Position Estimation of Near Point Light Sources Using a Clear Hollow Sphere

Takahito Aoto†, Takafumi Taketomi†, Tomokazu Sato†, Yasuhiro Mukaigawa‡, Naokazu Yokoya†

† Nara Institute of Science and Technology, Japan ‡ ISIR, Osaka University, Japan

Motivation

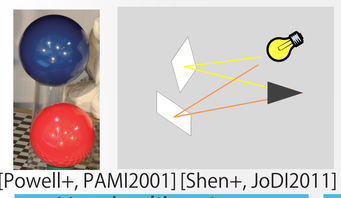
Near point light source

Incident direction and intensity are different at each surface position

This model draws much attention

Related work

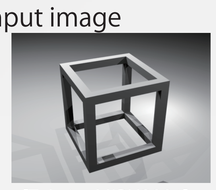
Triangulation using mirror objects



[Powell+, PAMI2001] [Shen+, JoDI2011]

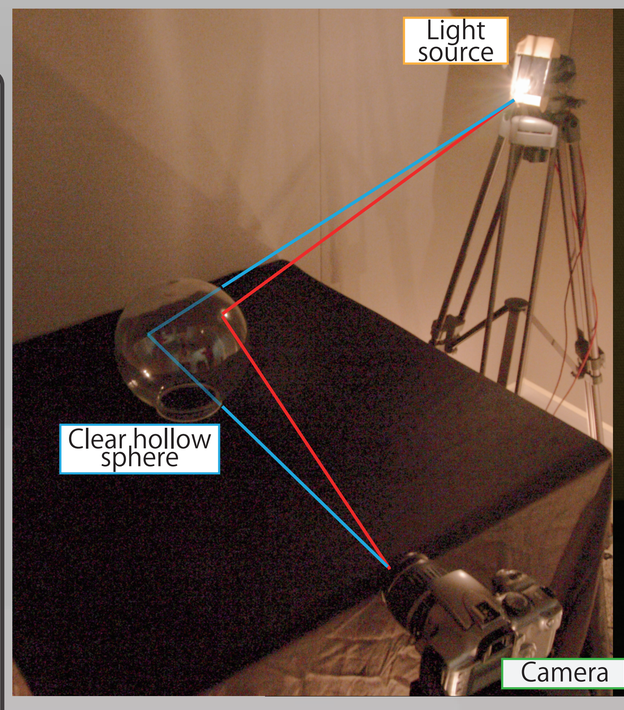
Need calibration among reference objects

Analysis of distribution of intensities over an input image



[Takai+, MIRU2004]

Unstable results due to many estimating parameters



Outline view Captured image

Goal and Approach

Goal

Accurate position estimation of near light sources with easy setup

Approach

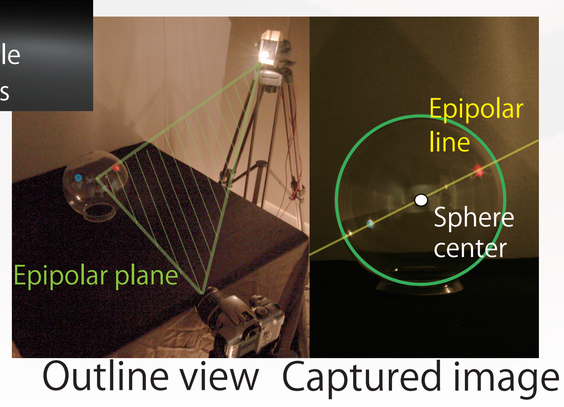
Triangulation from reflected lights on a clear hollow sphere

Three advantage

1. Geometric calibration for multiple reference objects is not required
2. Re-projection errors in image can be minimized
3. Determining pairs of corresponding highlights is easy

Three challenges and their solutions

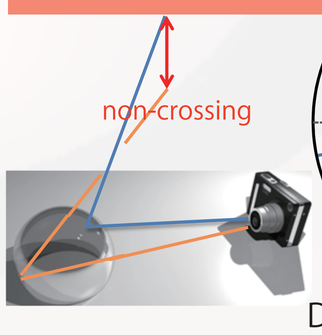
Finding pairs of corresponding highlights

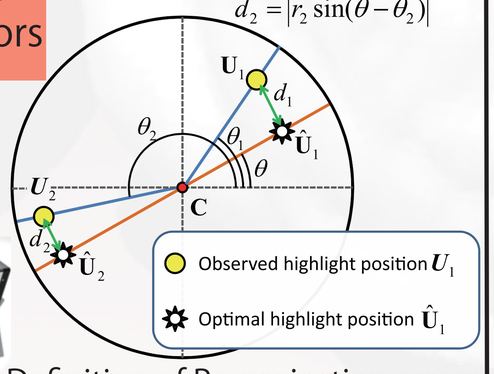


Outline view Captured image

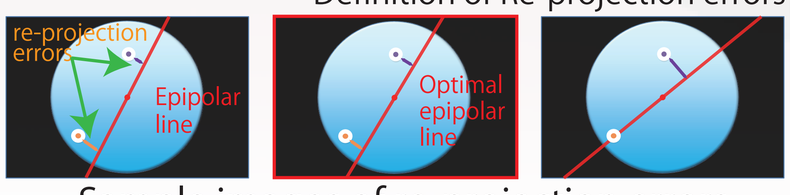
Minimization of re-projection errors

$$E(\theta) = d_1^2 + d_2^2 \Rightarrow \min$$
$$d_1 = |r_1 \sin(\theta - \theta_1)|$$
$$d_2 = |r_2 \sin(\theta - \theta_2)|$$





Definition of Re-projection errors

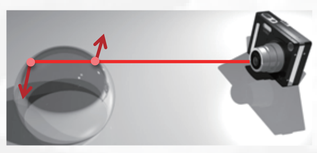


Sample images of re-projection errors

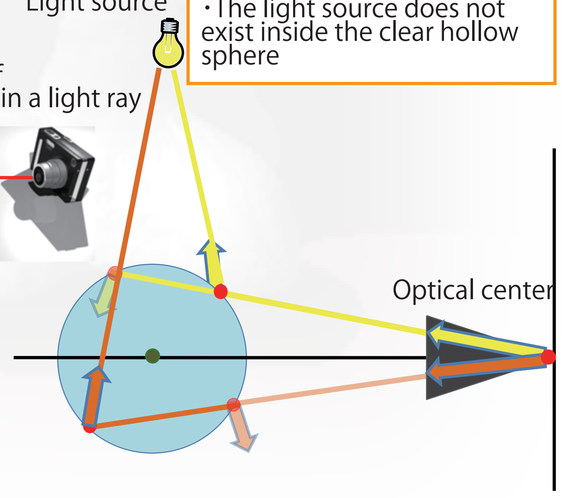
Determination of reflected position on sphere

Two constraints

- The light source does not exist in the opposite direction
- The light source does not exist inside the clear hollow sphere

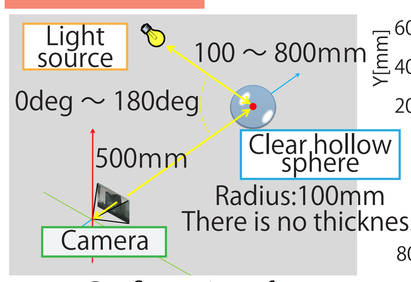


Two candidates of reflected position in a light ray

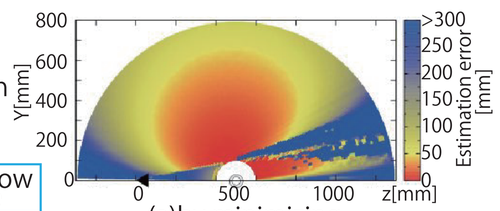


Quantitative evaluation of accuracy

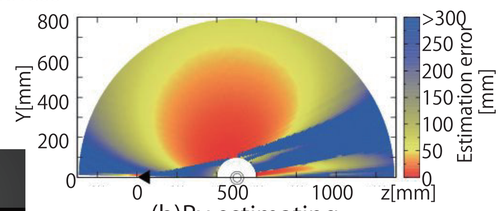
Simulation



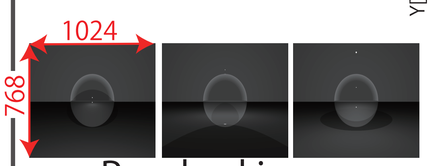
Configuration of simulation experiment



(a)by minimizing re-projection errors

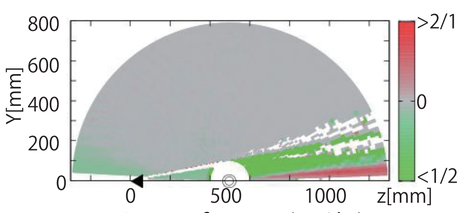


(b)By estimating middle point of rays



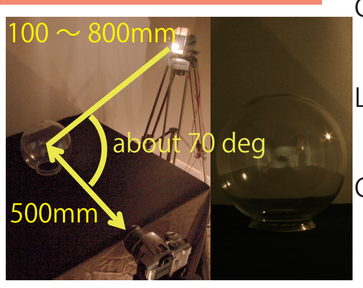
Renderd image

※10,000 trials for each light position with different levels of detection errors that are the Gaussian errors of the Standard deviation



Ratio of errors (a / b)

Real environment

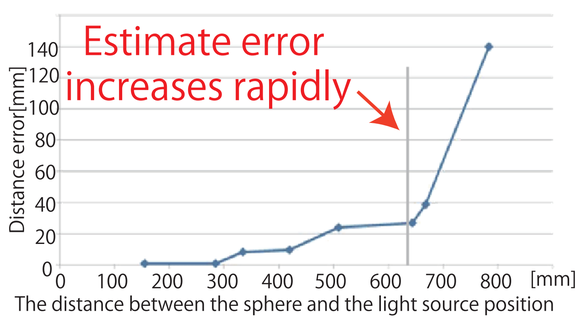


Camera
Cannon Eos Kiss
1024×768

Light source
Halogen light

Clear hollow sphere
Radius:100mm
Thickness: 2mm

Configuration of real experiment

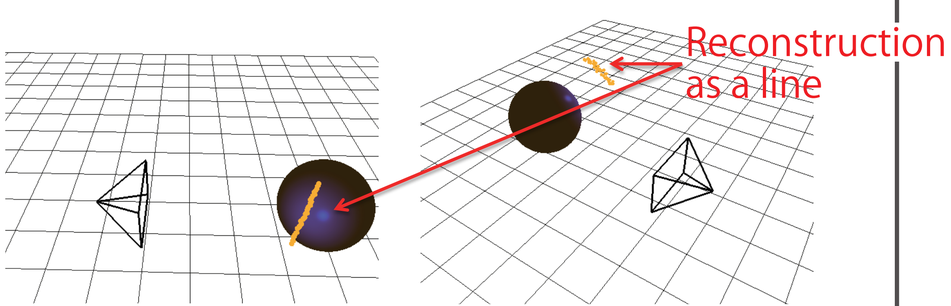


Position errors in a real environment

Light position estimation for desk lamp

Captured image

Outline view



Estimated light positions