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Geometrical product specifications (GPS) — Filtration —

Part 1: Overview and basic concepts

Spécification géométrique des produits (GPS) — Filtrage —

Partie 1: Vue d'ensemble et concepts de base

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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

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary Information

The committee responsible for this document is ISO/TC 213, *Dimensional and geometrical product specifications and verification*.

This first edition cancels and replaces ISO/TS 16610-1:2006 which has been technically revised.

ISO 16610 consists of the following parts, under the general title *Geometrical product specifications (GPS) — Filtration*:

— *Part 1: Overview and basic concepts*

— *Part 20: Linear profile filters: Basic concepts*

— *Part 21: Linear profile filters: Gaussian filters*

— *Part 22: Linear profile filters: Spline filters*

— *Part 28: Profile filters: End effects*

— *Part 29: Linear profile filters: Spline wavelets*

— *Part 30: Robust profile filters: Basic concepts*

— *Part 31: Robust profile filters: Gaussian regression filters*

— *Part 32: Robust profile filters: Spline filters*

— *Part 40: Morphological profile filters: Basic concepts*

— *Part 41: Morphological profile filters: Disk and horizontal line-segment filters*

— *Part 49: Morphological profile filters: Scale space techniques*

— *Part 60: Linear areal filters — Basic concepts*

— *Part 61: Linear areal filters — Gaussian filters*

— *Part 71: Robust areal filters: Gaussian regression filters*

— *Part 85: Morphological areal filters: Segmentation*

The following parts are planned:

— *Part 26: Linear profile filters: Filtration on nominally orthogonal grid planar data sets*

— *Part 27: Linear profile filters: Filtration on nominally orthogonal grid cylindrical data sets*

— *Part 45: Morphological profile filters: Segmentation*

— *Part 62: Linear areal filters: Spline filters*

— *Part 69: Linear areal filters: Spline wavelets*

— *Part 70: Robust areal filters: Basic concepts*

— *Part 72: Robust areal filters: Spline filters*

— *Part 80: Morphological areal filters: Basic concepts*

— *Part 81: Morphological areal filters: Sphere and horizontal planar segment filters*

— *Part 89: Morphological areal filters: Scale space techniques*

Introduction

This part of ISO 16610 is a geometrical product specification (GPS) standard and is to be regarded as a general GPS standard (see ISO/TR 14638). It influences chain links 3 and 6 in the GPS matrix structure.

The ISO/GPS Masterplan given in ISO 14638 gives an overview of the ISO/GPS system of which this part of ISO 16610 is a part of. The fundamental rules of ISO/GPS given in ISO 8015 apply to this part of ISO 16610 and the default decision rules given in ISO 14253-1 apply to the specifications made in accordance with this part of ISO 16610, unless otherwise indicated.

For more detailed information about the relation of this part of ISO 16610 to the GPS matrix model, see Annex F.

This part of ISO 16610 also develops the terminology and concepts for GPS filtration. This part of ISO 16610 generalizes the concept of filtration. The series of ISO 16610 presents a toolbox of filtration techniques to enable the user to choose an appropriate filter for the functional requirements. They are fundamental International Standards upon which other ISO documents are built.

Geometrical product specifications (GPS) — Filtration —

Part 1:
Overview and basic concepts

1 Scope

This part of ISO 16610 defines the basic terminology for GPS filtration and the framework for the fundamental procedures used in GPS filtration.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 17450-1:2011, *Geometrical product specifications (GPS) — General concepts — Part 1: Model for geometrical specification and verification*

ISO 17450-2:2012, *Geometrical product specifications (GPS) — General concepts — Part 2: Basic tenets, specifications, operators, uncertainties and ambiguities*

ISO/IEC Guide 99:2007, *International vocabulary of metrology — Basic and general concepts and associated terms (VIM)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC Guide 99, ISO 17450-1, ISO 17450-2, and the following apply.

3.1
integral feature
geometrical feature belonging to the real surface of the workpiece or to a surface model

Note 1 to entry: An integral feature is intrinsically defined, e.g. skin of the workpiece.

Note 2 to entry: For a statement of specifications, geometrical features obtained from partition of the surface model or of real surface of workpiece shall be defined. These features, called “integral features”, are models of the different physical parts of the workpiece that have specific functions, especially those in contact with adjacent workpieces.

Note 3 to entry: An integral feature can be identified, for example, by

— a partition of the surface model,

— a partition of another integral feature, or

— a collection of other integral features.

[SOURCE: ISO 17450-1:2011, 3.3.5]

3.1.1
surface portion
SP
portion of a partitioned *integral feature* (3.1)

3.1.2
surface profile
line resulting from the intersection between a *surface portion* (3.1.1) and an ideal plane

Note 1 to entry: The orientation of the ideal plane is usually perpendicular to the tangent plane of the surface portion.

Note 2 to entry: The concept of profiles is under development and it is possible that the definition of surface profile will be revised.

3.2
primary mathematical model
set of nested hierarchical mathematical models of the *surface portion* (3.1.1), wherein each model in the set can be described by a finite number of parameters

Note 1 to entry: Examples include truncated Fourier series, curvature limited (zero to ± value) profiles, and limited Wolf pruning height (100 % to smaller positive percentage) segments.

Note 2 to entry: An example of a primary mathematical model using a truncated Fourier series is given in A.1.

3.2.1
nesting index
NI
value indicating the relative level of nested hierarchy for a particular *primary mathematical model* (3.2)

Note 1 to entry: Given a particular nesting index, models with lower indices contain more surface information, whereas models with higher nesting indices contain less surface information.

Note 2 to entry: By convention, as the nesting index approaches zero (or a series of all zeros), there exists a primary mathematical model that approximates the real surface of a workpiece to within any given measure of closeness.

Note 3 to entry: The cut-off wavelength for the Gaussian filter is an example of a nesting index (see 3.2.1.1). For the morphological filter, the nesting index is the size of the structuring element (e.g. the radius of the disc) which is different from the wavelength concept that underlies the notion of "cut-off" (see 3.2.1.2 and 3.2.1.3).

Note 4 to entry: The term nesting index is derived from a combination of index from index set and nesting from nested hierarchy, both of which are mathematical terms.

3.2.1.1
cut-off wavelength
particular type of *nesting index* (3.2.1) applicable to linear filters, used to separate surface components into long and short wavelengths

Note 1 to entry: See, for example, ISO 16610-21, ISO 16610-22, and ISO 16610-61.

3.2.1.2
vertical circular disc radius
particular type of *nesting index* (3.2.1) applicable to profile morphological filters with a structuring element in terms of a circular disc

Note 1 to entry: See, for example, ISO 16610-41 and ISO 16610-49.

3.2.1.3
horizontal line length
particular type of *nesting index* (3.2.1) applicable to profile morphological filters with a structuring element in terms of a horizontal line

Note 1 to entry: See, for example, ISO 16610-41 and ISO 16610-49.

3.2.1.4
sphere radius
particular type of *nesting index* (3.2.1) applicable to areal morphological filters with a structuring element in terms of a sphere radius

3.2.1.5
circular disc radius
particular type of *nesting index* (3.2.1) applicable to areal morphological filters with a structuring element in terms of a circular disc

Note 1 to entry: See, for example, ISO 16610-40 and ISO 16610-41.

3.2.1.6
Wolf pruning height
particular type of *nesting index* (3.2.1) applicable to areal segmentation filters used to discriminate between significant and non-significant surface features

Note 1 to entry: See, for example, ISO 16610-85.

3.2.2
degree of freedom
primary mathematical model number of independent parameters required to fully describe a particular *primary mathematical model* (3.2)

3.3
primary surface
PS
surface portion (3.1.1) obtained when the latter is represented as a specified *primary mathematical model* (3.2) with specified *nesting index* (3.2.1)

3.3.1
primary profile
line resulting from the intersection between the *primary surface* (3.3) and an ideal plane

Note 1 to entry: The concept of profiles is under development and it is possible that the definition of primary profile will be revised.

3.4
primary mapping
mapping indexed by the *nesting index* (3.2.1) used to identify a particular *primary surface* (3.3) with a specified *nesting index* (3.2.1) in order to represent a *surface portion* (3.1.1) that satisfies the sieve and projection criteria

Note 1 to entry: A primary mapping identifies surface portions which have “features” larger than a particular nesting index.

3.4.1
sieve criterion
criterion where two *primary mappings* (3.4) applied one after another to a surface portion is entirely equivalent to only applying one of these two primary mappings to the surface portion namely that primary mapping with the highest *nesting index* (3.2.1)

3.4.2
projection criterion
criterion wherein a *primary surface* (3.3) with a specified *nesting index* (3.2.1) is mapped onto itself using the *primary mapping* (3.4) with the same specified *nesting index* (3.2.1)

Note 1 to entry: This implies that if you apply the primary mapping twice with the same nesting index to a surface, one obtains the same surface as if the primary mapping was applied only once. For example, applying a closing filter with a circular structural element of a given radius twice to a profile results in the same filtered profile as if the closing filter is only applied once.

3.4.3
basic scale
scale established when using a *nesting index* (3.2.1) assigned to an associated *primary mapping* (3.4) as a numerical relational system

Note 1 to entry: An example is a basic scale based on sinewaves when using cut-off values associated with a primary mapping derived from a truncated Fourier series.

Note 2 to entry: For a relational system to be stable, the set of entities with their relations have to form a partially ordered set with a greatest element.

3.5
filtration
feature operation used to create a non-ideal feature from a non-ideal feature or to transform one variation curve to another by reducing the level of information

Note 1 to entry: For the purposes of this series of International Standards, a filter is either a primary mapping or can be constructed using a combination of primary mappings, e.g. the weighted mean of primary mappings, the supremum of primary mappings, etc. For example, a Gaussian filter can be constructed from a weighted sum of primary mappings derived from a truncated Fourier series.

[SOURCE: ISO 17450-1:2011, 3.4.1.3, modified — Note 1 to entry has been added.]

3.5.1
profile filter
operator consisting of a *filtration* (3.5) operation for use on a *surface profile* (3.1.2)

Note 1 to entry: Throughout this International Standard, the term "operator" is interpreted in its mathematical context. When it is used in the context of ISO 17450-2:2012, the qualifier "specification" or "verification" is used in front of the term "operator".

3.5.2
areal filter
operator consisting of a *filtration* (3.5) operation for use on a *surface portion* (3.1.1)

3.6
outlier
local portion in a data set that is not representative or not typical for the partitioned *integral feature* (3.1) and which is characterized by magnitude and scale

Note 1 to entry: Not all outliers can be determined using data alone, but only those that are physically inconsistent with stylus tip geometry. It is sometimes possible to give a warning based on magnitude/scale criteria.

3.7
open profile
finite length *surface profile* (3.1.2) with two ends

Note 1 to entry: The surface profile does not intersect with itself.

3.8
closed profile
connected finite length *surface profile* (3.1.2) without ends

Note 1 to entry: The surface profile does not intersect with itself, i.e. it is a simple closed curve or Jordan curve.

3.9
robustness
insensitivity of the output data against specific phenomena in the input data

Note 1 to entry: Outliers, scratches, and steps are examples of specific phenomena. More details can be found in ISO 16610-30.

3.10
filter equation
equation for the mathematical description of the filter

Note 1 to entry: Filter equations do not necessarily specify an algorithm for the numerical realization of the filter.

4 General discussion

4.1 General

Filtration is a way of separating features of interest from other features in the data.

EXAMPLE Sieving particles where soil particles are filtered into different sizes, depending on the size of the sieve holes.

The nesting index is the size at which features are separated. In the above example, the nesting index corresponds to the size of the holes in the sieve.

More precisely, filtration exists in the first place of defining a set of nested hierarchical representations (similar to a set of Russian dolls), to be used to model the real surface, such that the further into the nesting hierarchy, the smoother the model used to represent the surface. The nesting index is a number that indicates the level of the hierarchy (nesting/smoothness) of the model, such that the higher the value of the nesting index, the smoother the model used to represent the surface. By convention, as the nesting index approaches zero, there exists a model that represents the real surface.

Secondly, a primary mapping is defined. The primary mapping is a method of choosing a particular model with a specified nesting index and which satisfies certain properties to represent a real surface. The primary mapping is a basic filter from which other filters can be constructed. Illustrative examples are given in Annex A.

A toolbox of new and novel filter tools is recommended which includes mean line filters, morphological filters, robust filters, and techniques that decompose surface texture into different scale components. The filtration masterplan (see Annex B) shows the structure of the part number allocation for the ISO 16610-series. The particular filter tool and its default value are provided in other ISO application documents.

The advantages and disadvantages of different filter types are given in Annex C, concept diagrams for the basic concepts of filtration are given in Annex D, and the relationship to the filtration matrix is given in Annex E.

4.2 Primary mathematical models

The primary mathematical models have been developed to generalize the concept of wavelength band. The aim of the nesting index is to generalize the concept of wavelength value.

Given a particular model within a set of nested models, higher nestings (with a smaller nesting index) contain more surface information, whereas lower nestings (with a larger nesting index) contain less surface information. By convention, as the nesting index approaches zero, there exists a primary mathematical model that approximates the partitioned integral feature to within any given measure of closeness (as defined by a suitable mathematical norm).

The sieve criterion is derived from Matheron's size criterion[35] and is a necessary condition for the following reason; if a primary mapping is applied to a partitioned integral feature, any further primary mapping with a larger nesting index is exactly equivalent to applying the second primary mapping with the larger nesting index directly to the partitioned integral feature. In other words, for a primary mapping with a specified nesting index, no information is lost concerning primary mappings of the partitioned integral feature with a larger nesting index.

The projection criterion is necessary in order to ensure that the primary mapping is idempotent and that the nesting index corresponds to Matheron's definition of size. The projection criterion, together with the sieve criterion, ensures that the nesting index assigned to a primary mapping is a basic scale.

Since the nesting index of the primary mathematical models corresponds to scale, the nesting index can be used to define the generalized concept of wavelength.

5 Filter designations

Table 1 indicates the basic semantics in designating filters. Table 2, on the other hand, indicates the filter designations.

Table 1 — Basic semantics in designating filters

Filter	Type	Category
F = Filter	A = Areal (3D)	L = Linear
		M = Morphological
		R = Robust
	P = Profile (2D)	L = Linear
		M = Morphological
		R = Robust

Table 2 — Filter designations

Type	Category	Symbol	Designation	Name	ISO document
FA	FAL	G	FALG	Gaussian	16610-61
		S	FALS	Spline	16610-62 [a]
		SW	FALSW	Spline Wavelet	16610-69 [a]
	FAM	CB	FAMCB	Closing Ball	16610-81 [a]
		CH	FAMCH	Closing Horizontal segment	16610-81 [a]
		OB	FAMOB	Opening Ball	16610-81 [a]
		OH	FAMOH	Opening Horizontal segment	16610-81 [a]
		AB	FAMAB	Alternating series Ball	16610-89 [a]
		AH	FAMAH	Alternating series Horizontal segment	16610-89 [a]
	FAR	G	FARG	Gaussian	16610-71
		S	FARS	Spline	16610-72 [a]

[a] Planned.

