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Image CRSs for IH4DS

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Contents

Page

Figures Page

i. Preface

NOTE The previous version of this document was numbered 04-065r1, now renumbered 05-014 after approval and final editing in 2005.

This document was prepared as an Interoperability Program Report under the Image Handling for Decision Support (IH4DS) thread of the OGC Web Services interoperability initiative Phase 2 (OWS 2). This document is now released as an OGC Discussion Paper.

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

ii. Document contributor contact points

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iii. Changes to the OGC Abstract Specification

The OGC™ Abstract Specification requires a change to accommodate the technical contents of this document. The needed change is proposed in OGC change proposal 04-064.

iv. Future work

Improvements in this document are desirable to:

a) Discuss transformation of the CRS of georectified images

b) Add examples

Foreword

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. Open Geospatial Consortium Inc. shall not be held responsible for identifying any or all such patent rights. However, to date, no such rights have been claimed or identified.

Introduction

This Discussion Paper specifies image coordinate reference system (CRS) definitions designed for possible use by WCTS and WCS servers and clients, initially in the IH4DS thread of the OWS 2 interoperability initiative. This report specifies image CRS definitions suitable for both ungeorectified and georectified images, where an ungeorectified image can be georeferenced or not.

Image CRSs for IH4DS

1 Scope

This Discussion Paper specifies image coordinate reference system (CRS) definitions designed for possible use by WCTS and WCS servers and clients, initially in the IH4DS thread of the OWS 2 interoperability initiative. This report specifies image CRS definitions suitable for both ungeorectified and georectified images, where an ungeorectified image can be georeferenced or not.

This report specifies only the image CRS definitions which the author thinks should be used. Other CRSs that might be used for georectified images are not discussed. This report does not fully specify georectification or other image exploitation coordinate Transformations. It does include one coordinate Conversion needed to define the recommended DerivedCRS for a georectified image.

These image CRS definitions are expected to be referenced by coordinate transformations implemented by WCTS servers. Such coordinate transformations are needed to georectify an image and to convert positions measured in images, both georectified and ungeorectified, to positions in another CRS. Such coordinate transformations are probably also required by some WCS servers, when the client requests an image coverage in a CRS different from the one in which that coverage is stored.

These image CRS definitions are required to unambiguously identify that CRS and to provide the basic definition of that CRS. The image CRSs must be identified to support checking for equality or inequality with other CRSs known to a client or server. The image CRSs must be defined to support properly defining a coordinate transformation to or from that CRS. However, the CRS definition is not always used in performing a coordinate transformation.

2 Normative references

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

ISO 19123 version 211n1682: *Geographic information — Schema for coverage geometry and functions* (earlier version included in OpenGIS® Abstract Specification Topic 6: The Coverage Type and its Subtypes)

OGC 03-105r1: *Geography Markup Language (GML)*, v 3.1

OGC 03-107r1: *Geography Markup Language (GML) Schemas*, v 3.1

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

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

W3C Recommendation 04 February 2004, *Extensible Markup Language (XML) 1.0* (Third Edition), http://www.w3.org/TR/REC-xml

This document includes a normative XML Schema file bundled with this document.

3 Terms and definitions

3.1
client
software component that can invoke an **operation** from a **server**

3.2
operation
specification of a transformation or query that an object may be called to execute [ISO 19119]

3.3
request
invocation of an **operation** by a **client**

3.4
response
result of an **operation,** returned from a **server** to a **client**

3.5
server
service instance
a particular instance of a **service** [ISO 19119 edited]

3.6
service
distinct part of the functionality that is provided by an entity through interfaces [ISO 19119]

3.7
continuous coverage
coverage that returns different values for the same feature attribute at different **direct position**s within a single **spatial object**, temporal object, or **spatiotemporal object** in its **domain**

NOTE Although the domain of a continuous coverage is ordinarily bounded in terms of its spatial and/or temporal extent, it can be subdivided into an infinite number of direct positions.

3.8
coordinate reference system
coordinate system which is related to the real world by a datum [ISO 19111]

3.9
coverage
feature that acts as a **function** to return values from its **range** for any **direct position** within its spatial, temporal, or **spatiotemporal domain**

EXAMPLE Examples include a **raster** image, polygon overlay, or digital elevation matrix.

3.10
coverage geometry
configuration of the **domain** of a **coverage** described in terms of **coordinates**

3.11
direct position
position described by a single set of **coordinates** within a **coordinate reference system** [ISO 19107]

3.12
feature
abstraction of real world phenomena [ISO 19101]

3.13
grid
network composed of two or more sets of **curves** in which the members of each set intersect the members of the other sets in an algorithmic way

NOTE The curves partition a space into grid cells.

3.14
grid point
point located at the intersection of two or more **curves** in a **grid**

3.15
point
0-dimensional **geometric primitive**, representing a position

3.16
rectified grid
grid for which there is an affine transformation between the grid **coordinates** and the coordinates of an external **coordinate reference system**

NOTE If the coordinate reference system is related to the earth by a datum, the grid is a georectified grid.

3.17
referenceable grid
grid associated with a transformation that can be used to convert grid **coordinate** values to values of coordinates referenced to an external **coordinate reference system**

NOTE If the coordinate reference system is related to the earth by a datum, the grid is a georeferenceable grid.

3.18
vector
quantity having direction as well as magnitude

NOTE A directed line segment represents a vector if the length and direction of the line segment are equal to the magnitude and direction of the vector. The term vector data refers to data that represents the spatial configuration of features as a set of directed line segments.

3.19
Cartesian coordinate system
coordinate system which gives the position of points relative to n mutually perpendicular axes [proposed ISO 19111]

NOTE *n* is 1, 2 or 3 for the purposes of this International Standard.

3.20
compound coordinate reference system
coordinate reference system using at least two independent **coordinate reference systems** describing horizontal position and/or vertical position and/or temporal position or positions [proposed ISO 19111]

NOTE A compound coordinate reference system does not contain another compound coordinate reference system.

3.21
concatenated operation
coordinate operation consisting of sequential application of multiple **coordinate operations** [proposed ISO 19111]

3.22
coordinate
one of a **sequence** of *n* numbers designating the position of a point in *n*-dimensional space [proposed ISO 19111]

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

3.23
coordinate conversion
change of **coordinates**, based on a one-to-one relationship, from one **coordinate reference system** to another based on the same **datum** [proposed ISO 19111]

EXAMPLE Between ellipsoidal and Cartesian coordinate systems or between geographic coordinates and projected coordinates, or change of units such as from radians to degrees or feet to meters.

NOTE A coordinate conversion uses parameters which have specified values, not empirically determined values.

3.24
coordinate operation
change of **coordinates**, based on a one-to-one relationship, from one **coordinate reference system** to another [proposed ISO 19111]

NOTE Supertype of coordinate transformation and coordinate conversion.

3.25
coordinate reference system
coordinate system which is related to the real world by a **datum** [proposed ISO 19111]

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

3.26
coordinate system
set of mathematical rules for specifying how **coordinates** are to be assigned to points [proposed ISO 19111]

3.27
coordinate transformation
change of **coordinates** from one **coordinate reference system** to another **coordinate reference system** based on a different **datum** through a one-to-one relationship [proposed ISO 19111]

NOTE A coordinate transformation uses parameters which are derived empirically by a set of points with known coordinates in both coordinate reference systems.

3.28
geographic coordinate reference system
coordinate reference system using an **ellipsoidal coordinate system** and based on an **ellipsoid** that approximates the shape of the Earth [proposed ISO 19111]

NOTE A geographic coordinate system can be 2D or 3D. In a 3D geographic coordinate system, the third dimension is height above the ellipsoid surface.

3.29
image datum
engineering datum which defines the origin of an **image coordinate reference system** [proposed ISO 19111]

3.30
map projection
coordinate conversion from an **ellipsoidal coordinate system** to a plane [proposed ISO 19111]

3.31
pixel
smallest element of a digital image to which attributes are assigned [proposed ISO 19111]

NOTE This term originated as a contraction of “picture element”.

3.32
projected coordinate reference system
coordinate reference system derived from a two-dimensional **geographic coordinate reference system** by applying a **map projection** and using a **Cartesian coordinate system** [proposed ISO 19111]

3.33
vertical coordinate reference system
one-dimensional **coordinate reference system** used for **gravity-related height** or **depth** measurements [proposed ISO 19111]

4 Conventions

4.1 Abbreviated terms

CRS	Coordinate Reference System
GML	Geography Markup Language
IH4DS	Image Handling for Decision Support
ISO	International Organization for Standardization
OGC	Open GIS Consortium
OWS	OGC Web Service, or Open Web Service
OWS 2	OGC Web Services interoperability initiative, phase 2
UML	Unified Modeling Language
WCS	Web Coverage Service
WCTS	Web Coordinate Transformation Service
XML	Extensible Markup Language
1D	One Dimensional
2D	Two Dimensional
3D	Three Dimensional

4.2 UML notation

Most diagrams in this document are presented using the Unified Modeling Language (UML) static structure diagram, as described in Subclause 5.2 of [OGC 05-012].

Some diagrams in this document are object diagrams instead of class diagrams, using the same graphical notation. In an object diagram, each box is named with the object name followed by the class name. However, these compound object names are not underlined herein as they should be. Links between these objects are shown like class associations, with visibility arrowheads and role names. Multiplicities are not shown on these links, since all object link multiplicities are one (1) by definition.

Object diagrams usually show the values of selected class attributes, to show how these objects are being used. The object diagrams used in this document do not show the values of selected class attributes because use of these objects is not reflected in specific attribute values. The uses of objects in this document are reflected instead in the object associations and realizations shown.

5 Background

5.1 Introduction

This clause provides partial UML models extracted from the OGC Abstract Specification that are believed to be useful in understanding the UML models in the following clauses.

5.2 Grid coverage UML model

Subclause 8 of ISO 19123 “Geographic information — Schema for coverage geometry and functions” specifies an abstract UML model of coverages, where an image is a Continuous Quadrilateral Grid Coverage as defined therein. Figure 1 is a class diagram containing the subset of the ISO 19123 UML model that seems applicable to images, including both ungeorectified and georectified images.

NOTE 1 This class diagram omits the class operations shown in ISO 19123, because they are not relevant in this document. The descriptions of some of those class operations include the statement: “It is a coordinate conversion operation as defined by ISO 19111.” or “This is a coordinate transformation operation as defined by ISO 19111.” However, ISO 19111 does not define any operations in any classes. ISO 19111 does define a CC_CoordinateOperation abstract class with the non-abstract subclasses CC_Conversion and CC_Transformation. Those subclasses include all the information needed to perform a class operation that would correspond to the referencing operation in a CV_ class.

NOTE 2 The CV_GeoreferenceableGrid class does not show any of the attributes that are required to perform the operations defined in that class. I assume these attributes are not shown in ISO 19123 because they would be considerably different for different georeferencing methods.

As I interpret this UML model, the CV_GridValuesMatrix class (without the CV_RectifiedGrid class) models information that should be included in an image file. However, some of this information is fixed and implicit in some image file formats.

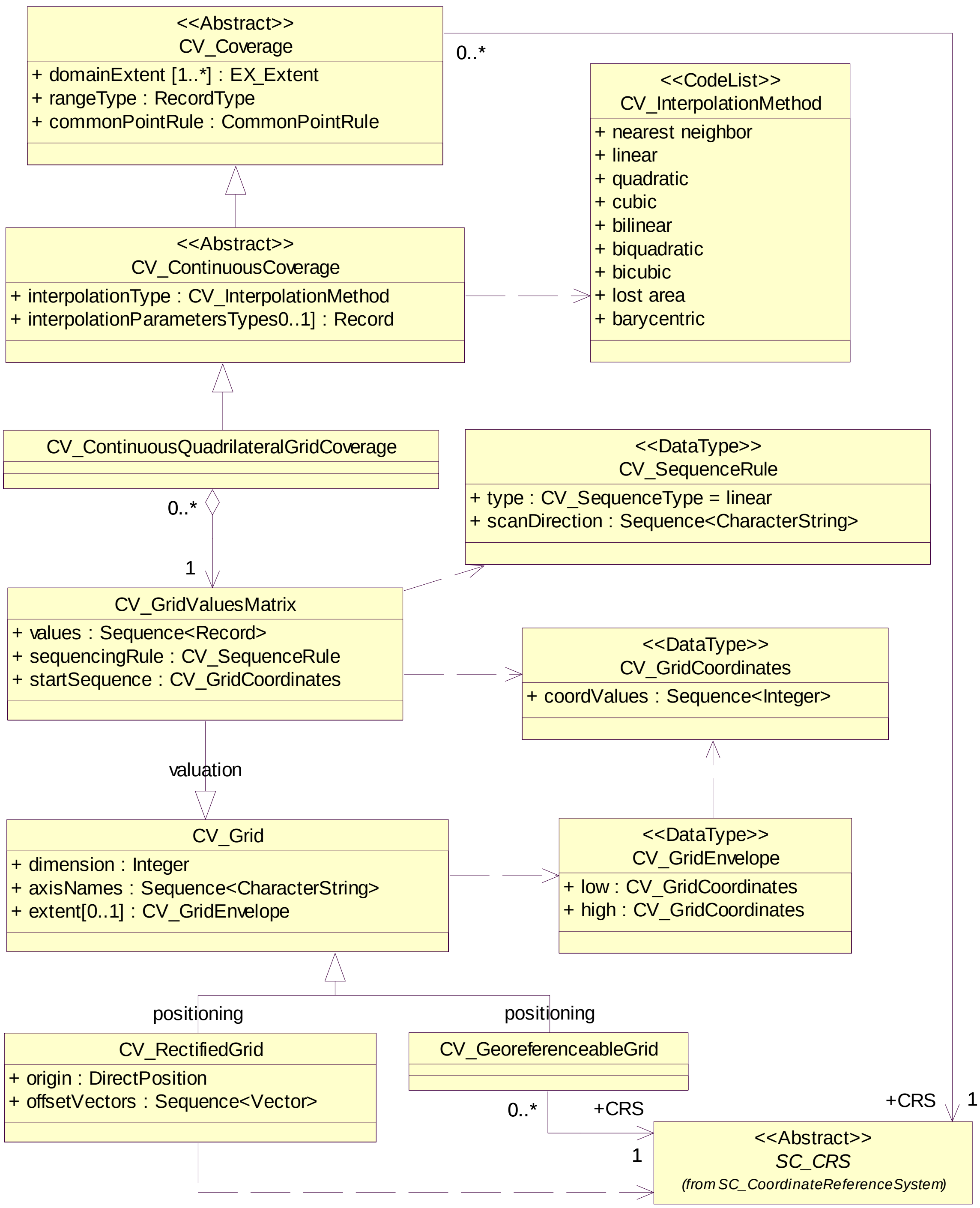

Figure 1 — Image coverages UML class diagram

The attributes whose values are variable and thus must be explicit in (or with) each image file are:

a) values : Sequence<Record> (the pixel values)

b) high : CV_GridCoordinates (the image size in pixels, if low=1,1)

The attributes whose values are often fixed and thus can be implicit in a specific image file format are:

a) startSequence : CV_GridCoordinates (the first pixel index, may be 1,1)

b) type : CV_SequenceType (the pixel sequencing method, often linear)

c) scanDirection : Sequence<CharacterString> (the pixel sequencing axes names, may be row, column)

d) dimension : Integer (the number of image pixel dimensions, usually 2)

e) axisNames : Sequence<CharacterString> (the pixel axes names, may equal scanDirection : Sequence<CharacterString>)

f) low : CV_GridCoordinates (usually the first pixel index, may be 1,1)

5.3 WCTS Transform operation

A primary objective of the image CRSs being defined in this document is to be useful in a Transform operation of a WCTS. The input information needed to control a WCTS Transform operation should be represented as an object of the CC_CoordinateOperation abstract class, since all the concrete subclasses of that abstract class were designed to fully specify a coordinate operation.

If additional information is found to be needed to control a WCTS Transform operation, it is thus desirable to expand the CC_CoordinateOperation class and/or its subclasses, instead of providing additional inputs to the WCTS Transform operation. Such expansion might be done by defining a GML Application Schema that adds such information to the CC_CoordinateOperation class and/or its subclasses.

Alternately, a GML Application Schema might be defined that adds information to the SC_CRS class or a subclass thereof. All coordinate operations have (direct or indirect) associations to their sourceCRS and targetCRS. However, those SC_CRS classes are not allowed to contain any information in a CRS different from itself, with the exception of the definedByConversion in each SC_ProjectedCRS and SC_DerivedCRS.

This document thus explores how a concrete subclass of the CC_CoordinateOperation abstract class can be used to control a WCTS Transform operation to georectify an image or transform coordinates measured in a georectified or ungeorectified image.

5.4 ImageCRS UML model

Figure 2 is a UML class diagram for an image CRS, extracted from the UML models in OGC Abstract Specification Topic 2, document 04-046r3. This diagram shows essentially all the classes and associations related to the SC_ImageCRS class.

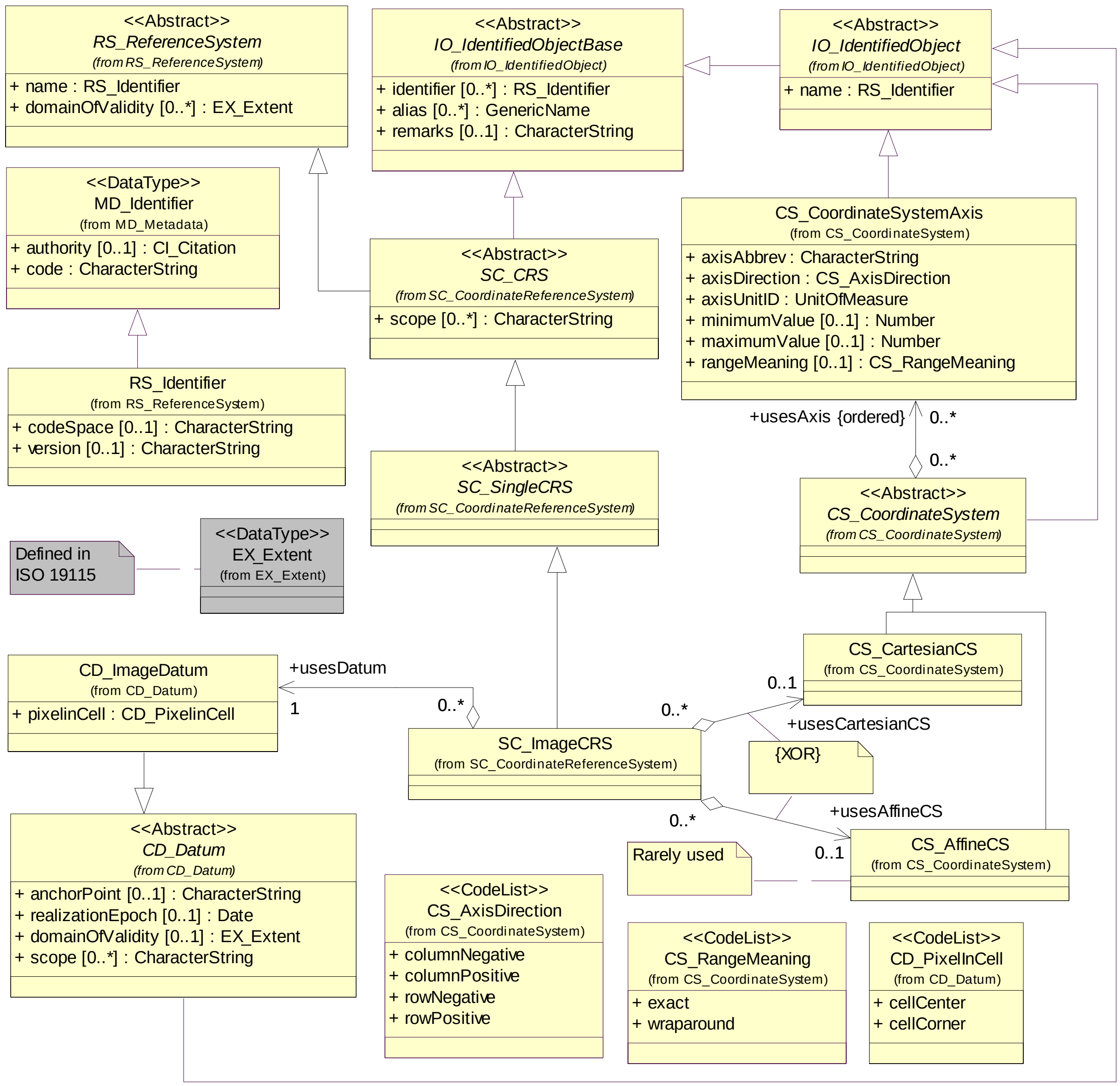

Figure 2 — ImageCRS UML class diagram

5.5 Rectified grid CRS UML model

Figure 3 is a UML class diagram for a CRS for a rectified grid, analogous to the CV_RectifiedGrid class in OGC Abstract Specification Topic 2, document 04-046r3. This diagram shows the classes and associations related to the SC_DerivedCRS class when used for a rectified grid coverage, except for the classes and associations for the CC_Conversion class used as the definedByConversion and the other concrete subclasses of the SC_SingleCRS class that might be used as the baseCRS. That base CRS is most likely to be a SC_ProjectedCRS or 2D SC_GeographicCRS. For a rectified grid, this diagram has been modified to show the SC_DerivedCRS having a usesCS role association to the CS_CartesianCS class, instead of to the more general CS_CoordinateSystem abstract class.

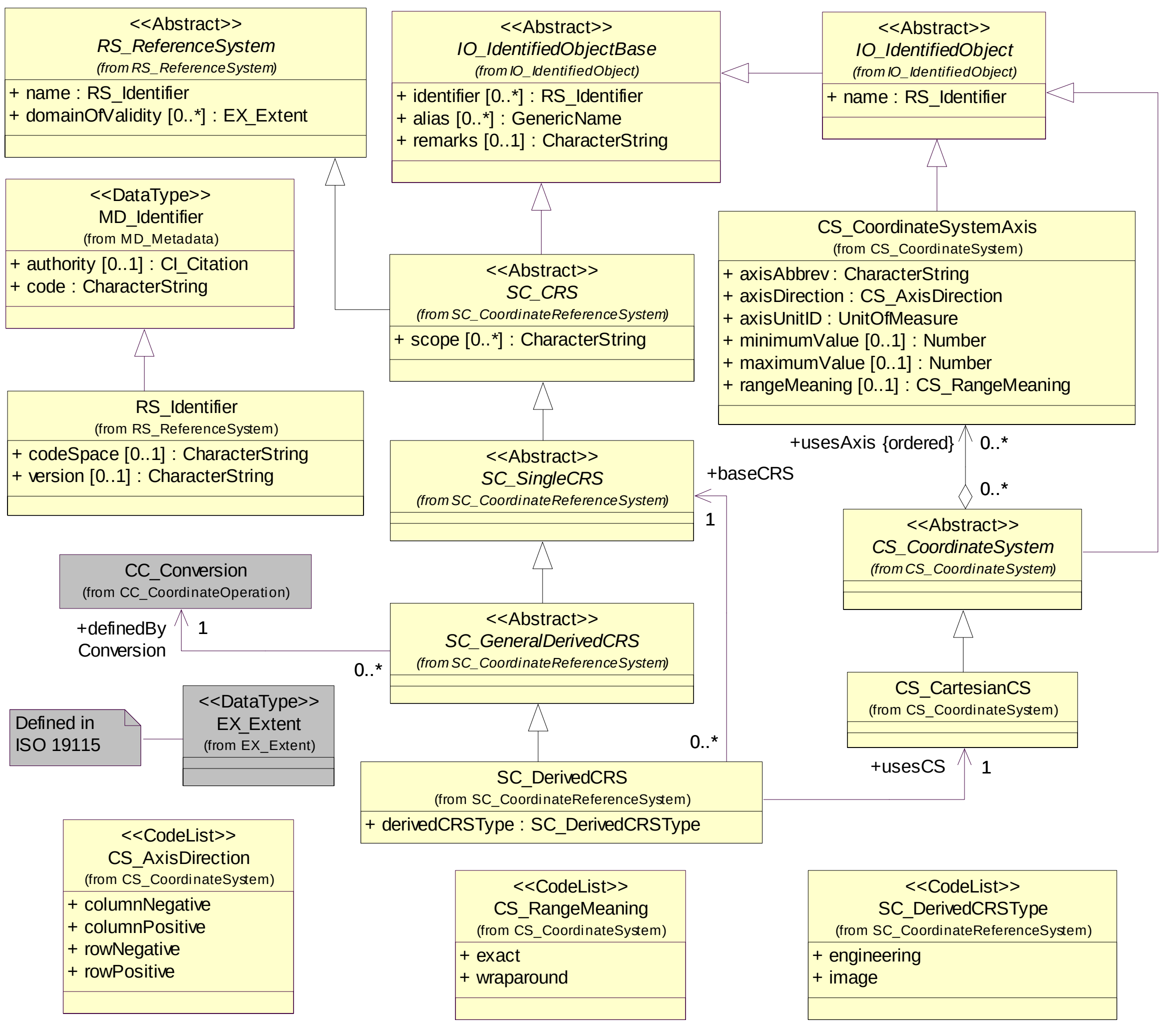

Figure 3 — Rectified grid DerivedCRS UML class diagram

This rectified grid is called a georectified grid when the baseCRS has a datum tying it to the earth, which occurs when that SC_SingleCRS is a GeographicCRS, ProjectedCRS, or GeocentricCRS. This georectified grid CRS can thus be used for a georectified image when the definedByConversion is not (partially) determined by characteristics of a specific image. If a georectified grid CRS is defined within a GeographicCRS or ProjectedCRS in a manner determined by characteristics of a specific image, a coordinate Transformation must be used, instead of a coordinate Conversion, between that georectified grid CRS and the corresponding GeographicCRS, ProjectedCRS, or GeocentricCRS.

Using the concepts defined in Topic 2, the CRS of a georectified image (or other grid coverage) must define the grid positions within the corresponding GeographicCRS, ProjectedCRS, or GeocentricCRS, and cannot directly use that GeographicCRS, ProjectedCRS, or GeocentricCRS. The relationship between the CRS of a georectified image and the corresponding GeographicCRS, ProjectedCRS, or GeocentricCRS must be defined by a coordinate Transformation or Conversion. This discussion has described how and when a Conversion can be used.

5.6 Conversion UML model

As stated above, a SC_DerivedCRS is defined by a CC_Conversion, which is a concrete subtype of the CC_CoordinateOperation class. Figure 4 is a UML class diagram for a CC_Conversion for a rectified grid. This diagram shows the classes and associations related to the CC_Conversion class when used to define a SC_DerivedCRS for a rectified grid, except for the:

a) CC_ParameterValueGroup and CC_OperationParameterGroup classes, which are not believed useful in defining a grid

b) Details of the SC_GeneralDerivedCRS class, because they are shown on the preceding diagram.

c) Contents of the DQ_PositionalAccuracy and EX_Extent classes, defined in ISO 19115

For a rectified grid CRS, this Conversion is defined by six instances of the CC_OperationParameter and CC_ParameterValue classes, as needed by a 2D affine CC_OperationMethod used by the conversion.

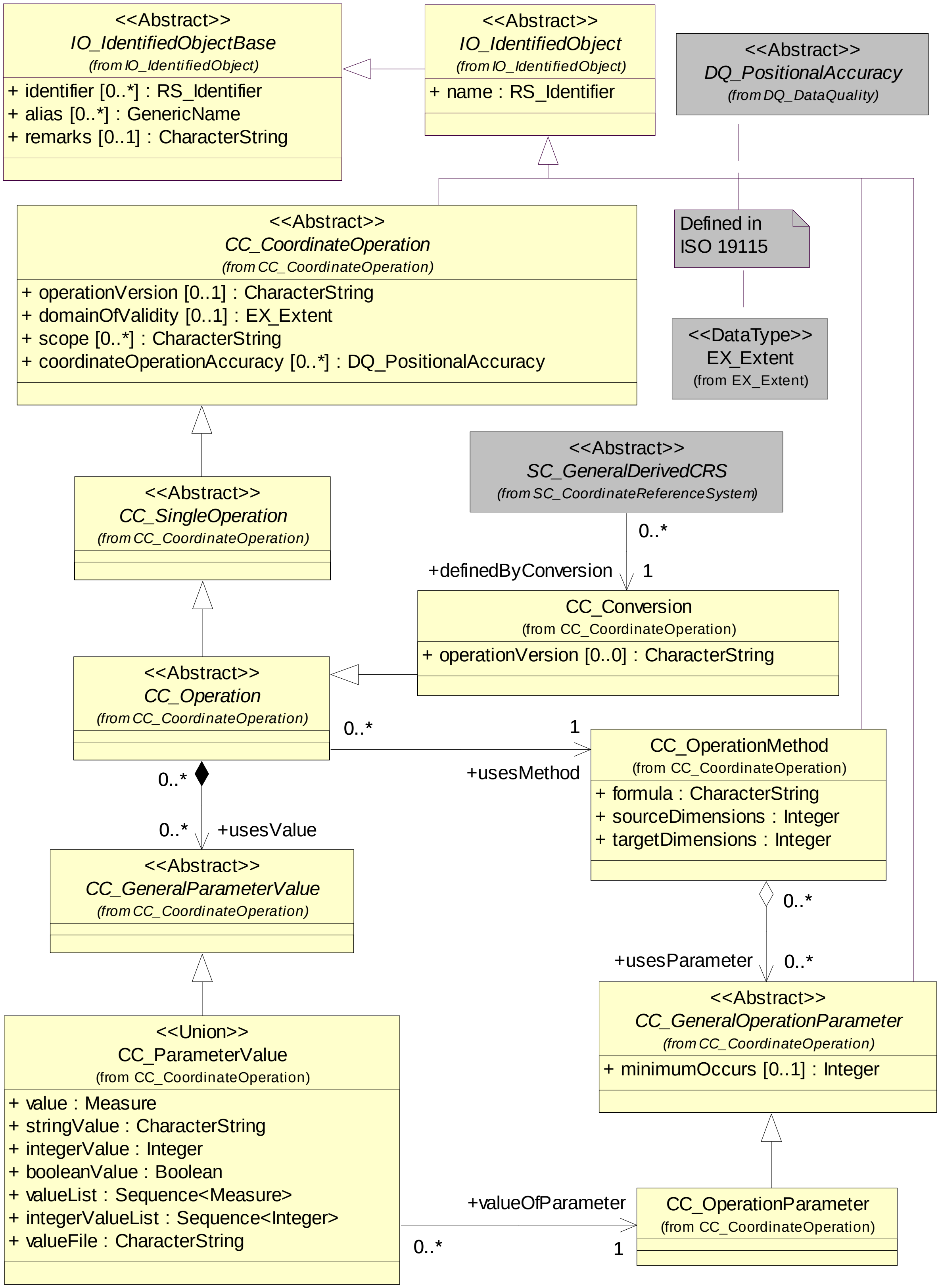

Figure 4 — Conversion for grid UML model

5.7 Transformation UML model

Figure 5 is a UML class diagram for a coordinate CC_Transformation. This diagram shows the classes and associations related to the CC_Transformation class, except for the:

a) Contents of the SC_CRS class, defined by most of the UML model in Topic 2

b) Contents of the DQ_PositionalAccuracy and EX_Extent classes, defined in ISO 19115

c) CC_ParameterValueGroup and CC_OperationParameterGroup classes, which are not always useful

Notice that the ImageCRS and DerivedCRS classes previously discussed do NOT include or reference any coordinate Transformations that can be for georeferencing of an ImageCRS. However, each Transformation always references or includes both a sourceCRS and a targetCRS, and either the sourceCRS or targetCRS could be an ImageCRS or DerivedCRS in a Transformation used for georeferencing.

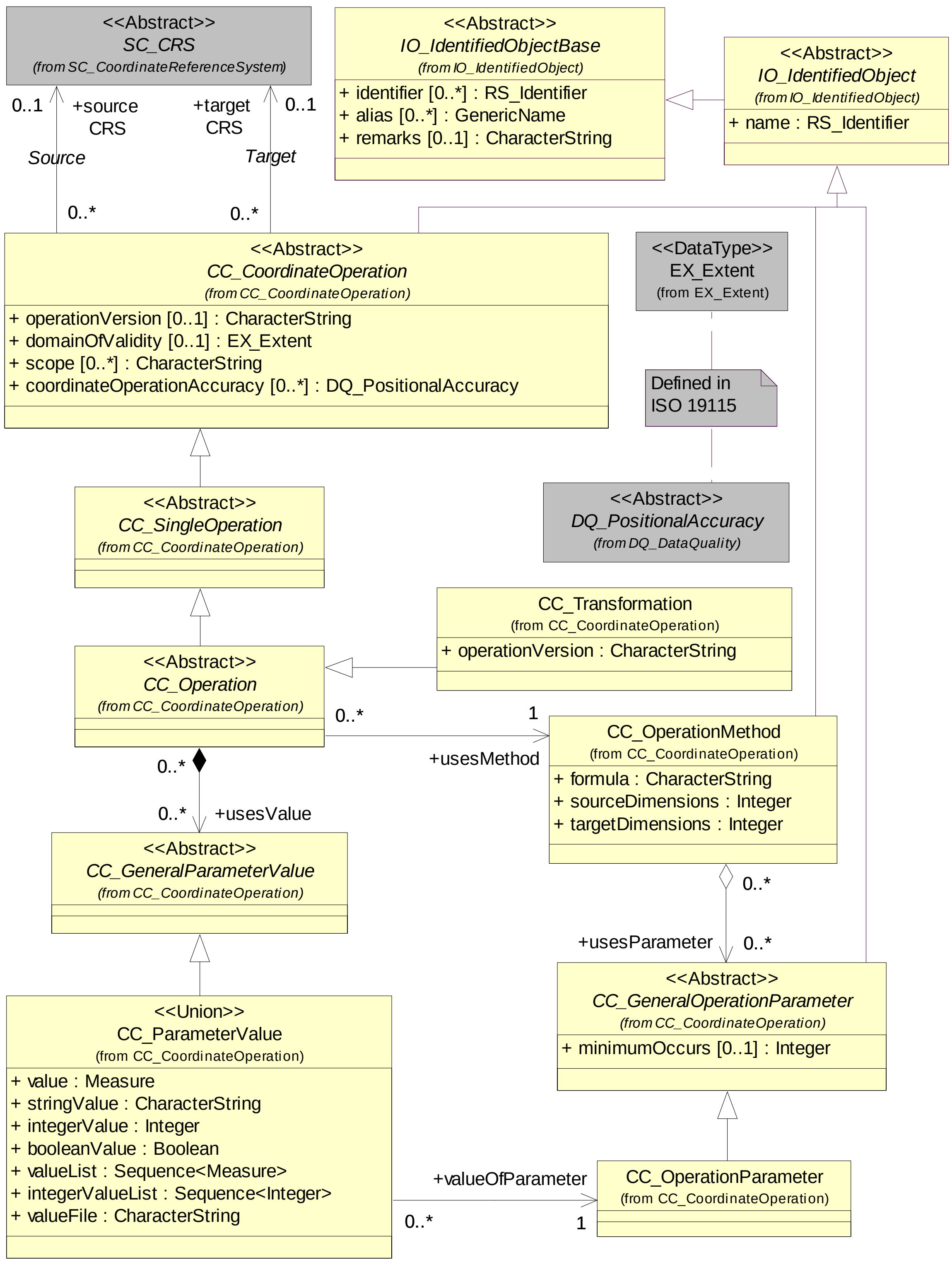

Figure 5 — Transformation UML model

6 Image georectification

6.1 Introduction

This clause describes image georectification, by a WCTS Transform operation, and provides a UML model for such georectification.

6.2 Georectification process

A frequently-used image georectification process can be summarized as follows, using current CRS and coverage terms:

a) Define the georectified image CRS that specifies the desired georectified image pixel locations in a georectification base CRS, which is a DerivedCRS. The georectification base CRS is usually a ProjectedCRS or 2D GeographicCRS.

NOTE 1 This DerivedCRS is defined by a coordinate Conversion that is specified, rather than being empirically derived for a specific image. The same georectified image CRS is sometimes used for a group of existing and future images that are expected to be used together, with pixel spacing appropriate to that expected use. That DerivedCRS is often defined based on the general characteristics of a group or series of images. In constructing this DerivedCRS, we are NOT trying to approximate the reverse of an existing georeferencing coordinate Transformation for one image.

b) Obtain elevation data covering the area of interest in the georectification base CRS, usually grid elevation data. Define the 3D georectification CRS into which image(s) will be georectified. This georectification base CRS is usually a 3D GeographicCRS or CompoundCRS that combines a ProjectedCRS with a VerticalCRS. If the elevation changes and the imaging ray angles from vertical are both small, a constant elevation value can be used with little degradation of position accuracy.

c) Select the (ungeorectified) image to be georectified, and define the ImageCRS to be used for positions in this ungeorectified image.

d) Determine or obtain a georeferencing coordinate Transformation between the ImageCRS of the ungeorectified image and the georectification base CRS. This Transformation is often from the 3D georectification base CRS to the 2D ImageCRS.

NOTE 2 The above steps are not always performed in the order listed.

e) Determine the pixel values in the georectified image CRS by resampling or otherwise using the pixel values in the ungeorectified image.

NOTE 3 This process expands step 4) of the Display Image With Overlaid Graphics use case in Section 2.1.3.1 of OGC Abstract Specification Topic 15, document 00-115, for orthorectification. This process similarly expands step 7) of the “Agricultural irrigation use case” use case in Table A.7 of document 04-052.

A georectification image resampling process frequently-used in step e) above can be summarized as follows: Determine the georectified image pixels to be output, by doing the following for each pixel:

a) Compute the horizontal position of this output pixel in the georectification base CRS, using the georectified image CRS which specifies the georectification base CRS location corresponding to the georectified image pixel location.

b) Determine the vertical coordinate corresponding to the horizontal position of this output pixel, in the georectification base CRS, using available surface elevation information such as grid elevation data. If the elevation changes and the imaging ray angles from vertical are both small, a constant elevation value can be used with little degradation of position accuracy.

c) Compute the 2D position of this output pixel in the ImageCRS of the ungeorectified image, using the georeferencing coordinate Transformation from the 3D georectification base CRS to the ImageCRS of the ungeorectified image. This position is computed with a precision of a fraction of a pixel spacing.

d) Interpolate the value of this output pixel between the values of the surrounding pixels in the ungeorectified image, and assign the interpolated value to this output pixel. Various interpolation methods can be used, including nearest-neighbor, bilinear, biquadratic, and bicubic.

AUTHOR'S NOTE The author has used both of the georectification procedures outlined above. These orthorectification procedures are appropriate for high accuracy photogrammetric image exploitation, and are outlined in Sections 13.2.2 and 10.6 of the Fifth edition of the Manual of Photogrammetry, published by ASPRS. Other georectification procedures probably exist and are used under appropriate conditions, such as less-rigorous procedures.

Another possible method of determining the pixel values in the georectified image CRS, using the pixel values in the ungeorectified image, in step e) above is the following:

a) Process each pixel in the ungeorectified image as follows:

   1) Compute the 3D position of this pixel in the georectification base CRS, using the georeferencing coordinate Transformation from the 2D ImageCRS of the ungeorectified image to the 3D georectification base CRS. This should be done using available surface elevation information such as grid elevation data. If the elevation changes and the imaging ray angles from vertical are both small, a constant elevation value can be used with little degradation of position accuracy.

   2) Compute the 2D indexes of this pixel in the georectified image CRS which defines the georectification base CRS locations corresponding to the georectified image pixel indexes, discarding the elevation in the 3D georectification base CRS.

   3) Assign the value of this ungeorectified image pixel to the georectified image pixel with these 2D position indexes.

b) Process each pixel in the georectified image as follows:

   1) If this pixel in the georectified image has had no value assigned, determine an appropriate pixel value. This value could be determined in various ways, such as by interpolation between surrounding pixels in the georectified image. (If the

output pixel size is approximately the same as the typical input pixel size, this missing value problem should not be very significant.)

2) If this pixel in the georectified image has had multiple values assigned, determine a single appropriate pixel value. This might be done in various ways, such as by averaging the multiple values assigned. (If the output pixel size is approximately the same as the typical input pixel size, this duplication problem should not be very significant.)

AUTHOR'S NOTE The above method is not completely defined, especially for step b). In addition, this method does not use any of the interpolation methods defined in ISO 19123 and used in the WCTS interface. What InterpolationMethod should be specified in the Transform operation request? I consider this InterpolationMethod parameter to be required now when a grid coverage is being transformed. What InterpolationMethod(s) should be specified in the CoverageAbilities element in the Capabilities document? At least one of these InterpolationMethod parameters is now required.

6.3 Georectification simple UML model

The image georectification process described above can be implemented by the WCTS Transform operation. A simple UML object diagram for georectification is shown in Figure 6. In this diagram, the GeorectifyImage:WCTS_Transform object represents a WCTS server performing image georectification, operating on the inputImage, producing the outputImage, and using the "transformation" object. That transformation will indirectly reference the inputImage and outputImage, not shown in this simple diagram.

NOTE The graphical notation used in object diagrams is described in Subclause 4.2.

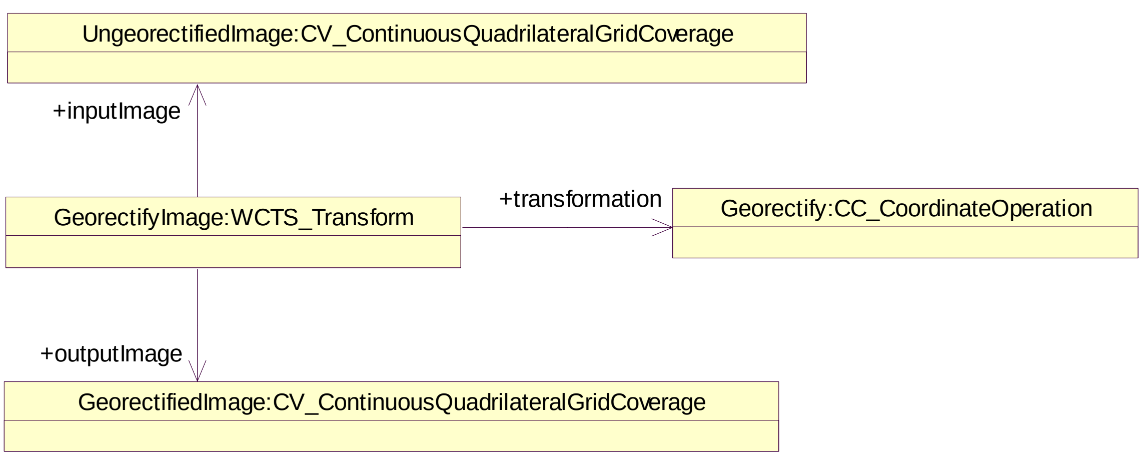

Figure 6 — Georectification simple UML object diagram

The input information needed to control a WCTS Transform operation is here represented as an object of the CC_CoordinateOperation abstract class, as discussed in Subclause 5.3. The following subclauses thus explore how a concrete subclass of the CC_Coordinate-Operation abstract class can be used to control a WCTS Transform operation to georectify an image coverage.

6.4 Georectification expanded UML model

An expanded UML object diagram for image georectification is shown in Figure 7. In this diagram, the Georectify:WCTS_Transform object has been divided into two objects, with the Georectify:WCTS_TransformedData object representing the Transform operation response, while the GeorectifyImage:WCTS_Transform object represents the Transform operation request. The UngeorectifiedImage:CV_ContinuousQuadrilateral-GridCoverage and GeorectifiedImage:CV_ContinuousQuadrilateralGridCoverage objects have each been replaced with three objects using coverage classes (see Figure 1).

The UngeorecifiedImageCRS:SC_CRS object has been added to represent the sourceCRS of the Georectify:CC_CoordinateOperation, although it uses the abstract SC_CRS class. This UngeorecifiedImageCRS:SC_CRS object can be considered to be a partial realization of the UngeorectifedImageGrid:CV_Grid object, not including the UngeorectifedImage:CV_GridValuesMatrix.

The GeorecifiedImageCRS:SC_CRS object has been added to represent the targetCRS of the Georectify:CC_CoordinateOperation, although it uses the abstract SC_CRS class. This GeorecifiedImageCRS:SC_CRS object can be considered to be a partial realization of the GeorectifiedImageGrid:CV_RectifiedGrid object.

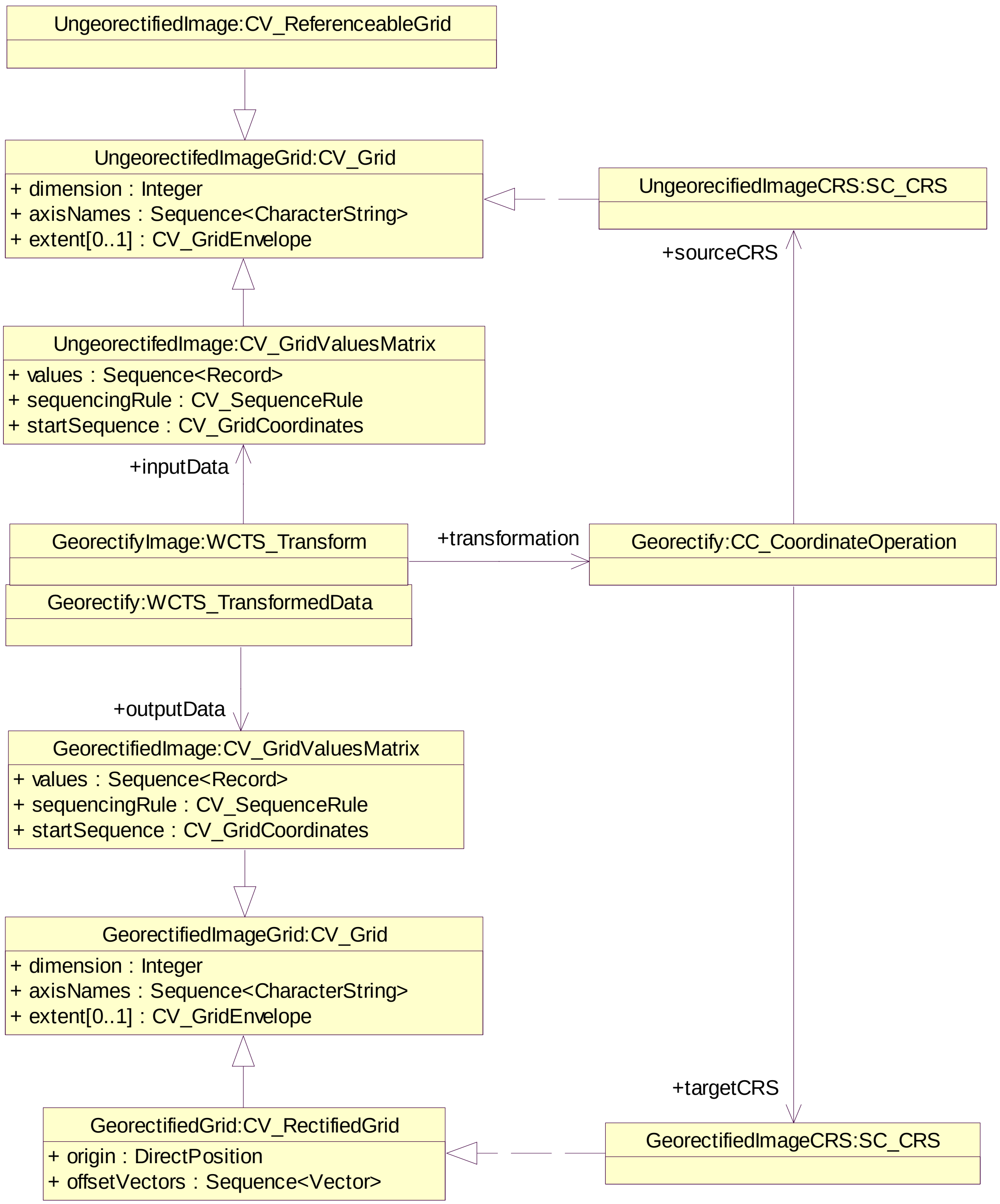

Figure 7 — Georectification expanded UML object diagram

6.5 Georectification complete UML model

A further expanded UML object diagram for georectification is shown in Figure 8. In this diagram, the previous Georectify:CC_CoordinateOperation object has been further expanded using objects from more specific classes in the UML model in OGC Abstract Specification Topic 2. This has been done to show one way of specifying how to georectify the image. The previous Georectify:CC_CoordinateOperation was changed to Georectify:CC_ConcatenatedOperation.

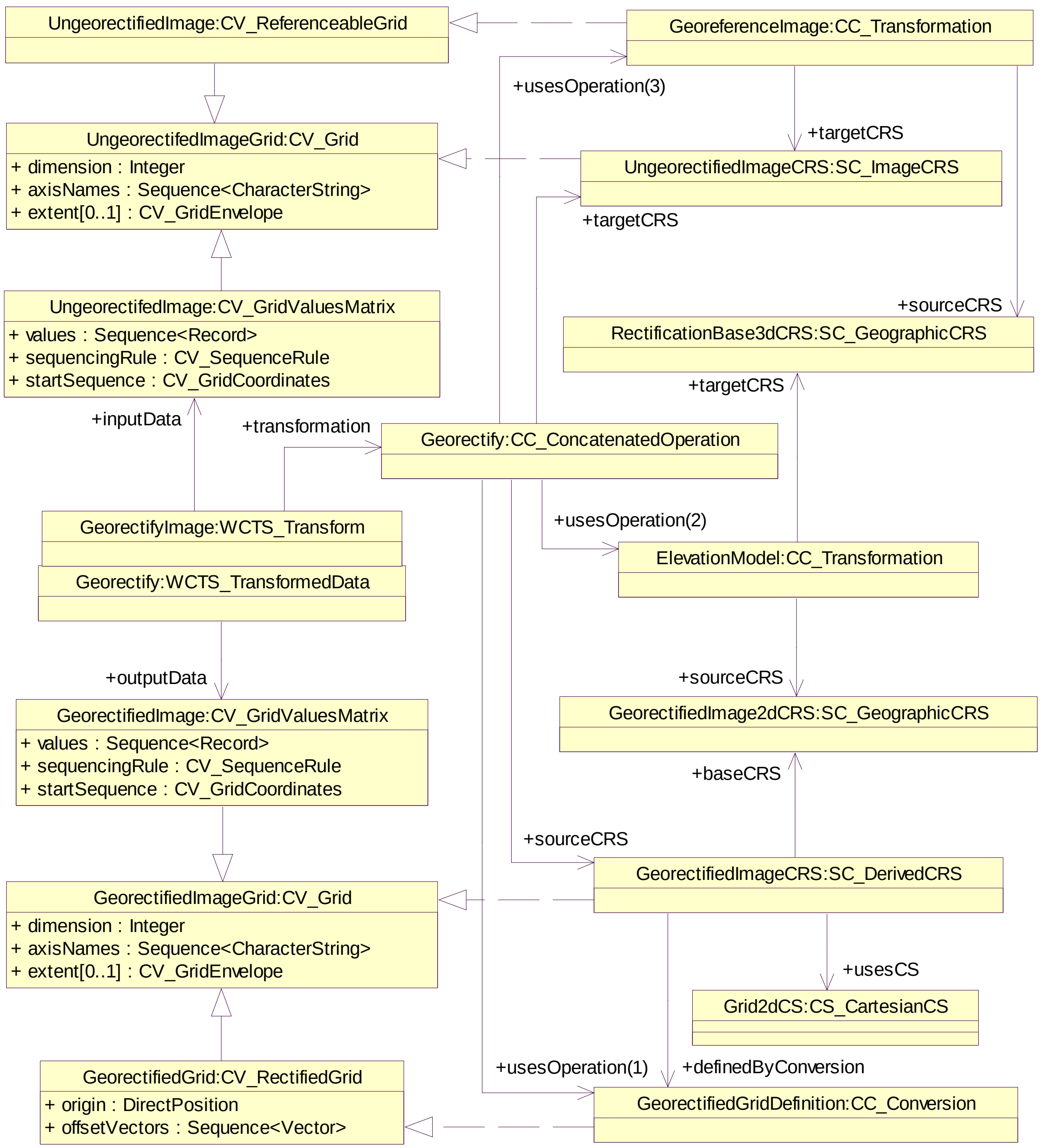

Figure 8 — Georectification complete UML object diagram

In this diagram, the UngeorectifiedImageCRS:SC_ImageCRS is used to define the CRS of the ungeorectified image as a SC_ImageCRS. This object is considered to be a partial realization of the UngeorectifedImageGrid:CV_Grid object, not including the two objects that inherit this object.

Similarly, the GeorectifiedImageCRS:SC_DerivedCRS object is used to define the CRS of the georectified image as a SC_DerivedCRS. This object is considered to be a partial realization of the GeorectifiedImageGrid:CV_Grid, not including the Georectified-Image:CV_GridValuesMatrix. This GeorectifiedImageCRS:SC_DerivedCRS specifies the positions of the pixels in the georectified image, including the spacing between pixels and the CRS origin in the GeorectifiedImage2dCRS:SC_GeographicCRS. This pixel grid CRS is specified within the baseCRS GeorectifiedImage2dCRS:SC_GeographicCRS by the GeorectifiedGridDefinition:CC_Conversion (and is not the same CRS as that GeorectifiedImage2dCRS:SC_GeographicCRS).

The CRS of the georectified image is defined as a CS_DerivedCRS because that grid is specified in the GeorectifiedImage2dCRS:SC_GeographicCRS, before the corresponding pixels in the GeorectifiedImage:CV_GridValuesMatrix are produced. This Georectified-ImageCRS:SC_DerivedCRS uses the GeorectifiedGridDefinition:CC_Conversion to define the rectified image grid, in the GeorectifiedImage2dCRS:SC_GeographicCRS baseCRS. Although shown here as an object of the SC_GeographicCRS class, this baseCRS GeorectifiedImage2dCRS:SC_GeographicCRS can be a SC_ProjectedCRS. The GeorectifiedGridDefinition:CC_Conversion is considered to be a partial realization of GeorectifiedGrid:CV_RectifiedGrid, not including the GeorectifiedImage-Grid:CV_Grid. The GeorectifiedImageCRS:SC_DerivedCRS also uses the Grid2dCS:CS_CartesianCS defining the coordinate system of the georectified image.

NOTE The CRS of the georectified image could also be defined as an object of the SC_ImageCRS class. This was not done here because a SC_ImageCRS does not specify (or indicate) the Georectified-GridDefinition:CC_Conversion. That CC_Conversion is required by the Georecitify:WCTS_Transform operation request, as part of the Georectify:CC_ConcatenatedOperation. That SC_ImageCRS object would serve a function similar to the CS_CartesianCS object described below.

The GeoreferenceImage:CC_Transformation contains the coordinate transformation used to georeference the ungeorectified image. This transformation is between the RectificationBase3dCRS:SC_GeographicCRS and the UngeorectifiedImage-CRS:SC_ImageCRS. The GeoreferenceImage:CC_Transformation is considered to be a realization of the UngeorectifiedImage:CV_ReferenceableGrid. Although shown as a CC_Transformation, this georeferencing transformation could be a CC_ConcatenatedOperation that combines multiple CC_Transformations, and may include CC_Conversions.

The RectificationBase3dCRS:SC_GeographicCRS object is the 3D CRS into which that the image is being georectified. Although shown as an object of the SC_GeographicCRS class, it can be a SC_ConcatenatedCRS object that adds a VerticalCRS object to a SC_ProjectedCRS.

The ElevationModel:CC_Transformation represents a coordinate transformation that changes coordinates between the RectificationBase3dCRS:SC_GeographicCRS and the GeorectifiedImage2dCRS:SC_GeographicCRS. This object uses the elevation model which relates these 2D and 3D positions.

The Georectify:CC_ConcatenatedOperation uses the coordinate operations Georectified-GridDefinition:CC_Conversion, ElevationModel:CC_Transformation, and Georeference-

Image:CC_Transformation. Alternately, the GeorectifiedGridDefinition:CC_Conversion might be used directly from the sourceCRS GeorectifiedImageCRS:SC_DerivedCRS.

The sourceCRS and targetCRS roles of CRSs could be reversed if the various CC_Transformation objects could change coordinates in either direction. If these sourceCRS and targetCRS roles are reversed, the usesOperation(1), and usesOperation-(2), and usesOperation(3) roles would also be reversed. The (1), (2), and (3) parts are added to these role names to indicate the order in the Georectify:CC_Concatenated-Operation.

7 Georectified image measurement

7.1 Introduction

This clause describes georectified image measurement, and provides a UML model for such measurement. In this example, feature geometries are measured in a georectified image. These feature geometries are then transformed into the desired coordinate reference system (CRS), by a WCTS Transform operation.

7.2 Georectified image measurement process

A frequently-used georectified image measurement process can be summarized as follows, using current CRS and coverage terms:

a) Select the georectified image to be measured.

b) Obtain the identifications of the CRS of the pixels in this georectified image, and of the georectification base CRS used. This georectification base CRS might be a 2D GeographicCRS.

c) Choose the desired CRS for the features to be extracted from this georectified image. This desired CRS might be a ProjectedCRS using a different GeographicCRS as its baseCRS.

d) Obtain the coordinate Transformation from the georectification base CRS to the desired CRS for the features.

e) Measure the positions of the geometries of one or more features, in the CRS of the pixels in this georectified image, attaching the identification of that CRS as the value of the gml:srsName attribute.

f) Convert the geometries of the measured features, from the CRS of the pixels in the georectified image into the desired CRS for the extracted features, using the WCTS Transform operation and the coordinate Transformation from step d).

g) If needed, return to step e) and measure more features.

NOTE This process expands steps 1) and 2) of the Extract Feature from Image use case in Section 2.1.2.2 of OGC Abstract Specification Topic 15, document 00-115, for georectified image measurement.

This process similarly expands steps 6) and 7) of the “Exploit images and other data” use case in Table A.6 of document 04-052.

7.3 Georectified image measurement simple UML model

A simple UML object diagram for georectified image measurement is shown in Figure 9. In this diagram, the MeasureGeorecifiedImage:ClientOperation object represents the (manual or automated) measurement of features, operating on the inputImage and producing its outputFeatures. The TransformGeorectified:WCTS_Transform object represents a WCTS server converting the coordinates inside the inputFeatures and producing its outputFeatures, using its “transformation”. That transformation will reference the CRSs of the inputFeatures and outputFeatures, not shown in this simple diagram.

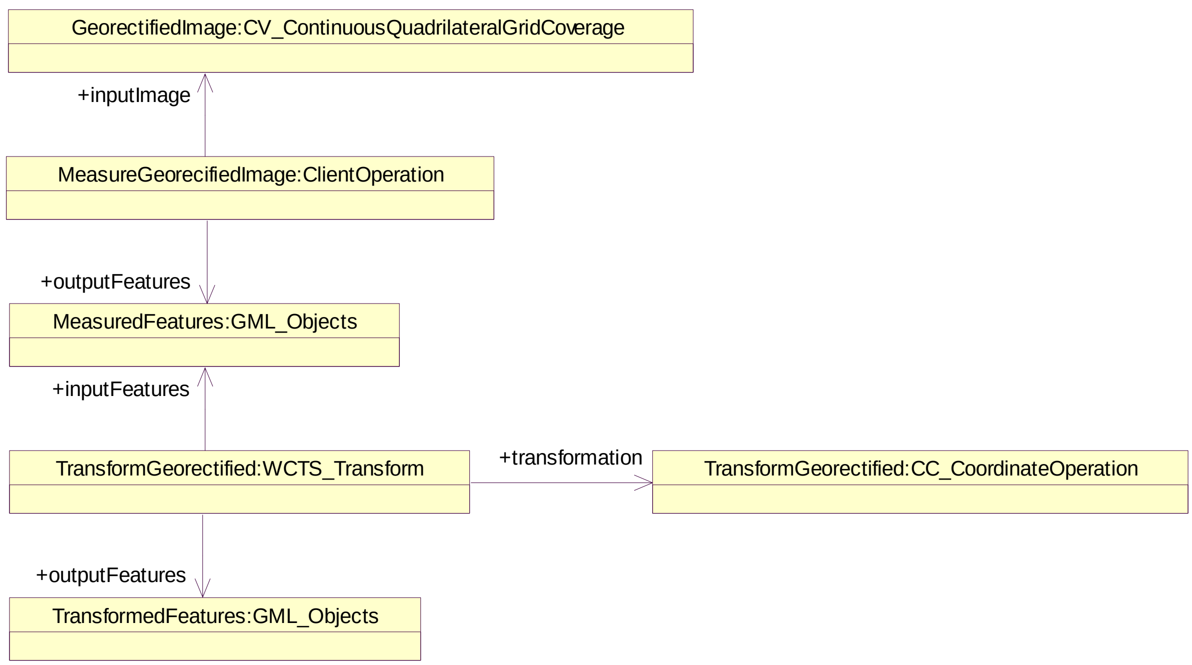

Figure 9 — Georectified image measurement simple UML object diagram

The input information needed to control a WCTS Transform operation is again represented as an object of the CC_CoordinateOperation abstract class, as discussed in Subclause 5.3. The following subclauses thus explore how a concrete subclass of the CC_CoordinateOperation abstract class can be used to control a WCTS Transform operation to transform positions measured in a georectified image coverage.

7.4 Georectified image measurement expanded UML model

An expanded UML object diagram for georectified image measurement is shown in Figure 10. In this diagram, the TransformGeorectified:WCTS_Transform object has been divided into two objects, with the TransformGeorectified:WCTS_TransformedData object representing the Transform operation response, while the Georectify:WCTS_-Transform object represents the Transform operation request. The GeorectifiedImage:-

CV_ContinuousQuadrilateralGridCoverage object has been replaced with three objects using coverage classes (see Figure 1).

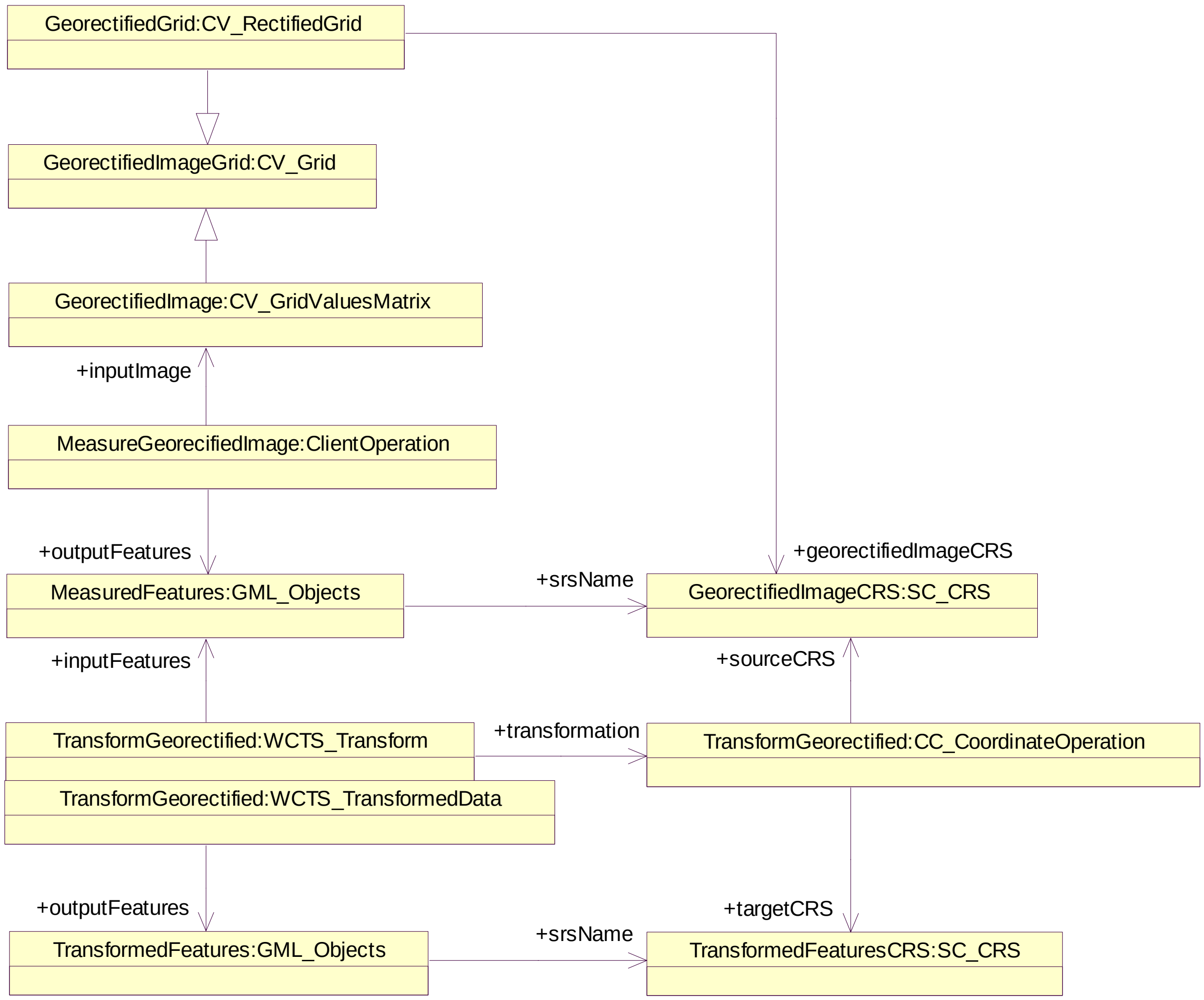

Figure 10 — Georectified image measurement expanded UML object diagram

The MeasuredFeatures:GML_Objects will include a srsName referencing the georectified image CRS, which is shown as the GeorectifiedImageCRS:SC_CRS object, although it uses the abstract SC_CRS class. The outputFeatures will include a srsName referencing the CRS into which feature positions are transformed, which is shown as Transformed-FeaturesCRS:SC_CRS object, although it uses the abstract SC_CRS class. The “transformation” TransformGeorectified:WCTS_Transform references the GeorectifiedImageCRS:SC_CRS and TransformedFeaturesCRS:SC_CRS as shown.

7.5 Georectified image measurement further expanded UML model

A further expanded UML object diagram for georectified image measurement is shown in Figure 11. In this diagram, the TransformGeorectified:CC_CoordinateOperation object has been expanded using objects from more specific classes in the UML model in OGC Abstract Specification Topic 2. This has been done to show one way of specifying how to convert positions measured in a georectified image to positions in the georectification base CRS. The previous TransformGeorectified:CC_CoordinateOperation was changed toGeorectifiedGridDefinition:CC_Conversion.

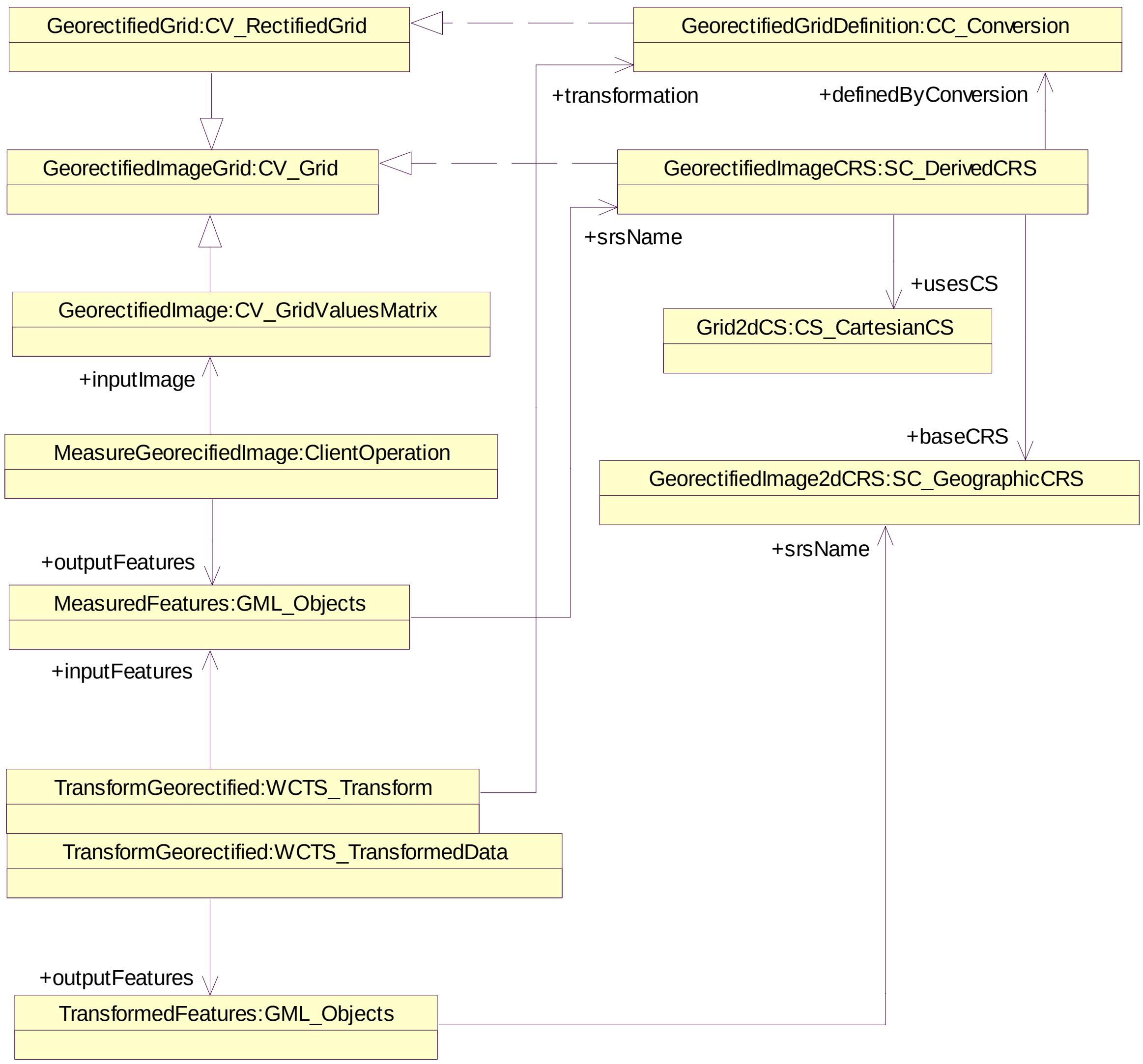

Figure 11 — Georectified image measurement further expanded UML object diagram

In this diagram, the GeorectifiedImageCRS:SC_DerivedCRS object is used to define the CRS of the georectified image as a SC_DerivedCRS. This GeorectifiedImageCRS:-SC_DerivedCRS object is considered to be a partial realization of the GeorectifiedImage-Grid:CV_Grid, not including the two objects that inherit this object. This Georectified-ImageCRS:SC_DerivedCRS specifies the positions of the pixels in the georectified image, including the spacing between pixels and the CRS origin in the baseCRS GeorectifiedImage2dCRS:SC_GeographicCRS. This pixel grid CRS is specified within the GeorectifiedImage2dCRS:SC_GeographicCRS by the GeorectifiedGridDefinition:-CC_Conversion (and is not the same CRS as that GeorectifiedImage2dCRS:SC_-GeographicCRS).

The CRS of the georectified image is defined as a CS_DerivedCRS because that grid is assumed to have been specified in the GeorectifiedImage2dCRS:SC_GeographicCRS, before the corresponding pixels in the GeorectifiedImage:CV_GridValuesMatrix object were produced. This GeorectifiedImageCRS:SC_DerivedCRS uses the GeorectifiedGrid-Definition:CC_Conversion to define the rectified image grid, in the GeorectifiedImage-2dCRS:SC_GeographicCRS baseCRS. Although shown here as an object of the SC_GeographicCRS class, this GeorectifiedImage2dCRS:SC_GeographicCRS could be a SC_ProjectedCRS object. The GeorectifiedGridDefinition:CC_Conversion object is considered to be a partial realization of the GeorectifiedGrid:CV_RectifiedGrid, not including the GeorectifiedImageGrid:CV_Grid.

NOTE The CRS of the georectified image could also be defined as an object of the SC_ImageCRS class. This was not done here because a SC_ImageCRS does not specify (or indicate) the Georectified-GridDefinition:CC_Conversion. That CC_Conversion is required by the TransformGeorecitified:-WCTS_Transform operation request, as part of the TransformGeorecitified:CC_ConcatenatedOperation. That SC_ImageCRS object would serve a function similar to the CS_CartesianCS object described below.

In this diagram, the GeorectifiedImage2dCRS:SC_GeographicCRS defines the CRS referenced by the srsName in the TransformedFeatures:GML_Objects.

7.6 Georectified image measurement complete UML model

A further expanded UML object diagram for georectified image measurement is shown in Figure 12. In this diagram, the TransformGeorectified:CC_CoordinateOperation object has been expanded again using objects from more specific classes in the UML model in OGC Abstract Specification Topic 2. This has been done to show one way of specifying how to convert positions measured in a georectified image to positions in a different desired CRS.

In this diagram, the GeorectifiedImageCRS:SC_DerivedCRS and its associated objects are the same as in the previous diagram.

The TransformedFeatureCRS:SC_ProjectedCRS defines the CRS referenced by the srsName in the TransformedFeatures:GML_Objects. This CRS is shown as using the SC_ProjectedCRS class. A frequently used alternative would use the SC_Geographic-CRS class with 2 dimensions for this object. This ProjectedCRS references or includes the baseCRS ProjectedCRSBase:SC_GeographicCRS, the definedByConversion ProjectedCRSDefinition:CC_Conversion, and the usesCS ProjectedCS:CS_CartesianCS.

In this diagram, we assume that the GeorectifiedImage2dCRS:SC_GeographicCRS is different from the ProjectedCRSBase:SC_GeographicCRS, so the GeographicToGeographic:CC_Transformation is included to specify the transformation between these two SC_GeographicCRSs.

The TransformGeorectified:CC_ConcatenatedOperation uses the coordinate operations GeorectifiedGridDefinition:CC_Conversion, GeographicToGeographic:CC_-Transformation, and ProjectedCRSDefinition:CC_Conversion. Alternately, the GeorectifiedGridDefinition:CC_Conversion might be used as included in the sourceCRS GeorectifiedImageCRS:SC_DerivedCRS.

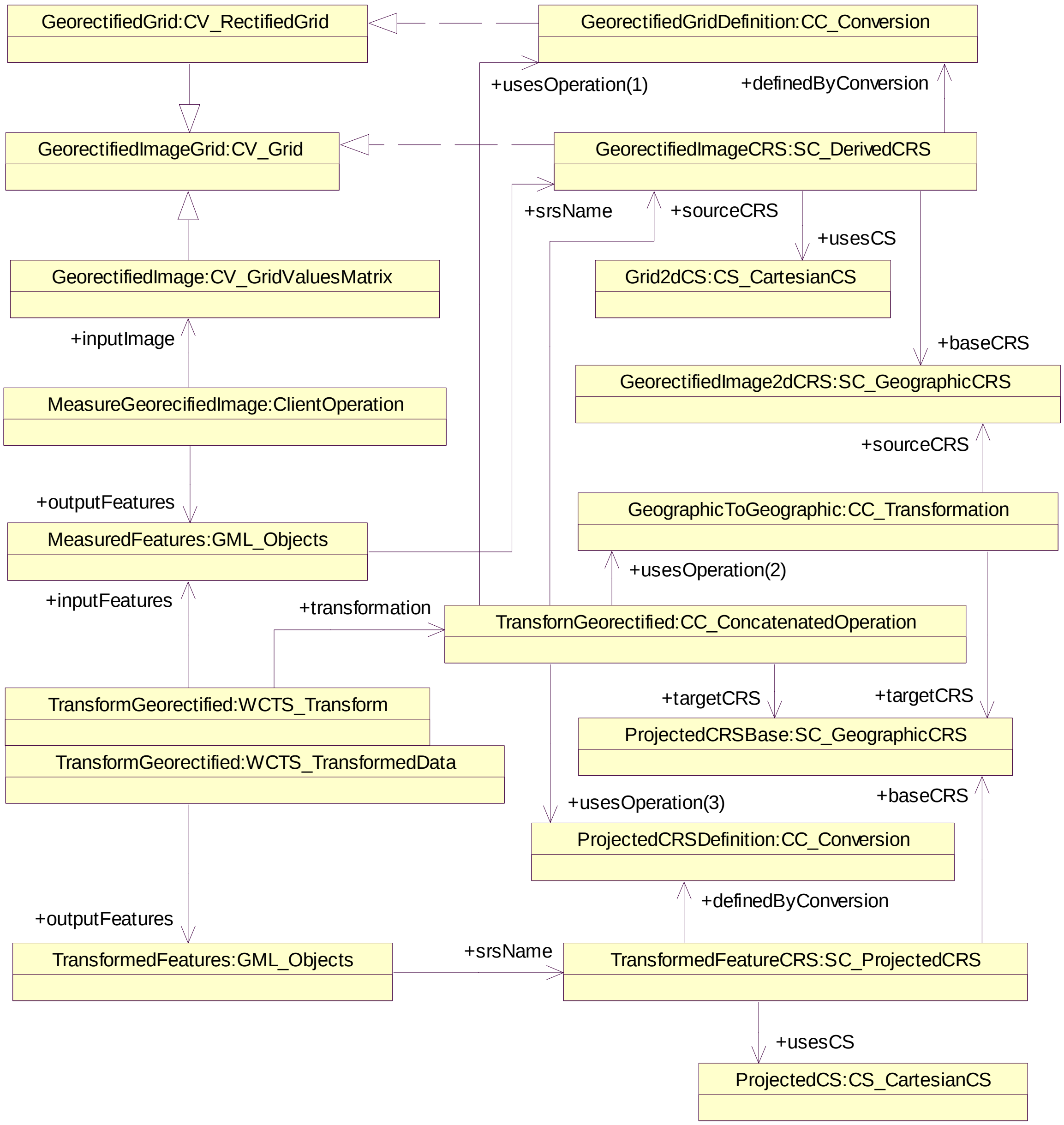

Figure 12 — Georectified image measurement complete UML object diagram

The sourceCRS and targetCRS roles of CRSs could be reversed if the GeographicTo-Geographic:CC_Transformation object could change coordinates in either direction. If these sourceCRS and targetCRS roles are reversed, the usesOperation(1), and usesOperation(2), and usesOperation(3) roles would also be reversed. The (1), (2), and (3) parts are added to these role names to indicate the order in the Georectify:CC_ConcatenatedOperation.

8 Ungeorectified image measurement

8.1 Introduction

This clause describes ungeorectified image measurement, and provides a UML model for such measurement. In this example, feature geometries are measured in an ungeorectified image. These feature geometries are then transformed into the desired coordinate reference system (CRS), by a WCTS Transform operation.

8.2 Ungeorectified image measurement process

A frequently-used ungeorectified image measurement process can be summarized as follows, using current CRS and coverage terms:

a) Select the ungeorectified image to be measured, and determine the ImageCRS to be used for positions in this ungeorectified image.

b) Obtain or determine a georeferencing coordinate Transformation between the ImageCRS of the ungeorectified image and some reference CRS. This Transformation is often from the 3D reference CRS to the 2D ImageCRS. This reference CRS might be a 3D GeographicCRS.

c) Choose the desired CRS for the features to be extracted from this ungeorectified image. This desired CRS might be a ProjectedCRS using a different GeographicCRS as its baseCRS.

d) Obtain the coordinate Transformation from the 3D reference CRS to the desired CRS for the features.

e) Measure the positions of the geometries of one or more features, in the ImageCRS of the pixels in this ungeorectified image, attaching the identification of that ImageCRS as the value of the gml:srsName attribute.

f) Convert the geometries of the measured features, from the ImageCRS of the pixels in the ungeorectified image into the desired CRS for the extracted features, using the WCTS Transform operation and the coordinate Transformations from steps c) and e). If needed, return to step e) and measure more features.

NOTE This process also expands steps 1) and 2) of the “Extract Feature from Image” use case in Section 2.1.2.2 of OGC Abstract Specification Topic 15, document 00-115, for ungeorectified image measurement. This process similarly expands steps 6) and 7) of the “Exploit images and other data” use case in Table A.6 of document 04-052.

8.3 Ungeorectified image measurement simple UML model

A simple UML object diagram for ungeorectified image measurement is shown in Figure 13. In this diagram, the MeasureUngeorecifiedImage:ClientOperation object represents the (manual or automated) measurement of features, operating on the inputImage and producing its outputFeatures. The TransformUngeorectified:WCTS_Transform object represents a WCTS server converting the coordinates inside the inputFeatures and producing its outputFeatures, using its “transformation”. That transformation will reference the CRSs of the inputFeatures and outputFeatures, not shown in this simple diagram

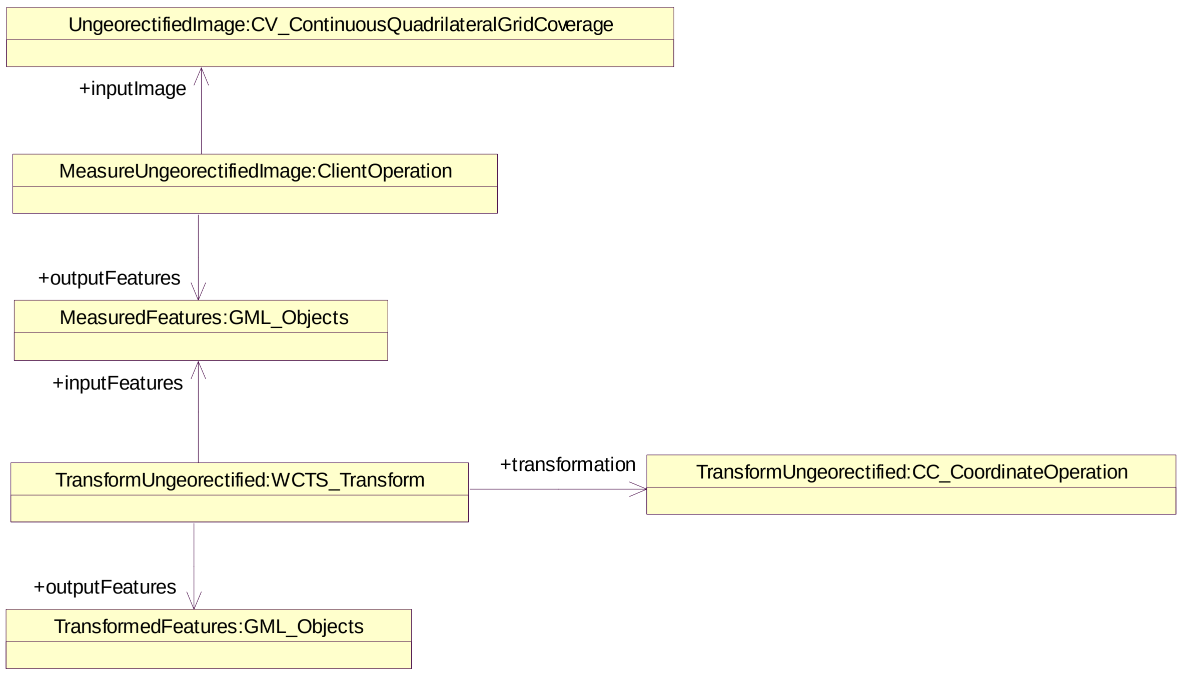

Figure 13 — Ungeorectified image measurement simple UML object diagram

The input information needed to control a WCTS Transform operation is again represented as an object of the CC_CoordinateOperation abstract class, as discussed in Subclause 5.3. The following subclauses thus explore how a concrete subclass of the CC_CoordinateOperation abstract class can be used to control a WCTS Transform operation to transform positions measured in an ungeorectified image coverage.

8.4 Ungeorectified image measurement expanded UML model

An expanded UML object diagram for ungeorectified image measurement is shown in Figure 14. In this diagram, the TransformUngeorectified:WCTS_Transform has been divided into two objects, with TransformUngeorectified:WCTS_TransformedData representing the Transform operation response, while TransformUngeorectified:-WCTS_Transform represents the Transform operation request. The GeorectifiedImage:-CV_ContinuousQuadrilateralGridCoverage object has been replaced with three objects using coverage classes (see Figure 1).

The MeasuredFeatures:GML_Objects will include a srsName referencing the ungeorectified image CRS, which is shown as the UngeorectifiedImageCRS:-SC_ImageCRS. The outputFeatures will include a srsName referencing the CRS into which feature positions are transformed, which is shown as TransformedFeaturesCRS:-SC_CRS object, although it uses the abstract SC_CRS class. The “transformation” TransformUngeorectified:WCTS_Transform object must reference the

UngeorectifiedImageCRS:SC_ImageCRS and TransformedFeaturesCRS:SC_CRS as shown.

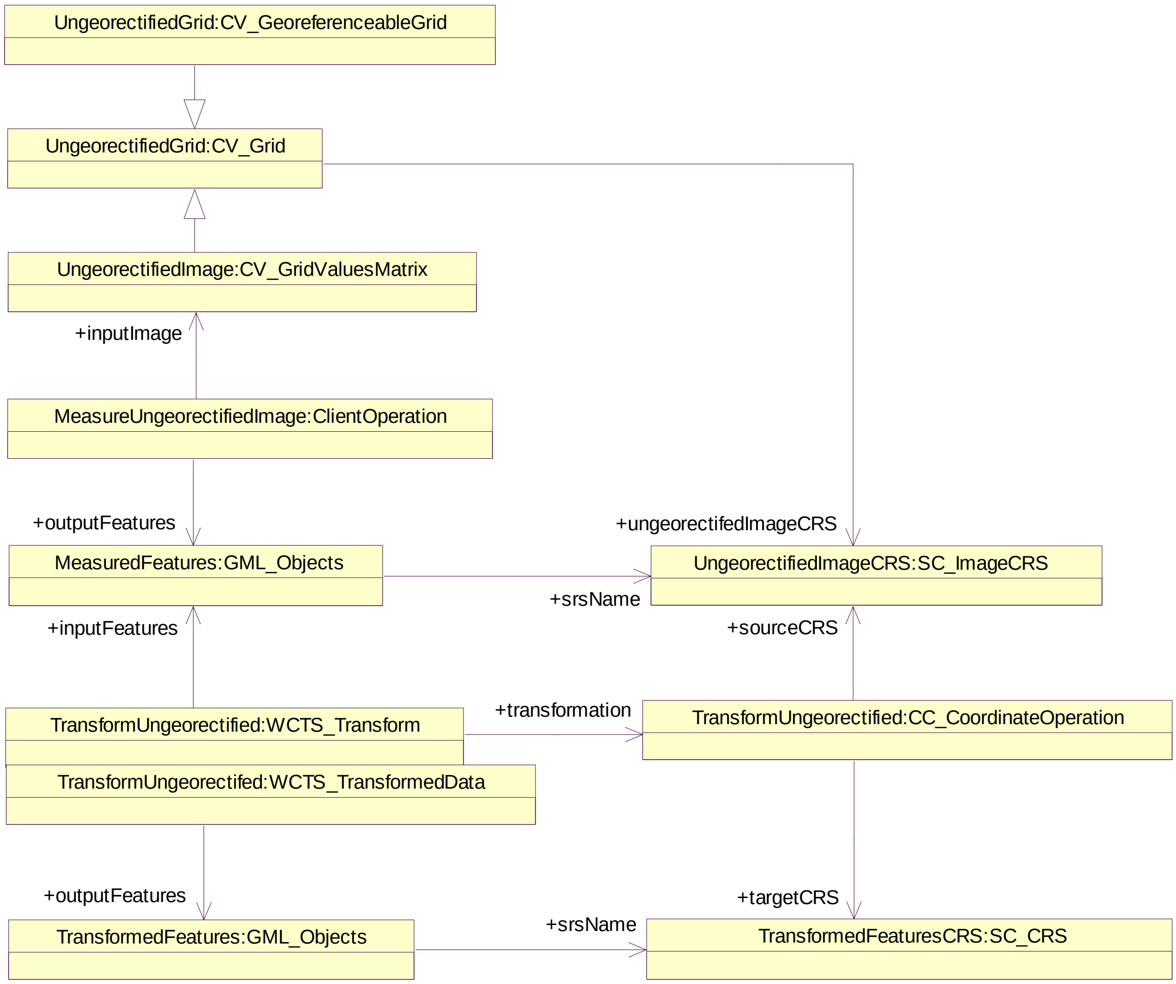

Figure 14 — Ungeorectified image measurement expanded UML object diagram

8.5 Ungeorectified image measurement further expanded UML model

A further expanded UML object diagram for ungeorectified image measurement is shown in Figure 15. In this diagram, the previous TransformUngeorectified:CC_Coordinate-Operation has been expanded using objects from more specific classes in the UML model in OGC Abstract Specification Topic 2. This has been done to show one way of specifying how to convert positions measured in an ungeorectified image. The previous TransformUngeorectified:CC_CoordinateOperation was changed to Transform-Ungeorectified:CC_ConcatenatedOperation.

In this diagram, the UngeorectifiedImageCRS:SC_ImageCRS is used to define the CRS of the ungeorectified image as a SC_ImageCRS. This object is considered to be a partial realization of the UngeorectifedImageGrid:CV_Grid object, not including the two objects that inherit this object.

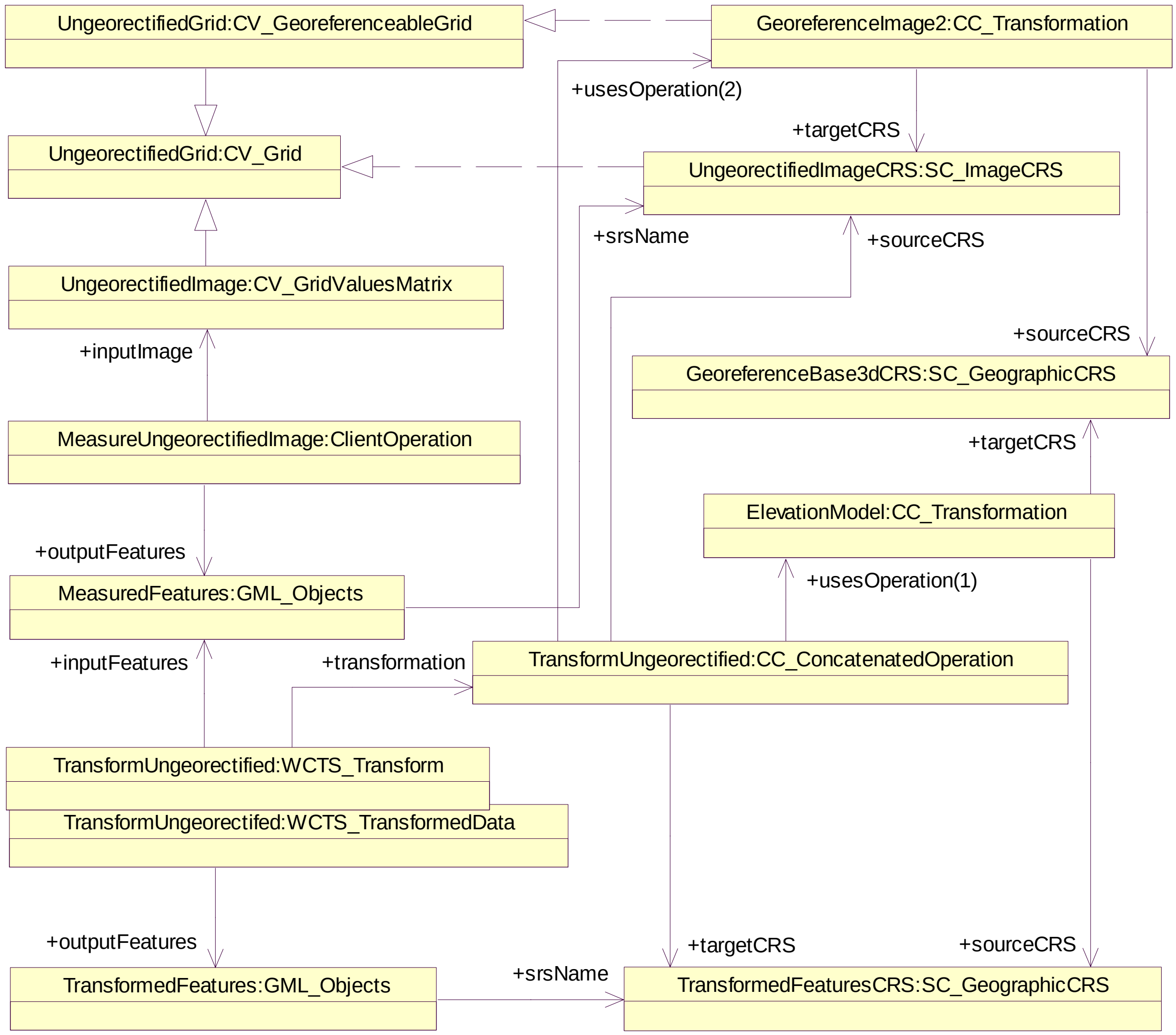

Figure 15 — Ungeorectified image measurement further expanded UML object diagram

The GeoreferenceBase3dCRS:SC_GeographicCRS object is the 3D CRS into which that the image was georeferenced. Although shown as an object of the SC_GeographicCRS class, it can be a SC_CompoundCRS object that adds a VerticalCRS object to a SC_ProjectedCRS.

The GeoreferenceImage:CC_Transformation contains the coordinate transformation used to georeference this ungeorectified image. That transformation is between the GeoreferenceBase3dCRS:SC_GeographicCRS and the UngeorectifiedImageCRS:SC_-ImageCRS. The GeoreferenceImage:CC_Transformation is considered to be a realization of the UngeorectifiedImage:CV_ReferenceableGrid. Although shown as a CC_Transformation, this georeferencing transformation could be a CC_ConcatenatedOperation that combines multiple CC_Transformations, and can include CC_Conversions.

In this diagram, the TransformedFeatureCRS:SC_GeographicCRS object defines the CRS referenced by the srsName in TransformedFeatures:GML_Objects.

The ElevationModel:CC_Transformation represents a coordinate transformation that changes coordinates between the GeoreferenceBase3dCRS:SC_GeographicCRS and the TransformedFeaturesCRS:SC_GeographicCRS. This TransformedFeaturesCRS:SC_GeographicCRS might have 2 or 3 dimensions, where the elevation is ignored in the 2D case. This object uses the elevation model which relates these 2D and 3D positions.

The TransformUngeorectified:CC_ConcatenatedOperation uses the coordinate operations ElevationModel:CC_Transformation and GeoreferenceImage:CC_Transformation. The sourceCRS and targetCRS roles of CRSs could be reversed if these objects could change coordinates in either direction. If these sourceCRS and targetCRS roles are reversed, the usesOperation(1) and usesOperation(2) roles would also be reversed. The (1) and (2) parts are added to these role names to indicate the order in the Georectify:CC_ConcatenatedOperation.

8.6 Ungeorectified image measurement complete UML model

A further expanded UML object diagram for ungeorectified image measurement is shown in Figure 16. In this diagram, the TransformGeorectified:CC_ConcatenatedOperation object has been further expanded using objects from more specific classes in the UML model in OGC Abstract Specification Topic 2. This has been done to show one way of specifying how to convert positions measured in an ungeorectified image into a CRS different that the georeferenced base CRS.

In this diagram, the GeoreferenceBase3dCRS:SC_GeographicCRS and its associated objects are the same as in the previous diagram.

In this diagram, the TransformedFeatureCRS:SC_ProjectedCRS defines the CRS referenced by the srsName in the TransformedFeatures:GML_Objects. This CRS is shown as using the SC_ProjectedCRS class. A frequently used alternative would use the SC_GeographicCRS class with 2 dimensions for this object. This ProjectedCRS references or includes the baseCRS ProjectedCRSBase:SC_GeographicCRS, the definedByConversion ProjectedCRSDefinition:CC_Conversion, and the usesCS ProjectedCS:CS_CartesianCS.

In this diagram, we assume that the GeorectifiedImage2dCRS:SC_GeographicCRS is different from the ProjectedCRSBase:SC_GeographicCRS, so the GeographicTo-Geographic:CC_Transformation is included to specify the transformation between these two SC_GeographicCRSs.

The TransformUngeorectified:CC_ConcatenatedOperation uses the coordinate operations GeoreferenceImage:CC_Transformation, ElevationModel:CC_Transformation, GeographicToGeographic:CC_Transformation, and ProjectedCRSDefinition:-CC_Conversion. Alternately, the ProjectedCRSDefinition:CC_Conversion might be treated as being included in the targetCRS TransformedFeaturesCRS:SC_ProjectedCRS.

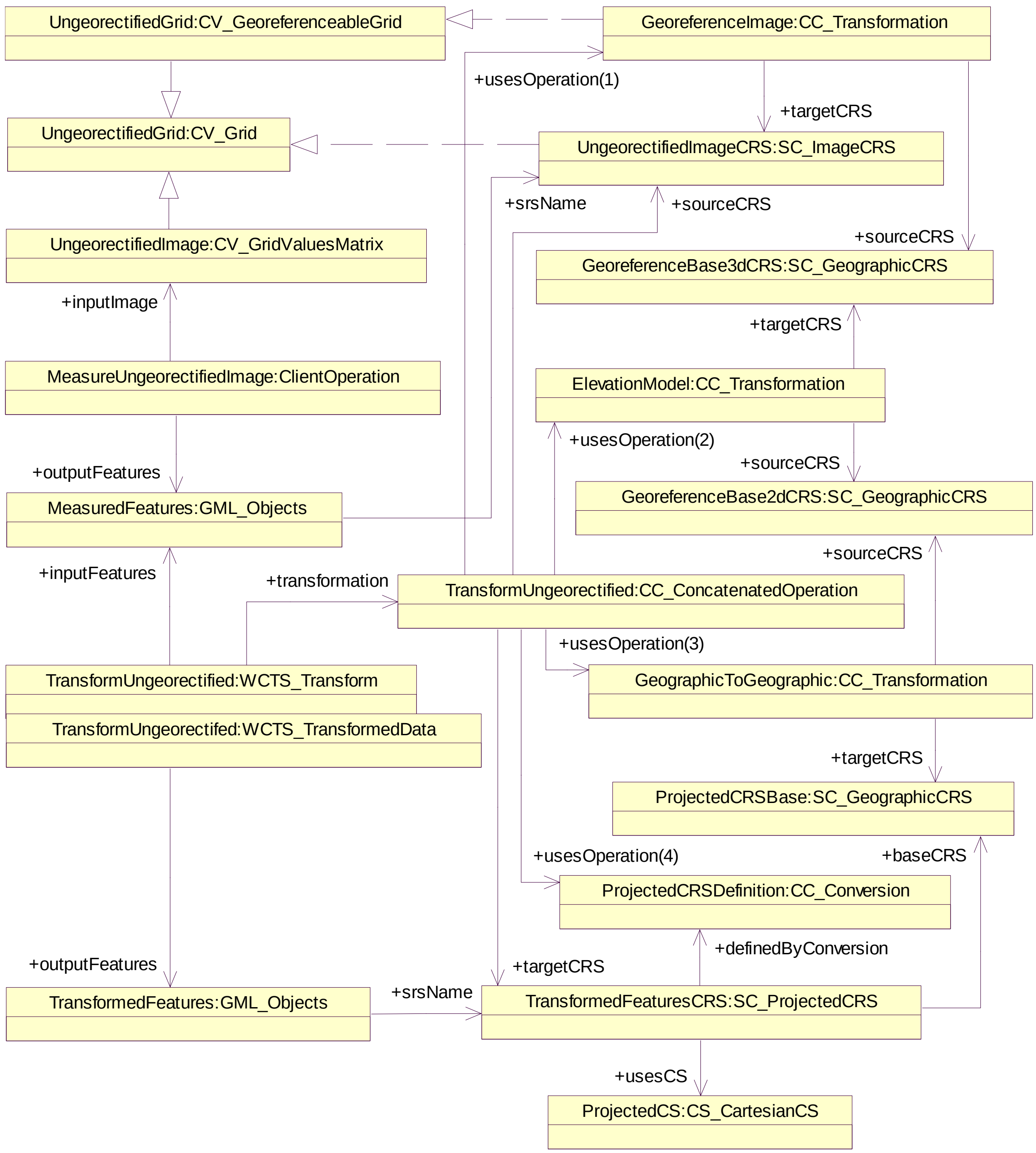

Figure 16 — Ungeorectified image measurement complete UML object diagram

The sourceCRS and targetCRS roles of various CRSs could be reversed if the CC_Transformation objects could change coordinates in either direction. If these sourceCRS and targetCRS roles are reversed, the usesOperation(1), and usesOperation(2), usesOperation(3), and usesOperation(4) roles would also be reversed. The (1), (2), (3), and (3) parts are added to these role names to indicate the order in the Georectify:CC_ConcatenatedOperation.

9 Image CRS definition templates

The attached XML file, named imageCRSDictionary.xml, contains image CRS definition templates for three image CRS definitions. These templates are all contained in a gml:Dictionary element that also includes XML encoded definitions of all the components used by those templates. Most elements contain description or remarks elements that try to define the meaning and use of that element.

AUTHOR'S NOTE The two templates for unrectified image CRSs have now been updated and included in Recommendation Paper 05-012 "Recommended XML/GML 3.1.1 encoding of image CRS definitions".

These templates are designed to be specialized to produce an XML-encoded definition of the image CRS for each image. That specialization often includes inserting the identification of that specific image. Each specific image file is associated with a specific image CRS.

The same georectified image DerivedCRS can be used for multiple images which are georectified into the same DerivedCRS (e.g., in preparation for mosaicking). In general, a different image CRS is required for each ungeorectified image, so that this image CRS can be referenced by different georeferencing transformations for different images, thus distinguishing those transformations. However, there are some cases where the same image CRS can be used for multiple ungeorectified images. For example, multiple images taken by the same camera from the same location with the same orientation could use the same image CRS.

An alternative to these image CRS templates would be preparation and use of a GML Application Schema that defines XML elements specific to each type of image CRS. Each specific element would have a name specific to that type of image CRS, and would contain fixed values for all contents items that do not depend on a specific image. For example, a GeorectifiedGridCRS element would be defined, which always contained a reference to the Grid2dCS CartesianCS.

Each specific image file is expected to be associated with a specific image CRS definition, in order to exploit that image using a coordinate operation (Transformation or Conversion). Such a coordinate operation can be used by a WCTS as described in Clauses 6-8.

These image CRSs could be defined before or after the corresponding image file is recorded. If defined after the corresponding image file is recorded, that definition must match the corresponding image file already recorded. If defined before the corresponding image file is recorded, that definition must be used to record an image file which conforms to that definition.

AUTHOR'S NOTE Wenli Yang prefers to think that the image CRS would be defined before the corresponding image file is recorded, that definition would then be used to record an image file which conforms to that definition.

The same "Grid2dSquareCS" CartesianCRS is currently used by all three of these templates, and is defined to be independent of certain terms sometimes used for a grid or array of data. Those terms include left/right, top/bottom, and up/down. There are four possible origin positions using such terms:

a) Origin at UpperLeft – First row is top row in grid, and row direction points from top to bottom. First column is the leftmost column in grid, and column direction points from left to right.

b) Origin at UpperRight – First row is top row in grid, and row direction points from top to bottom. First column is the rightmost column in image array grid, and direction points from right left.

c) Origin at LowerLeft – First row is bottom row in grid, and row direction points from bottom to top. First column is the leftmost column in grid, and column direction points from left to right.

d) Origin at LowerRight – First row is bottom row in grid, and row direction points from bottom to top. First column is the rightmost column in grid, and column direction points from right to left.

AUTHOR’S NOTE Wenli Yang suggested using these origin positions and terms in the image CRS definitions.

Using these terms to define the origin of a grid is possible, but seems to require definition of a different CartesianCS for each of the four cases listed above. Four different CartesianCS definitions would require defining four different templates corresponding to each of the three templates now defined. Such multiple XML elements are not included in the attached imageCRSDictionary.xml due to lack of the resources needed to produce these multiple elements. In addition, the net benefits of using such multiple XML elements are not clear to the author.

Bibliography

[1] Guidelines for Successful OGC Interface Specifications, OGC document 00-014r1