
**Industrial automation systems and
integration — Product data representation
and exchange —**

Part 50:

**Integrated generic resource: Mathematical
constructs**

iTeh STANDARD PREVIEW

(standards.iteh.ai)

*Systèmes d'automatisation industrielle et intégration — Représentation
et échange de données de produits —*

Partie 50: Ressources génériques intégrées: Constructions mathématiques

<https://standards.iteh.ai/catalog/standards/sist/9ffc0b5-4717-4ce4-a7bb-3e6b6f4eeb48/iso-10303-50-2002>



PDF disclaimer

This PDF file may contain embedded typefaces. In accordance with Adobe's licensing policy, this file may be printed or viewed but shall not be edited unless the typefaces which are embedded are licensed to and installed on the computer performing the editing. In downloading this file, parties accept therein the responsibility of not infringing Adobe's licensing policy. The ISO Central Secretariat accepts no liability in this area.

Adobe is a trademark of Adobe Systems Incorporated.

Details of the software products used to create this PDF file can be found in the General Info relative to the file; the PDF-creation parameters were optimized for printing. Every care has been taken to ensure that the file is suitable for use by ISO member bodies. In the unlikely event that a problem relating to it is found, please inform the Central Secretariat at the address given below.

iTeh STANDARD PREVIEW
(standards.iteh.ai)

[ISO 10303-50:2002](#)

<https://standards.iteh.ai/catalog/standards/sist/9ffc0b5-4717-4ce4-a7bb-3e6b6f4eeb48/iso-10303-50-2002>

© ISO 2002

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either ISO at the address below or ISO's member body in the country of the requester.

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

Printed in Switzerland

Contents	Page
1 Scope	1
2 Normative references	1
3 Terms, definitions, and symbols	2
3.1 Terms defined in ISO 10303-1	2
3.2 Other terms and definitions	2
3.3 Symbols	5
4 Mathematical functions	6
4.1 Introduction	8
4.2 Fundamental concepts and assumptions	8
4.2.1 Mathematical function	8
4.2.2 Mathematical object or value	9
4.2.3 Mathematical expression	10
4.2.4 Mathematical space	10
4.2.5 Mathematical tuple	11
4.2.6 Function domains and ranges	11
4.2.7 Spaces of one-tuples	12
4.2.8 Array function	12
4.2.9 Table function	12
4.2.10 Matrix	12
4.2.11 Inputs and Parameters	13
4.2.12 Function evaluation	14
4.2.13 Function application	14
4.3 Mathematical functions schema constant definitions	14
4.3.1 schema_prefix	15
4.3.2 the elementary spaces	15
4.3.3 the empty space	15
4.3.4 real intervals	15
4.3.5 tuple spaces	16
4.3.6 empty values	16
4.4 Mathematical functions schema type definitions	17
4.4.1 nonnegative_integer	17
4.4.2 positive_integer	17
4.4.3 zero_or_one	17
4.4.4 one_or_two	18
4.4.5 local names for simple types	18
4.4.6 maths_simple_atom	18
4.4.7 maths_atom	19
4.4.8 atom_based_tuple	19
4.4.9 atom_based_value	19
4.4.10 maths_tuple	20
4.4.11 maths_value	20
4.4.12 maths_expression	20
4.4.13 maths_function_select	21
4.4.14 input_selector	21
4.4.15 elementary_space_enumerators	22
4.4.16 ordering_type	23
4.4.17 lower_upper	24
4.4.18 symmetry_type	24

4.4.19	elementary_function_enumerators	25
4.4.20	open_closed	31
4.4.21	space_constraint_type	31
4.4.22	repackage_options	32
4.4.23	extension_options	32
4.4.24	maths_enum_atom	33
4.4.25	dotted_express_identifier	34
4.4.26	express_identifier	34
4.4.27	product_space	34
4.4.28	tuple_space	35
4.4.29	maths_space_or_function	35
4.4.30	real_interval	35
4.5	Mathematical functions schema entity definitions	36
4.5.1	quantifier_expression	36
4.5.2	dependent_variable_definition	37
4.5.3	bound_variable_semantics	37
4.5.4	free_variable_semantics	38
4.5.5	complex_number_literal	38
4.5.6	logical_literal	39
4.5.7	binary_literal	39
4.5.8	maths_enum_literal	39
4.5.9	real_tuple_literal	40
4.5.10	integer_tuple_literal	40
4.5.11	atom_based_literal	40
4.5.12	maths_tuple_literal	41
4.5.13	maths_variable	41
4.5.14	maths_real_variable	42
4.5.15	maths_integer_variable	42
4.5.16	maths_boolean_variable	43
4.5.17	maths_string_variable	43
4.5.18	function_application	44
4.5.19	maths_space	45
4.5.20	elementary_space	46
4.5.21	finite_integer_interval	46
4.5.22	integer_interval_from_min	47
4.5.23	integer_interval_to_max	47
4.5.24	finite_real_interval	47
4.5.25	real_interval_from_min	48
4.5.26	real_interval_to_max	49
4.5.27	cartesian_complex_number_region	49
4.5.28	polar_complex_number_region	50
4.5.29	finite_space	51
4.5.30	uniform_product_space	52
4.5.31	listed_product_space	53
4.5.32	extended_tuple_space	54
4.5.33	function_space	55
4.5.34	maths_function	56
4.5.35	finite_function	57
4.5.36	constant_function	58
4.5.37	selector_function	59
4.5.38	elementary_function	60
4.5.39	restriction_function	60

PRELIMINARY STANDARD PREVIEW

(standards.iteh.ai)

ISO 10303-50:2002

<https://standards.iteh.ai/catalog/standards/sist/9ffc0b5-4717-4ce4-a7bb-3e6b64eeb48/iso-10303-50-2002>

4.5.40	repackaging_function	61
4.5.41	reindexed_array_function	63
4.5.42	series_composed_function	64
4.5.43	parallel_composed_function	64
4.5.44	explicit_table_function	67
4.5.45	listed_real_data	68
4.5.46	listed_integer_data	69
4.5.47	listed_logical_data	69
4.5.48	listed_string_data	70
4.5.49	listed_complex_number_data	71
4.5.50	listed_data	72
4.5.51	externally_listed_data	72
4.5.52	linearized_table_function	73
4.5.53	standard_table_function	75
4.5.54	regular_table_function	76
4.5.55	triangular_matrix	78
4.5.56	strict_triangular_matrix	78
4.5.57	symmetric_matrix	79
4.5.58	symmetric_banded_matrix	80
4.5.59	banded_matrix	81
4.5.60	basic_sparse_matrix	83
4.5.61	homogeneous_linear_function	85
4.5.62	general_linear_function	86
4.5.63	b_spline_basis	87
4.5.64	b_spline_function	88
4.5.65	rationalize_function	89
4.5.66	partial_derivative_function	91
4.5.67	partial_derivative_expression	92
4.5.68	definite_integral_function	94
4.5.69	definite_integral_expression	95
4.5.70	abstracted_expression_function	97
4.5.71	expression_denoted_function	98
4.5.72	imported_point_function	99
4.5.73	imported_curve_function	100
4.5.74	imported_surface_function	100
4.5.75	imported_volume_function	101
4.5.76	application_defined_function	102
4.5.77	mathematical_description	103
4.6	Mathematical functions schema function definitions	104
4.6.1	all_members_of_es	104
4.6.2	any_space_satisfies	106
4.6.3	assoc_product_space	107
4.6.4	atan2	109
4.6.5	bool	110
4.6.6	check_sparse_index_domain	110
4.6.7	check_sparse_loc_range	111
4.6.8	check_sparse_index_to_loc	112
4.6.9	compare_basis_and_coef	113
4.6.10	compare_list_and_value	113
4.6.11	compare_values	114
4.6.12	compatible_complex_number_regions	115
4.6.13	compatible_es_values	117

4.6.14	compatible_intervals	118
4.6.15	compatible_spaces	118
4.6.16	composable_sequence	124
4.6.17	convert_to_literal	124
4.6.18	convert_to_maths_function	125
4.6.19	convert_to_maths_value	125
4.6.20	convert_to_operand	126
4.6.21	convert_to_operands	127
4.6.22	convert_to_operands_premfn	128
4.6.23	definite_integral_check	128
4.6.24	definite_integral_expr_check	129
4.6.25	derive_definite_integral_domain	130
4.6.26	derive_elementary_function_domain	132
4.6.27	derive_elementary_function_range	135
4.6.28	derive_finite_function_domain	137
4.6.29	derive_finite_function_range	138
4.6.30	derive_function_domain	138
4.6.31	derive_function_range	141
4.6.32	domain_from	144
4.6.33	dot_count	145
4.6.34	dotted_identifiers_syntax	145
4.6.35	drop_numeric_constraints	146
4.6.36	enclose_cregion_in_pregion	147
4.6.37	enclose_pregion_in_cregion	151
4.6.38	enclose_pregion_in_pregion	154
4.6.39	equal_cregion_pregion	160
4.6.40	equal_maths_functions	162
4.6.41	equal_maths_spaces	163
4.6.42	equal_maths_values	166
4.6.43	es_subspace_of_es	168
4.6.44	expression_is_constant	169
4.6.45	extract_factors	169
4.6.46	extremal_position_check	170
4.6.47	factor1	171
4.6.48	factor_space	172
4.6.49	free_variables_of	172
4.6.50	function_applicability	173
4.6.51	function_is_1d_array	174
4.6.52	function_is_1d_table	175
4.6.53	function_is_2d_table	176
4.6.54	function_is_array	177
4.6.55	function_is_table	177
4.6.56	has_values_space	178
4.6.57	list_selected_components	180
4.6.58	make_abstracted_expression_function	180
4.6.59	make_atom_based_literal	181
4.6.60	make_b_spline_basis	181
4.6.61	make_b_spline_function	182
4.6.62	make_banded_matrix	182
4.6.63	make_basic_sparse_matrix	183
4.6.64	make_binary_literal	184
4.6.65	make_boolean_literal	184

STANDARD PREVIEW
(standards.iteh.ai)

ISO 10303-50:2002
<https://standards.iteh.ai/catalog/standards/sist/9ffc0b5-4717-4ce4-a7bb-3e6b64eeb48/iso-10303-50-2002>

4.6.66	make_cartesian_complex_number_region	185
4.6.67	make_complex_number_literal	185
4.6.68	make_constant_function	186
4.6.69	make_cos_expression	186
4.6.70	make_definite_integral_expression	187
4.6.71	make_definite_integral_function	187
4.6.72	make_elementary_function	188
4.6.73	make_elementary_space	188
4.6.74	make_environment	189
4.6.75	make_expression_denoted_function	189
4.6.76	make_extended_tuple_space	190
4.6.77	make_finite_function	190
4.6.78	make_finite_integer_interval	191
4.6.79	make_finite_real_interval	191
4.6.80	make_finite_space	192
4.6.81	make_function_application	192
4.6.82	make_function_space	193
4.6.83	make_general_linear_function	194
4.6.84	make_int_literal	194
4.6.85	make_integer_interval_from_min	195
4.6.86	make_listed_complex_number_data	195
4.6.87	make_listed_data	196
4.6.88	make_listed_integer_data	196
4.6.89	make_listed_product_space	197
4.6.90	make_listed_real_data	197
4.6.91	make_logical_literal	198
4.6.92	make_maths_enum_literal	198
4.6.93	make_maths_real_variable	199
4.6.94	make_maths_tuple_literal	199
4.6.95	make_mult_expression	200
4.6.96	make_parallel_composed_function	200
4.6.97	make_partial_derivative_expression	201
4.6.98	make_partial_derivative_function	201
4.6.99	make_polar_complex_number_region	202
4.6.100	make_rationalize_function	202
4.6.101	make_real_interval_from_min	203
4.6.102	make_real_interval_to_max	203
4.6.103	make_real_literal	204
4.6.104	make_regular_table_function	204
4.6.105	make_reindexed_array_function	205
4.6.106	make_repackaging_function	205
4.6.107	make_selector_function	206
4.6.108	make_series_composed_function	207
4.6.109	make_sin_expression	207
4.6.110	make_standard_table_function	208
4.6.111	make_strict_triangular_matrix	208
4.6.112	make_string_literal	209
4.6.113	make_unary_minus_expression	210
4.6.114	make_uniform_product_space	210
4.6.115	max_exists	211
4.6.116	max_included	211
4.6.117	member_of	212

4.6.118	min_exists	217
4.6.119	min_included	217
4.6.120	no_cyclic_domain_reference	218
4.6.121	no_cyclic_space_reference	219
4.6.122	nondecreasing	220
4.6.123	number_superspace_of	220
4.6.124	number_tuple_subspace_check	221
4.6.125	one_tuples_of	221
4.6.126	parallel_composed_function_composability_check	222
4.6.127	parallel_composed_function_domain_check	222
4.6.128	parse_express_identifier	223
4.6.129	partial_derivative_check	224
4.6.130	real_max	225
4.6.131	real_min	225
4.6.132	regular_indexing	226
4.6.133	remove_first	227
4.6.134	repackage	227
4.6.135	shape_of_array	228
4.6.136	simplify_function_application	229
4.6.137	simplify_generic_expression	243
4.6.138	simplify_maths_space	249
4.6.139	simplify_maths_value	250
4.6.140	singleton_member_of	251
4.6.141	space_dimension	252
4.6.142	space_is_continuum	252
4.6.143	space_is_singleton	253
4.6.144	stripped_typeof	254
4.6.145	subspace_of	254
4.6.146	subspace_of_es	260
4.6.147	substitute	261
4.6.148	values_space_of	263
Annex A (normative) Short names of entities		266
Annex B (normative) Information object registration		269
Annex C (informative) Computer-interpretable listings		270
Annex D (informative) EXPRESS-G diagrams		271
Bibliography		282
Index		283

Figures

Figure 1	— Schema relationships of the mathematical_functions_schema	xi
Figure D.1	— EXPRESS-G diagram of the mathematical_functions_schema (1 of 10) . . .	272
Figure D.2	— EXPRESS-G diagram of the mathematical_functions_schema (2 of 10) . . .	273
Figure D.3	— EXPRESS-G diagram of the mathematical_functions_schema (3 of 10) . . .	274
Figure D.4	— EXPRESS-G diagram of the mathematical_functions_schema (4 of 10) . . .	275
Figure D.5	— EXPRESS-G diagram of the mathematical_functions_schema (5 of 10) . . .	276
Figure D.6	— EXPRESS-G diagram of the mathematical_functions_schema (6 of 10) . . .	277

Figure D.7 — EXPRESS-G diagram of the mathematical_functions_schema (7 of 10) . . . 278
Figure D.8 — EXPRESS-G diagram of the mathematical_functions_schema (8 of 10) . . . 279
Figure D.9 — EXPRESS-G diagram of the mathematical_functions_schema (9 of 10) . . . 280
Figure D.10 — EXPRESS-G diagram of the mathematical_functions_schema (10 of 10) . . 281

Tables

Table 1 — Mathematical symbology 6
Table 2 — Orderings indicated by ordering_type 23
Table A.1 — Short names of entities 266

iTeh STANDARD PREVIEW
(standards.iteh.ai)

[ISO 10303-50:2002](https://standards.iteh.ai/catalog/standards/sist/9ffc0b5-4717-4ce4-a7bb-3e6b6f4eeb48/iso-10303-50-2002)

<https://standards.iteh.ai/catalog/standards/sist/9ffc0b5-4717-4ce4-a7bb-3e6b6f4eeb48/iso-10303-50-2002>

Foreword

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

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

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

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

ISO 10303-50 was prepared by Technical Committee ISO/TC 184, *Industrial automation systems and integration*, Subcommittee SC4, *Industrial data*.

This International Standard is organized as a series of parts, each published separately. The structure of this International Standard is described in ISO 10303-1.

Each part of this International Standard is a member of one of the following series: description methods, implementation methods, conformance testing methodology and framework, integrated generic resources, integrated application resources, application protocols, abstract test suites, application interpreted constructs, and application modules. This part is a member of the integrated generic resources series. The integrated generic resources and the integrated application resources specify a single conceptual product data model.

A complete list of parts of ISO 10303 is available from the Internet:

<http://www.nist.gov/sc4/editing/step/titles/>

Annexes A and B form a normative part of this part of ISO 10303. Annexes C and D are for information only.

Introduction

ISO 10303 is an International Standard for the computer-interpretable representation of product information and for the exchange of product data. The objective is to provide a neutral mechanism capable of describing products throughout their life cycle. This mechanism is suitable not only for neutral file exchange, but also as a basis for implementing and sharing product databases, and as a basis for archiving.

This part of ISO 10303 is a member of the integrated resource series. This part of ISO 10303 specifies the **mathematical_functions_schema**.

This part of ISO 10303 specifies EXPRESS data representations for a large class of mathematical functions, expressions, and arrays. They are intended to be used to communicate product property data and related engineering analysis data. Familiarity with the branches of mathematics commonly used in engineering applications is assumed. The central concept is that mathematical functions and arrays are the abstract data objects of interest for expressing any property which requires more than a single number as a value, for describing deterministic relationships between properties, and for documenting behavioural responses of products to varying conditions.

The relationships of the schema in this part of ISO 10303 to other schemas that define the integrated resources of this International Standard are illustrated in Figure 1 using the EXPRESS-G notation. EXPRESS-G is defined in annex D of ISO 10303-11. The documents containing the specifications for these related schemas are identified in note 1 at the beginning of clause 4.

ITIH STANDARD PREVIEW
(standards.iteh.ai)

ISO 10303-50:2002

<https://standards.iteh.ai/catalog/standards/sist/9ffc0b5-4717-4ce4-a7bb-3e6b6f4eeb48/iso-10303-50-2002>

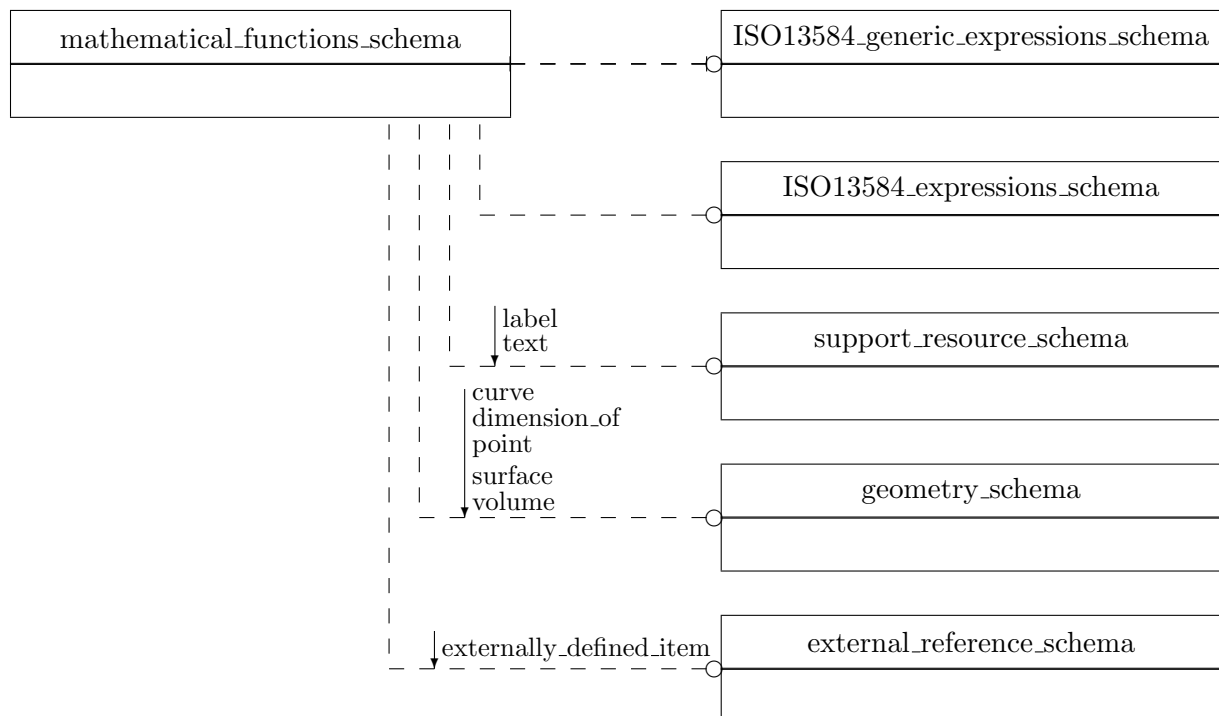


Figure 1 – Schema relationships of the mathematical_functions_schema

iTeh STANDARD PREVIEW
(standards.iteh.ai)

[ISO 10303-50:2002](https://standards.iteh.ai/catalog/standards/sist/9ffc0b5-4717-4ce4-a7bb-3e6b6f4eeb48/iso-10303-50-2002)

<https://standards.iteh.ai/catalog/standards/sist/9ffc0b5-4717-4ce4-a7bb-3e6b6f4eeb48/iso-10303-50-2002>

Industrial automation systems and integration — Product data representation and exchange — Part 50 : Integrated generic resource: Mathematical constructs

1 Scope

This part of ISO 10303 specifies the resource constructs for the explicit representation of mathematical structures and data related to properties of a product.

The following are within the scope of this part of ISO 10303:

- multi-dimensional tables;
- mathematical expressions;
- mathematical functions;
- mathematical spaces.

ITeH STANDARD PREVIEW
(standards.iteh.ai)

[ISO 10303-50:2002](https://standards.iteh.ai/standards/ISO/10303-50:2002)

The following are outside the scope of this part of ISO 10303:

- context of application;
- physical units;
- non-mathematical semantics.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 10303. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 10303 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO/IEC 8824-1:1998, *Information technology — Abstract Syntax Notation One (ASN.1): Specification of basic notation*

ISO 10303-1:1994, *Industrial automation systems and integration — Product data representation and exchange — Part 1: Overview and fundamental principles*

ISO 10303-50:2002(E)

ISO 10303-11:1994, *Industrial automation systems and integration — Product data representation and exchange — Part 11: Description methods: The EXPRESS language reference manual*

ISO 10303-41:2000, *Industrial automation systems and integration — Product data representation and exchange — Part 41: Integrated generic resource: Fundamentals of product description and support*

ISO 10303-42:2000, *Industrial automation systems and integration — Product data representation and exchange — Part 42: Integrated generic resource: Geometric and topological representation*

ISO 13584-20:1998, *Industrial automation systems and integration — Parts Library — Part 20: Logical resource: Logical model of expressions*

3 Terms, definitions, and symbols

3.1 Terms defined in ISO 10303-1

For the purpose of this part of ISO 10303, the following terms defined in ISO 10303-1 apply:

— integrated resource

3.2 Other terms and definitions

iTeh STANDARD PREVIEW
(standards.iteh.ai)

For the purposes of this part of ISO 10303, the following definitions apply:

[ISO 10303-50:2002](https://standards.iteh.ai/catalog/standards/sist/9ffc0b5-4717-4ce4-a7bb-3e6b6f4eeb48/iso-10303-50-2002)

3.2.1

actual function domain

mathematical space containing precisely the tuples of inputs to the function which are related to some tuple of outputs

<https://standards.iteh.ai/catalog/standards/sist/9ffc0b5-4717-4ce4-a7bb-3e6b6f4eeb48/iso-10303-50-2002>

NOTE See the definitions for “mathematical function” and “function domain”. See also 4.2.1 and 4.2.6.

3.2.2

actual function range

mathematical space containing precisely the tuples of outputs from the function which are related to some tuple of inputs

NOTE See the definitions for “mathematical function” and “function range”. See also 4.2.1 and 4.2.6.

3.2.3

array function

function whose domain is either a Cartesian product of finite intervals of integers or the one-tuples from such a Cartesian product

NOTE An element of such a domain is a subscript tuple. Evaluation of the function at such an element produces the “array entry” for that subscript tuple.

3.2.4

bound variable

variable which has been specifically referenced by a quantifier in a quantifier expression

NOTE A bound variable is no longer available for substitution by a constant value. The semantics of the quantifier expression uses all possible values of the variable rather than one (perhaps undetermined) value.

EXAMPLE 1 The variable x in the statement $\forall x(x = x)$.

EXAMPLE 2 The variable x in the set declaration $\{x \mid x^2 = x\}$.

EXAMPLE 3 The variable x in the definite integral $\int_1^2 \ln(x) dx$.

EXAMPLE 4 The variable x in the function definition $f(x) \equiv x + 2$.

3.2.5

Cartesian product space

mathematical space consisting of all ordered tuples whose components are members of the corresponding factor spaces of the product

NOTE Some care must be taken to be explicit about which spaces are the factors entering into the Cartesian product. For example, $R^3 \times R^3$ is the space of ordered pairs of ordered triples from space R , not the space of ordered sextuples from space R . When the factor spaces of the explicit factors are to be treated as the factor spaces of the Cartesian product, that is, the member tuples are to be concatenated rather than entupled, a subscript ‘ a ’ (indicating the “associative” product) is appended to the Cartesian product symbol. Thus, $R^3 \times_a R^3 \equiv R^6$.

3.2.6

compatible spaces

mathematical spaces whose intersection is not empty by the algorithm represented by the EXPRESS function `compatible_spaces`

NOTE Two spaces are compatible if their intersection is not “obviously” empty. In practice, “obvious” is defined by what is detected by the algorithm. The purpose is to rule out some obvious nonsense while permitting ignorance.

3.2.7

computable function

mathematical function for which the relationship between tuples of inputs and tuples of outputs is expressible by means of an algorithm which takes the inputs and produces the related outputs

NOTE All the mathematical functions of interest in the intended applications of this part of ISO 10303 are computable. Nevertheless, the possibility of representing non-computable functions is not ruled out.

3.2.8

expression

language construct composed of constants, variables, operators, quantifiers, and grouping markers, organized in accordance with the language’s grammar and denoting some object in the domain of the language

3.2.9

free variable

variable which has not been bound by a quantifier in the expression in which it is used

NOTE A free variable denotes an undetermined member of some set of possible values. There is an implicit assumption that it may be substituted by any constant denoting one of those values.