Development of mathematical reference standards for the validation of surface texture parameter calculation software

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Abstract

A framework for the validation of surface texture parameter calculation software is proposed. The framework utilises mathematically defined surfaces and mathematically calculated surface texture parameter values to produce a reference against which third-party software can be compared; in principle, free from the approximations that are intrinsic when applying numerical methods and algorithms to discrete data in order to realise continuous definitions [1]. This poster provides a proof-of-concept of the new framework using a simple two-term cosine surface. The required steps to enable meaningful comparison and subsequent validation of surface texture parameter calculation software are showcased.

Step one: Defining a continuous mathematical surface

A function $z(x,y)$ must be defined such that for any position on the surface (given as x and y coordinates), the function describes a height value, z. A useful approach is to utilise Fourier series, combining cosine terms to enable the creation of complex, well-defined continuous surfaces with a simple basic structure. A simple example surface created using this method is one with two cosine terms, given as

$$z(x,y) = \alpha[\cos(\pi x) + \cos(\pi y)]$$

Step two: Surface texture parameter calculation

Using the surface texture parameter definitions given in ISO 25178-2, continuous mathematical surface equations can be evaluated directly [2,3]. The S_{ku} parameter, for example, can be evaluated for the cosine surface defined above for a surface area of -5 m to 5 m in the x and y directions:

$$S_{ku} = \frac{1}{\sqrt{\frac{1}{|A|}\iint_A z^2(x,y)dxdy}^{\,4}}\left(\frac{1}{|A|}\iint_A z^4(x,y)dxdy\right)$$

$$S_{ku} = \left(\frac{1}{100}\iint_{-5}^{5}(\cos\pi x + \cos\pi y)^2 dxdy\right)^{-2}\left(\frac{1}{100}\iint_{-5}^{5}(\cos\pi x + \cos\pi y)^4 dxdy\right)$$

$$S_{ku} = \frac{9}{4}\ \text{mm}$$

Step three: Discrete dataset representation

Creating a discrete dataset from the mathematical surface can be achieved by calculating height values at uniformly separated positions within a defined area and storing the values in a grid array [4]. Creating the discrete dataset by evaluating the mathematical surface at each point ensures numerical agreement between the mathematical surface and the discrete surface, up to the finite precision of the data file.

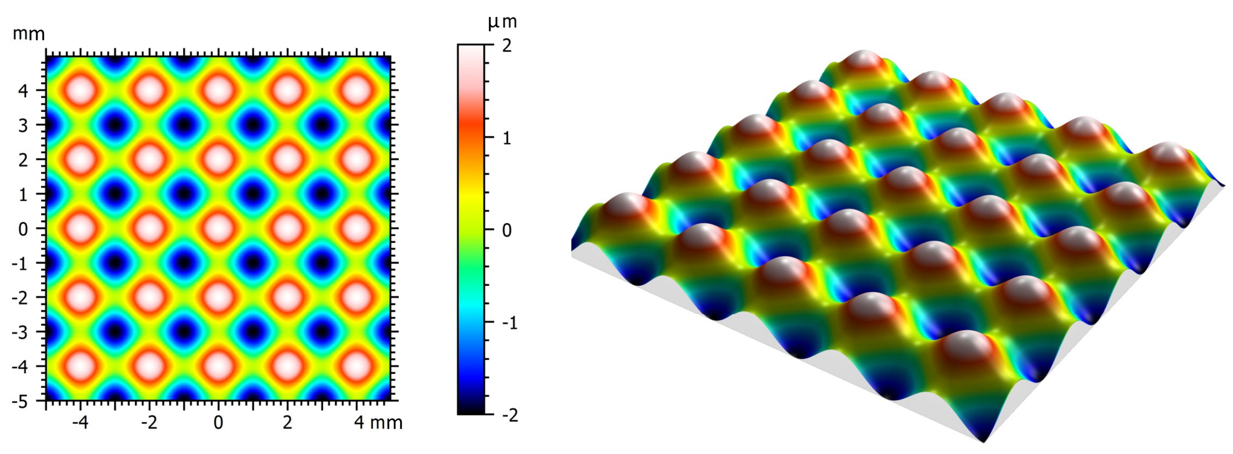

Figure 1. Discrete dataset representation of the cosine surface. *Left*: Top-down colour-map. *Right*: 3D view.

Step four: Software validation

Using the discrete dataset, it is now possible to obtain surface texture parameter values from the software under test and compare them to the mathematical values.

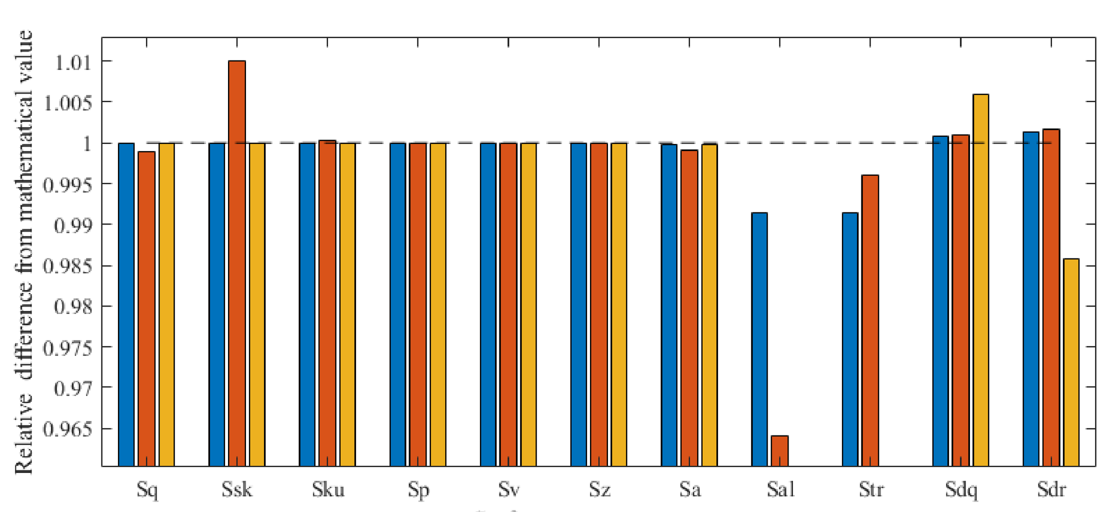

Figure 2. Surface texture parameter values for three software packages, normalised to the mathematical value.

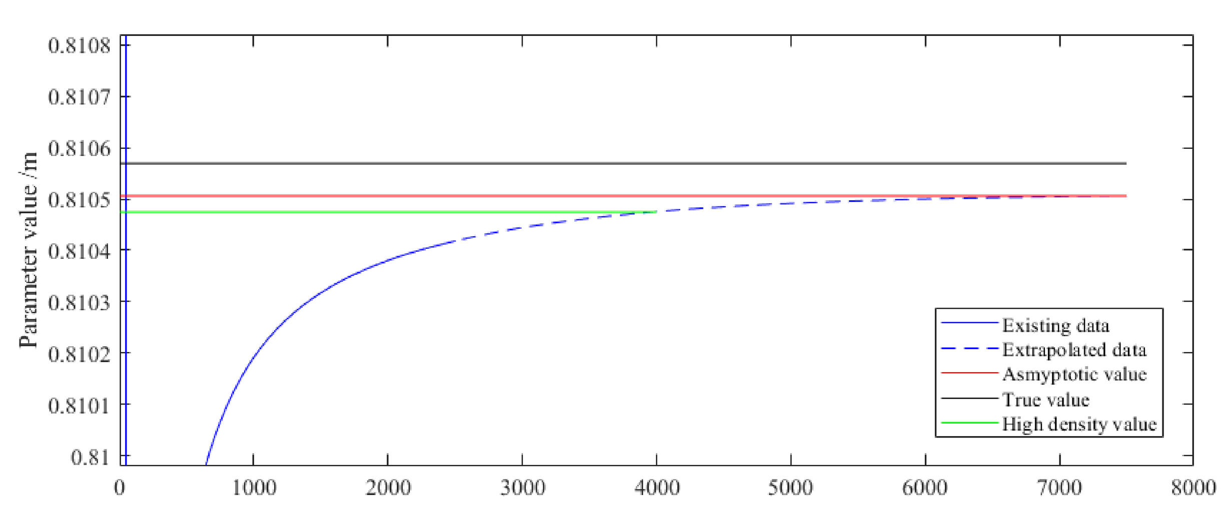

Figure 3. Extrapolation of S_a parameter values from software, obtained for a range of dataset densities from 10 × 10 to 500 × 500 pixels, extrapolated to find an asymptote.

Conclusions & Future work

The proposed methods provide a way of validating software by using mathematically defined surface functions. Sampling these surfaces to produce discrete datasets enables comparison with numerical algorithms used in surface texture parameter calculation software and allows validation of the software to occur.

Extending the concept introduced in this paper to more complex surfaces will better represent surfaces obtained from real-world measurements. Additionally, work needs to be done to calculate a wide range of surface texture parameter values for these complex surfaces, as simple symbolic mathematics software methods are limited in their solving power, even on high specification machines.

Future work aims to develop performance metrics that assess the deviation from the mathematical value in combination with the measurement error of a real input surface, to determine whether the software is a significant factor in the overall uncertainty.

References

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