TECHNICAL SPECIFICATION

ISO/TS 8000-311

First edition
2012-04-15

Data quality —

Part 311:
Guidance for the application of product data quality for shape (PDQ-S)

Qualité des données —

Partie 311: Directives pour l'application de la qualité des données de produit pour les formes (PDQ-S)

Reference number
ISO/TS 8000-311:2012(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 in 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.

In other circumstances, particularly when there is an urgent market requirement for such documents, a technical committee may decide to publish other types of normative documents:
— an ISO Publicly Available Specification(ISO/PAS) represents an agreement between technical experts in an ISO working group and is accepted for publication if it is approved by more than 50% of the members of the parent committee casing a vote;
— an ISO Technical Specification(ISO/TS) represents an agreement between the members of a technical committee and is accepted for publication if it is approved by 2/3 of the members of the committee casting a vote.
An ISO/PAS or ISO/TS is reviewed every three years with a view to deciding whether it can be transformed into an International Standard.

Attention is drawn to the possibility that some of the elements of this part of ISO 8000 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO/TS 8000-311 was prepared by Technical Committee ISO/TC184, *Automation systems and integration*, Subcommittee SC4, *Industrial data*.

ISO 8000 is organized as a series of parts, each published separately. The structure of ISO 8000 is described in ISO/TS 8000-1.

Each part of ISO 8000 is a member of one of the following series: general data quality, master data quality, transactional data quality and product data quality. This part of ISO 8000 is a member of the product data quality series.

A complete list of parts of ISO 8000 is available from the Internet:

<http://www.tc184-sc4.org/titles/DATA QUALITY Titles.htm.>

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Introduction

The ability to create, collect, store, maintain, transfer, process and present data to support business processes in a timely and cost effective manner requires both an understanding of the characteristics of the data that determine its quality, and an ability to measure, manage and report on data quality.

ISO 8000 defines characteristics that can be tested by any organization in the data supply chain to objectively determine conformance of the data to ISO 8000.

ISO 8000 provides a framework for improving data quality that can be used independently or in conjunction with quality management systems.

ISO 8000 covers industrial data quality characteristics throughout the product life cycle from conception to disposal. ISO 8000 addresses specific kinds of data including, but not limited to, master data, transaction data, and product data.

Assets can be grouped into real and intellectual property. Information is intellectual property. Data is a prerequisite to information. Thus, the quality of data is a key determiner of an organization's ability to preserve and transfer intellectual property.

A characteristic of data is its portability from one system to another. Syntax and semantics encoding determine whether data is portable in a reliable way. ISO 8000 specifies requirements for the declaration of syntax and semantic encoding. This allows the user to determine the limitations of data portability. By requesting data that conforms to ISO 8000, the user is able to manage data portability and protect its intellectual property assets.

Data quality is the degree to which data meets user requirements. ISO 8000 contains specifications for the declaration of the conformance to stated data requirements. This allows the user to request data that meets its requirements and to determine if the data received meets its requirements.

This part of ISO 8000 is a member of the product data quality series and aims at facilitating effective use of product data quality for shape (PDQ-S), as described in ISO 10303-59.

Since the publication of ISO 10303-59, the worldwide automotive industry has made use of PDQ-S in ISO/PAS 26183, whilst the joint automotive and aerospace project, ISO 10303-242, will make use of the PDQ modules, which are a modular version of PDQ-S.

NOTE The first edition of ISO 10303-59, published in 2008, provides general specifications for the representation of quality criteria, quality measurement requirements, quality assessment specifications and quality inspection results for product data. These specifications are provided so that PDQ-S can be extended to deal with the quality of non-shape product data in the future. Extensions to externally conditioned data quality and geometric dimensioning and tolerance (GD&T) data quality, which are currently under development in the revision of ISO 10303-59, are examples of such extension. By focusing on three dimensional shape data, PDQ-S also provides detailed specifications for the representation of shape data quality criteria, together with associated measurement requirements, shape data quality assessment specifications and detailed results of shape data quality inspections.

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PDQ-S is applicable to any International Standard dealing with product data. In order to further extend its usage, this part of ISO 8000 provides the necessary background knowledge to enable the effective use of PDQ-S in various circumstances.

Clause 4 provides a condensed description of PDQ-S.

Clause 5 facilitates the use of PDQ-S.

Clause 6 focuses on ensuring conformance with PDQ-S.

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Data quality —
Part 311:
Guidance for the application of product data quality for shape (PDQ-S)

1. Scope

This part of ISO 8000 provides guidance for the application of product data quality for shape (PDQ-S), as described in ISO 10303-59.

The following are within the scope of this part of ISO 8000:

— purpose, approach and expected usage scenarios;

— the structure of PDQ-S;

— PDQ-S schema structure;

— target shape model;

— the relationship between ISO 10303-59 and other International Standards dealing with the nominal representation of product data;

— the major characteristics of PDQ-S;

— the relationship between product data quality problems and quality criteria in PDQ-S;

— some examples for selecting appropriate quality criteria;

— ensuring conformance with PDQ-S.

The following is outside the scope of this part of ISO 8000:

— guidance relating to the quality of product data other than shape data.

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2. Normative references

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

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

ISO 10303-59, *Industrial automation systems and integration — Product data representation and exchange — Part 59: Integrated generic resource: Quality of product shape data*

ISO 8000-2, *Data quality — Part 2: Vocabulary*

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3. Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 8000-2 and the following apply.

3.1.1
application
group of one or more processes creating or using product data

[ISO 10303-1:1994, definition 3.2.2]

3.1.2
application protocol
AP
part of ISO 10303 that specifies an application interpreted model satisfying the scope and information requirements for a specific application

NOTE Adapted from ISO 10303-1:1994, definition 3.2.7

3.1.3
application reference model
ARM
information model that describes the information requirements and constraints of a specific application context

[ISO 10303-1: 1994, definition 3.2.8]

3.1.4
data exchange
storing, accessing, transferring and archiving of data

[ISO 10303-1:1994, definition 3.2.15]

3.1.5
product
thing or substance produced by a natural or artificial process

[ISO 10303-1:1994, definition 3.2.26]

3.1.6
product data
representation of information about a product in a formal manner suitable for communication, interpretation or processing by human beings or by computers

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[ISO 10303-1:1994, definition 3.2.27]

3.1.7
accuracy
specification to control precision of approximate solution

NOTE The intended interpretation of the accuracy is that an approximate solution is acceptable if the difference between that approximate solution and any other approximate solution obtained by calculation with a finer distribution of sampling points is smaller than the given accuracy. There are two types of accuracy:

— general accuracy applied to all the measurement, and
— specific accuracy applied only to specified measurement.

3.1.8
inspection result
result of inspection which indicates whether, or not, the product shape data inspected contains quality defects

NOTE Such results can also include detailed information on what type of quality defects exist, and how serious the defect is, together with the shape element data where the problem is detected.

3.1.9
measurement requirement
textual description of how a criterion is measured, including any necessary additional attributes and rules to control the test and the element or elements to be tested, and which plays the role of an external specification for reliable measurement algorithm

NOTE It is important to take care that the measurement requirement does not provide an algorithm for the measurement process, since it is understood that algorithm development is a competitive arena for engineering system vendors and cannot be standardized by an International Standard.

3.1.10
product data quality
consistency, completeness, and suitability for its purpose of the product data

[ISO 10303-59:2008, definition 3.5.2]

3.1.11
product shape data
data representing product shape with geometric and topological information in accordance with ISO 10303-42

[ISO 10303-59:2008, definition 3.5.4]

3.1.12
quality criterion
criterion for evaluating product data quality

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3.1.13
threshold
allowance used for the assessment of shape data quality by numerical test

NOTE An example of a typical threshold is distance threshold for evaluating the gap between a base surface and bounding curves for trimming the effective portion of the surface. That distance threshold implies that if the maximum distance between the surface and the curves is greater than or equal to the specified minimum value, then the gap is understood as a quality defect.

3.1.14
inspection
conformity evaluation by observation and judgement accompanied as appropriate by measurement, testing or gauging

[ISO 9000:2005, definition 3.8.2]

3.1.15
quality
degree to which a set of inherent characteristics fulfils requirements

NOTE 1 The term "quality" can be used with adjectives such as poor, good or excellent.

NOTE 2 "Inherent" as opposed to "assigned" means existing in something, especially as a permanent characteristic.

[ISO 9000:2005, definition 3.1.1]

3.1.16
quality requirement
need or expectation that is stated, generally implied or obligatory
NOTE Adapted from ISO 9000:2005, definition 3.1.2.

3.2 Abbreviated terms

AP application protocol

ARM application reference model

AM application module

B-rep boundary representation

IR integrated resource (of ISO 10303)

PDQ-S product data quality for shape (as described in ISO 10303-59)

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4. Overview of PDQ-S

4.1 Purpose, approach and expected usage scenarios

The purpose of PDQ-S, as described in ISO 10303-59, is to eliminate inadequate quality product data which is a major reason for rework and repair of data by the data receiver. The approach of PDQ-S is to enumerate concrete measures for eliminating inadequate quality product data.
Amongst the expected scenarios for the use of PDQ-S are as follows.

— **Requirement of quality:** The company placing an order requires the company receiving the order to create product data that satisfies prescribed quality requirements. Examples are exclusion of infinitesimal geometry smaller than the given tolerance and exclusion of redundant geometry not contributing to the representation of product shape. Very limited information, namely relevant criteria together with required thresholds from those provided in PDQ-S, is necessary in this scenario. The information is transferred together with the order.
— **Declaration of quality:** The creator of a product data uses quality information for explicitly declaring the quality level satisfied by the product model. Depending on the design method and the CAD system used, the quality of the product data can be unambiguously declared without any inspection. Selective criteria and thresholds for which the model is judged to be free from quality defects are required information in this scenario. The quality information is transferred together with the corresponding product model data.
— **Assurance of quality:** A quality assurance organization uses quality information for representing the results of quality inspection for a particular product model. This scenario will require inspected quality criteria together with thresholds used, measurement requirements deployed and inspection results obtained. The accuracies used can also be included. The information is transferred together with the corresponding product model data.
— **Quality information for use in quality improvement:** If a quality defect is detected by quality inspection, necessary actions for improving critical data will be required. For that purpose, information on the nature and severity of any quality defects is provided. Therefore, this scenario will require a detailed inspection result report at the level of geometric entity instances. The information is transferred together with the corresponding product model data.
— **Long-term archiving of product data:** It is desirable that a detailed record of product model data quality is archived with product data. The data requirement for this purpose is similar to that needed for assurance of quality.

4.2 Structure of ISO 10303-59

Terminology specific to ISO 10303-59:2008 is described in Clause 3. The main body of ISO 10303-59 contains the following schemas:

— Clause 4: Product data quality definition schema;
— Clause 5: Product data quality criteria schema;
— Clause 6: Product data quality inspection result schema;
— Clause 7: Shape data quality criteria schema;
— Clause 8: Shape data quality inspection result schema.

Appendices include EXPRESS-G diagrams, graphical notation of EXPRESS schemas to ease understanding of structure and relationships of entity data types, technical discussion that summarizes

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basic understanding of standard developers on key technical issues, expected usage scenarios and some examples in entity instance level.

4.3 PDQ-S schema structure

PDQ-S consists of five mutually related schemas. Each schema is a collection concepts, functions and entities.

Product data quality definition schema defines high-level data elements for managing product data quality information.

Product data quality criteria schema provides general specifications for the representation of quality criteria, quality measurement requirements and quality assessment specifications for product data.

Product data quality inspection result schema provides general specifications for the representation of quality inspection results for a particular product data.

Shape data quality criteria schema provides representations of shape data quality criteria together with corresponding measurement requirements, thresholds for judging the existence or absence of quality defects and assessment specifications for product shape data.

Shape data quality inspection result schema provides representations of quality inspection results for a particular product shape data with regard to specified quality criteria. Detailed information on what type of quality defect is existing, and how serious the defect is, together with the shape element data where the problem is detected can also be represented.

These schemas are related as depicted in Figure 1 where the number in each block indicates the relevant clause number in ISO 10303-59:2008. The product data quality definition schema plays the role of a root node for a set of quality information. The shape data quality criteria schema is a specialization of the product data quality criteria schema to three dimensional shape data. In the same way, the shape data quality inspection result schema is a specialization of the product data quality inspection result schema to three dimensional shape data.

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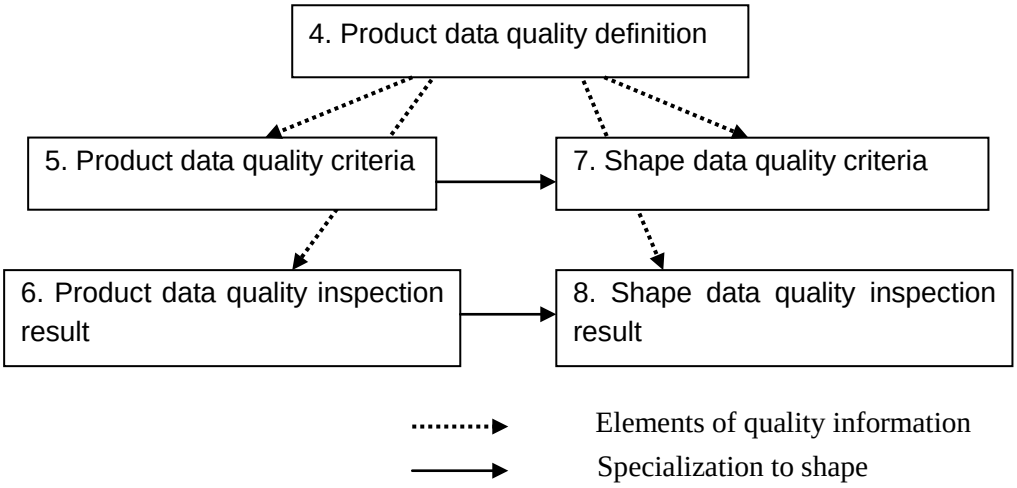

Figure 1 — Structure of PDQ-S schemas

In ISO 10303-59:2008, each schema is structured in the following way, where X is a schema number:

X.1: Introduction
X.2: Fundamental concepts and assumptions
X.3: Type definitions
X.4: Entity definitions
X.5: Function definitions

X.2 describes the basic concepts and assumptions of schema-X. X.3 defines schema-X specific data type definitions that are used in the EXPRESS specifications in X.4. X.4 is the main body of schema-X where criteria are described as entity data types. Functions used in the EXPRESS specifications of X.4 are described in X.5.

4.4 Target shape model

The target shape model of PDQ-S is a boundary representation (B-rep) model conformant to the manifold_solid_brep entity definition in ISO 10303-42. Such models are implemented in many of today's commercial CAD system for representing product shape. In APs and modules they typically form part of an advanced_brep_shape_representation.

4.5 Relationship between ISO 10303-59 and other International Standards dealing with nominal representation of product data

The direct relationship between PDQ-S schemas and other resource schemas is depicted in Figure 2.

A major difference between PDQ-S and other International Standards dealing with nominal representation of product data is that PDQ-S deals with quality aspect of instanced data. The major reason why data exchange between two IT systems which claim STEP conformance(such as CAD systems), frequently fails due to instanced data quality problems is that the implementation of B-rep model and the guaranteed numerical accuracy guaranteed are IT system dependent. Therefore, STEP conformance is not a sufficient condition for successful data exchange or sharing but it is also necessary that the quality of instanced data should be satisfactory.

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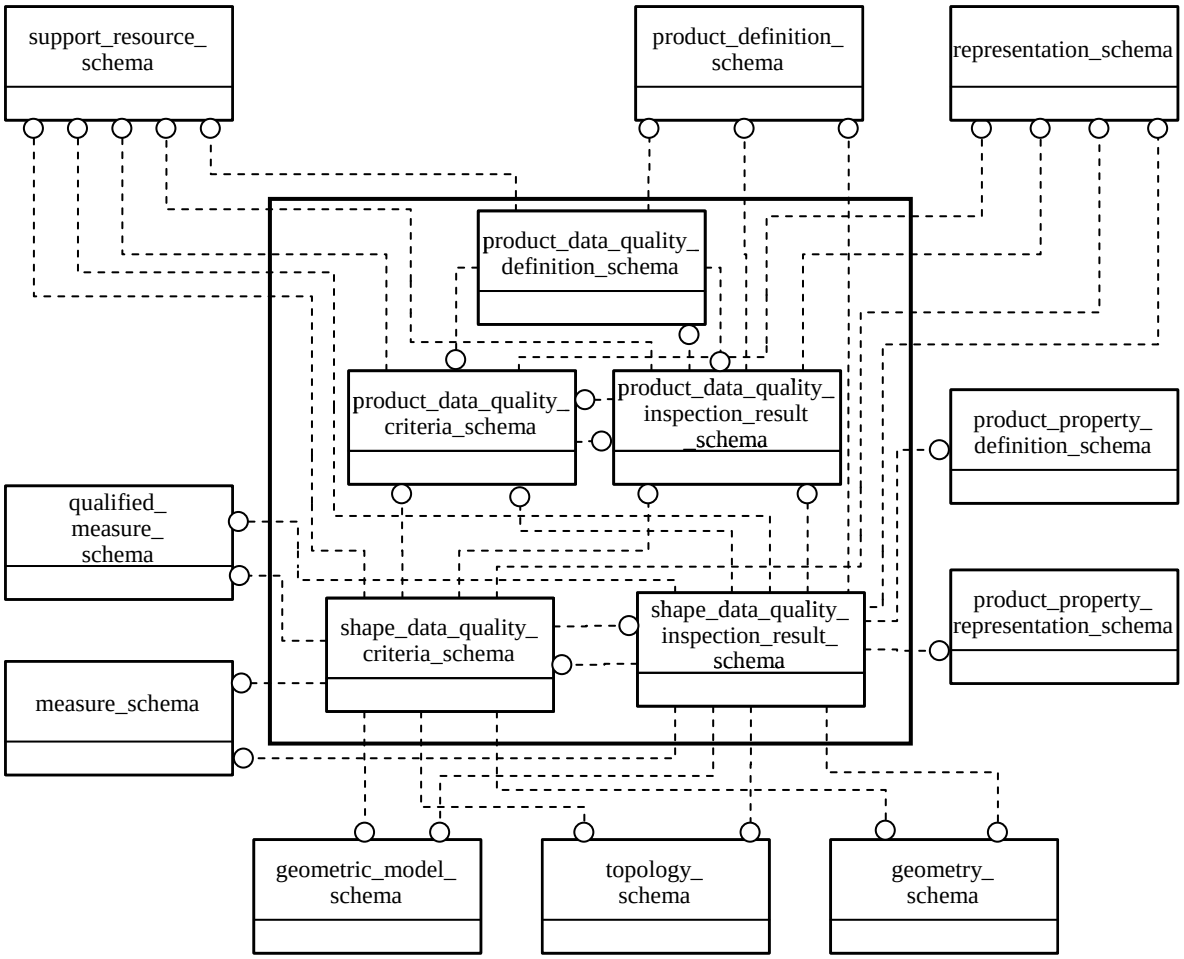

Figure 2 — Schema level diagram of relationships between PDQ-S schemas (inside the box) and other resource schemas

The schemas occurring in Figure 2 are components of ISO 10303 integrated generic resources, and they are specified in the following resource parts:

measure_schema	ISO 10303-41
product_definition_schema	ISO 10303-41
product_property_definition_schema	ISO 10303-41
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
qualified_measure_schema	ISO 10303-45

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4.6 Major characteristics of PDQ-S

4.6.1 Quality criteria of three dimensional shape data

Quality criteria of three-dimensional shape data fall into the following classes:

— Erroneous data;

— Inapt data;

Each of these classes is further categorized into the following sub-classes:

— Geometry specific issue;

— Topology specific issue;

— Combined geometry and topology issue;

— Geometric model issue.

‘Erroneous data’ implies a mathematically invalid product shape data. Typical examples are erroneous b_spline surface definition, open edge loop and inconsistent face and underlying surface normals. An example of an erroneous instance of a b_spline_surface is one in which there is an inconsistency between the degrees, the number of knots, the knot multiplicities and the number of control points. Such an instance will violate one, or more, of the WHERE rules in the definition of the corresponding b_spline_surface_with_knots entity. The judgement of erroneous data is generally a binary decision as to whether or not rules in the entity definition are broken and does not involve a numerical threshold value.

‘Inapt data’ implies data inappropriate for some applications though it is not necessarily mathematically incorrect. Amongst examples are self-intersecting curve, excessively high curve degree, surface with small radii of curvature and narrow width surface patches. Even when shape data have acceptable quality in the senses described above, there exists a number of cases where engineers in downstream processes have to rework the data so that it can be effectively used.

For example, mould design engineers have to modify a product shape data if an appropriate draft angle is not taken into account in the data. The knowledge as to whether various manufacturing requirements are incorporated into the data or not may save the cost of rework.

4.6.2 Enabler of better association between PDQ checking systems and healing systems

There is basically no association between separate PDQ checking and healing systems. Lack of reliable inspection result representation at the entity instance level is the major reason of this non association. Even when results of a PDQ check by some checking system exist, any separate PDQ healing system tends to check data quality again for obtaining reliable check results before starting the healing process. Inspection result representation at the entity instance level provided by PDQ-S may

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be used to resolve this redundant check situation.

The shape data quality inspection result schema provides representation of quality inspection results for specific product shape data with regard to specified quality criteria. The inspection result indicates whether or not the product shape data inspected contains quality defects. It may also include detailed information on what type of quality defect exists, and how serious the defect is, together with the shape element data where the problem is detected. This information is expected to be useful for quality healing processes and to help efficient cooperation between quality checking systems and healing systems for product shape data.

4.6.3 Standardization of the external specifications of quality checking algorithms

Two different PDQ checking systems may produce different check results for inspection of the same product data where the same criteria and the same thresholds are specified for the check, which deteriorates reliability of PDQ checking systems. The reason why this problem occurs is that the quality check algorithm for each quality criterion is left to the PDQ checking system vendor's freedom and there is no guideline for acceptable quality check algorithm.

The solution by PDQ-S to this problem is the introduction of a concept named 'measurement requirement', which is an external specification of an acceptable algorithm. Each shape quality criterion includes a pertaining measurement requirement, which is a textual description of how the criterion is to be measured and may have additional attributes and rules to control the test and the element or elements to be tested. It is expected that the dependence of check results on individual PDQ checking systems be drastically reduced if developers of a PDQ checking system review their system as to whether or not they satisfy the requested measurement requirements and improve the system as necessary

NOTE Measurement algorithms are outside the scope of PDQ-S since it is understood that algorithm development is a competitive arena for engineering system vendors and cannot be standardized by an international standard.

4.6.4 Optimization of data quality check environment by the user

Data quality requirements, thresholds to be applied for quality test and numerical calculation accuracies to be applied in the quality test algorithm are obviously dependent on the target design/manufacturing object and/or design/manufacturing activity. Therefore, these should be user definable. PDQ-S provides sufficient resources for the users to select the most appropriate quality criteria together with thresholds to be applied for the 3D shape data under development. Assuming that some users may even want to specify the accuracy of numerical calculations, the accuracy to be applied in a quality test by PDQ checking systems is also user definable. This standard provides some examples and suggestions for selecting appropriate criteria in Clause 5.

User definable thresholds from application protocols supporting shape models, such as ISO 10303-203 and ISO 10303-214, play a key role in the assessment of shape data quality by numerical test. An example of a typical threshold is a distance threshold for evaluating a gap between a base surface and bounding curves for trimming the effective portion of the surface. That distance threshold implies that if the maximum distance between the surface and the curves is greater than or equal to the specified

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minimum value, then the gap should be understood as a quality defect. Appropriate thresholds depend on many factors such as the size of a product, design requirements and the sensitivity of engineering systems to numerical imprecision, etc. Therefore, the actual threshold value to use needs to be carefully determined in each business situation based on agreement among the business partners.

In most cases, especially when free form geometry is involved, the measurement algorithm calculates an approximate solution not an exact solution. In the above example, surfaces and curves consist of an infinite number of points. Since calculation on an infinite number of points is impossible, any algorithm tries to calculate the solution using a sufficient finite number of points. In order to require the difference of the approximate solution and the exact solution, even when it is unknown, to be smaller than the expected value, an accuracy specification is provided. An approximate solution is acceptable if the difference of the approximate solution and another approximate solution obtained by calculation with another finer set of sampling points is smaller than the specified accuracy. There are two types of accuracy specification, general accuracy applied to all the measurements or specific accuracy applied only to a specified measurement.

Thus, users can optimize the data quality check environment by an appropriate combination of quality criteria, thresholds and accuracy.

NOTE The above focuses on how to optimize data quality testing so that it is appropriate for the target shape data. The underlying assumption is that the shape data are suited for quality testing. The general requirement for this suitability is that precision of the shape data satisfies the requirements of ISO 16792:2006, 6.2.

4.6.5 Extensibility to non-shape product data quality problems

Although the detailed specification of PDQ-S currently focuses on product shape data, it has two general schemas for representing any quality related property of product data. One is **product data quality criteria schema** and the other is **product data quality inspection result schema**.

The **product data quality criteria schema** and **product data quality inspection result schema** may be applied to non-shape data quality issues such as externally conditioned data quality problems and GD&T data quality problems.

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5. Considerations for facilitating the use of PDQ-S

5.1 General

This clause discusses the following considerations:

— the relationship between practical data quality problems and PDQ criteria in PDQ-S, from the point of view of standard developers (see 5.2);
— concrete PDQ criteria deployed for three different scenarios (see 5.3);
— the processes by which to promote PDQ activity (see 5.4).

The latter two considerations (see 5.3 and 5.4) are based on actual deployment of PDQ criteria in the Japanese automotive industry.

5.2 Relationship between product data quality problems and quality criteria

5.2.1 Types of product data quality problem

The following three different types of practical data quality problem have corresponding PDQ criteria.

a) B-rep is not appropriate (see 5.2.2).
b) Accuracy of B-rep does not satisfy requirements (see 5.2.3).
c) Shape manipulation process by CAX systems fails (see 5.2.4).

Of the above, item a) is the most basic and critical problem for all type of 3D shape data, while b) and c) are problems for which the severity depends on the use case.

5.2.2 B-rep is not appropriate (erroneous_data)

The B-rep of 3D shape data shall conform to ISO 10303-42. All the shape data quality criteria that are subtypes of **erroneous_data** in PDQ-S are those to check for conformance to ISO 10303-42. Quality defects detected by those criteria are regarded as illegal data and are useless in any application. The spread of 3D CAD systems has promoted improvement of these systems. Therefore, it is very rare today that quality defects of this category are detected against data created by modern CAD systems. The check for quality defects of this category is especially meaningful for legacy CAD data or for CAD data obtained by unstable data transformation systems.

5.2.3 Accuracy of B-rep is not satisfactory

The tolerance within which to regard two different points in 3D space as coincident plays a key role in numerical error analysis of a B-rep model. If the distance between two geometric entities, one of which is defined as being on the other (including, point on curve, curve on surface and curve bounded surface), is actually greater than the coincidence tolerance, or if there exists a curve or a surface having an extent that is smaller than the coincidence tolerance, it may cause various unsatisfactory results, including unexpected untrimmed surface, missing entities and erroneous termination of CAD commands.

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