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Entwurf**Geoinformation- Coverage Geometrie- und Funktionsschema –
Teil 3: Grundlagen der Verarbeitung (ISO/DIS 19123-3:2021);
Englische Fassung prEN ISO 19123-3:2022**

Geographic information –
Schema for coverage geometry and functions –
Part 3: Processing fundamentals (ISO/DIS 19123-3:2021);
English version prEN ISO 19123-3:2022

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Nationales Vorwort

Dieses Dokument (prEN ISO 19123-3:2022) wurde vom Technischen Komitee ISO/TC 211 „Geographic information/Geomatics“ in Zusammenarbeit mit dem Technischen Komitee CEN/TC 287 „Geoinformation“ erarbeitet, dessen Sekretariat von BSI (Vereinigtes Königreich) gehalten wird.

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Nationaler Anhang NA (informativ)

Begriffe, Abkürzungen und Schreibweisen

Die Benennungen der folgenden Begriffe, Abkürzungen und Schreibweisen sind identisch mit den Benennungen in der englischen Fassung.

3 Begriffe, Abkürzungen und Schreibweisen

3.1 Begriffe

Für die Anwendung dieses Dokuments gelten die folgenden Begriffe.

ISO und IEC stellen terminologische Datenbanken für die Verwendung in der Normung unter den folgenden Adressen bereit:

- ISO Online Browsing Platform: verfügbar unter <https://www.iso.org/obp>
- IEC Electropedia: verfügbar unter <https://www.electropedia.org/>

3.1.1

Achse

<Koordinatengeometrie> lineares Merkmal, aus dem ein eindimensionales Koordinatensystem konstruiert wird

Anmerkung 1 zum Begriff: Diese Definition wird in Übereinstimmung mit ISO 19111:2019, 10.4 festgelegt.

[QUELLE: ISO 19123-1:2021, 3.1.2]

3.1.2

Koordinate

eine der Sequenzen von Nummern, die die Position eines Punkts bezeichnen

Anmerkung 1 zum Begriff: Eine direkte Position wird durch eine geordnete Folge von Koordinaten beschrieben. Die Anzahl der Elemente in einer direkten Position wird durch die Anzahl der Achsen der Coverage bestimmt.

[QUELLE: ISO 19123-1:2021, 3.1.2]

3.1.3

Koordinatenreferenzsystem

Koordinatensystem, das über ein Datum mit einem Objekt verbunden ist

Anmerkung 1 zum Begriff: Geodätische und vertikale Daten werden als Referenzrahmen bezeichnet.

Anmerkung 2 zum Begriff: Das Objekt für geodätische und vertikale Referenzrahmen ist die Erde. In planetarischen Anwendungen können geodätische und vertikale Referenzrahmen auf andere Himmelskörper angewendet werden.

[QUELLE: ISO 19111:2019, 3.1.9]

3.1.4

Coverage

Merkmal, das als Funktion fungiert, um Werte aus seinem Bereich für eine beliebige direkte Position innerhalb seines Bereichs zurückzugeben

[QUELLE: ISO 19123-1:2021, 3.1.8]

3.1.5

Coverage CRS

gemeinsames CRS, in dem alle Koordinaten eines Coverages ausgedrückt werden

Anmerkung 1 zum Begriff: Manchmal wird das CRS eines Coverages auch als natives Coverage des CRS bezeichnet.

[QUELLE: ISO 19123-1:2021, 3.1.9]

3.1.6

(Coverage) dimension

Koordinatendimension

<Koordinatengeometrie> Anzahl der Einzelentscheidungen, die zur Beschreibung einer Position in einem Koordinatensystem erforderlich sind

Anmerkung 1 zum Begriff: Dies ist gleichbedeutend mit „Anzahl der Achsen im Koordinatenreferenzsystem des Erfassungsbereichs“.

[QUELLE: ISO 19123-1:2021, 3.1.10]

3.1.7

direkte Position

<geographische Information> durch eine einzelne Menge von Koordinaten beschriebene Position innerhalb eines Koordinatenreferenzsystems

Anmerkung 1 zum Begriff: Zellen in einem Raster-Coverage werden durch ihre direkte Position im Domain-Set dieses Coverage identifiziert.

[QUELLE: ISO 19123-1:2021, 3.1.13]

3.1.8

Bereich

wohldefiniertes (Fach-) Gebiet oder bestimmter Wertebereich

Anmerkung 1 zum Begriff: Alle Elemente innerhalb eines Bereichs sind von einem bestimmten Typ.

[QUELLE: ISO 19123-1:2021, 3.1.16]

3.1.9

Evaluation

<coverage> Bestimmung der Werte eines Coverage an einer direkten Position innerhalb des Bereichs des Coverage

[QUELLE: ISO 19123-1:2021, 3.1.18]

3.1.10

Gitter

<coverage> nicht leere, geordnete Menge von Achsen mit einer Menge von Positionen entlang jeder Achse, die als Referenzpunkte für zusammenhängende kompakte glatte Hypersurfaceflächen dienen

Anmerkung 1 zum Begriff: In ISO 19123:2005 besteht ein Gitter aus einem Netz, das aus einer oder mehreren Gruppen von Kurven besteht, in denen sich die Elemente jeder Gruppe mit den Elementen der anderen Gruppen schneiden. Diese Definition soll auch auf den 1-D-Fall anwendbar sein.

Anmerkung 2 zum Begriff: Die Definition nach ISO 19123:2005 entspricht der überarbeiteten Definition in diesem Dokument.

[QUELLE: ISO 19123-1:2021, 3.1.28]

3.1.11

Gitterkoordinatenreferenzsystem

Gitter-CRS

Koordinatenreferenzsystem für die Positionen in einem Gitter, das ein festgelegtes Koordinatensystem verwendet, das mit dem durch das „GridEnvelope“ (Gitterwerk) und die „axisLabels“ (Achsenbezeichnungen) von `gml:GridType` beschriebenen Koordinatensystem kongruent ist

Anmerkung 1 zum Begriff: Der Gitter-CRS ist identisch mit dem CRS der durch dieses Gitter definierten Coverage.

[QUELLE: ISO 19123-1:2021, 3.1.29]

3.1.12

Rasterkoordinaten

Folge von zwei oder mehr Zahlen, die eine Position in Bezug auf deren Lage in einem Raster angeben

[QUELLE: ISO 19115-2:2019, 3.15]

3.1.13

Indexkoordinatenreferenzsystem

Index CRS

mehrdimensionales, nicht georeferenziertes kartesisches Gitterkoordinaten-Referenzsystem

[QUELLE: ISO 19115-2:2019, 3.1.39]

3.1.14

(Coverage) Abtastfunktion

Funktion zur Extraktion von Informationen aus dem Coverage

3.1.15

Bereich

<Coverage> Wertevorrat, der durch eine Funktion, den Coverage, mit den Elementen des Bereichs des Coverage verbunden ist

Anmerkung 1 zum Begriff: Dies ist konsistent mit der allgemeineren Definition des Bereichs in ISO 19107:2019.

[QUELLE: ISO 19123-1:2021, 3.1.47]

3.2 Abkürzungen

CRS Koordinatenreferenzsystem (en: Coordinate Reference System)

3.3 Schreibweisen

Tabelle 1 listet die anderen Standards und Pakete auf, in denen die in diesem Dokument verwendeten UML-Klassen definiert wurden.

Tabelle 1 — Quellen von extern definierten UML-Klassen

Präfix	ISO Standard	Paket
CV	ISO 19123-1	Coverage Core

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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).

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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*.

A list of all parts in the ISO 19123 series can be found on the ISO website.

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

This standard defines, at a high, implementation-independent level, operations on coverages – i.e., digital representations of space-time varying geographic phenomena – as defined in ISO 19123-1. Specifically, regular and irregular grid coverages are addressed. The operations can be applied through an expression language allowing composition of unlimited complexity and combining an unlimited number of coverages for data fusion.

- Entwurf -

Geographic information — Schema for coverage geometry and functions — Part 3: Processing Fundamentals

1 Scope

This document defines a coverage processing language for server-side extraction, filtering, processing, analytics, and fusion of multi-dimensional geospatial coverages representing, for example, spatio-temporal sensor, image, simulation, or statistics datacubes. Services implementing this language provide access to original or derived sets of coverage information, in forms that are useful for client-side consumption.

ISO 19123-3 relies on the abstract coverage model defined in ISO 19123-1. In this document, regular and irregular multi-dimensional grids are supported, for axis that may carry spatial, temporal, or any other semantics. Future versions may additionally support further axis types as well as point clouds and meshes.

The language is functionally defined and free of any side effects has a solid conceptual foundation; only two constructs establish all coverage processing:

A coverage constructor builds a coverage, either from scratch or by deriving it from one or more other coverages.

The ISO 19123-3 language is independent from any particular request and response encoding, as no concrete request/response protocol is assumed. Hence, this standard does not define a service, but acts as the foundation for defining service standards functionality. One such target framework is OGC Web Coverage Service (WCS)^[3].

In its current version ISO 19123-3 supports ISO 19123-1 grid coverages with index, regular, and irregular axes. In the future it is foreseen that the standard gets extended so as to address all coverage types of ISO 19123-1.

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 19123-1:2021, *Geographic information — Coverage Fundamentals*

3 Terms, definitions, abbreviated terms and notation

3.1 Terms and definitions

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

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

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1.1

axis

(coordinate geometry) linear feature from which a one-dimensional coordinate system is constructed

Note 1 to entry: This definition is established in accordance with ISO 19111:2019, Clause 10.4.

[SOURCE: ISO 19123-1:2021, 3.1.2]

3.1.2

coordinate

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

Note 1 to entry: A direct position is described by an ordered sequence of coordinates. The number of elements in a direct position is established by the number of axes of the coverage.

[SOURCE: ISO 19123-1:2021, 3.1.2]

3.1.3

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.

[SOURCE: ISO 19111:2019, 3.1.9]

3.1.4

coverage

feature that acts as a function to return values from its range for any direct position within its domain

[SOURCE: ISO 19123-1:2021, 3.1.8]

3.1.5

coverage CRS

the common CRS in which all coordinates of a coverage are expressed

Note 1 to entry: Sometimes a coverage's CRS is also referred to as the coverage's native CRS.

[SOURCE: ISO 19123-1:2021, 3.1.9]

3.1.6

(coverage) dimension

coordinate dimension

<coordinate geometry> number of separate decisions needed to describe a position in a coordinate system

Note 1 to entry: This is equivalent to "the number of axes in the coordinate reference system of the coverage domain set".

[SOURCE: ISO 19123-1:2021, 3.1.10]

3.1.7

direct position

<geographic information> position described by a single set of coordinates within a coordinate reference system

Note 1 to entry: Cells in a grid coverage are identified by their direct position in the domain set of this coverage.

[SOURCE: ISO 19123-1:2021, 3.1.13]

3.1.8

domain

well-defined set

Note 1 to entry: All elements within a domain (set) are of a given type.

[SOURCE: ISO 19123-1:2021, 3.1.16]

3.1.9

evaluation

<coverage> determination of the values of a coverage at a direct position within the domain of the coverage

[SOURCE: ISO 19123-1:2021, 3.1.18]

3.1.10

grid

<coverage> nonempty, ordered set of axes with a set of positions along each axis acting as reference points for connected compact smooth hypersurfaces

Note 1 to entry: In ISO 19123:2005, a grid consists of a network composed of one or more sets of curves in which the members of each set intersect the members of the other sets. This definition is intended to be applicable also to the 1-D case.

Note 2 to entry: The ISO 19123:2005 definition is equivalent to the revised definition of this document.

[SOURCE: ISO 19123-1:2021, 3.1.28]

3.1.11

grid coordinate reference system

coordinate reference system for the positions in a grid that uses a defined coordinate system congruent with the coordinate system described by the GridEnvelope and axisLabels of gml:GridType

Note 1 to entry: The grid's CRS is identical to the CRS of the coverage defined by that grid.

[SOURCE: ISO 19123-1:2021, 3.1.29]

3.1.12

grid coordinates

sequence of two or more numbers specifying a position with respect to its location on a grid

[SOURCE: ISO 19115-2:2019, 3.15]

3.1.13

index coordinate reference system

Index CRS

multi-dimensional non-georeferenced Cartesian grid coordinates reference system

[SOURCE: ISO 19115-2:2019, 3.1.39]

3.1.14

(coverage) probing function

function extracting information from the coverage

3.1.15

range

<coverage> set of feature attribute values associated by a function, the coverage, with the elements of the domain of a coverage

Note 1 to entry: This is consistent with the more generic definition of range in ISO 19107:2019.

[SOURCE: ISO 19123-1:2021, 3.1.47]

3.2 Abbreviated terms

CRS Coordinate Reference System

3.3 Notation

Table 1 lists the other standards and packages in which UML classes used in this document have been defined.

Table 1 — Sources of externally defined UML classes

Prefix	International Standard	Package
CV	ISO 19123-1	Coverage Core

4 Conformance

4.1 Interoperability and Conformance Testing

This document being an abstract standard allows for multiple different implementations and does not define a standardized interoperable implementation. Hence, standardization target primarily are specifications of coverage operations and services which may use this language to describe the semantics of their operations.

Conformance testing is accomplished by validating a candidate concretization against all requirements by exercising the tests set out in Annex A.

4.2 Organization

Table 2 — Conformance classes

Conformance class	Clause	Identifying URL
Coverage Processing	6	https://standards.iso211.org/19123/-3/1/conf/coverage-processing

5 Coverage model

5.1 Overview

This standard defines a language whose expressions accept any number of input coverages (together with further common inputs like numbers) to generate any number of output coverages. Coverages are defined in ISO 19123-1.

5.2 Coverage model

For the reader's convenience a brief informal (and non-normative) recapitulation is given. Following the mathematical notion of a function that maps elements of a domain (here: spatio-temporal coordinates) to a range (here: "pixel", "voxel", etc. values), a coverage consists of (Figure 1):

- an *identifier* which uniquely identifies a coverage in some context (here: the context of an expression)
- a *domain set* of coordinate points (expressed in a common Coordinate Reference System, CRS): “*where in the multi-dimensional space can I find values?*”
- a probing function which answers for each coverage coordinate in the domain set (“*direct position*”): “*what is the value here?*”
- a *range type*: “*what do those values mean?*”
- optional *metadata*: “*what else should I know about these data?*”

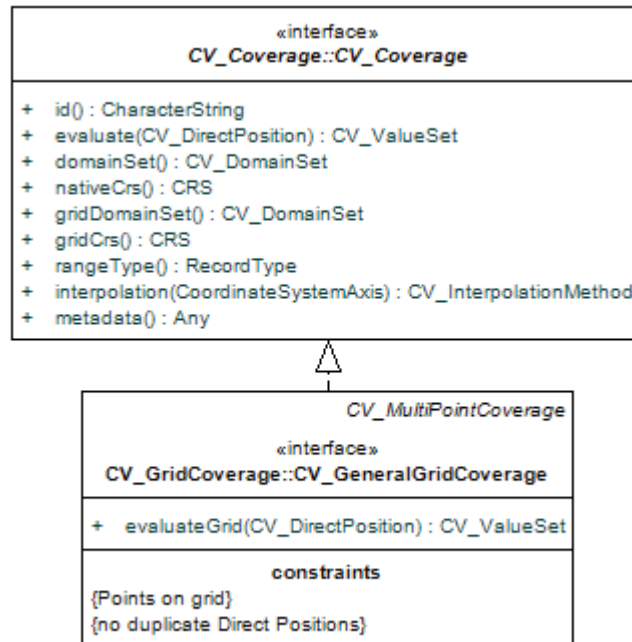


Figure 1 — CV_Coverage and CV_GeneralGridCoverage with CV_Grid (ISO 19123-1)

NOTE CV_Coverage in ISO 19123-1 defines an interface which describes such an object’s behavior, but does not yet assume any particular data structure.

Below a brief recapitulation of ISO 19123-1 grid coverages is given; at the same time, probing functions are introduced which extracts components from some given coverage. These probing functions are defined as part of the ISO 19123-1 interface class definition. They serve to define this standard’s language semantics in Clause 6.

5.3 Coverage Identifier

Coverages have an identifier which is used in a ISO 19123-3 query to address a coverage. Therefore, this identifier must be unique within some context (here: an ISO 19123-3 query).

NOTE In a concrete service, coverages available typically would be those which are stored on this server, where access control allows addressing the coverage according to the user sending the request, etc. All these aspects are out of scope of this standard.

The corresponding ISO 19123-1 probing function for a coverage *C* is:

id(C)

Frequently new coverages are created in a query; initially, they do not carry any identifier, rather their id value is the empty string.

5.4 Domain Set

The domain set contains the coordinate tuples describing the coverage’s direct positions, which for the purpose of this standard all sit on a multi-dimensional grid. Informally speaking this means that every

direct position inside the grid has exactly one next neighbor in both directions of every axis, except for the rim where obviously less neighbours are available. Figure 2 shows some regular and irregular grid examples.

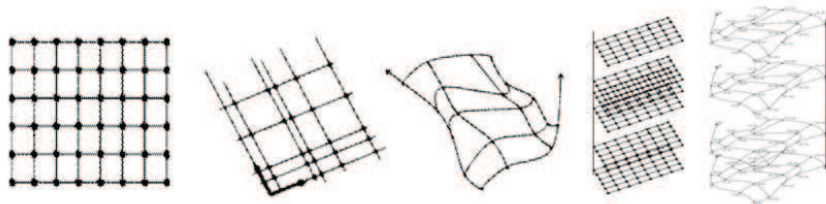


Figure 2 — Sample regular and irregular grid structures (ISO 19123-1)

The grid description depends on the complexity of the grid. As a grid is composed from an ordered sequence of axes the resulting complexity is determined by the types of axes (such as integer versus Lat versus time) as well as the rules determining the direct positions along these axes. The following axis types defined in ISO 19123-1 are supported by ISO 19123-3:

- A **Cartesian** (“index”) axis just requires lower and upper bound (which are of type integer).
- A **regular** axis which can be described by lower and upper bounds together with a constant distance, the resolution.
- An **irregular** axis which has individual distances, described by a sequence of coordinates.

NOTE 1 As explained in ISO 19123-1, the specialized grid types of superseded ISO 19123:2005 can be modeled through the ISO 19123-1 GeneralGridCoverage concept: a RectifiedGrid is a grid where all axes are of type Cartesian or regular; a ReferenceableGrid is a grid where at least one axis is not of these types.

As per ISO 19123-1, the coverage domain set with its axes has a single native CRS which may allow georeferencing. Additionally, the underlying grid structure is defined through a Cartesian grid CRS. Both CRSs have the same dimension, i.e.: number of axes. CRSs are addressed by name in ISO 19123-3 expressions. Both ISO 19123-1 and ISO 19123-3 do not make any assumptions about the nature of identifying CRSs, but rather treat them as opaque strings.

The native CRS of a domain set is obtained through function $crs(C)$, its grid CRS through function $gridCrs(C)$.

$nativeCrs(C)$
 $gridCrs(C)$

The particular definition of CRSs and axes is out of the scope of this standard, rather this is defined in ISO 19111. That said, this standard assumes an auxiliary probing function $axisList()$ which extracts the ordered list of axes $(a_1, \dots, a_d)$ from such a d-dimensional CRS:

$axisList(crs)$

NOTE 2 This function can be applied to both native and grid CRSs, so only one such function is necessary.

Each axis contributes coordinates from some nonempty, totally ordered set of values which can be numeric or, in the general case, strings (such as “2020-08-05T”).

For some given coverage C , two probing functions deliver the domain set of a coverage in its native CRS and in its Cartesian grid CRS, respectively:

$domainSet(C)$
 $gridDomainSet(C)$

The contents of the domain information describes the coverage's extent:

- a) for each axis the lower and upper bound of the Direct Positions are listed in axis order
- b) per axis, the following information is available:
 - 1) for index axes: nothing further;
 - 2) for regular axes: the resolution;
 - 3) for irregular axes: the sequence of points.

The contents of the grid information usually is simpler than the native domain because the underlying CRS is always index-only. Consequently, it consists of a list of lower bound / upper bound pairs, one per axis.

This information is accessible through overloaded versions of the abovementioned functions. For some coverage C that has an axis a , the following expressions return lower and upper bound, respectively:

$domainSet(C, a).lo$
 $domainSet(C, a).hi$
 $gridDomainSet(C, a).lo$
 $gridDomainSet(C, a).hi$

5.5 Interpolation

In ISO 19123-1 a coverage contains admissible interpolation information, characterized individually per axis.

NOTE 1 As per ISO 19123-1 every coverage has one interpolation method associated per axis. In practice, coverages may allow several interpolation methods to be picked by the user. Conceptually, however, two coverages differing only in the interpolation methods are distinct as they will deliver identical range values on their direct positions, but differing values in between those. On the abstract level of ISO 19123-1 this ambiguity is not desirable.

For the purpose of this standard a special interpolation method *none* is assumed in addition to those defined, e.g., in ISO 19123-1, Annex B. *None* indicates that no interpolation is possible along the axis under consideration.

NOTE 2 Interpolation method *none* is different from nearest-neighbor: An interpolation of nearest-neighbor provides values inbetween Direct Positions which are derived from the closest Direct Position. Interpolation *none* means that no values are provided between Direct Positions, in other words: the evaluation function is undefined on any non-Direct Position.

Function $interpolation(C, a)$ returns the list of interpolation methods applicable on each axis of coverage C , in order of the axis sequence. For $dimension(C)=d$ the probing function delivers interpolation method list $(m_1, \dots, m_d)$:

$interpolation(C)$

This function is overloaded to extract the interpolation method associated with axis a of C :

$interpolation(C, a)$

NOTE 3 Interpolation is particularly relevant with functions *scale()* and *project()*.

5.6 Range Values

The range value at some direct position can be obtained with function $evaluate_c(p)$ which, for some given coverage C , returns the value associated with $p \in domainSet(C)$ expressed in the coverage's native CRS. Simultaneously, function $evaluateGrid_c(p)$ does the same for some $p \in gridDomainSet(C)$ expressed in the coverage's grid CRS. The mechanics of a coverage, as per ISO 19123-1, ensures coherence between native and (Cartesian) grid coordinates.

The corresponding probing function integrates native CRS and grid CRS based access as per ISO 19123-1:

$value(C,p) := evaluateC(p)$ for some location $p \in domainSet(C)$
 $value(C,p) := evaluateGridC(p)$ for some location $p \in gridDomainSe(C)$

Interpolation guides whether the *value* () function is defined on coordinates outside the Direct Position set, and how this value is determined from the values available at the Direct Positions.

5.7 Range Type

A coverage's range type description can be obtained through probing function *rangeType*() which delivers a set of tuples containing at least field names and field type:

rangeType(C)

Again, this function gets overloaded to obtain the coverage range type of some particular range field component *f*:

rangeType(C, f)

For the purpose of this standard only the common programming language data types are considered, and only on a high, abstract level: Boolean, integer, float, complex, as well as records over those are assumed to be available.

NOTE The concrete range types available in coverage processing are determined by concretizations of ISO 19123-3. Typically, the standard programming language data types will be available, such as (unsigned) short, int, and long, as well as float and double. For example, the range type (aka pixel) of an 8-bit RGB image normally is given by the triple < red: unsigned char; green: unsigned char; blue: unsigned char>. Further, a concretization may add more information such as null values, accuracy, etc. such as described in the OGC Sensor Web Enablement (SWE).

5.8 Metadata

The metadata component of a coverage can contain any information. Therefore, its syntax and semantics is not defined in ISO 19123-1 nor in ISO 19123-3. Consequently, the metadata component is treated as an abstract container without any operation beyond getting and setting the complete metadata string of a coverage. The corresponding probing function is:

metadata(C)

5.9 Coverage probing functions synopsis

Requirement 1 <https://standards.iso/211.org/19123/-3/1/req/core/probingFunctions>

The semantics of the probing functions used for the ISO 19123-1 language semantics definition **shall** be given by Table 3.

Table 3 — Coverage probing functions synopsis

Coverage characteristic	Probing function for some coverage C, based on ISO 19123-1	Comment
Coverage identifier	<i>id(C)</i> as per ISO 19123-1	Identifier of the coverage
Coverage native CRS	<i>nativeCrs(C)</i> as per ISO 19123-1	Native CRS of the coverage
Coverage grid CRS	<i>gridCrs(C)</i> as per ISO 19123-1	Grid CRS of the coverage

Coverage characteristic	Probing function for some coverage C , based on ISO 19123-1	Comment
CRS axis list	$axisList(crs)$ = $(a_1, \dots, a_d)$ for some d -dimensional CRS crs establishing this axis sequence	List of all axes of the CRS, in proper sequence
Domain extent of coverage, in its native CRS	$domainSet(C)$ as per ISO 19123-1 $domainSet(C, a)$ = domain extent along axis a $domainSet(C, a).lo$ = lower bound of domain extent along axis a $domainSet(C, a).hi$ = upper bound of domain extent along axis a	Extent of the coverage in native CRS coordinates
Domain extent of coverage, in its grid CRS	$gridDomainSet(C)$ as per ISO 19123-1 $gridDomainSet(C)$ = grid domain extent along axis a $gridDomainSet(C, a).lo$ = lower bound of grid domain extent along axis a $gridDomainSet(C, a).hi$ = upper bound of grid domain extent along axis a	Extent of the coverage in Cartesian grid coordinates, relative to the coverage's grid CRS
Range type	$rangeType(C)$ as per ISO 19123-1 $rangeType(C, f)$ = t where $(f, t, \dots) \in rangeType(C)$	The range type record is described by a list describing its components in sequence; for the purpose of 190123-3 only component name and its data type are considered.
Range field name list	$rangeFieldNames(C)$ = $(f_1, \dots, f_n)$ where $rangeType(C) = ((f_1, t_1, \dots), \dots, (f_n, t_n, \dots))$, with field names f_i and types t_i	Ordered list all of the coverage's range fields names and their data types; possible further constituents in a record component are ignored in this standard, their values are to be defined elsewhere (e.g., implementation dependent)
Range values	$value(C, p)$ = $evaluate_C(p), p \in domainSet(C)$ $value(C, p)$ = $evaluateGrid_C(p), p \in gridDomainSet(C)$ with $evaluate()$ as per ISO 19123-1	Direct Positions can be expressed either in the native or the grid CRS
Interpolation	$interpolation(C)$ as per ISO ISO 19123-1 $interpolation(C, a)$ = interpolation method of axis a	List of the interpolation method allowed per axis, in axis order Interpolation associated with a particular axis
Metadata of coverage	$metadata(C)$ as per ISO 19123-1	a string without further structure nor semantics, seen from a ISO 19123-1 perspective

6 Coverage Processing Language

The ISO 19123-3 coverage processing language defines expressions on coverages which evaluate to ordered lists of either coverages or scalars (whereby “scalar” here is used as a summary term of all data structures that are not coverages). In the sequel, the terms *processing expression* and *query* are used interchangeably.

An ISO 19123-3 coverage processing expression consists of a **processCoveragesExpr** (see Subclause 6.2). Each standard claiming to support ISO 19123-3 must provide the coverage processing operation as specified in the following subclauses.

NOTE 1 ISO 19123-3 has been designed so as to be “safe in evaluation” – i.e., implementations are possible where any valid ISO 19123-3 request can be evaluated in a finite number of steps, based on the operation primitives. Hence, services based on the ISO 19123-3 constructs can be built in a way that no single request can render the service permanently unavailable. This notwithstanding, it still is possible to send requests that will impose high workload on a server.

NOTE 2 Data items within a ISO 19123-3 query result list can be heterogeneous in size and structure. In particular, the coverages within an evaluation result list can have different dimensions, domains, range types, etc. However, a result list always consists of either coverages or scalar values, no mix of both.

6.1 Syntax and Semantics Definition Style

6.1.1 Expression Syntax

The ISO 19123-3 primitives plus the nesting capabilities form an expression language which is independent from any particular encoding and service protocol; collectively it is referred to as the **ISO 19123-3 language**. In the following subsections the language elements are detailed. The complete syntax is listed in Appendix B.

An ISO 19123-3 expression is called **admissible** if and only if it adheres to the syntax of the ISO 19123-3 language definition.

Requirement 2 <https://standards.iso/211.org/19123/-3/1/req/core/syntax>
ISO 19123-3 expressions **shall** adhere to the ISO 19123-3 syntax definition of Annex B.

EXAMPLE The coverage expression fragment $\$c * 2$ is admissible as it adheres to ISO 19123-3 syntax whereas $\$c \c seen as part of a coverage expression violates ISO 19123-3 syntax and, hence, is not admissible.

6.1.2 Expression Semantics

The semantics of a ISO 19123-3 expression is defined recursively by indicating, for all admissible expressions, the semantics. An expression is **valid** if and only if it is admissible and complies with all rules imposed by the ISO 19123-3 language semantics.

Requirement 3 <https://standards.iso/211.org/19123/-3/1/req/core/semantics>
ISO 19123-3 expressions **shall** adhere to all semantics rules of this standard.

EXAMPLE The coverage expression following is valid if and only if the coverage bound to variable $\$c$ has a numeric range component named `red`.

$\$c.red * 2.5$

NOTE In the remainder of this clause, tables are used to describe the effect of an operation on each coverage constituent. For the reader's convenience an extra column “Changed?” is provided containing an “X” character whenever the operation changes the resp. constituent, and left blank whenever the operation does not affect the resp. constituent.

The semantics of ISO 19123-3 expressions is defined via so-called *probing functions* which extract information from a coverage.

6.2 Coverage Processing Expressions

6.2.1 processCoveragesExpr

A **processCoveragesExpr** element processes a list of coverages in turn. Each coverage is optionally checked first for fulfilling some predicate, and gets selected – i.e., contributes to an element of the result list – only if the predicate evaluates to *true*. Each coverage selected will be processed, and the result will

be appended to the result list. This result list, finally, is returned as the *ProcessCoverages* response unless no exception was generated.

Requirement 4 <https://standards.iso/211.org/19123/-3/1/req/core/processCoveragesExpr>
A **processCoveragesExpr** shall be defined as follows.

Let

$v_1, \dots, v_n$ be n pairwise different **iteratorVars** ($n \in \mathbb{N}$),
 $L_1, \dots, L_n$ be n **coverageLists** ($n \in \mathbb{N}$),
 b be a **booleanScalarExpr** possibly containing occurrences of one or more v_i ($1 \leq i \leq n$),
 P be a **processingExpr** possibly containing occurrences of v_i ($1 \leq i \leq n$).

Then,

$m, n \in \mathbb{N}$ be natural numbers,
 $v_1, \dots, v_n$, be **iteratorVars**,
 $c_1, \dots, c_m$, be n pairwise different **variableNames**,
 $e_1, \dots, e_m$, be $n+m$ optional **coverageExprs** or **scalarExprs** or bracket-enclosed **intervalExprs**,
which may contain occurrences of $v_1, \dots, v_n$ and $c_1, \dots, c_m$,
 c be a **coverageExpr** or **scalarExpr**,
where every c_i is defined before used in an expression.

Then,

for any **processCoveragesExpr** E
where

```

E = for v1 in ( L1 ),
    v2 in ( L2 ),
    ... ,
    vn in ( Ln )
    [ let c1 := e1, ..., cm := em ]
    [ where b ]
    return P

```

the result R of evaluating **processCoveragesExpr** E is constructed as:

```

Let R be the empty sequence;
while L1 is not empty:
{ assign the first element in L1 to iteration variable v1;
  while L2 is not empty:
  { assign the first element in L2 to iteration variable v2;
    ...
    while Ln is not empty:
    { assign the first element in Ln to iteration variable vn;
      substitute every occurrence of ci in E by ei;
      substitute every occurrence of vi in E by the corresponding
coverage;

      evaluate b;
      if (b)
      then
        evaluate P;
        append evaluation result to R;
        remove the first element from Ln;
      }
    }
  }
}

```

```

        remove the first element from  $L_2$ ;
    }
    remove the first element from  $L_1$ ;
}

```

The elements contained in the **coverageList** clause, constituting coverage identifiers, are taken from the coverage identifiers advertised by the server.

NOTE 1 Coverage identifiers may occur more than once in a **coverageList**. In this case the coverage will be evaluated each time it appears, respecting the overall inspection sequence.

EXAMPLE 1 Assume availability of coverages A, B, and C. Then, the following ISO 19123-3 request:

```

for $c in ( A, B, C )
return encode( $c, "image/tiff" )

```

will produce a result list containing three TIFF-encoded coverages.

Assume availability of satellite images A, B, and C and a coverage M acting as a mask (i.e., with range values of 0 and 1 and the same extent as A, B, and C). Then, masking each satellite image can be performed with this query:

```

for $s in ( A, B, C ),
    $m in ( M )
return encode( $s * $m, "image/tiff" )

```

The **let** clause declares a named constant and gives it a value.

EXAMPLE 2 The following statement defines a constant of name \$timeAxis with value "date".

```

let $timeAxis := "date"

```

NOTE 2 In most cases, named constants are used purely for convenience, to simplify the expressions and make the code more readable.

In a **let** clause the named constant only takes one value. This can be a single item or a sequence (there is no real distinction — an item is just a sequence of length one), and the sequence can contain nodes, or atomic values, or (beware!) a mixture of the two.

Named constants cannot be updated – something like `let $x:=$x+1` is not allowed. More specifically, it will not lead to an evaluation error, but the result will not be as expected (cf. XPath literature). This rule might seem very strange if you are expecting ISO 19123-3 to behave in the same way as procedural languages such as JavaScript or python. But ISO 19123-3 isn't that kind of language, it's a declarative language and works at a higher level. This constraint is essential to give optimizers the chance to find execution strategies that can search vast databases in fractions of a second. SQL, XSLT, and XQuery users have found that this declarative style of programming grows on you. You start to realize that it enables you to code at a higher level: you tell the system what results you want, rather than telling it how to go about constructing those results.

6.2.2 processingExpr

Requirement 5 <https://standards.iso/211.org/19123/-3/1/req/core/processingExpr>

A **processingExpr** element shall be either a **encodeCoverageExpr** (see Subclause 6.8.1) or a **scalarExpr** (see Subclause 6.4.1).

6.2.3 coverageExpr

Requirement 6 <https://standards.iso/211.org/19123/-3/1/req/core/coverageExpr>

A **coverageExpr** shall be either a **coverageIdExpr** (see Subclause 6.2.4) or a **coverageConstructorExpr** (see Subclause 6.3.1.1) or a **coverageConstantExpr** (see Subclause 6.3.1.1) or a **agetComponentExpr** (see Subclause 6.4.1) or an **inducedExpr** (see Subclause 6.5.1) or a **subsetExpr** (see Subclause 6.5.6.1) or a **crsTransformExpr** (see Subclause 6.6) or a **scaleExpr** (see Subclause 6.5.7) or a **decodeCoverageExpr** (see Subclause 6.8.2).

NOTE A **coverageExpr** always evaluates to a single coverage.

6.2.4 coverageIdExpr

The **coverageIdExpr** element represents the name of a single coverage available. It is represented by a coverage variable indicated in the **processCoveragesExpr** clause (see Subclause 6.2).

Requirement 7 <https://standards.iso/211.org/19123/-3/1/req/core/coverageIdentifier>
A **coverageIdExpr** shall be defined as follows.

Let

id be a **variableName** bound to a coverage C_1 available.

Then,

for any **coverageExpr** C_2 ,
where

$$C_2 = id$$

C_2 is defined as:

Coverage constituent
$id(C_2) = id(C_1)$
$nativeCrs(C_2) = nativeCrs(C_1)$
$gridCrs(C_2) = gridCrs(C_1)$
$domainSet(C_2) = domainSet(C_1)$
$gridDomainSet(C_2) = gridDomainSet(C_1)$
$interpolation(C_2) = interpolation(C_1)$
$rangeType(C_2) = rangeType(C_1)$
for all $p \in domainSet(C_2)$: $value(C_2, p) = value(C_1, p)$
for all $p \in gridDomainSet(C_2)$: $value(C_2, p) = value(C_1, p)$
$metadata(C_2) = metadata(C_1)$

EXAMPLE The following coverage expression evaluates to the complete, unchanged coverage C , assuming that coverage iteration variable $\$C$ is bound to it at the time of evaluation:

$\$C$

6.3 Coverage-Generating Expressions

6.3.1 Coverage Constructor Expressions

6.3.1.1 coverageConstructorExpr

The **coverageConstructorExpr** element creates a d -dimensional grid coverage for some $d \geq 1$ by defining the coverage's domain set, range type, range set, and metadata through expressions. This allows deriving entirely new shapes, dimensions, and values (see examples below).

The coverage domain set is built from a CRS defining the multi-dimensional axes and the meaning of coordinates, including units of measure; indicating the coordinates of the direct positions, i.e., the points where values sit.

Axis names can be chosen according to the rules of ISO 19123-1; it is recommended to keep native and grid CRS axis names disjoint.

A range type expression optionally creates the coverage range type. In the scope of the embedding ISO 19123-3 condenses this expression defines the range component names as known (immutable) variables. Values derived for some such range component will automatically be cast to the target type of that range component.

A range set expression creates the coverage range set. A **scalarExpr** is evaluated at every direct position of the coverage's domain set.

An optional metadata expression creates the coverage metadata component. As such metadata are not interpreted by the coverage they are represented as a string which may contain any character, depending on the character set supported (which is out of scope of this standard).

Requirement 8 <https://standards.iso/211.org/19123/-3/1/req/core/coverageConstructorExpr>
A **coverageConstructorExpr** shall be defined as follows.

Let

id be an **identifier**,
 D be a **domainExpr**,
 T be a **rangeTypeExpr**,
 R be a **rangeSetExpr**,
 M be a **metadataExpr**.

Where

C is a **coverageConstructorExpr**
with
 $C = \text{coverage } id[D] [T] R [M]$

Let further

d be an **integer** with $d > 0$,
 c be a **crsName** representing a d -dimensional CRS,
 a_i be pairwise distinct **variableNames** for $1 \leq i \leq d$,
 $axis_i$ be pairwise distinct **axisNames** for $1 \leq i \leq d$,
 $ie_{i,1}, ie_{i,2}$ be integer-valued **indexExprs** for $1 \leq i \leq d$ with $ie_{i,1} \leq ie_{i,2}$,
 $ce_{i,1}, ce_{i,2}$ be **indexExprs** for $1 \leq i \leq d$, which are valid coordinates for axis i as per CRS c with $ce_{i,1} \leq ce_{i,2}$,
 res_i be **indexExprs** with $res_1 < \dots < res_d$ for $1 \leq i \leq d$ valid for the i^{th} axis as per c ,
 $xe_{i,1}, \dots$ be **indexExprs** for $1 \leq i \leq d$, which are valid coordinates for axis $axis_i$ as per CRS c with $xe_{i,1} < xe_{i,2} < \dots$,
 $im_1, \dots, im_m$ be **interpolationMethods** for $1 \leq i \leq m$ with $m > 0$.

Where

D is a **domainExpr**

with

```

D = domain set
    crs with
        axis1 axisdef1 [ interpolation1 ],
        ...,
        axisd axisdefd [ interpolationd ]
    
```

And

axisdef_i is one of

```

axisdefi,index      = index(iei,1:iei,2)
axisdefi,regular   = regular (cei,1:cei,2) resolutionresi
axisdefi,irregular = irregular (xei,1, ..., xei,n)
    
```

And

axis names used in the **domainExpr** shall match pairwise against the CRS axes based on their order of occurrence in the *D* expression.

NOTE The axis names *axis_i* are made available in the current context for use as iteration variables in the range set computation where coordinate values get bound to each direct position in turn allowing to inspect each direct position of the coverage. Iterator names may use the axis names defined in the CRS, or may define aliases which are matched with the CRS axis names by their position in the expression.

Let further

n be an **integer** with *d* > 0,
*f*₁, ..., *f*_{*n*} be **fieldNames**,
*t*₁, ..., *t*_{*n*} be **rangeTypes**.

Where

T is a **rangeTypeExpr**

with

```

T = range type
    f1: t1,
    ...
    fn: tn
    
```

Let further

r be a **scalarExpr** possibly containing occurrences of Direct Position coordinates *axis_i* as defined in *D* and range component identifiers *f_j* as defined in *T*,
*c*₁, ..., *c*_{*m*} be **constants** where *m* = |domainSet(*C*)| and all *c_i* have a common type (after applying type coercion as necessary).

Where

R is a **rangeSetExpr**

with *R* one of

```

R1 = range set r
R2 = range set < c1, ..., cm >
    
```

And

R is part of a **coverageConstructorExpr** containing a **domainExpr**.

Let further

m be a **stringExpr**

Where

M is a *metadataExpr*
with
 $M = \text{metadata } m$

Then,

C is defined as the following ISO 19123-1 grid coverage:

Coverage constituent
$id(C) = id$
$nativeCrs(C) = c$ if D is present, otherwise the native CRS resulting from evaluating r
$gridCrs(C) = d$ -dimensional Index CRS of D if present, otherwise the grid CRS resulting from evaluating r
$domainSet(C) =$ domain extent resulting from evaluating D if present, otherwise the domain extent resulting from evaluating r
$gridDomainSet(C) =$ grid domain extent resulting from evaluating D if present, otherwise the grid domain extent resulting from evaluating r
$interpolation(C) = (x_1, \dots, x_d)$ where $x_i = im_i$ where im_i is indicated, otherwise $x_i = none$.
$rangeType(C) = (f_1, t_1), \dots, (f_n, t_n)$ if T is present, otherwise the range type resulting from evaluating r ; if no field names are provided (such as with R_2) then the range field names are implementation-dependent.
for all $p \in domainSet(C)$ and scalarExpr r : $value(C, p) =$ range value resulting from evaluating r , with possible occurrences of a_i substituted by the corresponding p_i coordinate value for all $p \in gridDomainSet(C)$ and scalarExpr r : $value(C, p) =$ range value resulting from evaluating r , with possible occurrences of a_i substituted by the corresponding p_i coordinate value where the may be embedded in a gridPointExpr for all $p \in domainSet(C)$ and rangeConstantExpr r : $value(C, p)$ is determined by assigning each value c_i in turn to a grid point location, whereby assignment proceeds in row-major order (per dimension from the lowest to the highest coordinate, and loops over the grid points with the first axis listed as outermost loop, the next axis listed as next-to-outermost loop, etc., and the last axis listed as innermost loop).
$metadata(C) = m$ if M is present, otherwise the empty string ""

NOTE 1 A concretization of ISO 19123-1 may extend the capabilities of the coverage constant expression by allowing records at Direct Positions, rather than only atomic values.