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

Part 52:
Integrated generic resource: Mesh-based topology

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

Partie 52: Ressources génériques intégrées: Topologie fondée sur la maille

Reference number
ISO 10303-52:2011(E)

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

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

Attention is drawn to the possibility that some of the elements of this part of ISO 10303 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 10303-52 was prepared by Technical Committee ISO TC184/SC4. *Automation systems and integration,* Subcommittee SC4 *Industrial data.*

ISO 10303 is organised as a series of parts, each published separately. The structure of ISO 10303 is described in ISO 10303-1.

Each part of ISO 10303 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 resource 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 Internet:

`<http://www.tc184-sc4.org/titles/STEP_titles.rtf>`

Should further parts of ISO 10303 be published, they will follow the same numbering pattern.

Introduction

ISO 10303 is an International Standard for the computer-interpretable representation and 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 resources series. Major subdivisions of this part of ISO 10303 are:

— **mesh_topology_schema**;

— **mesh_connectivity_schema**.

— **mesh_function_schema**.

The relationships of the schemas 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 ISO 10303-11. The schemas identified in the bold boxes are specified in this part of ISO 10303. The **support_resource_schema** is specified in ISO 10303-41. The **topology_-schema** is specified in ISO 10303-42. The **mathematical_constructs_schema** and the **mathematical_-functions_schema** are specified in ISO 10303-50. The **mathematical_description_of_distribution_-schema** is specified in ISO 10303-51. The **structural_response_representation_schema** is specified in ISO 10303-104. The **ISO13584_generic_expressions_schema** is specified in ISO 13584-20. Except for **ISO13584_generic_expressions_schema**, the schemas illustrated in Figure 1 are components of the integrated resources.

There are many applications that have to deal with massive amounts of data, which is normally numerical in nature. The quantity of data may be measured in gigabytes and in some cases terabytes. Examples include computational fluid dynamics, dynamic simulation of vehicle behaviour, and experimental data of many kinds ranging from high energy physics to global weather measurements.

A major concern in dealing with such data is to optimise the data representation and structure with respect to data transmission and storage. As part of the optimisation, the data tends to be maintained in large arrays where any particular data element can be referenced by a simple index into the array. When the data is part of a computer simulation the data is usually associated with a mesh of some kind — either structured or unstructured. The data can be bound to the vertices of the mesh or to the cells of the mesh. In any case, it is also possible to represent the simpler kinds of meshes by an indexing scheme. Within this part illustrative examples have been principally taken from the field of computational fluid dynamics.

This part of ISO 10303 provides general, application independent, means of representing indexible data and meshes.

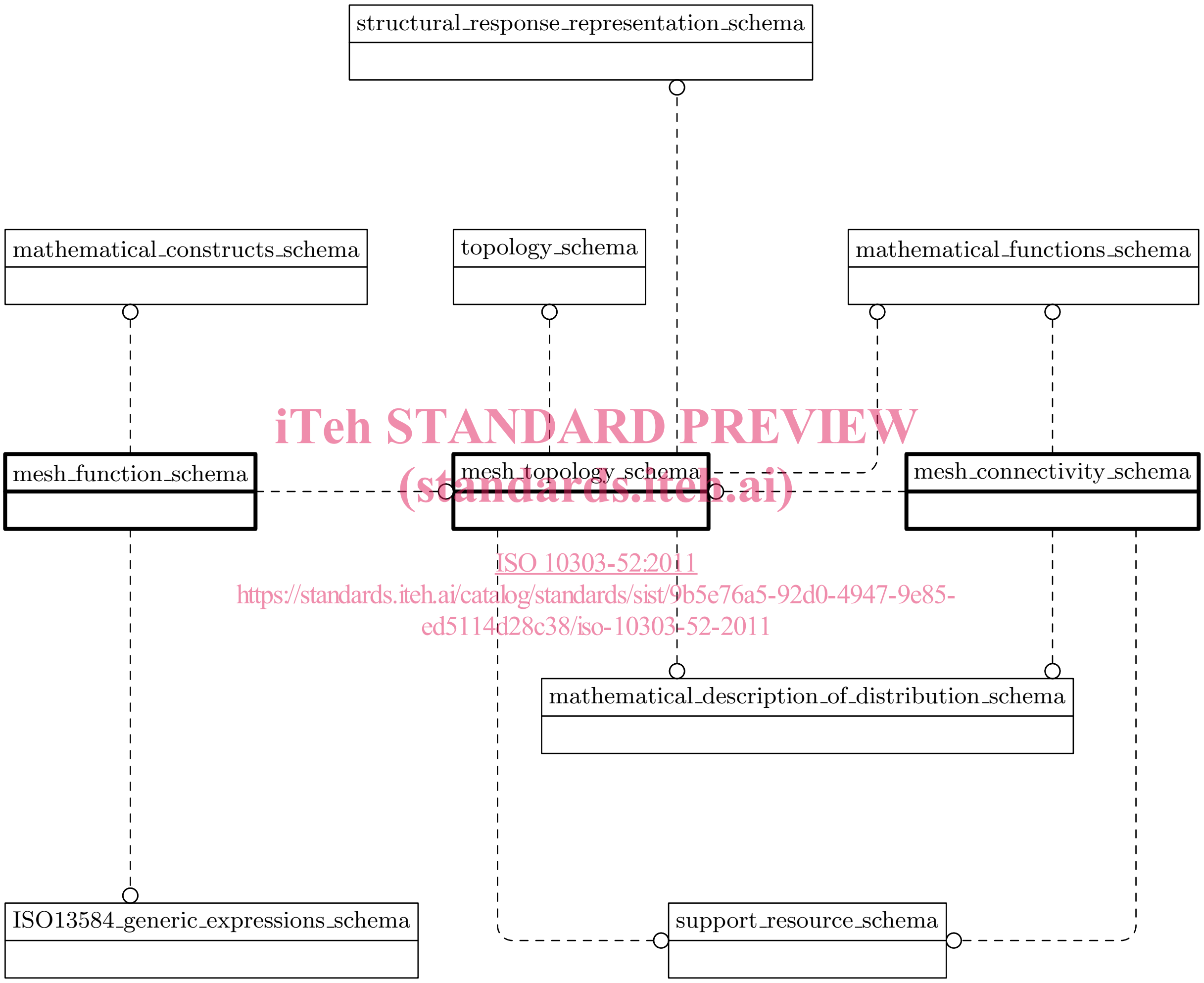

Figure 1 – Schema relationships

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

Part 52:
Integrated generic resource: Mesh-based topology

1 Scope

This part of ISO 10303 provides general and application-independent means of representing structured and unstructured meshes, and mathematical functions and numeric data defined over such meshes. The schemas in this document are specified in the EXPRESS language; EXPRESS is defined in ISO 10303-11.

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

— mesh-based topologies;

— cell connectivity and multiblock mesh interfaces;

— mathematical functions defined over meshes;

— the association of numeric data with the cells, faces, edges, and vertices of a mesh.

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

— applications of mesh topologies;

— applications of mesh interfaces;

— the semantics of data associated with a mesh.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For updated references, the latest edition of the referenced document (including any amendments) applies.

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

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

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

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

ISO 10303-50, *Industrial automation systems and integration — Product data representation and exchange — Part 50: Integrated generic resource: Mathematical constructs.*

ISO 10303-51, *Industrial automation systems and integration — Product data representation and exchange — Part 51: Integrated generic resource: Mathematical description.*

ISO 10303-104, *Industrial automation systems and integration — Product data representation and exchange — Part 104: Integrated application resource: Finite element analysis.*

ISO 10303-110, *Industrial automation systems and integration — Product data representation and exchange — Part 110: Integrated application resource: Mesh-based computational fluid dynamics.*

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

3 Terms, definitions and abbreviated terms

3.1 Terms defined in ISO 10303-1

For the purposes of this document, the following terms defined in ISO 10303-1 apply.

— application protocol (AP)

— integrated resource

— product

3.2 Terms defined in ISO 10303-110

For the purposes of this document, the following term defined in ISO 10303-110 applies.

— rind

3.3 Other terms and definitions

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

3.3.1
cell
manifold of dimensionality one or higher that is a part of, or the whole of, a mesh

3.3.2
cell edge
one-dimensional manifold that is on the boundary of a cell and that joins two cell vertices

3.3.3
cell face
two-dimensional manifold that is on the boundary of a cell and that is enclosed by one or more cell edges

3.3.4
cell vertex
vertex that is at the end of one or more cell edges

3.3.5
mesh
arrangement of cells with connectivity between the cells defined by the possession of common cell faces or cell edges

3.3.6
topological region
point set with a single topological dimension

3.3.7
vertex
point within, or on the boundary of, a cell

NOTE 1 A vertex can, but need not, be a cell vertex.

NOTE 2 In some applications, particularly in finite element analysis, the word node is used as an equivalent term to vertex.

3.4 Abbreviated terms

CFD	computational fluid dynamics
URL	Universal Resource Locator

4 Mesh topology

The following EXPRESS declaration begins the **mesh_topology_schema** and identifies the necessary external references.

EXPRESS specification:

```
*)
SCHEMA mesh_topology_schema;
  REFERENCE FROM mathematical_description_of_distribution_schema  -- ISO 10303-51
    (property_distribution_description);
  REFERENCE FROM mathematical_functions_schema                    -- ISO 10303-50
    (maths_space);
  REFERENCE FROM structural_response_representation_schema        -- ISO 10303-104
    (element_order,
     element_representation,
     fea_model);
  REFERENCE FROM support_resource_schema                          -- ISO 10303-41
    (identifier,
     label,
     text);
  REFERENCE FROM topology_schema                                  -- ISO 10303-42
    (topological_representation_item,
     vertex, vertex_point);
(*
```


NOTE The schemas referenced above can be found in the following parts of ISO 10303:

mathematical_description_of_distribution_schema	ISO 10303-51
mathematical_functions_schema	ISO 10303-50
structural_response_representation_schema	ISO 10303-104
support_resource_schema	ISO 10303-41
topology_schema	ISO 10303-42

4.1 Fundamental concepts and assumptions

A mesh is defined by its vertices and the connections between the vertices. A mesh is a connected graph.

4.1.1 Structured mesh

In a structured mesh the cells are arranged in a regular pattern and their shapes are implied by the particular kind of mesh.

A 3–D rectangular mesh is a mesh of hexahedral cells. Each cell is a dimensionality 3 hexahedral region defined by eight vertices forming the corners of the hexahedron. Each cell is bounded by six faces, where each face is the quadrilateral defined by four vertices. A face is limited by the four edges that connect the four vertices.

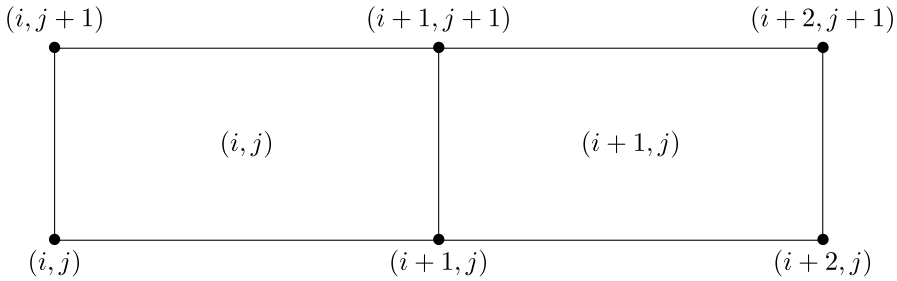

Figure 2 – Example convention for a 2-D cell centre

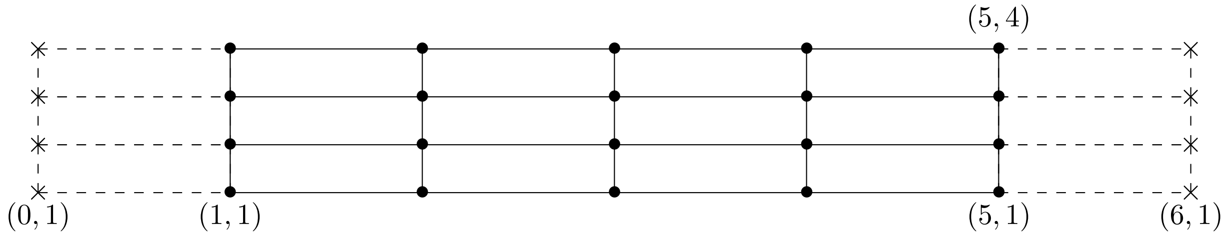

Figure 3 – Example mesh with rind vertices

A 2–D rectangular mesh is a mesh of quadrilaterals. Each cell is a dimensionality two quadrilateral region defined by four vertices forming the corners of the quadrilateral. Each cell is limited by the four edges that connect the four vertices.

A 1–D mesh is of linear form. Each cell is a dimensionality one linear region bounded by two vertices.

Indices describing a structured mesh are ordered: for 3–D (i, j, k); (i, j) is used for 2–D; and (i) for 1–D.

Cell centres, face centres, and edge centres are indexed by the minimum of the connecting vertices.

EXAMPLE 1 For example a 2-D cell center (or face centre on a 3-D mesh) would have the conventions shown in Figure 2.

In addition, the default beginning vertex for a regular mesh is $(1, 1, 1)$; this means the default beginning cell centre of a regular mesh is also $(1, 1, 1)$.

There may be locations outside the mesh itself. These are referred to as ‘rind’ or ghost points and may be associated with fictitious vertices or cell centres. They are distinguished from the vertices and cells making up the mesh (including its boundary vertices), which are referred to as ‘core’ points.

EXAMPLE 2 Figure 3 shows a 2–D mesh with a single row of ‘rind’ vertices at the minimum and maximum i-faces. The mesh size (i.e., the number of ‘core’ vertices in each direction) is 5×4. ‘Core’ vertices are designated by ‘•’, and ‘rind’ vertices by ‘$\times$’. Default indexing is also shown for the vertices.