INTERNATIONAL STANDARD

ISO 19111

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Geographic information — Spatial referencing by coordinates

Information géographique — Système de références spatiales par coordonnées

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Contents

Page

Foreword

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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.

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ISO 19111 was prepared by Technical Committee ISO/TC 211, *Geographic information/Geomatics*.

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.

This International Standard deals only with spatial referencing by coordinates. Spatial referencing by geographic identifiers is the subject of ISO 19112, *Geographic information — Spatial referencing by geographic identifiers*.

Coordinates are unambiguous only when the coordinate reference system to which those coordinates are related has been fully defined. A coordinate reference system is a coordinate system which has a reference to the Earth. This International Standard describes the elements that are necessary to define fully 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. A set of coordinates on the same coordinate reference system requires one coordinate reference system description.

In addition to describing a coordinate reference system, this International Standard provides for the description of a coordinate transformation or coordinate conversion between two different coordinate reference systems. With such information, geographic data referred to different coordinate reference systems can be merged together for integrated manipulation. 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. It describes the minimum data required to define one-, two- and three-dimensional coordinate reference systems. It allows additional descriptive information to be provided. It also describes the information required to change coordinate values from one coordinate reference system to another.

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.

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 Annex A, Clause A.1. Any coordinate operation claiming conformance to this International Standard shall satisfy the requirements given in Annex A, Clause A.2.

3 Normative references

The following referenced documents are indispensable for the application 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 1000, *SI units and recommendations for use of their multiples and of certain other units*

ISO/TS 19103:—[1)], *Geographic information — Conceptual schema language*

ISO 19113:2002, *Geographic information — Quality principles*

ISO 19114:—[1)], *Geographic information — Quality evaluation procedures*

4 Terms and definitions

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

4.1
Cartesian coordinate system
coordinate system which gives the position of points relative to n mutually perpendicular axes

1) To be published.

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

4.2
compound coordinate reference system
coordinate reference system using two other independent coordinate reference systems to describe a position

EXAMPLE One coordinate reference system based on a two- or three-dimensional coordinate system and the other coordinate reference system based on a gravity-related height system.

4.3
coordinate
one of a sequence of n numbers designating the position of a point in n-dimensional space

NOTE 1 In a coordinate reference system, the numbers must be qualified by units.

NOTE 2 A coordinate operation is performed on coordinates in a source system resulting in coordinates in a target system.

4.4
coordinate conversion
change of **coordinates**, based on a one-to-one relationship, from one **coordinate system** to another based on the same **datum**

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

NOTE A coordinate conversion uses parameters which have constant values.

4.5
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.

4.6
coordinate reference system
coordinate system that is related to the real world by a **datum**

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

4.7
coordinate system
set of mathematical rules for specifying how **coordinates** are to be assigned to points

4.8
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

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

4.9
datum
parameter or set of parameters that serve as a reference or basis for the calculation of other parameters

NOTE A datum defines the position of the origin, the scale, and the orientation of the axes of a coordinate system.

4.10
easting
E
distance in a **coordinate system**, eastwards (positive) or westwards (negative) from a north-south reference line

4.11
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.

4.12
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 geodetic coordinate system and never on its own.

4.13
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.

4.14
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.

4.15
geodetic coordinate system
ellipsoidal coordinate system
coordinate system in which position is specified by **geodetic latitude**, **geodetic longitude** and (in the three-dimensional case) **ellipsoidal height**

4.16
geodetic datum
datum describing the relationship of a **coordinate system** to the Earth

NOTE In most cases, the geodetic datum includes an ellipsoid definition.

4.17
geodetic latitude
ellipsoidal latitude
φ
angle from the equatorial plane to the perpendicular to the **ellipsoid** through a given point, northwards treated as positive

4.18
geodetic longitude
ellipsoidal longitude
λ
angle from the prime **meridian** plane to the **meridian** plane of a given point, eastward treated as positive

4.19
geoid
level surface which best fits mean sea level either locally or globally

NOTE "Level surface" means an equipotential surface of the Earth's gravity field which is everywhere perpendicular to the direction of gravity.

4.20
gravity-related height
H
height dependent on the Earth's gravity field

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

4.21
Greenwich meridian
meridian that passes through the position of the Airy Transit Circle at the Royal Observatory Greenwich, United Kingdom

NOTE Most geodetic datums use the Greenwich meridian as the prime meridian. Its precise position differs slightly between different datums.

4.22
height
h, H

distance of a point from a chosen reference surface along a line perpendicular to that surface

NOTE 1 See ellipsoidal height and gravity-related height.

NOTE 2 Height of a point outside the surface treated as positive; negative height is also called depth.

4.23
map projection
coordinate conversion from a **geodetic coordinate system** to a plane

4.24
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.

4.25
meridian
intersection of an **ellipsoid** by a plane containing the **semi-minor axis** of the **ellipsoid**

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

4.26
northing
N
distance in a **coordinate system**, northwards (positive) or southwards (negative) from an east-west reference line

4.27
polar coordinate system
coordinate system in which position is specified by distance and direction from the origin

NOTE In three dimensions also called spherical coordinate system.

4.28
prime meridian
zero meridian
meridian from which the longitudes of other **meridians** are quantified

4.29
projected coordinate system
two-dimensional **coordinate system** resulting from a **map projection**

4.30
semi-major axis
a
longest radius of an **ellipsoid**

NOTE For an ellipsoid representing the Earth, it is the radius of the equator.

4.31
semi-minor axis
b
shortest radius of an **ellipsoid**

NOTE For an ellipsoid representing the Earth, it is the distance from the centre of the ellipsoid to either pole.

4.32
spatial reference
description of position in the real world

NOTE This may take the form of a label, code or set of coordinates.

4.33
vertical datum
datum describing the relation of gravity-related **heights** to the Earth

NOTE In most cases the vertical datum will be related to a defined mean sea level based on water level observations over a long time period. 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 and abbreviated terms

a	semi-major axis
b	semi-minor axis
CCRS	Compound coordinate reference system
E	easting
h	ellipsoidal height
N	northing
SC	Spatial referencing by Coordinates

SI	le Système International d'unités
UML	Unified Modeling Language
λ	geodetic longitude
φ	geodetic latitude
x, y, z	Cartesian coordinates in a geodetic datum
i, j, k	Cartesian coordinates in a engineering datum
r, Ω, θ	spherical polar coordinates

5.2 UML notation

The diagrams that appear in this International Standard are presented using the Unified Modeling Language (UML) static structure diagram with the ISO Interface Definition Language (IDL) basic type definitions and the UML Object Constraint Language (OCL) as the conceptual schema language. The UML notations used in this International Standard are described in Figure 1.

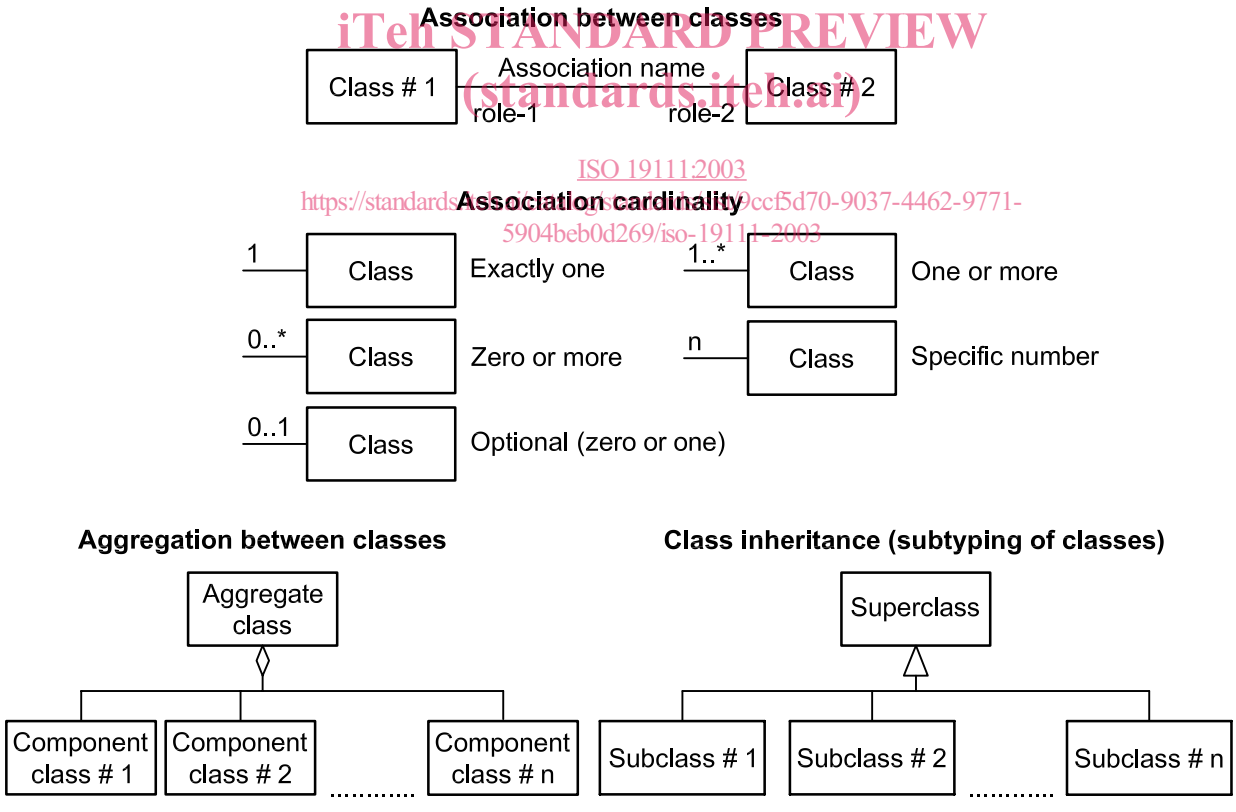

Figure 1 — UML notation

6 Definition of the conceptual schema for coordinate reference systems

6.1 Introduction

Location or position on or near the Earth's surface may be described using coordinates. Coordinates are unambiguous only when the coordinate reference system to which those coordinates are related has been fully defined. Each position shall be described by a set of coordinates in a coordinate reference system.

Coordinates supplied in a dataset shall belong to the same coordinate reference system. A description of this coordinate reference system shall be supplied with the dataset. Coordinate data shall be accompanied by information sufficient to make the coordinates unambiguous. This information varies by coordinate system type and datum type.

In the clauses below, attributes are given a requirement status:

Requirement	Definition	Comment
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.

The Maximum Occurrence column in the following tables indicates the maximum number of occurrences of attribute values that are permissible, with N indicating no upper limit. The conceptual schema for describing coordinate reference systems is modelled with the Unified Modeling Language (UML) in Annex B. In case of inconsistency between the metadata textual description and the UML model (re: Annex B), the textual description shall prevail. The basic data types are defined in ISO/TS 19103.

6.2 Coordinate reference system

6.2.1 Type of coordinate reference system

A coordinate reference system may be either single or compound. A single coordinate reference system is defined in 6.2.2 and a compound coordinate reference system is defined in 6.2.3. The requirements for describing the type of coordinate reference system shall be in accordance with Table 1.

Table 1 — Requirements for describing the type of coordinate reference system

Element name	UML identifier	Data type	Obligation	Maximum occurrence	Description
Coordinate reference system type code	typeCode	SC_TypeCode	M	1	Code denoting the type of coordinate reference system: 1 — a single coordinate reference system 2 — a compound coordinate reference system
Coordinate reference system remarks	remarks	CharacterString	O	1	Comments on the coordinate reference system including source information.

To determine whether the coordinate reference system is compound or single, decision tree 1 in Annex C may be used (see Figure C.1).

6.2.2 Single coordinate reference system

A position of a feature can be given by a set of coordinates. Coordinates are unambiguous if the coordinate reference system to which those coordinates are related has been fully defined.

A coordinate reference system is realized by a set of coordinates. The realization is sometimes known as a reference frame.

A coordinate reference system shall be defined by one datum and by one coordinate system; see Figure 2.

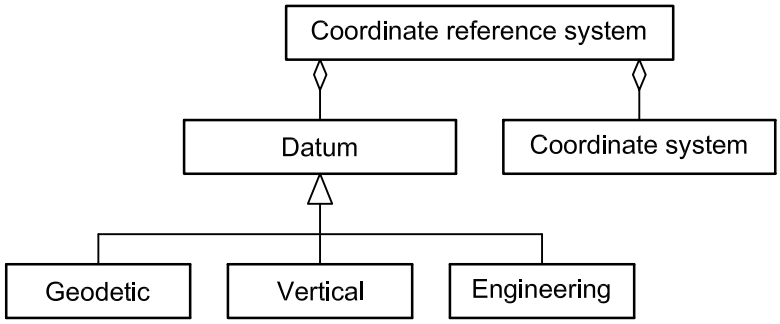

Figure 2 — Coordinate reference system

For the purposes of this International Standard, a coordinate reference system shall not change with time. When a reference frame changes with time, a new datum and coordinate reference system shall be created, with date of realization of the datum and coordinate reference system included in their names or identifiers.

The requirements for describing a coordinate reference system shall be in accordance with Table 2.

Table 2 — Requirements for describing a coordinate reference system

Element name	UML identifier	Data type	Obligation	Maximum occurrence	Description
Coordinate reference system identifier	CRSID	RS_Identifier	M	1	Identifier of the coordinate reference system.
Coordinate reference system alias	alias	CharacterString	O	N	Alternative name or identifier by which this coordinate reference system is known.
Coordinate reference system valid area	validArea	EX_Extent	O	1	Area for which the coordinate reference system is valid.
Coordinate reference system scope	scope	CharacterString	O	N	Application for which the coordinate reference system is valid.

6.2.3 Compound coordinate reference system

The horizontal and vertical components of a description of position in three dimensions may sometimes come from different coordinate reference systems rather than through a single three-dimensional coordinate reference system. This is always the case for positions where vertical coordinates are related to mean sea level. This shall be handled through a compound coordinate reference system (CCRS) which identifies the two coordinate reference systems utilized, see Figure 3. Vertical datum and gravity-related height are an example of a datum and coordinate system for coordinate reference system 2.

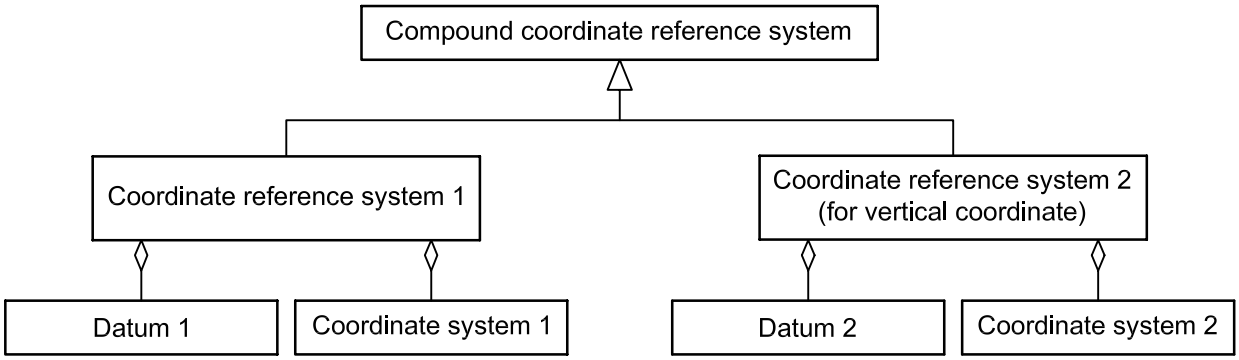

Figure 3 — Compound coordinate reference system

The requirements for describing a compound coordinate reference system shall be in accordance with Table 3. Each of the two coordinate reference systems shall then be described in the normal way.

The compound coordinate reference system identifier may be a concatenation of the coordinate reference system identifiers for the component coordinate reference systems.

Table 3 — Requirements for describing a compound coordinate reference system

Element name	UML identifier	Data type	Obligation	Maximum occurrence	Description
Compound coordinate reference system identifier	CCRSID	RS_Identifier	O	1	Identifier of the compound coordinate reference system.
Compound coordinate reference system alias	alias	CharacterString	O	N	Alternative name or identifier by which this compound coordinate reference system is known.
Compound coordinate reference system valid area	validArea	EX_Extent	O	1	Area for which the compound coordinate reference system is valid.
Compound coordinate reference system scope	scope	CharacterString	O	N	Application for which the compound coordinate reference system is valid.

6.3 Datum

6.3.1 Types of datums

A datum is geodetic, vertical or engineering. A geodetic datum gives the relationship of a coordinate system to the Earth and is used as the basis for two- or three-dimensional systems. In most cases, it shall require an ellipsoid definition. A vertical datum gives the relationship of gravity-related heights to a surface known as the geoid. The geoid is a surface close to mean sea level. In this International Standard, a datum shall be engineering if it is neither geodetic nor vertical.

For geographic information purposes it is necessary to identify a datum, but the definition of the datum itself is optional.

If the type of coordinate reference system is not known, decision tree 2 in Annex C may be used in the determination of the datum type (see Figure C.2).