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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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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.

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 of ISO 16610-30 cancels and replaces ISO/TS 16610-30:2009, 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 14638). It influences chain links C and F of all chains of standards.

The ISO/GPS matrix model given in ISO 14638 gives an overview of the ISO/GPS system of which this part of ISO 16610 is a part. 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 specifications made in accordance with this part of ISO 16610, unless otherwise indicated.

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

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

ISO/IEC Guide 99, *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 16610-1, ISO 16610-20, and the following apply.

3.1
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.

[SOURCE: ISO 16610-1, 3.9]

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

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

Note 1 to entry: See Figure 1.

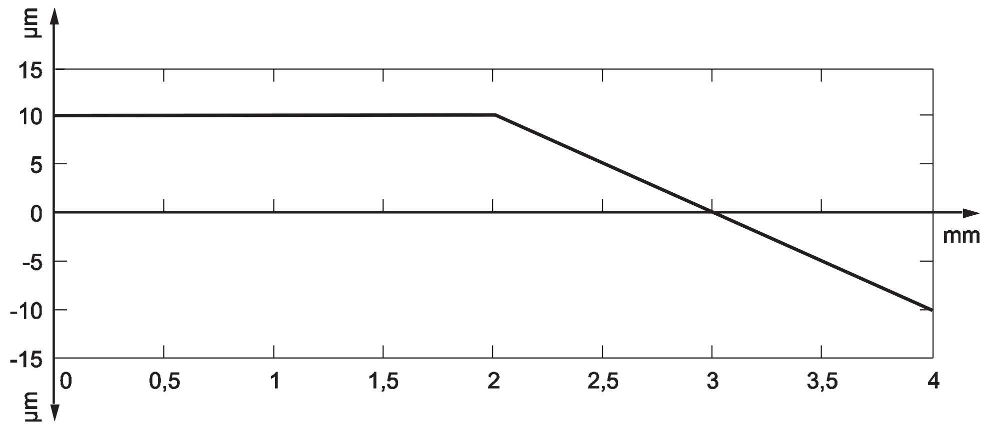

Figure 1 — Example of slope discontinuity

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

Note 1 to entry: See Figure 2.

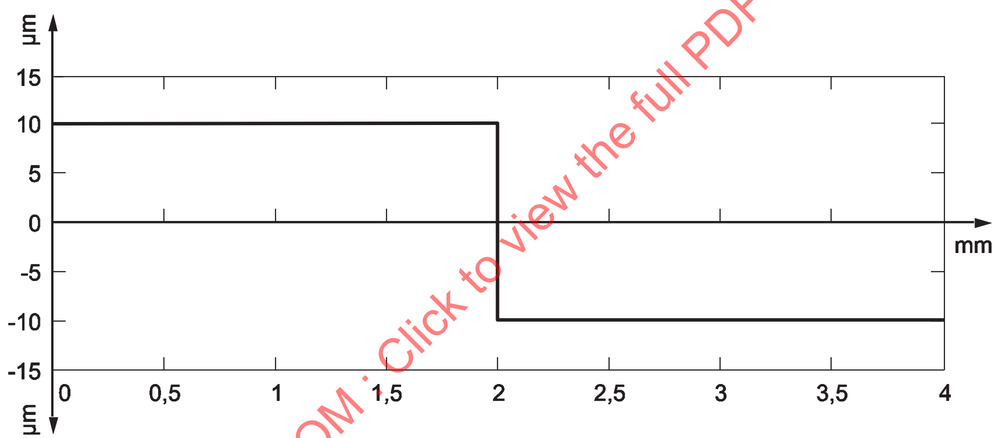

Figure 2 — Example of step discontinuity

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

Note 1 to entry: See Figure 3.

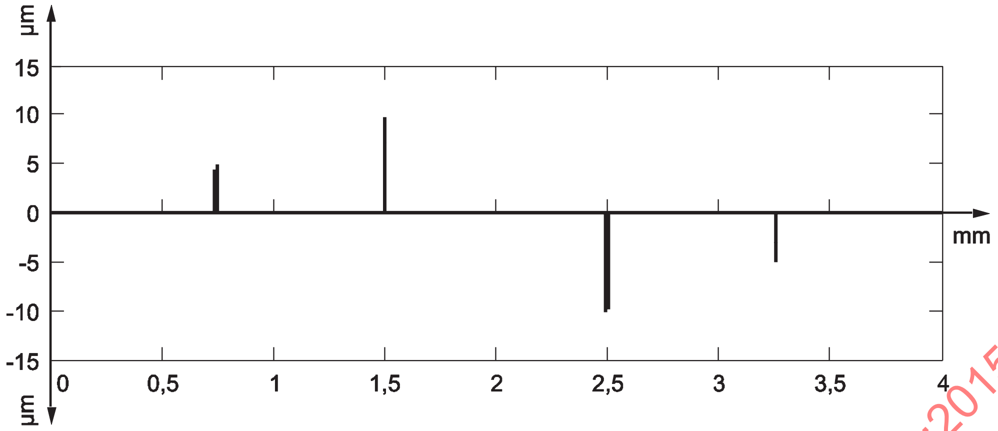

Figure 3 — Example of a series of spike discontinuities

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

Positivity	i.e. $\delta\left(p_1(x), p_2(x)\right) \geq 0$ 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. $\delta\left(p_1(x), p_2(x)\right) + \delta\left(p_2(x), p_3(x)\right) \geq \delta\left(p_1(x), p_3(x)\right)$

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 formula:

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

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

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

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

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

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

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

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

Note 2 to entry: For additional information on the median, see Reference [10] and Reference [11].

Note 3 to entry: See Figure 4.

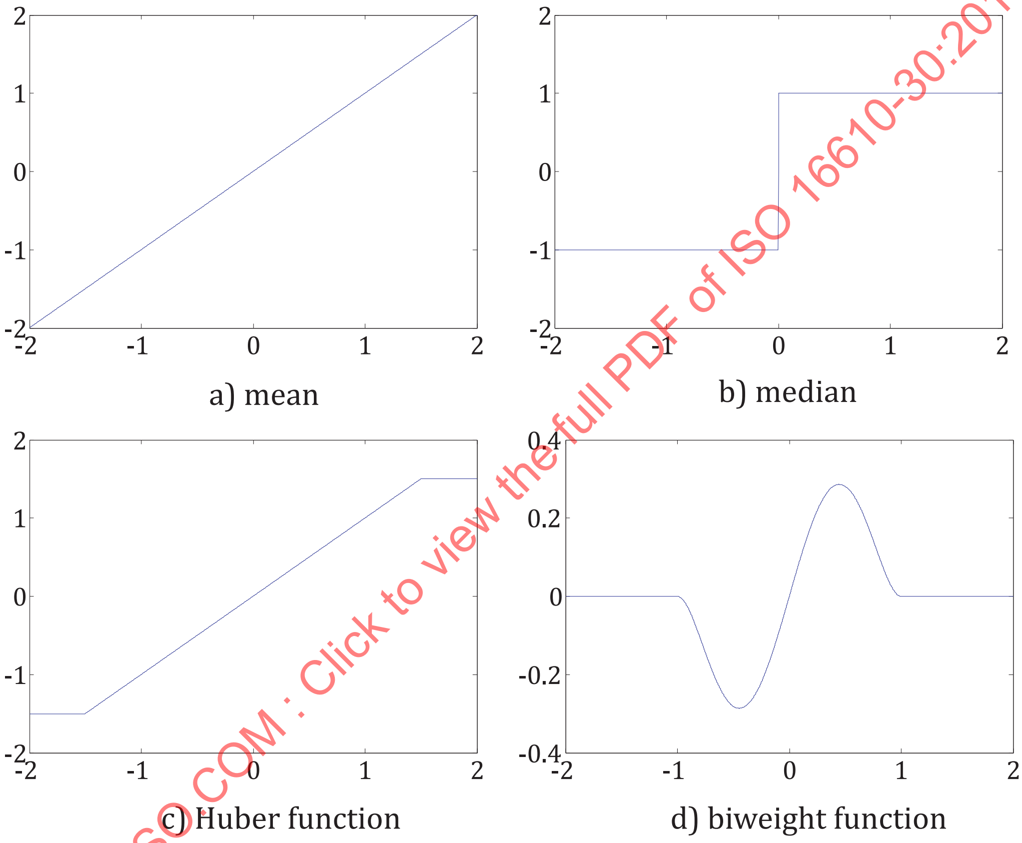

Figure 4 — Examples of influence functions that have been considered in connection with M-estimators

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 part of ISO 16610 is the class of linear profile filters (see ISO 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 part of ISO 16610, 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. See Reference [10].

4.3.2 M-estimator

Each point on the profile is weighed 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 (see Reference [10] and Reference [11]).

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.

4.4.2 Scale-space pre-processing

In this case, scale-space techniques (see ISO 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 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 A.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.

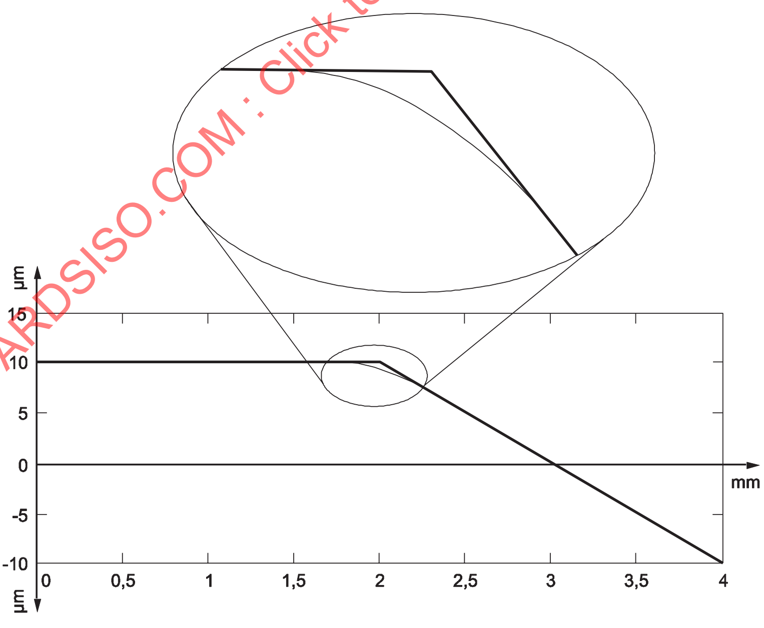

Figure A.1 — Example of a filter over the slope discontinuity data set

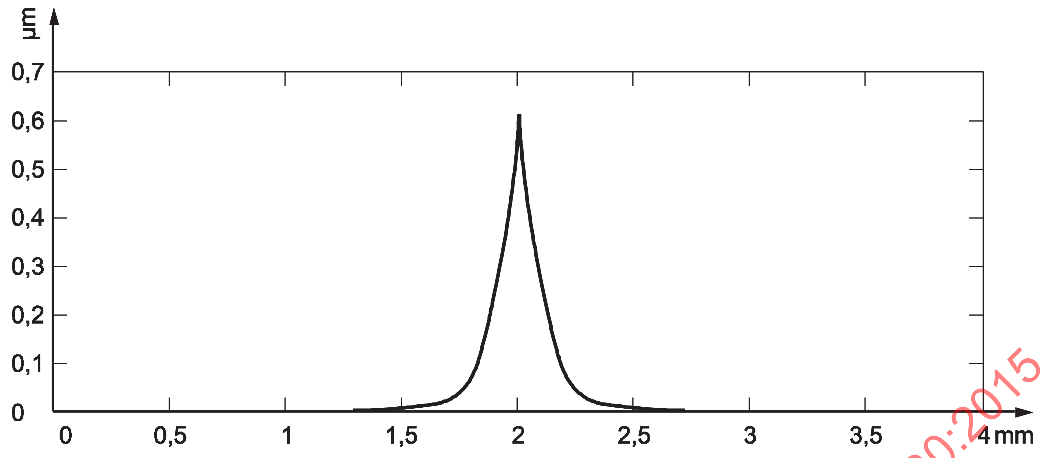

Figure A.2 — Example of the difference between the filter and original profiles for the slope discontinuity data set

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 A.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.

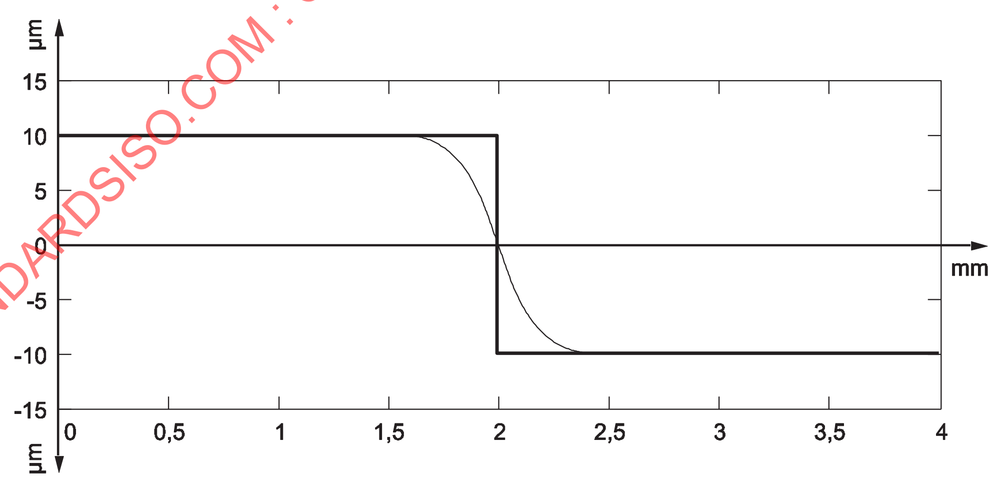

Figure A.3 — Example of a filter over the step discontinuity data set

A.4 Spike discontinuity

The spike 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 A.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.

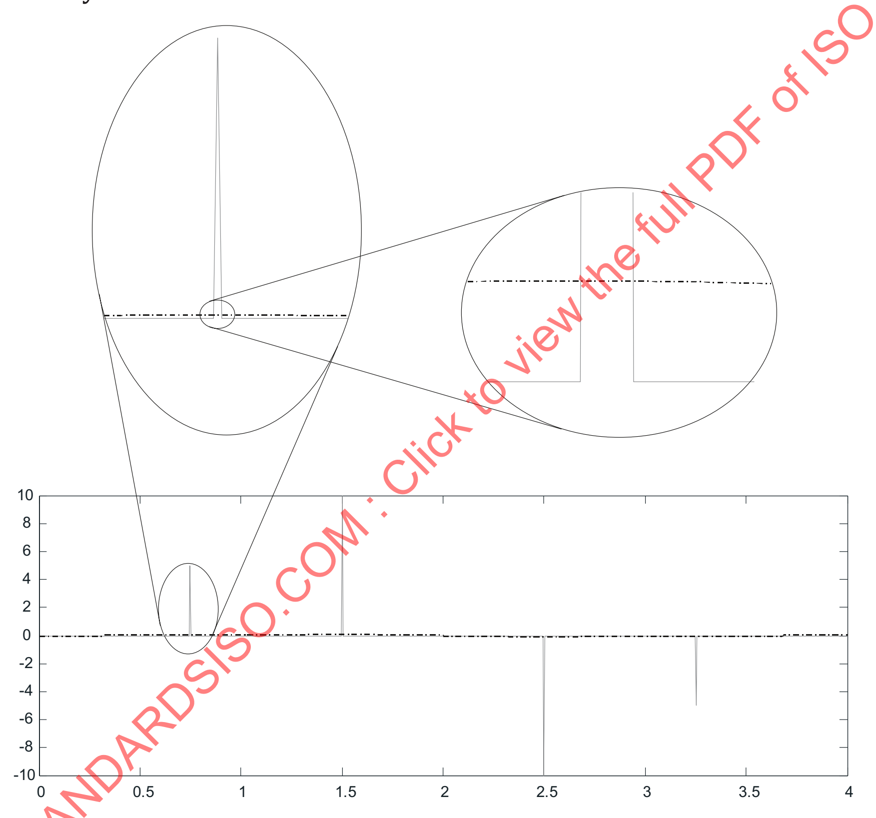

Figure A.4 — Example of a filter over the spike discontinuity data set

Annex B
(informative)

Concept diagram

See Figure B.1.

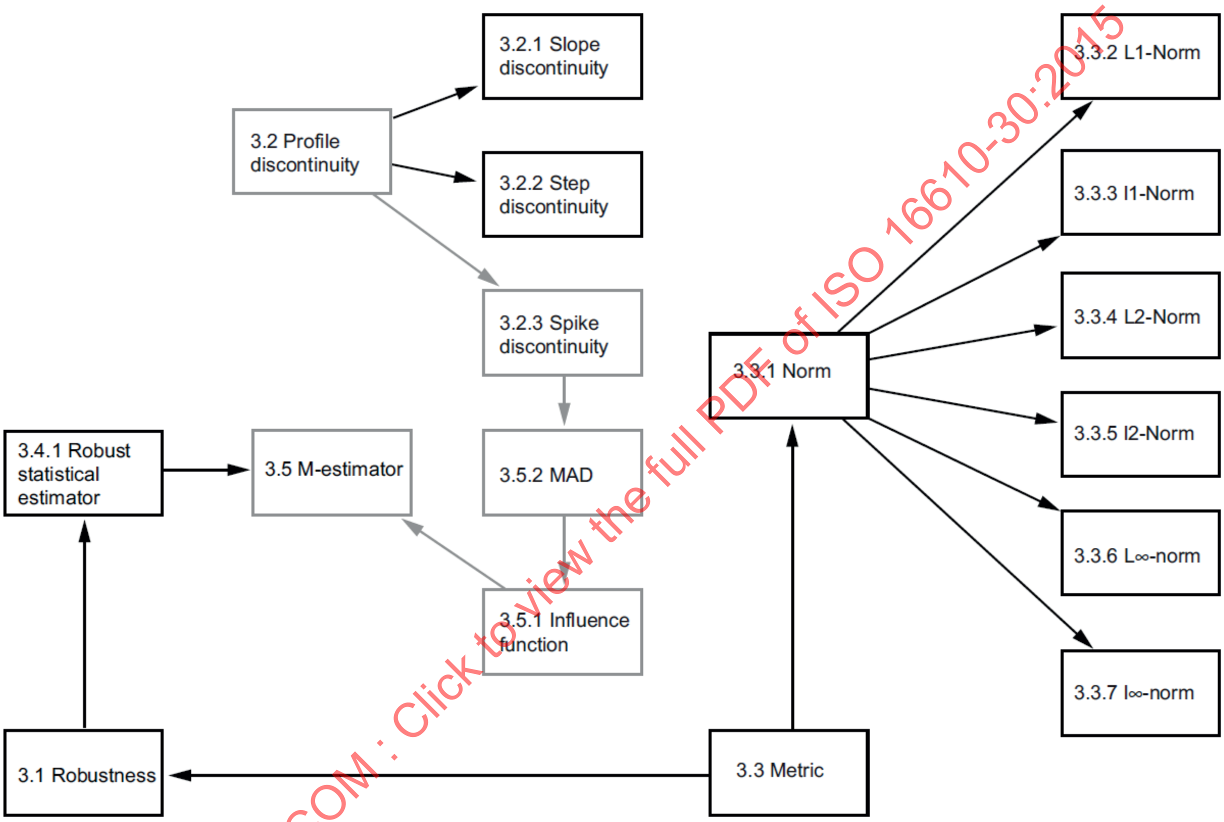

Figure B.1 — Concept diagram