Design of Surface Roughness Evaluation System Based on UWP

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Abstract. The surface roughness algorithm and its evaluation system is the key factor of surface morphology measurement. This paper studies the UWP (Universal Windows Platform) platform and uses C# language to realize surface roughness evaluation system. The system can accurately calculate 4 commonly used surface roughness parameters based on the established mathematical model. The system includes 3D surface data reading, surface roughness calculation, graphic interaction and other functions. Experiments results show that the system can realize rapid and multi-parameter measurement of the workpiece’s surface roughness, and is adequate for surface morphology characterization. The cross-platform evaluation system is user-friendly with visualized 3D data and reliable results.

1. Introduction

The surface texture is the repetitive or random deviations from the geometrical surface which form the three-dimensional topography of the surface [1]. It includes roughness and waviness. And it affects the performance, the characteristics and the quality of the workpiece. The surface roughness refers to the finer spaced irregularities of the surface texture that usually result from the inherent action of the production process or material condition [2]. It plays a significant role to evaluate the surface morphology. Surface profilometer is an important measuring instrument for modern manufacturing to evaluate the surface quality of workpieces. Its evaluation software system is important to the promotion and improvement of the instrument. Therefore, a surface roughness evaluation system based on UWP (Universal Windows Platform) technology is designed and developed.

UWP is a Windows universal application platform launched by Microsoft. Unlike traditional exe and apk files, UWP provides a common applications platform on every device that runs Windows10, such as PCs, mobile phones, Surface, Xbox and HoloLens [3]. The interface style of the UWP platform is simple and smooth. And it works well with touch screens and multi-size displays.

In this paper, four commonly used roughness parameters are studied and evaluated. They are arithmetic mean deviation of assessed profile Ra, the maximum profile peak height Rp, root mean square deviation of assessed profile Rq and the maximum height of profile Rz. According to the national standard GB/T 3505-2009 [4], a mathematical model for the calculation of the parameters based on UWP is designed and developed to do the comprehensive evaluation of roughness parameters. The system can run on different terminals, with visualized interactive interface, and easy to use. It meets the requirements of accuracy for surface topography analysis.
2. Advantages of UWP technology

The UWP is introduced with Windows10 for all their drivers for the first time in 2015. A unified app store makes UWP apps available on Windows 10 devices such as PC, tablet, Xbox, HoloLens, Surface Hub, and Internet of Things (IoT) devices [5]. Once developing on the UWP platform, the application can run on all devices equipped with the Windows 10 operating system by referencing the Extension SDKs (software development kit) for different platforms. Thanks to UWP, the surface roughness evaluation system can be run on both a PC and a tablet. On one hand, running the same application on different devices has similar operating logic, which saves users' learning costs. On the other hand, it is more extensible and maintainable for the developers after once development.

Compared to the unsatisfactory touch experience of traditional Windows applications, UWP provides good support for touch screens. At present, some nano-instruments such as Olympus@ OLS4500 have been equipped with LCD multi-touch screen. Therefore, support for touch screen has become the trend of many instrument software. UWP can optimize the UI elements for the size and DPI (Deep Packet Inspection) of the screen by adjusting the layout and scale, which are clearly visible on all devices.

Finally, the evaluation system has a large amount of calculation and the traditional .Net runtime library is less efficient. The UWP technology uses WinRT (Windows Runtime) development framework, which is directly built on the system kernel. It can automatically obtain hardware acceleration with higher execution efficiency. We choose Win2D image processing auxiliary library, which can make full use of hardware acceleration of UWP technology and therefore improve efficiency of the software.

3. A model for the calculation of Surface roughness parameters

3.1. Surface Profile

In GB/T 3505-2009, the surface profile is the profile that results from the intersection of the real surface by a specified plane, which is composed of the primary profile, roughness profile, and waviness profile [4]. The figure below shows the outline curve.

![Surface Profile Curve](image)

**Figure 1.** Surface Profile Curve [6].

The primary profile is the total profile after application of the short wavelength filter $\lambda_s$ [7]. The roughness profile is the profile derived from the primary profile by suppressing the longwave component using a high-pass filter with a cutoff value of $\lambda_c$. The surface roughness profile is intentionally modified, which is the basis for evaluation of the roughness parameters. Therefore, the precise separation of roughness profile can help us obtain the accurate roughness information.

3.2. Surface roughness

The Surface roughness is the most commonly used parameter of surface micro morphology. It refers to the small spacing and small peaks and valleys of the surface topography. The smaller the surface
roughness, the smoother the surface. Surface roughness parameters are stipulated in national standard GB3505-2009. The system selects four of the more commonly used roughness parameters for calculation: arithmetic mean deviation of assessed profile Ra, the maximum profile peak height Rp, root mean square deviation of assessed profile Rq and the maximum height of profile Rz [4].

3.2.1. Maximum profile peak height Rp. The Maximum profile peak height Rp is the largest profile peak height Zp within a sample length. See figure 2:

\[
RP = \max(Z(x))
\]  

3.2.2. The maximum height of the profile Rz. The maximum height of the profile Rz is the sum of height of the largest profile peak height RP and the largest profile valley depth Rv within a sample length. See figure 3:

\[
Rz = RP + Rv
\]  

3.2.3. Arithmetic mean deviation of assessed profile Ra. Arithmetic mean deviation of assessed profile Ra is the arithmetic mean of the absolute ordinate values Z(x) within a sample length. The mathematical function is given by equation 3:
The discrete form is given by equation 4:

\[ R_\alpha = \frac{1}{L_r} \sum_{n=0}^{N} |Z_n| \]

\[ (4) \]

3.2.4. Root mean square deviation of assessed profile \( R_q \). Root mean square deviation of assessed profile \( R_q \) is the root mean square value of the ordinate values \( Z(x) \) within a sampling length. The calculation formula is given by equation 5:

\[ R_q = \sqrt{\frac{1}{L_r} \int_{0}^{L_r} Z^2(x)dx} \]

\[ (5) \]

4. Approach and Design of the Surface Roughness Evaluation System

4.1. Overall Structure of the System
In this project, the program used to code and execute each function or algorithm has been Visual Studio 2017 Community Version, 64 bit. And it is coded with C#/XAML programming language, with MVVM (Model-View-ViewModel) as the main design architecture. The software is designed with modularized method [9]. It is structured and easy to expand. The software is divided into the following three modules according to functions: graphical interaction module, parameter measurement module and file operation module. The following figure shows the overall system framework and software workflow:

Figure 4. System Framework.
4.2. **Graphical Interaction**

Graphic interaction is an important function of the software, including graphic display and operation. In order to facilitate code management, the user-defined tokens are used for graphical interaction. The Win2D API class is used to create basic classes such as points, lines, rectangles and graphics drawing classes. In addition, Win2D can build real-time rendering model of 2D image through GPU acceleration, and improve the efficiency. The graphic interface consists of a graphic display area, an information display area and a function area.

The graphic display area provides users with the functions such as graphic display and size measurement. By selecting the measurement data with the mouse, the surface profile and surface roughness parameters will be displayed in the information display area.

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**Figure 5.** Software Flowchart.
4.3. Parameter measurement module

The parameter measurement module realizes the fitting and the calculation of the parameters, mainly including filter design and two-dimensional parameter evaluation.

The Filter design provides the least square filter and the Gaussian filter according to the definition of the surface profile [10]. First, the actual surface data is curve-fitted with a least square filter to obtain the primary profile. Then the primary profile is separated by a Gaussian filter to obtain the roughness profile. On the roughness profile, use the roughness calculation model to calculate the surface roughness parameter. The filters and the roughness calculation model are encapsulated into the Filter class and the Roughness class. Figure 7 shows the design idea of parameter measurement module.

4.4. File operation module

The file operation module can read and save the 3D surface data. The binary file has many advantages, such as less internal storage, quick read-write speed, high data security and convenient usage. Therefore, the surface profile file is stored as binary file. In order to meet the needs of users, the profile files can be stored in txt, sur formats for users to use the data without this system.
5. System Verification
To verify the accuracy of the evaluation system, the roughness standard block with nominal values of $Ra = 0.41 \, \mu m$ and $Rz = 1.6 \, \mu m$ was measured by white light interference lens. The sampling length of 200$\mu$m, 500$\mu$m and 800$\mu$m are selected for calculation. The experimental results are shown in Table 1. The result reveals that the algorithm developed in this work calculates the surface roughness with high accuracy.

| lr = 500 | 0.665 | 0.698 | 1.896 | 1.040 |
| lr = 700 | 0.671 | 0.687 | 1.849 | 1.059 |
| lr = 900 | 0.667 | 0.684 | 1.991 | 1.11  |

6. Conclusion
This paper reports a work related to development of a cross-platform surface roughness evaluation system. It is designed with modularized method and easy to expand. The system is divided into three main modules: graphical interaction module, parameter measurement module and file operation module. It achieves one-time compilation, a set of business logic, and a unified user interface which can be applied to the devices equipped with Windows 10. And it can perfectly support the touch screen.

According to the GB/T 3505-2009, the calculation model of surface roughness parameters is designed to realize the comprehensive evaluation of the surface roughness. The UWP application developed for calculating the 2D surface roughness parameters from the data points generated by white light interference lens were found to be highly accurate.

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