3 Specification of Parameters

It is well known that the definitions of parameters should be unambiguous to avoid being open to different interpretations by both users and metrology software developers. What is not so well known is that parameters should also have stable or robust definitions in order that they reflect genuine properties of a surface. Here a parameter definition is considered mathematically stable if a ‘small’ change in the profile implies a ‘small’ change in the parameter value. Unfortunately the parameter definitions given in ISO 4287 – 1997[4] (and ISO 4288 - 1996)[5] are not always unambiguous or stable. Since these specification standards were first drafted, much knowledge has been gained into unambiguous and stable definitions of surface texture parameters. This new knowledge has been used in the present project to re-evaluate the parameter definitions and produce unambiguous stable definitions that are consistent (where possible) with those in the international standards.

The basic framework of the softgauges developed within the project is shown in figure 3.1.

Softgauge Basic Framework

ISO 4287-1997

(ISO 4288-1996)

SOFTGAUGE POINTS

ASSUME: Ls Filtered
Equally spaced
No Form

↓

FILTRATION

Gaussian Filter (ISO 11056)

R	W	P
Lc High pass	Lc Low pass	No Filter

↓

	FIELD PARAMETERS		FEATURE PARAMETERS	
	Amplitude	Other	Peak/Valley	Spacing
	Ra, *Rq*, *Rsk*,*Rku*, *Rp*, *Rv*, *Rz*	*Rt*	*Rc*	*RSm*
Feature Type[1]	Points	Points	Local Peak/Valley	Crossovers
Segmentation[2]	Cut-off	Evaluation	Based on feature	Based on feature
Combination[3]	None	None	Remove insignificant features	Remove insignificant features
Attributes	Cut-off	Evaluation	Significant features	Significant features
Statistics	Mean/Max	Value	Mean/Max	Mean/Max

Notes

1. Feature type is the basic element from which subsequent calculations are determined.

2. Segmentation is used to determine the initial portions of the profile.

3. Combination removes “insignificant” segments to leave significant segments. This removes artificially small segments due to noise, etc. making the measurand stable.

Figure 3.1 Softgauge basic framework

3.1 Gaussian Filter

The Gaussian filter is currently the only standardised surface texture filter (ISO 11562 – 1996)[6]. This standard defines the long wave (low pass) Gaussian filter as a continuous weighted convolution for an open profile, with the weights taking the classic Gaussian bell shape and a cut-off wavelength value of 50 % transmission. The short wave (high pass) Gaussian filter is defined as the difference between the surface profile and the long wave profile component resulting from the long wave Gaussian filter with the same 50 % cut-off wavelength. ISO 11562-1996[6] does not give any information on implementation (algorithms, implementation problems, etc.) of the Gaussian filter. There are no tolerance values given within this standard. Instead of tolerances, a graphical representation of the deviations of the realised Gaussian filter from the defined Gaussian filter shall be given as a percentage value over the wavelength range 0.01 to 100 cut-offs.

In practice, measured surface texture data is not continuous but takes discrete values. In some very special cases it may be possible to reconstruct the continuous profile from these discrete points using a kernel function and thus implement the Gaussian filter directly as a continuous weighted convolution. In this project, it is assumed that this is not the case and a discrete approximation to the definition given in ISO 11562 – 1996[6] will be used. Further, it will also be assumed that the data points are equally spaced along the *X*-axis.

There are principally two equally valid approaches to implementing a discrete approximation to the long wave Gaussian filter:

1. Via a discrete weighted convolution in the spatial domain.

2. Via a transformation to the Fourier domain, applying a transmission weighting to the individual wavelengths and transforming back to the spatial domain.

The first approach is implemented here since it is less complicated to implement with differing numbers of points in the profile. An outline algorithm can be found in Krystek 2004[7] (Algorithm 1). The short wave Gaussian filter can be implemented as the difference between the surface profile and the long wave profile component resulting from the long wave Gaussian filter with the same 50 % cut-off wavelength.

Other considerations in a discrete implementation are distortion effects due to:

The ends of the profile: To minimise this distortion a portion of the profile at the beginning (run-up) and at the end (run-down) of the profile is removed. It is recommended that one cut-off at each end of the profile be removed.

The finite length of the profile: To minimise this distortion there should be a minimum number of cut-offs in the measured profile (evaluation length). It is recommended that this minimum number be three cut-offs. This recommendation together with the previous recommendation means that one cut-off is left for further evaluation (three cut-offs minus one cut-off at each end).

The number of points per cut-off wavelength: To minimise this distortion there should be a minimum number of points per cut-off. It is recommended that there should be at least fifty points per cut-off.

Form present in the profile: It has been assumed that there is no form present in the profile so distortion due to form can be safely ignored.

All of these above recommendations are on the very cautious side, resulting in insignificant distortions. Detailed calculations on the magnitudes of these distortions can be found in Krystek 2004 [7].

ISO 3274 - 1996[2] standardises the nominal values of the cut-off wavelengths of the profile filter, with values obtained from the series:

... mm; 0,08 mm; 0,25 mm; 0,8 mm; 2,5 mm; 8,0 mm; ... mm

It is recommended that only the values 0,25 mm; 0,8 mm and 2,5 mm are used since these are the most common in practice.

3.1.1 Gaussian Filter in Summary

Assumptions:

Profile has already been Ls filtered.
The profile has equally spaced points along the *X*-axis.
There is no form present in the profile.

Algorithm:

1. **Long wave Gaussian filter:** a discrete weighted convolution in the spatial domain.

2. **Short wave Gaussian filter:** the difference between the surface profile and the long wave profile component, resulting from the long wave Gaussian filter with the same cut-off wavelength.

Recommendations:

One cut-off at each end of the profile is removed, to minimise the distortion at the ends of the profile.

The minimum number of cut-offs in the measured profile (evaluation length) is three, to minimise the distortion of the profile due to the finite length of the profile.

There should be at least fifty points per cut-off wavelength, to minimise the distortion of the profile due to the number of points per cut-off wavelength.

Recommended cut-off wavelength values:

0,25 mm; 0,8 mm and 2,5 mm.

3.2 Surface Texture Parameters

There are three types of surface texture profiles currently defined in the ISO standards:

Primary profile (ISO 3274 – 1996)[2]. A primary profile has had the nominal form removed and has been Ls filtered. The primary profile is the basis for evaluation of the primary profile parameters. The sampling length *lp* is numerically equal to the evaluation length.

Roughness profile (ISO 4287 – 1997)[4]. A profile derived from the primary profile by suppressing the long wave component using the short wave Gaussian profile filter with a cut-off wavelength value Lc. The roughness profile is the basis for evaluation of the roughness profile parameters. The sampling length *lr* is numerically equal to the cut-off wavelength Lc

Waviness profile (ISO 4287 – 1997)[4]. A profile derived by suppressing the long-wave component using the `*profile filter Lf*', and suppressing the short-wave component using the long-wave Gaussian profile filter with a cut-off wavelength value of Lc. The waviness profile is the basis for evaluation of the waviness profile parameters. The sampling length *lw* is numerically equal to the cut-off wavelength Lf.

> Note: No current ISO standard currently defines the "*profile filter Lf*'. Current industrial practice therefore ignores this filter step and uses a sampling length *lw* equal to the cut-off wavelength Lc.

3.2.1 Primary Profile

For the softgauge data the assumptions are that the form has been removed, the data has already been Ls filtered, and it is equally spaced. In other words the softgauge describes a primary profile with equally spaced data points. Thus to obtain the primary profile no action is necessary.

Calculation of the P parameters is over the sample length *lp*, that is all the data points in the softgauge.

3.2.2 Roughness Profile

To obtain the roughness profile the primary profile is first filtered using the short wave Gaussian profile filter with a cut-off wavelength value Lc. This will result in the loss of one sampling length *lr* at the beginning and one sampling length *lr* at the end of the profile.

The remaining profile is then partitioned into adjacent segments. Apart from possibly the last segment at the end of the profile, each segment is equal in length to the sampling length. If the last segment is not equal in length to the sampling length then it is removed. The resulting profile is called the roughness profile

Calculation of the R parameters is over a previously specified number of segments, which here is called the *Calculation Number CN*. The default CN given in ISO 4288-1996[5] is five. If the roughness profile contains more than CN segments then only the first CN segments are used in subsequent calculations. If the roughness profile contains less than CN segments then all segments are used in subsequent calculations together with a warning stating how many segments were actually used.

3.2.3 Waviness Profile

The waviness profile is not well defined in current ISO standards. The following represents current industrial practice of ignoring the "*profile filter Lf*" step and using a sampling length *lw* equal to the cut-off wavelength Lc.

To obtain the waviness profile the primary profile is first filtered using the long wave Gaussian profile filter with a cut-off wavelength value Lc. This will result in the loss of one sampling length *lw* at the beginning and one sampling length *lw* at the end of the profile.

The remaining profile is then partitioned into adjacent segments. Apart from possibly the last segment at the end of the profile, each segment is equal in length to the sampling length. If the last segment is not equal in length to the sampling length then it is removed. The resulting profile is called the waviness profile

Calculation of the W parameters is over a previously specified number of segments, which here is called the *Calculation Number CN*. There is no default CN given in current ISO standards. Current industrial practice uses five as the default CN. If the waviness profile contains more than CN segments then only the first CN segments are used in subsequent calculations. If the waviness profile contains less than CN segments then all segments are used in subsequent calculations together with a warning stating how many segments were actually used.

3.2.4 Parameter definitions

ISO standards define surface texture parameters in terms of a continuous profile. In practice measured surface texture data are not continuous but take discrete values. It has been found (see Brennan et. al. 2004)[8] that changing the continuous definition "*directly*" to a discrete form (replacing integrals to summations etc.) can lead to unacceptable errors for a reference algorithm. Brennan et. al. (2004)[8] recommended the following points as improvements over the "direct" discretisation method:

- The need to include implied mean line crossing points simply by interpolating the data where these occur (see figure 3.2) and provide each profile peak or valley element with calculated boundary values.

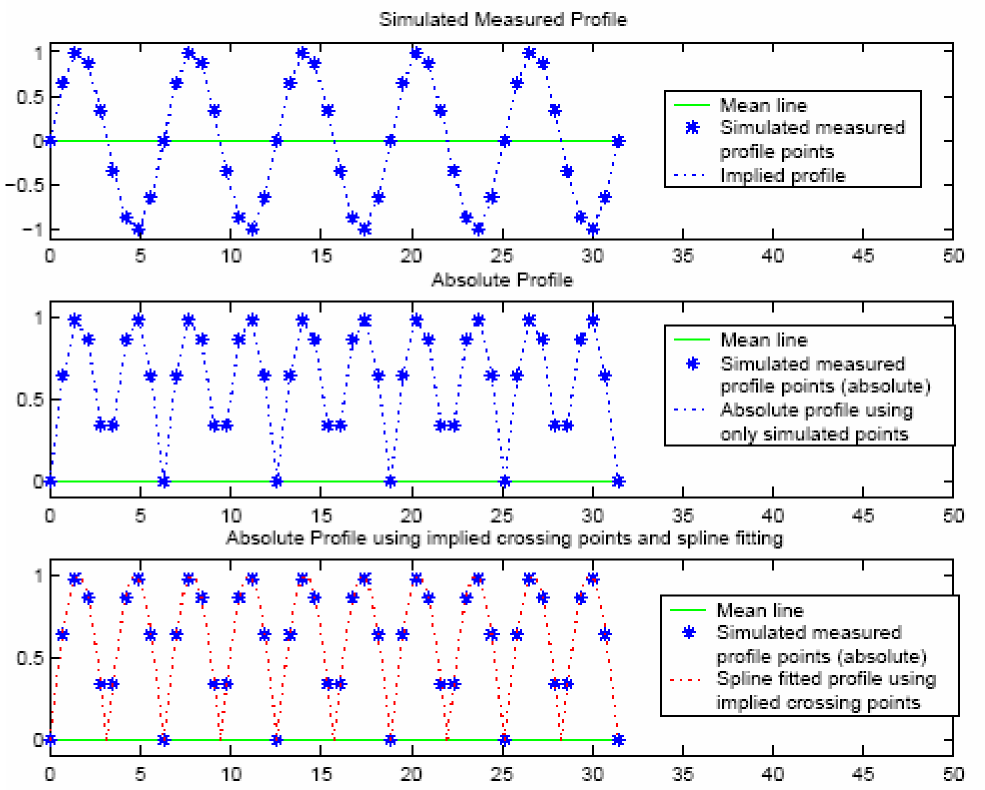

Figure 3.2 Example where a larger error for Ra is obtained using the absolute profile compared to the absolute profile that uses interpolation beforehand to determine the mean line crossing points

Brennan et. al. (2004)[8] recommends using a piecewise natural cubic spline to interpolate through the discrete data values to ensure *"a smooth approximation to the underlying function, without undue oscillation, in contrast to polynomial interpolation at all data points*". No value of "smoothness" is used since this is interpolation between points. The continuous definitions, contained in ISO 4287-1997[4], can now be used to calculate parameter values from the interpolated piecewise natural cubic spline.

3.2.5 Amplitude Parameters (average of ordinates)

NAME	***Ra***	Type	Amplitude (average)
Calculated from	Roughness Profile		
DEFINITION			
Description	Arithmetical mean deviation of the assessed profile *Pa, Ra, Wa* arithmetic mean of the absolute ordinate values *Z(x)* within a sampling length		
Mathematical	$Pa, Ra, Wa = \frac{1}{l}\int_0^l \lvert Z(x)\rvert dx$ with *l* = *lp, lr* or *lw* according to the case.		
Graphic			
Source	**ISO 4287 – 1996 section 4.2.1**		
Digital Implementation	Use a natural cubic spline to interpolate through the discrete data values. For each sample length *i* = 1, …, *CN* Calculate $Ra_i = \frac{1}{l}\int_0^l \lvert Z(x)\rvert dx$ Calculate $Ra = \frac{1}{CN}\sum_{i=1}^{CN} Ra_i$		
Other Information	1. Care required to determine crossover points.		

NAME	***Rq***	Type	Amplitude (average)
Calculated from	Roughness Profile		
DEFINITION			
Description	**Root mean square deviation of the assessed profile** *Pq, Rq, Wq* root mean square value of the ordinate values *Z(x)* within a sampling length		
Mathematical	$Pq, Rq, Wq = \sqrt{\frac{1}{l}\int_0^l Z^2(x)\,dx}$ with *l* = *lp, lr* or *lw* according to the case.		
Graphic			
Source	**ISO 4287-1996 section 4.2.2**		
Digital Implementation	Use a natural cubic spline to interpolate through the discrete data values. For each sample length *i* = 1, …, *CN* Calculate $Rq_i = \sqrt{\frac{1}{l}\int_0^l Z^2(x)dx}$ Calculate $Rq = \frac{1}{CN}\sum_{i=1}^{CN} Rq_i$		
Other Information	1. Alternative industrial definition over evaluation length rather than sampling length.		

NAME	***Rsk***	Type	Amplitude (average)
Calculated from	Roughness Profile		
DEFINITION			
Description	**Skewness of the assessed profile** *Psk, Rsk, Wsk* quotient of the mean cube value of the ordinate values *Z(x)* and the cube of *Pq*, *Rq* or *Wq* respectively, within a sampling length		
Mathematical	$Rsk = \frac{1}{Rq^3}\left[\frac{1}{lr}\int_0^{lr} Z^3(x)\,dx\right]$ The above equation defines *Rsk; Psk* and *Wsk* are defined in a similar manner.		
Graphic			
Source	**ISO 4287-1996 section 4.2.3**		
Digital Implementation	Use a natural cubic spline to interpolate through the discrete data values. For each sample length *i* = 1, …, *CN* Calculate $Rsk_i = \frac{1}{(Rq_i)^3}\left[\frac{1}{l}\int_0^{l} Z^3(x)dx\right]$ Calculate $Rsk = \frac{1}{CN}\sum_{i=1}^{CN} Rsk_i$		
Other Information	1. Alternative industrial definition over evaluation length rather than sampling length.		

NAME	***Rku***	Type	Amplitude (average)
Calculated from	Roughness Profile		
DEFINITION			
Description	**Kurtosis of the assessed profile** *Pku, Rku, Wku* quotient of the mean quartic value of the ordinate values *Z(x)* and the fourth power of *Pq, Rq* or *Wq* respectively within a sampling length.		
Mathematical	$Rku = \frac{1}{Rq^4}\left[\frac{1}{lr}\int_0^{lr} Z^4(x)\,dx\right]$ The above equation defines *Rku; Pku* and *Wku* are defined in a similar manner.		
Graphic			
Source	**ISO 4287-1996 section 4.2.4**		
Digital Implementation	Use a natural cubic spline to interpolate through the discrete data values. For each sample length i = 1, …, *CN* Calculate $Rku_i = \frac{1}{(Rq_i)^4}\left[\frac{1}{l}\int_0^{l} Z^4(x)dx\right]$ Calculate $Rku = \frac{1}{CN}\sum_{i=1}^{CN} Rku_i$		
Other Information	1. Alternative industrial definition over evaluation length rather than sampling length.		

3.2.6 Amplitude Parameters (peak & valley)

NAME	***Rp***	Type	Amplitude (peak & valley)
Calculated from	Roughness Profile		
DEFINITION			
Description	**Maximum profile peak height of the assessed profile** *Pp*, *Rp*, *Wp* Largest profile peak height *Zp* within a sampling length		
Mathematical	With *m* profile peaks in sampling length *l* $Pp, Rp, Wp = \max_{1 \le j \le m} Zp_j$ where Zp_j is the height of the *j*th profile peak within the sampling length and *l* = *lp*, *lr* or *lw* according to the case.		
Graphic			
Source	**ISO 4287 – 1996 section 4.1.1**		
Digital Implementation	Use a natural cubic spline to interpolate through the discrete data values. For each sample length *i* = 1,…, *CN* Determine portions of the profile above the mean line, these are the profile peaks. For each profile peak *j*= 1,…, *m*, determine the supremum height Zp_j. Calculate $Rp_i == \max_{1 \le j \le m} Zp_j$ Calculate $Rp = \frac{1}{CN}\sum_{i=1}^{CN} Rp_i$		
Other Information	1. Care required to determine crossover points for profile peaks 2. Care required at end of sampling lengths; see following note: *Note: The positive or negative portion of the assessed profile at the beginning or end of the sample length should always be considered as a profile peak or profile valley. When determining a number of profile elements over several successive sampling lengths the peaks and valleys of the assessed profile at the beginning or end of each sampling length are taken into account once only at the beginning of each sampling length.*		

NAME	***Rv***	Type	Amplitude (peak & valley)
Calculated from	Roughness Profile		
DEFINITION			
Description	**Maximum profile valley depth of the assessed profile** *Pv*, *Rv*, *Wv* Largest profile valley depth *Zv* within a sampling length		
Mathematical	With *m* profile valleys in sampling length *l* $Pv, Rv, Wv = \underset{1 \le j \le m}{Max} Zv_j$ where Zv_j is the depth of the *j*th profile valley within the sampling length and $l = lp$, *lr* or *lw* according to the case.		
Graphic			
Source	**ISO 4287 – 1996 section 4.1.2**		
Digital Implementation	Use a natural cubic spline to interpolate through the discrete data values. For each sample length $i = 1,\ldots, CN$ Determine portions of the profile below the mean line, these are the profile valleys. For each profile valley $j = 1,\ldots, m$, determine the supremum depth Zv_j. Calculate $Rv_i == \underset{1 \le j \le m}{Max} Zv_j$ Calculate $Rv = \frac{1}{CN}\sum_{i=1}^{CN} Rv_i$		
Other Information	1. Care required to determine crossover points for profile valleys 2. Care required at end of sampling lengths; see following note: *Note: The positive or negative portion of the assessed profile at the beginning or end of the sample length should always be considered as a profile peak or profile valley. When determining a number of profile elements over several successive sampling lengths the peaks and valleys of the assessed profile at the beginning or end of each sampling length are taken into account once only at the beginning of each sampling length.*		

NAME	***Rz***	Type	Amplitude (peak & valley)
Calculated from	Roughness Profile		
DEFINITION			
Description	**Maximum height of the assessed profile** *Pz*, *Rz*, *Wz* Sum of height of the largest profile peak height *Zp* and the largest profile valley depth *Zv* within a sampling length.		
Mathematical	$Pz = Pp + Pv$, $Rz = Rp + Rv$, $Wz = Wp + Wv$ all calculated over a sampling length		
Graphic			
Source	**ISO 4287 – 1996 section 4.1.3**		
Digital Implementation	Calculate *Rp* and *Rv* over the appropriate number of sampling lengths and add the calculated values together.		
Other Information			

NAME	***Rt***	Type	Amplitude (peak & valley)
Calculated from	Roughness Profile		
DEFINITION			
Description	**Total height of the assessed profile** *Pt*, *Rt*, *Wt* Sum of height of the largest profile peak height *Zp* and the largest profile valley depth *Zv* within an evaluation length.		
Mathematical	$Pz = Pp + Pv$, $Rz = Rp + Rv$, $Wz = Wp + Wv$ all calculated over the evaluation length		
Graphic			
Source	**ISO 4287 – 1996 section 4.1.5**		
Digital Implementation	Calculate *Rp* and *Rv* over the evaluation length and add the calculated values together.		
Other Information			

3.3 Feature Parameters

According to ISO 4287-1997[4], feature parameters are based on the three concepts of profile peak, profile valley, and profile element. These are accordingly defined in this standard as:

3.2.4 Profile peak

> *An outwardly directed (from material to surrounding medium) portion of the assessed profile connecting two adjacent points of the profile with the X-axis.*

3.2.5 Profile valley

> *An inwardly directed (from surrounding medium to material) portion of the assessed profile connecting two adjacent points of the profile with the X-axis.*

3.2.7 Profile element

> *Profile peak and the adjacent profile valley*.
>
> *Note: The positive or negative portion of the assessed profile at the beginning or end of the sample length should always be considered as a profile peak or profile valley. When determining a number of profile elements over several successive sampling lengths the peaks and valleys of the assessed profile at the beginning or end of each sampling length are taken into account once only at the beginning of each sampling length.*

The note gives a method to deal with end effects and allocation of features to particular cut-offs that inevitably occur with profile feature parameters.

Also in this standard is an attempt to deal with insignificant features with the following:

3.2.6 Height and/or spacing discrimination

> *Minimum height and maximum spacing of profile peaks and profile valleys of the assessed profile which should be taken into account.*
>
> *Note: The minimum height of the profile peaks and valleys are usually specified as a percentage of Pz, Rz, Wz or another amplitude parameter and the minimum spacing as a percentage of the sampling length.*

Typically the minimum height discrimination is set as 10 % of *Pz, Rz, Wz* and minimum spacing discrimination is set as 1 % of the sampling length. The height and spacing discrimination, as stated in this standard, is ambiguous with many different interpretations.

The commonest interpretation of minimum height discrimination used in practice is based on up and down crossings. For a given height discrimination, 2H say, take two straight lines, one at height H above and parallel to the mean line, and the other at H below and parallel to the mean line. Traversing along the profile from left to right, an up-crossing is defined at an upward crossing of the upper parallel line and a down-crossing is defined as a downward crossing of the lower parallel line. Starting at the left end of the profile and traversing along the profile from left to right, mark the first up-crossing/down crossing. Then continue alternatively from a marked up-crossing marking the next down-crossing or from a marked down-crossing marking the next up-crossing, until the end of the profile is reached. The profile peaks at 2H height discrimination are defined as the portions of the profile between a marked up-crossing on the right and a marked down crossing on the left. The profile valleys at 2H-height discrimination are defined as the portions of the profile between a marked down-crossing on the right and a marked up-crossing on the left.

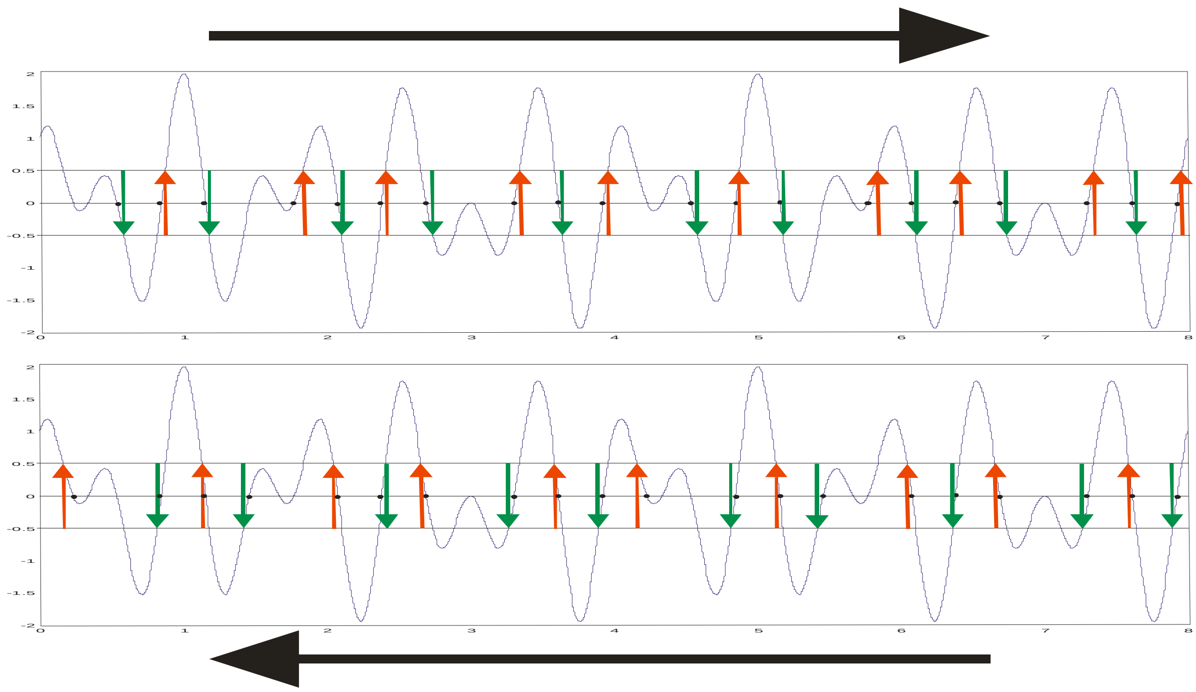

Figure 3.3 Different directions produced different marked crossings (up-crossing red, down-crossing green).

This approach has one severe problem, if the profile is reversed in direction, different up and down crossing could be marked (see Figure 3.3). This leads to the philosophical problem of *"are the identified features genuine features of the profile?"* With the difference in results when the profile is reversed, the answer is clearly NO.

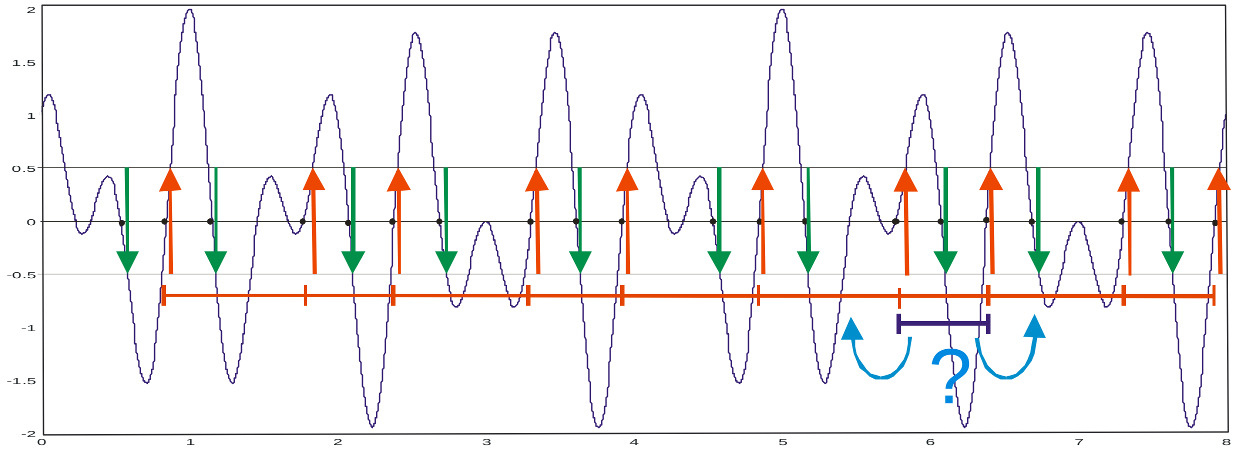

Figure 3.4 Which direction is an insignificant profile element combined?

Analysing the above algorithm, if the height discrimination is set to zero then all up and down crossings are through the mean line. As the height discrimination is gradually increased, adjacent pairs of up/down crossings, corresponding to profile elements insignificant at the given height discrimination, will be eliminated. The difference in results when the profile is reversed is caused by the direction in which these insignificant profile elements are combined to adjacent profile elements. When traversing from left to right they are always combined with the left profile element and when traversing from right to left they are always combined with the right profile element. What is required is a way of choosing which direction to combine insignificant profile elements independent of the direction of traverse (see Figure 3.4). Using concepts from pattern analysis (Scott 2004)[9] the following algorithm achieves this aim and is the one recommended.

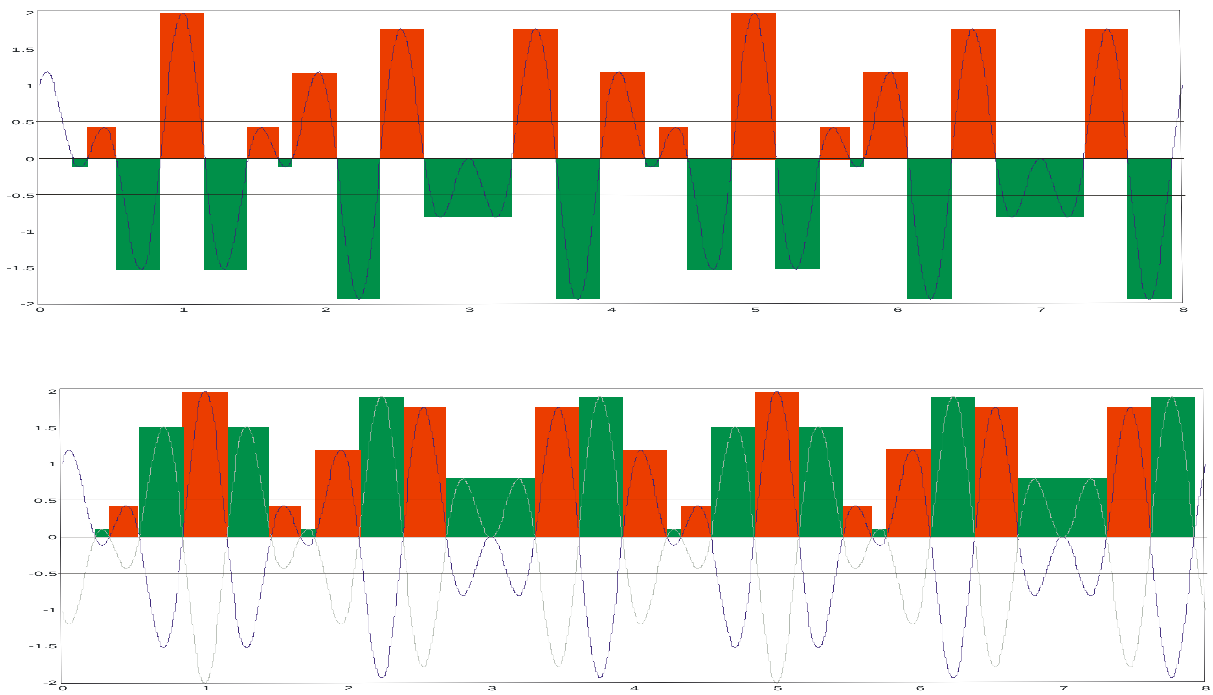

Figure 3.5 Portions above mean line are marked red, portions below green; the below portions are then reflected about the mean line.

For either height discrimination, 2H say, or spacing discrimination S, mark all portions of the profile above the mean line with one colour and all portions of the mean line below with another colour. The segments of the profile below the mean line are then reflected about the mean line so they are now above the mean line (see Figure 3.5).

Find the smallest segment (for height discrimination this is the smallest in height, for spacing discrimination this is the smallest width). If the smallest segment is lower than the discrimination level (H for height, S for spacing), combine it with its two adjacent neighbouring segments so they become one segment at the same height as the largest neighbour (see figure 3.6). If the smallest segment is at the end of the profile discard it. If there are two or more smallest segments then start with the segments that were originally below the mean line (green segments); otherwise it does not matter what order they are processed. Continue until all segments are above the discrimination level (height or spacing).

The segments left are the required segments after either height or spacing discrimination.

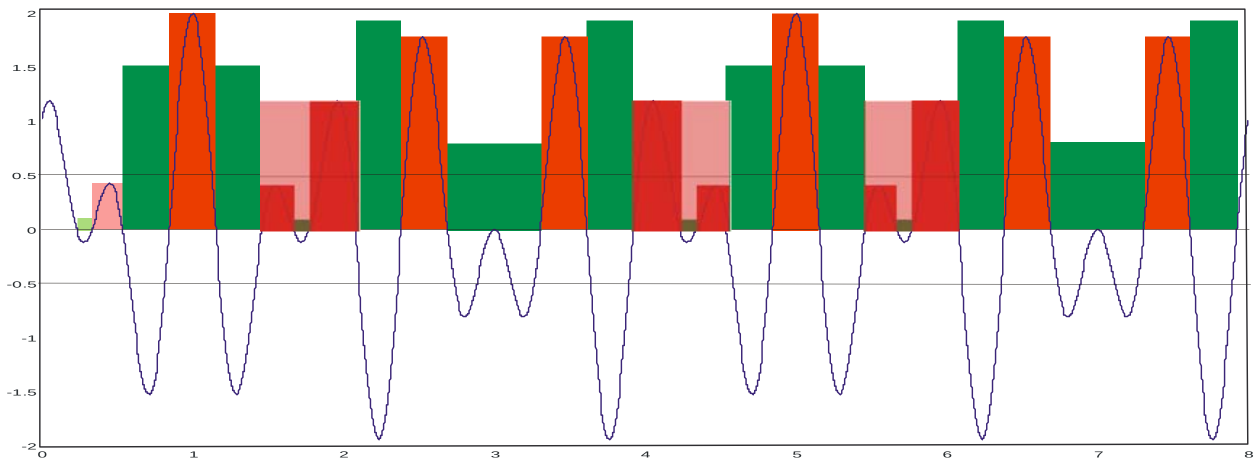

Figure 3.6 Start with smallest segments and combine with two adjacent segments, If the smallest segment is at an end just remove the segment.

NAME	***Rc***	Type	Feature Parameter
Calculated from	Roughness Profile		
DEFINITION			
Description	**Mean height of profile elements of the assessed profile** *Pc*, *Rc*, *Wc* Mean value of the profile element heights *Zt* within a sampling length		
Mathematical	With *m* profile elements in sampling length *l* $Pc, Rc, Wc = \frac{1}{m}\sum_{j=1}^{m} Zt_j$ where Zt_j is the height of the *j*th profile element within the sampling length and $l = lp$, *lr* or *lw* according to the case.		
Graphic			
Source	**ISO 4287 – 1996 section 4.1.4**		
Digital Implementation	Use a natural cubic spline to interpolate through the discrete data values. For each sample length,. determine portions of the profile above the mean line, these are the profile peaks and portions of the profile below the mean line, these are the profile valleys. Use the height discrimination algorithm, recommended above, at 10 % of *Rz* to eliminate insignificant profile elements. Use the spacing discrimination algorithm, recommended above, at 1 % of *lr* to eliminate insignificant profile elements. For the evaluation length: If an even number 2*m* of profile peaks and profile valleys Calculate $Rc = \frac{1}{m}\sum_{i=1}^{m} Zt_i$ where Zt_i is the height of the *i*th profile element. If an odd number of profile peaks and profile valleys *Rc* is the mean of the two even segment calculations of *Rc*, one with the first segment after combination removed and the second with the last segment after combination removed.		
Other Information	The algorithm here is for the evaluation length and not for the mean of sampling lengths as defined in ISO 4287-1996, since this latter definition is metrologically unstable.		

<table>
<tr><td>NAME</td><td>RSm</td><td>Type</td><td>Feature Parameter</td></tr>
<tr><td>Calculated from</td><td colspan="3">Roughness Profile</td></tr>
<tr><td colspan="4">DEFINITION</td></tr>
<tr><td>Description</td><td colspan="3">Mean width of profile elements of the assessed profile
PSm, RSm, WSm
Mean value of the profile element widths Xs within a sampling length</td></tr>
<tr><td>Mathematical</td><td colspan="3">With m profile elements in sampling length l
$PSm, RSm, WSm = \frac{1}{m}\sum_{j=1}^{m} Xs_j$
where Xs_j is the width of the jth profile element within the sampling length and $l = lp, lr$ or lw according to the case.</td></tr>
<tr><td>Graphic</td><td colspan="3"></td></tr>
<tr><td>Source</td><td colspan="3">ISO 4287 – 1996 section 4.3.1</td></tr>
<tr><td>Digital Implementation</td><td colspan="3">Use a natural cubic spline to interpolate through the discrete data values.
For each sample length, determine portions of the profile above the mean line, these are the profile peaks and portions of the profile below the mean line, these are the profile valleys. Use the height discrimination algorithm, recommended above, at 10 % of Rz to eliminate insignificant profile elements. Use the spacing discrimination algorithm, recommended above, at 1 % of lr to eliminate insignificant profile elements.

For the evaluation length:

If an even number 2m of profile peaks and profile valleys
Calculate $RSm = \frac{1}{m}\sum_{i=1}^{m} Xs_i$ where Xs_i is the width of the ith profile element.

If an odd number of profile peaks and profile valleys

RSm is the mean of the two even segment calculations of RSm, one with the first segment after combination removed and the second with the last segment after combination removed.</td></tr>
<tr><td>Other Information</td><td colspan="3">The algorithm here is for the evaluation length an not for the mean of sampling lengths as defined in ISO 4287-1996, since this latter definition is metrologically unstable.</td></tr>
</table>

3.4 Conclusion

The above parameter definitions represent the re-evaluation of the definitions given in ISO 4287 – 1997[4] (and ISO 4288 - 1996)[3]. These definitions are, to the best of our knowledge, unambiguous stable definitions that are consistent (where possible) with those in the international standards. These definitions have been implemented in software as Reference Standard Algorithms (Type F2 Measurement Standards): see section 5. This software is open source so any remaining ambiguities can be resolved.