A boundary segmentation algorithm for extracting micro-scale dimensional parameters in the measurement of structured surfaces

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Abstract

Measurement and characterisation techniques for structured surfaces are now under development. The recently published international standard ISO 25178 - part 2, introduces feature characterisation that provides a stable solution for segmentation of areal geometric features. However, unambiguously understanding the boundaries of the areal features has received little attention. A boundary analysis method is proposed in this paper based on a tangent analysis algorithm. Following a four-stage feature characterisation procedure, dimensional parameters that relate to individual surface features, or relations between them, can be determined.

1 Introduction

Structured surfaces [1] often consist of repeated geometric structures on the micro- or nano-scale. Characterising these types of surfaces using conventional field parameters has been recognised as being highly inefficient [2]. Determination of the dimensional parameters relating to the surface features would be an effective characterisation methodology e.g. the standardised "feature characterisation" in ISO 25178 part 2 [3].

There are two major drawbacks with the current standards. Firstly, most attributes of the surface features are a measure of size of simple geometries (see Table 1), whereas possible feature attributes of functional surfaces are far more comprehensive than those listed in [2]. For example, eighteen classes of characteristics of geometric features are described in ISO Technical Report ISO/TR 14638. Secondly, characterisation of the feature boundaries has received little attention. With correct recognition of the areal features [3] and the line features, the dimension related parameters of an areal surface can be quantified. In this work, a segmentation solution for simple closed planar boundaries is developed based on a tangent analysis.

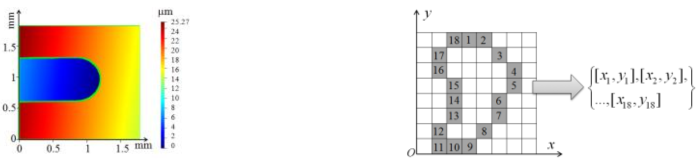
Table 1: Common feature attributes in [3]

Feature Class	Feature Attributes	Designated Symbol
Areal	Local peak/pit height	lpvh
	Volume of areal feature	VolS/VolE
	Area of areal feature	Area
	Circumference of areal feature	Circ
Line	Length of line	Leng
Point	Local peak/pit height	lpvh
	Local curvature at critical point	Curvature
Areal, Line, Point	Attribute takes value of one	Count

2 The algorithm

2.1 Boundary data preparation

Surface topography measurement results are usually expressed as a point cloud. Aided by a feature characterisation toolbox [3], different areal features can be segmented by recognising their boundaries (see Fig 1a). Boundary data is usually expressed as a simple closed planar curve (see Fig 1b).



(a) (b)

Figure 1: (a) a point cloud data with a boundary (green curve) (b) a planar boundary.

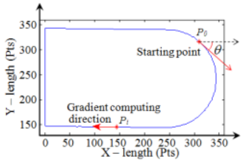
2.2 Initial recognition

This algorithm assumes that all the simple closed curves are comprised of straight line and arc segments. This initial recognition is carried out by sequential computation of tangent angles, histogram projection and straight line extraction.

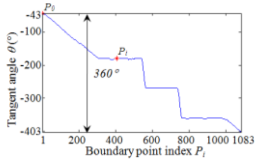
(1) From a starting point, each boundary point and its neighbouring points are successively fitted to a straight line (Fig 2a). Then the tangent angles, θ, are recorded according to their boundary point position (Fig 2b).

(2) A histogram (Fig 2c) is generated by counting the frequency of occurrence of the tangent angles. In this way, straight lines on a boundary become discrete high peaks, while arcs become valleys which connect neighbouring peaks.

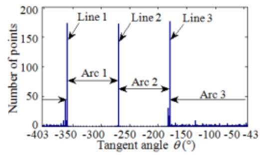
(3) A peak-search algorithm is used to find those highest peaks in the histogram. To reduce the influence of noise, a peak height threshold and an angle threshold are pre-set to discriminate the neighbouring peaks. Straight lines can then be identified as shown in Fig 2d. The straight line and arc segments are identified by mapping the boundary indices to the original boundary graph, (see Fig 2e).



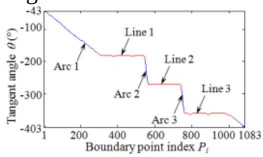
(a) Computing the tangent angle



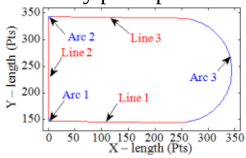
(b) Tangent angle vs. boundary point position



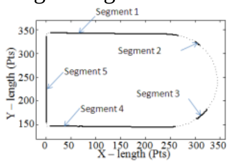
(c) Histogram of the tangent angle



(d) Recognised straight lines and arcs on the tangent angle graph



(e) Recognised straight lines and arcs on the boundary graph



(f) A noised segmentation

Fig 2: Illustration of tangent analysis for a simple boundary.

2.3 Merging of segments

Noise always disturbs a correct identification (see Fig 2f). A final merge is needed to prune the small segments. This process involves merging neighbouring straight line segments that are very close.

3 Four steps to a micro-scale dimensional parameter

Dimensional parameters of interest can be easily extracted from a point cloud by following the four steps in sequence.

1) Areal feature segmentation [3] of a surface by separating different areal features.
2) Line feature segmentation of a boundary by generating different line features.
3) Selection of the parameters of interest and reference features (e.g. in Table 2).
4) Parameter calculation and/or statistics.

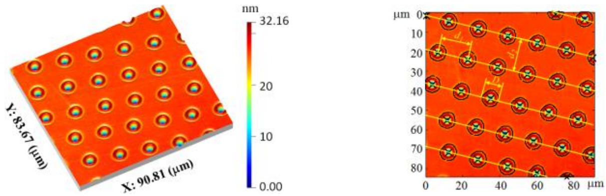
Table 2: Some commonly used dimensional parameters.

Size (areal)	***Distance (areal, line, point)***
Area Volume Circle diameter Square side width Rectangle width/length	Plane to plane Line to plane Point to plane Line to line Point to line Point to point
Radius (line)	***Angle (line)***
Of a circle or arc	Absolute Relative

4 An example

A laser textured zone on a hard disk surface is tested (see Fig 3). It has been stated [4] that statistical dimensional parameters such as the average bump rim heights and the average pitches of neighbouring bumps have significant influence on friction control. In this example, the bump features and the boundary circles are recognised successively. By selecting all the circle boundaries, or adjacent boundary centres, the diameter D, and the pitches, d_1 and d_2, can be obtained on average:

$$d_1 = 16.177\ \mu\text{m},\qquad d_2 = 16.324\ \mu\text{m},\qquad D = 8.341\ \mu\text{m}.$$



(a) Laser textured zone of a hard disk surface

(b) Recognised areal features, boundaries and concerned parameters

Figure 3. A boundary analysis case.

5 Conclusions

The boundary analysis module based on a tangent analysis algorithm is developed. Following a four-step feature characterisation procedure, the performance of this algorithm has been presented. Future improvement needs to consider fully the boundaries in three-dimensions and a stable solution needs to be finally determined.

6 Acknowledgements

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References:

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