CE7453 Photogrammetric Computer Vision – Due Sep 28th, 2017
Assignment 1

Photometric Stereo

Photometric stereo is a technique to recover local surface orientations, i.e. surface normals, from images under different illumination conditions. In this project, you will be given multiple images of an object captured under different directional illuminations and the same viewpoint. Your program should be able to calibrate the illumination direction, estimate the surface normal direction at every pixel. All the given images are linearlized, i.e. the pixel value is the irradiance.
There are mainly two steps:

(40%)
Calibration of illumination direction and intensity: in all the provided images, there will be a metal sphere and a white matte Lambertian sphere imaged together with the testing object. Since we know the shape of a sphere, a normal direction can be decided at each pixel on the sphere. Hence, we can estimate the illumination direction from the brightest point on the metal sphere. Further, for the matte Lambertian sphere, its brightest point should have a normal direction coincident as the lighting direction. Hence, we can obtain the lighting intensity from the pixel value of that point (i.e. $I = L_i \rho \bar{n} \cdot \bar{l} = L_i$).

(60%)
Estimation of normal: The intensity of a pixel (i.e. the radiance of the corresponding surface point) is decided by reflectance models. For example, according to the Lambert's model, $I = \rho \bar{n} \cdot \bar{l}$. Here, ρ is the surface albedo, $\bar{n}, \bar{l}$ are the surface normal and illumination direction. According to the photometric stereo algorithm we studied in the class, $\vec{n}$ and ρ can both be uniquely determined when at least three images are provided with known $\vec{l}$. Implement this algorithm in Matlab or C/C++ and test your implementation with the provided data.

You are required to submit both your source code (Matlab or C/C++) in the Carman system. Please also submit a **pdf** or **doc** format report with no more than 4 pages. Your report should include **at least three** results for each example data: a) a normal map linearly encoded in RGB; (You can use the RGB three channels to represent the x,y,z three components of a normal direction. However, xyz vary from -1 to 1, while RGB are only between 0 and 1. So we can store (x+1)/2 in R, (y+1)/2 in G and (z+1)/2 in B.) b) and albedo (ρ) map; c) a re-rendered picture of the object with your recovered normal and albedo under illumination direction that is the same as the viewing direction. You can also upload an additional supplementary file without page limit. Please pack all your files together, and submit only one zip file. Name the file with your metric card id for easy reference. In the report, you are expected to discuss your findings through the experiment. For example, what makes trouble to photometric stereo? What kind of data works best/worst? How the implemented algorithm can be improved? You will get extra points if you implement the following features.

Bonus **(20%)**
Based on the normal, use method 2 to recover the surface of the object, and render a grey-level image based on the Z value.

Bonus **(20%)**

Photometric stereo with non-Lambertian reflectance models: An alternative way to handle non-Lambertian surface is to use more complicated reflectance models. We might fit a Phong, Blinn-Phong model to the observed pixel intensities to better recover the surface normal at highlight pixels. To simplify the problem, we can further assume the BRDF of the surface has the form of $\rho(x, y) + f(a, \theta_i, \varphi_i, \theta_o, \varphi_o)$ In other words, the diffuse component can have texture (i.e. spatially variant albedo ρ (x, y)), but the specular component is homogenous over the whole surface.