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

Part 111:

**Integrated application resource: Elements
for the procedural modelling of solid
shapes**

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

*Partie 111. Ressources d'application intégrée: Éléments pour la
modélisation procédurale des formes solides*



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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.org
Web www.iso.org

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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 document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 10303-111 was prepared by Technical Committee ISO/TC184/SC4, *Industrial automation systems and integration*, Subcommittee SC4, *Industrial data*.

ISO 10303 is organized 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. ISO 10303-111 is a member of the integrated application 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 following URL:

http://www.tc184-sc4.org/titles/STEP_Titles.htm

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 resources series. This part of ISO 10303 specifies the **solid_shape_element_schema**.

A set of solid modelling shape elements is defined that provide a capability for the exchange of feature-based CAD solid models, expressed in terms of the sequence of successive creation or modification operations used to build them. This kind of representation of a product shape model is referred to as a *procedural, history-based or construction history model*. The essential underlying resource for the representation of models of this type is ISO 10303-55, which provides the mechanism for capturing the sequence of operations, and defines the intended interpretation of the entities defined in this part of ISO 10303 as modelling operations. This part of ISO 10303 contains a single schema, the **solid_shape_element_schema**, which defines a set of complex geometric elements that can be incorporated into a solid shape model. The relationship of this schema to other schemas that define the integrated resources of ISO 10303 is illustrated in Figure 1 using the EXPRESS-G notation. EXPRESS-G is defined in annex D of ISO 10303-11:2004. The schemas occurring in Figure 1 are components of ISO 10303 integrated resources, and they are specified in the following resource parts:

support_resource_schema	ISO 10303-41
measure_schema	ISO 10303-41
geometry_schema	ISO 10303-42
topology_schema	ISO 10303-42
geometric_model_schema	ISO 10303-42
representation_schema	ISO 10303-43
mathematical_functions_schema	ISO 10303-50
explicit_geometric_constraint_schema	ISO 10303-108
sketch_schema	ISO 10303-108

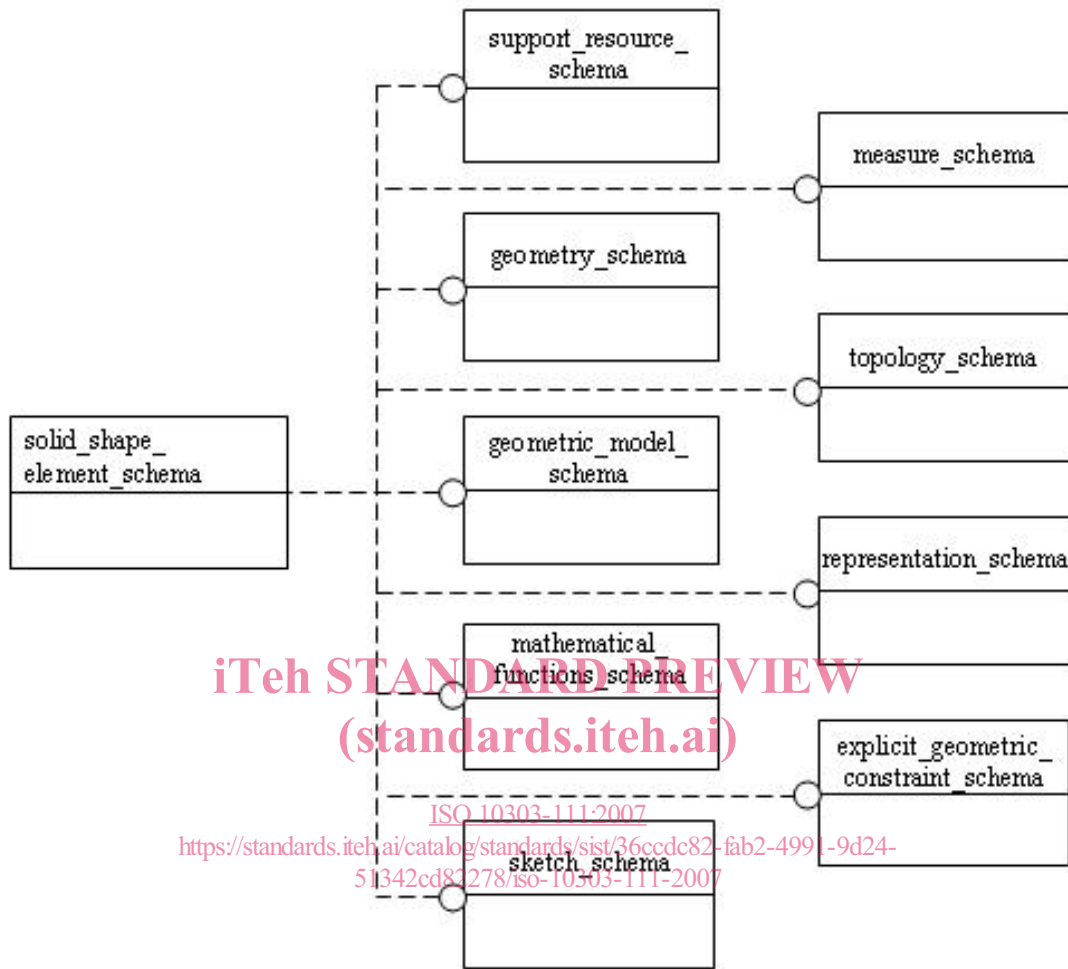


Figure 1 – Schema level diagram of relationships between the solid_shape_element_schema of this part of ISO 10303 and other resource schemas

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

Part 111:

Integrated application resource: Elements for the procedural modelling of solid shapes

1 Scope

This part of ISO 10303 specifies resource constructs for representing the complex shape elements, sometimes known as form features, that are supported by the solid modelling capabilities of modern CAD systems. The elements are defined in such a way as to facilitate the exchange of solid models of products represented in terms of their constructional history.

NOTE 1 Procedural or constructional history models of solids can also include operations based directly on entities defined in ISO 10303-42, in particular Boolean operations and operations based on the various subtypes of **swept_face_solid** and **swept_area_solid**.

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

- the representation of solids having shape configurations resulting from blending and chamfering operations;
- the representation of solids with shape configurations resulting from offsetting, thickening, shelling and sculpturing operations;
- the representation of solids having shape configurations characteristic of certain manufacturing features, including several types of holes, pockets, slots and grooves;
- the representation of solids having circular and rectangular patterns of the types of shape configurations mentioned in the previous item of this list;
- the representation of solids that are generalizations of the solids of extrusion and revolution defined in ISO 10303-42.

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

- the representation of shape configurations on a model as *aspects* of the shape of the model, in the sense defined by ISO 10303-41;

NOTE 2 For design purposes the configurations specified in this part of ISO 10303 are regarded as shape elements in their own right, and not as local aspects of more complex shapes. These configurations can be created, subjected to modification and even subsequently deleted during the design process, so that they do not in general appear in their original form as shape aspects of the final model.

- the representation of features relating to manufacturing or other applications downstream of design.

NOTE 3 Such features have associated semantics that are absent from the shape configurations defined in this part of ISO 10303, which are purely concerned with the form of the modelled object.

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

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

ISO 10303-11:2004, *Industrial automation systems and integration — Product data representation and exchange — Part 11: Description methods: 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 10303-43, *Industrial automation systems and integration — Product data representation and exchange — Part 43: Integrated generic resource: Representation structures*

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

ISO 10303-55:2005, *Industrial automation systems and integration — Product data representation and exchange — Part 55: Integrated generic resource: Procedural and hybrid representation*

ISO 10303-108, *Industrial automation systems and integration — Product data representation and exchange — Part 108: Integrated application resource: Parameterization and constraints for explicit geometric product models*

3 Terms, definitions and abbreviations

3.1 Terms defined in ISO 10303-1

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

- application;
- application context;
- application protocol (AP);
- data exchange;

- exchange structure;
- implementation method;
- integrated resource (IR);
- product;
- product data.

3.2 Terms defined in ISO 10303-11

For the purposes of this document, the following terms defined in ISO 10303-11 apply.

- entity;
- entity data type;
- entity (data type) instance;
- instance;
- value.

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3.3 Terms defined in ISO 10303-42

For the purposes of this document, the following terms defined in ISO 10303-42 apply.

- boundary representation solid model (B-rep);
- constructive solid geometry (CSG);
- coordinate space;
- dimensionality;
- model space.

3.4 Terms defined in ISO 10303-43

For the purposes of this document, the following terms defined in ISO 10303-43 apply.

- context of representation;
- element of representation;
- representation.

3.5 Terms defined in ISO 10303-55

For the purposes of this document, the following terms defined in ISO 10303-55 apply.

- design rationale.

3.6 Terms defined in ISO 10303-108

For the purposes of this document, the following terms defined in ISO 10303-108 apply.

- design intent;
- element;
- feature;
- history-based model;
- procedural model;
- sketch.

3.7 Other terms and definitions

For the purposes of this document, the following definition applies.

3.7.1 track

continuous chain of edges

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NOTE The ISO 10303-42 entity **path** has a similar definition, but requires all the edges in the chain to be consistently oriented, which is not a requirement for a track.

3.8 Abbreviations

For the purposes of this document, the following abbreviations apply:

AP	application protocol (of ISO 10303)
B-rep	boundary representation
CAD	computer aided design
CSG	constructive solid geometry
IR	integrated resource (of ISO 10303)

4 Solid shape element

4.1 Introduction

The following EXPRESS declaration begins the solid shape element schema and identifies the necessary external references.

EXPRESS specification:

```

*)
SCHEMA solid_shape_element_schema;

REFERENCE FROM support_resource_schema          -- ISO 10303-41
  (text);

REFERENCE FROM measure_schema                  -- ISO 10303-41
  (length_measure,
   plane_angle_measure,
   positive_length_measure,
   positive_plane_angle_measure);

REFERENCE FROM geometry_schema                -- ISO 10303-42
  (axis2_placement_3d,
   bounded_curve,
   bounded_surface,
   curve_bounded_surface,
   geometric_representation_item,
   point,
   point_on_curve,
   surface);

REFERENCE FROM topology_schema                --ISO 10303-42
  (connected_face_set,
   edge_curve,
   face_surface,
   open_shell,
   topological_representation_item,
   vertex);

REFERENCE FROM geometric_model_schema         --ISO 10303-42
  (boolean_result,
   csg_primitive,
   extruded_face_solid,
   primitive_2d,
   revolved_face_solid,
   solid_model,
   swept_face_solid);

REFERENCE FROM representation_schema         --ISO 10303-43
  (representation_item,
   using_items);

```

```

REFERENCE FROM mathematical_functions_schema          --ISO 10303-50
  (positive_integer);

REFERENCE FROM explicit_geometric_constraint_schema    --ISO 10303-108
  (non_negative_length_measure);

REFERENCE FROM sketch_schema                          --ISO 10303-108
  (positioned_sketch);
(*

```

NOTE 1 The schemas referenced above can be found in the following parts of ISO 10303:

support_resource_schema	ISO 10303-41
measure_schema	ISO 10303-41
geometry_schema	ISO 10303-42
topology_schema	ISO 10303-42
geometric_model_schema	ISO 10303-42
representation_schema	ISO 10303-43
mathematical_functions_schema	ISO 10303-50
explicit_geometric_constraint_schema	ISO 10303-108
sketch_schema	ISO 10303-108

NOTE 2 See annex D for a graphical presentation of this schema using the EXPRESS-G notation.

NOTE 3 A listing of the complete EXPRESS schema specified in this part of ISO 10303, without comments or other explanatory text, is available from the Internet – see annex C.

4.2 Fundamental concepts and assumptions

The fundamental types of operation available to the user of a modern CAD system are

- a) Extrusion and revolution operations based on 2D sketches;
- b) Boolean operations, for the combination of simpler shapes into more complex ones;
- c) ‘Local operations’ that create local modifications on a pre-existing solid.

The use of ISO 10303-55, which provides the mechanisms needed for the capture and transfer of procedural models, allows operations of the types (a) and (b) to be represented by means of entities defined in ISO 10303-42, although the range of extrusion possibilities provided there is rather limited.

This part of ISO 10303 is mainly concerned with operations of type (c). It provides representations for complex geometric elements that can be used to create local modifications of a solid shape model during the course of a design procedure. Again, the essential underlying resource is ISO 10303-55, whose primary mechanism is based on the interpretation of an instance of a geometric element, if it occurs in the specialized context of a **procedural representation sequence** (as defined in ISO 10303-55), as an instruction to the receiving system to create such an element.

A type (c) operation assumes the pre-existence of a solid that will be modified by the operation. For that reason, many of the entities defined in the **solid_shape_element_schema** define a solid that has a new shape configuration of a specific type created upon it. The shape configurations available are described as *features* in the documentation of many CAD systems, but in a strict sense they are not features because they have no associated application semantics. The system user doubtless has some intended design functionality in mind when creating such a configuration on the model, but with current systems that

intended functionality is not recorded. All that is captured by the system is the modified shape, and so it is better to think of the operations as shape creation operations rather than feature creation operations.

For the above reason, and also for more technical reasons spelled out in annex E, the use of the word 'feature' is henceforth avoided as far as possible in this part of ISO 10303.

NOTE 1 Some of the shape configurations defined in this schema have names that reflect methods of manufacture that might be used to produce them when the modelled part is actually made. This is because such names are typically employed in the user interfaces of CAD systems to denote those configurations; their use in this schema is not intended to imply any manufacturing-related semantics.

EXAMPLE Shape configurations such as slots, grooves, countersunk and counterbored holes provide illustrations of commonly occurring shape configurations named in terms of manufacturing processes.

Other operations defined in the **solid_shape_element_schema** are type (a) operations that generalize the basic extrusion and revolution operations specified in ISO 10303-42.

Some of the entities defined in this schema specify operations which, in the originating system, required the user to select one or more elements from the model as displayed on the screen of that system. In all such cases, the selection operations are captured and transferred by requiring the originating system to transmit explicit representations of the selected entities that enable the receiving system to reconstruct the selection procedure. The mechanism underlying this process is fully described in ISO 10303-55, a knowledge of which is fundamental to the understanding of this part of ISO 10303.

NOTE 2 Proof-of-concept transfers have confirmed that all major CAD systems can support the ISO 10303-55 approach for the capture and transfer of user-selected elements in exchanges of procedurally defined models.

The initial application context for the shape configurations defined in this part of ISO 10303 is the detail design of mechanical engineering parts without complex sculptured geometry. The use of ISO 10303-55 allows the procedural modelling of that type of geometry, if required, through the direct invocation of B-spline and related types of geometric entities defined in ISO 10303-42. That approach is possibly not optimal, and more convenient procedures for the creation and modification of free-form surface geometry may be included in a future edition of this document.

4.3 Solid shape element type definitions

4.3.1 base_solid_select

The **base_solid_select** type specifies those types of entity which may be used as the base solid for the creation of shape elements defined in this schema. The selection **solid_model** includes solids of extrusion and revolution generated by sweeping 2D sketches.

The entity **csg_primitive** in the SELECT list is itself a SELECT type, allowing the entity **primitive_2d** as a choice. This two-dimensional entity is out of scope for the modelling of solid shapes, and a WHERE rule is therefore imposed to disallow **primitive_2d** as a value of **base_solid_select**.