TECHNICAL SPECIFICATION

ISO/TS 16610-30

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Geometrical product specifications (GPS) — Filtration —

Part 30: Robust profile filters: Basic concepts

Spécification géométrique des produits (GPS) — Filtrage —

Partie 30: Filtres de profil robustes: Concepts de base

Reference number
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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.

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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 document:

— 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 casting 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 after three years in order to decide whether it will be confirmed for a further three years, revised to become an International Standard, or withdrawn. If the ISO/PAS or ISO/TS is confirmed, it is reviewed again after a further three years, at which time it must either be transformed into an International Standard or be withdrawn.

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/TS 16610-30 was prepared by Technical Committee ISO/TC 213, *Dimensional and geometrical product specifications and verification.*

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

— *Part 1: Overview and basic concepts* [Technical Specification]

— *Part 20: Linear profile filters: Basic concepts* [Technical Specification]

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

— *Part 22: Linear profile filters: Spline filters* [Technical Specification]

— *Part 29: Linear profile filters: Spline wavelets* [Technical Specification]

— *Part 30: Robust profile filters: Basic concepts* [Technical Specification]

— *Part 32: Robust profile filters: Spline filters* [Technical Specification]

- *Part 40: Morphological profile filters: Basic concepts* [Technical Specification]
- *Part 41: Morphological profile filters: Disk and horizontal line-segment filters* [Technical Specification]
- *Part 49: Morphological profile filters: Scale space techniques* [Technical Specification]

The following parts are under preparation:

- *Part 28: Profile filters: End effects* [Technical Specification]
- *Part 31: Robust profile filters: Gaussian regression filters* [Technical Specification]

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 42: Morphological profile filters: Motif filters*
- *Part 60: Linear areal filters: Basic concepts*
- *Part 61: Linear areal filters: Gaussian filters*
- *Part 62: Linear areal filters: Spline filters*
- *Part 69: Linear areal filters: Spline wavelets*
- *Part 70: Robust areal filters: Basic concepts*
- *Part 71: Robust areal filters: Gaussian regression filters*
- *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 82: Morphological areal filters: Motif 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 global GPS standard (see ISO/TR 14638). It influences the chain links 3 and 5 of all chains of standards.

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

This part of ISO 16610 develops the basic concepts for robust profile filters.

Geometrical product specifications (GPS) — Filtration —

Part 30:
Robust profile filters: Basic concepts

1 Scope

This part of ISO 16610 specifies the basic concepts of robust profile filters.

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/TS 16610-1:2006, *Geometrical product specifications (GPS) — Filtration — Part 1: Overview and basic concepts*

ISO/TS 16610-20:2006, *Geometrical product specifications (GPS) — Filtration — Part 20: Linear profile filters: Basic concepts*

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/TS 16610-1, ISO/TS 16610-20 and the following apply.

3.1
robustness
insensitivity of the output data against specific phenomena in the input data

NOTE Outliers, scratches and steps are examples of specific phenomena.

[ISO/TS 16610-1:2006, definition 3.9]

3.2
profile discontinuity
portion of a profile where there is a sudden change in profile properties

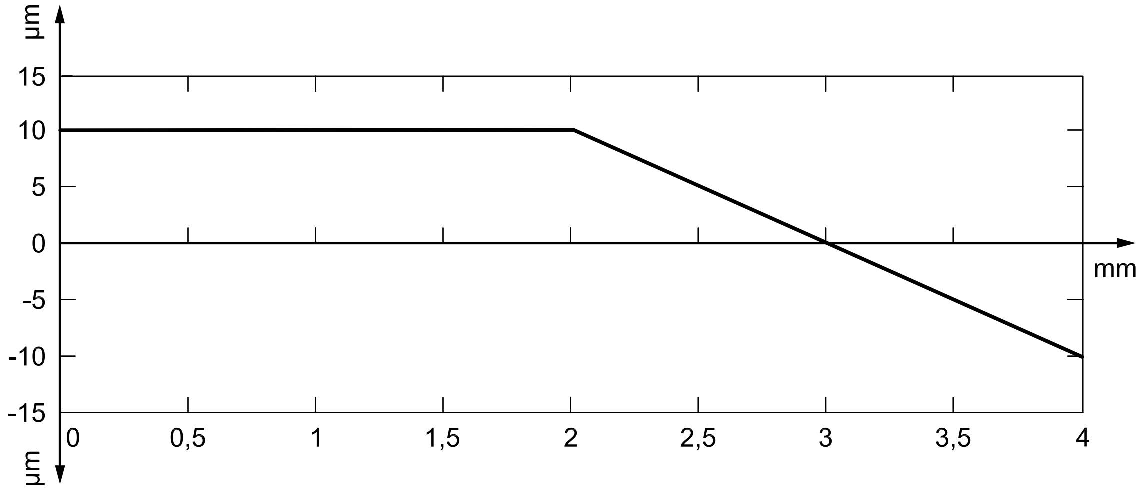


Figure 1 — Example of slope discontinuity

3.2.1
slope discontinuity
profile discontinuity (3.2) consisting of a sudden change in the slope of the profile

See Figure 1.

3.2.2
step discontinuity
profile discontinuity (3.2) consisting of a sudden change in the height of the profile

See Figure 2.

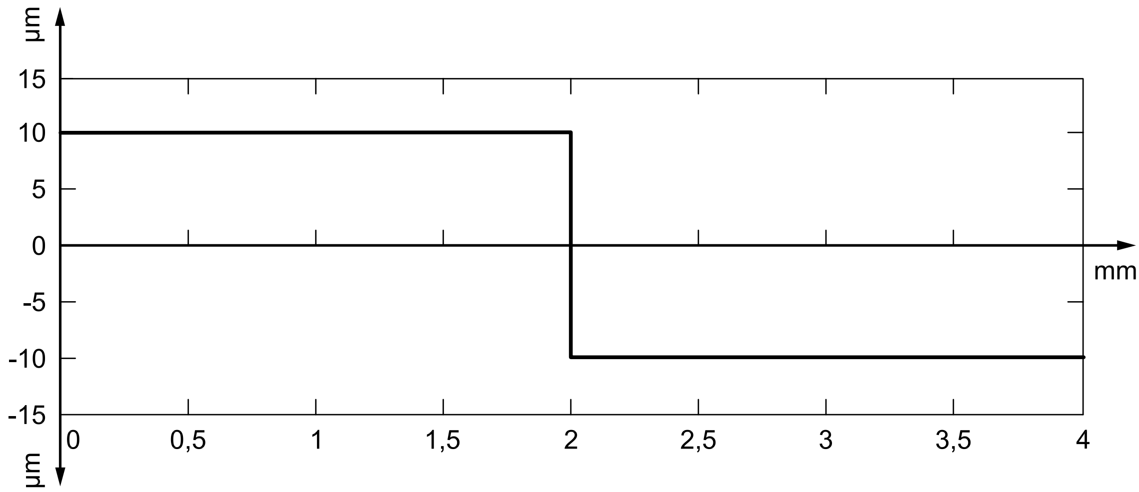


Figure 2 — Example of step discontinuity

3.2.3
spike discontinuity
profile discontinuity (3.2) consisting of an upward or downward portion of the profile with a narrow base

See Figure 3.

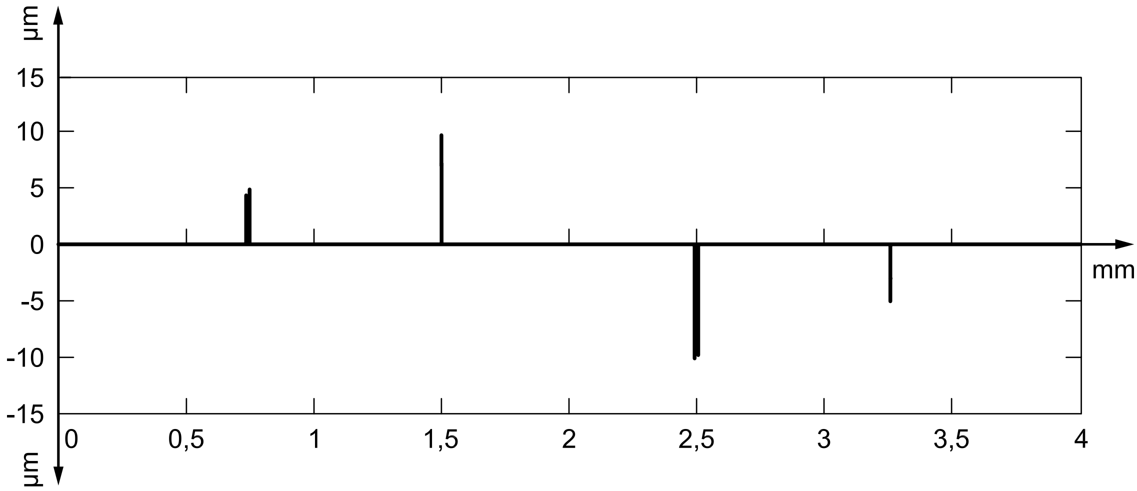


Figure 3 — Example of a series of spike discontinuities

3.3
metric
⟨profile⟩ property between two profiles obeying the following three conditions:

Positivity i.e. $\delta\left(p_1(x), p_2(x)\right) \geqslant 0$ with equality if and only if $p_1(x) = p_2(x)$

Commutativity i.e. $\delta\left(p_1(x), p_2(x)\right) = \delta\left(p_2(x), p_1(x)\right)$

Triangular inequality i.e. $\delta\left(p_1(x), p_2(x)\right) + \delta\left(p_2(x), p_3(x)\right) \geqslant \delta\left(p_1(x), p_3(x)\right)$

where $\delta(\ldots, \ldots)$ is a function of two profiles, p_1 and p_2, resulting in a real number

3.3.1
norm
⟨profile⟩ function of two profiles which can be used to define a **metric** (3.3)

3.3.2
L1-norm
continuous absolute deviation norm
⟨profile⟩ **norm** (3.3.1) defined by the following integral

$$\delta\left(p_1(x), p_2(x)\right) = \int_x \left|p_1(x) - p_2(x)\right| \mathrm{d}x$$

3.3.3
l1-norm
discrete absolute deviation norm
⟨profile⟩ **norm** (3.3.1) defined by the following summation

$$\delta\left(p_1(x), p_2(x)\right) = \sum_{i=1}^{n} \left|p_1(x_i) - p_2(x_i)\right|$$

3.3.4
L2-norm
continuous least squares norm
⟨profile⟩ **norm** (3.3.1) defined by the following integral

$$\delta\left(p_1(x), p_2(x)\right) = \sqrt{\int_x \left(p_1(x) - p_2(x)\right)^2 \mathrm{d}x}$$

3.3.5
l2-norm
discrete least squares norm
⟨profile⟩ **norm** (3.3.1) defined by the following summation

$$\delta\left(p_1(x), p_2(x)\right) = \sqrt{\sum_{i=1}^{n} \left(p_1(x_i) - p_2(x_i)\right)^2}$$

3.3.6
L∞-norm
continuous Chebychev norm
⟨profile⟩ **norm** (3.3.1) defined by the following formula

$$\delta\left(p_1(x), p_2(x)\right) = \max_{x} \left|p_1(x) - p_2(x)\right|$$

3.3.7
l∞-norm
discrete Chebychev norm
⟨profile⟩ **norm** (3.3.1) defined by the following formula

$$\delta\left(p_1(x), p_2(x)\right) = \max_{i=1,\ldots n} \left|p_1(x_i) - p_2(x_i)\right|$$

3.4
statistical estimator
rule that indicates how to calculate an estimate based on sample data from a population

3.4.1
robust statistical estimator
statistical estimator (3.4) that is insensitive against specific phenomena in the input data

3.5
M-estimator
robust statistical estimator (3.4.1) which uses an **influence function** (3.5.1) to weight points according to their signed distance from the reference line

3.5.1
influence function
function which is asymmetric and scale invariant

NOTE 1 If the value of a point in the data is replaced by an arbitrary value, the influence of this modified point on the output of the **M-estimator** (3.5) is proportional to the influence function.

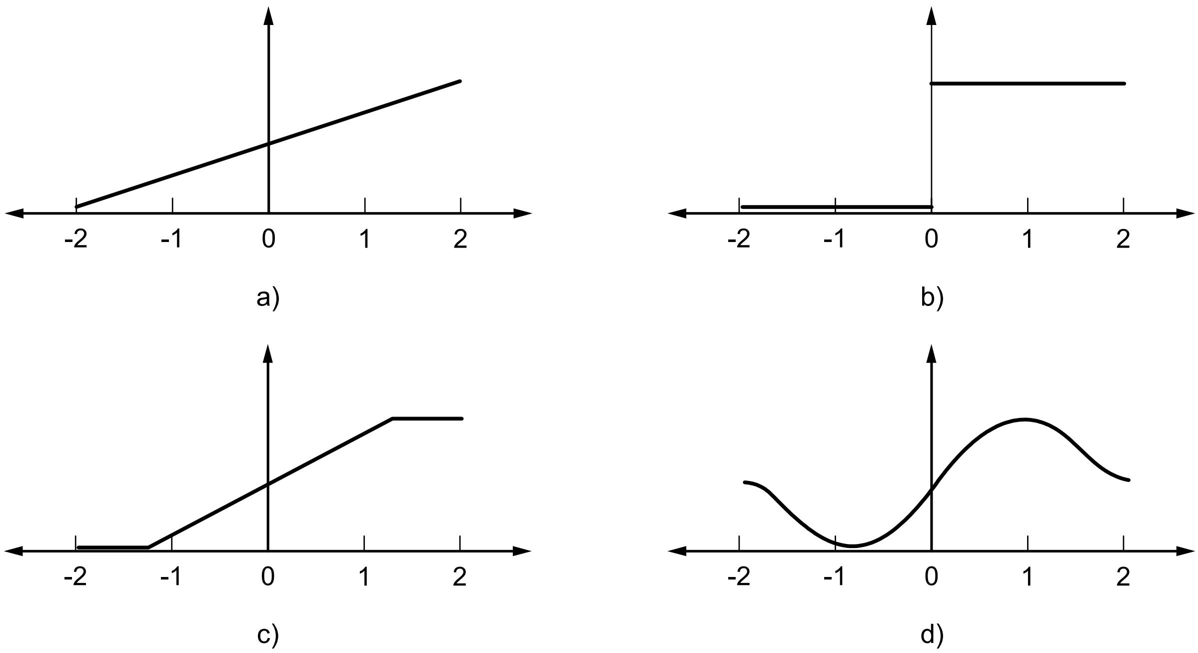
NOTE 2 To be scale invariant, many influence functions use a scale parameter which needs to be determined. An estimate of the dispersion of the profile from the reference line, such as **median absolute deviation** (3.5.2), can be used to determine the scale parameter.

3.5.2
median absolute deviation
MAD
measure of dispersion of a set of observations which is robust against **spike discontinuities** (3.2.3) and computed by taking the median of the absolute deviations of each observation from the median of the observations

NOTE 1 For a Gaussian probability distribution, the standard deviation equals 1,482 6 × MAD.

NOTE 2 For additional information on the median, see References [9] and [10].

See Figure 4.



NOTE a) is the mean; b) is the median; c) is the Huber function; d) is the biweight function.

Figure 4 — Examples of influence functions that have been considered in connection with M-estimators

3.6
Bayesian estimator
robust statistical estimator (3.4.1) which uses Bayesian statistics to weight points according to their signed distance from the reference line

4 Robustness

4.1 General

Robustness is not in general an absolute property of a profile filter but a relative one. One can only say that a particular profile filter is more robust against a particular phenomenon than another alternative profile filter if there is less distortion in that profile filter's response to that phenomenon than in the response of the alternative profile filter.

To make robustness an absolute property of profile filters, we need to define a reference class of profile filters with which to compare. The reference class of profile filters used in this technical specification is the class of linear profile filters (see ISO/TS 16610-20). Hence by this definition, all robust profile filters have a nonlinear part in their implementation. There are several well-known techniques (all nonlinear) which can produce robust filters for a particular phenomenon. These are described in 4.2, 4.3, 4.3.1, 4.3.2, 4.4, 4.4.1 and 4.4.2.

4.2 Metric-based methods

Here, the metric used to fit the filtered profile to the profile is altered to a more “robust” metric.

For example, the metric based on the L1-norm is more robust against spike discontinuities than the metric based on the least squares norm (L2-norm), which in turn is more robust than the metric based on the Chebychev norm (L∞-norm).

NOTE The equivalent roughness parameters to these metrics are *R*a (L1-norm), *R*q (L2-norm) and *R*z (L∝-norm), respectively. These parameters become increasingly more sensitive to changes in the profile.

4.3 Statistical-based methods

4.3.1 General

In this document, only the M-estimator and the Bayesian estimator are used as statistical-based methods to determine a robust fit of the filter to the profile, although other possibilities exist[1)].

4.3.2 M-estimator

Each point on the profile is weighted according to an influence function using the profile filter’s low-pass response as a reference line. As a result, points further away are given less relative weight than would be the case with points nearer to the low pass response. This is an attempt to make the filtered profile more robust against spike discontinuities. There are several common influence functions used to allocate the weights to points (Huber, Beaton functions, etc.) which can be found in any standard book on robust statistics[2)].

NOTE This approach to robustness is usually implemented using an iterative approach, since the profile filter's response is required to calculate the weights.

4.3.3 Bayesian estimator

A statistical model is built that models the representative component of the profile together with the spike discontinuity component. Starting with a prior distribution for each component, Bayesian statistical methods are then used to determine the probability that each point of the profile is either a spike discontinuity or a representative point of the profile and to give that point a weight according to the determined Bayesian probability. These weights are then used to determine the filtered profile in a similar way to the M-estimator approach.

4.4 Pre-processing methods

4.4.1 General

Pre-processing is a technique where an unwanted phenomenon in the profile is removed or greatly reduced, by other means, before filtration, thus removing or greatly reducing any effect the unwanted phenomenon can have on the profile filter’s response. In other words, pre-processing followed by a filter results in a robust filter. This approach has the advantage that once a method has been found to remove unwanted phenomena, then it will work with any profile filter.

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1) See Reference [9].

2) See References [9] and [10].

4.4.2 Scale-space pre-processing

In this case, scale-space techniques (see ISO/TS 16610-49) can be used to remove profile discontinuities before filtration. Profile discontinuities are identified by locating coefficients above a hard threshold on each scale of the scale space. Profile discontinuities can be removed by setting each of the previously located coefficients above the hard threshold to zero and reconstructing the profile. Scale-space pre-processing allows all profile filters to be robust against profile discontinuities.

4.4.3 Wavelet pre-processing

In this case, wavelets (see ISO/TS 16610-29) can be used to remove profile discontinuities before filtration. Profile discontinuities are identified by locating coefficients above a hard threshold on each level of the scale wavelet space. Profile discontinuities can be removed by setting each of the previously located coefficients above the hard threshold to zero and reconstructing the profile. Wavelet pre-processing allows all profile filters to be robust against profile discontinuities.

Annex A
(informative)

Illustrative data sets — Input of profile discontinuities

A.1 General

An important property of a profile filter is how it responds to profile discontinuities. The three basic types of profile discontinuities considered here are: slope, step and spike type discontinuities.

A.2 Slope discontinuity

The slope discontinuity data set is defined as follows:

$0 < X < 2$	$Z = 10$ µm
$2 < X < 4$	$Z = (3 \text{ mm} - X)/100$
Other X	Z not defined
X spacing is 0,5 µm	

See Figure 1 for an illustration of this data set.

Figure A.1 illustrates a Gaussian filter according to ISO 16610-21 with a 0,8 mm cut-off value over the slope discontinuity data set, and Figure A.2 illustrates the difference between the original and filtered profiles.

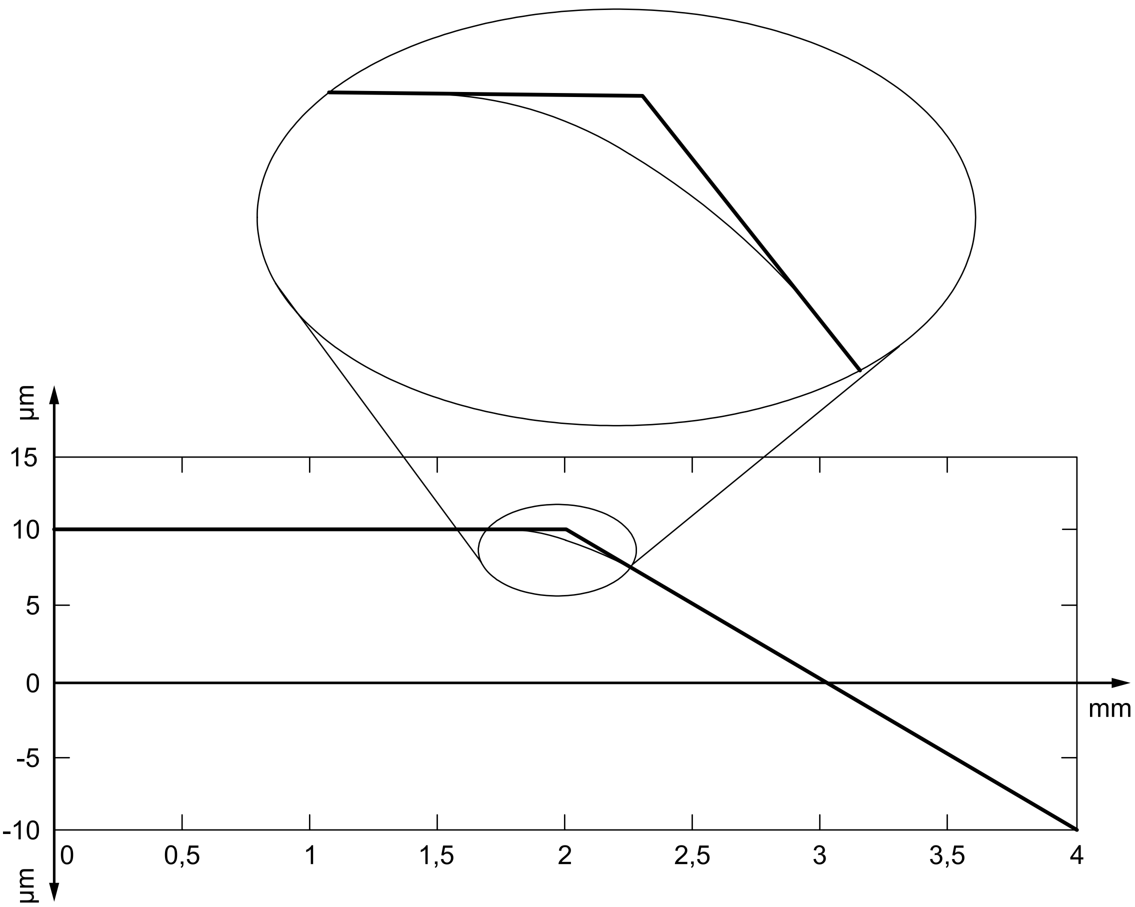

Figure A.1 — Example of a filter over the slope discontinuity data set

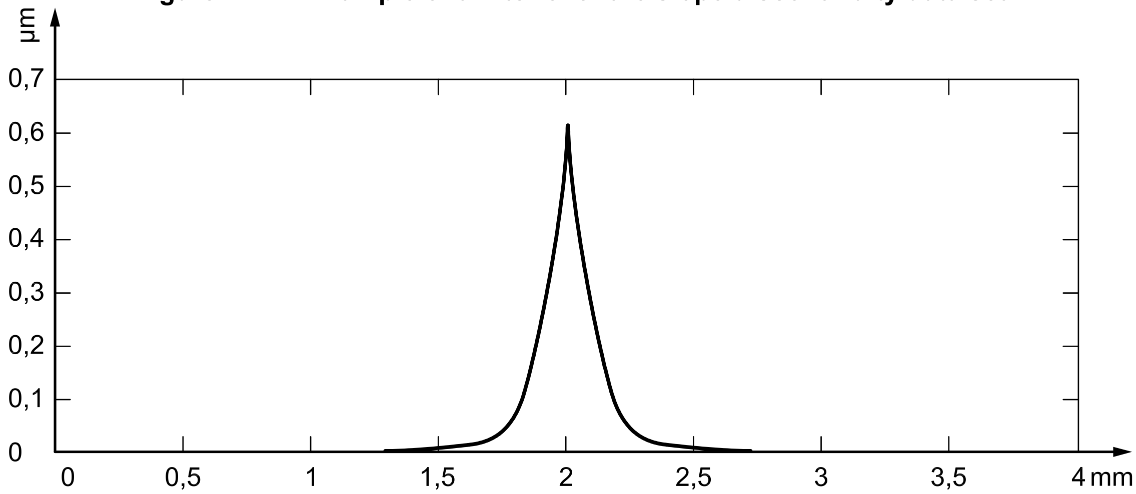

Figure A.2 — Example of the difference between the filter and original profiles for the slope discontinuity data set

A.3 Step discontinuity

The step discontinuity data set is defined as follows:

$0 < X < 2$	$Z = 10$ µm
$2 < X < 4$	$Z = -10$ µm
Other X	Z not defined
X spacing is 0,5 µm	

See Figure 2 for an illustration of this data set.

Figure A.3 illustrates a Gaussian filter according to ISO 16610-21 with a 0,8 mm cut-off value over the step discontinuity data set.

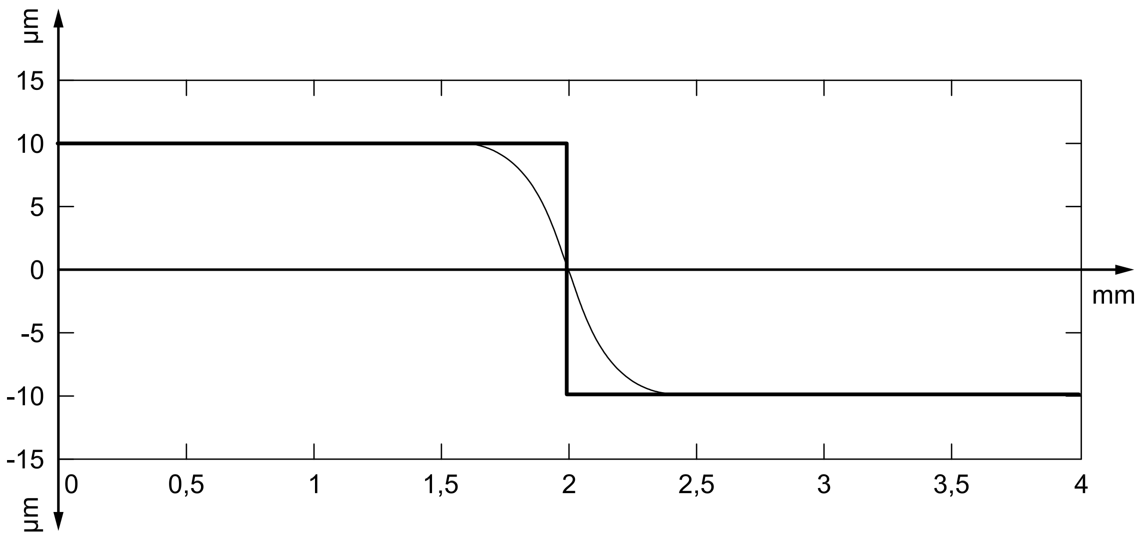

Figure A.3 — Example of a filter over the step discontinuity data set

A.4 Spike discontinuity

The slope discontinuity data set is defined as follows:

$0 < X < 4$	$Z = 0$ µm
$X = 0{,}75$	$Z = 5$ µm
$X = 1{,}5$	$Z = 10$ µm
$X = 2{,}5$	$Z = -10$ µm
$X = 3{,}25$	$Z = -5$ µm
Other X	Z not defined
X spacing is 0,5 µm	

See Figure 3 for an illustration of this data set.

Figure A.4 illustrates a Gaussian filter according to ISO 16610-21 with a 0,8 mm cut-off value over the spike discontinuity data set.

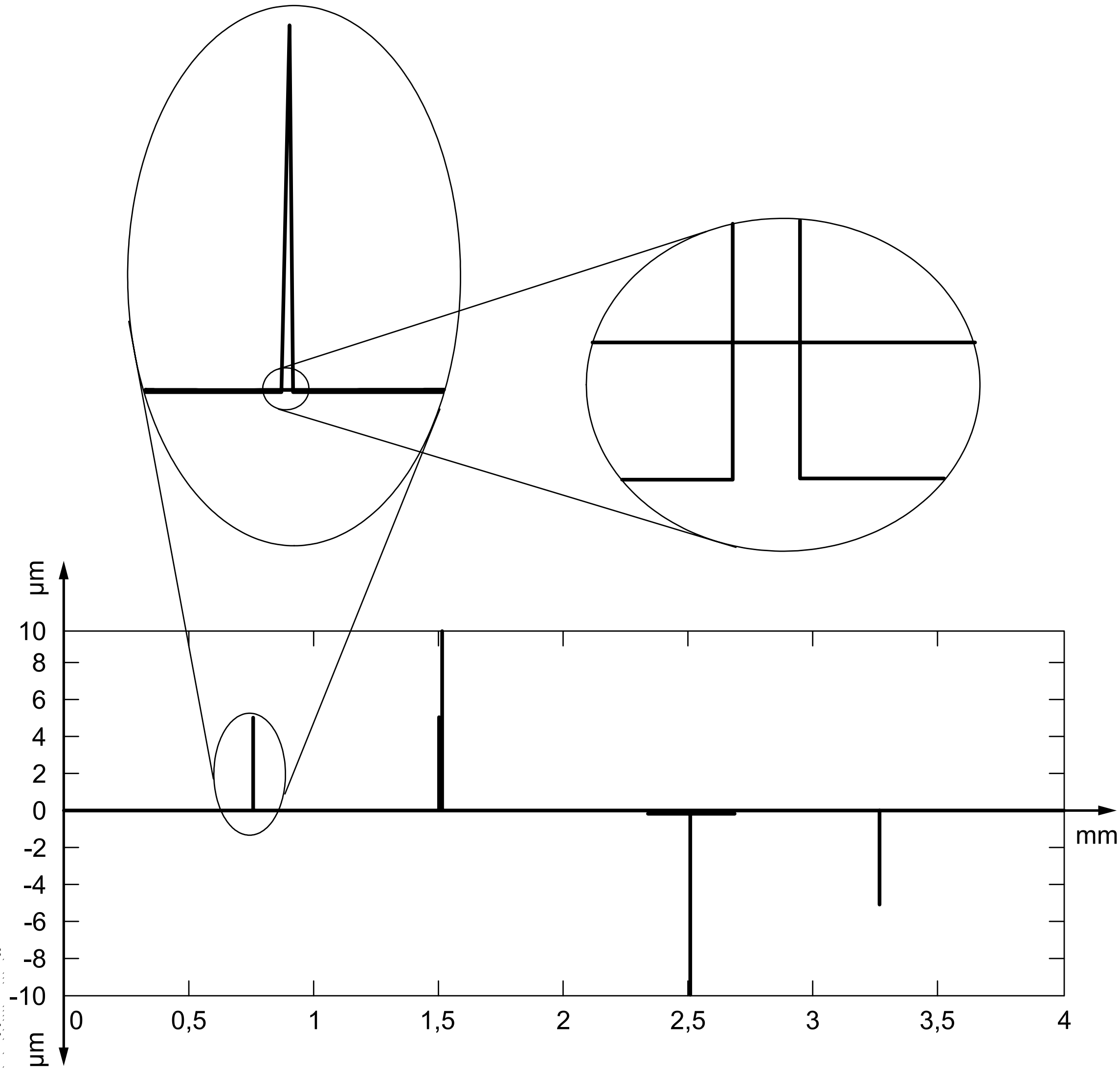

Figure A.4 — Example of a filter over the spike discontinuity data set

Annex B
(informative)

Concept diagram

See Figure B.1.

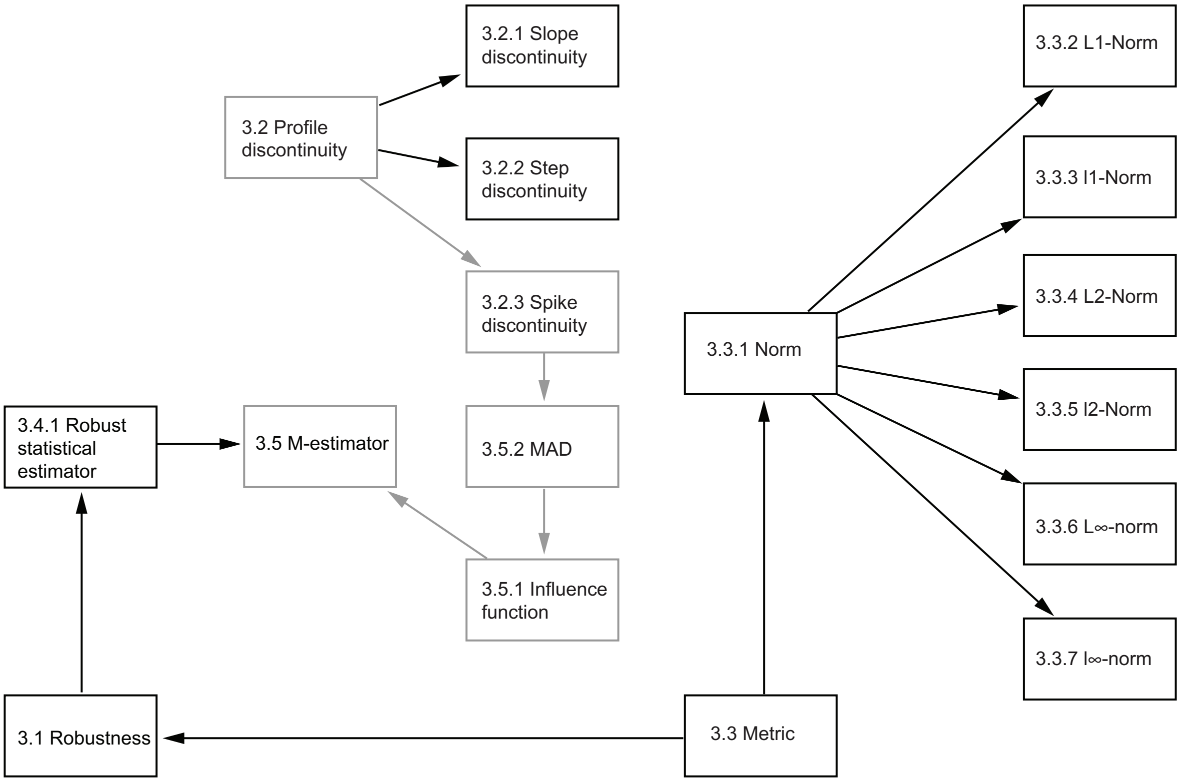

Figure B.1 — Concept diagram

Annex C
(informative)

Relationship to the filtration matrix model

C.1 General

For full details about the filtration matrix model, see ISO/TS 16610-1.

C.2 Position in the filtration matrix model

This part of ISO 16610 is a basic concept document that influences all filtration standards in the column "Profile filters, Robust" (see Figure C.1).

General	Filters: ISO 16610 series					
	Part 1					
Fundamental	Profile filters			Areal filters		
	Part 11[a]			Part 12[a]		
	Linear	**Robust**	**Morphological**	**Linear**	**Robust**	**Morphological**
Basic concepts	Part 20	Part 30	Part 40	Part 60	Part 70	Part 80
Particular filters	Parts 21-25	Parts 31-35	Parts 41-45	Parts 61-65	Parts 71-75	Parts 81-85
How to filter	Parts 26-28	Parts 36-38	Parts 46-48	Parts 66-68	Parts 76-78	Parts 86-88
Multiresolution	Part 29	Part 39	Part 49	Part 69	Part 79	Part 89

[a] At present included in Part 1.

Figure C.1 — Relationship to the filtration matrix model

Annex D
(informative)

Relation to the GPS matrix model

D.1 General

For full details about the GPS matrix model, see ISO/TR 14638.

D.2 Information about this Technical Specification and its use

This part of ISO 16610 defines the basic concepts for robust profile filters.

D.3 Position in the GPS matrix model

This part of ISO 16610 is a global GPS standard, which influences the chain links number 3 and 5 in all the chain of standards in the GPS matrix structure, as graphically illustrated in Figure D.1.

Fundamental GPS standards

Global GPS standards

General GPS standards						
Chain link number	1	2	3	4	5	6
Size			X		X	
Distance			X		X	
Radius			X		X	
Angle			X		X	
Form of a line independent of datum			X		X	
Form of a line dependent of datum			X		X	
Form of a surface independent of datum			X		X	
Form of a surface dependent of datum			X		X	
Orientation			X		X	
Location			X		X	
Circular run-out			X		X	
Total run-out			X		X	
Datums			X		X	
Roughness profile			X		X	
Waviness profile			X		X	
Primary profile			X		X	
Surface imperfections			X		X	
Edges			X		X	

Figure D.1 — Position in the GPS matrix model

D.4 Related International Standards

The related International Standards are those of the chains of standards indicated in Figure D.1.

Bibliography

[1] ISO 11562, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Metrological characteristics of phase correct filters*

[2] ISO/TR 14638, *Geometrical product specification (GPS) — Masterplan*

[3] ISO 16610-21 [3)], *Geometrical product specifications (GPS) — Filtration — Part 21: Linear profile filters: Gaussian filters*

[4] ISO/TS 16610-22, *Geometrical product specifications (GPS) — Filtration — Part 22: Linear profile filters: Spline filters*

[5] ISO/TS 16610-29, *Geometrical product specifications (GPS) — Filtration — Part 29: Linear profile filters: Spline wavelets*

[6] ISO/TS 16610-31 [3)], *Geometrical product specifications (GPS) — Filtration — Part 31: Robust profile filters: Gaussian regression filters*

[7] ISO/TS 16610-32, *Geometrical product specifications (GPS) — Filtration — Part 32: Robust profile filters: Spline filters*

[8] ISO/TS 16610-49, *Geometrical product specifications (GPS) — Filtration — Part 49: Morphological profile filters: Scale space techniques*

[9] HUBER, P.J. (2004), *Robust Statistics*, New York: John Wiley & Sons, ISBN 0-471-65072-2

[10] WILCOX, Rand R. (2001), *Fundamentals of Modern Statistical Methods — substantially improving power and accuracy*. Springer-Verlag New York, ISBN 0-387-95157-1

3) To be published.

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