Shape Recovery

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ABSTRACT

The main interest of previous researches for shape from shading was only on Lambertian surface which consists of diffuse reflectance surface. In practice, natural objects have hybrid reflectance, which limits the recovery of shape from intensity distribution[1][2]. In this paper, we propose the method of determining shape using neural network and diffuse illumination. The segmented region of sphere surface is used for training set, which can be determined by shadow line and edge of surface. Diffuse illumination is used to avoid specular spike and highlight which usually cause many problems such as intensity disparities. Diffuse illumination method using flat paper allows us to reduce these phenomena with simple scheme. Neural network and Diffuse illumination method are useful for shape from shading, because it can be applied to objects of unknown reflectance properties, but it is applied only to Torrance-Sparrow style reflectance.

1. Reflectance properties

1.1 Torrance-Sparrow Reflection Model

Most previous researches are based on Lambertian model which mainly consists of diffuse reflection component. However, in the real scene, many objects have hybrid reflectance property, and Torrance-Sparrow model[4] has been used for that purpose. In Torrance-sparrow model, it is assumed that objects have two main reflectance of diffuse and specular components which are linearly combined. Specular reflection from mirror-like facets and diffuse component of multiple reflections and internal scattering have their weights and are approximated by Lambertian's law and Gaussian distribution. So, the brightness distribution of an object can be represented as

$$I = I_{diff} + I_{spec} = k_d f_d + k_s f_s$$
$$k_d + k_s = 1, \qquad (1)$$

where k_d, k_s, f_d, and f_s are diffuse and specular weights, intensity power, respectively. Figure 1. shows the geometry of Torrance-Sparrow model.

1.2 Diffuse illumination method

Diffuse illumination can illuminate objects uniformly in order to reduce specular spike and highlight component[3]. We propose plate diffuser illumination which has very simple scheme and easy structure for analyzing. We use flat paper for diffuse mechanism. Irradiance(E) of a point on a diffuser can be modeled as $E = \frac{I_{source} \cos\phi}{r^2}$, where I_{source} is light source intensity, r is distance between light source and diffuse plate, and ϕ is the angle between normal of diffuser and light source position. Figure 2. shows the proposed diffuse illumination method.

2. Segmentation of reference sphere by direction of light source

The region on the sphere surface can be segmented by shadow lines and surface edge according to the direction of light sources[5]. That region can be represented as in Figure 3. The region 1 is the part which is illuminated by three light sources, and the region 2 is by two light sources, and the region 3 is by only one light source. Each light source which consists of diffuse illumination mentioned above section is arranged at uniform intervals of 120 degrees, so it can enlarge the region which is illuminated by all the light sources. Each region can be determined by shadow information, surface edge, and inclination of light source. We use the segmented region in the sphere image as training set to select the target normal vector.

3. Shape reconstruction using neural network

3.1 Neural network for determining surface normal vector

In this paper we propose shape reconstruction method which is based on photometric stereo and neural network. The structure of neural network proposed in this paper is shown in Figure 4. The input of neural network is image intensity obtained by each light source, and target value is corresponds to normal vector. First, segmented sphere image is trained to determine weights and biases in the neural network, and then object image is reconstructed by trained neural network. The surface normal vector can be represented by the gradient space component p, q. If we take the normal vector as $n=(n_x, n_y, n_z)$,then p and q is written as $p=-n_x/n_y$, $q=-n_y/n_z$.

3.2 Region selection and reconstruction of image pixel

We must select the region corresponding image pixels for shape reconstruction. This process must be preceded before trained neural network for each region calculates the normal vector. We can determine the corresponding region by taking threshold of intensity difference of neighbor pixels. It does not determine the correct normal vector, but it takes the segmented region which is used for training set.

$$\sum_{source} I_{mean}(i) - I_{(x,y)}(i) < T \qquad (2)$$

The large size region is divided into subregion and then subregion matches object image pixels. In the region 1 and 2, neural network has insufficient convergence because some region information has been lost. Additionally, if specular reflection occurs in that region, worse result is caused as ill-posed problem.

4. Experiment result of neural network based photometric stereo

We use the sample sphere images of Real-World. First, we segment the region by using shadow lines and edge of surface. The result of segmentation is shown in Figure 5. The segmented regions are used for neural network training, it shows training process for each region in Figure 6. We compose the three layer neural network using adaptive learning rate and momentum. The region which all the three light sources illuminate has good convergence result, but the other region does not well converge. The example of training process is shown in Figure 6. Finally, recovered sample spheres by neural network is shown in Figure 7.

References

[1] K. Nayar, K. Ikeuchi and Kanade,"Determining Shape and Reflectance of Hybrid Surfaces by Photometric Sampling", *IEEE Trans. on Robotics and Automation*, vol. 6, no. 4, August 1990

[2] S. Bakshi and Y. H. Yang,"Salhpe From Shading Non-Lambertian Surfaces", Proc. of ICIP, pp.130-134, 1994

[3] T. E. Kim and J. S. Choi ,"3-D Shape Recovery of Hybrid Reflectance Surface Using Indirect Diffuse Illumination", Proc. of ICIP, pp.354-357, 1995

[4] K. E. Torrance and E. M. Sparrow,"Theory for off-specular reflection from roughned surface for ray reflection", *Journal of Optical Society of America*, vol. 65, pp.531-536, 1967

[5] F. Solomon and K. Ikeuchi, "Extracting the Shape and Roughness of Specular Lobe Objects Using Four Light Photometric Stereo", Proc. of CVPR, pp.446-471, 1992.1.

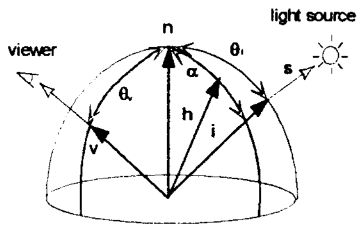


Figure 1. Torrance-Sparrow model

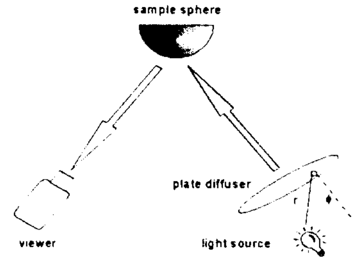
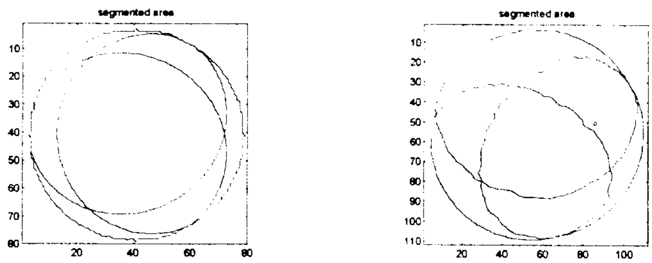


Figure 2. Geometry of diffuse illumination



(a) (b)

Figure 5. The segmented region by direction of light source
(a) ping-pong ball (b) plastic sphere

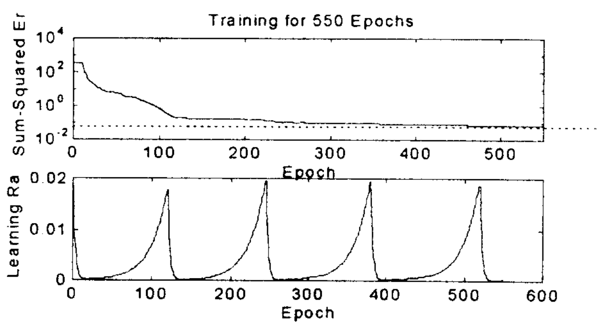
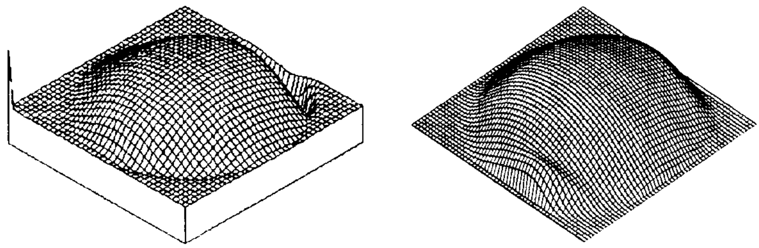


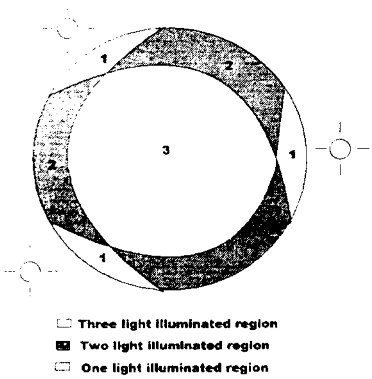
Figure 6. Training process for determining surface normal (Three light source illuminated region)



(a) (b)

Figure 7. Reconstruction sample sphere using neural network

(a) pin-pong ball (b) plastic sphere



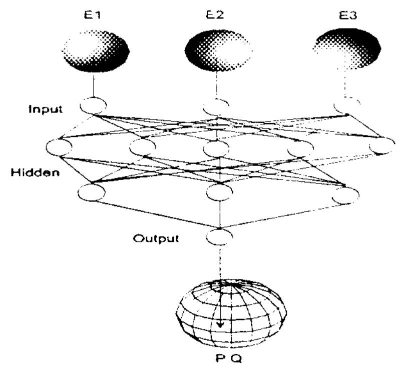


Figure 3. Figure 4.

Figure 3. The region information segmented by light source location

Figure 4. The structure of surface normal determining neural network