INTERNATIONAL STANDARD

ISO 16610-41

First edition
2015-06-15

Geometrical product specifications (GPS) — Filtration —

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

Spécification géométrique des produits (GPS) — Filtrage —

Partie 41: Filtres de profil morphologiques: Filtre disque et filtre segment de droite horizontal

Reference number
ISO 16610-41:2015(E)

Contents

Page

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).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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 16610-41:2006 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 5 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. 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 about the relation of this part of ISO 16610 to the GPS matrix model, see Annex B.

This part of ISO 16610 provides guidelines for computing profile morphological operations and filters with disk and horizontal segment structuring elements. It also describes techniques for applying morphological filters, including envelope filters, for open profiles.

Geometrical product specifications (GPS) — Filtration —

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

1 Scope

This part of ISO 16610 specifies techniques for computing morphological filters with disk and horizontal segment structuring elements, including envelope 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 14660-1, *Geometrical Product Specifications (GPS) — Geometrical features — Part 1: General terms and definitions*

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

ISO 16610-40, *Geometrical product specifications (GPS) — Filtration — Part 40: Morphological profile filters: Basic concepts*

3 Terms and definitions

For the purposes of this document, the terms and definition givens in ISO 14660-1, ISO 16610-1, and ISO 16610-40 apply.

4 Morphological filters

4.1 General

The morphological filters described in this part of ISO 16610 are defined using Minkowski sums. There are two primary morphological operations (dilation and erosion) and two secondary morphological operations (opening and closing). The opening and closing operators are also called morphological filters. Any technique that can compute Minkowski additions and subtractions can be used to compute closing and opening morphological filters and the respective envelope filters. Computation of morphological filters can be greatly simplified by using with discrete morphological filters, which are described in the rest of this part of ISO 16610. The main body of this part of ISO 16610 covers general computational techniques; Annexes A and B deal with specific implementations of discrete morphological operations and filters for profiles.

A morphological filter conforming to this part of ISO 16610 shall exhibit the characteristics described in 4.3, 4.4, 4.5, 4.6, 5.1, 5.2, and 5.3.

NOTE The relationship of morphological profile filters: disk and horizontal line-segment filters to the filtration matrix model is given in Annex A.

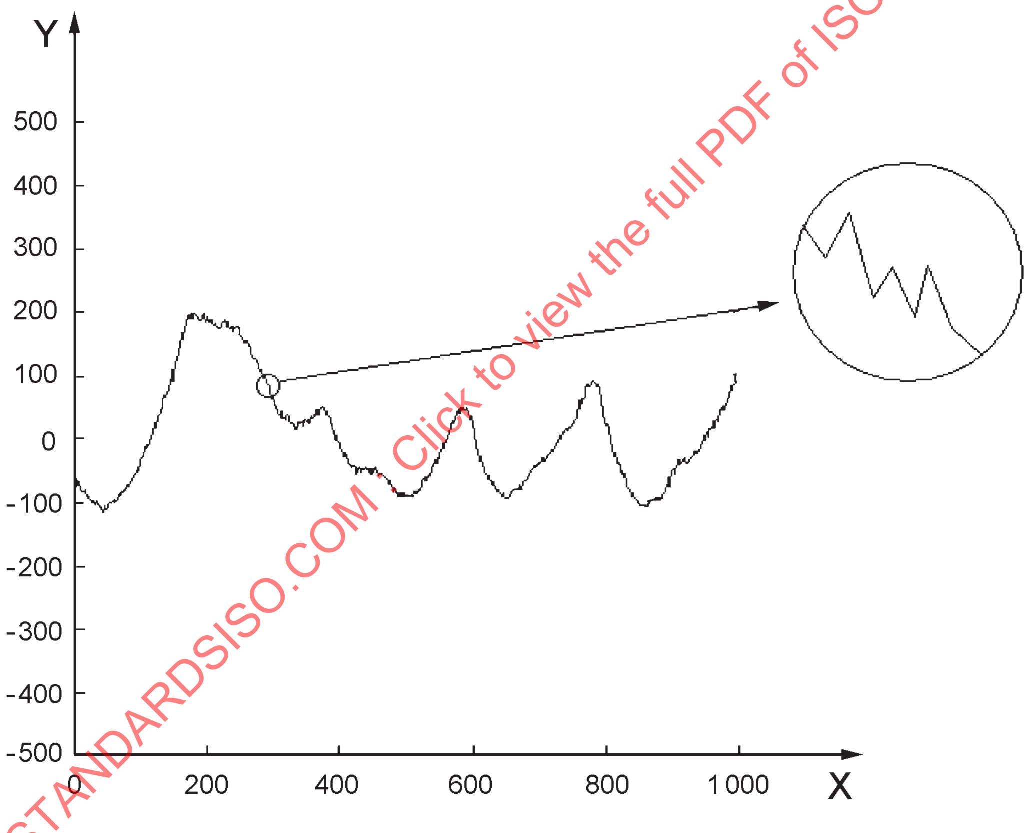
4.2 Discrete representation of input data

An extracted profile is represented as a vector z of finite size n. This is a discrete representation of a profile. For computational convenience, the sampling is assumed to be uniform with a sampling interval Δ. z_i, the ith component of z, is the value of the function evaluated at $i\Delta$.

A continuous representation of the extracted profile can be obtained by an appropriate interpolation, e.g. a simple linear interpolation piece by piece of the discrete data. Figure 1 illustrates the graph of this kind of continuous representation, starting with a discrete representation using vector $\vec{z}$.

4.3 Discrete representation of structuring element

In the process of filtering profiles, a circular disk is used, as outlined in Figure 2. Due to its symmetry about the origin, it is sufficient to consider only its first quadrant form and represent it discretely as the vector $\vec{b}$. The same applies with a horizontal straight line segment, as shown in Figure 3. Again, due to its symmetry about the origin, it is sufficient to consider only its right half and represent it discretely as the vector $\vec{b}$. The length of the structuring element vector $\vec{b}$ is much smaller than that of the input of vector $\vec{z}$. For ease of computation, input $\vec{z}$ and structuring element $\vec{b}$ are sampled at the same interval Δ.

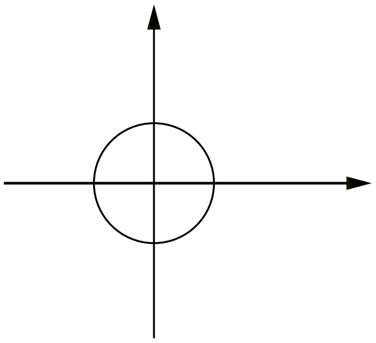


Key

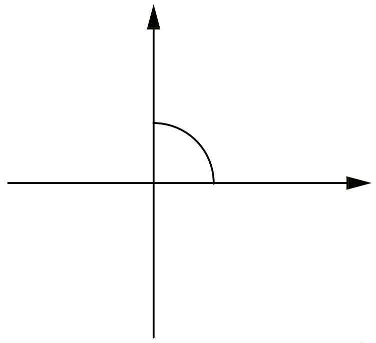
X distance, µm

Y height, µm

Figure 1 — Example of extracted profile graphed after linear interpolation of its discrete representation



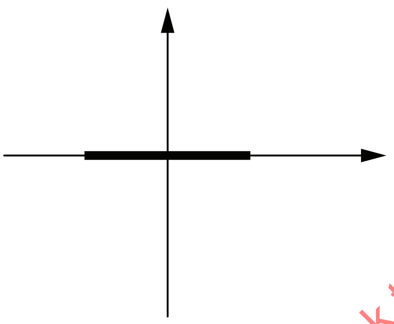
a) Representation in full form



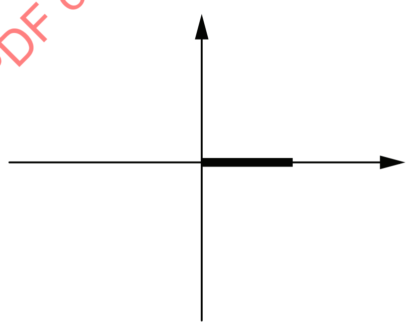
b) Representation in economic form in the first quadrant due to its symmetry

NOTE 1 For example, an economic representation of a circular disk of radius 2 µm is $\vec{b}$ = [2,00; 1,93; 1,732 1; 1,32; 0,00], where the dimensions are in µm and the sampling interval is 0,5 µm. In Figure 2 b), only the circular arc in the first quadrant is represented due the symmetry of the circular disk.

Figure 2 — Example of a circular disk structuring element



a) Representation in full form



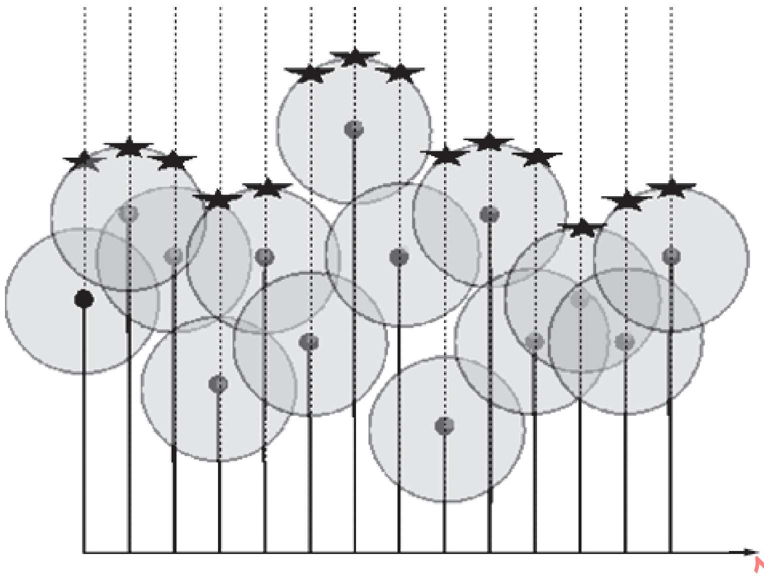
b) Representation in economic form showing only its right half due to its symmetry

NOTE 2 An economic representation of a horizontal line-segment of total length 4 µm is $\vec{b}$ = [0; 0; 0; 0; 0], where the dimensions are in µm and the sampling interval is 0,5 µm. In Figure 3 b), only the right half of the line-segment is represented due the symmetry of the line-segment.

Figure 3 — Example of a horizontal line-segment structuring element

4.4 Discrete morphological filters

A discrete morphological filter takes $\vec{z}$ and $\vec{b}$ as input and produces a filtered output of the same array length as the input $\vec{z}$. It is a discrete representation of the filtered profile. The basic idea behind the computation of dilation and erosion is to position the origin of the structuring element at every point of the input and to sum them, as illustrated for a few positions of a circular structuring element for dilation in Figure 4. The extreme value at each sampling point is then collected and these values are reported as the output. For example, in Figure 4, the top-most star in each vertical line is collected after all the disks are positioned, and the array of the vertical coordinates of all the top-most stars form the output for dilation.

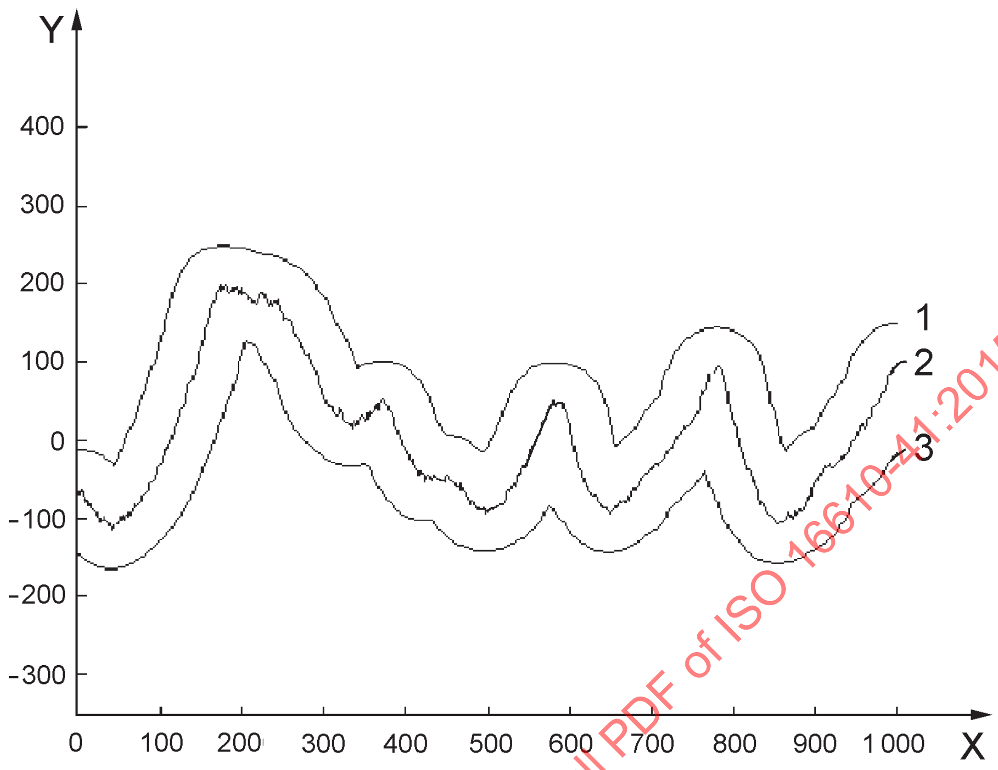


NOTE The centre of the disk is positioned at every input data point. The stars are the maximum height of all the results calculated by adding the coordinates of input points (filled dots) to the coordinates of sampled points on the circle.

Figure 4 — Illustration of dilation with a circular disk

Closing and opening filters can be computed by applying the dilation and erosion in a specific sequence. Figure 5 illustrates how an input profile is dilated and eroded by a disk structuring element. Figures 6 and 7 show the results of opening and closing filters. In these figures, the input function and the structuring element are uniformly sampled at 0,5 µm intervals. In general, dilation and closing produce outputs that are above the input function (extensivity), whereas erosion and opening result in outputs that are below the input function (anti-extensivity). Figures 8, 9, and 10 show the effect of a horizontal line-segment structuring element.

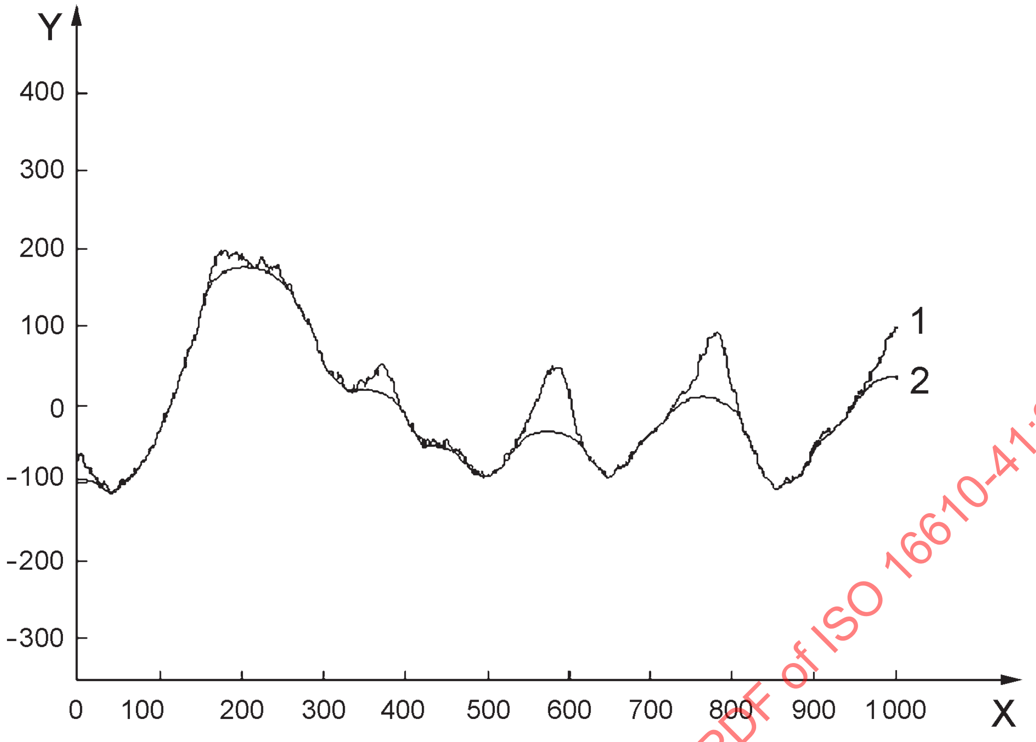
NOTE The same technique of positioning, summing, and taking the extremes can be applied to discrete morphological filtering of surfaces.



Key

X distance, µm
Y height, µm
1 dilation
2 input function
3 erosion

Figure 5 — Input profile and output profiles of dilation and erosion operations by using a circular disk of 50 µm radius as the structuring element



Key

X distance, µm

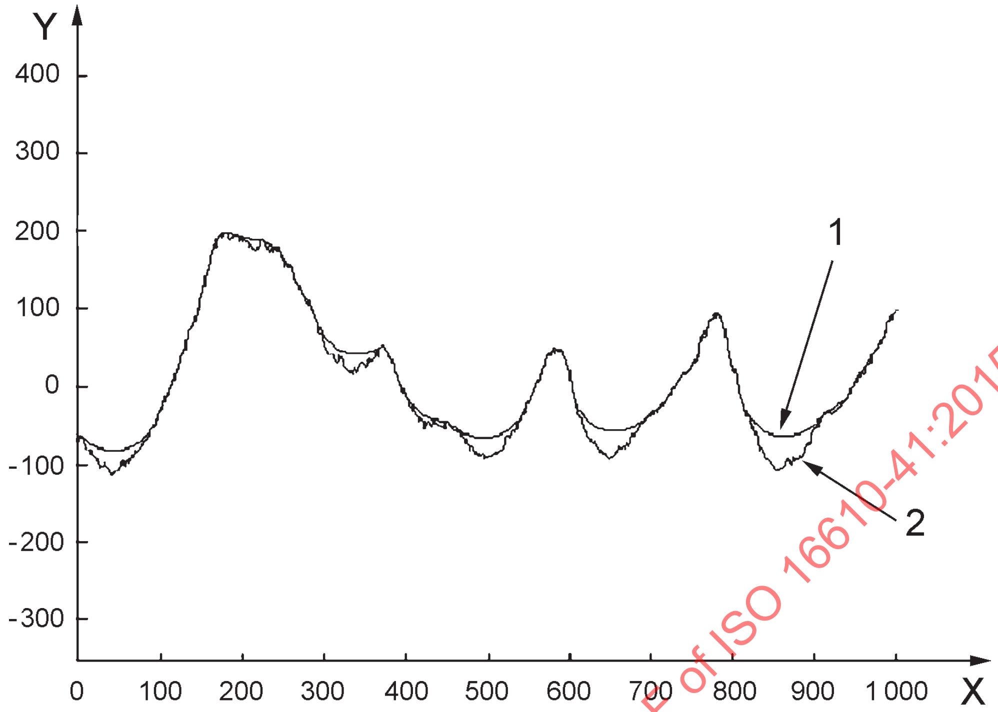
Y height, µm

1 input function

2 output

NOTE The structuring element is a circular disk of 50 µm radius.

Figure 6 — Input profile and output profile of an opening filter by using a circular disk of 50 µm radius as the structuring element



Key

X distance, µm

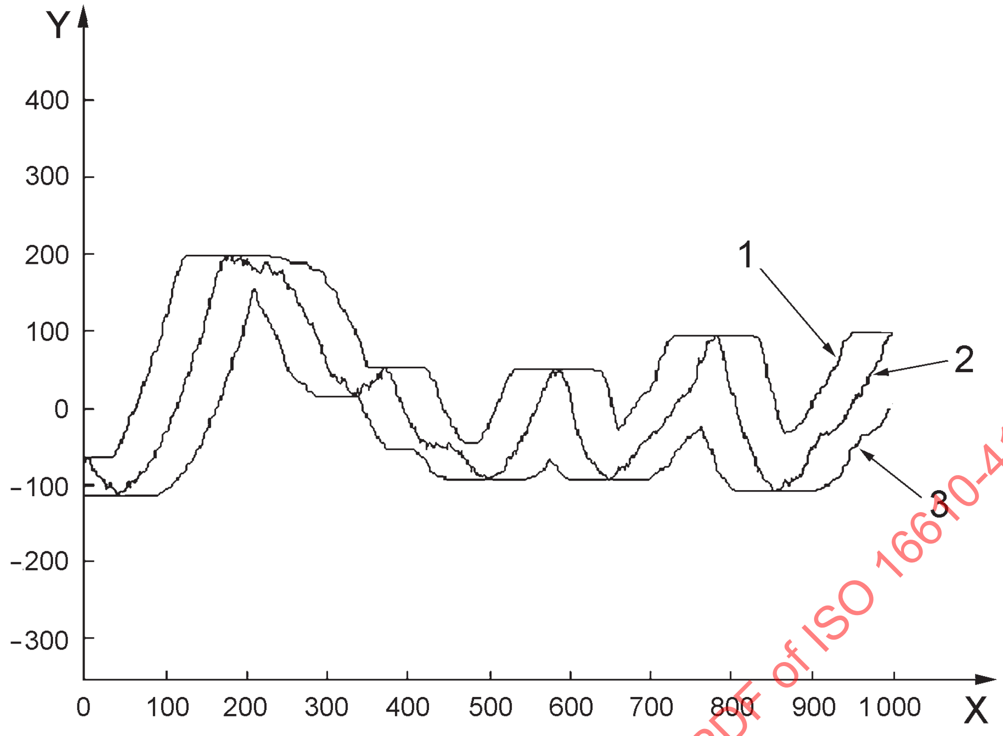
Y height, µm

1 output

2 input function

NOTE The closing filter is also the envelope filter. The structuring element is a circular disk of 50 µm radius.

Figure 7 — Input profile and output profile of a closing filter by using a circular disk of 50 µm radius as the structuring element



Key

X distance, µm

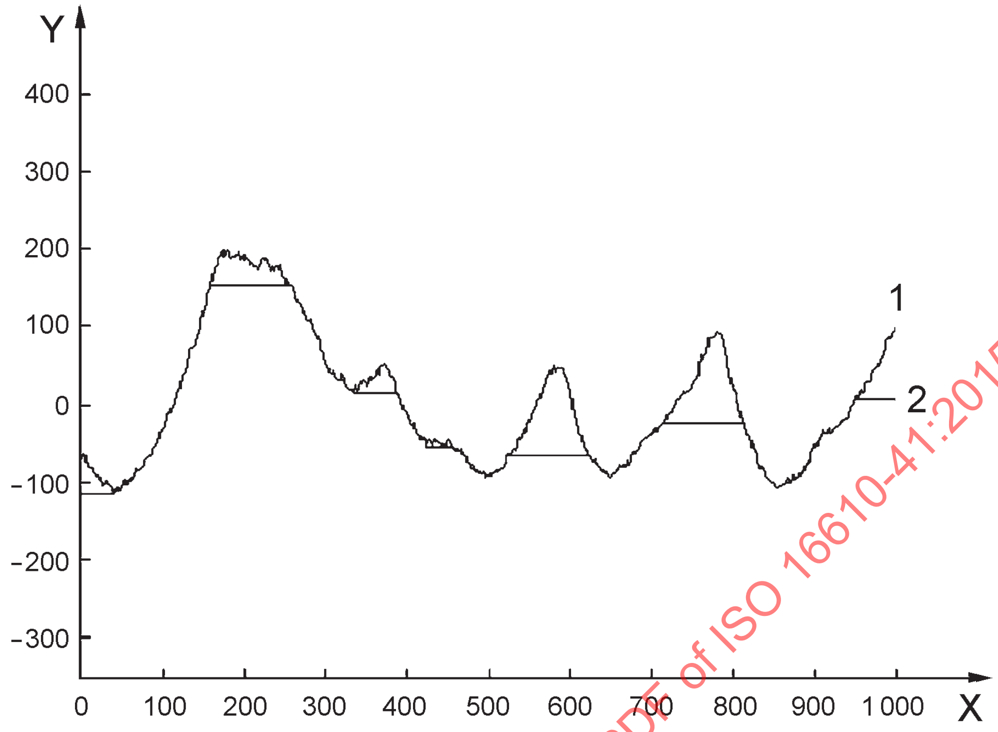
Y height, µm

1 dilation

2 input function

3 erosion

Figure 8 — Input profile and output profiles of dilation and erosion operations by using a horizontal line-segment of 100 µm length as the structuring element

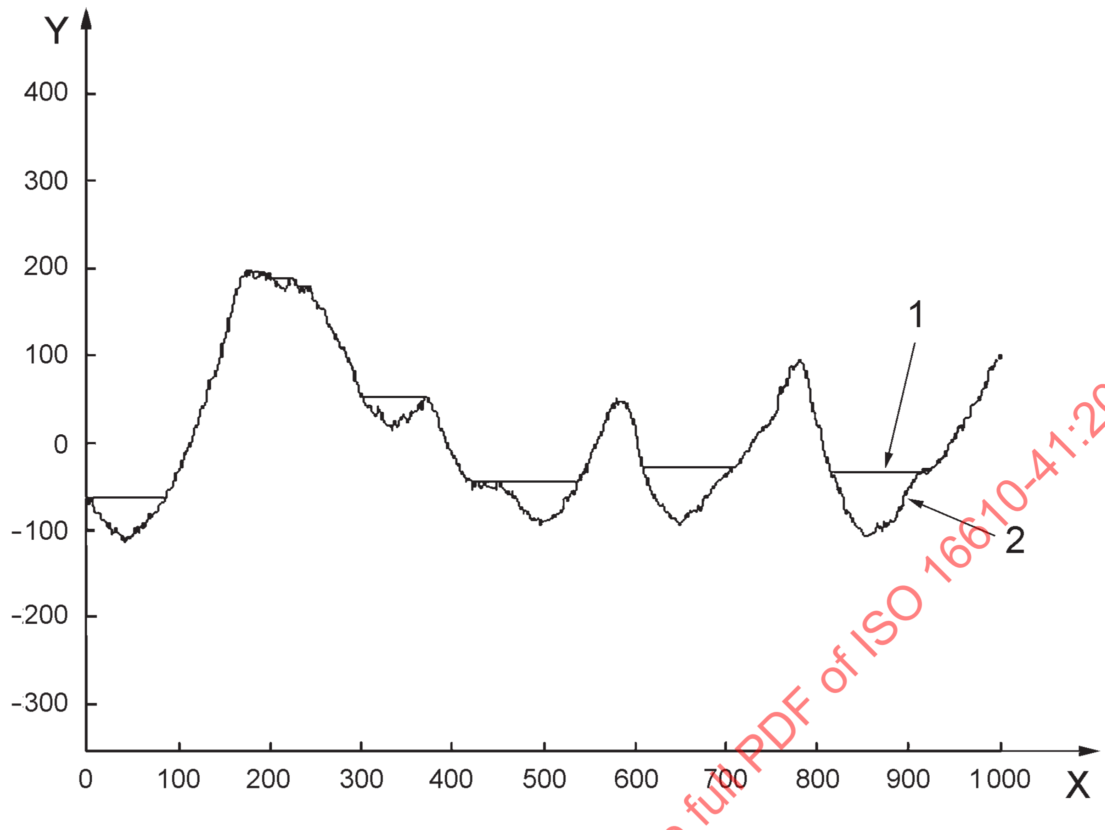


Key

X distance, µm
Y height, µm
1 input function
2 output

NOTE The structuring element is a horizontal line-segment of 100 µm length.

Figure 9 — Input profile and output profiles of an opening filter by using a horizontal line-segment of 100 µm length as the structuring element



Key

X distance, µm

Y height, µm

1 output

2 input function

NOTE The closing filter is also an envelope filter. The structuring element is a horizontal line-segment of 100 µm length.

Figure 10 — Input profile and output profile of a closing filter by using a horizontal line-segment of 100 µm length as the structuring element

4.5 Discrete envelope filters

Discrete envelope filters are the same as discrete closing and opening filters. Figure 7 shows the input function along with the output of an envelope filter using a circular disk structuring element. Figure 10 presents similar results where the structuring element is a horizontal line-segment.

4.6 End conditions

As stated in 4.2, the input is confined to a finite interval. The input is assumed to drop down to negative infinity outside the interval, for dilation. This "infinity padding" approach is similar to the "zero padding" technique used in studies on linear filtering. When the input function is subjected to dilation, the output extends beyond the finite interval of interest. Only that part of the output which falls within the interval is retained; the output is assumed to drop down to negative infinity outside this interval, for dilation.

For erosion, end conditions are handled by assuming that the input moves up to positive infinity outside the interval. After applying erosion, the output is cropped and only that which falls within the input interval is retained.

Since closing and opening filters are defined using the dilation and erosion, the end conditions for these secondary filters are handled automatically.

5 Recommendations

5.1 Circular disk structuring element

It is recommended that the nesting index (the radius of the circular disk of the structuring element) be chosen from a logarithmic series (constant ratio) of scale values. Experience has shown that a constant ratio of around 2 between successive scale values is optimum. The nesting index should be chosen to be greater than or equal to the stylus tip radius, used to define the mechanical surface, from the following series of values:

...1 µm, 2 µm, 5 µm, 10 µm, 20 µm, 50 µm, 100 µm, 200 µm, 500 µm, 1 mm, 2 mm, 5 mm, 10 mm, ...

This series has the added advantage that it is consistent with the recommended stylus tip radii for surface texture (see ISO 3274:1996) and form documents (see ISO 12180-2:2011, ISO 12181-2:2011, ISO 12780-2:2011, ISO 12781-2:2011). Hence, surfaces measured with different styli have an overlap of scale values and so are directly comparable.

5.2 Horizontal line structuring element

It is recommended that the nesting index (the length of the horizontal line of the structuring element) be chosen from a logarithmic series (constant ratio) of scale values. Experience has shown that a constant ratio of around two between successive scale values is optimum. The nesting index should be chosen to be greater than or equal to the stylus tip radius, used to define the mechanical surface, from the following series of values:

...1 µm, 2 µm, 5 µm, 10 µm, 20 µm, 50 µm, 100 µm, 200 µm, 500 µm, 1 mm, 2 mm, 5 mm, 10 mm, ...

This series has the added advantage that it is consistent with the recommended stylus tip radii for surface texture (see ISO 3274:1996). Hence, surfaces measured with different styli have an overlap of scale values and so are directly comparable.

5.3 Default morphological filter

If not otherwise specified, the default profile morphological filter shall be a morphological filter with a circular disk structuring element.

6 Filter designation

Morphological profile filters according to this part of ISO 16610 are designated as follows:

	Closing	Opening
Horizontal line-segment	**FPMCH**	**FPMOH**
Disk	**FPMCD**	**FPMOD**

See also ISO 16610-1:2014, Clause 5.

