INTERNATIONAL STANDARD

ISO 10303-55

First edition
2005-02-01

Industrial automation systems — Product data representation and exchange —

Part 55: Integrated generic resource: Procedural and hybrid representation

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

Partie 55: Ressources génériques intégrées — Représentation procédurale et hybride

Reference number
ISO 10303-55:2005(E)

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Published in Switzerland

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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.

ISO 10303-55 was prepared by Technical Committee ISO/TC 184/SC 4, *Industrial automation systems and integration*, Subcommittee SC 4, *Industrial data*.

ISO 10303 consists of a series of parts, under the general title *Industrial automation systems and integration — Product data representation and exchange*. 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 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.tc184-sc4.org/titles/STEP_Titles.htm>

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 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. Major subdivisions of this part of ISO 10303 are:

— Procedural model schema;

— Procedural shape model schema.

This part of ISO 10303 provides general mechanisms for the representation of models defined in terms of the operations used to construct them. The constructional operations themselves are represented by entity data types defined in other parts of ISO 10303, interpreted as constructors. Procedural models have the advantage of being easy to edit, simply by changing values of parameters used as arguments of their constructional operations. Such models are said to embody *design intent* information, in the sense that modifications to them conform to the scheme of parameterization imposed by their original creator, and also comply with any constraints implied by the particular constructional operations used. Thus the transfer of a procedural model into a receiving system carries with it information as to how the model will behave when edited following the transfer.

However, procedural models also have the disadvantage of containing (in their purest form) little or no explicit information about the result of actually performing the sequence of operations. This fact makes them unsuitable as a basis for the automation of many engineering processes that depend on the use of explicit geometric information, for example numerically controlled machining or inspection.

Systems for engineering purposes commonly achieve the advantages of both modelling approaches through the use of a *dual* representation, comprising a primary representation of the *procedural* or *construction history* type together with a secondary explicit representation. Other ISO 10303 resources provide the elements needed for explicit represention. This part of the standard not only specifies resources for procedural representations but also provides a dual model capability by enabling the association of such a model with its corresponding explicit counterpart.

The initial focus of this part of ISO 10303 was to allow the capture and exchange of CAD shape representations of the procedural and hybrid types (a *hybrid representation* is basically procedural but also contains some explicit elements). However, the capabilities provided also have general applicability for the transfer of any type of procedurally represented or hybrid model, whether geometric or non-geometric. In the case of shape models, ISO 10303-42 is the primary resource for the corresponding explicit representations.

Because procedural representations are inherently parametric, they can be edited by changing the values of input arguments of constructional procedures. However, this requires that the system operator has an appropriate level of understanding of the rationale underlying the original constructional method. At the time of writing, no method is known for capturing design rationale information automatically during model construction, and provision is therefore made in this part of ISO 10303 for its representation as descriptive text, assumed to be supplied by the original designer.

It is useful to emphasize the distinction between design intent and design rationale. *Design intent* is captured in the schemes of parameterization and constraints imposed upon models during their construction.

It therefore governs the ways in which a model may be edited. *Design rationale*, on the other hand, is concerned with the reasons *why* a particular configuration or constructional process was adopted, and therefore with the logic underlying the design intent.

The industry motivation for the exchange of procedural, hybrid and dual representations arises from the difficulties that have been encountered in the editing of ISO 10303 explicit models in a receiving system, following a model transfer. If only an explicit model is transferred, as in the past, the design intent embodied in the procedural component of the dual model in the sending system is lost in the transfer. The consequences are that received model is incomplete in vital respects, and that editing it is difficult or impossible.

Three books and a conference paper providing further background on the topics covered by this part of ISO 10303 are given in the Bibliography [6 – 9].

The contents of the two schemas making up this part of ISO 10303 are as follows:

procedural_model_schema: Fundamental mechanisms for the representation of procedural and hybrid models, and for the capture of design rationale.

procedural_shape_model_schema: Specialization of the foregoing schema for the specific case of geometric models.

The relationships of the schemas in this part of ISO 10303 to other schemas that define the integrated resources of ISO 10303 are illustrated in Figure 1 using the EXPRESS-G notation. EXPRESS-G is defined in annex D of ISO 10303-11. The schemas occurring in Figure 1 are components of ISO 10303 integrated resources, and they are specified in the following resource parts:

product_property_representation_schema	ISO 10303-41
support_resource_schema	ISO 10303-41
geometric_model_schema	ISO 10303-42
geometry_schema	ISO 10303-42
topology_schema	ISO 10303-42
representation_schema	ISO 10303-43
variational_representation_schema	ISO 10303-108

NOTE 1 A procedural model is a representation of a constructional process, and it may therefore be envisaged that ISO 10303-49 ('Process structure and properties') [1] would be a suitable underlying resource for this part of ISO 10303. However, the definition of 'process' as given in ISO 10303-49 is a narrow one:

process: a particular procedure for doing something involving one or more steps or operations. The process may produce *a product, a property of a product, or an aspect of a product.*

Thus the ISO 10303-49 view of a process is one that is concerned with the generation of a physical object or some characteristic of it. The purpose of this part of ISO 10303, by contrast, is to provide the means for capturing and transferring constructional processes for *representations or models of general objects*, which only exist as abstractions in a computer or database. For this reason, and also because advantage can be taken of the very close relationship between procedural modelling operations and existing entities defined in other ISO 10303 integrated resources, ISO 10303-49 has not been used as the basis for the present part of ISO 10303.

NOTE 2 In the diagram on the following page, the schemas occurring in this part of ISO 10303 are enclosed in a heavy rectangular box. The specific entities interfaced are not indicated.

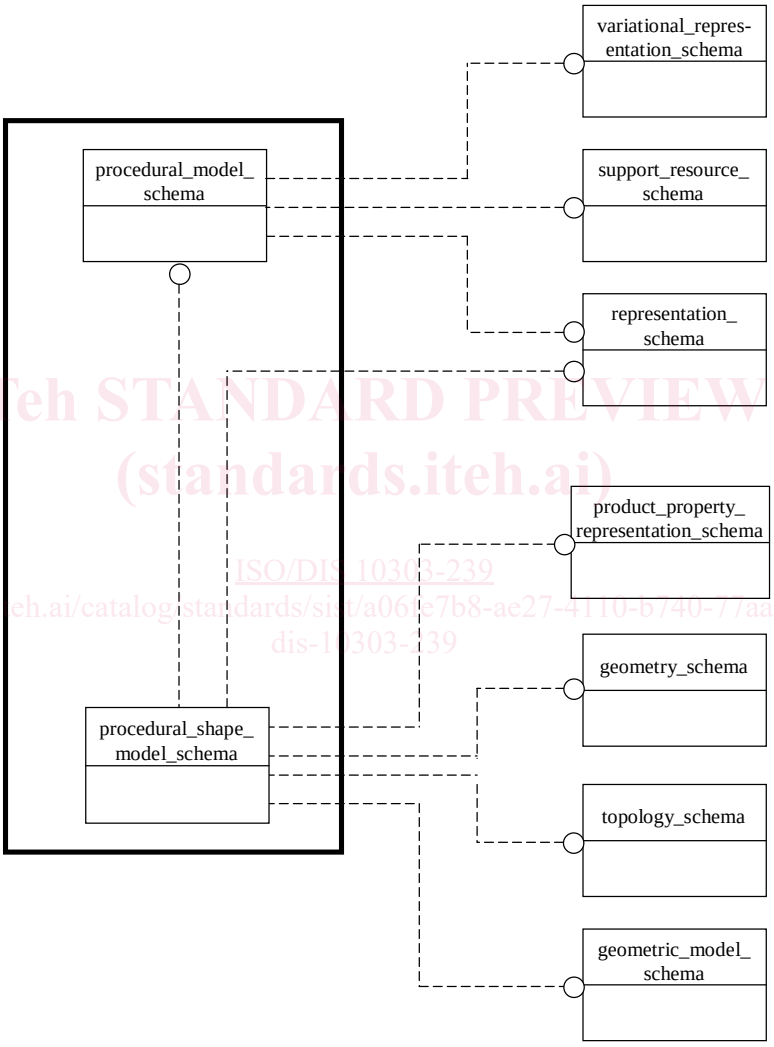

Figure 1 – Schema level diagram of relationships among ISO 10303-55 schemas (inside the box) and other resource schemas

Industrial automation systems and integration — Product data representation and exchange — Part 55: Integrated generic resource: Procedural and hybrid representation

1 Scope

This part of ISO 10303 specifies resource constructs for the representation of models of the procedural or construction history type, defined in terms of the sequence of constructional operations used to build them. Representations of the operations themselves are not specified here; the mechanisms provided in this document allow the use of entity data types defined in other parts of ISO 10303 for that purpose (see clause 4.2.5).

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

— The specification of sequences of constructional operations for the generation of any kind of explicit representation or model;

— The hierarchical structuring of constructional sequences;

— The embedding of explicitly defined elements in constructional sequences for the representation of hybrid models;

— The use of **representation_item** definitions from other parts of ISO 10303 to represent constructional operations for instances of those **representation_item**s;

— The definition of a dual representation by association of a procedural model with an explicit 'current result' model, the latter acting as a representative example of the parametric family of models defined by the former;

— The association of design rationale information with a procedural model;

— The identification, in a procedural model, of explicit elements selected by interactive picking from the visual display of the model in the sending system;

— The identification, in a procedural model, of constructional operations that can be suppressed for purposes of model simplification;

— Specialization of the foregoing capabilities for the procedural representation of shape models.

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

— Any mechanism for the 'persistent naming' of elements of an explicit model based on details of the procedural sequence used to create them;

— 'Macro' capabilities requiring the use of control structures such as IF... THEN... ELSE or REPEAT... UNTIL. Such structures are defined in ISO 10303-11 for use in local and global rules, but no analogous facilities are provided in this document to allow conditional operations in procedural models.

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): 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, *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 10303-108, *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 part of ISO 10303, the following terms defined in ISO 10303-1 apply.

— application;

— application context;

— application protocol (AP);

— assembly;

— component;

— data exchange;

— exchange structure;

— implementation method;

— integrated resource (IR);

— product;

— product data;

— structure.

3.2 Terms defined in ISO 10303-11

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

— entity;

— entity data type;

— entity (data type) instance;

— instance;

— value.

3.3 Terms defined in ISO 10303-42

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

— context of representation;

— element of representation;

— founded;

— representation.

3.5 Terms defined in ISO 10303-108

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

NOTE The capabilities specified in ISO 10303-108 are very closely related to those specified in this part of ISO 10303. Consequently, acquaintance with these terms and their definitions is crucial for understanding the present document.

— constraint;

— constraint solution;

— current result;

— current value;

— declarative constraint;

— declarative model;

— design intent;

— element;

— evaluated model;

— explicit constraint;

— explicit model;

— feature;

— generative model;

— history-based model;

— hybrid model;

— implicit constraint;

— model parameter;

— procedural constraint;

— procedural model;

— sketch;

— unevaluated model;

— variational.

3.6 Other terms and definitions

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

3.6.1
design rationale
logic underlying the methodology used in constructing the design

3.6.2
dual model
combination of a procedural or hybrid representation with an explicit representation, the second of which represents an example of the parametric class of models defined by the first

3.7 Abbreviations

For the purposes of this part of ISO 10303 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 Procedural model

The following EXPRESS declaration begins the procedural model schema and identifies the necessary external references.

EXPRESS specification:

```
*)
SCHEMA procedural_model_schema;

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

REFERENCE FROM representation_schema                      -- ISO 10303-43
  (item_in_context,
   representation,
   representation_item,
   representation_item_relationship,
   representation_relationship,
   using_representations);

REFERENCE FROM variational_representation_schema          -- ISO 10303-108
  (variational_representation);
(*
```


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

support_resource_schema	ISO 10303-41
representation_schema	ISO 10303-43
variational_representation_schema	ISO 10303-108

NOTE 2 See annex D, Figure D.1, for a graphical presentation of this schema.

4.1 Introduction

The subject of the **procedural_representation_schema** is representation or modelling in terms of constructional operations. This may be contrasted with representation or modelling in terms of elements that are explicitly created as the result of performing those operations.

EXAMPLE ISO 10303-42 defines the entity data type **manifold_solid_brep**. This is a representation of a solid shape in terms of the faces, edges and vertices occurring in the boundary separating the interior from the exterior of the solid. Such a representation contains no information as to how the shape was actually created, though whatever constructional operations were used clearly had the effect of generating all the low-level geometrical and topological elements involved in the **manifold_solid_brep**. This part of ISO 10303 provides an alternative method of representing such a shape, in terms of the manner of its generation.

4.2 Fundamental concepts and assumptions

This schema provides representation methods for the following:

— The specification of sequences of constructional operations for the generation of models or representations of any type;

— The hierarchical structuring of constructional sequences;

— The embedding of explicitly defined elements in constructional sequences for the representation of hybrid models;

— The use of **representation_item** definitions from other parts of ISO 10303 to represent constructional operations for instances of **representation_item** in procedural and hybrid models;

— The definition of a dual representation by association of a procedural model with an explicit 'current result' model, the latter acting as a representative example of the parametric family of models defined by the former;

— The association of design rationale information with procedural models;

— The identification, in a procedural model, of explicit elements selected by interactive picking from the visual display of the model in the sending system;

— The identification, in a procedural model, of constructional operations that can be suppressed for purposes of model simplification.

The primary initial aim of this part of ISO 10303 is to provide the means for representing procedural and hybrid models of geometric shapes as generated by CAD systems. For this reason, many of the examples given in the descriptive text of this schema are concerned with aspects of CAD modelling. However, the resource constructs provided in the schema are of general utility in the representation, exchange and sharing of procedurally defined and hybrid models for any application. An example of a non-geometric application of procedural modelling is given in clause E.1 of annex E.

4.2.1 Procedural models

A *procedural model* is represented in terms of the operations used in its creation. For this reason it is also frequently known as a *construction history model*. A pure procedural model is defined exclusively in terms of operations, and it is therefore impossible to refer in such a model to most specific constituents of the explicit model that is generated when the operations are performed.

EXAMPLE A shape model of a cylindrical solid with radius R and height H may be generated from a procedural model containing just two operations:

a) Create a circular area with radius R;

b) Sweep the circular area through a distance H normal to its plane.

The cylinder resulting from the performance of these operations has two circular edges. One of them will correspond to the boundary of the circular area created by the first operation, but even this will not exist explicitly until that first operation has been carried out. The second edge will only be called into existence by the performance of the second operation. The two operations represent the shape of the cylinder, but by themselves provide no means of referencing its individual geometrical or topological elements.

In a data exchange context, a transferred procedural model will specify only operations, and the generation of an explicit model from them will occur after the transfer, in the receiving system. This process is called *evaluation*; its input is the *unevaluated* procedural model, and its output is the *evaluated* explicit model.

