Measuring Microstructures Using Confocal Laser Scanning Microscopy for Estimating Surface Roughness

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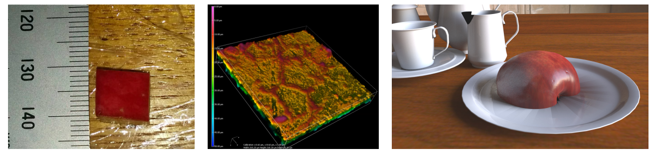

Figure 1: *The image on the right shows a synthetic apple rendered with the estimating surface roughness from microstructures shown in the center, which is measured on the surface of a small piece of an apple shown in the left image.*

1 Introduction

Realistic image synthesis is an important research goal in computer graphics. One important factor to achieve this goal is a bidirectional reflectance distribution function (BRDF) that mainly governs an appearance of an object. Many BRDF models have therefore been developed. A physically-based BRDF based on microfacet theory [Cook and Torrance 1982] is widely used in many applications since it can produce highly realistic images. The microfacet-based BRDF consists of three terms; a Fresnel, a normal distribution, and a geometric functions. There are many analytical and approximate models for each of these terms.

Our ultimate goal of this research project is to find an accurate and analytical expression of BRDFs for rendering different foods by measuring their microstructures using microscopic imaging devices. Although there have been many researches on measuring BRDFs,they basically measure reflected light with different lighting and viewing directions. We instead measure the microstructures and construct microfacet-based BRDFs from the measurements. We begin with estimation of surface roughness, which is presented in this poster.

2 Estimation of Surface Roughness

We first measure the surface microstructure using a confocal laser scanning microscopy. This device can acquire thin three-dimensional structures on a microscopic scale ranging from $1\mu m$ to $1mm$.The device measures fluorescent light excited by a laser beam illuminating a sample. The microstructure is obtained in the form of three-dimensional volume data structure; the intensity of the fluorescent light is recorded at each voxel.

The normal distribution function (NDF) is then computed from the measured microstructure. We extract the isosurface from the volume data by using the marching cubes algorithm and apply a Laplacian smoothing operator to the isosurface in order to reduce the noise in the measured data. The NDF is computed by using the part of the isosurface that is visible from the average normal direction, i.e., the vertical direction. We represent the NDF by using a cube map texture. Each texel of the texture stores the number of normal vectors that lie within the solid angle represented by the texel. Finally, the surface roughness is estimated by fitting the GGX normal distribution function [Walter et al. 2007] to the measured NDF. We optimize the roughness parameter to minimize the squared difference between the GGX function and the measured NDF. We use the Levenberg-Marquardt method for the optimization.

3 Results and Future Work

We applied our framework to the rendering of an apple. We cut a small piece near the surface (Fig. 1 left) and measured its microstructures at three different spots on the surface. The center image in Fig. 1 shows one of the measured microstructures whose dimension is $318.2\mu m \times 318.2\mu m \times 50.0\mu m$. We then fit the roughness parameter of the GGX function to each of the three microstructures and compute an average of them. We verify our framework by comparing a photograph and a synthetic image of the apple as shown in Fig. 2. We extract the diffuse texture from its photographs. The index of refraction used for the Fresnel term is manually adjusted. This comparison indicates that our approach is promising. The right image in Fig. 1 shows an image of the synthetic apple. These synthetic images are rendered by using Mitsuba renderer [Jakob 2010]. In future, we would like to extend our framework to estimating other optical parameters.

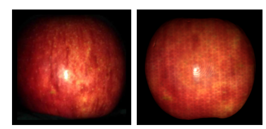

Figure 2: *A real (left) and synthetic (right) images.*

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