TECHNICAL SPECIFICATION

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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

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Foreword

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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 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order to decide whether it will be confirmed for a further three years, revised to become an International Standard, or withdrawn.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again after a further three years, at which time it must either be transformed into an International Standard or be withdrawn.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 16610-41 was prepared by Technical Committee ISO/TC 213, *Dimensional and geometrical product specifications and verification*.

ISO/TS 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 22: Linear profile filters: Spline filters*

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

— *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*

The following parts are under preparation:

- *Part 21: Linear profile filters: Gaussian filters*
- *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 30: Robust profile filters: Basic concepts*
- *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/TS 16610 is a geometrical product specification (GPS) Technical Specification and is to be regarded as a global GPS Technical Specification (see ISO/TR 14638). It influences the chain links 3 and 5 of all chains of standards.

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

This part of ISO/TS 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/TS 16610 specifies techniques for computing morphological filters with disk and horizontal segment structuring elements, including envelope 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 14660-1:1999, *Geometrical Product Specifications (GPS) — Geometrical features — Part 1: General terms and definitions*

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

ISO/TS 16610-40:2006, *Geometric 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/TS 16610-1 and ISO/TS 16610-40 apply.

4 Morphological filters

4.1 General

The morphological filters described in this part of ISO/TS 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 addition and subtraction can be used to compute closing and opening morphological filters and the respective envelope filters. Computation of morphological filters can be greatly simplified if we deal with discrete morphological filters, which are described in the rest of this document. The main body of the document deals with 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/TS 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 B.

4.2 Discrete representation of input data

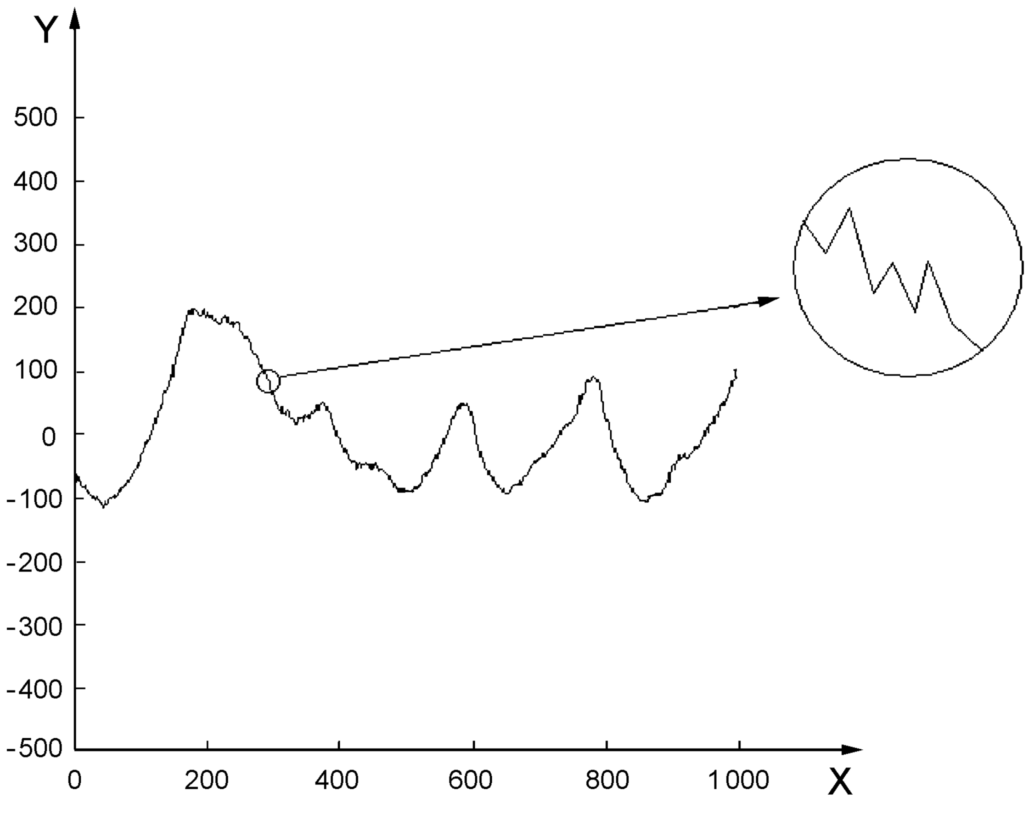
An extracted profile is represented as a vector z of finite size n. This is a discrete representation of a profile. For computational convenience, the sampling is assumed to be uniform with a sampling interval Δ. z_i, the ith component of z, is the value of the function evaluated at $i\Delta$.

EXAMPLE The first five entries in a long input vector are given in z = [−63,3; −65,0; −67,0; −70,4; −69,6; …] where the dimensions are in µm. The interval Δ is 0,5 µm. The input vector can easily contain several thousand entries.

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 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 its symmetry about the origin, it is sufficient to consider only its first quadrant form, and represent it discretely as the vector b. The same applies with a horizontal straight line segment, as shown in Figure 3. Again, due its symmetry about the origin, it is sufficient to consider only its right half, and represent it discretely as the vector b. The length of the structuring element vector b is much smaller than that of the input vector z. For ease of computation, input z and structuring element b are sampled at the same interval Δ.

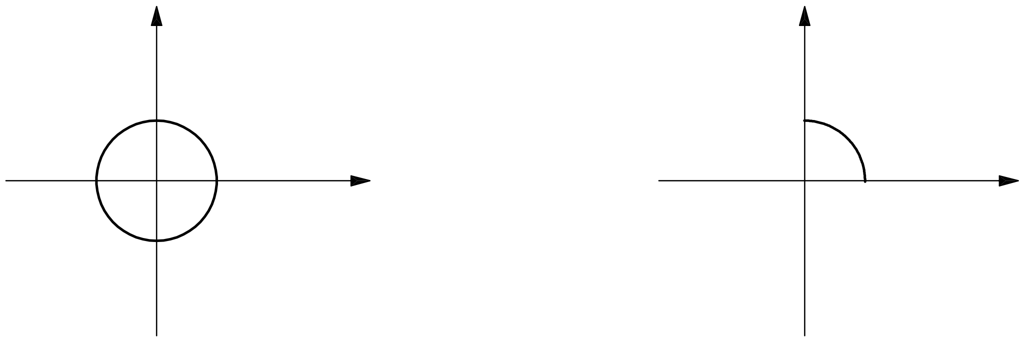


Key

X distance, µm

Y height, µm

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

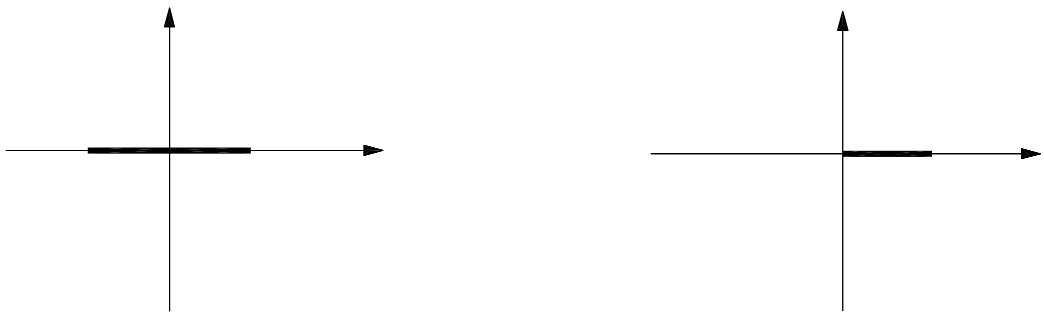


a) Representation in full form

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

NOTE For example, an economic representation of a circular disk of radius 2 µm is b = [2,000 0; 1,936 5; 1,732 1; 1,322 9; 0], 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

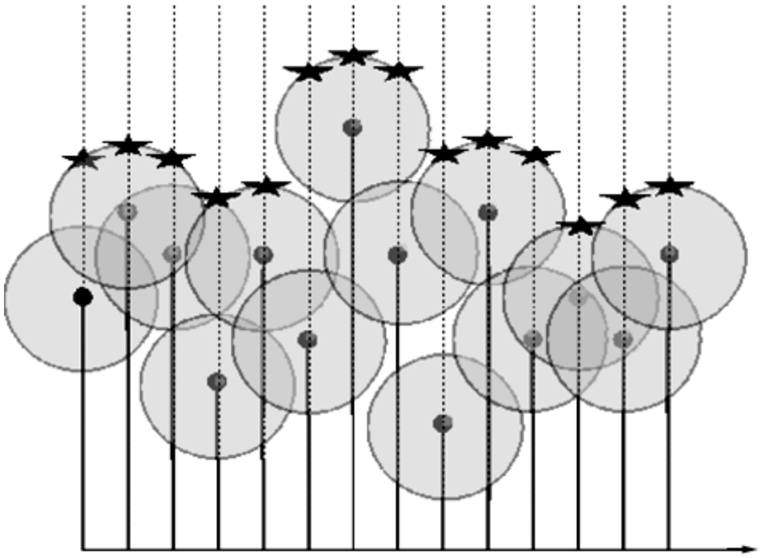
b) Representation in economic form showing only its right half due to its symmetry

NOTE An economic representation of a horizontal line-segment of total length 4 µm is 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 z and b as input and produces a filtered output of the same array length as the input 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.

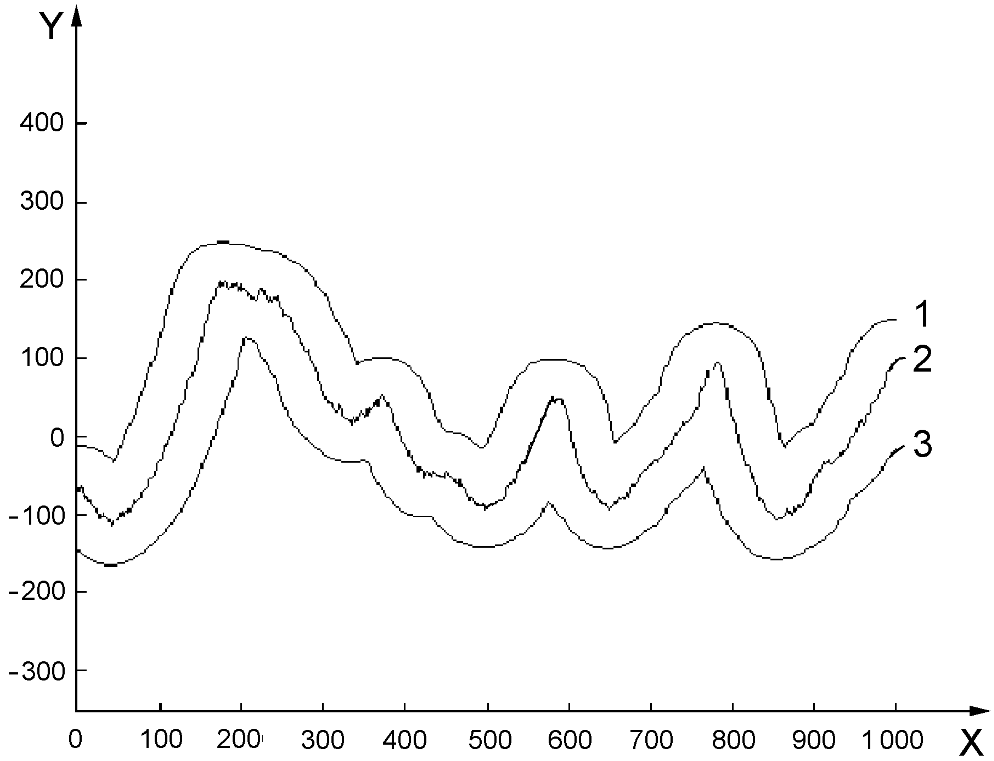


NOTE The centre of the disk is positioned at every input data point. The stars are the maximum height of all the results calculated by adding the coordinates of input points (filled dots) to the coordinates of sampled points on the circle.

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

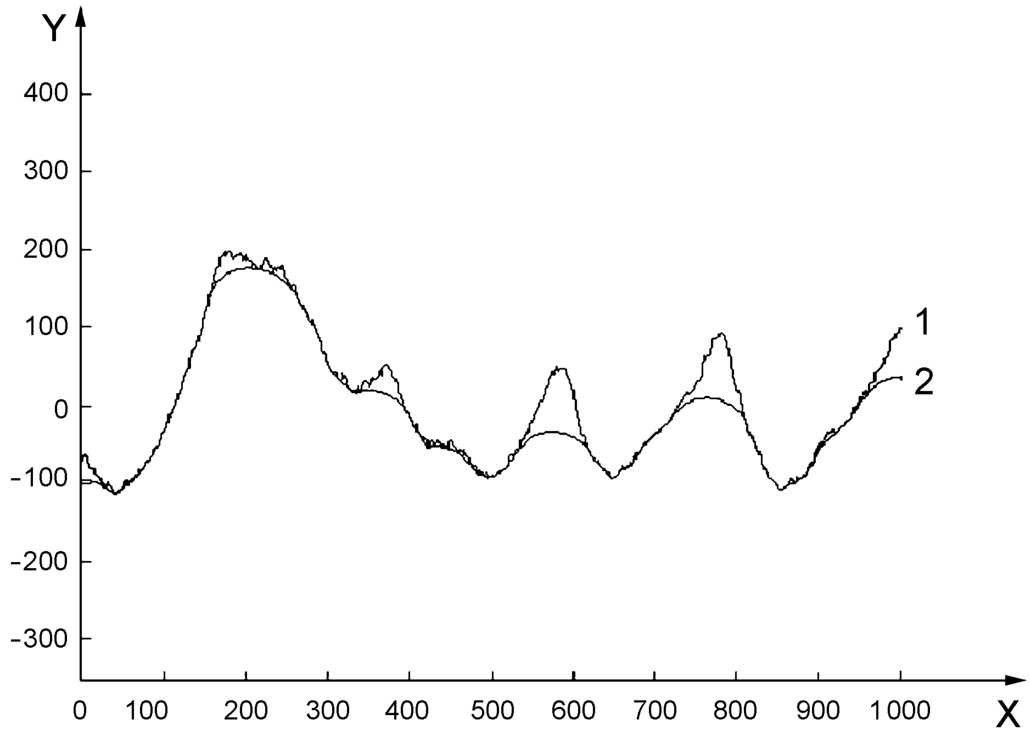
Y height, µm

1 dilation

2 input function

3 erosion

Figure 5 — Input profile, its dilation and its erosion by a circular disk of 50 µm **radius**



Key

X distance, µm

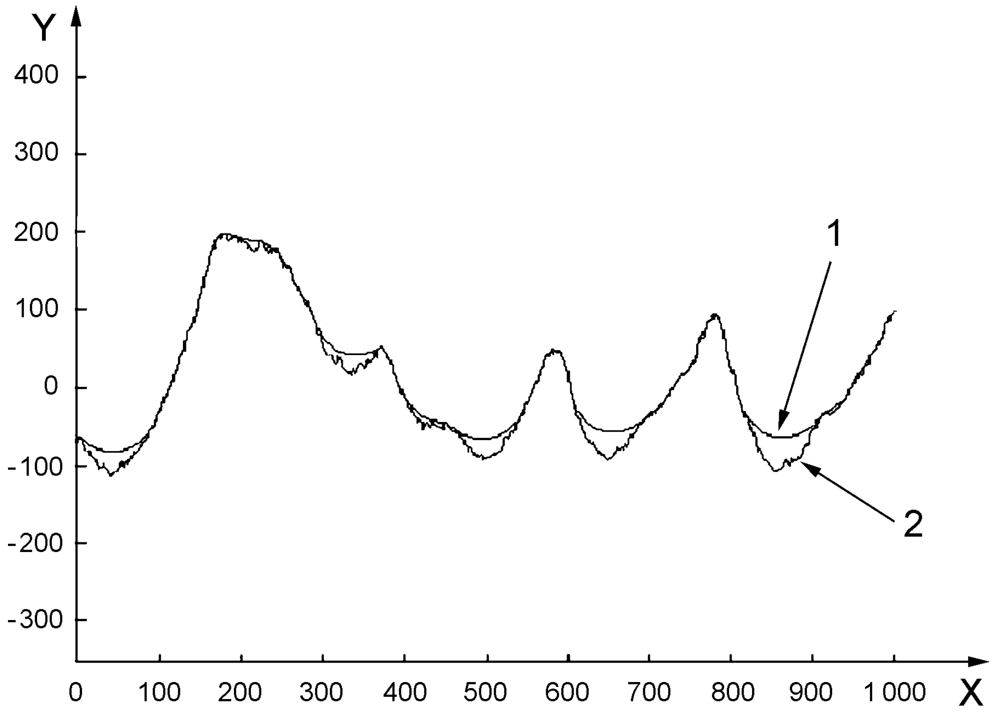
Y height, µm

1 input function

2 output

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

Figure 6 — Input profile and output of an opening filter



Key

X distance, µm

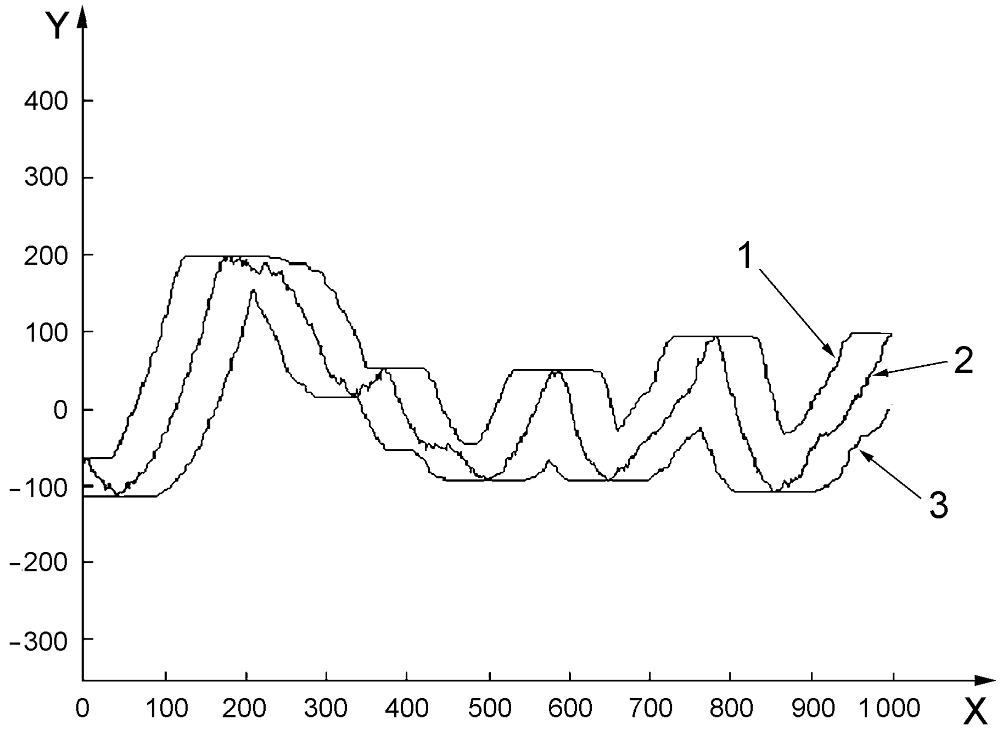
Y height, µm

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.

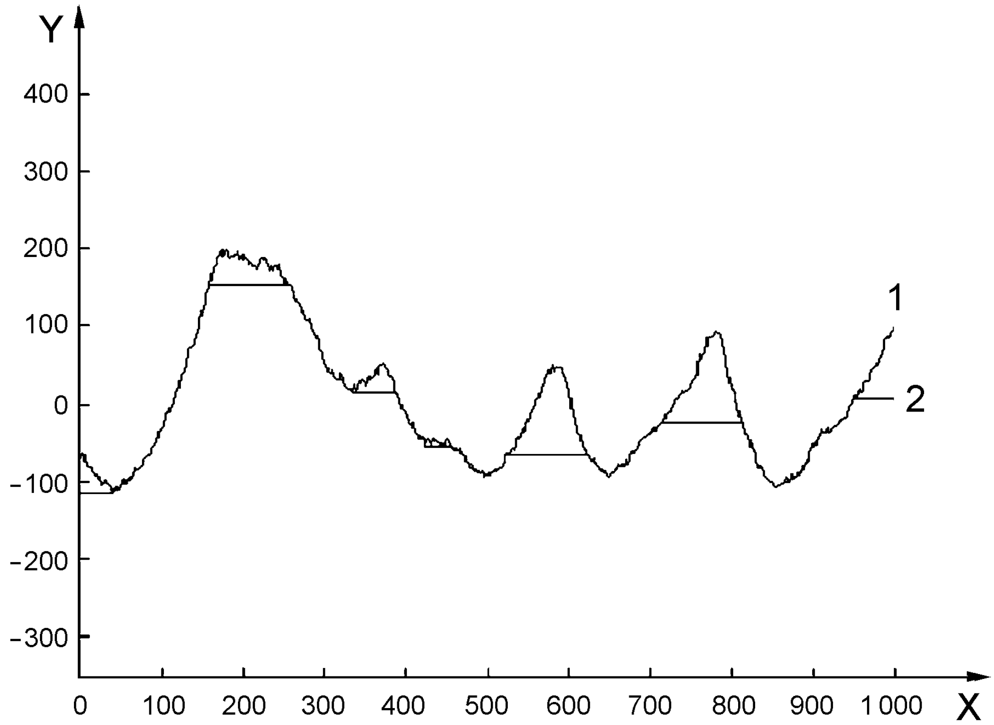
Figure 7 — Input profile and output of a closing filter



Key

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

Figure 8 — Input profile, its dilation and its erosion by a horizontal line-segment of 100 µm **length**



Key

X distance, µm

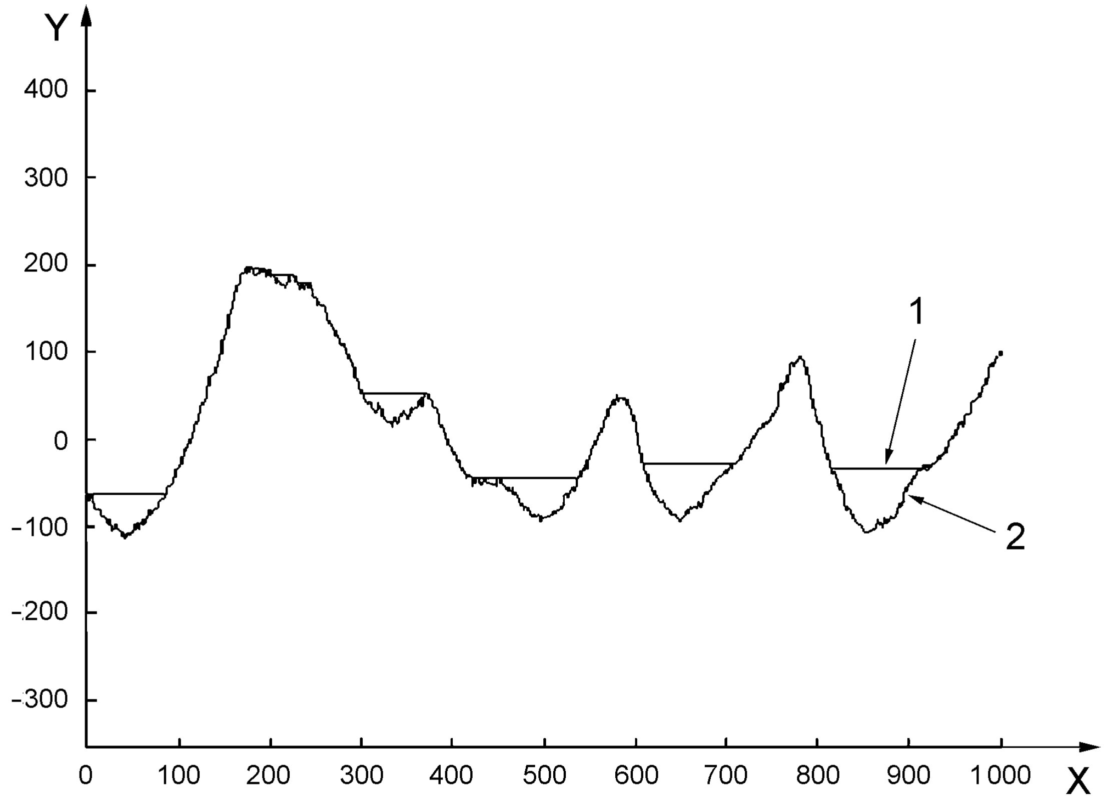
Y height, µm

1 input function

2 output

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

Figure 9 — Input profile and output of an opening filter



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 of a closing filter

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 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) and form documents (see ISO/TS 12180-2, ISO/TS 12181-2, ISO/TS 12780-2, ISO/TS 12781-2). 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/TS 16610 are designated as follows:

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

See also ISO/TS 16610-1:2006, Clause 5.

Annex A
(informative)

Relationship to the filtration matrix model

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

A.1 Position in the filtration matrix model

This part of ISO/TS 16610 is a specific document that influences particular filters in the column: Profile filters, Morphological (see Figure A.1).

General	Filters: ISO/TS 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 A.1 — Relationship to the filtration matrix model

Annex B
(informative)

Relationship to the GPS matrix model

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

B.1 Information about this Technical Specification and its use

This part of ISO/TS 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, which include envelope filters, for open profiles.

B.2 Position in the GPS matrix model

This part of ISO/TS 16610 is a global GPS Technical Specification, which influences chain links 3 and 5 of all chains of standards in the GPS matrix model, as graphically illustrated in Figure B.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 line independent of datum			X		X	
Form of line dependent of datum			X		X	
Form of surface independent of datum			X		X	
Form of 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 B.1 — Position in the GPS matrix model

B.3 Related International Standards

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

Bibliography

[1] ISO 3274, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Nominal characteristics of contact (stylus) instruments*

[2] ISO/TS 12180-2, *Geometrical Product Specifications (GPS) — Cylindricity — Part 2: Specification operators*

[3] ISO/TS 12181-2, *Geometrical Product Specifications (GPS) — Roundness — Part 2: Specification operators*

[4] ISO/TS 12780-2, *Geometrical Product Specifications (GPS) — Straightness — Part 2: Specification operators*

[5] ISO/TS 12781-2, *Geometrical Product Specifications (GPS) — Flatness — Part 2: Specification operators*

[6] ISO/TR 14638:1995, *Geometrical product specification (GPS) — Masterplan*

[7] MATHERON, G., *Random sets and integral geometry*, John Wiley & Sons, New York, 1975

[8] SERRA, J., (Editor), *Image analysis and mathematical morphology*, Vols. 1 and 2, Academic Press, San Diego, 1988

[9] DOUGHERTY, E. R., *An introduction to morphological image processing*, SPIE Optical Engineering Press, Bellingham, 1992

[10] SRINIVASAN, V., *Discrete Morphological Filters for Metrology*, Proceedings of the 6th IMEKO ISMQC Symposium on Metrology for Quality Control in Production, TU Wien, Austria, Sept. 8-10, 1998

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