Photometric Stereo

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I. INTRODUCTION

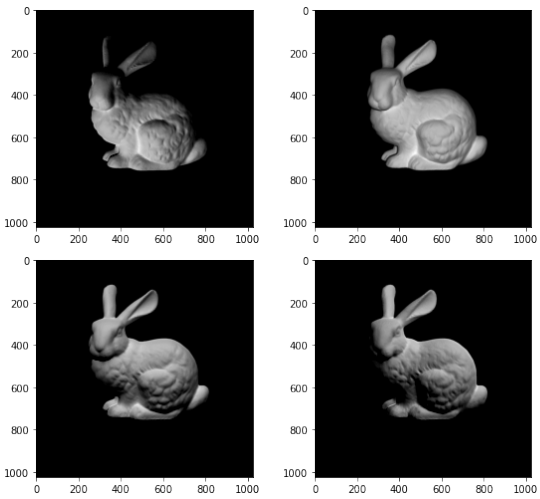
This project focuses on photometric Stereo, and lighting within a scene. Scene lighting is calculated from a collection of images using photometric Stereo, and is then processed into scenes by calculating albedos, normals, and light direction values.

II. SCENE LIGHTING

For this section of the project, albedo, normal, and light direction values were used to recalculate and process the scene lighting with different light positions using the formula below.

$$\text{Observed Brightness}(\mathbf{x}) = \text{Albedo}(\mathbf{x}) \cos(\theta_{\mathbf{x}}) = \text{Albedo}(\mathbf{x}) \left[\hat{l} \cdot \hat{n}(\mathbf{x})\right]$$

These were the results of this section:



Different Lighting of a bunny

III. PHOTOMETRIC STEREO

For this section the function goes through a stack of images and calculate the albedo and normal values using pixel intensity. The formula below is used to calculate pseudo normal b.

$$I_{N\times 1} = L_{N\times 3} \cdot b_{3\times 1}$$

$$b_{3\times 1} = \left(L^T L\right)^{-1} \cdot L^T I$$

After calculating the pseudo normal b. This is the formula used for calculating the albedo and the normal:

$$\hat{n} = b/||b|| \quad \& \quad a = ||b||$$

These are the results of the Photometric stereo. The first column consists of the albedo. The second of the normal, and the third images is the reconstructed depth image.

A. *Imperfections*

For this section The re-lit images are compared to the original images to give us the difference. The first column is the original image. The second column is the re-lit image, and the third column is the difference between the first two images.

QUESTION Explain why there is a significant difference between the two images to the lower-left of the scholar's face.

There is a significant difference between the two shadows on the lower-left of the scholar's face in the first two images because in the stack of given images some had higher and lower light intensities which effected the albedo. As a result this effected the overall brightness of the scholar's body in the re-lit image.

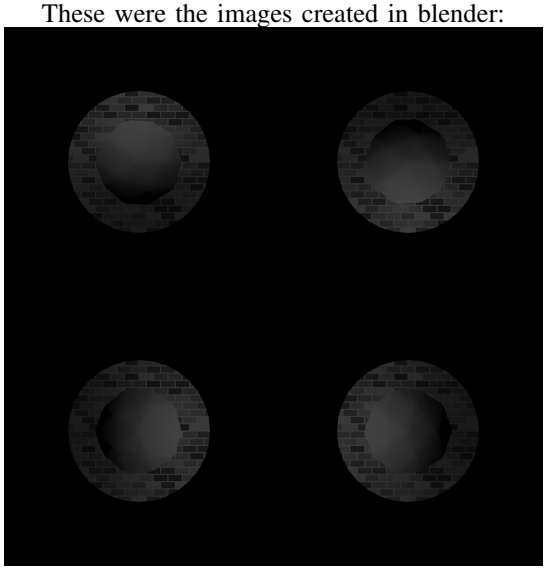
QUESTION why the body of the scholar is (on average) darker in the original image than in the reconstruction.

Since the light intensity fluctuated in the stack of given images the albedo was changed and resulted in an overall brighter re-lit image.

B. Lambertian Objects

For this section 4 images were created in blender with different light positions. The light positions and the images were then fed into the photometric stereo function to output the albedo, normal, and reconstructed depth image.

These were the images created in blender:

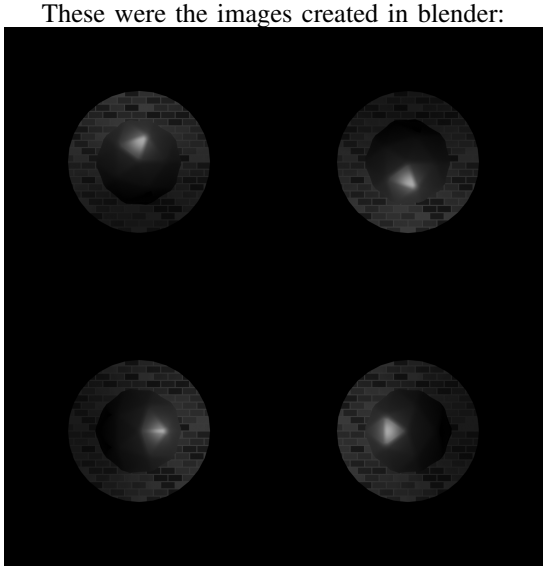


These were the results from the photometric stereo:

C. Non-Lambertian Objects

For this section we did the same thing as the previous section except the material was changed to a metallic material.

These were the images created in blender:



These were the results from the photometric stereo:

QUESTION Explain why the albedo and normals change. Is there a linear solution to finding the correct normals?

The albedo and normals changed because photometric stereo doesn't work well with reflective surfaces like the matallic surface used here. No, there isnt a linear solution to finding the correct normals.

QUESTION Find a research paper (I recommend using Google Scholar) that attempts "non-lambertian Photometric Stereo": trying to recover material properties for a non-lamberitan object, like the one shown above. Include a citation of the paper and (in 3–5 sentences) explain how it works and how the approach differs from the lambertian photometric stereo we studied in class.

Chen, Guanying, Kai Han, Boxin Shi, Y. Matsushita and K. Wong. "Deep Photometric Stereo for Non-Lambertian Surfaces." IEEE transactions on pattern analysis and machine intelligence PP (2020): n. pag.

This research paper's approach involves using neural networks to make better albedos and normals for reflective materials. This is different from our approach because we use a formula that applies the same rules to any image while neural networks use different weights.

IV. STRUCTURE FROM MOTION