EE 576 - Photometric Stereo

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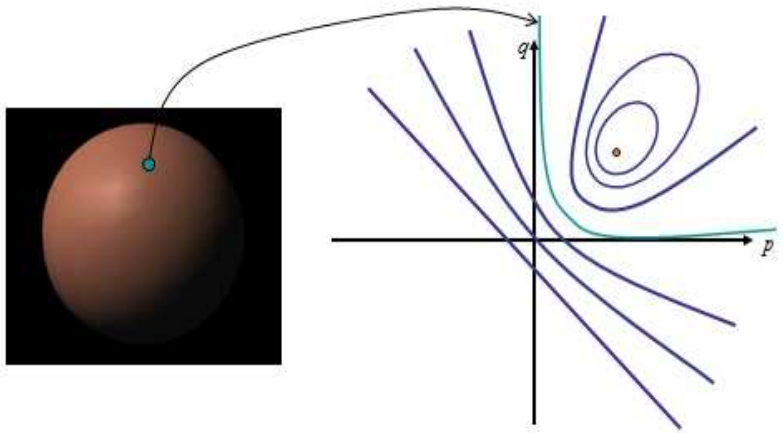
Photometric Stereo

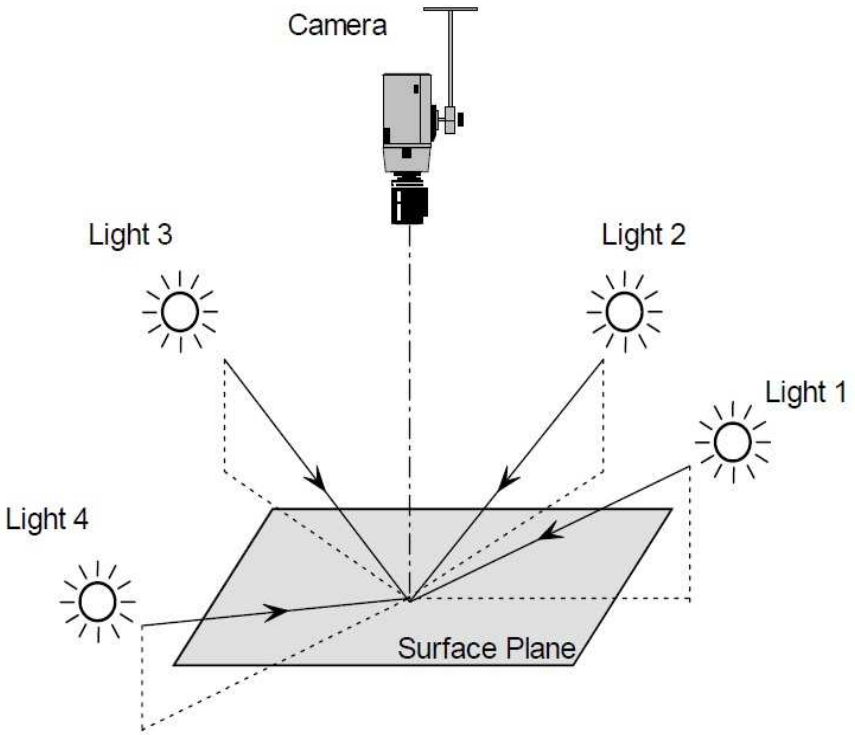
Unique Shape?

- Given a single image of an object with known surface reflectance taken under a known light source, can we recover the shape of the object?
- Given $R(p,q)$ ((p_S,q_S) and surface reflectance) can we determine (p,q) uniquely for each image point?



NO

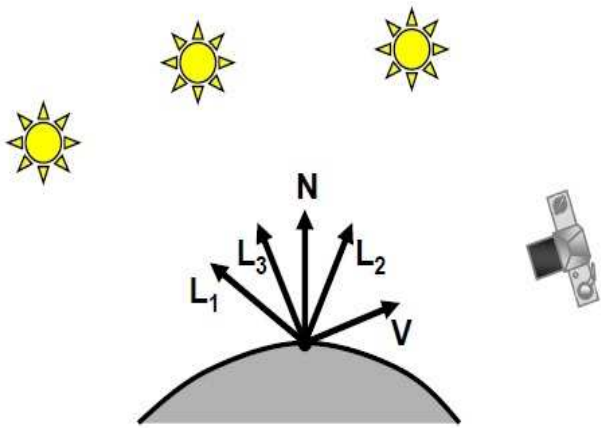
Photometric Stereo



Variation of images




Problem Setup



$$I_1 = k_d \mathbf{N} \cdot \mathbf{L_1}$$
$$I_2 = k_d \mathbf{N} \cdot \mathbf{L_2}$$
$$I_3 = k_d \mathbf{N} \cdot \mathbf{L_3}$$

Can write this as a matrix equation:

$$\begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = k_d \begin{bmatrix} \mathbf{L_1}^T \\ \mathbf{L_2}^T \\ \mathbf{L_3}^T \end{bmatrix} \mathbf{N}$$

Solving Equations

$$\underbrace{\begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix}}_{\mathbf{I}_{3\times 1}} = \underbrace{\begin{bmatrix} \mathbf{L_1}^T \\ \mathbf{L_2}^T \\ \mathbf{L_3}^T \end{bmatrix}}_{\mathbf{L}_{3\times 3}} \underbrace{k_d \mathbf{N}}_{\mathbf{G}_{3\times 1}}$$

$$\mathbf{G} = \mathbf{L}^{-1}\mathbf{I}$$

$$k_d = \|\mathbf{G}\|$$

$$\mathbf{N} = \frac{1}{k_d}\mathbf{G}$$

More than 3 Light sources

Get better results by using more lights

$$\begin{bmatrix} I_1 \\ \vdots \\ I_n \end{bmatrix} = \begin{bmatrix} \mathrm{L_1} \\ \vdots \\ \mathrm{L_n} \end{bmatrix} k_d \mathrm{N}$$

Least squares solution:

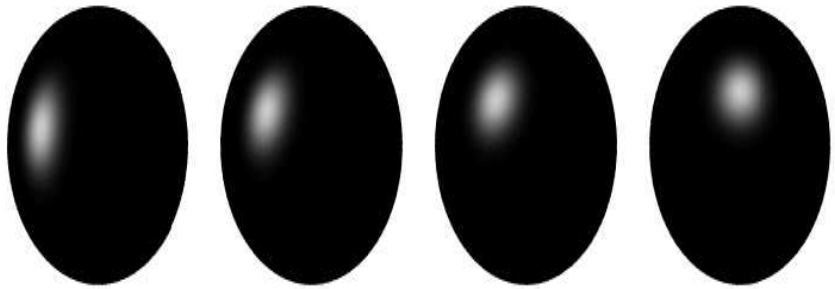
$$\begin{aligned} \mathrm{I} &= \mathrm{LG} \\ \mathrm{L^T I} &= \mathrm{L^T LG} \\ \mathrm{G} &= (\mathrm{L^T L})^{-1}(\mathrm{L^T I}) \end{aligned}$$

Solve for N, k_d as before

What's the size of $\mathbf{L^T L}$?

Light Source Directions

Trick: place a chrome sphere in the scene



- the location of the highlight tells you where the light source is