Photometric Stereo

MATLAB Implementation of the basic photometric stereo algorithm

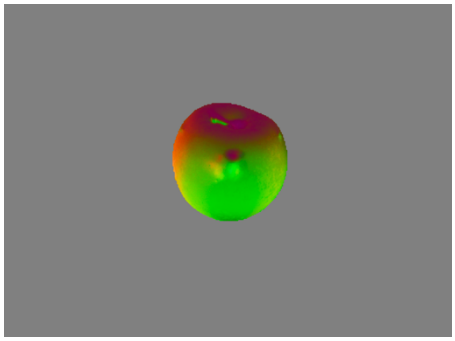
The project implements a basic photometric stereo algorithm that uses linear least squares method. Given a list of photometric images of a sample object with two metal spheres and a white matte Lambertian sphere illuminated under different positions of the same light source, the implementation computes the following items:

- The illumination direction that is computed from the highlighted portion on the metal spheres
- The illumination intensity computed using Lambertian sphere
- The surface normals of the sample object as an overdetermined linear system. Since the pixel intensity is proportional to the dot product of the light direction and surface normal at that pixel, the method uses least squares to compute the albedo and surface normals
- A re-rendered picture of the object using surface normals and albedo under illumination direction, same as viewing direction
- Z values are computed based the normals, using method 2 discussed in the lectures and a grey level image of the object is obtained

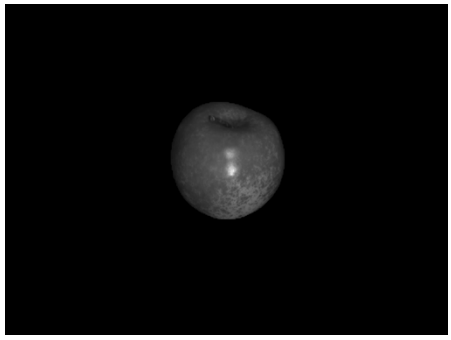
Results and Discussion

Results:

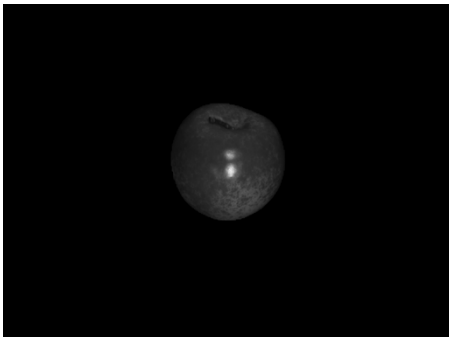
1. Apple



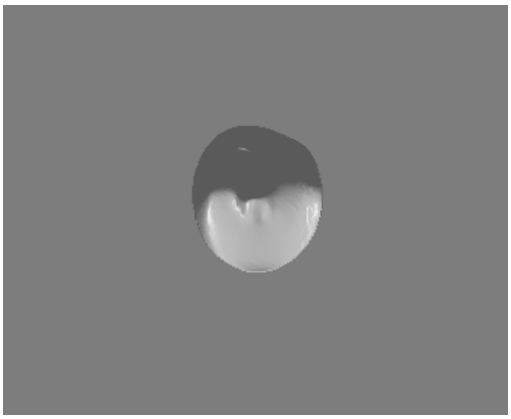
Normal Map



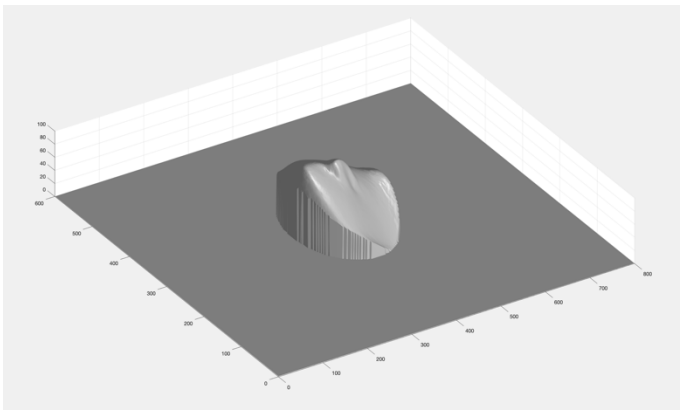
Albedo Map



Re-rendered Image

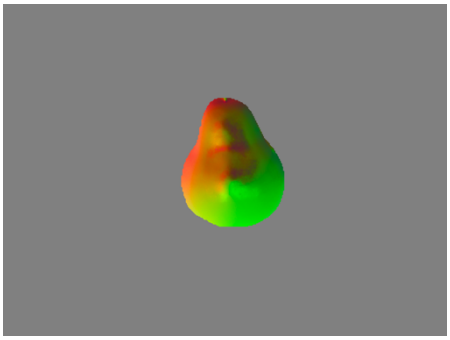


Depth Map

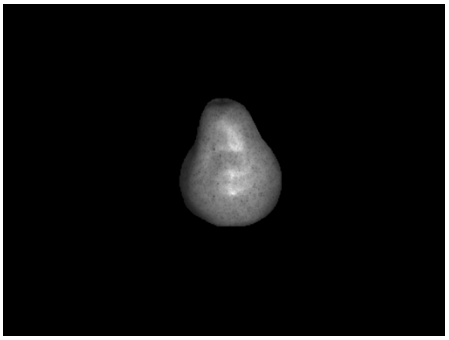


Depth Map(3D)

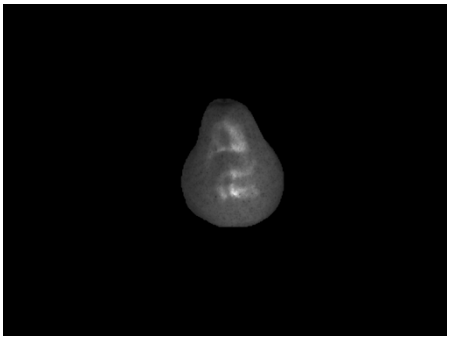
2. Pear



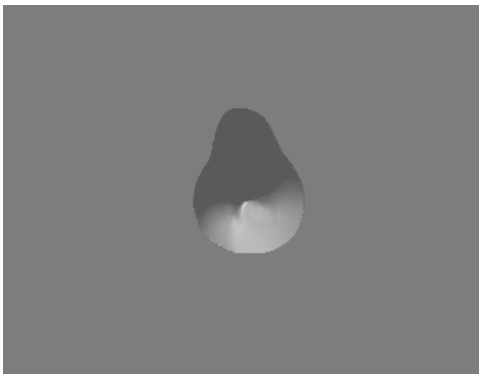
Normal Map



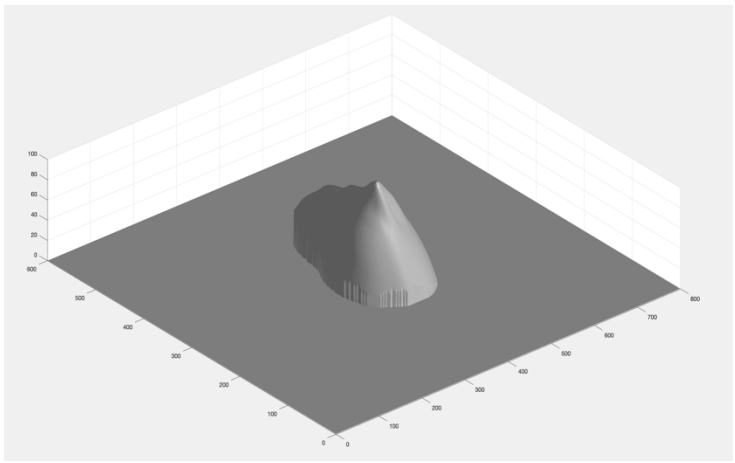
Albedo Map



Re-rendered Image



Depth Map



Depth Map (3D)

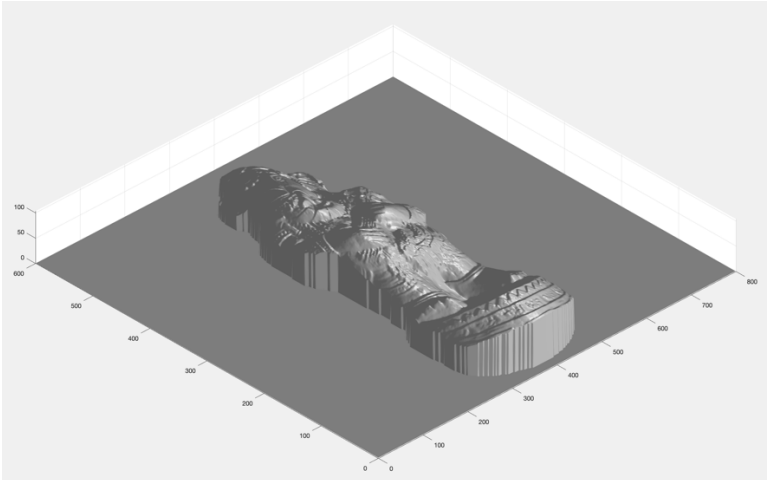
3. Elephant

Normal Map

Albedo Map

Re-rendered Image

Depth Map



Depth Map (3D)

Discussions:
There are certain limitations to photometric stereo algorithm which can be stated as under: -

- It cannot handle shiny and semi translucent objects.
- In case of shadows or multiple reflections, the algorithm may fail
- Light source and the camera have to be place at a certain distance apart.
- The algorithm concerns itself to only Lambertian surfaces with perfectly diffused reflections and may not work for other types of materials like metals, glass, smooth plastics etc. and can lead to abnormalities in the resulting normal vectors
- Algorithm can only by taking certain assumptions like using orthographic camera, directional illuminations, Lambert's reflectance model and camera centered coordinate system

The photometric stereo works better for objects with specular reflections. In order to deal with shadows, a lot of pictures of the sample object, are taken under different light directions and the darkest pixels are discarded. Similarly, the pixels that are too bright can also be discarded. Also, the algorithm makes no assumption about the smoothness of the surface.

The object surface sharing depends on various factors like illumination, camera geometry, and reflectance. Such issues can be addressed by using orientation consistency cue where two points with same surface orientation reflects same light towards viewer, given that the points have same BRDFs, camera being orthographic, light sources being directional. This can be used to improve the photometric stereo. For e.g., if the surface orientation for some points are known, this knowledge can be propagated to other points. The calibration requirements are also minimal. It also enables us to use area light sources instead of point sources, which is especially useful as Area sources are potentially useful for highly specular surfaces that do not have a strong diffuse component.
Hence, we can use example based photometric stereo approach to make improvements.