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Geographic information — Referencing by coordinates

Information géographique — Système de références par coordonnées

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

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

This third edition cancels and replaces the second edition (ISO 19111:2007), which has been technically revised. This document also incorporates the provisions of ISO 19111-2:2009, which is cancelled.

The changes in this edition compared to the previous edition are:

— inclusion of applicable modern geodetic terminology;

— extension to describe dynamic geodetic reference frames;

— extension to describe geoid-based vertical coordinate reference systems;

— extension to allow triaxial ellipsoid for planetary applications;

— extension to describe three-dimensional projected coordinate reference systems;

— addition of 'datum ensembles' to allow grouping of related realizations of a reference frame where for lower accuracy applications the differences are insignificant;

— clarification in the modelling of derived coordinate reference systems;

— remodelling of the metadata elements scope and extent;

— addition of requirements to describe coordinate metadata and the relationship between spatial coordinates;

— additional modelling of temporal coordinate reference system components sufficient for spatio-temporal coordinate referencing;

— consolidation of the provisions of ISO 19111-2:2009 (*Spatial referencing by coordinates — Extension for parametric values*) into this document;

— change in name from 'Spatial referencing by coordinates' to 'Referencing by coordinates', due to the inclusion of the non-spatial coordinate reference system subtypes of parametric (from ISO 19111-2) and temporal;

— the correction of minor errors.

Further details are given in Annex G.

In accordance with the ISO/IEC Directives, Part 2, 2018, *Rules for the structure and drafting of International Standards*, in International Standards the decimal sign is a comma on the line. However the General Conference on Weights and Measures (*Conférence Générale des Poids et Mesures*) at its meeting in 2003 passed unanimously the following resolution:

“The decimal marker shall be either a point on the line or a comma on the line.”

In practice, the choice between these alternatives depends on customary use in the language concerned. In the technical areas of geodesy and geographic information it is customary for the decimal point always to be used, for all languages. That practice is used throughout this document.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Geographic information is inherently four-dimensional and includes time. The spatial component relates the features represented in geographic 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[5]. This document describes the data elements, relationships and associated metadata required for spatial referencing by coordinates, expanded from a strictly spatial context to include time. The temporal element is restricted to temporal coordinate systems having a continuous axis. The temporal element excludes calendars and ordinal reference systems due to their complexities in definition and in transformation. The context is shown in Figure 1.

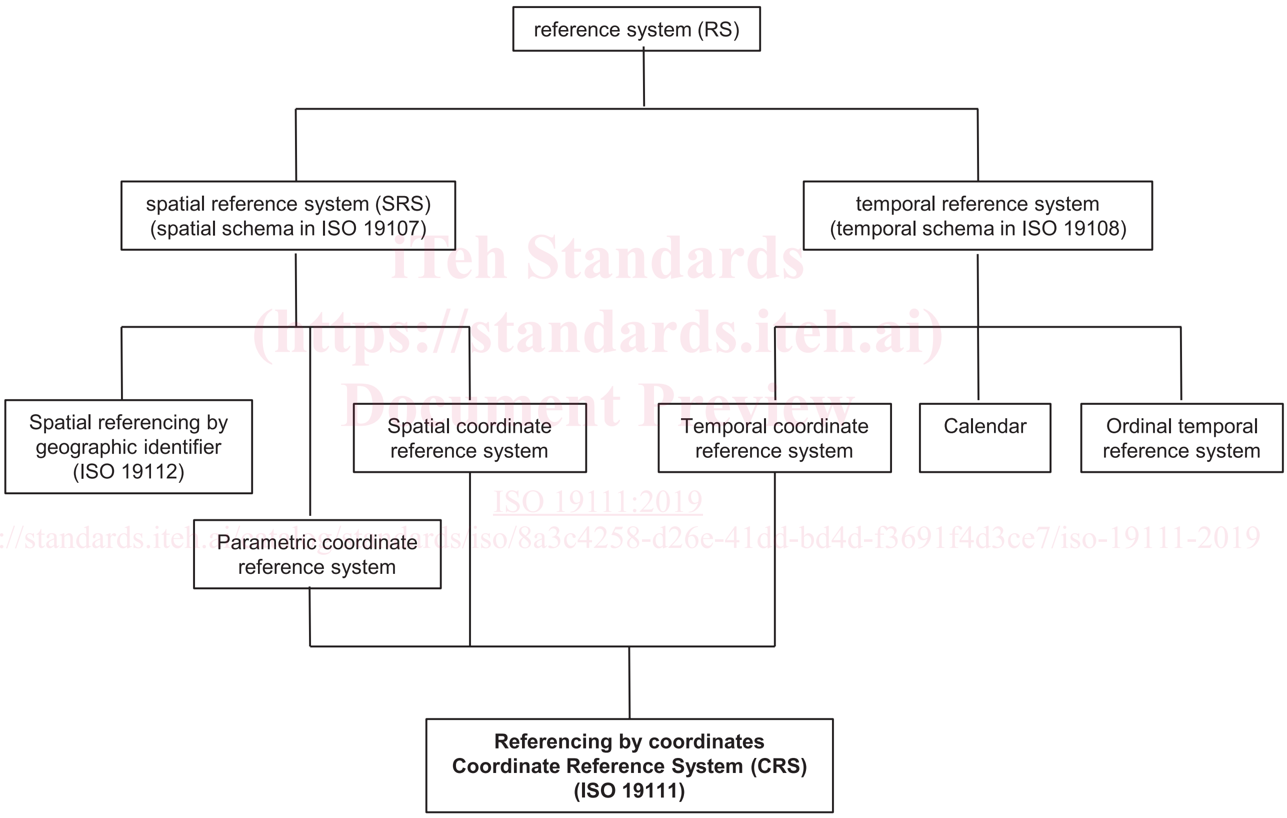

Figure 1 — Context of referencing by coordinates

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 height 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 and parametric coordinate reference system modelling constructs were previously described in ISO 19111-2:2009 but have been incorporated into this revision because the modelling constructs are identical to the other coordinate reference system types included in this document.

This document describes the elements that are necessary to fully define various types of coordinate reference systems applicable to geographic information. The subset of elements required is partially dependent upon the type of coordinates. This document also includes optional fields to allow for the inclusion of metadata about the coordinate reference systems. The elements are intended to be both machine and human readable.

In addition to describing a coordinate reference system, this document provides for the description of a coordinate operation between two different coordinate reference systems or a coordinate operation to account for crustal motion over time. With such information, spatial data referenced to different coordinate reference systems can be referenced to one specified coordinate reference system at one specified time. This facilitates spatial data integration. Alternatively, an audit trail of coordinate manipulations can be maintained.

Geographic information — Referencing by coordinates

1 Scope

This document defines the conceptual schema for the description of referencing by coordinates. It describes the minimum data required to define coordinate reference systems. This document supports the definition of:

— spatial coordinate reference systems where coordinate values do not change with time. The system may:

  — be geodetic and apply on a national or regional basis, or

  — apply locally such as for a building or construction site, or

  — apply locally to an image or image sensor;

  — be referenced to a moving platform such as a car, a ship, an aircraft or a spacecraft. Such a coordinate reference system can be related to a second coordinate reference system which is referenced to the Earth through a transformation that includes a time element;

— spatial coordinate reference systems in which coordinate values of points on or near the surface of the earth change with time due to tectonic plate motion or other crustal deformation. Such dynamic systems include time evolution, however they remain spatial in nature;

— parametric coordinate reference systems which use a non-spatial parameter that varies monotonically with height or depth;

— temporal coordinate reference systems which use dateTime, temporal count or temporal measure quantities that vary monotonically with time;

— mixed spatial, parametric or temporal coordinate reference systems.

The *definition* of a coordinate reference system does not change with time, although in some cases some of the defining parameters can include a rate of change of the parameter. The coordinate values within a dynamic and in a temporal coordinate reference system can change with time.

This document also describes the conceptual schema for defining the information required to describe operations that change coordinate values.

In addition to the minimum data required for the definition of the coordinate reference system or coordinate operation, the conceptual schema allows additional descriptive information - coordinate reference system metadata - to be provided.

This document is applicable to producers and users of geographic information. Although it is applicable to digital geographic data, the principles described in this document can be extended to many other forms of spatial data such as maps, charts and text documents.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

ISO 19103, *Geographic information — Conceptual schema language*

ISO 19115-1:2014, *Geographic information — Metadata — Part 1: Fundamentals*

3 Terms, definitions, symbols and abbreviated terms

3.1 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at https://www.iso.org/obp

3.1.1
affine coordinate system
coordinate system in Euclidean space with straight axes that are not necessarily mutually perpendicular

3.1.2
Cartesian coordinate system
coordinate system in Euclidean space which gives the position of points relative to *n* mutually perpendicular straight axes all having the same unit of measure

Note 1 to entry: *n* is 2 or 3 for the purposes of this document.

Note 2 to entry: A Cartesian coordinate system is a specialisation of an affine coordinate system.

3.1.3
compound coordinate reference system
coordinate reference system using at least two independent coordinate reference systems

Note 1 to entry: Coordinate reference systems are independent of each other if coordinate values in one cannot be converted or transformed into coordinate values in the other.

3.1.4
concatenated operation
coordinate operation consisting of the sequential application of multiple coordinate operations

3.1.5
coordinate
one of a sequence of numbers designating the position of a point

Note 1 to entry: In a spatial coordinate reference system, the coordinate numbers are qualified by units.

3.1.6
coordinate conversion
coordinate operation that changes coordinates in a source coordinate reference system to coordinates in a target coordinate reference system in which both coordinate reference systems are based on the same datum

Note 1 to entry: A coordinate conversion uses parameters which have specified values.

EXAMPLE 1 A mapping of ellipsoidal coordinates to Cartesian coordinates using a map projection.

EXAMPLE 2 Change of units such as from radians to degrees or from feet to metres.

3.1.7
coordinate epoch
epoch to which coordinates in a dynamic coordinate reference system are referenced

3.1.8
coordinate operation
process using a mathematical model, based on a one-to-one relationship, that changes coordinates in a source coordinate reference system to coordinates in a target coordinate reference system, or that changes coordinates at a source coordinate epoch to coordinates at a target coordinate epoch within the same coordinate reference system

3.1.9
coordinate reference system
coordinate system that is related to an object by a datum

Note 1 to entry: Geodetic and vertical datums are referred to as reference frames.

Note 2 to entry: For geodetic and vertical reference frames, the object will be the Earth. In planetary applications, geodetic and vertical reference frames may be applied to other celestial bodies.

3.1.10
coordinate set
collection of coordinate tuples referenced to the same coordinate reference system and if that coordinate reference system is dynamic also to the same coordinate epoch

3.1.11
coordinate system
set of mathematical rules for specifying how coordinates are to be assigned to points

3.1.12
coordinate transformation
coordinate operation that changes coordinates in a source coordinate reference system to coordinates in a target coordinate reference system in which the source and target coordinate reference systems are based on different datums

Note 1 to entry: A coordinate transformation uses parameters which are derived empirically. Any error in those coordinates will be embedded in the coordinate transformation and when the coordinate transformation is applied the embedded errors are transmitted to output coordinates.

Note 2 to entry: A coordinate transformation is colloquially sometimes referred to as a 'datum transformation'. This is erroneous. A coordinate transformation changes coordinate values. It does not change the definition of the datum. In this document coordinates are referenced to a coordinate reference system. A coordinate transformation operates between two coordinate reference systems, not between two datums.

3.1.13
coordinate tuple
tuple composed of coordinates

Note 1 to entry: 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.

3.1.14
cylindrical coordinate system
three-dimensional coordinate system in Euclidean space in which position is specified by two linear coordinates and one angular coordinate

3.1.15
datum
reference frame
parameter or set of parameters that realize the position of the origin, the scale, and the orientation of a coordinate system

3.1.16
datum ensemble
group of multiple realizations of the same terrestrial or vertical reference system that, for approximate spatial referencing purposes, are not significantly different

Note 1 to entry: Datasets referenced to the different realizations within a datum ensemble may be merged without coordinate transformation.

Note 2 to entry: 'Approximate' is for users to define and typically is in the order of under 1 decimetre but may be up to 2 metres.

EXAMPLE "WGS 84" as an undifferentiated group of realizations including WGS 84 (TRANSIT), WGS 84 (G730), WGS 84 (G873), WGS 84 (G1150), WGS 84 (G1674) and WGS 84 (G1762). At the surface of the Earth these have changed on average by 0.7 m between the TRANSIT and G730 realizations, a further 0.2 m between G730 and G873, 0.06 m between G873 and G1150, 0.2 m between G1150 and G1674 and 0.02 m between G1674 and G1762).

3.1.17
depth
distance of a point from a chosen vertical reference surface downward along a line that is perpendicular to that surface

Note 1 to entry: The line direction may be straight, or be dependent on the Earth's gravity field or other physical phenomena.

Note 2 to entry: A depth above the vertical reference surface will have a negative value.

3.1.18
derived coordinate reference system
coordinate reference system that is defined through the application of a specified coordinate conversion to the coordinates within a previously established coordinate reference system

Note 1 to entry: The previously established coordinate reference system is referred to as the base coordinate reference system.

Note 2 to entry: A derived coordinate reference system inherits its datum or reference frame from its base coordinate reference system.

Note 3 to entry: The coordinate conversion between the base and derived coordinate reference system is implemented using the parameters and formula(s) specified in the definition of the coordinate conversion.

3.1.19
dynamic coordinate reference system
coordinate reference system that has a dynamic reference frame

Note 1 to entry: Coordinates of points on or near the crust of the Earth that are referenced to a dynamic coordinate reference system may change with time, usually due to crustal deformations such as tectonic motion and glacial isostatic adjustment.

Note 2 to entry: Metadata for a dataset referenced to a dynamic coordinate reference system should include coordinate epoch information.

3.1.20
dynamic reference frame
dynamic datum
reference frame in which the defining parameters include time evolution

Note 1 to entry: The defining parameters that have time evolution are usually a coordinate set.

3.1.21
easting
E
distance in a coordinate system, eastwards (positive) or westwards (negative) from a north-south reference line

3.1.22
ellipsoid
reference ellipsoid
<geodesy> geometric reference surface embedded in 3D Euclidean space formed by an ellipse that is rotated about a main axis

Note 1 to entry: For the Earth the ellipsoid is bi-axial with rotation about the polar axis. This results in an oblate ellipsoid with the midpoint of the foci located at the nominal centre of the Earth.

3.1.23
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

3.1.24
ellipsoidal height
geodetic height
h
distance of a point from the reference ellipsoid along the perpendicular from the reference ellipsoid to this point, positive if upwards or outside of the reference ellipsoid

Note 1 to entry: Only used as part of a three-dimensional ellipsoidal coordinate system or as part of a three-dimensional Cartesian coordinate system in a three-dimensional projected coordinate reference system, but never on its own.

3.1.25
engineering coordinate reference system
coordinate reference system based on an engineering datum

EXAMPLE 1 System for identifying relative positions within a few kilometres of the reference point, such as a building or construction site.

EXAMPLE 2 Coordinate reference system local to a moving object such as a ship or an orbiting spacecraft.

EXAMPLE 3 Internal coordinate reference system for an image. This has continuous axes. It may be the foundation for a grid.

3.1.26
engineering datum
local datum
datum describing the relationship of a coordinate system to a local reference

Note 1 to entry: Engineering datum excludes both geodetic and vertical reference frames.

3.1.27
epoch
<geodesy> point in time

Note 1 to entry: In this document an epoch is expressed in the Gregorian calendar as a decimal year.

EXAMPLE 2017-03-25 in the Gregorian calendar is epoch 2017.23.

3.1.28
flattening
f
ratio of the difference between the semi-major axis (a) and semi-minor axis (b) of an ellipsoid to the semi-major axis: $f = (a - b)/a$

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

3.1.29
frame reference epoch
epoch of coordinates that define a dynamic reference frame

3.1.30
geocentric latitude
angle from the equatorial plane to the direction from the centre of an ellipsoid through a given point, northwards treated as positive

3.1.31
geodetic coordinate reference system
three-dimensional coordinate reference system based on a geodetic reference frame and having either a three-dimensional Cartesian or a spherical coordinate system

Note 1 to entry: In this document a coordinate reference system based on a geodetic reference frame and having an ellipsoidal coordinate system is geographic.

3.1.32
geodetic latitude
ellipsoidal latitude
φ
angle from the equatorial plane to the perpendicular to the ellipsoid through a given point, northwards treated as positive

3.1.33
geodetic longitude
ellipsoidal longitude
λ
angle from the prime meridian plane to the meridian plane of a given point, eastward treated as positive

3.1.34
geodetic reference frame
reference frame or datum describing the relationship of a two- or three-dimensional coordinate system to the Earth

Note 1 to entry: In the data model described in this document, the UML class GeodeticReferenceFrame includes both modern terrestrial reference frames and classical geodetic datums.

3.1.35
geographic coordinate reference system
coordinate reference system that has a geodetic reference frame and an ellipsoidal coordinate system

3.1.36
geoid
equipotential surface of the Earth's gravity field which is perpendicular to the direction of gravity and which best fits mean sea level either locally, regionally or globally

3.1.37
gravity-related height
H
height that is dependent on the Earth's gravity field

Note 1 to entry: This refers to, amongst others, orthometric height and Normal height, which are both approximations of the distance of a point above the mean sea level, but also may include Normal-orthometric heights, dynamic heights or geopotential numbers.

Note 2 to entry: The distance from the reference surface may follow a curved line, not necessarily straight, as it is influenced by the direction of gravity.

