EE 576 - Photometric Stereo

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May 9, 2018
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?
Photometric Stereo
Variation of images
Problem Setup

Can write this as a matrix equation:

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

\[
I_1 = k_d N \cdot L_1 \\
I_2 = k_d N \cdot L_2 \\
I_3 = k_d N \cdot L_3
\]
Solving Equations

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

\[
G = L^{-1} I
\]

\[
k_d = \|G\|
\]

\[
N = \frac{1}{k_d} G
\]
More than 3 Light sources

Get better results by using more lights

\[
\begin{bmatrix}
I_1 \\
\vdots \\
I_n \\
\end{bmatrix} = \begin{bmatrix}
L_1 \\
\vdots \\
L_n \\
\end{bmatrix} k_d N
\]

Least squares solution:

\[
I = LG = L^T I = L^T L G
\]

\[
G = (L^T L)^{-1} (L^T I)
\]

Solve for \(N, k_d\) as before

What's the size of \(L^T L\)?
Light Source Directions

Trick: place a chrome sphere in the scene

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