Computer Engineering, Mechanical Engineering

SURFACE PROFILE ANALYSIS PACKAGE

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Abstract: *In the article it has been presented the Robust Gaussian regression filtering techniques. Several typical robust weight functions have been adopted and compared with each other. Next the surface profile analysis software was shown which enables for the analysis of actual and simulated surface roughness profile. The application enables to choose the filter parameters that will be determined and gives the result of filtering in the form of a graph, and values of parameters.*

Keywords: *surface profile analysis, filtering techniques, Visual C++*

ACM Classification Keywords: *J. Computer Applications, J.2 Physical Sciences And Engineering, G. Mathematics Of Computing, G.4 Mathematical Software*

Introduction

An assessment of microtopography by surface parameters is useful when long wavelength components are removed from the measured surface data. Surface characterization is based on the separation of surface components. A necessary preliminary to numerical assessment of surface profiles is to extract the frequency components representative of the roughness and to eliminate those that would be irrelevant. The unwanted elements of the surface geometry are commonly referred to the waviness, due to imperfections in the manufacturing process. The cut-off length is selected to separate roughness and waviness for a given surface. The methods of separation of profile on roughness and waviness are described in Reference [Raja, Muralikrishnan, Fu 2002]. The choice of filtering methods has an important influence on surface characterization. Recently, Gaussian filtering technique was adopted to filtration of surface profiles. This technique solved the problems of phase distortion and complex design of filters. The performance of Gaussian filtering technique is affected by certain conditions, especially for the surfaces having freak signals (outliers) such as grooves, scratches and scores. The question of finding reference lines is very difficult for multi-process texture. One finishing process of this type is called plateau honing. The problem is that control of such surface texture requires a complementary response from surface metrologists. Without adequate measurement technique the control and hence any attempt to maintain quality is lost. Although the fine texture marks fall well within the accepted bandwidth for the sample length (cut-off) the scratches do not. They are too wide. For these surfaces, the distortion after Gaussian filtering can be also big.

Gaussian filtering technique

Robust Gaussian filtering

The impulse response function of Gaussian filtering is described by its weighting function s(x).

$$s(x) = \frac{1}{\alpha\lambda_C}\exp\left[-\pi\left(\frac{x}{\alpha\lambda_C}\right)^2\right] \tag{1}$$

where:
x – distance from the center of weight function
λc –cut-off
$\alpha = \sqrt{\ln 2/\pi}$.

With the convolution operation, the original measured profile z(x) can be divided into low-frequency reference w(x) and high-frequency roughness r(x) [Li, Jiang, Li 2004].

$$w(x) = \int_{-\infty}^{\infty} z(x-\xi) \cdot s(\xi) \cdot d\xi \tag{2}$$

$$r(x) = z(x) - w(x) \tag{3}$$

where: $r(x)$ – roughness profile .

$$w(x) = \int_{-\infty}^{\infty} z(x-\xi) \cdot \rho(x) s(\xi) \cdot d\xi \tag{4}$$

Strictly speaking, we used modified Gaussian weight function in running-in and running-out lengths in order to eliminate edge effects (regression filtering).

Robust weight functions

According to M-estimation, different robust weight function can lead to various results for the same observed signal. So several typical weight function were selected and compared with each other.

Sometimes the standard deviation is used as the estimating scale. However it is less robust than a median MED or median absolution deviation MAD. So only MED or MAD robust scale parameters were used. In initial calculations we analyzed a lot of weight functions. As the result of it, several selected typical weight functions were compared [Dobrzański, Pawlus 2005]:

WLAV

$$\rho(x) = \frac{1}{|v|} \tag{5}$$

where: $v = r(x)/s$, $s = MED = |med(r(x))|$ lub $s = MAD = med(|r(x) - med(r(x))|)$.

Tukey

$$\rho(x) = \begin{cases} \left(1 - v^2\right)^2, & |v| \le 1 \\ 0, & |v| > 1 \end{cases} \tag{6}$$

where: $v = r(x)/cs$.

Huber

$$\rho(x) = \begin{cases} 1, & |v| \le c \\ \dfrac{c}{|v|}, & |v| > c \end{cases} \tag{7}$$

where: $c > 0$, $v = r(x)/s$.

$$s = \begin{cases} \sigma, & |v| \le c \\ MAD, & |v| > c \end{cases} \tag{8}$$

where: σ – standard deviation.

Hampel

$$\rho(x) = \begin{cases} 1, & |v| \le a \\ a/|v|, & |v| \in (a,b] \\ a\dfrac{c-|v|}{(c-b)|v|}, & |v| \in (b,c] \\ 0, & |v| > c \end{cases} \tag{9}$$

where: $v = r(x)/s$, $0 < a < b < c < \infty$.

Andrews

$$\rho(x)=\begin{cases}\dfrac{1}{\pi v}\sin(\pi v), & |v|\le 1\\ 0, & |v|>1\end{cases} \tag{10}$$

where: $v = r(x)/cs$.

ADRF

$$\rho(x)=\begin{cases}1, & |v|\le a\\ a/|v|, & |v|\in(a,b]\\ b/v^2, & |v|\in(b,c]\\ 0, & |v|>c\end{cases} \tag{11}$$

where: $v = r(x)/s$, a= 1, b= 2.5, c=3.

Fair

$$\rho(x)=\frac{2}{1+|r(x)|/k\sigma} \tag{12}$$

Denmark

$$\rho(x)=\begin{cases}1, & |x|\le k\sigma\\ \exp\left(-\dfrac{|r(x)|}{k\sigma}+1\right), & |x|>k\sigma\end{cases} \tag{13}$$

IGGI

$$\rho(x)=\begin{cases}1, & |x|\le a\sigma\\ k\sigma/|r(x)|, & |x|\in(a\sigma,b\sigma]\\ 0, & |x|>b\sigma\end{cases} \tag{14}$$

QC

$$\rho(x)=\begin{cases}1, & |v|\le k\\ 0, & |v|>k\end{cases} \tag{15}$$

where: $v = r(x)/\sigma$.

Surface Profile Analysis Package

On the commercial market there are many applications for the analysis of surface profiles. Unfortunately, these applications are expensive and not available educational version. Therefore, the authors made attempts to write such an application, which can be used both in scientific work and teaching. With Surface Profile Analysis Package a user can analyze data files collected from a variety of instruments from most major manufacturers.

Designed application enables for the analysis of real and simulated surface roughness profile. The application enables to choose the kind of filter and parameters that will be determined and gives the result of filtering in the form of a graph, and the selected parameters.

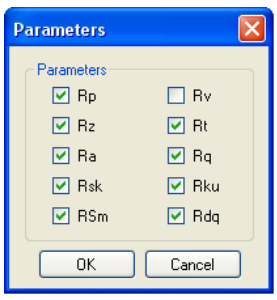

Figure 1. Determined parameters selection window

The user after loading the data (Files-> Open) can choose the parameters which undergo subsequent analysis does this in the Options menu-> Parameters (fig. 1).

The program sets the basic roughness parameters such as:

Ra Roughness Average (Ra)

Rq Root Mean Square (RMS) Roughness

Rt Maximum Height of the Profile

Rv, Rm Maximum Profile Valley Depth

Rp Maximum Profile Peak Height

Rz Average Maximum Height of the Profile

Sm, RSm Mean Spacing of Profile Irregularities

Rsk, Sk Skewness

Rku Kurtosis is a measure of the randomness of heights, and of the sharpness of a surface.

Rdq Mean absolute slope

By default, all parameters are selected, i.e. all the parameters will be determined. The next step is to choose the filter/s (from the menu Filtering) fig.2 by which will be analyzed and loaded surface profile. Therefore, some filters that can be run with different parameter values and therefore the user has the option after selecting a filter, for example, Tukey determines the value of the parameter. Another choice which the user must make is the cut-off by default is set to 0.8 mm.

a) b)

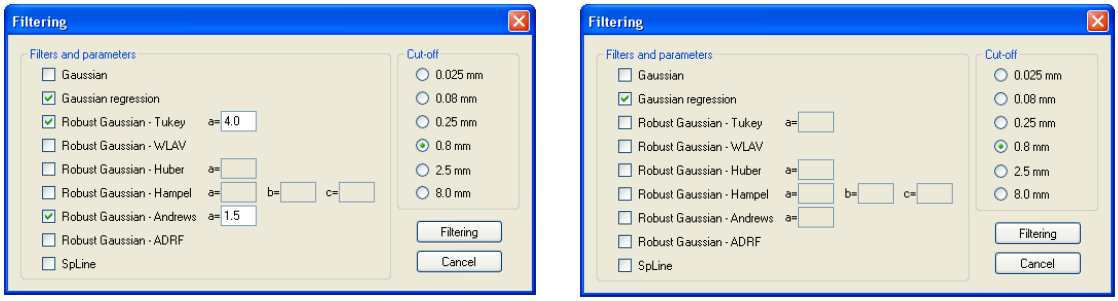

Figure 2. The selection of filters used in the analysis of surface profiles

Often the user wants to be able to compare the effects of several filters on the same surface profile analyzed. Therefore, the application gives the user to create this possibility. A surface profile can be analyzed by using several filters, then get a summary table of results (in the form of a graph and calculated values of parameters).

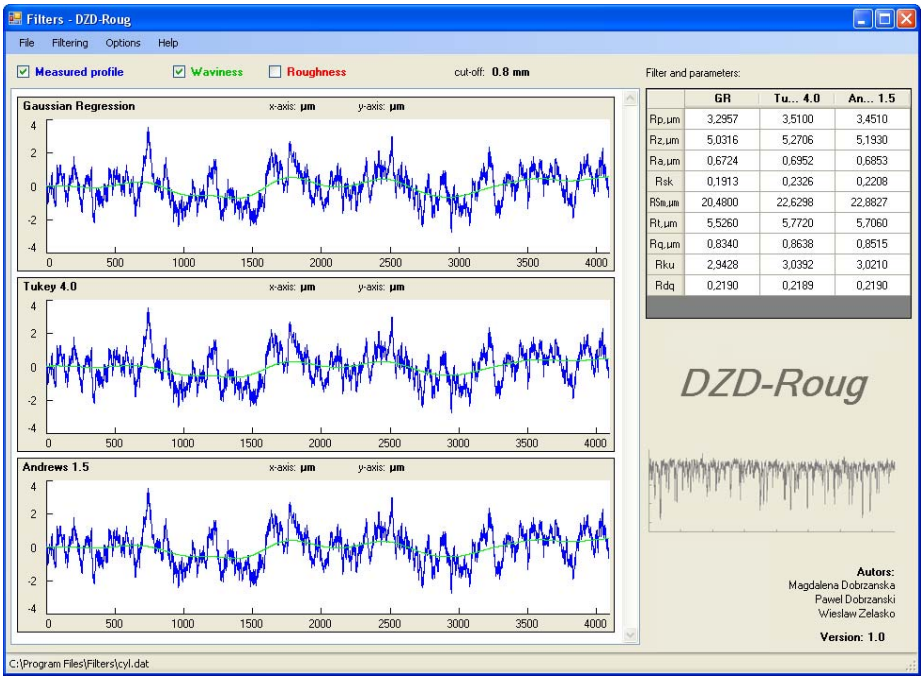

Figure 3. Result analysis of the surface profile as a graph (blue - measured profile, green-waviness, red - roughness) and calculated values.

What will user observe the graph depends on itself and setting what will. The choice is between a profile without filtration, waviness and roughness, and their combinations. Result of filtration (graph/s and the parameters) can be written on the example of later analysis.

Conclusion

The article presents the software written in Visual C++. The software is the part of the system which has been created for the need of the analysis of surface profiles. The software will be extended with new modules such as 3D analysis. Created application is very helpful in the analysis of surface profiles. It allows user to efficiently carry out studies designed to perform data analysis profiles of the surface.

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