INTERNATIONAL STANDARD

ISO 19123

First edition
2005-08-15

Geographic information — Schema for coverage geometry and functions

Information géographique — Schéma de la géométrie et des fonctions de couverture

Reference number
ISO 19123:2005(E)

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Published in Switzerland

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Foreword

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ISO 19123 was prepared by Technical Committee ISO/TC 211, *Geographic information/Geomatics*.

Introduction

Geographic phenomena fall into two broad categories — discrete and continuous. Discrete phenomena are recognizable objects that have relatively well-defined boundaries or spatial extent. Examples include buildings, streams and measurement stations. Continuous phenomena vary over space and have no specific extent. Examples include temperature, soil composition and elevation. A value or description of a continuous phenomenon is only meaningful at a particular position in space (and possibly time). Temperature, for example, takes on specific values only at defined locations, whether measured or interpolated from other locations.

These concepts are not mutually exclusive. In fact, many components of the landscape may be viewed alternatively as discrete or continuous. For example, a stream is a discrete entity, but its flow rate and water quality index vary from one position to another. Similarly, a highway can be thought of as a feature or as a collection of observations measuring accidents or traffic flow, and an agricultural field is both a spatial object and a set of measurements of crop yield through time.

Historically, geographic information has been treated in terms of two fundamental types called vector data and raster data.

“Vector data” deals with discrete phenomena, each of which is conceived of as a feature. The spatial characteristics of a discrete real-world phenomenon are represented by a set of one or more geometric primitives (points, curves, surfaces or solids). Other characteristics of the phenomenon are recorded as feature attributes. Usually, a single feature is associated with a single set of attribute values. ISO 19107:2003 provides a schema for describing features in terms of geometric and topological primitives.

“Raster data”, on the other hand, deals with real-world phenomena that vary continuously over space. It contains a set of values, each associated with one of the elements in a regular array of points or cells. It is usually associated with a method for interpolating values at spatial positions between the points or within the cells. Since this data structure is not the only one that can be used to represent phenomena that vary continuously over space, this International Standard uses the term “coverage,” adopted from the Abstract Specification of the Open GIS Consortium [1], to refer to any data representation that assigns values directly to spatial position. A coverage is a function from a spatial, temporal or spatiotemporal domain to an attribute range. A coverage associates a position within its domain to a record of values of defined data types.

In this International Standard, coverage is a subtype of feature. A coverage is a feature that has multiple values for each attribute type, where each direct position within the geometric representation of the feature has a single value for each attribute type.

Just as the concepts of discrete and continuous phenomena are not mutually exclusive, their representations as discrete features or coverages are not mutually exclusive. The same phenomenon may be represented as either a discrete feature or a coverage. A city may be viewed as a discrete feature that returns a single value for each attribute, such as its name, area and total population. The city feature may also be represented as a coverage that returns values such as population density, land value or air quality index for each position in the city.

A coverage, moreover, can be derived from a collection of discrete features with common attributes, the values of the coverage at each position being the values of the attributes of the feature located at that position. Conversely, a collection of discrete features can be derived from a coverage, each discrete feature being composed of a set of positions associated with specified attribute values.

Geographic information — Schema for coverage geometry and functions

1 Scope

This International Standard defines a conceptual schema for the spatial characteristics of coverages. Coverages support mapping from a spatial, temporal or spatiotemporal domain to feature attribute values where feature attribute types are common to all geographic positions within the domain. A coverage domain consists of a collection of direct positions in a coordinate space that may be defined in terms of up to three spatial dimensions as well as a temporal dimension. Examples of coverages include rasters, triangulated irregular networks, point coverages and polygon coverages. Coverages are the prevailing data structures in a number of application areas, such as remote sensing, meteorology and mapping of bathymetry, elevation, soil and vegetation. This International Standard defines the relationship between the domain of a coverage and an associated attribute range. The characteristics of the spatial domain are defined whereas the characteristics of the attribute range are not part of this standard.

2 Conformance

This International Standard specifies interfaces for several types of coverage objects. In addition, it supports the interchange of coverage data independently of those interfaces. Thus, it specifies two sets of conformance classes: one for implementation of the interfaces, the other for the exchange of coverage data. Each set includes one conformance class for each type of coverage specified in this International Standard (Table 1).

Table 1 — Conformance classes

Conformance class	Subclause
Simple coverage interface	A.1.1
Discrete coverage interface	A.1.2
Thiessen polygon coverage interface	A.1.3
Quadrilateral grid coverage interface	A.1.4
Hexagonal grid coverage interface	A.1.5
TIN coverage interface	A.1.6
Segmented curve coverage interface	A.1.7
Discrete coverage interchange	A.2.1
Thiessen polygon coverage interchange	A.2.2
Quadrilateral grid coverage interchange	A.2.3
Hexagonal grid coverage interchange	A.2.4
TIN coverage interchange	A.2.5
Segmented curve coverage interchange	A.2.6

In general, the interface conformance classes require implementation of all attributes, associations and operations of relevant classes. This set includes a single conformance class (A.2.1) that supports a simple interface for evaluation of any coverage type, but exposes none of the internal structure of the coverage. The remainder of the set are conformance classes that support interfaces to specific coverage types that expose additional information about the internal structure of the coverage.

The interchange conformance classes require only implementation of the attributes and associations of the relevant classes.

The Abstract Test Suite in Annex A shows the implementation requirements necessary to conform to this International Standard. Table 1 lists the subclauses of the Abstract Test Suite that apply for each conformance class.

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/TS 19103:2005, *Geographic information — Conceptual schema language*

ISO 19107:2003, *Geographic information — Spatial schema*

ISO 19108:2002, *Geographic information — Temporal schema*

ISO 19109:2005, *Geographic information — Rules for application schema*

ISO 19111:2003, *Geographic information — Spatial referencing by coordinates*

ISO 19115:2003, *Geographic information — Metadata*

4 Terms, definitions, abbreviated terms and notation

4.1 Terms and definitions

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

4.1.1
continuous coverage
coverage that returns different values for the same feature attribute at different **direct positions** 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.

4.1.2
convex hull
smallest **convex set** containing a given **geometric object**

[adapted from *Dictionary of Computing*:1996 [2]]

4.1.3
convex set
geometric set in which any **direct position** on the straight-line segment joining any two **direct positions** in the **geometric set** is also contained in the **geometric set**

[*Dictionary of Computing*:1996 [2]]

4.1.4
coordinate
one of a sequence of *n* numbers designating the position of a **point** in *n*-dimensional space

[ISO 19111:2003]

4.1.5
coordinate dimension
number of measurements or axes needed to describe a position in a coordinate system

[ISO 19107:2003]

4.1.6
coordinate reference system
coordinate system that is related to the real world by a datum

[ISO 19111:2003]

41.7
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.

NOTE In other words, a coverage is a feature that has multiple values for each attribute type, where each direct position within the geometric representation of the feature has a single value for each attribute type.

4.1.8
coverage geometry
configuration of the **domain** of a **coverage** described in terms of **coordinates**

4.1.9
curve
1-dimensional **geometric primitive**, representing the continuous image of a line

[ISO 19107:2003]

NOTE The boundary of a curve is the set of points at either end of the curve.

4.1.10
Delaunay triangulation
network of triangles such that the circle passing through the vertices of any triangle does not contain, in its interior, the vertex of any other triangle

4.1.11
direct position
position described by a single set of **coordinates** within a **coordinate reference system**

[ISO 19107:2003]

4.1.12
discrete coverage
coverage that returns the same **feature attribute** values for every **direct position** within any single **spatial object**, **temporal object** or **spatiotemporal object** in its **domain**

NOTE The domain of a discrete coverage consists of a finite set of spatial, temporal, or spatiotemporal objects.

4.1.13
domain
well-defined set

[ISO/TS 19103]

NOTE Domains are used to define the domain and range of operators and functions.

4.1.14
evaluation
⟨**coverage**⟩ determination of the values of a **coverage** at a **direct position** within the **domain** of the coverage

4.1.15
feature
0 abstraction of real world phenomena

[ISO 19101]

4.1.16
feature attribute
characteristic of a **feature**

[ISO 19101]

4.1.17
function
rule that associates each element from a **domain** (source or domain of the function) to a unique element in another **domain** (target, co-domain or **range**)

[ISO 19107:2003]

4.1.18
geometric object
spatial object representing a **geometric set**

[ISO 19107:2003]

4.1.19
geometric primitive
geometric object representing a single, connected, homogeneous element of space

[ISO 19107:2003]

4.1.20
geometric set
set of **direct positions**

[ISO 19107:2003]

4.1.21
geometry value object
object composed of a set of **geometry value pairs**

4.1.22
geometry value pair
ordered pair composed of a **spatial object**, a temporal object or a **spatiotemporal object** and a **record** of **feature attribute values**

4.1.23
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.

4.1.24
grid point
point located at the intersection of two or more **curves** in a **grid**

4.1.25
inverse evaluation
⟨coverage⟩ selection of a set of objects from the **domain** of a **coverage** based on the **feature attribute** values associated with the objects

4.1.26
point
0-dimensional **geometric primitive**, representing a position

[ISO 19107:2003]

NOTE The boundary of a point is the empty set.

4.1.27
point coverage
coverage that has a **domain** composed of **points**

4.1.28
polygon coverage
coverage that has a **domain** composed of polygons

4.1.29
range
⟨coverage⟩ set of **feature attribute** values associated by a **function** with the elements of the **domain** of a **coverage**

4.1.30
raster
usually rectangular pattern of parallel scanning lines forming or corresponding to the display on a cathode ray tube

NOTE A raster is a type of grid.

4.1.31
record
finite, named collection of related items (objects or values)

[ISO 19107:2003]

NOTE Logically, a record is a set of pairs <name, item>.

4.1.32
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.

4.1.33
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.

4.1.34
solid
3-dimensional **geometric primitive**, representing the continuous image of a region of Euclidean 3-space

[ISO 19107:2003]

NOTE A solid is realizable locally as a three-parameter set of direct positions. The boundary of a solid is the set of oriented, closed surfaces that comprise the limits of the solid.

4.1.35
spatial object
object used for representing a spatial characteristic of a **feature**

[ISO 19107:2003]

4.1.36
spatiotemporal domain
⟨coverage⟩ **domain** composed of **spatiotemporal objects**

NOTE The spatiotemporal domain of a continuous coverage consists of a set of direct positions defined in relation to a collection of spatiotemporal objects.

4.1.37
spatiotemporal object
object representing a set of **direct positions** in space and time

4.1.38
surface
2-dimensional **geometric primitive**, locally representing a continuous image of a region of a plane

[ISO 19107:2003]

NOTE The boundary of a surface is the set of oriented, closed curves that delineate the limits of the surface.

4.1.39
tessellation
partitioning of a space into a set of conterminous subspaces having the same dimension as the space being partitioned

NOTE A tessellation composed of congruent regular polygons or polyhedra is a regular tessellation. One composed of regular, but non-congruent polygons or polyhedra is a semi-regular tessellation. Otherwise, the tessellation is irregular.

EXAMPLES Graphic examples of tessellations may be found in Figures 11, 13, 20 and 22 of this International Standard.

4.1.40
Thiessen polygon
polygon that encloses one of a set of **points** on a plane so as to include all **direct positions** that are closer to that point than to any other point in the set

4.1.41
topological dimension
minimum number of free variables needed to distinguish nearby **direct positions** within a **geometric object** from one another

[ISO 19107:2003]

4.1.42
triangulated irregular network
tessellation composed of triangles

4.1.43
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.

4.2 Abbreviated terms

GIS Geographic Information System

TIN Triangulated Irregular Network

UML Unified Modelling Language

4.3 Notation

The conceptual schema specified in this International Standard is described using the Unified Modelling Language (UML) [4], following the guidance of ISO/TS 19103. Annex B describes UML notation as used in this International Standard.

Several model elements used in this schema are defined in other International Standards developed by ISO/TC 211. By convention within ISO/TC 211, names of UML classes, with the exception of basic data type classes, include a two-letter prefix that identifies the standard and the UML package in which the class is defined. UML classes defined in this International Standard have the two-letter prefix of CV. Table 2 lists the other standards and packages in which UML classes used in this International Standard have been defined.

Table 2 — Sources of externally defined UML classes

Prefix	International Standard	Package
EX	ISO 19115	Extent
GF	ISO 19109	General Feature Model
GM	ISO 19107	Geometry
SC	ISO 19111	Spatial Coordinates
TM	ISO 19108	Temporal Schema

5 Fundamental characteristics of coverages

5.1 The context for coverages

5.1.1 General

A coverage is a feature that associates positions within a bounded space (its domain) to feature attribute values (its range). In other words, it is both a feature and a function. Examples include a raster image, a polygon overlay or a digital elevation matrix.

A coverage may represent a single feature or a set of features.

5.1.2 Domain of a coverage

A coverage domain is a set of geometric objects described in terms of direct positions. It may be extended to all of the direct positions within the convex hull of that set of geometric objects. The direct positions are associated with a spatial or temporal coordinate reference system. Commonly used domains include point sets, grids, collections of closed rectangles, and other collections of geometric objects. The geometric objects may exhaustively partition the domain, and thereby form a tessellation such as a grid or a TIN. Point sets and other sets of non-conterminous geometric objects do not form tessellations. Coverage subtypes may be defined in terms of their domains.

Coverage domains differ in both the coordinate dimension of the space in which they exist and in the topological dimension of the geometric objects they contain. Clearly, the geometric objects that make up a domain cannot have a topological dimension greater than the coordinate dimension of the domain. A domain of coordinate dimension 3 may be composed of points, curves, surfaces, or solids, while a domain of coordinate dimension 2 may be composed only of points, curves or surfaces. ISO 19107:2003 defines a number of geometric objects (subtypes of the UML class GM_Object) to be used for the description of features. Many of these geometric objects can be used to define domains for coverages. In addition, ISO 19108:2002 defines TM_GeometricPrimitives that may also be used to define domains of coverages.

Generally, the geometric objects that make up the domain of a coverage are disjoint, but this International Standard does allow a coverage domain to contain overlapping geometric objects.

5.1.3 The range of a coverage

The range of a coverage is a set of feature attribute values. It may be either a finite or a transfinite set. Coverages often model many associated functions sharing the same domain. Therefore, the value set is represented as a collection of records with a common schema.

EXAMPLE A coverage might assign to each direct position in a county the temperature, pressure, humidity, and wind velocity at noon, today, at that point. The coverage maps every direct position in the county to a record of four fields.

A feature attribute value may be of any data type. However, evaluation of a continuous coverage is usually implemented by interpolation methods that can be applied only to numbers or vectors. Other data types are almost always associated with discrete coverages.

Given a record from the range of a coverage, inverse evaluation is the calculation and exposure of a set of geometric objects associated with specific values of the attributes. Inverse evaluation may return many geometric objects associated with a single feature attribute value.

EXAMPLE Inverse evaluation is used for the extraction of contours from an elevation coverage and the extraction of classified regions in an image.

5.1.4 Discrete and continuous coverages

Coverages are of two types. A discrete coverage has a domain that consists of a finite collection of geometric objects and the direct positions contained in those geometric objects. A discrete coverage maps each geometric object to a single record of feature attribute values. The geometric object and its associated record form a geometry value pair. A discrete coverage is thus a discrete or step function as opposed to a continuous coverage. Discrete functions can be explicitly enumerated as (input, output) pairs. A discrete coverage may be represented as a collection of ordered pairs of independent and dependent variables. Each independent variable is a geometric object and each dependent variable is a record of feature attribute values.

EXAMPLE A coverage that maps a set of polygons to the soil type found within each polygon is an example of a discrete coverage.

A continuous coverage has a domain that consists of a set of direct positions in a coordinate space. A continuous coverage maps direct positions to value records.

EXAMPLE Consider a coverage that maps direct positions in San Diego County to their temperature at noon today. Both the domain and the range may take an infinite number of different values. This continuous coverage would be associated with a discrete coverage that holds the temperature values observed at a set of weather stations.

A continuous coverage may consist of no more than a spatially bounded, but transfinite set of direct positions, and a mathematical function that relates direct position to feature attribute value. This is called an analytical coverage.

EXAMPLE A statistical trend surface that relates land value to position relative to a city centre is an example of a continuous coverage.

More often, the domain of a continuous coverage consists of the direct positions in the union or in the convex hull of a finite collection of geometric objects; it is specified by that collection. In most cases, a continuous coverage is also associated with a discrete coverage that provides a set of control values to be used as a basis for evaluating the continuous coverage. Evaluation of the continuous coverage at other direct positions is done by interpolating between the geometry value pairs of the control set. This often depends upon additional geometric objects constructed from those in the control set; these additional objects are typically of higher topological dimension than the control objects. In this International Standard, such objects are called geometry value objects. A geometry value object is a geometric object associated with a set of geometry value pairs that provide the control for constructing the geometric object and for evaluating the coverage at direct positions within the geometric object.

EXAMPLE Evaluation of a triangulated irregular network involves interpolation of values within a triangle composed of three neighbouring point value pairs.

5.2 The coverage schema

The coverage schema is organized into seven packages with the inter-package dependencies shown in Figure 1. The Coverage Core package is documented in this clause, and each of the other packages is described in a separate clause as shown in Table 3.