Open Geospatial Consortium Inc.

Date: 2009-10-13

Reference number of this document: OGC 09-085r2

Version: 0.3.2

Category: OGC Public Discussion Paper

Editor: Arliss Whiteside

Grid coverage Coordinate Reference Systems (CRSs)

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Document type:	Candidate OpenGIS® Discussion Paper
Document subtype:	NA
Document stage:	Proposed new Discussion Paper
Document language:	English

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1. Introduction

This document summarizes the types of Coordinate Reference Systems (CRSs) that are recommended for use with grid (including image) coverages. This document specializes Best Practice Paper OGC 09-076r3 "Uses and Summary of Topic 2: Spatial referencing by coordinates" for grid coverages. Topic 2 is almost the same as ISO 19111:2007, but includes some corrections. This document includes some best practices for defining and using ImageCRSs and other CRSs for grid coverages.

Abstract Specification Topic 2 specifies the concepts, definitions, and data model of a coordinate reference system (CRS) and its various parts. A CRS definition provides the meaning of position coordinates using that CRS, and includes an identifier and a somewhat detailed description of that CRS. A CRS is essential (meta) data for sharing most geospatial data, in which spatial positions are represented by coordinates. This subject is discussed in proposed Best Practice Paper OGC 09-076r3.

Readers of this document are encouraged to reference the UML diagrams in Topic 2 (OGC 08-015), especially Figures 2, 3, 6, 7, 9, 11, and 12. They are also encouraged to

reference the terms and definitions in Clause 4 of Topic 2, and reorganized in Clause 7 of OGC 09-076r3.

2. Coordinate Reference System (CRS) definition

A Coordinate Reference System (CRS) as specified in Topic 2, with some of the best practices defined in OGC 09-076r3, can be summarized:

a) A CRS specifies the meaning for point position coordinates.

NOTE Without a CRS, point position coordinates are essentially meaningless.

b) A CRS relates a coordinate system to a specific object by a datum.

NOTE The specific object is often a physical object, such as the earth or a specific moving platform. However, the object may be a specific image or other grid coverage.

c) A CRS definition combines a coordinate system (CS) with a datum, and includes identifiers for that CRS, CS, datum, and each coordinate axes in that CS.

NOTE One CS will often be used with many different datums. One datum may be used with several different CSs.

d) The location of the origin of the datum should be an identified point on some identified object, where an image or other grid coverage is considered such an object. [Best Practice]

NOTE A datum may identify the location of the origin by means other than identifying the origin point. For example, a GeodeticDatum often identifies the location of the origin by specifying the geographic coordinates of an identified “fundamental point”.

e) A datum also (often implicitly) identifies one or more sets of orientation directions that are referenced by the coordinate axes in that CS.

NOTE This interpretation of a datum is not always fully understood. If a datum identifies more than one alternate set of orientation directions, as a geodetic datum does, the type of the associated CS selects the proper set of datum orientation directions.

f) A coordinate system (CS) specifies an ordered sequence of the position coordinate axes in that CS. The specified axes and axis order **shall** be used when recording coordinate values (or ordinates) in recorded coordinate tuples.

g) Each coordinate axis specifies the name(s) of that axis (or ordinate), the axis direction, and the units that **shall** be used for recording positions along that axis.

h) Each axis direction (informally) references a direction in the orientation of the datum with which this CS is used by a CRS. [Best Practice]

NOTE This meaning of the axis direction is not explicitly stated in Topic 2, and thus not always understood. The purpose of the axis direction is to prevent ambiguity in associating the axes of a coordinate system with the directions defined by the datum. However, the exact direction of a coordinate axis can never be defined in absolute terms, since absolute directions do not exist.

i) Topic 2 specifies 7 concrete types of CRS, namely GeodeticCRS, VerticalCRS, ImageCRS, EngineeringCRS, ProjectedCRS, DerivedCRS, and CompoundCRS.

j) Topic 2 specifies 4 concrete types of datum, namely GeodeticDatum, VerticalDatum, ImageDatum, and EngineeringDatum.

k) Topic 2 specifies 9 concrete types of CS, namely EllipsoidalCS, CartesianCS, VerticalCS, LinearCS, CylindricalCS, PolarCS, AffineCS, and UserDefinedCS.

NOTE The LinearCS, CylindricalCS, PolarCS, AffineCS, and UserDefinedCS are rarely used.

3. CartesianCS definition for a grid

All three types of CRS useful for direct positions in grid coverage domains can and should use a CartesianCS (Cartesian Coordinate System), as discussed in the following clauses. A CartesianCS as specified in Topic 2 can be summarized:

a) A CartesianCS specifies an ordered sequence of position coordinate axes in that CS, where the specified axis order **shall** be used when recording coordinate values.

NOTE Spatial axes in a CartesianCS must be mutually perpendicular. [Best Practice]

b) The units of all axes of a CartesianCS for a grid domain should be grid spacings, with the grid points having integer coordinate values and fractional ("real" or xsd:Double) values being allowed. [Best Practice]

NOTE Fractional values are required for continuous grid coverages, where values at positions between grid points are interpolatable.

c) A CartesianCS can and should specify multiple names for each coordinate axis, allowing different axes names to be used with the same CS. [Best Practice]

NOTE A CartesianCS does NOT specify whether this coordinate system is right or left handed. [Best Practice]

d) All 2D grid CRSs can and should use the same 2D CartesianCS. [Best Practice]

NOTE Different CartesianCSs are required for different numbers of coordinate axes.

4. ImageCRS definition

As specified in OGC Abstract Specification Topic 7, a (geographic) image is a gridded coverage whose range values quantitatively describe physical phenomena. (The physical parameters are the result of measurement by a sensor or a prediction from a model.) A grid coverage can have any number of dimensions, including a time dimension, but often has two spatial dimensions (as largely assumed in OGC Abstract Specification Topic 6 "Schema for coverage geometry and functions").

An ImageCRS as specified in Topic 2 can be summarized:

a) An ImageCRS specifies the meaning for point position coordinates in an image.

b) An original image should have only one ImageCRS. [Best Practice]

c) An ImageCRS combines a Cartesian coordinate system (CartesianCS) with an ImageDatum, including identifiers for that CRS, CS, datum, and each coordinate axes in that CS.

NOTE The same CartesianCS should be used by all ImageCRSs with the same number of axes. Topic 2 also allows an ImageCRS to use an AffineCS. However, this document recommends always using a Cartesian CS. [Best Practice]

d) An ImageDatum identifies the location of the origin of the CartesianCS, plus a set of orientation directions that are referenced by the coordinate axes in that CartesianCS.

NOTE An ImageDatum specifies whether the associated CartesianCS is right or left handed. [Best Practice]

e) The location of the origin of an ImageDatum should be an identified position in a specific rectangular array of grid coverage range (or pixel) values. [Best Practice]

NOTE Because different origins are needed by different images, the ImageDatum and ImageCRS must be different for each image. [Best Practice]

f) The location of the origin of the ImageDatum **shall** be identified by the anchorDefinition parameter, which **shall** be included in the ImageDatum definition. [Best Practice]

NOTE Although the anchorDefinition is optional in Topic 2, it must be included in an ImageDatum. The anchorDefinition was previously called the anchorPoint, in GML 3.1.1 and ISO 19111:2003.

g) The location of the origin of the ImageDatum should be the grid point in a corner of the rectangular array of pixel values, at the center of a pixel. [Best Practice]

NOTE As stated in Clause B.3.5 of Topic 2, the anchorDefinition pixel is usually either the centre or a corner of the image. This document recommends that the origin be a corner of the rectangular array. Notice that the anchorDefinition is different from the pixelInCell, which specifies whether the origin is centered on a pixel or is halfway between pixel centers. This document recommends that the origin always be centered on a corner pixel

h) The location of the origin of the ImageDatum should be the lower-indices-corner of the rectangular array of pixel values, as those grid position indices are specified in the image-recording format being used. [Best Practice]

NOTE This lower-indices-corner has no standardized relationship to how the digital image should be displayed or printed. Most image recording formats specify where this lower-indices-corner should be displayed, usually at the upper left corner or lower left corner of the display.

i) The anchorDefinition in the definition of an ImageDatum also implicitly defines an "orientation" set of directions in the image object, which are parallel to the image pixel columns and rows, in the directions of increasing indices. The CS axes are then defined to be in the directions of these implicit ImageDatum orientation directions. [Best Practice]

j) The first axis identified by the image-recording format should be used by the first axis specified of the CS, and the second identified axis should be used by the second axis of the CS. [Best Practice]

5. EngineeringCRS definition for a grid

Topic 2 states that an Image CRS is a specialization of an EngineeringCRS, and thus has a similar definition. An EngineeringCRS can be used for a variety of purposes, including for a grid coverage that is not an image. (An EngineeringCRS can also be used for other purposes.) An EngineeringCRS as specified in Topic 2 when used for a grid coverage that is not an image can be summarized:

a) An EngineeringCRS for a grid coverage specifies the meaning for point position coordinates in that grid coverage domain.

b) An EngineeringCRS for a grid coverage combines a Cartesian coordinate system (CartesianCS) with an EngineeringDatum, and includes identifiers for that CRS, CS, datum, and each coordinate axes in that CS.

NOTE Topic 2 also allows an EngineeringCRS to use any type of coordinate system, with any number of axes. However, an EngineeringCRS most frequently uses a 3D, 2D, or 1D CartesianCS. The same CartesianCS should be used by all EngineeringCRSs with the same number of axes. [Best Practice]

c) An EngineeringDatum for a grid coverage identifies the location of the origin of the CartesianCS, plus a set of orientation directions that are referenced by the coordinate axes in that CartesianCS.

NOTE Because different origins are needed by different objects, the EngineeringDatum and EngineeringCRS will often be different for each grid coverage.

d) The location of the origin of the EngineeringDatum **shall** be identified by the anchorDefinition parameter, which **shall** be included in the EngineeringDatum definition. [Best Practice]

NOTE Although the anchorDefinition is optional in Topic 2, it must be included in an EngineeringDatum. The anchorDefinition was previously called the anchorPoint, in GML 3.1.1 and ISO 19111:2003.

e) The location of the origin of the EngineeringDatum for grid coverages may be any point in the rectangular array of coverage range values, or may be a point outside the array of positions where coverage values exist. [Best Practice]

NOTE An EngineeringDatum for grid coverages specifies whether the associated CartesianCS is right or left handed. [Best Practice]

f) The anchorDefinition in the definition of an EngineeringDatum for grid coverages also (often implicitly) defines an "orientation" set of directions in the grid coverage, which are parallel to the grid coverage position rows and columns, in the directions of increasing indices. The CS axes are then defined to be parallel to these (implicit) EngineeringDatum orientation directions. [Best Practice]

g) If used for grid data recorded in an image-recording format, the first axis identified by the image-recording format should be used by the first specified axis of the CS, and the second identified axis should be used by the second axis of the CS. [Best Practice]

6. DerivedCRS definition for a grid

A DerivedCRS inherits its datum from its baseCRS, and changes the CS using a coordinate Conversion between the original and new CRSs. A DerivedCRS is thus very useful for a grid coverage whose point locations are defined in another CRS, especially a georectified grid coverage whose locations are specified as regularly spaced in a GeodeticCRS or ProjectedCRS. That rectified grid coverage may be a rectified image, or a grid coverage that is not an image.

A DerivedCRS may also be used by a modified version of an original image that is not georectified. Such a modified image may be a subset of the original image and/or have a modified pixel spacing. Such a modified image may also be (affine) rectified, but not georectified.

A DerivedCRS as specified in Topic 2 when used for a grid coverage can be summarized:

a) A DerivedCRS for a grid coverage specifies the meaning for point position coordinates in that grid coverage domain.

b) A DerivedCRS for a grid coverage combines a Cartesian coordinate system (CartesianCS), a baseCRS, and a coordinate Conversion, and includes unique identifiers for that CRS, Conversion, baseCRS, CS, and each coordinate axes in that CS.

c) The CartesianCS of a DerivedCRS for a grid coverage defines the coordinate system of that DerivedCRS.

NOTE The same CartesianCS should be used by all DerivedCRSs for grid coverages with the same number of axes. [Best Practice]

d) The baseCRS of a DerivedCRS supplies a datum and a base coordinate system (CS).

e) The coordinate Conversion of a DerivedCRS converts positions in the CS of the baseCRS into positions in the CartesianCS of that DerivedCRS.

7. ImageCRS uses

An ImageCRS is primarily useful for an unrectified image. For a rectified image, a DerivedCRS can be used to represent the pixel positions in the CRS into which the image was rectified, referenced by the baseCRS in the definition of the DerivedCRS. Although an ImageCRS exists for a rectified image, the definition of that ImageCRS contains less information than the definition of the DerivedCRS. This document thus recommends that a DerivedCRS be used for a rectified image, and not an ImageCRS.

NOTE This document assumes that a rectified image is still considered to be an image, as would be collected by a "perfect" image sensor or camera.

The ImageCRS for an unrectified image is useful whether that image is georeferenced or not. For an unrectified image that is not georeferenced, the ImageCRS may be its only CRS. For an unrectified image that is georeferenced, the ImageCRS is the target CRS of each geopositioning (or georeferencing) coordinate Transformation for that image. (A georeferenced image has one or more geopositioning coordinate Transformations. Multiple Transformations may have different source CRSs and/or different error statistics.)

In addition, a DerivedCRS for a grid may be used for an unrectified but (possibly) modified image. Such modifications of an original image include extraction of a section (or tile) from a larger image, and resampling into a different pixel spacing. Such a DerivedCRS will have the ImageCRS of the original complete image as its baseCRS.

An ImageCRS might be used for a grid coverage that is unrectified and not an image (whose range values do NOT quantitatively describe physical phenomena). This unrectified grid coverage will have grid point positions like an unrectified image, which are not evenly spaced in any geodetic or projected CRS.

EXAMPLE An example of a non-image unrectified grid coverage is a multi-spectral image whose pixels have been automatically classified into categories. Those classifications may have been later "improved" is some manner, including using a coarser grid and manual editing.

Use of an ImageCRS in this way was not intended by the authors of Topic 2, and could be considered a non-compliant use. However, all parts of an ImageCRS definition except the names ImageCRS and ImageDatum seem appropriate for such use. Topic 2 thus might be extended to change the ImageCRS and ImageDatum names to GridCRS and GridDatum, or to allow these alternative names.

8. CRSs for grid coverages

CRS definitions are needed for sharing all types of geospatial data, including grid coverages. However, Topic 6 "Schema for coverage geometry and functions" does not currently clearly indicate that CRS identifiers for grid point positions shall be encoded, or what type(s) of CRSs should be referenced. Nevertheless, gml:Grid should reference the CRS for that geometry, since it is encoded using the gml:AbstractGeometryType (which includes the gml:SRSInformationGroup). [Best Practice]

In addition, Topic 2 does not clearly indicate which types of CRSs can or should be used for the grid point positions in grid coverages. Furthermore, there are at least four different types of grid coverages, with somewhat differing CRS definition requirements. A grid coverage can be either (geo)rectified or unrectified. An unrectified grid coverage can be either an image or not an image. Furthermore, the grid points in a (geo)rectified grid coverage can be either equally-spaced or unevenly-spaced in the CRS into which the coverage was rectified. The following paragraphs discuss the types of CRSs specified in Topic 2 that should be used for different types of grid coverages.

NOTE 1 Topic 6 distinguishes between rectified and referenceable grids. We interpret Topic 6 to mean that a referenceable grid is NOT (geo) rectified, but is one for which a referencing coordinate Transformation is known and supplied. In general, an unrectified but referenceable grid coverage may be referenced or not. Furthermore, an unrectified but referenceable grid coverage may be referenced multiple times, to different CRSs and/or with different error statistics.

A **(geo)rectified coverage** should use a DerivedCRS with a baseCRS that is the CRS into which that coverage was rectified into a regularly-spaced grid. [Best Practice] For a georectified coverage, that baseCRS may be a GeodeticCRS or ProjectedCRS. [Best Practice] Alternately, a (geo)rectified coverage could use an EngineeringCRS as the CRS of grid point positions. However, use of an EngineeringCRS requires use of a coordinate Transformation to capture the relationship between positions in the CRS of that grid and positions in the other CRS into which that coverage has been rectified.

NOTE 2 A rectified grid coverage has grid points equally spaced in its baseCRS, like CV_RectifiedGrid in Topic 6 and gml:RectifiedGrid. An irregular grid coverage as proposed in GML Change Request 07-112 has grid points unevenly spaced in the CRS into which the coverage was rectified, and is considered different from a gml:RectifiedGrid. This is here considered to be an "irregular grid coverage".

An **irregular grid coverage** should use a DerivedCRS with a baseCRS that is the CRS in which the irregular grid point positions are defined. [Best Practice] That baseCRS may be a GeodeticCRS or ProjectedCRS. [Best Practice] Alternately, an irregular grid coverage could use an EngineeringCRS as the CRS of the irregularly spaced grid point positions. This coverage could then use a coordinate Transformation to capture the corresponding irregular grid point positions in another CRS, such as in a GeodeticCRS or ProjectedCRS.

An **unrectified original image** may use an ImageCRS, with regularly-spaced grid points. In this use, each unique image must have a unique ImageDatum that references this unique image, and thus must have a unique ImageCRS. [Best Practice] Better, an unrectified but possibly modified image should use a DerivedCRS with a baseCRS that is an ImageCRS. Using such a DerivedCRS is useful to allow multiple unrectified images derived from the same original image (e.g., by subsetting or subsampling) to references the same ImageCRS for the original image. The original image then uses an identity coordinate Conversion in its DerivedCRS.

An **unrectified grid coverage** that is not an image should use an EngineeringCRS as the CRS of grid point positions. [Best Practice] Such an unrectified grid coverage is assumed to have regularly-spaced grid points in that EngineeringCRS. Better, the ImageCRS should be renamed or re-interpreted for this use.

9. Planned Abstract Specification Topic 19

The CRS WG has started to develop a new Topic 19 of the OGC Abstract Specification. That Topic 19 will extend Topic 2 for more general reference systems. That new Topic 19 (tentatively) will also redefine the current ImageCRS and ImageDatum for use by all grid coverages, re-naming them GridCRS and GridDatum. That GridCRS should then be used for all grids, no longer using an EngineeringCRS for a grid. That new Topic 19 (tentatively) will also define a new "RectifiedGridCRS" subclass of DerivedCRS that should be used instead of a DerivedCRS as recommended above.

10. References

[1] OGC 08-015, The OpenGIS® Abstract Specification Topic 2: Spatial referencing by coordinates

[2] OGC 08-010r1, Topic 2 change request - Correct grid cell terms"

[3] OGC 08-089r3, Topic 2 change request - Correct inconsistencies "

[4] OGC 08-149, Topic 2 change request - Change associations to GeneralParameterValue"

NOTE The three Topic 2 change requests listed above were accepted by the OGC Technical Committee in their September 2008 meeting.

[5] OGC 09-076r3, Uses and Summary of Topic 2: Spatial referencing by coordinates

[6] OGC 07-011, The OpenGIS® Abstract Specification Topic 6: Schema for coverage geometry and functions

[7] OGC 07-036, Geography Markup Language (GML), version 3.2.1

[8] OGC 06-121r7, OGC Web Services Common, version 1.2

[9] OGC 04-107, The OpenGIS® Abstract Specification Topic 7: The Earth Imagery Case

