INTERNATIONAL STANDARD

ISO 19111

Second edition
2007-07-01

Geographic information — Spatial referencing by coordinates

Information géographique — Système de références spatiales par coordonnées

Reference number
ISO 19111:2007(E)

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

Published in Switzerland

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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

ISO 19111 was prepared by Technical Committee ISO/TC 211, *Geographic information/Geomatics*, in close collaboration with the Open Geospatial Consortium (OGC).

This second edition cancels and replaces the first edition (ISO 19111:2003), which has been technically revised.

Introduction

Geographic information contains spatial references which relate the features represented in the data to positions in the real world. Spatial references fall into two categories:

— those using coordinates;

— those based on geographic identifiers.

Spatial referencing by geographic identifiers is defined in ISO 19112 [4]. This International Standard describes the data elements, relationships and associated metadata required for spatial referencing by coordinates. It describes the elements that are necessary to fully define various types of coordinate systems and coordinate reference systems applicable to geographic information. The subset of elements required is partially dependent upon the type of coordinates. This International Standard also includes optional fields to allow for the inclusion of non-essential coordinate reference system information. The elements are intended to be both machine and human readable.

The traditional separation of horizontal and vertical position has resulted in coordinate reference systems that are horizontal (2D) and vertical (1D) in nature, as opposed to truly three-dimensional. It is established practice to define a three-dimensional position by combining the horizontal coordinates of a point with a height or depth from a different coordinate reference system. In this International Standard, this concept is defined as a compound coordinate reference system.

The concept of coordinates can be expanded from a strictly spatial context to include time. ISO 19108 describes temporal schema. Time can be added as a temporal coordinate reference system within a compound coordinate reference system. It is even possible to add two time-coordinates, provided the two coordinates describe different independent quantities.

EXAMPLE An example is the time/space position of a subsurface point of which the vertical coordinate is expressed as the two-way travel time of a sound signal in milliseconds, as is common in seismic imaging. A second time-coordinate indicates the time of observation, usually expressed in whole years.

Certain scientific communities use three-dimensional systems where horizontal position is combined with a non-spatial parameter. In these communities, the parameter is considered to be a third, vertical axis. The parameter, although varying monotonically with elevation or depth, does not necessarily vary in a simple manner; thus, conversion from the parameter to height or depth is non-trivial. The parameters concerned are normally absolute measurements and the datum is taken with reference to a direct physical measurement of the parameter. These non-spatial parameters are beyond the scope of this International Standard. However, the modelling constructs described within this International Standard can be applied through a profile specific to a community.

In addition to describing a coordinate reference system, this International Standard provides for the description of a coordinate transformation or a coordinate conversion between two different coordinate reference systems. With such information, spatial data referred to different coordinate reference systems can be related to one specified coordinate reference system. This facilitates spatial data integration. Alternatively, an audit trail of coordinate reference system manipulations can be maintained.

Geographic information — Spatial referencing by coordinates

1 Scope

This International Standard defines the conceptual schema for the description of spatial referencing by coordinates, optionally extended to spatio-temporal referencing. It describes the minimum data required to define one-, two- and three-dimensional spatial coordinate reference systems with an extension to merged spatial-temporal reference systems. It allows additional descriptive information to be provided. It also describes the information required to change coordinates from one coordinate reference system to another.

In this International Standard, a coordinate reference system does not change with time. For coordinate reference systems defined on moving platforms such as cars, ships, aircraft and spacecraft, the transformation to an Earth-fixed coordinate reference system can include a time element.

This International Standard is applicable to producers and users of geographic information. Although it is applicable to digital geographic data, its principles can be extended to many other forms of geographic data such as maps, charts and text documents.

The schema described can be applied to the combination of horizontal position with a third non-spatial parameter which varies monotonically with height or depth. This extension to non-spatial data is beyond the scope of this International Standard but can be implemented through profiles.

2 Conformance requirements

This International Standard defines two classes of conformance, Class A for conformance of coordinate reference systems and Class B for coordinate operations between two coordinate reference systems. Any coordinate reference system claiming conformance to this International Standard shall satisfy the requirements given in A.1. Any coordinate operation claiming conformance to this International Standard shall satisfy the requirements given in A.2.

3 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the cited edition applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/TS 19103, *Geographic information — Conceptual schema language*

ISO 19108, *Geographic information — Temporal schema*

ISO 19115, *Geographic information — Metadata*

Normative reference to ISO 19115 is restricted as follows. In this International Standard, normative reference to ISO 19115 excludes the MD_CRS class and its component classes. ISO 19115 class MD_CRS and its component classes specify descriptions of coordinate reference systems elements. These elements are modelled in this International Standard.

NOTE The MD_CRS class and its component classes were deleted from ISO 19115:2003 through Technical Corrigendum 1:2006.

4 Terms and definitions

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

4.1
affine coordinate system
coordinate system in Euclidean space with straight axes that are not necessarily mutually perpendicular

4.2
Cartesian coordinate system
coordinate system which gives the position of points relative to n mutually perpendicular axes

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

4.3
compound coordinate reference system
coordinate reference system using at least two independent **coordinate reference systems**

NOTE Coordinate reference systems are independent of each other if coordinate values in one cannot be converted or transformed into coordinate values in the other.

4.4
concatenated operation
coordinate operation consisting of sequential application of multiple **coordinate operations**

4.5
coordinate
one of a **sequence** of n numbers designating the position of a point in n-dimensional space

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

4.6
coordinate conversion
coordinate operation in which both **coordinate reference systems** are based on the same **datum**

EXAMPLE Conversion from an ellipsoidal coordinate reference system based on the WGS 84 datum to a Cartesian coordinate reference system also based on the WGS 84 datum, or change of units such as from radians to degrees or feet to meters.

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

4.7
coordinate operation
change of **coordinates**, based on a one-to-one relationship, from one **coordinate reference system** to another

NOTE Supertype of coordinate transformation and coordinate conversion.

4.8
coordinate reference system
coordinate system that is related to an object by a **datum**

NOTE For geodetic and vertical datums, the object will be the Earth.

4.9
coordinate set
collection of **coordinate tuples** related to the same **coordinate reference system**

4.10
coordinate system
set of mathematical rules for specifying how **coordinates** are to be assigned to points

4.11
coordinate transformation
coordinate operation in which the two **coordinate reference systems** are based on different **datums**

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

4.12
coordinate tuple
tuple composed of a **sequence** of **coordinates**

NOTE The number of coordinates in the coordinate tuple equals the dimension of the coordinate system; the order of coordinates in the coordinate tuple is identical to the order of the axes of the coordinate system.

4.13
cylindrical coordinate system
three-dimensional **coordinate system** with two distance and one angular **coordinates**

4.14
datum
parameter or set of parameters that define the position of the origin, the scale, and the orientation of a **coordinate system**

4.15
depth
distance of a point from a chosen reference surface measured downward along a line perpendicular to that surface

NOTE A depth above the reference surface will have a negative value.

4.16
easting
E
distance in a **coordinate system**, eastwards (positive) or westwards (negative) from a north-south reference line

4.17
ellipsoid
surface formed by the rotation of an ellipse about a main axis

NOTE In this International Standard, ellipsoids are always oblate, meaning that the axis of rotation is always the minor axis.

4.18
ellipsoidal coordinate system
geodetic coordinate system
coordinate system in which position is specified by **geodetic latitude**, **geodetic longitude** and (in the three-dimensional case) **ellipsoidal height**

4.19
ellipsoidal height
geodetic height
h
distance of a point from the **ellipsoid** measured along the perpendicular from the **ellipsoid** to this point, positive if upwards or outside of the **ellipsoid**

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

4.20
engineering coordinate reference system
coordinate reference system based on an engineering datum

EXAMPLES Local engineering and architectural grids; coordinate reference system local to a ship or an orbiting spacecraft.

4.21
engineering datum
local datum
datum describing the relationship of a **coordinate system** to a local reference

NOTE Engineering datum excludes both geodetic and vertical datums.

EXAMPLE A system for identifying relative positions within a few kilometres of the reference point.

4.22
flattening
f
ratio of the difference between the **semi-major** (a) and **semi-minor axis** (b) of an **ellipsoid** to the **semi-major axis**; $f = (a - b)/a$

NOTE Sometimes inverse flattening $1/f = a/(a - b)$ is given instead; $1/f$ is also known as reciprocal flattening.

4.23
geodetic coordinate reference system
coordinate reference system based on a geodetic datum

4.24
geodetic datum
datum describing the relationship of a two- or three-dimensional **coordinate system** to the Earth

4.25
geodetic latitude
ellipsoidal latitude
φ
angle from the equatorial plane to the perpendicular to the **ellipsoid** through a given point, northwards treated as positive

4.26
geodetic longitude
ellipsoidal longitude
λ
angle from the **prime meridian** plane to the **meridian** plane of a given point, eastward treated as positive

4.27
geoid
equipotential surface of the Earth's gravity field which is everywhere perpendicular to the direction of gravity and which best fits **mean sea level** either locally or globally

4.28
gravity-related height
H
height dependent on the Earth's gravity field

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

4.29
height
h, H
distance of a point from a chosen reference surface measured upward along a line perpendicular to that surface

NOTE A height below the reference surface will have a negative value.

4.30
image coordinate reference system
coordinate reference system based on an image datum

4.31
image datum
engineering datum which defines the relationship of a **coordinate system** to an image

4.32
linear coordinate system
one-dimensional **coordinate system** in which a linear feature forms the axis

EXAMPLES Distances along a pipeline; depths down a deviated oil well bore.

4.33
map projection
coordinate conversion from an **ellipsoidal coordinate system** to a plane

4.34
mean sea level
average level of the surface of the sea over all stages of tide and seasonal variations

NOTE Mean sea level in a local context normally means mean sea level for the region calculated from observations at one or more points over a given period of time. Mean sea level in a global context differs from a global **geoid** by not more than 2 m.

4.35
meridian
intersection of an **ellipsoid** by a plane containing the shortest axis of the **ellipsoid**

NOTE This term is often used for the pole-to-pole arc rather than the complete closed figure.

4.36
northing
N
distance in a **coordinate system**, northwards (positive) or southwards (negative) from an east-west reference line

4.37
polar coordinate system
two-dimensional **coordinate system** in which position is specified by distance and direction from the origin

NOTE For the three-dimensional case, see **spherical coordinate system (4.44)**.

4.38
prime meridian
zero meridian
meridian from which the longitudes of other **meridians** are quantified

4.39
projected coordinate reference system
coordinate reference system derived from a two-dimensional **geodetic coordinate reference system** by applying a **map projection**

4.40
semi-major axis
a
semi-diameter of the longest axis of an **ellipsoid**

NOTE This equates to the semi-diameter of the ellipsoid measured in its equatorial plane.

4.41
semi-minor axis
b
semi-diameter of the shortest axis of an **ellipsoid**

NOTE The shortest axis coincides with the rotation axis of the ellipsoid and therefore contains both poles.

4.42
sequence
finite, ordered collection of related items (objects or values) that may be repeated

[ISO 19107]

4.43
spatial reference
description of position in the real world

NOTE This may take the form of a label, code or coordinate tuple.

4.44
spherical coordinate system
three-dimensional **coordinate system** with one distance measured from the origin and two angular **coordinates**, commonly associated with a **geodetic coordinate reference** system

NOTE Not to be confused with an ellipsoidal coordinate system based on an ellipsoid 'degenerated' into a sphere.

4.45
tuple
ordered list of values

[ISO 19136]

4.46
unit
defined quantity in which dimensioned parameters are expressed

NOTE In this International Standard, the subtypes of units are length units, angular units, time units, scale units and pixel spacing units.

4.47
vertical coordinate reference system
one-dimensional **coordinate reference system** based on a **vertical datum**

4.48
vertical coordinate system
one-dimensional **coordinate system** used for **gravity-related height** or **depth** measurements

4.49
vertical datum
datum describing the relation of **gravity-related heights** or **depths** to the Earth

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

5 Conventions

5.1 Symbols

a	semi-major axis
b	semi-minor axis
E	easting
f	flattening
H	gravity-related height
h	ellipsoidal height
N	northing
λ	geodetic longitude
φ	geodetic latitude
E, N	Cartesian coordinates in a projected coordinate reference system
X, Y, Z	Cartesian coordinates in a geodetic coordinate reference system
i, j, [k]	Cartesian coordinates in an engineering coordinate reference system
r, θ	polar coordinates in a 2D engineering coordinate reference system
r, Ω, θ	spherical coordinates in a 3D engineering or geodetic coordinate reference system

5.2 Abbreviated terms

CC	change coordinates (package abbreviation in UML model)
CD	coordinate datum (package abbreviation in UML model)
CCRS	compound coordinate reference system
CRS	coordinate reference system
CS	coordinate system (also, package abbreviation in UML model)
IO	identified object (package abbreviation in UML model)
MSL	mean sea level

pixel a contraction of “picture element”, the smallest element of a digital image to which attributes are assigned

RS reference system (package abbreviation in UML model)

SC spatial referencing by coordinates (package abbreviation in UML model)

SI le Système International d’unités

UML Unified Modeling Language

URI Uniform Resource Identifier

1D one-dimensional

2D two-dimensional

3D three-dimensional

5.3 UML notation

In this International Standard, the conceptual schema for describing coordinate reference systems and coordinate operations is modelled with the Unified Modelling Language (UML). The basic data types and UML diagram notations are defined in ISO/TS 19103 and ISO/IEC 19501 [9].

In this International Standard, the following stereotypes of UML classes are used:

a) <<DataType>> a descriptor of a set of values that lack identity (independent existence and the possibility of side effects); a DataType is a class with no operations whose primary purpose is to hold the information;

b) <<Type>> a class used for specification of a domain of objects together with operations applicable to the objects;

c) <<CodeList>> a flexible enumeration that uses string values for expressing a list of potential values;

d) <<Union>> contains a list of attributes where only one of those attributes can be present at any time.

The following data types defined in ISO/TS 19103 are used:

— Angle amount of rotation required to bring one line or plane into coincidence with another;

— Boolean a value specifying TRUE or FALSE;

— CharacterString a sequence of characters;

— Date a character string which comprises year, month and day in the format as specified by ISO 8601;

— GenericName a generic name structure in the context of namespaces, defined in ISO/TS 19103;

— Integer an integer number;

— Length the measure of distance;

— Measure result from performing the act or process of ascertaining the extent, dimensions or quantity of some entity;

— Number abstract class that can be subtyped to a specific number type (real, integer, decimal, double, float);

— Scale the ratio of one quantity to another;

— Unit of Measure any of the systems devised to measure some physical quantity.

In addition, a Sequence type of collection is used, which contains an ordered list of values with the specified data type. The format used is “Sequence<DataType>”.

In the UML diagrams in this International Standard, grey boxes indicate classes from other packages.

5.4 Attribute status

In this International Standard, attributes are given an obligation status:

Obligation	Definition	Meaning
M	mandatory	This attribute shall be supplied.
C	conditional	This attribute shall be supplied if the condition (given in the attribute description) is true. It may be supplied if the condition is false.
O	optional	This attribute may be supplied.

In this International Standard, the Maximum Occurrence column indicates the maximum number of occurrences of attribute values that are permissible, with N indicating no upper limit.

6 Spatial referencing by coordinates — Overview

6.1 Relationship between coordinates and coordinate reference system

In this International Standard, a *coordinate* is one of n scalar values that define the position of a single point. In other contexts, the term *ordinate* is used for a single value and coordinate for multiple ordinates. Such usage is not part of this International Standard.

A *coordinate tuple* is an ordered list of n coordinates that define the position of a single point. In this International Standard, the coordinate tuple shall be composed of one, two or three spatial coordinates. The coordinates shall be mutually independent and their number shall be equal to the dimension of the coordinate space.

EXAMPLE A coordinate tuple cannot contain two heights.

Coordinates are ambiguous until the system to which those coordinates are related has been fully defined. Without the full specification of the system, coordinates are ambiguous at best and meaningless at worst. A *coordinate reference system* (CRS) defines the coordinate space such that the coordinate values are unambiguous. In this International Standard, the order of the coordinates within the coordinate tuple and their unit(s) of measure shall be parts of the coordinate reference system definition.

In this International Standard, a *coordinate set* shall be a collection of coordinate tuples referenced to the same coordinate reference system. A CRS identification or definition in accordance with this International Standard shall be associated with every coordinate tuple. If only one point is being described, the association shall be direct. For a coordinate set, one CRS identification or definition may be associated with the coordinate set and then all coordinate tuples in that coordinate set inherit that association. The conceptual relationship of coordinate tuple and coordinate set to coordinate reference system is shown in Figure 1.