumID>
  <remarks>2D image datum with the origin at the outside corner of the
first pixel in the image file, usually the first pixel collected by the
image sensor. In an image file, the pixels in the first row are assumed
to be listed first, followed by other rows, with pixels in each row
listed (and collected) in column number order. </remarks>
  <anchorPoint>outside corner of first pixel</anchorPoint>
  <pixelInCell
codeSpace="urn:ogc:def:pixelInCell:OGC:1.0:">cellCorner</pixelInCell>
</ImageDatum>

```

9.9 Grid spacing unit of measure

The URN “urn:ogc:def:uom:OGC:0.0:GridSpacing” shall reference the definition of the grid spacing unit of measure (uom). The definition of this unit shall be the same as can be XML encoded using GML 3.1.1 as:

```
<?xml version="1.0" encoding="UTF-8"?>
<BaseUnit xmlns="http://www.opengis.net/gml"
xmlns:gml="http://www.opengis.net/gml"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.opengis.net/gml
../gml/3.1.1/base/datums.xsd" gml:id="GridSpacing">
  <!-- Primary editor: Arliss Whiteside. Last updated 2005-01-28-->
  <name>Spacing between adjacent grid points, or between centers of
adjacent pixels</name>
  <name codeSpace="urn:ogc:def:uom:OGC:1.0:">GridSpacing</name>
  <quantityType>Length</quantityType>
  <unitsSystem xlink:href="urn:ogc:def:uom:OGC:1.0:GridSpacing"/>
</BaseUnit>
```

10 Supporting information

This clause introduces information provided in the annexes supporting the encoding described in Clauses 6 and 7:

- Annex A (informative) provides example application schemas based on these XML Schemas, with corresponding example XML documents and UML models.
- Annex B (informative) describes some unrectified image operation methods.

Annex A (informative)

Application schema examples

A.1 Introduction

This annex provides two Application Schemas based on the CRS Schemas that are applicable to images. Each of these example Application Schemas includes a corresponding example XML document using that Application Schema plus the example UML model from which that Application Schemas was converted. For more information on Application Schemas, see Subclauses B.3 and B.4 of “Recommended XML encoding of common CRS definitions” [OGC 05-011].

These XML examples use URNs to reference known objects using "xlink:href" and "gml:uom" XML attributes, based on documents [OGC 05-010] and [OGC 05-011].

A.2 Extended operation parameter definition

A.2.1 Introduction

This subclause provides an example of encoding additional information for Operation Parameters. The following subclauses contain:

- a) A draft class diagram of a UML package for an Extended Operation Parameter, which builds on the UML model in OGC Abstract Specification Topic 2.
- b) A draft XML Schema for encoding an Extended Operation Parameter, produced by converting this UML package.
- c) A XML encoding of the possible contents of the <<CodeList>> stereotyped ParameterType class in this UML package.
- d) An example XML document based on this draft XML Schema for encoding an Extended Operation Parameter

A.2.2 UML package

Figure A.1 is a class diagram of an example UML package for an Extended Operation Method. This UML package builds on the UML model in OGC Abstract Specification Topic 2.

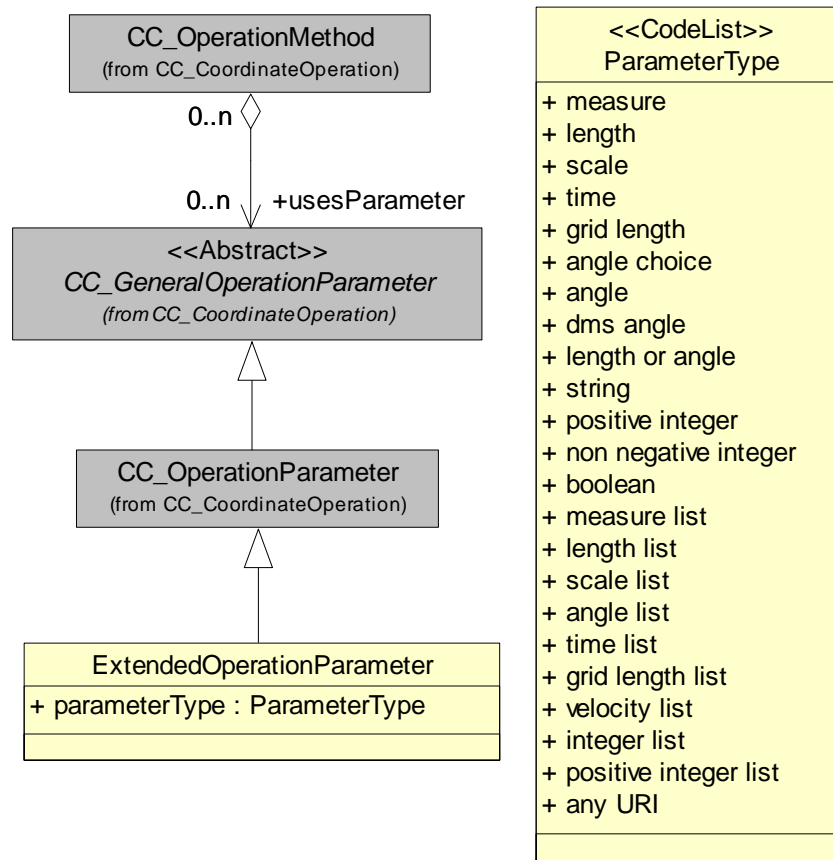


Figure A.1 — UML package for Extended Operation Method

A.2.3 Application schema

This subclause contains an example XML Schema for encoding an Extended Operation Parameter, produced by converting the above UML package. This XML Schema builds on the coordinateOperations.xsd XML Schema. This draft XML Schema is written following the same GML 3 patterns and ISO 19118 XML encoding rules as used in the CRS Schemas in GML 3.1.1. As required, this draft XML Schema is written as an Application Schema in a different namespace.

This example XML Schema is:

```

<?xml version="1.0" encoding="UTF-8"?>
<schema xmlns:ex="http://www.opengis.net/examples"
  xmlns:xlink="http://www.w3.org/1999/xlink"
  xmlns:gml="http://www.opengis.net/gml"
  xmlns="http://www.w3.org/2001/XMLSchema"
  targetNamespace="http://www.opengis.net/examples"
  elementFormDefault="qualified" xml:lang="en">
  <annotation>
    <documentation>
      <name>extendedOperationParameter.xsd</name>
      <scope>How to encode extended information for operation
parameters. </scope>
    
```

```

    <description>Example Application Schema to encode extended
information for operation parameters. Builds on
coordinateOperations.xsd, and follows same GML 3 patterns and ISO 19118
encoding. Written in the "ex" namespace. Primary editor: Arliss
Whiteside. Last updated 2005-01-28</description>
    <copyright>Copyright (c) 2Open Geospatial Consortium (2005)
</copyright>
    <conformance>This schema encodes a draft Extended Operation
Parameter package that builds on the Coordinate Operation (CC_) package
of the extended UML Model for OGC Abstract Specification Topic 2:
Spatial Referencing by Coordinates. That draft package defines a
subtype of the CC_OperationParameter class for recording more
information. </conformance>
</documentation>
</annotation>
<!-- =====
    includes and imports
===== -->
    <import namespace="http://www.opengis.net/gml"
schemaLocation="../gml/3.1.1/base/coordinateOperations.xsd"/>
    <!-- =====
    elements and types
===== -->
    <element name="ExtendedOperationParameter"
type="ex:ExtendedOperationParameterType"
substitutionGroup="gml:OperationParameter"/>
    <!-- ===== -->
    <complexType name="ExtendedOperationParameterType">
        <annotation>
            <documentation>Extended definition of an operation parameter.
</documentation>
        </annotation>
        <complexContent>
            <extension base="gml:OperationParameterType">
                <sequence>
                    <element ref="ex:parameterType"/>
                </sequence>
            </extension>
        </complexContent>
    </complexType>
    <!-- ===== -->
    <element name="parameterType" type="ex:ParameterTypeType"/>
    <!-- ===== -->
    <complexType name="ParameterTypeType">
        <annotation>
            <documentation>Data type of an operation parameter. Usually
refers to a data type defined in measures.xsd or allowed in the
ParameterValueType of coordinateOperations.xsd. </documentation>
            <documentation>A text string with a required codeSpace
attribute. Similar to gml:CodeType. </documentation>
        </annotation>
        <simpleContent>
            <extension base="string">
                <attribute name="codeSpace" type="anyURI" use="required">
                    <annotation>

```

```

        <documentation>Reference to a source of information
specifying the values and meanings of all the allowed string values for
this ParameterTypeType. </documentation>
        </annotation>
    </attribute>
</extension>
</simpleContent>
</complexType>
<!-- ===== -->
</schema>

```

A.2.4 Standard contents of parameterType

A standard set of allowed values and their meanings for the parameterType element is specified in the <<CodeList>> stereotyped class in the UML model that was converted. Those string values and their meanings are specified in the following UML document, using the gml:Dictionary element:

```

<?xml version="1.0" encoding="UTF-8"?>
<Dictionary xmlns="http://www.opengis.net/gml"
xmlns:gml="http://www.opengis.net/gml"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:xlink="http://www.w3.org/1999/xlink"
xsi:schemaLocation="http://www.opengis.net/gml
../gml/3.1.1/base/dictionary.xsd" gml:id="parameterTypeDictionary">
    <!-- Primary editor: Arliss Whiteside. Last updated 2005-04-13 -->
    <name>parameterType standard values</name>
    <name>Data type of an operation parameter. Usually refers to a data
type defined in measures.xsd or allowed in the ParameterValueType of
coordinateOperations.xsd. </name>
    <!-- ===== -->
    <dictionaryEntry>
        <Definition gml:id="measure">
            <description>General numeric value of an operation parameter,
with its associated unit of measure. </description>
            <name
codeSpace="urn:ogc:def:parameterType:OGC:1.0:">measure</name>
            </Definition>
        </dictionaryEntry>
        <!-- ===== -->
        <dictionaryEntry>
            <Definition gml:id="length">
                <description>Value of a length (or distance) quantity, with
its units. Uses the MeasureType with the restriction that the unit of
measure referenced by uom must be suitable for a length, such as metres
or feet. </description>
                <name
codeSpace="urn:ogc:def:parameterType:OGC:1.0:">length</name>
                </Definition>
            </dictionaryEntry>
            <!-- ===== -->
            <dictionaryEntry>
                <Definition gml:id="scale">
                    <description>Value of a scale factor (or ratio) that has no
physical unit. Uses the MeasureType with the restriction that the unit
of measure referenced by uom must be suitable for a scale factor, such
as one, percent, permil, or parts-per-million. </description>

```

```

        <name
codeSpace="urn:ogc:def:parameterType:OGC:1.0:">scale</name>
        </Definition>
    </dictionaryEntry>
    <!-- ===== -->
    <dictionaryEntry>
        <Definition gml:id="time">
            <description>Value of a time or temporal quantity, with its
units. Uses the MeasureType with the restriction that the unit of
measure referenced by uom must be suitable for a time value, such as
seconds or weeks. </description>
            <name
codeSpace="urn:ogc:def:parameterType:OGC:1.0:">time</name>
            </Definition>
        </dictionaryEntry>
        <!-- ===== -->
        <dictionaryEntry>
            <Definition gml:id="gridLength">
                <description>Value of a length (or distance) quantity in a
grid, where the grid spacing does not have any associated physical
units, or does not have a constant physical spacing. This grid length
will often be used in a digital image grid, where the base units are
likely to be pixel spacings. Uses the MeasureType with the restriction
that the unit of measure referenced by uom must be suitable for length
along the axes of a grid, such as pixel spacings or grid
spacings.</description>
                <name codeSpace="urn:ogc:def:parameterType:OGC:1.0:">grid
length</name>
                </Definition>
            </dictionaryEntry>
            <!-- ===== -->
            <dictionaryEntry>
                <Definition gml:id="angleChoice">
                    <description>Value of an angle quantity provided in either
degree-minute-second format or single value format. </description>
                    <name codeSpace="urn:ogc:def:parameterType:OGC:1.0:">angle
choice</name>
                    </Definition>
                </dictionaryEntry>
                <!-- ===== -->
                <dictionaryEntry>
                    <Definition gml:id="angle">
                        <description>Value of an angle quantity recorded as a single
number, with its units. Uses the MeasureType with the restriction that
the unit of measure referenced by uom must be suitable for an angle,
such as degrees or radians. </description>
                        <name
codeSpace="urn:ogc:def:parameterType:OGC:1.0:">angle</name>
                        </Definition>
                    </dictionaryEntry>
                    <!-- ===== -->
                    <dictionaryEntry>
                        <Definition gml:id="dmsAngle">
                            <description>Value of an angle operation parameter, in either
degree-minute-second format or single value format. </description>
                            <name codeSpace="urn:ogc:def:parameterType:OGC:1.0:">dms
angle</name>

```

```

    </Definition>
  </dictionaryEntry>
  <!-- ===== -->
  <dictionaryEntry>
    <Definition gml:id="lengthOrAngle">
      <description>Value of a length or angle quantity, where an
angle can be recorded in either degree-minute-second format or single
value format. Often used for horizontal ground coordinates.
</description>
      <name codeSpace="urn:ogc:def:parameterType:OGC:1.0:">length or
angle</name>
    </Definition>
  </dictionaryEntry>
  <!-- ===== -->
  <dictionaryEntry>
    <Definition gml:id="string">
      <description>String value of an operation parameter. A string
value does not have an associated unit of measure. </description>
      <name
codeSpace="urn:ogc:def:parameterType:OGC:1.0:">string</name>
    </Definition>
  </dictionaryEntry>
  <!-- ===== -->
  <dictionaryEntry>
    <Definition gml:id="positiveInteger">
      <description>Positive integer value of an operation parameter,
usually used for a count. An integer value does not have an associated
unit of measure. </description>
      <name codeSpace="urn:ogc:def:parameterType:OGC:1.0:">positive
integer</name>
    </Definition>
  </dictionaryEntry>
  <!-- ===== -->
  <dictionaryEntry>
    <Definition gml:id="nonNegativeInteger">
      <description>Zero or positive integer value of an operation
parameter. An integer value does not have an associated unit of
measure. </description>
      <name codeSpace="urn:ogc:def:parameterType:OGC:1.0:">non
negative integer</name>
    </Definition>
  </dictionaryEntry>
  <!-- ===== -->
  <dictionaryEntry>
    <Definition gml:id="boolean">
      <description>Boolean value of an operation parameter. A
Boolean value does not have an associated unit of measure.
</description>
      <name
codeSpace="urn:ogc:def:parameterType:OGC:1.0:">boolean</name>
    </Definition>
  </dictionaryEntry>
  <!-- ===== -->
  <dictionaryEntry>
    <Definition gml:id="measureList">
      <description>Ordered sequence of two or more numeric values of
an operation parameter list, where each value has the same associated

```

unit of measure. An element of this type contains a space-separated list of double values. </description>

```

    <name codeSpace="urn:ogc:def:parameterType:OGC:1.0:">measure
list</name>
    </Definition>
</dictionaryEntry>
<!-- ===== -->
<dictionaryEntry>
    <Definition gml:id="lengthList">
        <description>Ordered sequence of two or more numeric values of
an operation parameter list of Length measures. Each value has the same
associated unit of measure suitable for a length, such as metres or
feet. An element of this type contains a space-separated list of double
values. </description>
        <name codeSpace="urn:ogc:def:parameterType:OGC:1.0:">length
list</name>
    </Definition>
</dictionaryEntry>
<!-- ===== -->
<dictionaryEntry>
    <Definition gml:id="scaleList">
        <description>Ordered sequence of two or more numeric values of
an operation parameter list of Scale measures. Each value has the same
associated unit of measure suitable for a scale factor, such as one,
percent, permil, or parts-per-million. An element of this type contains
a space-separated list of double values. </description>
        <name codeSpace="urn:ogc:def:parameterType:OGC:1.0:">scale
list</name>
    </Definition>
</dictionaryEntry>
<!-- ===== -->
<dictionaryEntry>
    <Definition gml:id="angleList">
        <description>Ordered sequence of two or more numeric values of
an operation parameter list of Angle measures, each recorded as a
single number. Each value has the same associated unit of measure
suitable for an angle, such as degrees or radians. An element of this
type contains a space-separated list of double values. </description>
        <name codeSpace="urn:ogc:def:parameterType:OGC:1.0:">angle
list</name>
    </Definition>
</dictionaryEntry>
<!-- ===== -->
<dictionaryEntry>
    <Definition gml:id="timeList">
        <description>Ordered sequence of two or more numeric values of
an operation parameter list of Time measures, each recorded as a single
number. Each value has the same associated unit of measure suitable for
a time value, such as seconds or days. An element of this type contains
a space-separated list of double values. </description>
        <name codeSpace="urn:ogc:def:parameterType:OGC:1.0:">time
list</name>
    </Definition>
</dictionaryEntry>
<!-- ===== -->
<dictionaryEntry>
    <Definition gml:id="gridLengthList">

```

```

        <description>Ordered sequence of two or more numeric values of
an operation parameter list of Grid Length measures. Each value has the
same associated unit of measure suitable for length along the axes of a
grid, such as pixel spacings or grid spacings. An element of this type
contains a space-separated list of double values. </description>
        <name codeSpace="urn:ogc:def:parameterType:OGC:1.0:">grid
length list</name>
    </Definition>
</dictionaryEntry>
<!-- ===== -->
<dictionaryEntry>
    <Definition gml:id="velocityList">
        <description>Ordered sequence of two or more numeric values of
an operation parameter list of Velocity measures. Each value has the
same associated unit of measure suitable for a velocity, such as metres
per second or miles per hour. An element of this type contains a space-
separated list of double values. </description>
        <name codeSpace="urn:ogc:def:parameterType:OGC:1.0:">velocity
list</name>
    </Definition>
</dictionaryEntry>
<!-- ===== -->
<dictionaryEntry>
    <Definition gml:id="integerList">
        <description>Ordered sequence of two or more integer values of
an operation parameter list, usually used for counts. These integer
values do not have an associated unit of measure. An element of this
type contains a space-separated list of integer values. </description>
        <name codeSpace="urn:ogc:def:parameterType:OGC:1.0:">integer
list</name>
    </Definition>
</dictionaryEntry>
<!-- ===== -->
<dictionaryEntry>
    <Definition gml:id="positiveIntegerList">
        <description>Ordered sequence of two or more positive integer
values of an operation parameter list, usually used for counts. These
integer values do not have an associated unit of measure. An element of
this type contains a space-separated list of integer values.
</description>
        <name codeSpace="urn:ogc:def:parameterType:OGC:1.0:">positive
integer list</name>
    </Definition>
</dictionaryEntry>
<!-- ===== -->
<dictionaryEntry>
    <Definition gml:id="anyURI">
        <description>Reference to a file or a part of a file
containing one or more parameter values, each numeric value with its
associated unit of measure. When referencing a part of a file, that
file must contain multiple identified parts, such as an XML encoded
document. Furthermore, the referenced file or part of a file can
reference another part of the same or different files, as allowed in
XML documents. </description>
        <name
codeSpace="urn:ogc:def:parameterType:OGC:1.0:">anyURI</name>
    </Definition>
</dictionaryEntry>

```

</Dictionary>

A.2.5 Example XML document

An example XML document based on this example XML Schema for encoding Extended Operation Parameters applied to the Transverse Mercator Operation Method is:

```
<?xml version="1.0" encoding="UTF-8"?>
<OperationMethod xmlns="http://www.opengis.net/gml"
xmlns:gml="http://www.opengis.net/gml"
xmlns:ex="http://www.opengis.net/examples"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.opengis.net/examples
extendedOperationParameter.xsd" gml:id="EPSG9807">
  <!-- Primary editor: Arliss Whiteside. Last updated 2005-01-28-->
  <methodName>Transverse Mercator</methodName>
  <methodID>
    <name codeSpace="urn:ogc:def:method:EPSG:6.3:">9807</name>
  </methodID>
  <methodFormula>See Section 1.4.6 "Transverse Mercator" of EPSG
Guidance Note 7, December 2000. </methodFormula>
  <sourceDimensions>2</sourceDimensions>
  <targetDimensions>2</targetDimensions>
  <usesParameter>
    <ex:ExtendedOperationParameter gml:id="EPSG8801">
      <parameterName>Latitude of natural origin</parameterName>
      <parameterID>
        <name
codeSpace="urn:ogc:def:parameter:EPSG:6.3:">8801</name>
      </parameterID>
      <ex:parameterType
codeSpace="parameterTypeCodeList.xml">AngleChoiceType</ex:parameterType
>
    </ex:ExtendedOperationParameter>
  </usesParameter>
  <usesParameter>
    <ex:ExtendedOperationParameter gml:id="EPSG8802">
      <parameterName>Longitude of natural origin</parameterName>
      <parameterID>
        <name
codeSpace="urn:ogc:def:parameter:EPSG:6.3:">8802</name>
      </parameterID>
      <ex:parameterType
codeSpace="parameterTypeCodeList.xml">AngleChoiceType</ex:parameterType
>
    </ex:ExtendedOperationParameter>
  </usesParameter>
  <usesParameter>
    <ex:ExtendedOperationParameter gml:id="EPSG8805">
      <parameterName>Scale factor at natural origin</parameterName>
      <parameterID>
        <name
codeSpace="urn:ogc:def:parameter:EPSG:6.3:">8805</name>
      </parameterID>
      <ex:parameterType
codeSpace="parameterTypeCodeList.xml">ScaleType</ex:parameterType>
```

```

    </ex:ExtendedOperationParameter>
  </usesParameter>
  <usesParameter>
    <ex:ExtendedOperationParameter gml:id="EPSG8806">
      <parameterName>False Easting</parameterName>
      <parameterID>
        <name
codeSpace="urn:ogc:def:parameter:EPSG:6.3:">8806</name>
      </parameterID>
      <ex:parameterType
codeSpace="parameterTypeCodeList.xml">LengthType</ex:parameterType>
    </ex:ExtendedOperationParameter>
  </usesParameter>
  <usesParameter>
    <ex:ExtendedOperationParameter gml:id="EPSG8807">
      <parameterName>False Northing</parameterName>
      <parameterID>
        <name
codeSpace="urn:ogc:def:parameter:EPSG:6.3:">8807</name>
      </parameterID>
      <ex:parameterType
codeSpace="parameterTypeCodeList.xml">LengthType</ex:parameterType>
    </ex:ExtendedOperationParameter>
  </usesParameter>
</OperationMethod>

```

NOTE Subclause D.2.4 of document [OGC 05-011] provides a corresponding example XML document not using this Application Schema.

A.3 Universal image geometry model transformation

A.3.1 Introduction

Standardized XML encoding is needed for a number of frequently-used types of image coordinate transformations. This subclause provides an example of one such encoding, applied to an example image coordinate transformation. That example type of image coordinate transformation is the one described in Section 6.5 of OGC Abstract Specification old Topic 7: The Earth Imagery Case [OGC 99-107], namely the Universal Image Geometry Model (UIGM). That UIGM transformation is from a 3D ground coordinate reference system to a 2D image coordinate reference system, and has been simplified here for brevity. The following subclauses contain:

- a) A draft class diagram of a UML package for this simplified UIGM transformation, which builds on the UML model in OGC Abstract Specification Topic 2.
- b) Two draft XML Schemas for encoding this simplified UIGM transformation, produced by converting this UML package.
- c) An example XML document based on this draft XML Schema for encoding an example UIGM transformation, plus an example XML document based on the Application Schema in Subclause A.2.3 for encoding the Operation Method used by this UIGM transformation.

A.3.2 UML package

Figures A.3 to A.7 contain the five parts of a draft class diagram of a UML package for this simplified UIGM transformation. Figure A.3 shows the top level of the class diagram, without showing the components of the `SectionParametersGroup` and `MonoscopicErrorsGroup`. This diagram is incomplete in that some of the needed association role names and multiplicities are not shown due to lack of space. Figure A.3 shows the top level within the `SectionParametersGroup`, without showing the components of the `NormalizationParametersGroup` and `PolynomialGroup`. Figure A.5 shows one example parameter value in the `NormalizationParametersGroup`, with a note listing the other nine parameter values. Figure A.6 shows two example parameter values in the `PolynomialGroup`, with a note listing the six other parameter values. Figure A.7 shows the complete contents of the `MonoscopicErrorsGroup`.

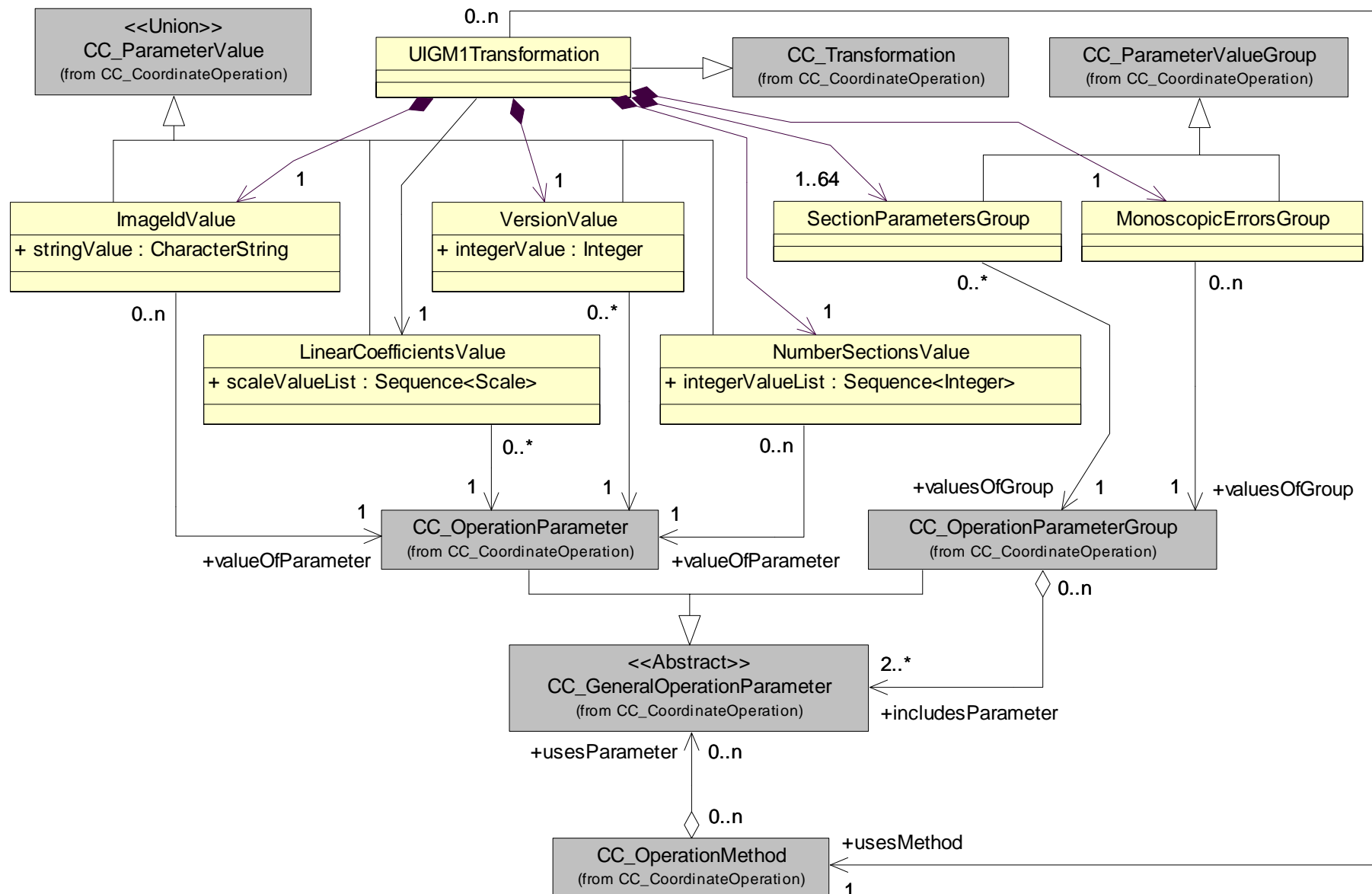


Figure A.3 — UML package for UIGM transformation, page 1

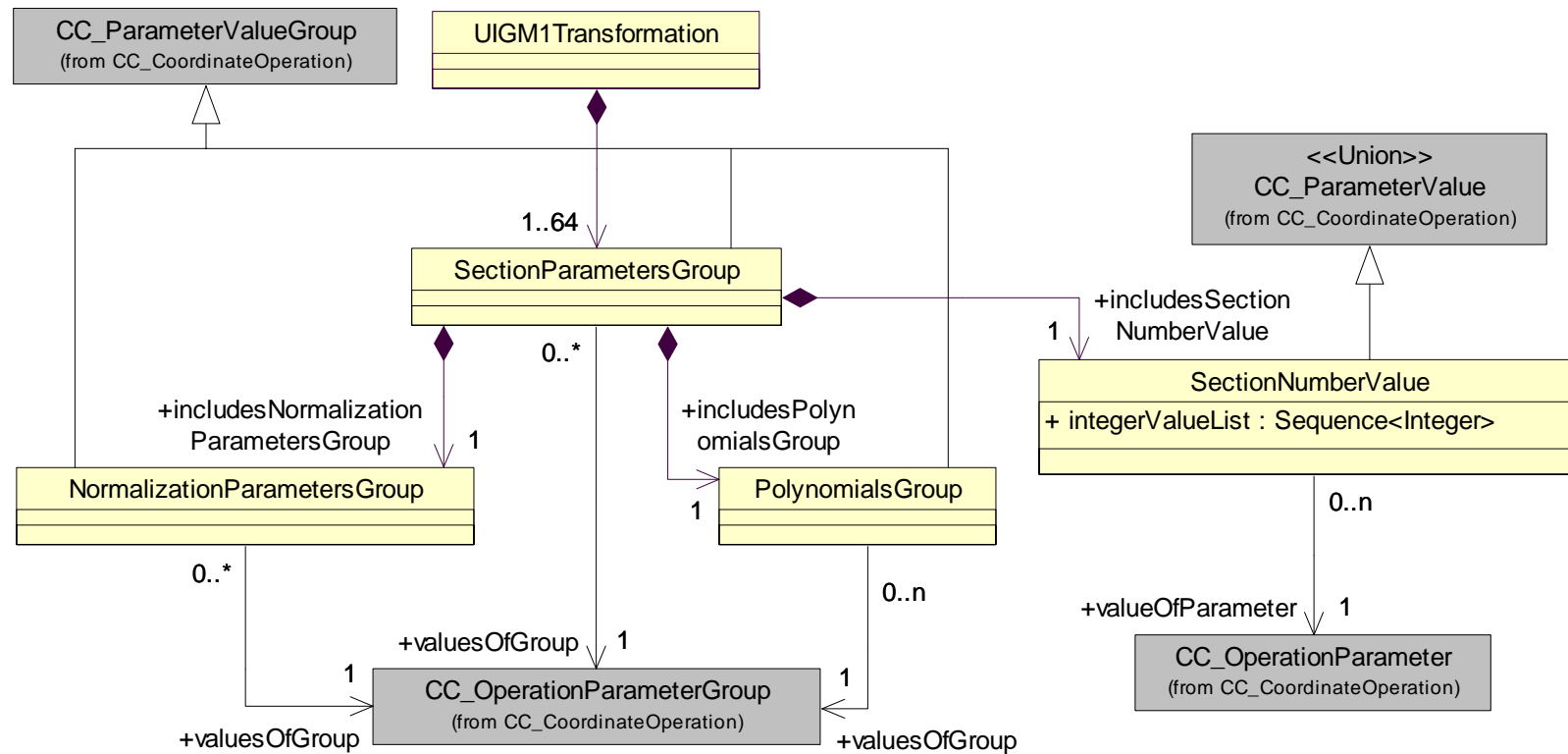


Figure A.3 — UML package for UIGM transformation, page 2

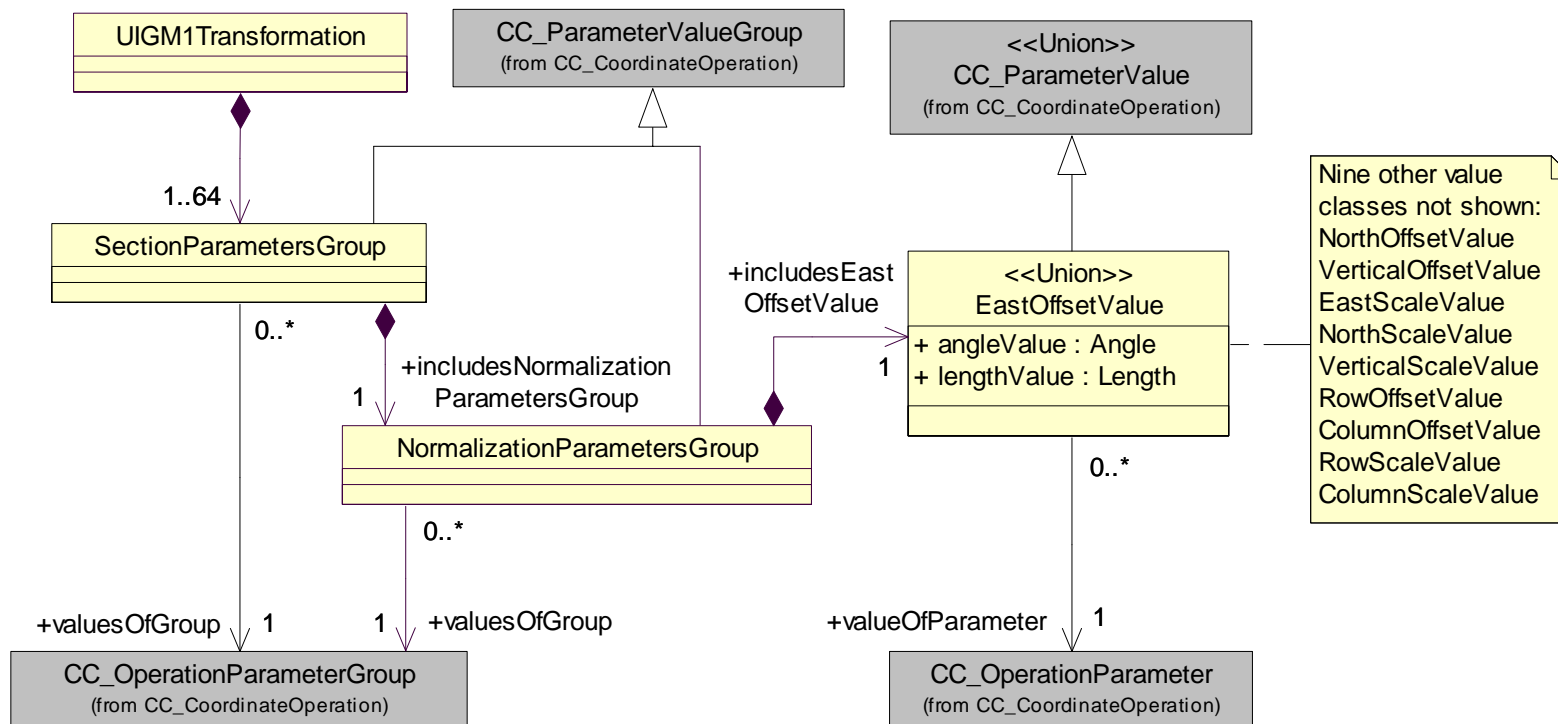


Figure A.5 — UML package for UIGM transformation, page 3



Figure A.6 — UML package for UIGM transformation, page 4

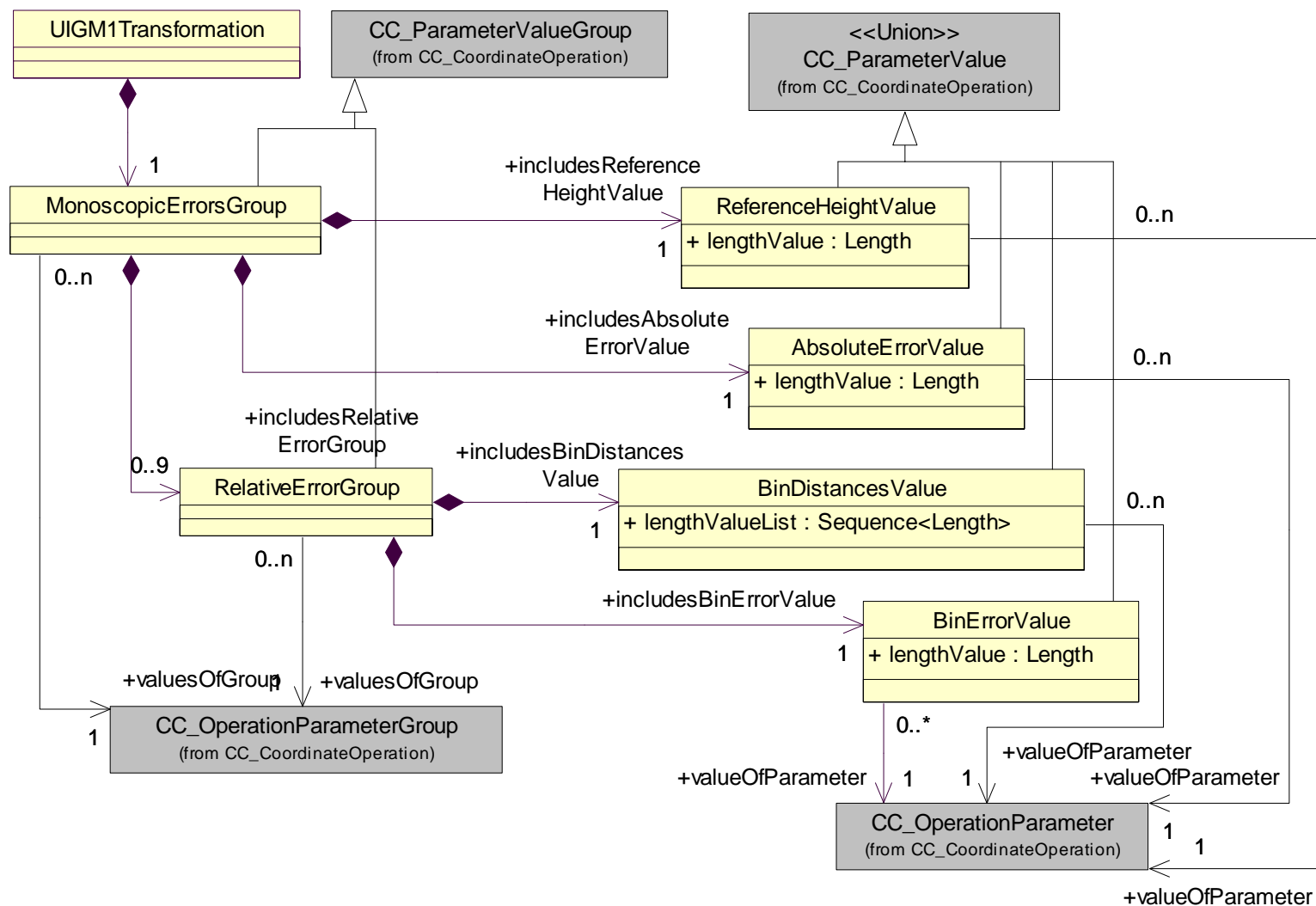


Figure A.7 — UML package for UIGM transformation, page 5

A.3.3 Application schemas

This subclause contains example XML Schemas for encoding this simplified UIGM transformation, produced by converting the above UML package. These XML Schemas build on coordinateOperations.xsd. These draft XML Schemas are written following the same GML 3 patterns and ISO 19118 XML encoding rules as used in the CRS Schemas in GML 3.1.1.

The first draft Application Schema is:

```
<?xml version="1.0" encoding="UTF-8"?>
<schema xmlns="http://www.w3.org/2001/XMLSchema"
xmlns:gml="http://www.opengis.net/gml"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:ex="http://www.opengis.net/examples"
targetNamespace="http://www.opengis.net/examples"
elementFormDefault="qualified" xml:lang="en">
  <annotation>
    <documentation>
      <name>UIGMltransformation.xsd</name>
      <scope>How to encode definition of Universal Image Geometry
Model for one image. </scope>
      <description>Example Application Schema to encode ground-to-
image coordinate transformation data for a specific image, using the
Universal Image Geometry Model type of coordinate transformation as
described in Section 6.5 of OGC Abstract Specification Topic 7 : The
Earth Imagery Case (OGC document 99-107). This example does not encode
data for the image correction tables, stereoscopic position error
estimates, and most information not used by the image geometry model.
Builds on coordinateOperations.xsd and typedValues.xsd, and follows
same GML 3 patterns and ISO 19118 encoding. Written in the "ex"
namespace. Primary editor: Arliss Whiteside. Last updated 2005-01-
28</description>
      <copyright>Copyright (c) Open Geospatial consortium (2005)
</copyright>
      <conformance>This schema encodes a draft UIGM package that
builds on the Coordinate Operation (CC_) package of the extended UML
Model for OGC Abstract Specification Topic 2: Spatial Referencing by
Coordinates. That draft package defines restricted subtypes of the
CC_Transformation, CC_ParameterValue, and CC_ParameterValueGroup
classes as needed for the UIGM transformation. </conformance>
    </documentation>
  </annotation>
  <!-- =====
includes and imports
===== -->
  <include schemaLocation="typedValues.xsd"/>
  <import namespace="http://www.opengis.net/gml"
schemaLocation=" ../gml/3.1.1/base/coordinateOperations.xsd"/>
  <import namespace="http://www.w3.org/1999/xlink"
schemaLocation=" ../gml/3.1.1/xlink/xlinks.xsd"/>
  <!-- =====
elements and types
===== -->
```

```

    <element name="UIGM1Transformation"
type="ex:UIGM1TransformationType"
substitutionGroup="gml:_GeneralTransformation"/>
    <!-- ===== -->
    <complexType name="UIGM1TransformationType">
        <annotation>
            <documentation>Specific Universal Image Geometry Model type of
coordinate transformation. Extends the
AbstractGeneralTransformationType with restricted values for included
elements, including elements in the coordinateOperationID element with
the IdentifierType. If appropriate, the "codeSpace" element could have
the string value "UIGM1", and the "code" element should then identify
the specific image. The other elements in the IdentifierType can be
omitted. The "coordinateOperationName" element shall have a string
value that names a UIGM1 Transformation for a specific image and
specific ground coordinate reference system. The "_PositionalAccuracy"
and "metaDataProperty" elements can be omitted. </documentation>
        </annotation>
        <complexContent>
            <extension base="gml:AbstractGeneralTransformationType">
                <sequence>
                    <element ref="ex:usesUIGM1Method"/>
                    <element ref="ex:usesImageIdValue"/>
                    <element ref="ex:usesVersionValue"/>
                    <element ref="ex:usesLinearCoefficientsValue"/>
                    <element ref="ex:usesNumberSectionsValue"/>
                    <element ref="ex:usesSectionParameters"/>
                    <element ref="ex:usesMonoscopicErrors"/>
                </sequence>
            </extension>
        </complexContent>
    </complexType>
    <!-- ===== -->
    <element name="usesUIGM1Method">
        <annotation>
            <documentation>Reference to UIGM1 operation method.
        </documentation>
        </annotation>
        <complexType>
            <sequence/>
            <attribute ref="xlink:href" use="required"
fixed="urn:ogc:def:method:UIGM:1.0:MethodUIGM1"/>
        </complexType>
    </element>
    <!-- ===== -->
    <element name="usesImageIdValue" type="ex:StringValueType">
        <annotation>
            <documentation>Alphanumeric text identifying one specific
original image. </documentation>
        </annotation>
    </element>
    <!-- ===== -->
    <element name="usesVersionValue" type="ex:IntegerValueType">
        <annotation>
            <documentation>Increasing numbers of the Image Support Data
Version integer are used to identify versions with increasing quality
of the image geometry model data for the same original image. This

```

Version shall be "0" before the original image support data is adjusted. The minimum value is 0, and the maximum value is 9.

```

</documentation>
  </annotation>
</element>
<!-- ===== -->
<element name="usesLinearCoefficientsValue"
type="ex:ScaleListValueType">
  <annotation>
    <documentation>The values of the coefficients of the
approximate linear sensor model, which is used to find the proper image
geometry model section for a ground coordinate position. The parameter
value shall contain an ordered list of eight double precision floating
point numbers, four for the section number in the image row axis
followed by four for the image column axis. These coefficients shall be
recorded with Scale units, but various implied units are used by the
various coefficients. </documentation>
  </annotation>
</element>
<!-- ===== -->
<element name="usesNumberSectionsValue"
type="ex:IntegerListValueType">
  <annotation>
    <documentation>The numbers of rows and columns of sections
into which the image geometry model is divided for this image. The
parameter value shall contain an ordered list of two small integers,
the first specifying the number of rows and the second specifying the
number of columns. For each integer, the minimum value is 1, and the
maximum value is 8. </documentation>
  </annotation>
</element>
<!-- ===== -->
<!-- ===== -->
<element name="usesSectionParameters">
  <annotation>
    <documentation>Group of parameters for one section of the
universal image geometry model. There shall be from 1 up to 64 model
sections for one image. If the model for this image is not divided into
sections, there shall be only one repetition of this group of
parameters. </documentation>
  </annotation>
  <complexType>
    <sequence>
      <element ref="ex:includesSectionNumberValue"/>
      <element ref="ex:includesNormalizationParameters"/>
      <element ref="ex:includesPolynomials"/>
      <element ref="gml:valuesOfGroup"/>
    </sequence>
  </complexType>
</element>
<!-- ===== -->
<element name="includesSectionNumberValue"
type="ex:IntegerListValueType">
  <annotation>
    <documentation>The row and column numbers of this section of
the universal image geometry model for this image. The parameter value
contains an ordered list of two small integers, the first specifying

```

the row number and the second specifying the column number. For each integer, the minimum value is 1, and the maximum value is

```

8.</documentation>
  </annotation>
</element>
<!-- ===== -->
<!-- ===== -->
<element name="includesNormalizationParameters">
  <annotation>
    <documentation>Group of ground position normalization
parameters and image position un-normalization parameters, for this
section of the universal image geometry model. </documentation>
  </annotation>
  <complexType>
    <sequence>
      <element ref="ex:includesEastOffsetValue"/>
      <element ref="ex:includesNorthOffsetValue"/>
      <element ref="ex:includesVerticalOffsetValue"/>
      <element ref="ex:includesEastScaleValue"/>
      <element ref="ex:includesNorthScaleValue"/>
      <element ref="ex:includesVerticalScaleValue"/>
      <element ref="ex:includesRowOffsetValue"/>
      <element ref="ex:includesColumnOffsetValue"/>
      <element ref="ex:includesRowScaleValue"/>
      <element ref="ex:includesColumnScaleValue"/>
      <element ref="gml:valuesOfGroup"/>
    </sequence>
  </complexType>
</element>
<!-- ===== -->
<element name="includesEastOffsetValue"
type="ex:AngleOrLengthValueType">
  <annotation>
    <documentation>East position offset for normalizing ground
coordinates. The units shall be either angle or length units.
</documentation>
  </annotation>
</element>
<!-- ===== -->
<element name="includesNorthOffsetValue"
type="ex:AngleOrLengthValueType">
  <annotation>
    <documentation>North position offset for normalizing ground
coordinates. The units shall be the same as for the East Offset, either
angle or length units. </documentation>
  </annotation>
</element>
<!-- ===== -->
<element name="includesVerticalOffsetValue"
type="ex:LengthValueType">
  <annotation>
    <documentation>Vertical position offset for normalizing ground
coordinates. The units shall be length units. </documentation>
  </annotation>
</element>
<!-- ===== -->

```

```

    <element name="includesEastScaleValue"
type="ex:AngleOrLengthValueType">
    <annotation>
        <documentation>East scale factor for normalizing ground
coordinates. The units shall be the same as for the East Offset, either
angle or length units. </documentation>
    </annotation>
    </element>
<!-- ===== -->
    <element name="includesNorthScaleValue"
type="ex:AngleOrLengthValueType">
    <annotation>
        <documentation>North scale factor for normalizing ground
coordinates. The units shall be the same as for the North Offset,
either angle or length units. </documentation>
    </annotation>
    </element>
<!-- ===== -->
    <element name="includesVerticalScaleValue"
type="ex:LengthValueType">
    <annotation>
        <documentation>Vertical scale factor for normalizing ground
coordinates. The units shall be the same as for the Vertical Offset,
and shall be length units. </documentation>
    </annotation>
    </element>
<!-- ===== -->
    <element name="includesRowOffsetValue"
type="ex:GridLengthValueType">
    <annotation>
        <documentation>Image row position offset for un-normalizing
image coordinates. The units shall be one grid spacing.
</documentation>
    </annotation>
    </element>
<!-- ===== -->
    <element name="includesColumnOffsetValue"
type="ex:GridLengthValueType">
    <annotation>
        <documentation>Image column position offset for un-normalizing
image coordinates. The units shall be one grid spacing.
</documentation>
    </annotation>
    </element>
<!-- ===== -->
    <element name="includesRowScaleValue" type="ex:GridLengthValueType">
    <annotation>
        <documentation>Image row scale factors for un-normalizing
image coordinates. The units shall be one grid spacing.
</documentation>
    </annotation>
    </element>
<!-- ===== -->
    <element name="includesColumnScaleValue"
type="ex:GridLengthValueType">
    <annotation>

```

```

        <documentation>Image column scale factors for un-normalizing
image coordinates. The units shall be one grid spacing.
</documentation>
    </annotation>
</element>
<!-- ===== -->
<!-- ===== -->
<element name="includesPolynomials">
    <annotation>
        <documentation>Numerator and denominator polynomial parameters
for this section of the universal image geometry model.
</documentation>
    </annotation>
    <complexType>
        <sequence>
            <element ref="ex:includesRowNumeratorPowersValue"/>
            <element ref="ex:includesRowNumeratorCoefficientsValue"/>
            <element ref="ex:includesRowDenominatorPowersValue"/>
            <element ref="ex:includesRowDenominatorCoefficientsValue"/>
            <element ref="ex:includesColumnNumeratorPowersValue"/>
            <element
ref="ex:includesColumnNumeratorCoefficientsValue"/>
            <element ref="ex:includesColumnDenominatorPowersValue"/>
            <element
ref="ex:includesColumnDenominatorCoefficientsValue"/>
            <element ref="gml:valuesOfGroup"/>
        </sequence>
    </complexType>
</element>
<!-- ===== -->
<element name="includesRowNumeratorPowersValue"
type="ex:IntegerListValueType">
    <annotation>
        <documentation>Maximum powers of the three ground coordinates
in the numerator polynomial for computing the image row coordinate. The
parameter value shall contain an ordered list of three small integers,
corresponding to the East, North, and Vertical ground coordinate axes.
For each integer, the minimum value is 1. For the East and North axis
integers, the maximum value is 5. For the Vertical axis integer, the
maximum value is 3. </documentation>
    </annotation>
</element>
<!-- ===== -->
<element name="includesRowNumeratorCoefficientsValue"
type="ex:ScaleListValueType">
    <annotation>
        <documentation>Polynomial coefficients in the numerator
polynomial for computing the image row coordinate. The parameter value
shall contain an ordered list of from 8 to 144 Scale measures.
</documentation>
    </annotation>
</element>
<!-- ===== -->
<element name="includesRowDenominatorPowersValue"
type="ex:IntegerListValueType">
    <annotation>

```

```

        <documentation>Maximum powers of the three ground coordinates
in the denominator polynomial for computing the image row coordinate.
The parameter value shall contain an ordered list of three small
integers, corresponding to the East, North, and Vertical ground
coordinate axes. For each integer, the minimum value is 1. For the East
and North axis integers, the maximum value is 5. For the Vertical axis
integer, the maximum value is 3. </documentation>
    </annotation>
</element>
<!-- ===== -->
<element name="includesRowDenominatorCoefficientsValue"
type="ex:ScaleListValueType">
    <annotation>
        <documentation>Polynomial coefficients in the denominator
polynomial for computing the image row coordinate. The parameter value
shall contain an ordered list of from 8 to 144 Scale measures.
</documentation>
    </annotation>
</element>
<!-- ===== -->
<element name="includesColumnNumeratorPowersValue"
type="ex:IntegerListValueType">
    <annotation>
        <documentation>Maximum powers of the three ground coordinates
in the numerator polynomial for computing the image column coordinate.
The parameter value shall contain an ordered list of three small
integers, corresponding to the East, North, and Vertical ground
coordinate axes. For each integer, the minimum value is 1. For the East
and North axis integers, the maximum value is 5. For the Vertical axis
integer, the maximum value is 3. </documentation>
    </annotation>
</element>
<!-- ===== -->
<element name="includesColumnNumeratorCoefficientsValue"
type="ex:ScaleListValueType">
    <annotation>
        <documentation>Polynomial coefficients in the numerator
polynomial for computing the image column coordinate. The parameter
value shall contain an ordered list of from 8 to 144 Scale measures.
</documentation>
    </annotation>
</element>
<!-- ===== -->
<element name="includesColumnDenominatorPowersValue"
type="ex:IntegerListValueType">
    <annotation>
        <documentation>Maximum powers of the three ground coordinates
in the denominator polynomial for computing the image column
coordinate. The parameter value shall contain an ordered list of three
small integers, corresponding to the East, North, and Vertical ground
coordinate axes. For each integer, the minimum value is 1. For the East
and North axis integers, the maximum value is 5. For the Vertical axis
integer, the maximum value is 3. </documentation>
    </annotation>
</element>
<!-- ===== -->

```

```

    <element name="includesColumnDenominatorCoefficientsValue"
type="ex:ScaleListValueType">
    <annotation>
        <documentation>Polynomial coefficients in the denominator
polynomial for computing the image column coordinate. The parameter
value shall contain an ordered list of from 8 to 144 Scale measures.
</documentation>
    </annotation>
</element>
<!-- ===== -->
<!-- ===== -->
    <element name="usesMonoscopicErrors">
        <annotation>
            <documentation>Group of parameters for horizontal error
estimates when a position in this one image is used to determine the
corresponding ground coordinates, using this universal image geometry
model for this image. </documentation>
        </annotation>
        <complexType>
            <sequence>
                <element ref="ex:includesReferenceHeightValue"/>
                <element ref="ex:includesAbsoluteErrorValue"/>
                <element ref="ex:includesRelativeError" minOccurs="0"
maxOccurs="9"/>
                <element ref="gml:valuesOfGroup"/>
            </sequence>
        </complexType>
    </element>
<!-- ===== -->
    <element name="includesReferenceHeightValue"
type="ex:LengthValueType">
        <annotation>
            <documentation>The value of the ground elevation or height
used to estimate the recorded horizontal error estimate when a position
in this one image is used to determine the corresponding ground
coordinates. This reference height is in the Vertical coordinate system
axis of the ground CRS used by the universal image geometry model for
this image. </documentation>
        </annotation>
    </element>
<!-- ===== -->
    <element name="includesAbsoluteErrorValue"
type="ex:LengthValueType">
        <annotation>
            <documentation>The value of the horizontal absolute error
estimate when a position in this one (monoscopic) image is used to
determine the corresponding ground coordinates. This error estimate
shall be recorded as the Circular Error (CE) with 90% confidence,
always in one meter units. The minimum value is 0.0. </documentation>
        </annotation>
    </element>
<!-- ===== -->
<!-- ===== -->
    <element name="includesRelativeError">
        <annotation>
            <documentation>Relative error estimate for one distance bin
between two points. These error estimates are for use when multiple

```

```

positions in one (monoscopic) image are used to determine the
corresponding ground coordinates. </documentation>
  </annotation>
  <complexType>
    <sequence>
      <element ref="ex:includesBinDistancesValue"/>
      <element ref="ex:includesBinErrorValue"/>
      <element ref="gml:valuesOfGroup"/>
    </sequence>
  </complexType>
</element>
<!-- ===== -->
<element name="includesBinDistancesValue"
type="ex:LengthListValueType">
  <annotation>
    <documentation>The minimum and maximum ground distances
between two points for this distance bin recorded for horizontal
relative error estimates. The parameter value shall contain an ordered
list of two Length measures, always in one meter units. The first value
specifies the bin minimum distance, and the second value specifies the
bin maximum distance. The minimum values are 0.0. </documentation>
  </annotation>
</element>
<!-- ===== -->
<element name="includesBinErrorValue" type="ex:LengthValueType">
  <annotation>
    <documentation>The value of the horizontal relative error
estimate between two points for this distance bin recorded for
horizontal relative error estimates. These error estimates are for use
when multiple positions in one (monoscopic) image are used to determine
the corresponding ground coordinates. The relative error estimate shall
be recorded as the Circular Error (CE) with 90% confidence, always in
one meter units. The minimum value is 0.0. </documentation>
  </annotation>
</element>
<!-- ===== -->
</schema>

```

The above example Application Schema is shortened by building on a separate example Application Schema. This other Application Schema defines XML Schema complexTypes for a number of types of operation parameter values. The complexTypes defined include 8 parameter types used in the Application Schema above, plus 8 TBD more types expected to be useful in other image geometry model transformations. This second draft XML Application Schema is:

```

<?xml version="1.0" encoding="UTF-8"?>
<schema xmlns="http://www.w3.org/2001/XMLSchema"
xmlns:gml="http://www.opengis.net/gml"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:ex="http://www.opengis.net/examples"
targetNamespace="http://www.opengis.net/examples"
elementFormDefault="qualified" xml:lang="en">
  <annotation>
    <documentation>
      <name>typedValues.xsd</name>

```

```

        <scope>How to encode operation parameter values with specific
types, including length, angle, and scale measures.. </scope>
        <description>Example Application Schema to encode operation
parameter values with specific types. Builds on measures.xsd, and
follows same GML 3 patterns. Written in the "ex" namespace. Primary
editor: Arliss Whiteside. Last updated 2005-01-28</description>
        <copyright>Copyright (c) Open Geospatial consortium (2005)
</copyright>
    </documentation>
</annotation>
<!-- =====
    includes and imports
===== -->
    <import namespace="http://www.opengis.net/gml"
schemaLocation="../../../gml/3.1.1/base/coordinateOperations.xsd"/>
    <!-- =====
    elements and types
===== -->
    <complexType name="StringValue" type="StringValueType">
        <annotation>
            <documentation>Alphanumeric text operation parameter value.
</documentation>
        </annotation>
        <complexContent>
            <extension base="gml:AbstractGeneralParameterValue">
                <sequence>
                    <element ref="gml:stringValue"/>
                    <element ref="gml:valueOfParameter"/>
                </sequence>
            </extension>
        </complexContent>
    </complexType>
    <!-- ===== -->
    <complexType name="IntegerValue" type="IntegerValueType">
        <annotation>
            <documentation>Integer operation parameter value.
</documentation>
        </annotation>
        <complexContent>
            <extension base="gml:AbstractGeneralParameterValue">
                <sequence>
                    <element ref="gml:integerValue"/>
                    <element ref="gml:valueOfParameter"/>
                </sequence>
            </extension>
        </complexContent>
    </complexType>
    <!-- ===== -->
    <complexType name="LengthValue" type="LengthValueType">
        <annotation>
            <documentation>Length measure operation parameter value.
</documentation>
        </annotation>
        <complexContent>
            <extension base="gml:AbstractGeneralParameterValue">
                <sequence>
                    <element ref="ex:lengthValue"/>

```

```

        <element ref="gml:valueOfParameter"/>
      </sequence>
    </extension>
  </complexContent>
</complexType>
<!-- ===== -->
<complexType name="ScaleValueType">
  <annotation>
    <documentation>Scale measure operation parameter value.
  </documentation>
  </annotation>
  <complexContent>
    <extension base="gml:AbstractGeneralParameterValueType">
      <sequence>
        <element ref="ex:scaleValue"/>
        <element ref="gml:valueOfParameter"/>
      </sequence>
    </extension>
  </complexContent>
</complexType>
<!-- ===== -->
<complexType name="AngleValueType">
  <annotation>
    <documentation>Angle measure operation parameter value.
  </documentation>
  </annotation>
  <complexContent>
    <extension base="gml:AbstractGeneralParameterValueType">
      <sequence>
        <element ref="ex:angleValue"/>
        <element ref="gml:valueOfParameter"/>
      </sequence>
    </extension>
  </complexContent>
</complexType>
<!-- ===== -->
<complexType name="AngleOrLengthValueType">
  <annotation>
    <documentation>Angle or Length measure operation parameter
value, sometimes used for horizontal coordinate parameters.
  </documentation>
  </annotation>
  <complexContent>
    <extension base="gml:AbstractGeneralParameterValueType">
      <sequence>
        <choice>
          <element ref="ex:angleValue"/>
          <element ref="ex:lengthValue"/>
        </choice>
        <element ref="gml:valueOfParameter"/>
      </sequence>
    </extension>
  </complexContent>
</complexType>
<!-- ===== -->
<complexType name="TimeValueType">
  <annotation>

```

```

        <documentation>Time measure operation parameter value.
</documentation>
    </annotation>
    <complexContent>
        <extension base="gml:AbstractGeneralParameterValueType">
            <sequence>
                <element ref="ex:gridLengthValue"/>
                <element ref="gml:valueOfParameter"/>
            </sequence>
        </extension>
    </complexContent>
</complexType>
<!-- ===== -->
<complexType name="GridLengthValueType">
    <annotation>
        <documentation>Grid Length measure operation parameter value.
</documentation>
    </annotation>
    <complexContent>
        <extension base="gml:AbstractGeneralParameterValueType">
            <sequence>
                <element ref="ex:gridLengthValue"/>
                <element ref="gml:valueOfParameter"/>
            </sequence>
        </extension>
    </complexContent>
</complexType>
<!-- ===== -->
<complexType name="SpeedValueType">
    <annotation>
        <documentation>Velocity measure operation parameter value.
</documentation>
    </annotation>
    <complexContent>
        <extension base="gml:AbstractGeneralParameterValueType">
            <sequence>
                <element ref="ex:speedValue"/>
                <element ref="gml:valueOfParameter"/>
            </sequence>
        </extension>
    </complexContent>
</complexType>
<!-- ===== -->
<complexType name="IntegerListValueType">
    <annotation>
        <documentation>Ordered sequence of two or more integer
operation parameter values. </documentation>
    </annotation>
    <complexContent>
        <extension base="gml:AbstractGeneralParameterValueType">
            <sequence>
                <element ref="gml:integerValueList"/>
                <element ref="gml:valueOfParameter"/>
            </sequence>
        </extension>
    </complexContent>
</complexType>

```

```

<!-- ===== -->
<complexType name="LengthListValueType">
  <annotation>
    <documentation>Ordered sequence of two or more Length
operation parameter values.</documentation>
  </annotation>
  <complexContent>
    <extension base="gml:AbstractGeneralParameterValue">
      <sequence>
        <element ref="ex:lengthValueList"/>
        <element ref="gml:valueOfParameter"/>
      </sequence>
    </extension>
  </complexContent>
</complexType>
<!-- ===== -->
<complexType name="ScaleListValueType">
  <annotation>
    <documentation>Ordered sequence of two or more Scale Factor
operation parameter values. </documentation>
  </annotation>
  <complexContent>
    <extension base="gml:AbstractGeneralParameterValue">
      <sequence>
        <element ref="ex:scaleValueList"/>
        <element ref="gml:valueOfParameter"/>
      </sequence>
    </extension>
  </complexContent>
</complexType>
<!-- ===== -->
<complexType name="AngleListValueType">
  <annotation>
    <documentation>Ordered sequence of two or more Angle operation
parameter values. </documentation>
  </annotation>
  <complexContent>
    <extension base="gml:AbstractGeneralParameterValue">
      <sequence>
        <element ref="ex:angleValueList"/>
        <element ref="gml:valueOfParameter"/>
      </sequence>
    </extension>
  </complexContent>
</complexType>
<!-- ===== -->
<complexType name="TimeListValueType">
  <annotation>
    <documentation>Ordered sequence of two or more Time operation
parameter values. </documentation>
  </annotation>
  <complexContent>
    <extension base="gml:AbstractGeneralParameterValue">
      <sequence>
        <element ref="ex:timeValueList"/>
        <element ref="gml:valueOfParameter"/>
      </sequence>
    </extension>
  </complexContent>
</complexType>

```

```

        </extension>
    </complexContent>
</complexType>
<!-- ===== -->
<complexType name="GridLengthListValueType">
    <annotation>
        <documentation>Ordered sequence of two or more Grid Length
operation parameter values. </documentation>
    </annotation>
    <complexContent>
        <extension base="gml:AbstractGeneralParameterValue">
            <sequence>
                <element ref="ex:gridLengthValueList"/>
                <element ref="gml:valueOfParameter"/>
            </sequence>
        </extension>
    </complexContent>
</complexType>
<!-- ===== -->
<complexType name="SpeedListValueType">
    <annotation>
        <documentation>Ordered sequence of two or more Velocity
operation parameter values. </documentation>
    </annotation>
    <complexContent>
        <extension base="gml:AbstractGeneralParameterValue">
            <sequence>
                <element ref="ex:speedValueList"/>
                <element ref="gml:valueOfParameter"/>
            </sequence>
        </extension>
    </complexContent>
</complexType>
<!-- ===== -->
<!-- ===== -->
    <element name="lengthValue" type="gml:LengthType"
substitutionGroup="gml:value">
        <annotation>
            <documentation>Length value of an operation parameter, with a
unit of measure suitable for a length, such as metres or feet.
</documentation>
        </annotation>
    </element>
<!-- ===== -->
    <element name="scaleValue" type="gml:ScaleType"
substitutionGroup="gml:value">
        <annotation>
            <documentation>Scale factor value of an operation parameter,
with a unit of measure suitable for a scale factor, such as one,
percent, permil, or parts-per-million. </documentation>
        </annotation>
    </element>
<!-- ===== -->
    <element name="angleValue" type="gml:AngleType"
substitutionGroup="gml:value">
        <annotation>

```

```

        <documentation>Angle value of an operation parameter, recorded
as a single number, with a unit of measure suitable for an angle, such
as degrees or radians. </documentation>
    </annotation>
</element>
<!-- ===== -->
    <element name="timeValue" type="gml:TimeType"
substitutionGroup="gml:value">
    <annotation>
        <documentation>Time value of an operation parameter, recorded
as a single number, with a unit of measure suitable for a time value,
such as seconds or days. </documentation>
    </annotation>
    </element>
    <!-- ===== -->
    <element name="gridLengthValue" type="gml:GridLengthType"
substitutionGroup="gml:value">
    <annotation>
        <documentation>Grid length value of an operation parameter,
with a unit of measure suitable for length along the axes of a grid,
such as pixel spacings or grid spacings. Used when the grid spacing
does not have any associated physical units, or does not have a
constant physical spacing. </documentation>
    </annotation>
    </element>
    <!-- ===== -->
    <element name="speedValue" type="gml:SpeedType"
substitutionGroup="gml:value">
    <annotation>
        <documentation>Speed value of an operation parameter, with a
unit of measure suitable for a speed, such as metres per second or
miles per hour. </documentation>
    </annotation>
    </element>
    <!-- ===== -->
    <element name="lengthValueList" type="gml:MeasureListType"
substitutionGroup="gml:valueList">
    <annotation>
        <documentation>Ordered sequence of two or more length values
of an operation parameter, with a unit of measure suitable for a
length, such as metres or feet. </documentation>
    </annotation>
    </element>
    <!-- ===== -->
    <element name="scaleValueList" type="gml:MeasureListType"
substitutionGroup="gml:valueList">
    <annotation>
        <documentation>Ordered sequence of two or more scale factor
values of an operation parameter, with a unit of measure suitable for a
scale factor, such as one, percent, permil, or parts-per-million.
</documentation>
    </annotation>
    </element>
    <!-- ===== -->
    <element name="angleValueList" type="gml:MeasureListType"
substitutionGroup="gml:valueList">
    <annotation>

```

```

        <documentation>Ordered sequence of two or more angle values of
an operation parameter, each recorded as a single number, with a unit
of measure suitable for an angle, such as degrees or radians.
</documentation>
    </annotation>
</element>
<!-- ===== -->
    <element name="timeValueList" type="gml:MeasureListType"
substitutionGroup="gml:valueList">

        <annotation>
            <documentation>Ordered sequence of two or more time values of
an operation parameter, each recorded as a single number, with a unit
of measure suitable for a time value, such as seconds or days.
</documentation>
        </annotation>
    </element>
    <!-- ===== -->
    <element name="gridLengthValueList" type="gml:MeasureListType"
substitutionGroup="gml:valueList">
        <annotation>
            <documentation>Ordered sequence of two or more grid length
values of an operation parameter, with a unit of measure suitable for
length along the axes of a grid, such as pixel spacings or grid
spacings. Used when the grid spacing does not have any associated
physical units, or does not have a constant physical spacing.
</documentation>
        </annotation>
    </element>
    <!-- ===== -->
    <element name="speedValueList" type="gml:MeasureListType"
substitutionGroup="gml:valueList">
        <annotation>
            <documentation>Ordered sequence of two or more speed values of
an operation parameter, with a unit of measure suitable for a speed,
such as metres per second or miles per hour. </documentation>
        </annotation>
    </element>
    <!-- ===== -->
</schema>

```

A.3.4 Example XML documents

An example XML document based on the above two example Application Schemas for encoding this simplified UIGM transformation is:

```

<?xml version="1.0" encoding="UTF-8"?>
<UIGM1Transformation xmlns="http://www.opengis.net/examples"
xmlns:gml="http://www.opengis.net/gml"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.opengis.net/examples
UIGM1transformation.xsd" gml:id="AaaaAaaa">
    <!-- Primary editor: Arliss Whiteside. Last updated 2005-01-28-->
    <gml:coordinateOperationName>Aaaa Aaaa</gml:coordinateOperationName>
    <gml:operationVersion>1</gml:operationVersion>

```

```

    <gml:sourceCRS xlink:href="urn:ogc:def:crs:EPSG:6.6:7405"
xlink:title="OSGB36 /British National Grid + ODN"/>
    <gml:targetCRS xlink:href="urn:ogc:def:crs:UIGM:1.0:mageCRS"/>
    <usesUIGM1Method
xlink:href="urn:ogc:def:method:UIGM:1.0:MethodUIGM1"/>
    <usesImageIdValue>
        <gml:stringValue>AAAAAA</gml:stringValue>
        <gml:valueOfParameter
xlink:href="urn:ogc:def:parameter:UIGM:1.0:mageID"/>
        </usesImageIdValue>
        <usesVersionValue>
            <gml:integerValue>1</gml:integerValue>
            <gml:valueOfParameter
xlink:href="urn:ogc:def:parameter:UIGM:1.0:Version"/>
            </usesVersionValue>
            <usesLinearCoefficientsValue>
                <scaleValueList uom="urn:ogc:def:uom:unity">9.999 9.999 9.999
9.999 9.999 9.999 9.999 9.999</scaleValueList>
                <gml:valueOfParameter
xlink:href="urn:ogc:def:parameter:UIGM:1.0:LinearCoefficients"/>
                </usesLinearCoefficientsValue>
                <usesNumberSectionsValue>
                    <gml:integerValueList>1 1</gml:integerValueList>
                    <gml:valueOfParameter
xlink:href="urn:ogc:def:parameter:UIGM:1.0:NumberSections"/>
                    </usesNumberSectionsValue>
                    <usesSectionParameters>
                        <includesSectionNumberValue>
                            <gml:integerValueList>1 1</gml:integerValueList>
                            <gml:valueOfParameter
xlink:href="urn:ogc:def:parameter:UIGM:1.0:SectionNumber"/>
                            </includesSectionNumberValue>
                            <includesNormalizationParameters>
                                <includesEastOffsetValue>
                                    <angleValue
uom="urn:ogc:def:uom:degree">99.999</angleValue>
                                    <gml:valueOfParameter
xlink:href="urn:ogc:def:method:UIGM:1.0:EastOffset"/>
                                    </includesEastOffsetValue>
                                    <includesNorthOffsetValue>
                                        <angleValue uom="urn:ogc:def:uom:degree">9.999</angleValue>
                                        <gml:valueOfParameter
xlink:href="urn:ogc:def:method:UIGM:1.0:NorthOffset"/>
                                        </includesNorthOffsetValue>
                                        <includesVerticalOffsetValue>
                                            <lengthValue
uom="urn:ogc:def:uom:metre">99.999</lengthValue>
                                            <gml:valueOfParameter
xlink:href="urn:ogc:def:method:UIGM:1.0:VerticalOffset"/>
                                            </includesVerticalOffsetValue>
                                            <includesEastScaleValue>
                                                <angleValue uom="urn:ogc:def:uom:degree">9.999</angleValue>
                                                <gml:valueOfParameter
xlink:href="urn:ogc:def:method:UIGM:1.0:EastScale"/>
                                                </includesEastScaleValue>
                                                <includesNorthScaleValue>
                                                    <angleValue uom="urn:ogc:def:uom:degree">9.999</angleValue>

```

```

        <gml:valueOfParameter
xlink:href="urn:ogc:def:method:UIGM:1.0:NorthScale"/>
        </includesNorthScaleValue>
        <includesVerticalScaleValue>
            <lengthValue
uom="urn:ogc:def:uom:metre">9.999</lengthValue>
            <gml:valueOfParameter
xlink:href="urn:ogc:def:method:UIGM:1.0:VerticalScale"/>
            </includesVerticalScaleValue>
            <includesRowOffsetValue>
                <gridLengthValue
uom="urn:ogc:def:uom:PixelSpacing">9999.99</gridLengthValue>
                <gml:valueOfParameter
xlink:href="urn:ogc:def:method:UIGM:1.0:RowOffset"/>
                </includesRowOffsetValue>
                <includesColumnOffsetValue>
                    <gridLengthValue
uom="urn:ogc:def:uom:PixelSpacing">9999.99</gridLengthValue>
                    <gml:valueOfParameter
xlink:href="urn:ogc:def:method:UIGM:1.0:ColumnOffset"/>
                    </includesColumnOffsetValue>
                    <includesRowScaleValue>
                        <gridLengthValue
uom="urn:ogc:def:uom:PixelSpacing">999.99</gridLengthValue>
                        <gml:valueOfParameter
xlink:href="urn:ogc:def:method:UIGM:1.0:RowScale"/>
                        </includesRowScaleValue>
                        <includesColumnScaleValue>
                            <gridLengthValue
uom="urn:ogc:def:uom:PixelSpacing">999.99</gridLengthValue>
                            <gml:valueOfParameter
xlink:href="urn:ogc:def:method:UIGM:1.0:ColumnScale"/>
                            </includesColumnScaleValue>
                            <gml:valuesOfGroup
xlink:href="urn:ogc:def:method:UIGM:1.0:NormalizationParameters"/>
                            </includesNormalizationParameters>
                            <includesPolynomials>
                                <includesRowNumeratorPowersValue>
                                    <gml:integerValueList>1 1 1</gml:integerValueList>
                                    <gml:valueOfParameter
xlink:href="urn:ogc:def:method:UIGM:1.0:RowNumeratorPowers"/>
                                    </includesRowNumeratorPowersValue>
                                    <includesRowNumeratorCoefficientsValue>
                                        <scaleValueList uom="urn:ogc:def:uom:unity">0.999999
0.999999 0.999999 0.999999 0.999999 0.999999 0.999999
0.999999</scaleValueList>
                                        <gml:valueOfParameter
xlink:href="urn:ogc:def:method:UIGM:1.0:RowNumeratorCoefficients"/>
                                        </includesRowNumeratorCoefficientsValue>
                                        <includesRowDenominatorPowersValue>
                                            <gml:integerValueList>1 1 1</gml:integerValueList>
                                            <gml:valueOfParameter
xlink:href="urn:ogc:def:method:UIGM:1.0:RowDenominatorPowers"/>
                                            </includesRowDenominatorPowersValue>
                                            <includesRowDenominatorCoefficientsValue>

```

```

        <scaleValueList uom="urn:ogc:def:uom:unity">0.999999
0.999999 0.999999 0.999999 0.999999 0.999999 0.999999
0.999999</scaleValueList>
        <gml:valueOfParameter
xlink:href="urn:ogc:def:method:UIGM:1.0:RowDenominatorCoefficients"/>
        </includesRowDenominatorCoefficientsValue>
        <includesColumnNumeratorPowersValue>
        <gml:integerValueList>1 1 1</gml:integerValueList>
        <gml:valueOfParameter
xlink:href="urn:ogc:def:method:UIGM:1.0:ColumnNumeratorPowers"/>
        </includesColumnNumeratorPowersValue>
        <includesColumnNumeratorCoefficientsValue>
        <scaleValueList uom="urn:ogc:def:uom:unity">0.999999
0.999999 0.999999 0.999999 0.999999 0.999999 0.999999
0.999999</scaleValueList>
        <gml:valueOfParameter
xlink:href="urn:ogc:def:method:UIGM:1.0:ColumnNumeratorCoefficients"/>
        </includesColumnNumeratorCoefficientsValue>
        <includesColumnDenominatorPowersValue>
        <gml:integerValueList>1 1 1</gml:integerValueList>
        <gml:valueOfParameter
xlink:href="urn:ogc:def:method:UIGM:1.0:ColumnDenominatorPowers"/>
        </includesColumnDenominatorPowersValue>
        <includesColumnDenominatorCoefficientsValue>
        <scaleValueList uom="urn:ogc:def:uom:unity">0.999999
0.999999 0.999999 0.999999 0.999999 0.999999 0.999999
0.999999</scaleValueList>
        <gml:valueOfParameter
xlink:href="urn:ogc:def:method:UIGM:1.0:ColumnDenominatorCoefficients"/>
        </includesColumnDenominatorCoefficientsValue>
        <gml:valuesOfGroup
xlink:href="urn:ogc:def:method:UIGM:1.0:Polynomials"/>
        </includesPolynomials>
        <gml:valuesOfGroup
xlink:href="urn:ogc:def:method:UIGM:1.0:SectionParameters"/>
        </usesSectionParameters>
        <usesMonoscopicErrors>
        <includesReferenceHeightValue>
        <lengthValue uom="urn:ogc:def:uom:metre">999</lengthValue>
        <gml:valueOfParameter
xlink:href="urn:ogc:def:method:UIGM:1.0:ReferenceHeight"/>
        </includesReferenceHeightValue>
        <includesAbsoluteErrorValue>
        <lengthValue uom="urn:ogc:def:uom:metre">99.99</lengthValue>
        <gml:valueOfParameter
xlink:href="urn:ogc:def:method:UIGM:1.0:AbsoluteError"/>
        </includesAbsoluteErrorValue>
        <includesRelativeError>
        <includesBinDistancesValue>
        <lengthValueList uom="urn:ogc:def:uom:metre">0
1000</lengthValueList>
        <gml:valueOfParameter
xlink:href="urn:ogc:def:method:UIGM:1.0:BinDistances"/>
        </includesBinDistancesValue>
        <includesBinErrorValue>
        <lengthValue uom="urn:ogc:def:uom:metre">9.99</lengthValue>

```

```

        <gml:valueOfParameter
xlink:href="urn:ogc:def:method:UIGM:1.0:BinError"/>
        </includesBinErrorValue>
        <gml:valuesOfGroup
xlink:href="urn:ogc:def:method:UIGM:1.0:RelativeError"/>
        </includesRelativeError>
        <includesRelativeError>
        <includesBinDistancesValue>
        <lengthValueList uom="urn:ogc:def:uom:metre">1000
10000</lengthValueList>
        <gml:valueOfParameter
xlink:href="urn:ogc:def:method:UIGM:1.0:BinDistances"/>
        </includesBinDistancesValue>
        <includesBinErrorValue>
        <lengthValueList uom="urn:ogc:def:uom:metre">9.99</lengthValue>
        <gml:valueOfParameter
xlink:href="urn:ogc:def:method:UIGM:1.0:BinError"/>
        </includesBinErrorValue>
        <gml:valuesOfGroup
xlink:href="urn:ogc:def:method:UIGM:1.0:RelativeError"/>
        </includesRelativeError>
        <gml:valuesOfGroup
xlink:href="urn:ogc:def:method:UIGM:1.0:MonoscopicErrors"/>
        </usesMonoscopicErrors>
</UIGM1Transformation>

```

The above XML example uses dummy values such as "Aaaa" in place of real values for some text string values. Similarly, this example also uses dummy values such as "99.99" in place of real values for some numerical values. This example assumes that the Application Schemas specified in Subclause A.3.3 are accessible using the location `UIGM1transformation.xsd`.

The above XML example also assumes that (complete) information for several items is available elsewhere. The definition of the `sourceCRS` and `targetCRS` are assumed to be available elsewhere, and can be encoded in XML as shown in the example XML in Clause 7 of this document and in Subclauses 6.2.2, 6.3.2, and 6.6.2 of “Recommended XML encoding of common CRS definitions” [OGC 05-011].

The definition of the simplified `UIGM OperationMethod` can be XML encoded using the example Application Schema from Subclause A.2.3, and could be:

```

<?xml version="1.0" encoding="UTF-8"?>
<OperationMethod xmlns="http://www.opengis.net/gml"
xmlns:gml="http://www.opengis.net/gml"
xmlns:ex="http://www.opengis.net/examples"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.opengis.net/examples
extendedOperationParameter.xsd http://www.opengis.net/gml
../gml/3.1.1/base/coordinateOperations.xsd" gml:id="MethodUIGM1">
  <!-- Primary editor: Arliss Whiteside. Last updated 2005-01-28-->
  <methodName>Universal Image Geometry Model Transformation
(simplified)</methodName>

```

<remarks>This operation method implements the universal image geometry model that transforms ground coordinates into georeferenced image coordinates. This image geometry model uses one ratio of two polynomial functions to compute the row image coordinate, and uses a similar ratio of two different polynomials to compute the column image coordinate. All four polynomials are functions of three ground coordinates: two horizontal coordinates and one vertical coordinate. In the polynomial functions, the three ground coordinates and two image coordinates are each offset and scaled to have a range from -1.0 to +1.0 over an image or image section. For brevity, this simplified operation method specification does not include all geometry model parameters or all optional XML elements. </remarks>

```

    <methodFormula>See Section 6.5 of document OGC 04-071.
</methodFormula>
    <sourceDimensions>3</sourceDimensions>
    <targetDimensions>2</targetDimensions>
    <usesParameter>
      <ex:ExtendedOperationParameter gml:id="ImageID">
        <parameterName>Image ID</parameterName>
        <remarks>Alphanumeric text identifying one specific original
image. </remarks>
        <ex:parameterType
codeSpace="parameterTypeCodeList.xml">string</ex:parameterType>
      </ex:ExtendedOperationParameter>
    </usesParameter>
    <usesParameter>
      <ex:ExtendedOperationParameter gml:id="Version">
        <parameterName>Image Support Data Version</parameterName>
        <remarks>Increasing numbers of the Image Support Data Version
Number are used to identify versions with increasing quality of the
image geometry model data for the same original image. This Image
Support Data Version field shall be 0 before the original image support
data is adjusted. Minimum value is 0, maximum value is 9. </remarks>
        <ex:parameterType
codeSpace="parameterTypeCodeList.xml">nonNegativeInteger</ex:parameterT
ype>
      </ex:ExtendedOperationParameter>
    </usesParameter>
    <usesParameter>
      <ex:ExtendedOperationParameter gml:id="LinearCoefficients">
        <parameterName>Linear Sensor Model
Coefficients</parameterName>
        <remarks>The values of the coefficients of the approximate
linear sensor model, which is used to find the proper image geometry
model section for a ground coordinate position. The parameter value
shall contain an ordered list of eight double precision floating point
numbers, four for the section number in the image row axis, followed by
four for the image column axis. These coefficients shall be recorded
with Scale units, but various implied units are used by the various
coefficients. </remarks>
        <ex:parameterType
codeSpace="parameterTypeCodeList.xml">ScaleListType</ex:parameterType>
      </ex:ExtendedOperationParameter>
    </usesParameter>
    <usesParameter>
      <ex:ExtendedOperationParameter gml:id="NumberSections">
        <parameterName>Number of Sections</parameterName>

```

```

    <remarks>The numbers of rows and columns of sections into
    which the image geometry model is divided for this image. The parameter
    value shall contain an ordered list of two small integers, the first
    specifying the number of rows and the second specifying the number of
    columns. For each integer, the minimum value is 1, and the maximum
    value is 8. </remarks>
    <ex:parameterType
codeSpace="parameterTypeCodeList.xml">integerList</ex:parameterType>
    </ex:ExtendedOperationParameter>
  </usesParameter>
  <usesParameter>
    <OperationParameterGroup gml:id="SectionParameters">
      <groupName>Image Section Parameters</groupName>
      <remarks>Parameters for one section of the universal image
      geometry model. There shall be from 1 up to 64 model sections for one
      image. If the model for this image is not divided into sections, there
      shall be only one repetition of this group of parameters. </remarks>
      <maximumOccurs>64</maximumOccurs>
      <includesParameter>
        <ex:ExtendedOperationParameter gml:id="SectionNumber">
          <parameterName>Section Number</parameterName>
          <remarks>The row and column numbers of this section of
          the universal image geometry model for this image. The parameter value
          contains an ordered list of two small integers, the first specifying
          the row number and the second specifying the column number. For each
          integer, the minimum value is 1, and the maximum value is 8. </remarks>
          <ex:parameterType
codeSpace="parameterTypeCodeList.xml">integerList</ex:parameterType>
          </ex:ExtendedOperationParameter>
        </includesParameter>
        <includesParameter>
          <OperationParameterGroup gml:id="NormalizationParameters">
            <groupName>Ground and Image Position Normalization
Parameters</groupName>
            <remarks>Ground position normalization parameters and
            image position un-normalization parameters, for this section of the
            universal image geometry model. </remarks>
            <includesParameter>
              <ex:ExtendedOperationParameter gml:id="EastOffset">
                <parameterName>East Ground Position
Offset</parameterName>
                <remarks>East position offset for normalizing
                ground coordinates. The units shall be either length or angle units.
                </remarks>
                <ex:parameterType
codeSpace="parameterTypeCodeList.xml">LengthOrAngleType</ex:parameterType>
                </ex:ExtendedOperationParameter>
              </includesParameter>
              <includesParameter>
                <ex:ExtendedOperationParameter gml:id="NorthOffset">
                  <parameterName>North Ground Position
Offset</parameterName>
                  <remarks>North position offset for normalizing
                  ground coordinates. The units shall be the same as for the East Offset,
                  and either length or angle units. </remarks>

```

```

        <ex:parameterType
codeSpace="parameterTypeCodeList.xml">LengthOrAngleType</ex:parameterTy
pe>
        </ex:ExtendedOperationParameter>
    </includesParameter>
    <includesParameter>
        <ex:ExtendedOperationParameter
gml:id="VerticalOffset">
            <parameterName>Vertical Ground Position
Offset</parameterName>
            <remarks>Vertical position offset for normalizing
ground coordinates. The units shall be length units. </remarks>
            <ex:parameterType
codeSpace="parameterTypeCodeList.xml">LengthType</ex:parameterType>
            </ex:ExtendedOperationParameter>
        </includesParameter>
        <includesParameter>
            <ex:ExtendedOperationParameter gml:id="EastScale">
                <parameterName>East Ground Position
Scale</parameterName>
                <remarks>East scale factor for normalizing ground
coordinates. The units shall be the same as for the East Offset, either
length or angle units. </remarks>
                <ex:parameterType
codeSpace="parameterTypeCodeList.xml">LengthOrAngleType</ex:parameterTy
pe>
                </ex:ExtendedOperationParameter>
            </includesParameter>
            <includesParameter>
                <ex:ExtendedOperationParameter gml:id="NorthScale">
                    <parameterName>North Ground Position
Scale</parameterName>
                    <remarks>North scale factor for normalizing ground
coordinates. The units shall be the same as for the North Offset,
either length or angle units. </remarks>
                    <ex:parameterType
codeSpace="parameterTypeCodeList.xml">LengthOrAngleType</ex:parameterTy
pe>
                    </ex:ExtendedOperationParameter>
                </includesParameter>
                <includesParameter>
                    <ex:ExtendedOperationParameter
gml:id="VerticalScale">
                        <parameterName>Vertical Ground Position
Scale</parameterName>
                        <remarks>Vertical scale factor for normalizing
ground coordinates. The units shall be the same as for the Vertical
Offset, and shall be length units. </remarks>
                        <ex:parameterType
codeSpace="parameterTypeCodeList.xml">LengthType</ex:parameterType>
                        </ex:ExtendedOperationParameter>
                    </includesParameter>
                    <includesParameter>
                        <ex:ExtendedOperationParameter gml:id="RowOffset">
                            <parameterName>Image Row Position
Offset</parameterName>

```

```

        <remarks>Image row position offset for un-
normalizing image coordinates. The units shall be one grid spacing.
</remarks>

        <ex:parameterType
codeSpace="parameterTypeCodeList.xml">GridLengthType</ex:parameterType>
        </ex:ExtendedOperationParameter>
    </includesParameter>
    <includesParameter>
        <ex:ExtendedOperationParameter gml:id="ColumnOffset">
            <parameterName>Image Column Position
Offset</parameterName>
            <remarks>Image column position offset for un-
normalizing image coordinates. The units shall be one grid spacing.
</remarks>

            <ex:parameterType
codeSpace="parameterTypeCodeList.xml">GridLengthType</ex:parameterType>
            </ex:ExtendedOperationParameter>
        </includesParameter>
        <includesParameter>
            <ex:ExtendedOperationParameter gml:id="RowScale">
                <parameterName>Image Row Position
Scale</parameterName>
                <remarks>Image row scale factors for un-
normalizing image coordinates. The units shall be one grid spacing.
</remarks>

                <ex:parameterType
codeSpace="parameterTypeCodeList.xml">GridLengthType</ex:parameterType>
                </ex:ExtendedOperationParameter>
            </includesParameter>
            <includesParameter>
                <ex:ExtendedOperationParameter gml:id="ColumnScale">
                    <parameterName>Image Column Position
Scale</parameterName>
                    <remarks>Image column scale factors for un-
normalizing image coordinates. The units shall be one grid spacing.
</remarks>

                    <ex:parameterType
codeSpace="parameterTypeCodeList.xml">GridLengthType</ex:parameterType>
                    </ex:ExtendedOperationParameter>
                </includesParameter>
            </OperationParameterGroup>
        </includesParameter>
        <includesParameter>
            <OperationParameterGroup gml:id="Polynomials">
                <groupName>Numerator and Denominator
Polynomials</groupName>
                <remarks>Numerator and denominator polynomial parameters
for this section of the universal image geometry model. </remarks>
                <includesParameter>
                    <ex:ExtendedOperationParameter
gml:id="RowNumeratorPowers">
                        <parameterName>Row Numerator Maximum
Powers</parameterName>
                        <remarks>Maximum powers of the three ground
coordinates in the numerator polynomial for computing the image row
coordinate. The parameter value shall contain an ordered list of three
small integers, corresponding to the East, North, and Vertical ground

```

coordinate axes. For each integer, the minimum value is 1. For the East and North axis integers, the maximum value is 5. For the Vertical axis integer, the maximum value is 3. </remarks>

```

    <ex:parameterType
codeSpace="parameterTypeCodeList.xml">integerList</ex:parameterType>
    </ex:ExtendedOperationParameter>
  </includesParameter>
</includesParameter>
  <ex:ExtendedOperationParameter
gml:id="RowNumeratorCoefficients">
    <parameterName>Row Numerator Polynomial
Coefficients</parameterName>
    <remarks>Polynomial coefficients in the numerator
polynomial for computing the image row coordinate. The parameter value
shall contain an ordered list of from 8 to 144 Scale measures.
</remarks>
    <ex:parameterType
codeSpace="parameterTypeCodeList.xml">ScaleListType</ex:parameterType>
    </ex:ExtendedOperationParameter>
  </includesParameter>
</includesParameter>
  <ex:ExtendedOperationParameter
gml:id="RowDenominatorPowers">
    <parameterName>Row Denominator Maximum
Powers</parameterName>
    <remarks>Maximum powers of the three ground
coordinates in the denominator polynomial for computing the image row
coordinate. The parameter value shall contain an ordered list of three
small integers, corresponding to the East, North, and Vertical ground
coordinate axes. For each integer, the minimum value is 1. For the East
and North axis integers, the maximum value is 5. For the Vertical axis
integer, the maximum value is 3. </remarks>
    <ex:parameterType
codeSpace="parameterTypeCodeList.xml">integerList</ex:parameterType>
    </ex:ExtendedOperationParameter>
  </includesParameter>
</includesParameter>
  <ex:ExtendedOperationParameter
gml:id="RowDenominatorCoefficients">
    <parameterName>Row Denominator Polynomial
Coefficients</parameterName>
    <remarks>Polynomial coefficients in the
denominator polynomial for computing the image row coordinate. The
parameter value shall contain an ordered list of from 8 to 144 Scale
measures. </remarks>
    <ex:parameterType
codeSpace="parameterTypeCodeList.xml">ScaleListType</ex:parameterType>
    </ex:ExtendedOperationParameter>
  </includesParameter>
</includesParameter>
  <ex:ExtendedOperationParameter
gml:id="ColumnNumeratorPowers">
    <parameterName>Column Numerator Maximum
Powers</parameterName>
    <remarks>Maximum powers of the three ground
coordinates in the numerator polynomial for computing the image column
coordinate. The parameter value shall contain an ordered list of three

```

small integers, corresponding to the East, North, and Vertical ground coordinate axes. For each integer, the minimum value is 1. For the East and North axis integers, the maximum value is 5. For the Vertical axis integer, the maximum value is 3. </remarks>

```

      <ex:parameterType
codeSpace="parameterTypeCodeList.xml">integerList</ex:parameterType>
    </ex:ExtendedOperationParameter>
  </includesParameter>
  <includesParameter>
    <ex:ExtendedOperationParameter
gml:id="ColumnNumeratorCoefficients">
      <parameterName>Column Numerator Polynomial
Coefficients</parameterName>
      <remarks>Polynomial coefficients in the numerator
polynomial for computing the image column coordinate. The parameter
value shall contain an ordered list of from 8 to 144 Scale measures.
</remarks>
      <ex:parameterType
codeSpace="parameterTypeCodeList.xml">ScaleListType</ex:parameterType>
    </ex:ExtendedOperationParameter>
  </includesParameter>
  <includesParameter>
    <ex:ExtendedOperationParameter
gml:id="ColumnDenominatorPowers">
      <parameterName>Column Denominator Maximum
Powers</parameterName>
      <remarks>Maximum powers of the three ground
coordinates in the denominator polynomial for computing the image
column coordinate. The parameter value shall contain an ordered list of
three small integers, corresponding to the East, North, and Vertical
ground coordinate axes. For each integer, the minimum value is 1. For
the East and North axis integers, the maximum value is 5. For the
Vertical axis integer, the maximum value is 3. </remarks>
      <ex:parameterType
codeSpace="parameterTypeCodeList.xml">integerList</ex:parameterType>
    </ex:ExtendedOperationParameter>
  </includesParameter>
  <includesParameter>
    <ex:ExtendedOperationParameter
gml:id="ColumnDenominatorCoefficients">
      <parameterName>Column Denominator Polynomial
Coefficients</parameterName>
      <remarks>Polynomial coefficients in the
denominator polynomial for computing the image column coordinate. The
parameter value shall contain an ordered list of from 8 to 144 Scale
measures. </remarks>
      <ex:parameterType
codeSpace="parameterTypeCodeList.xml">ScaleListType</ex:parameterType>
    </ex:ExtendedOperationParameter>
  </includesParameter>
</OperationParameterGroup>
</includesParameter>
</OperationParameterGroup>
</usesParameter>
<usesParameter>
  <OperationParameterGroup gml:id="MonoscopicErrors">
    <groupName>Monoscopic Error Estimates</groupName>

```

```

    <remarks>Horizontal error estimates for when a position in
this one image is used to determine the corresponding ground
coordinates, using this universal image geometry model for this image.
</remarks>
    <includesParameter>
      <ex:ExtendedOperationParameter gml:id="ReferenceHeight">
        <parameterName>Monoscopic Error Estimate Reference
Height</parameterName>
        <remarks>The value of the ground elevation or height
used to estimate the recorded horizontal error estimate when a position
in this one image is used to determine the corresponding ground
coordinates. This reference height is in the Vertical coordinate system
axis of the ground CRS used by the universal image geometry model for
this image. </remarks>
        <ex:parameterType
codeSpace="parameterTypeCodeList.xml">LengthType</ex:parameterType>
      </ex:ExtendedOperationParameter>
    </includesParameter>
    <includesParameter>
      <ex:ExtendedOperationParameter gml:id="AbsoluteError">
        <parameterName>Monoscopic Absolute Error
Estimate</parameterName>
        <remarks>The value of the horizontal absolute error
estimate when a position in this one (monoscopic) image is used to
determine the corresponding ground coordinates. This error estimate
shall be recorded as the Circular Error (CE) with 90% confidence,
always in one metre units. The minimum value is 0.0. </remarks>
        <ex:parameterType
codeSpace="parameterTypeCodeList.xml">LengthType</ex:parameterType>
      </ex:ExtendedOperationParameter>
    </includesParameter>
    <includesParameter>
      <OperationParameterGroup gml:id="RelativeError">
        <groupName>Bin Relative Error Estimates</groupName>
        <minimumOccurs>0</minimumOccurs>
        <remarks>Relative error estimate for one distance bin
between two points. These error estimates are for use when multiple
positions in one (monoscopic) image are used to determine the
corresponding ground coordinates. </remarks>
        <maximumOccurs>9</maximumOccurs>
      </includesParameter>
      <ex:ExtendedOperationParameter gml:id="BinDistances">
        <parameterName>Monoscopic Relative Error Estimate
Bin Distances</parameterName>
        <remarks>The minimum and maximum ground distances
between two points for this distance bin recorded for horizontal
relative error estimates. The parameter value shall contain an ordered
list of two Length measures, always in one metre units. The first value
specifies the bin minimum distance, and the second value specifies the
bin maximum distance. The minimum values are 0.0. </remarks>
        <ex:parameterType
codeSpace="parameterTypeCodeList.xml">LengthListType</ex:parameterType>
      </ex:ExtendedOperationParameter>
    </includesParameter>
    <includesParameter>
      <ex:ExtendedOperationParameter gml:id="BinError">

```

```

        <parameterName>Bin Monoscopic Relative Error
Estimate</parameterName>
        <remarks>The value of the horizontal relative
error estimate between two points for this distance bin recorded for
horizontal relative error estimates. These error estimates are for use
when multiple positions in one (monoscopic) image are used to determine
the corresponding ground coordinates. The relative error estimate shall
be recorded as the Circular Error (CE) with 90% confidence, always in
one metre units. The minimum value is 0.0. </remarks>
        <ex:parameterType
codeSpace="parameterTypeCodeList.xml">LengthType</ex:parameterType>
        </ex:ExtendedOperationParameter>
        </includesParameter>
        </OperationParameterGroup>
        </includesParameter>
        </OperationParameterGroup>
        </usesParameter>
</OperationMethod>

```

Annex B

(informative)

Image coordinate operation methods

B.1 Introduction

This annex discusses the following non-exhaustive list of coordinate transformation types applicable to image coordinate reference systems:

- a) Ground-to-image transformations
- b) Elevation coverage for 2D to 3D coordinate transformations
- c) Single-image-to-ground transformations
- d) Elevation coverage with single-image-to-ground transformations

B.2 Ground-to-image transformations

This set of operation methods defines transformations used for ground-to-image coordinate transformations, with one method used for each image geometry model type. The input to such a transformation is usually 3D ground coordinates, and the output is usually 2D image coordinates. These methods will usually use operation parameters for directly transforming 3D ground coordinates to 2D image coordinates.

B.3 Elevation coverage for 2D to 3D coordinate transformation

This operation method defines a transformation using an elevation coverage for 2D to 3D coordinate transformations. One operation method can be used for each elevation coverage format, with one operation parameter that references the elevation coverage data. The input to this transformation is 2D horizontal coordinates (plus the separately specified elevation coverage), and the output is 3D coordinates. This transformation can be used in a Concatenated Operation with a ground-to-image transformation, to go from 2D ground coordinates to 2D image coordinates.

B.4 Single-image-to-ground transformations

This set of operation methods defines transformations used for single (or monoscopic) image-to-ground transformations, with one operation method used for each image geometry model type. These methods could use parameters for directly transforming 2D image coordinates to multiple 3D ground coordinates. Alternately, these transformations could use parameters for directly transforming 3D ground coordinates to 2D image coordinates (like ground-to-image transformations).

The output from such a transformation is usually 3D ground coordinates, and the input can be 2D image plus 3D ground coordinates. In that case, the 3D ground coordinates are

used to provide a fixed elevation value, to be used with the 2D image input coordinates. The horizontal position is included with each elevation to facilitate ground coordinate transformations. Inclusion of the horizontal position also allows the client to provide an approximate horizontal ground position, when known. Server software implementing such transformations is allowed to make use of this approximate horizontal position, to speed computation.

B.5 Elevation coverage with single-image-to-ground transformation

This operation method defines a transformation using an elevation coverage with a single-image-to-ground transformation. One operation method can be used for each elevation coverage format, with one operation parameter that references the elevation coverage data. This assumes that interface implementations will first use a separate single-image-to-ground transformation to compute two or more points along the image ray. The implementation will then intersect this ray with the ground shape defined by the elevation coverage.

The output from this transformation is usually 3D ground coordinates, and the input can be 2D image plus 3D ground coordinates (plus the separately specified elevation coverage). In that case, the input 3D ground coordinates are used to provide an approximate elevation value, to be used with the 2D image input coordinates. The horizontal position is included with each elevation to facilitate ground coordinate transformations. Inclusion of the horizontal position also allows the client to provide an approximate horizontal ground position, when known. Server software implementing such transformations is allowed to make use of this approximate horizontal position, to speed computation.

Bibliography

- [1] ISO 19118, Geographic information – Encoding
- [2] Version N1316 of ISO CD 19118: Geographic information - Encoding is supplemented by XML Schema documents posted on David Skogan's web page on ISO 19118 encoding: <http://www.ifi.uio.no/~davids/encoding>.
- [3] OGC 00-045r1, Draft RFC on Image Coordinate Transformations
- [4] OGC 01-009, Implementation Specification: Coordinate Transformation Services
- [5] OGC 03-010r9, Recommended XML encoding of coordinate reference systems and coordinate transformations
- [6] OGC 04-071, Some image geometry models
- [7] OGC 05-013, Web Coordinate Transformation Service (WCTS) Implementation Specification (draft)
- [8] OGC 05-014, Image CRSs for IH4DS