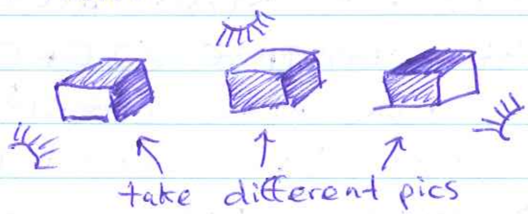
UNDERSTANDING PHOTOMETRIC STEREO

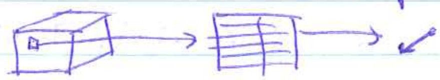
The idea behind photometric stereo is that we can obtain information about surface orientation from multiple images (in this case, considering different lighting conditions)

Basic algorithm:

1)



2) ~~Construct needle diag.~~
Compare to lookup table



3) Store as needle diagram

First, we need to understand radiance/irradiance

Reflectance Map

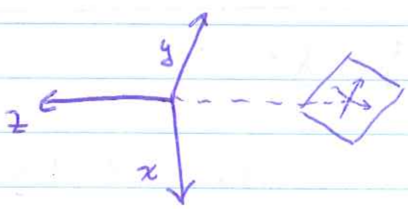
Assuming an Ideal Lambertian surface (one which is perfectly matte) the radiance is:

$$L = \frac{1}{\pi} E \cdot \cos\theta_i \;\rightarrow\; = \frac{1 + p_s \cdot p + q_s \cdot q}{\sqrt{1+p^2+q^2} \cdot \sqrt{1+p_s^2+q_s^2}}$$

(E: intensity of directional light)

~~p_s and q_s are the elements of the surface normal $(-p_s, -q_s, 1)$~~

p and q are the first partial derivatives of z w.r.t. x and y



$$\frac{\partial z}{\partial x} = p \qquad \frac{\partial z}{\partial y} = q$$

(p, q) is <u>gradient</u> of surface

$(p_s, q_s) \rightarrow$ light normal $\quad (p, q)$ surface normal

$R(p, q)$ is the reflectance map and it gives the coefficient of lighting $(\cos\theta)$

$$R(p,q) = \frac{1 + p_s p + q_s q}{\sqrt{1+p^2+q^2}\sqrt{1+p_s^2+q_s^2}}$$

↑ this is proportional to image brightness

pq-plane is called gradient space

The reflectance map is useful in translating gradient → reflectance, for graphics, but a difficulty arises since brightness → gradient is not unique.

This means we need additional constraints to correctly translate from one variable to two.

↳ Solution: use two images with different lighting!

Hilroy

We can also include a third lighting if we want to recover albedo (the amount of light reemitted based on the material [i.e. black or white])

↳ Brightness ∝ $\rho \cos\theta$

Recap of the Method:

The basic idea is to use 3 lightings to recover gradient (surface orientation) and albedo (darkness of material). Using a calibration object, we can experimentally generate a lookup table which is keyed by the three values of brightness which have been quantized. Alternatively, we can use the BRDF function to theoretically determine the reflectance map.