Assignment 5: Computational Photography

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1 Photometric Stereo

1.1 Initials

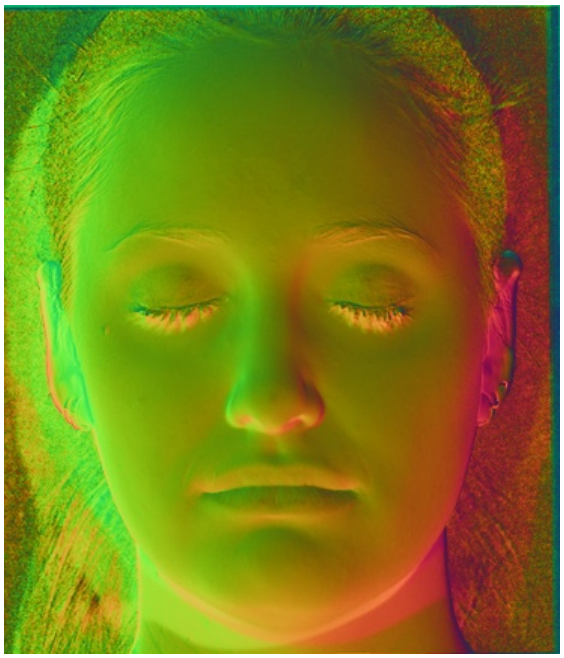
Following code used to load the 7 images (luminisence channel)

```
def read_data(data_dir):

output = []

for i in range(1,8):

    img = f'input_{str(i)}.tif'
    print(img)

    if '.tif' not in img:
        continue

    file_path = os.path.join(data_dir, img)
    raw_img = skimage.io.imread(file_path)/65535.0

    raw_img = raw_img*255.0

    raw_img = raw_img.astype('float32')

    xyz_img = cv2.cvtColor(raw_img, cv2.COLOR_BGR2XYZ)

    l_xyz = xyz_img[:,:,1]

    output.append(l_xyz)

return np.array(output)
```

1.2 Uncalibrated photometric stereo

Reshaped Albedo A_e and Normal N_e

Albedo (A_e)

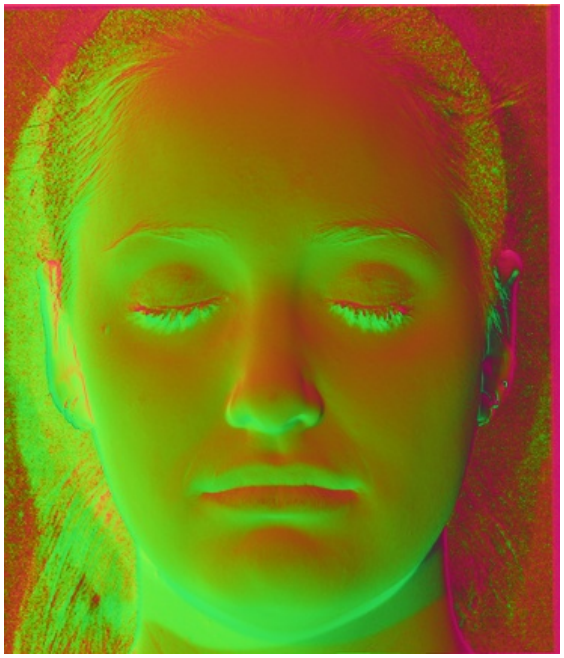


Normals (N_e)

Reshaped Albedo A_Q and Normal N_Q formed by B_Q where $B_Q = Q^{-1}.B$

Here, Q is any non-diagonal matrix

Albedo (A_Q)



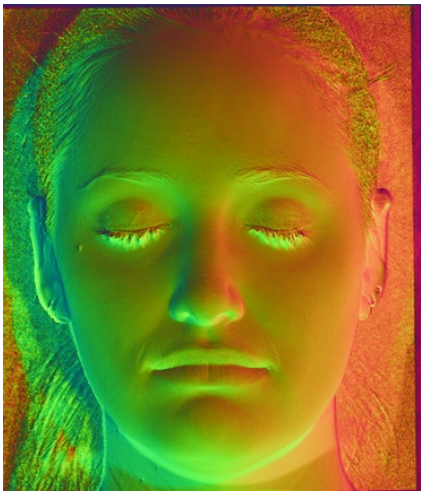
Normals (N_Q)

1.3 Enforcing integrability and Normal Integration

Albedo, Normals and depth image after enforcing integribility on the pseudo normals. These results were calculated for the following GBR parameters:

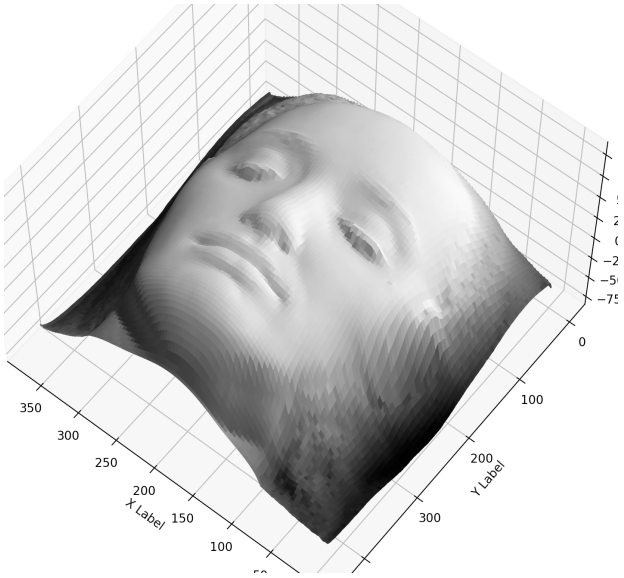
- $\upsilon = 0$
- $\mu = 0$
- $\lambda = 1$

Albedo (A_Q)

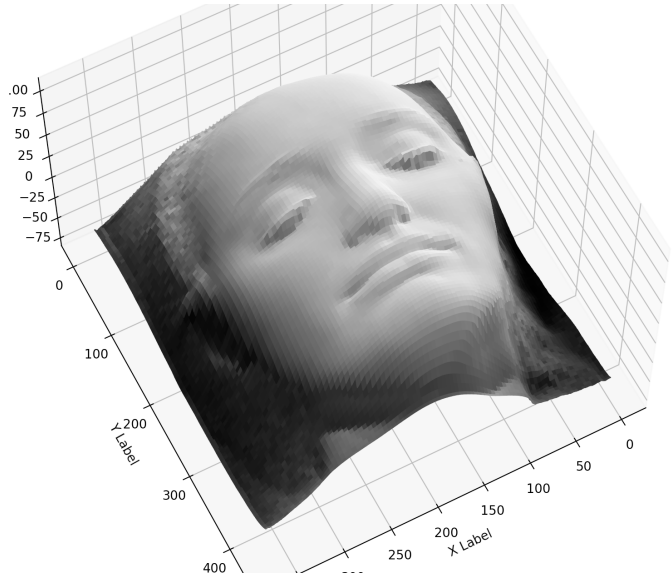


Normals (N_Q)

Depth Image



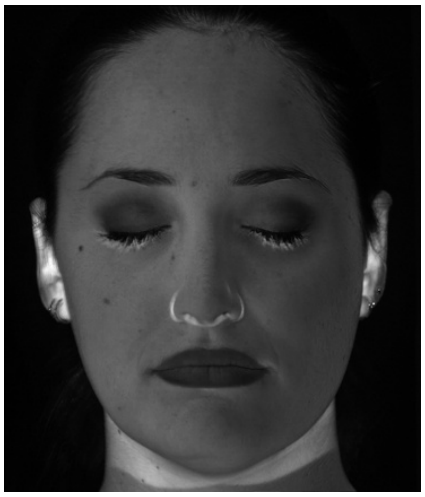
Surface Reconstruction View 1



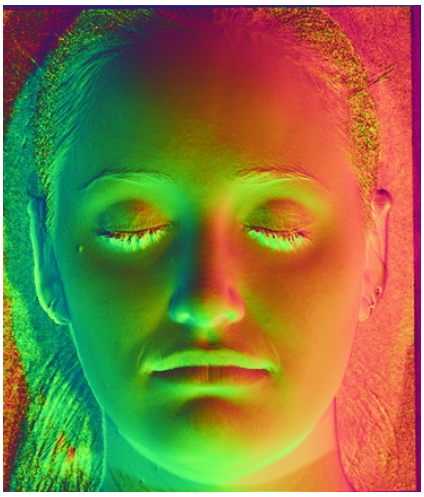
Surface Reconstruction View 2

Iterating on different values of υ, μ and λ I got the best results using these. I do feel there isn't a considerable difference from the original values classical bas-relief transformation. There are minor improvements on the depth image where the depth for the nose and mouth is slightly better represented with these values.

- $\upsilon = 0$
- $\mu = 0.5$
- $\lambda = 3$

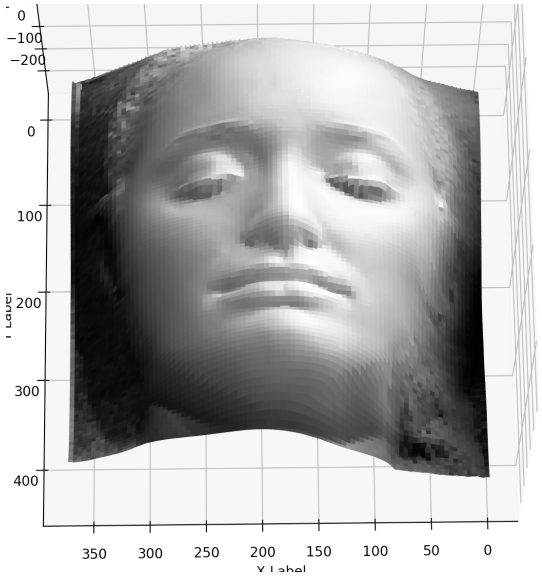


Albedo (A_Q)

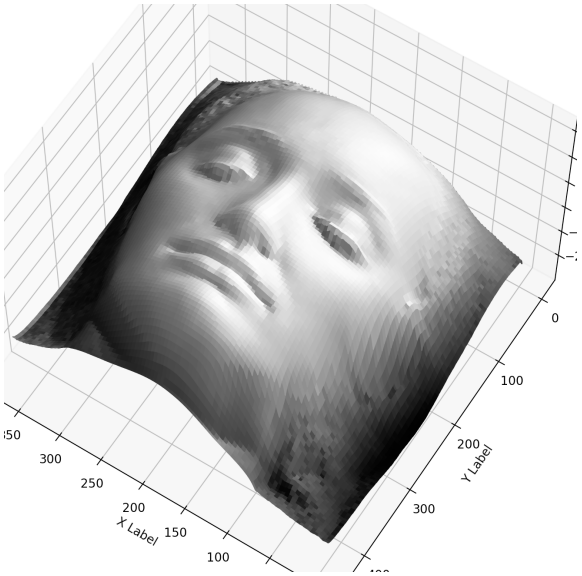


Normals (N_Q)

Depth Image



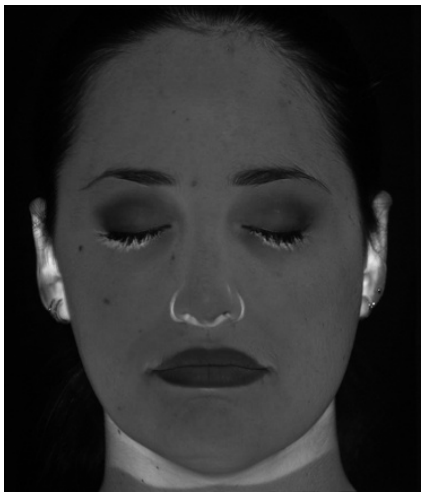
Surface Reconstruction View 1



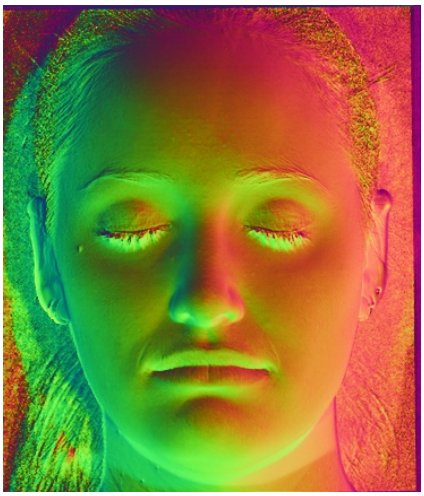
Surface Reconstruction View 2

1.4 Calibrated photometric stereo

Albedo, Normals and depth image for calibrated photometric stereo:

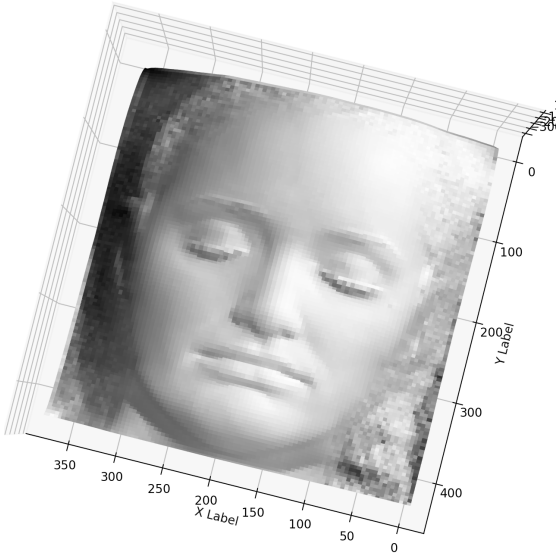


Albedo (A_Q)

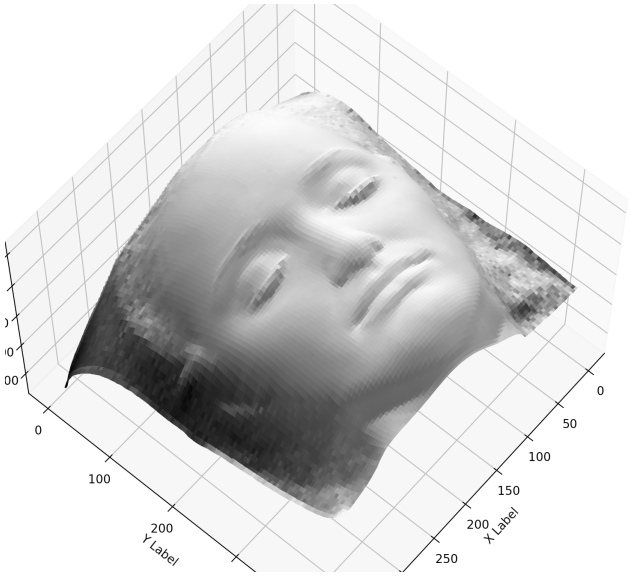


Normals (N_Q)

Depth Image



Surface Reconstruction View 1



Surface Reconstruction View 2

Low light regions are also represented well in the depth map and the surface reconstruction. For eg. the surface of the ears and the neck is more precise as compared to uncalibrated stereo.

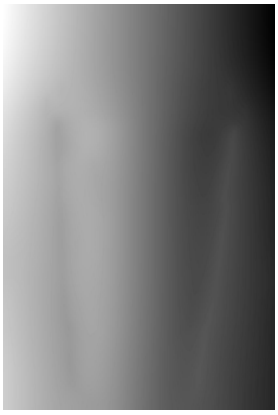
2 Capture and reconstruct your own shapes

Shape 1: Starbucks Cup

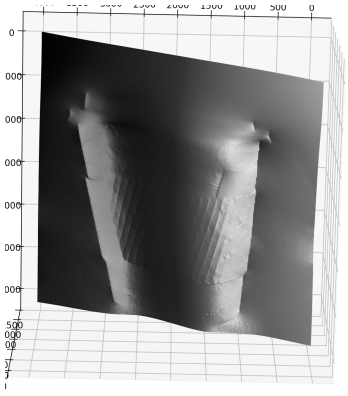
Sample Input from Dataset

Albedo (A_Q)

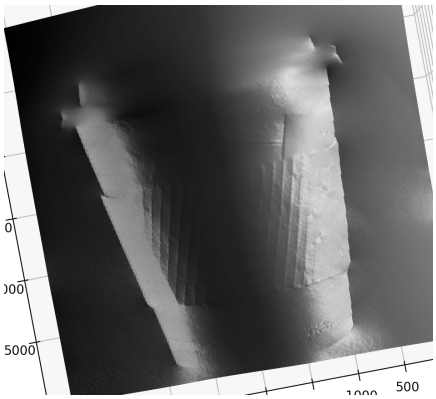
Normals (N_Q)



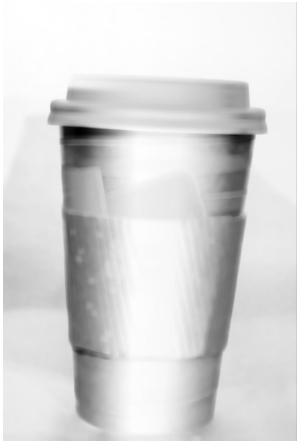
Depth Image



Surface Reconstruction View 1



Surface Reconstruction View 2



View from new lighting direction

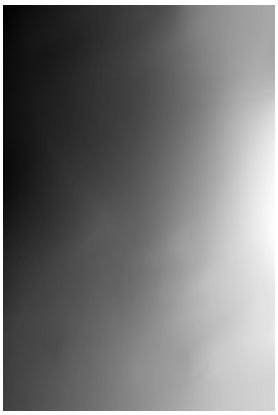
Observation: The shape of the constructed surface looks pretty accurate overall. However, the depth at the central surface of the cup is not entirely correct while the depth at the vertical edges is modelled accurately. I realized that the main reason for this could the noise from the input images. I tried a lot of techniques to minimize the noise such as setting the right ISO, applying a blur kernel, making sure the background is as dark as possible. I also tried a number of different GBR parameters to extract the best possible shape. However the noise due to the lighting conditions still seems to be significant for the depth reconstruction to be slightly off at the central part of the cup.

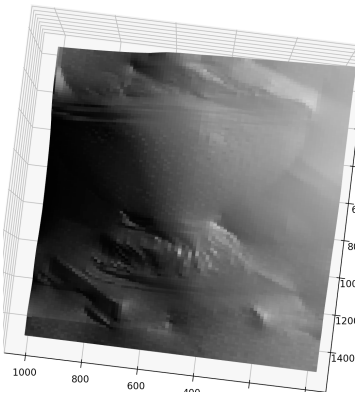
Shape 2: Lamp stand


Example Input Image

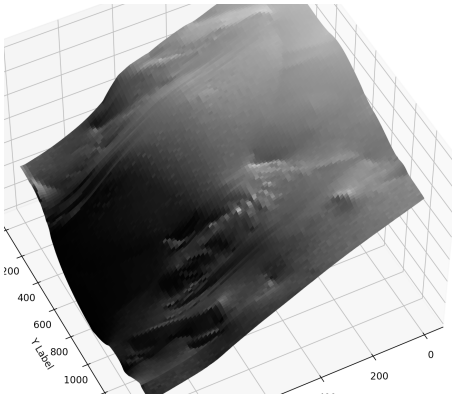

Albedo (A_Q)


Normals (N_Q)


Depth Image



Surface Reconstruction View 1



Surface Reconstruction View 2


View from new lighting direction

Observation : As expected, the reconstruction for the lamp stand is not accurate. If we look at the depth image and the reconstruction, it does capture basic structure of the shape of the object but fails to accurately depict any further details. This is mainly because the object is not fully Lambertian and has considerable glossiness to hinder with assumptions made for photometric stereo reconstruction.