Assignment 5

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1 Introduction

In this assignment the objective was to obtain 3D depth maps from two datasets using the Photometric Stereo method. We implemented our solution using the helper functions provided for the assignment to perform parts of the calculations. Our results will be presented in this report along with an explanation and evaluation of our approach.

2 Photometric Stereo

Photometric Stereo is an image processing technique that can be used to measure surface shapes and calculate (3D) depth maps from a series of images with different illuminations.[2]. This is accomplished by using a camera with a fixed view, capturing a fixed scene with different lighting directions, and measuring the light direction. Generally a minimum of three different lightings are needed to give a satisfactory result. The following are some limitations of this stereo imaging approach [1]:

- The light source must not be too far from or too close to the surface.
- Specularities or dark spots in the image negatively affect the results.

The following equation describes the optical relationship that provides the basis of the Photometric Stereo algorithm, from which the 3D model can be calculated. This is done with matrix calculation for each of the variables and thereby describing the different views corresponding to different lighting.

$$I = \rho * S * N$$

I = The intensity of the image/pixel.
rho = The albedo of the surface.
S = The illumination direction.
N = The surface normal [3].

3 Results

We were able to achieve satisfactory results on the first of the provided sets of images (displaying a bust of Beethoven) using our implementation. After slicing the mask and input images, we obtained the albedo modulated normal field, M, by multiplying with the matrix inverse of S when handling the Beethoven dataset containing 3 (synthetic) images, and the pseudo-inverse when handling the Buddha dataset which contained 10 (real) images. We then extracted and displayed the albedo within the mask of the objects (see below). Next, we extracted the components of the normal fields after normalizing M, and computed depth from them within the mask using the (given) unbiased integration function. Finally we visualized the results from 4 different viewpoints by rotating the scenes using the numpy function rot90, and showing them with the provided display methods.

As seen in our output images, the depth information recovered from the synthetic Beethoven dataset is much more accurate and detailed. Contrarily, perhaps due to the lower resolution, imperfect lighting conditions, and dark spots on the object (the latter can be observed on both the input images and the albedo image displayed below) the Buddha model is ill-defined, and its overall shape is somewhat distorted. For future work, improved results may be achievable by implementing a more advanced photometric stereo method like equation selection. While more complex, this approach could improve output on relatively small datasets (like the 10 images of the Buddha one) by selecting only the best measurements for each pixel. The integration function based on Symchony's method did not seem to yield any result in our Python3-based environment on either dataset.

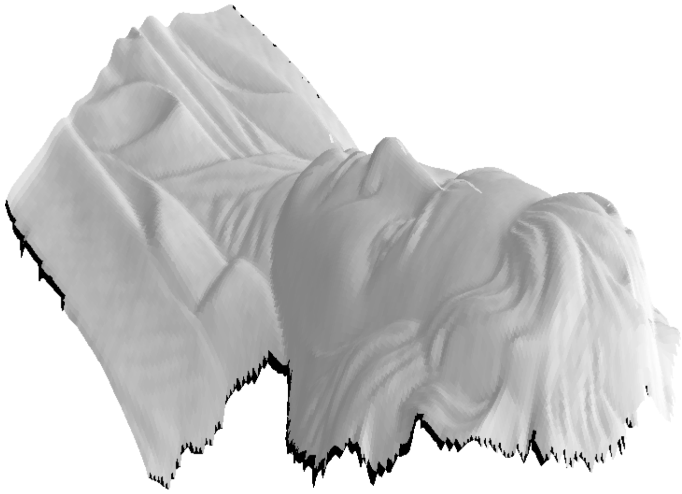

Figure 1: Beethoven output - viewpoint 1

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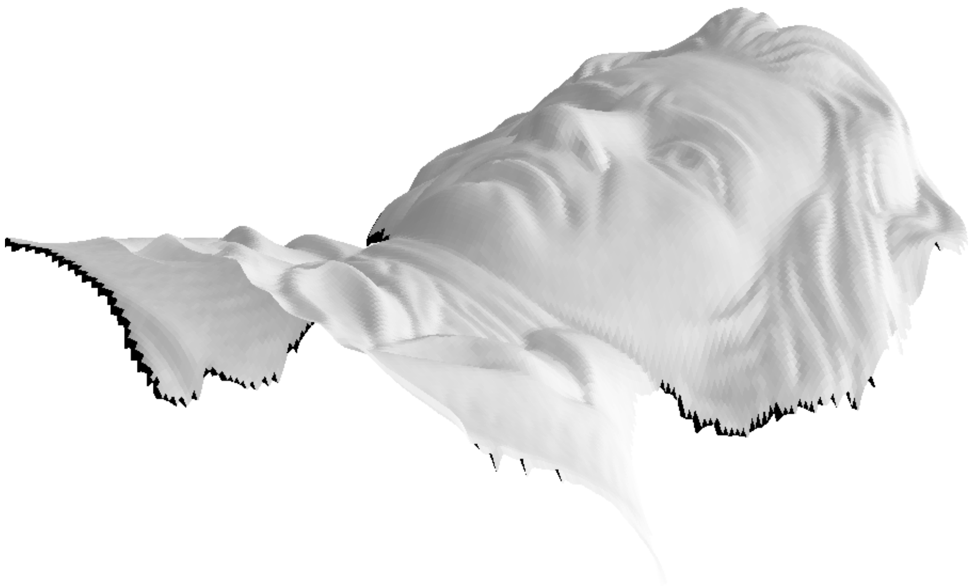

Figure 2: Beethoven output - viewpoint 2

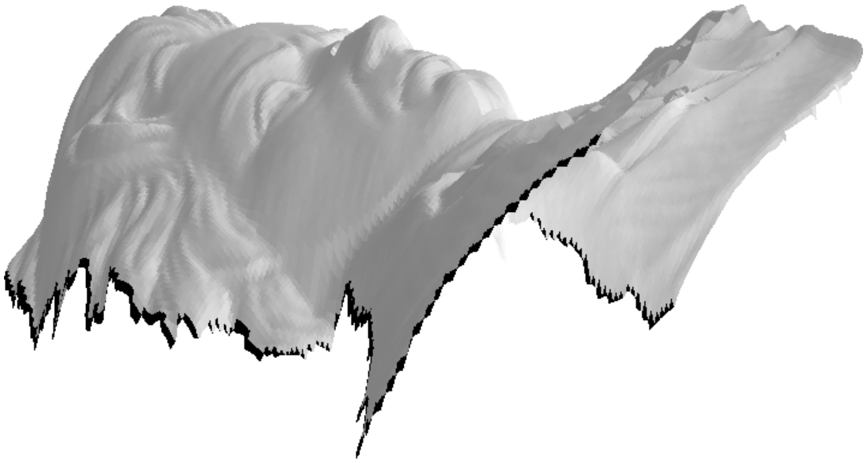

Figure 3: Beethoven output - viewpoint 3

Figure 4: Beethoven output - viewpoint 4

Figure 5: Albedo of Beethoven

Figure 6: Buddha output - viewpoint 1

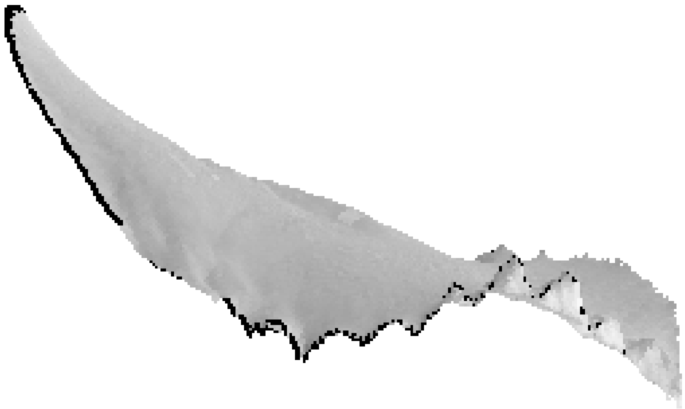

Figure 7: Buddha output - viewpoint 2

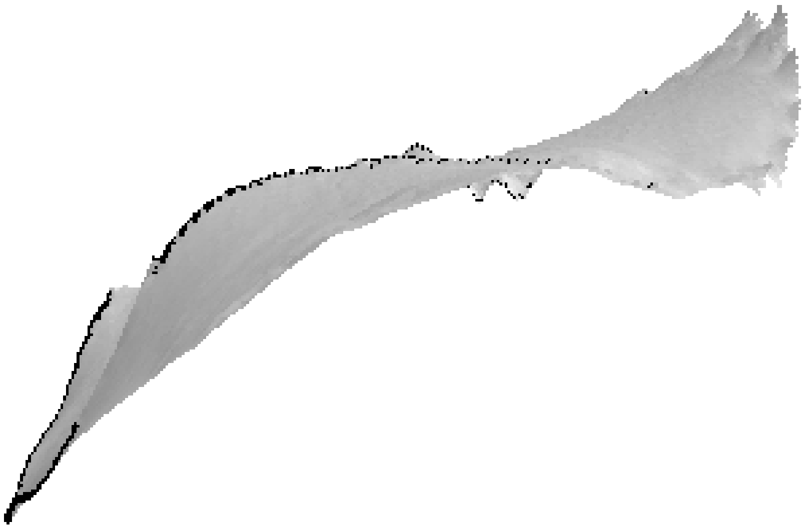

Figure 8: Buddha output - viewpoint 3

Figure 9: Buddha output - viewpoint 4

Figure 10: Albedo of Buddha

References

[1] Mon-Ju Wu Chaman Singh Verma. *Photometric Stereo*. Jan. 12, 2018. URL: http://pages.cs.wisc.edu/~csverma/CS766_09/Stereo/stereo.html.

[2] Jean Ponce David A. Forsyth. *Computer Vision – A Modern Approach*. Second Edition. Pearson Education, Inc., publishing as Prentice Hall., 2012.

[3] Jiahua Wu. "Rotation Invariant Classification of 3D Surface Texture Using Photometric Stereo - Chapter 4 Photometric Stereo". In: (2003), pp. 95–100. DOI: http://www.macs.hw.ac.uk/texturelab/files/publications/phds_mscs/JW/chapter4.pdf.