

*****Note*** : Late submission due to mother's funeral, permission granted by Dr.Lazebnik**

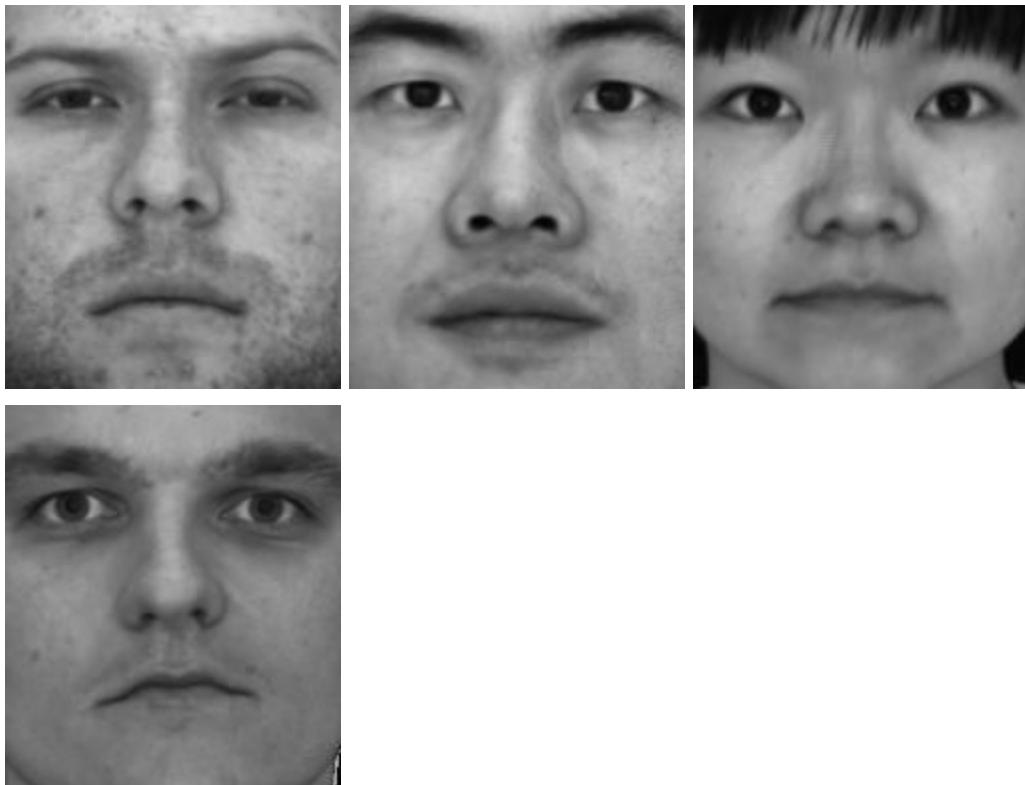
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Netid: rpn2

Part 1:

1. Albedos of test images

YaleB01, YaleB02, YaleB05, YaleB07 in order



2. Implementation choices:

Some of the highlights of implementation are discussed here:

Photometric_stereo method : A single call to linear solver was used to calculate the albedo and surface normals by transposing and reshaping the image array.

Get_surface method :

- 1) Row , Column and Average : These methods did not use any loop and cumsum function was used for integration to obtain surface height
- 2) Random :

The cumulative sum along X and Y direction was calculated and used in the random method. Subtraction of cumulative sum was used in needed directions to speed-up computation. The random path for a pixel (x,y) is limited to be in range $(0,0)$ to (x,y) , where $(0,0)$ is top-left pixel. By starting at $(0,0)$, at each step a random direction is chosen (horizontal moving towards right or vertical moving down). Further, a random step length not going beyond (x,y) in respective direction is chosen. Once the row/column of (x,y) is reached, then the direction is forced to be column/row of pixel. The number of random paths is fixed to be 60 after experimentation and viewing the quality of results, and runtime considerations

3. Limitations of implementation :

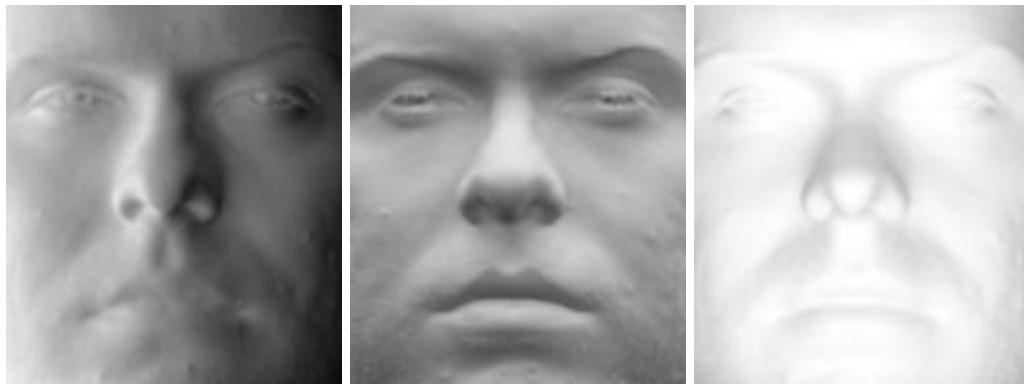
Random method : The direction of movement is limited to right and down. Furthermore, the initial start point is always top left pixel. The first row/column would not have randomized results as the direction for pixels along them will always be right/down respectively. The top and left edge of face is not quite randomized using such an algorithm.

General Integrability of images for height map calculation: The integration is performed by cumulative sum and constant factor is ignored. All methods have some artifacts including random method, likely due to second partial derivatives being not equal.

Artifacts observed in image: This is discussed below after the height map is displayed.

4. Surface Normal Images (in x,y,z order)

YaleB01(x,y,z)



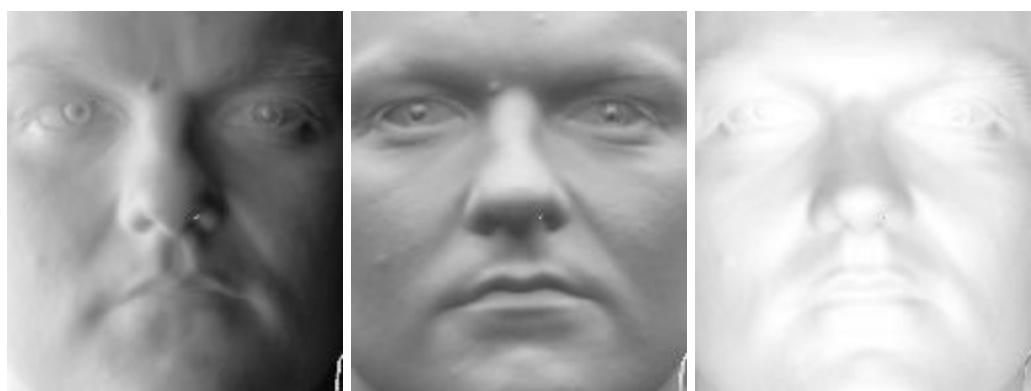
YaleB02(x,y,z)



YaleB05(x,y,z)



YaleB07(x,y,z)

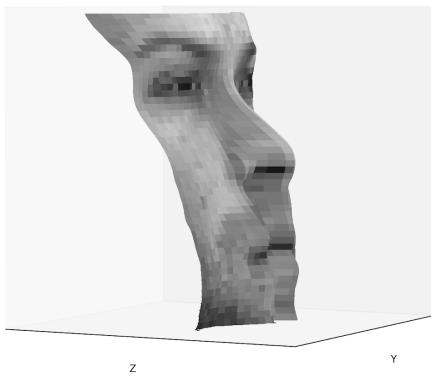
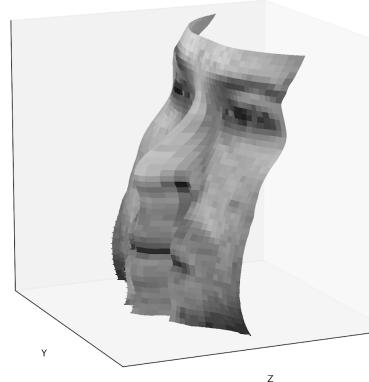
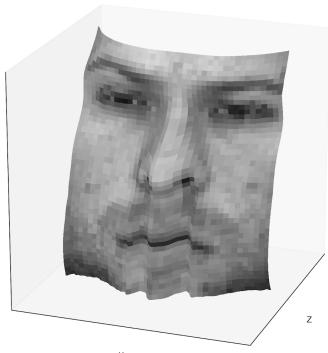


Part2:

Yale B01 is test subject:

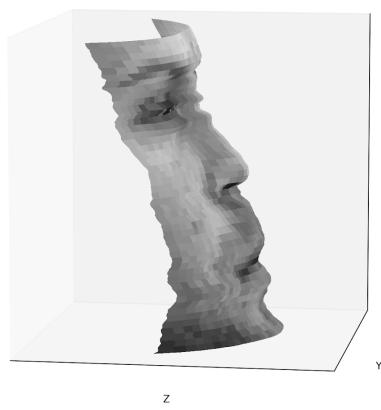
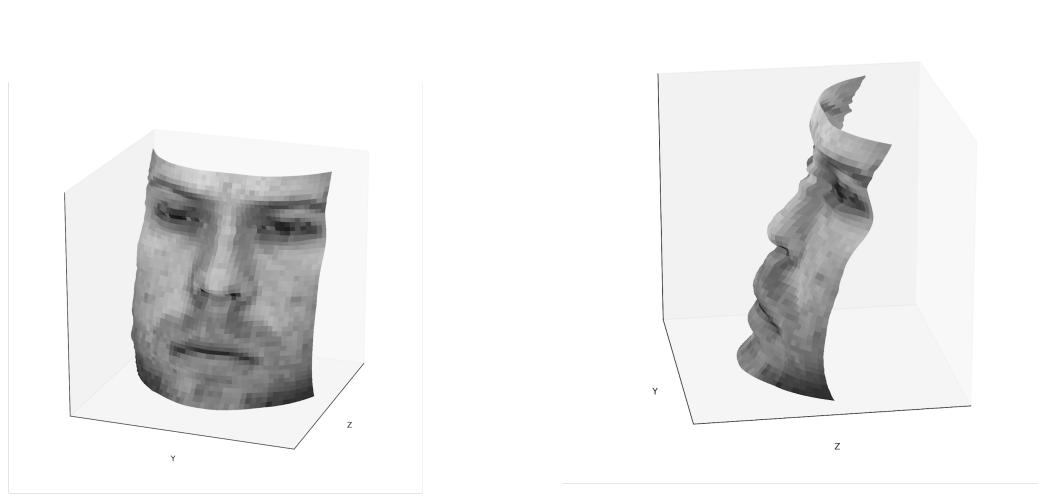
Row Integration views :

Visible artifacts near mouth and wave like pattern near bottom of face



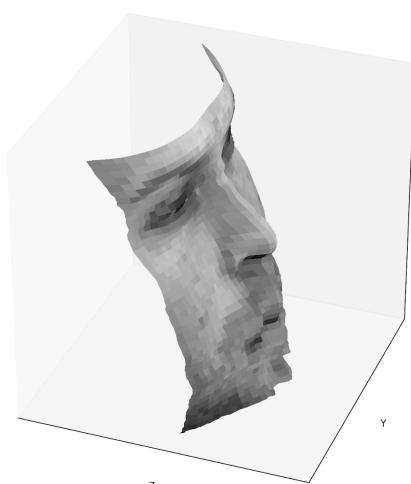
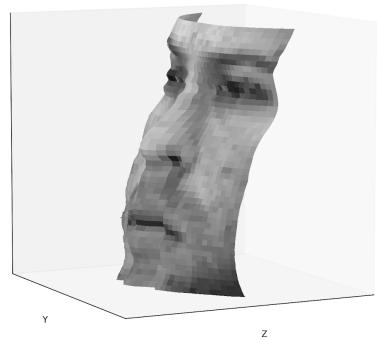
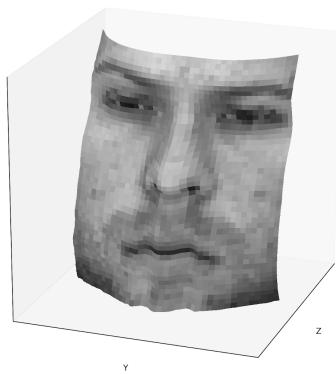
Column Integration views:

Better than row method, but artifacts near chin



Average Integration views :

The images have artifacts near mouth and chin, indicating that it an average of both the methods



Random Integration views:

The image looks better when compared to rest of the methods. There are minor spikes along the edges.



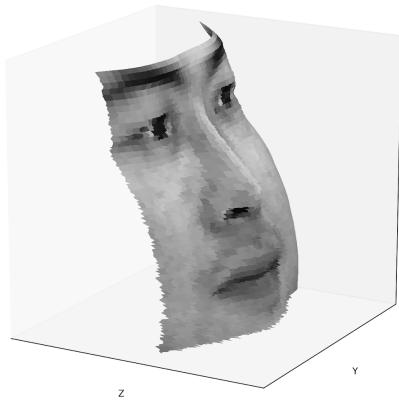
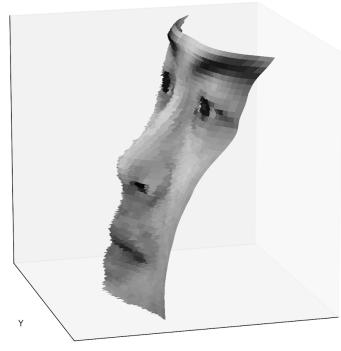
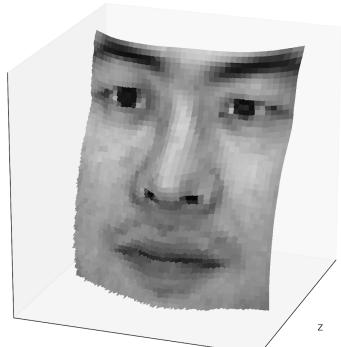
Integration method	Execution time
random	61.35 secs
average	0.00078 secs
row	0.00085 secs
column	0.00092 secs

Discussion:

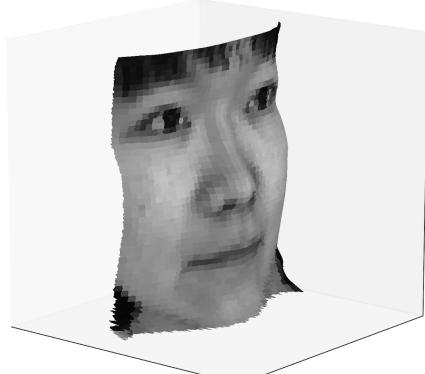
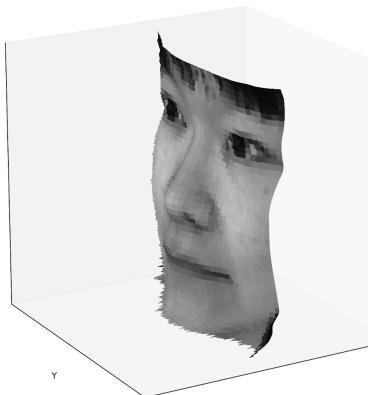
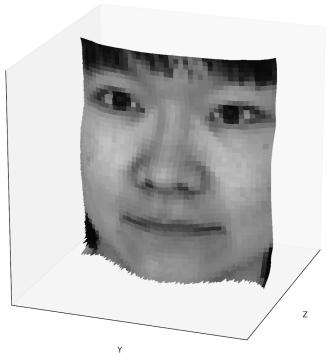
In row integration, the cumulative sum is along the height of the face. Height changes along the width of the face : especially lips are not captured correctly. In column integration, cumulative sum is along the width of the face. It appears better than row, however, the chin is broadened. The average method for height map, reduces the intensity of artifacts from both the row and column, but the problem areas of mouth/lips and chin persists. The height map of random appears best among the methods. However, there are still some spikes along the edges. The random produces best results because the path of integration is randomly chosen to be row or column with random step length. The artifacts of numerical cumulative integration are reduced when averaging over multiple random paths.

Height Map images of other images using random method:

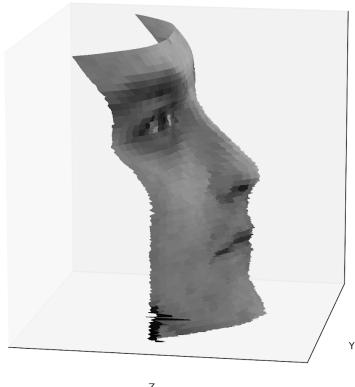
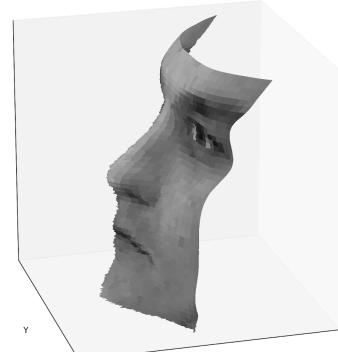
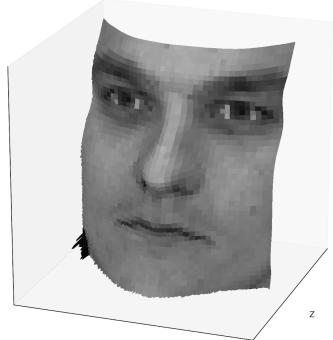
Yale B02



YaleB05



YaleB07



Part3 : Violation of assumptions:

Some of the assumptions of photometric stereo and violations are discussed below

1. Local shading model : Each point on the surface receives light from single source of light. When all light sources are switched off, ambient image would be dark. The ambient image has very small values, but not all zero indicating complete darkness. This

indicates there may be another very minor light source (like natural light peeking or light from camera itself) apart from 64 light sources.

2. Shadows : By looking through images captured from 64 cameras, there are some images that have shadows. This is one of the violation of photometric stereo assumption. Sample images YaleB01 for shadow are shown below



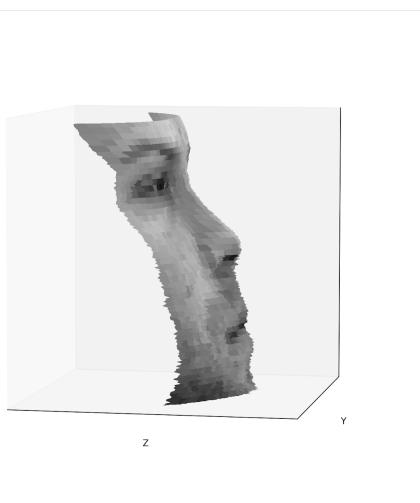
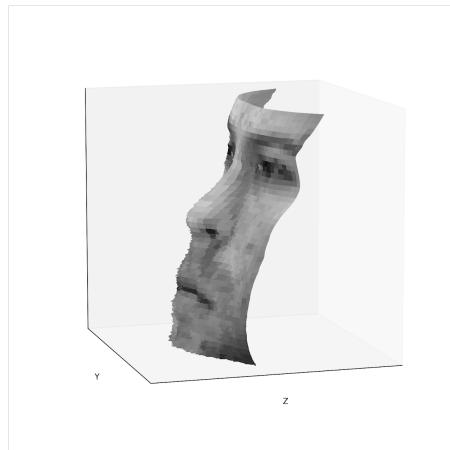
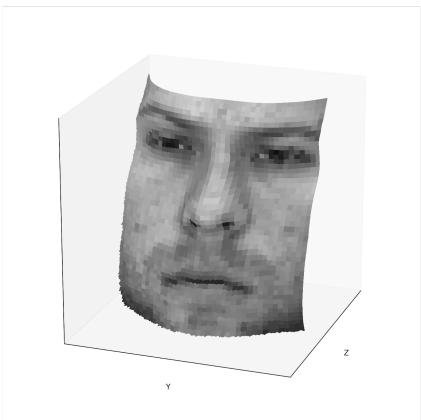
3. Tricky integration : Integration is performed by cumulative summation in all of the methods and by averaging over multiple random paths. The reconstructed surface height image suffers from artifacts due to numerical integration and probable mixed second partial derivatives not being equal in certain regions.
4. Set of images obtained during same object configuration: This is violated in human faces as they could blink and have minor facial expression changes when taking pictures using same camera with 64 different light sources. This could lead to errors in reconstruction as object is not perfectly still. Sample image that shows eye expression difference is shown below



Reconstruction using subset of images

YaleB01 was used :

Height Maps



Albedo



Discussion :

The albedo has more uniform skin tone with subset of images after removal of images with shadow and eyes almost closed. The areas around nose and eyes look better. The height map also captures this uniform skin tone. Thus, the reconstructed image is better by removing violating images.