Emailed November 9, 2000
Due back November 15, 2000

Homework 10

Shape from Shading

1. A sphere of Lambertian material of radius R lies on the ground.
A camera with its image plane at a distance D above the center of the sphere.looks down on the sphere. Its optical axis is vertical and passes through the center of the sphere.
We assume that orthographic projection is a good approximation of the imaging process, so that a point (x, y, z) of the scene (in camera coordinates) is projected to a pixel (x, y) of the image.
The image of the sphere just fits in a 256x256 image produced by the camera.
The sun illuminates the sphere. The sun is at an elevation of 45 degree above the ground, and at an azimuth of 45 degrees with respect to the x axis of the camera. The patch of sphere that faces the sun is white in the image.

a. Write the function z = f(x,y) that represents the half of the sphere that is visible from the camera.

b. Write the 3 coordinates of a unit normal to the sphere surface for a point of the sphere seen at a pixel (x, y).

c. Write a Matlab function that gives the gray level due to the sun illumination on the Lambertian surface of the sphere for each point of the sphere seen at a pixel (x, y).

d. Write a Matlab function that generates the image of the sphere and a black background. Print the image.

2. Now a face made of plaster with Lambertian reflecting properties is placed on the ground.
The image seen by the camera is shown at
http://umiacs.umd.edu/~ramani/cmsc828d/FACE.jpeg.
The sun is at a 45 degree azimuth and 45 degree elevation so that the left part of the forehead of the face is illuminated (depending on the frame of reference you select, this may be the same orientation as in problem 1 or a different orientation).

a. Transform the image into a gray level image. The brightest point on the mask is assumed to face the sun. Because of the imaging process and the albedo of the mask's material, this point is not white. Compute the proportionality constant due to these factors. Rescale the gray levels so that this point becomes white. Print the image.

b. Assume that the face is symmetrical with respect to a plane P parallel to the optical axis of the camera. This plane cuts the face along a curve C. This curve is seen from the camera as image column x = 68. The normals to the face along curve C are contained in plane P and have an x coordinate equal to zero. Show that there are generally 2 possible unit normals for each gray

levels along curve C. Write a Matlab function that computes the coordinates of the unit normals as a function of the gray level of a pixel along curve C.

c. Find a location along curve C where the surface patch faces the camera and is close to the tip of the nose. From this point, compute the z coordinate of the next pixel, using among the two possible orientations of the normal the orientation that causes the smallest change of orientation. Proceeding from pixel to pixel, reconstruct the profile of the face along curve C. Draw this profile from the edge of the face at the forehead (taken as origin of a (y, z) coordinate system for the curve C) to the edge at the chin.
Note: this reconstruction is qualitative, one of the problems being that we don't know the correct orientation of the light source. You may want to try orientations different from the 45 degree orientation proposed above.