Synthetic Image Generation of Microstructure Surfaces Using Physically Based Rendering Techniques

Zen-Wei Tsai[1], Chao-Ching Ho[2*]

[1] Graduate Institute of Automation technology, National Taipei University of Technology, Taipei, Taiwan,
[*2] Graduate Institute of Manufacturing Technology, National Taipei University of Technology, Taipei, Taiwan
E-mail: hochao@mail.ntut.edu.tw

1. Introduction

Among deep learning methods, robust and effective detection models often rely on a large amount of defect data. Insufficient or imbalanced defect data can have a negative impact on neural network training. However, the product production process aims at high yield, so defect data is difficult to obtain, which is inconsistent with the needs of training neural networks. To solve these problems, a physically based rendering method is adopted, using rendering software to build a virtual environment and generate many synthetic images [1]. This study introduces a method for synthesizing images of microstructure surfaces using physics-based rendering techniques. The method can be applied to objects with any micro-structured surface and can be rendered in any viewing direction and lighting conditions.

2. General Instructions

Microstructure Modeling

A 3D rendering engine is used and set the microstructure parameters to create the model. The groove size, depth and spacing were set during modeling in this study.

In the virtual environment, various parameters can be adjusted arbitrarily, such as the type and intensity of the light source, the size and position of the camera sensor, and even the material properties can be adjusted.

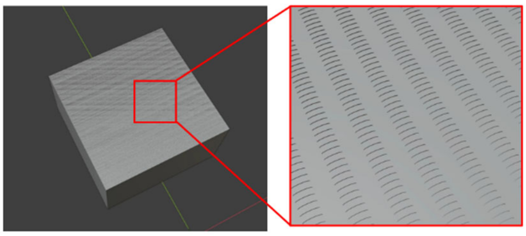

Fig.1 Magnified view of microstructure surface objects and their structures in the virtual environment.

Optical Path Difference Calculation

The variation in surface rendering depends on various factors such as viewpoint position, lighting environment, and wavelength. Due to differences in microscopic structures, a wide range of structural colors are produced. However, all structural colors result from the interference between multiple waves with optical path differences. Therefore, the optical path difference parameter alone can be used to represent various structural colors [2].

Representation of Interference Waves

The interference shader implemented in this study is based on the derivation results provided in [2]. The intensity of the interference wave caused by the microstructure surface is expressed as:

$$I(\lambda) = \sum_{i=1}^{n} A_i^2 + \sum_{i=1}^{n} \sum_{j=i+1}^{n} 2A_iA_j \cos\left(\frac{2\pi}{\lambda}(\Delta_i - \Delta_j)\right) \quad (1)$$

Color Calculations

To visualize color, the spectral distribution needs to be converted to the RGB color system. The spectral distribution is first converted to the XYZ color system, which is the basis for every color system that serves as the CIE standard color system. This is obtained by integrating wavelengths in the visible region (360 to 800 nm) using the following formula: for simplicity, only the results for X are shown here:

$$X = \int_{360}^{800} R(\lambda) \cdot I(\lambda) \cdot \bar{x}(\lambda) d\lambda \quad (2)$$

Equation (1) is treated as reflectivity, so $R(\lambda) = I(\lambda)$, and replaced it with $R(\lambda)$ of equation (2). The XYZ color system is then converted to the RGB color system using conversion formulas [3].

3. Conclusions

This research uses rendering software to create virtual environments and objects to produce virtual images. Combining rendering software with physically based methods is discussed. It is capable of rendering diffraction and interference phenomena on microstructure surfaces. In the future, quantitative metrics will be needed to evaluate whether rendered images are realistic enough compared to real captured images.

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References

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