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SOBEL OPERATOR FOR EDGES DETECTION IN SURFACE TEXTURE ANALYSIS

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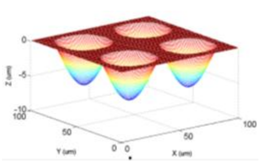
Graphical abstract



Abstract

The classification of surface textures has been changed for the convenience of design, manufacture and metrology. Surface texture can be divided into two types which are engineered and structured surface. One examples of structured surface is dimple edge type of surface. This kind of surface usually has a deterministic structure, with high aspect ratio geometric features. Modern dimple golf ball is the example of structured surface application witches its functional requirement, was to reduce air drag through better hydrodynamic flow around the ball. From the analysis of dimpled surface, process variation can be enhanced and the uniformity of the surface features can be improved. Hence, the work presented in this paper is intended to improve the quality of segmentation method for the dimple edges type of surface and Sobel Operator algorithm is proposed to be used. In Sobel Operator algorithm, two kernels is applied which one kernel identifies the horizontal edges and the other kernel identifies the vertical edges. By passing these two kernels, gradient along x direction and gradient along the y direction can be computed at the different location and finally determined the edges of the surface. Sobel operator application shows that the location of the edges becomes clearer and topography segmentation based on features edges is possible.

Keywords: Surface texture, profile, areal, leveling, filtering, segmentation, sobel operator

1.0 INTRODUCTION

Surface texture analysis refers to analyzing the topography or surface roughness of precision surfaces on machining processes. While, surface texture is the feature on a component or device that interacts with the environment in which the component is housed or the device operates. The surface texture and of course the material characteristics of a part can affect things such as how two bearing parts slide together, how light interacts with the part, or how the part looks and feels. The need to control and, hence, measure surface features becomes increasingly important as we move into a miniaturized world [1]. The surface features can become the dominant functional features of a part and may become large in comparison to the overall size of an object.

In surface texture analysis, there are two types of analysis method that has been explored which are profile method and areal method. Profile method measured surface in a line across the surface that can be represented mathematically as a height function with lateral displacement, z(x) and already been placed in ISO 4288 [2]. However, this profile method comes with several limitations such as its single line measurement cannot identify pits or valleys and peaks or ridges of the surface. Therefore, at the end of 2005, areal method has been allocated in ISO 25178 to give this areal surface texture its official standard that driven to more efficient shift to the surface metrology technology. Areal measurement gives more realistic representation of the whole surface and has more statistical significance. Also, there is less chance that significant features will be missed by an areal method and the manufacturer gains a better visual record of the overall structure of the surface. The classification of areal surface textures has also been changed for the convenience of design, manufacture and metrology. Based on Suh and Saka, surface texture can be divided into two types which are engineered and structured surface [3]. Dimple edges surface is one of the examples of the structured surface. This kind of surface usually has a deterministic structure, with high aspect ratio geometric features. All structured surfaces are designed to meet a specific functional requirement. Example of dimple edges surface is the modern dimple golf ball, whose functional requirement was to reduce air drag through better hydrodynamic flow around the ball, so that it could be hit further. From the analyzing of dimpled surface, process variation can be enhanced and the uniformity of the surface features can be improved. Hence, the work presented in this paper is intended to determine the correct segmentation method for the dimple edges type of surface which can be referred in Figure 1.

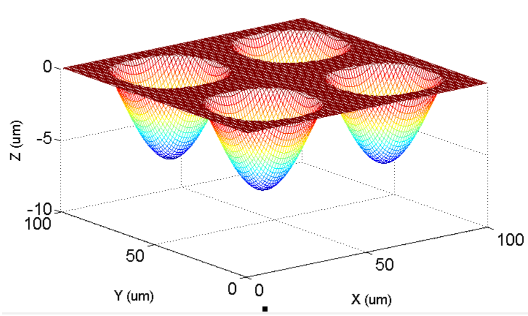


Figure 1 Dimples edges type of surface texture topography

2.0 PROCESS OF CHARACTERIZING SURFACE TEXTURE

With the help of this areal method analysis, there are a few steps involve in order to finally get the features parameter of the surface. Main steps that usually been used are preprocessing, segmentation and finally the surface features evaluation. Preprocessing involve leveling and filtering steps.

While in segmentation, detection of valley, hills or edges need to be determined before surface features finally been evaluated.

2.1 Preprocessing

During preprocessing, the surface data should be leveled where the measured surface texture is rotated in the image plane mathematically by using a least square algorithm. Then, filtration step is done in order to smoothing the pure surface texture from the noise. Filtration also required for several purposes such as to separate long-scale components from short-scale components, in other words to separate waviness from roughness and calculated parameters according to the specification. In ISO 11562, Gaussian filter was introduces which defines as a transfer for low pass filter that produces the waviness profile. When this waviness profile is subtracting from primary profile, it will give the roughness profile. Another type of filtration is Robust Gaussian filter which defines in ISO 16610-31 as an iterative algorithm that calculates local weight based on the distance between the primary profile and the waviness profile. When this waviness profile is subtracting from primary profile, it will give the roughness profile. Another type of filtration is Robust Gaussian filter which defines in ISO 16610-31 as an iterative algorithm that calculates local weight based on the distance between the primary profile and the waviness profile.

2.2 Segmentation

To identify features on a surface, an extra step is compulsory to segment the surface into regions of interest. Segmentation method starts with Maxwell [4] which he proposed to divide a landscape into regions consisting of hills and regions consisting of dales. A Maxwellian hill is an area from which maximum uphill paths lead to one particular peak, and a Maxwellian dale is an area from which maximum downhill paths lead to one particular pit. By definition, the boundaries between hills are course lines (watercourses), and the boundaries between dales are ridge lines (watershed lines). Maxwell was able to demonstrate that ridge and course lines are maximum uphill and downhill paths emanating from saddle points and terminating at peaks and pits. In 2013, Watershed algorithm segmentation has been described in ISO16661-85 [5]. The term "watershed" comes from daily life where water drops falling on a topography flow along the steepest slopes in the local minima, where a catchment basin arises. Lines, which separate adjacent catchment basin from each other, called watersheds. These watersheds provide a segmentation of the surface texture into different separate regions that represent possible object contours. Apart from the above statement, that segmentation method only suitable for the normal sine wave type of topography.

2.3 Edges Detection Segmentation Approaches

Consequently, the work presented here primarily proposed to used Sobel Operator algorithm to detect the edges of dimples surface type of topography where we defined edges itself as the boundary between different contours of the surface texture. In this paper, a dataset containing areal surface topography information is used. Data simulated consist of a rectangular matrix of height values (z values) arranged along the rows and columns of a regular x, y grid with constant Δx and Δy. Figure 2 below show the simulated data structure.

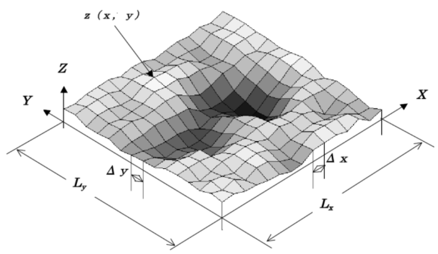


Figure 2 Simulated data structure

2.4 Sober Operator

In case of Sobel Operator algorithm, there are two kernels that have been used which one kernel identifies the horizontal edges and the other kernel identifies the vertical edges. The kernel which finds the horizontal kernel that is equivalent to having the gradient in vertical direction and the kernel which computes the vertical edges is equivalent to taking in the gradient in horizontal direction. Example of Sobel kernels is given in Figure 3.

-1	-2	-1
0	0	0
1	2	1

1	0	-1
2	0	-2
1	0	-1

Figure 3 Sobel kernels

By passing these two kernels, gradient along x direction (G_x) and gradient along the y direction (G_y) can be computed at the different location in the surface topography texture. Now the strength and the direction of the edge at that particular location can be computed by using the gradients G_x and G_y. The gradient of the surface at location is defined as the vector

$$\nabla f = \frac{G_x}{G_y} = \frac{\frac{\partial f}{\partial x}}{\frac{\partial f}{\partial x}} \qquad \text{(Eq. 1)}$$

Where G_x is the partial derivative of along x direction and G_y is the partial derivative of along the y direction. Computation of the magnitude of the gradient involves squaring the two components G_x and G_y adding them and takes the square root of this addition [6].

$$\nabla f = mag\,(\nabla f) = [G_x^2 \; + \; G_y^2 \;]^{\frac{1}{2}} \qquad \text{(Eq. 2)}$$

The approximation of this is taken as magnitude of the gradient to be sum of magnitude of G_x gradient in the x direction plus magnitude of G_y in the y direction.

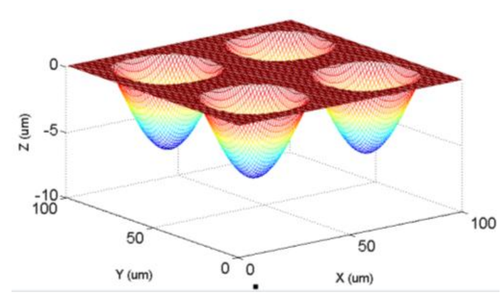
$$\approx [G_x + G_y\,] \qquad \text{(Eq. 3)}$$

The magnitude tells the strength of the edge at location it does not tell anything about the direction of the edge. To compute the direction of the gradient represent the direction angle of the vector, Sobel gives an averaging affect over the topography surface, so effect due to the presence of spurious noise in the surface is taken care of some extent by this Sobel gradient. Sobel also gives a smoothing effect by which we can reduce the spurious edge that can be generated because of the noise present in the surface texture.

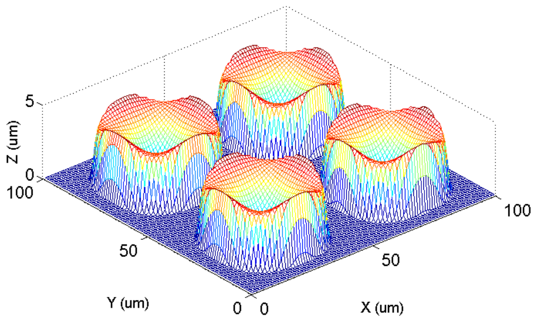
$$\alpha(x, y) = tan^{-1}(\frac{G_y}{G_x}) \qquad \text{(Eq. 4)}$$

2.5 Application of Result

Figure 4 shows the results of the Sobel operator algorithm after applied on the surface texture topography data. With the help of the Sobel kernel, detection of edges at the surface dimples can be determined. As in Figure 4, after undergo the Sobel operator, it can be seen that the detection of the edges become more clear which there are boundary detection at every dimple of the surface. Therefore, it is prove that Sobel operator algorithm is possible to be used to detect the edges and later segmented every dimple on the surface. Additionally, each segmented feature has its own functional effect that makes sense to classify them in groups according to their geometrical properties. When surface features want to be evaluate, these geometrical properties, which are used as a threshold, can be the area, roundness, height, compactness and etc.



(a)



(b)

Figure 4 Sobel operator segmentation (a) Input topography data (b) Output topography data (gradient information)

3.0 CONCLUSION

To be concluded, after undergo Sobel operator algorithm, it can be seen that the detection of the edges become clearer which there are boundary detection at every dimple of the surface. Therefore, it is prove that Sobel operator is possible to be used to detect the edges and later segmented every dimple on the surface.

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