Practice questions - photometric stereo

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1. In photometric stereo, we assumed that all images were taken from the same viewpoint/camera. Why is this assumption necessary? Because we need a given pixel to correspond to the same surface patch across the different images. Only then will it have the same albedo and surface normal across all images.

2. Consider a hypothetical material with a BRDF given by $\rho(\theta_i, \theta_r) = \frac{1}{\cos\theta_i}$, where θ_i is the angle made by the light direction with the surface normal, and θ_r is the angle made by the viewing direction with the surface normal.

   (a) Will the appearance of this surface vary with the viewing direction? Outgoing radiance $= \rho(\theta_i, \theta_r) L_i \cos\theta_i = \frac{1}{\cos\theta_i} L_i \cos\theta_i = L_i$. So no.

   (b) Will it vary with the incoming light direction? Outgoing radiance $= L_i$, which is independent of incoming light direction.

   (c) Will we be able to use photometric stereo to reconstruct an object made of this material? No. Outgoing radiance is the same no matter the angle between lighting direction and surface normal. All images will look the same,

3. In class, we derived how we can use the estimated normals to get some constraints on depth.

   (a) Are these constraints linear in depth? Yes. They take the form $N(x,y)^T \begin{bmatrix} c \\ 0 \\ Z(x+1,y) - Z(x,y) \end{bmatrix} = 0$ and $N(x,y)^T \begin{bmatrix} 0 \\ c \\ Z(x,y+1) - Z(x,y) \end{bmatrix} = 0$.

   (b) In class we derived these for the case of scaled orthographic projection. Rederive these equations for standard perspective projection. The image point (x, y) with depth $Z(x, y)$ will correspond to the

world point $(Z(x,y)x, Z(x,y)y, Z(x,y))$.

$$N(x,y)^T\left(\begin{bmatrix} Z(x+1,y)(x+1) \\ Z(x+1,y)y \\ Z(x+1,y) \end{bmatrix} - \begin{bmatrix} Z(x,y)x \\ Z(x,y)y \\ Z(x,y) \end{bmatrix}\right) = 0 \quad (1)$$

$$N(x,y)^T\left(\begin{bmatrix} Z(x,y+1)x \\ Z(x,y+1)(y+1) \\ Z(x,y+1) \end{bmatrix} - \begin{bmatrix} Z(x,y)x \\ Z(x,y)y \\ Z(x,y) \end{bmatrix}\right) = 0 \quad (2)$$

$$(3)$$

(c) Are the equations still linear? Yes