

Light Transport

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Global Illumination

- Lots of stuff going on…



Observation



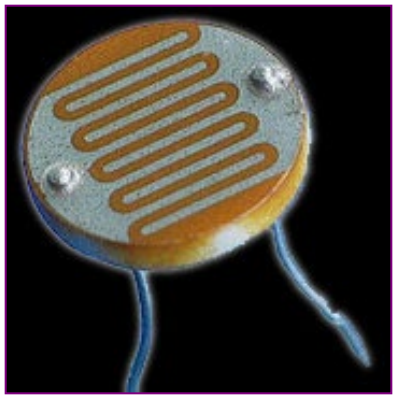
- Modeling illumination is hard
- “Undoing” physically-observed illumination in order to discover the underlying geometry is even harder

- Insight: let’s sample it and “re-apply” it!

Dual Photography

Sen et al., SIGGRAPH 2005

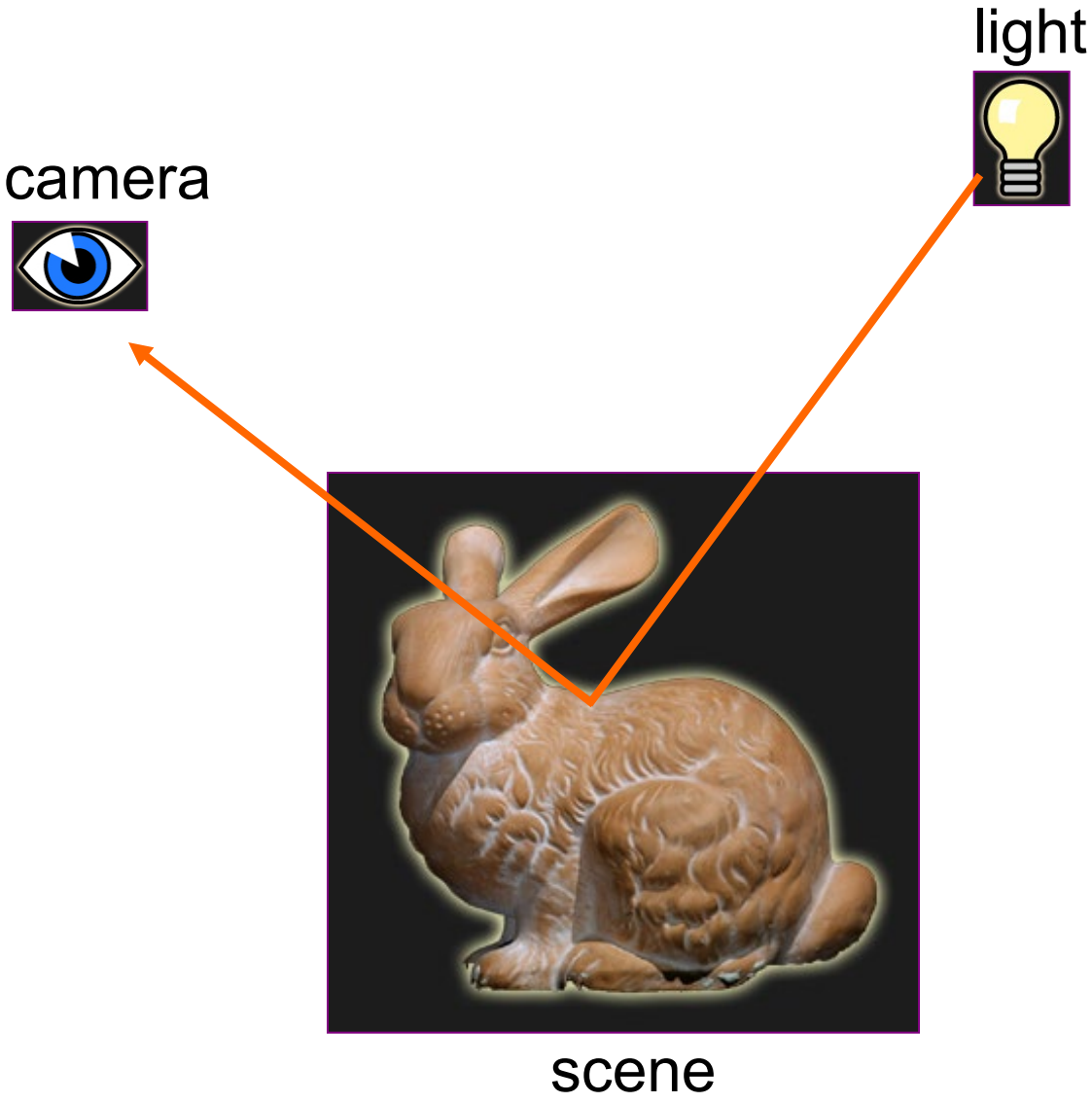
(slides courtesy of M. Levoy)



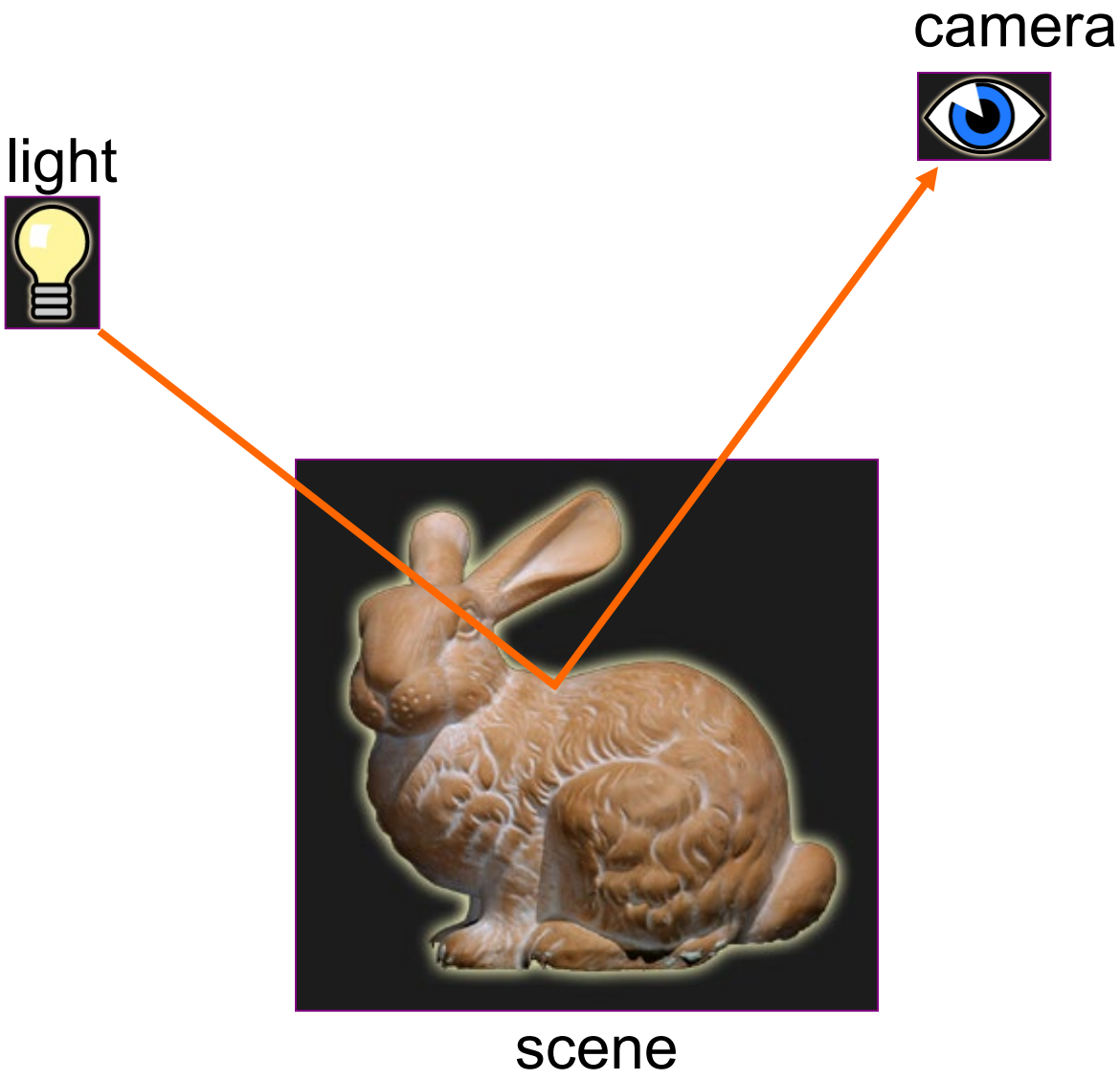




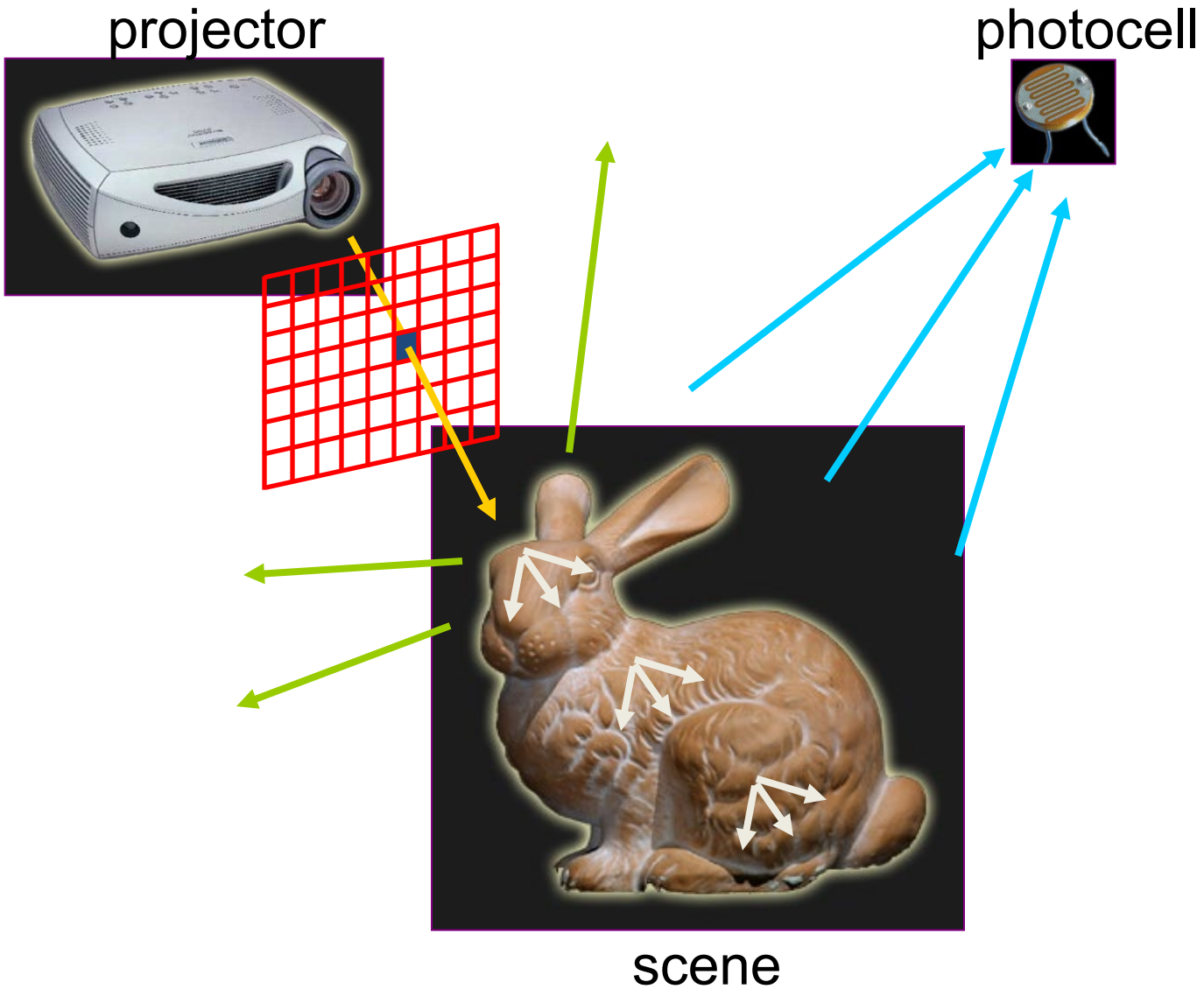
Helmholtz Reciprocity



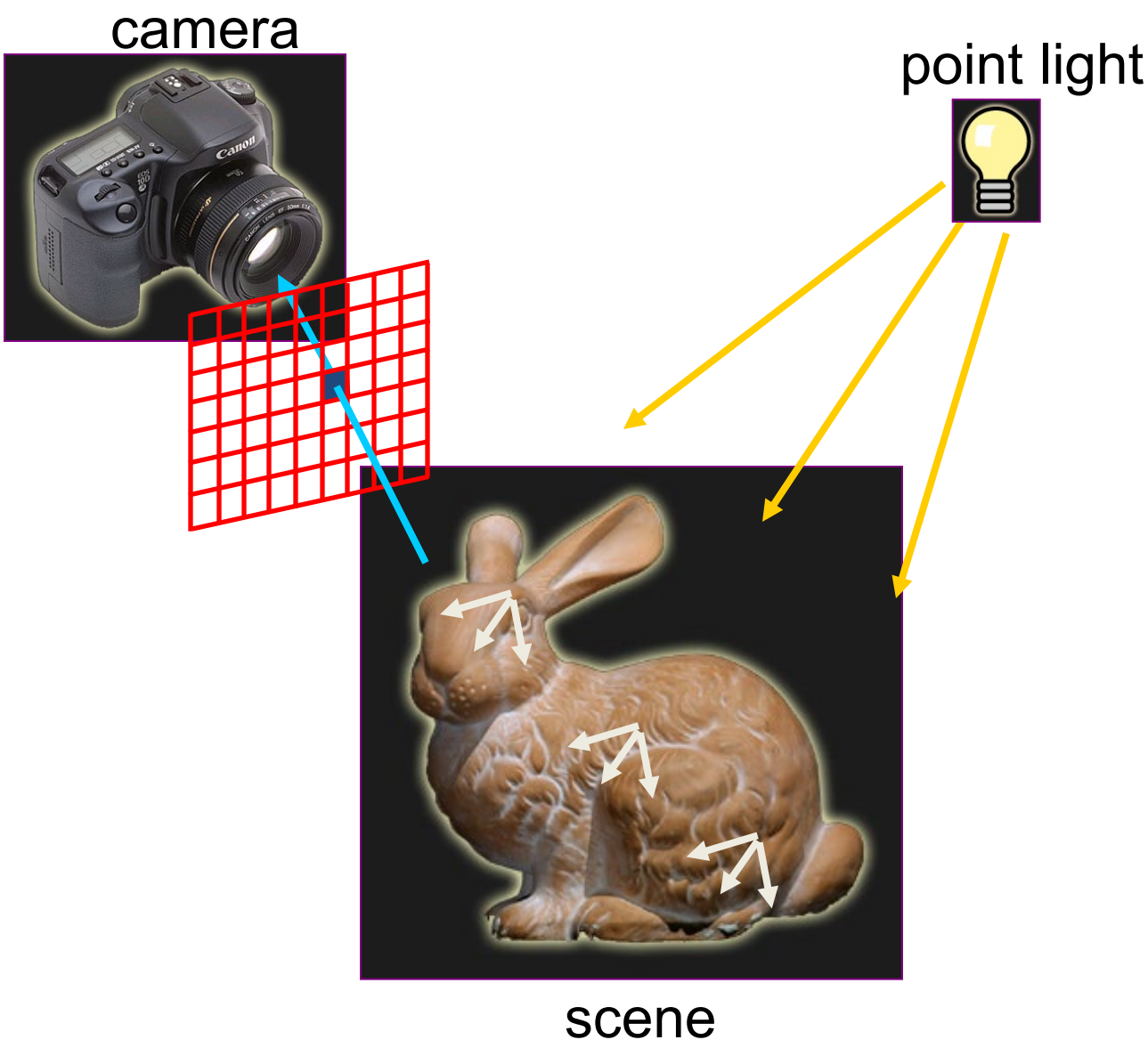
Helmholtz Reciprocity



Measuring transport along a set of paths



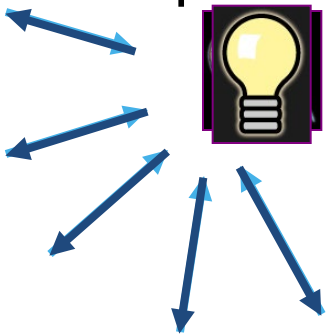
Reversing the paths



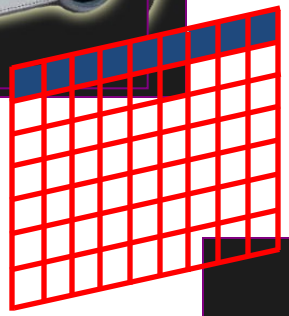
Forming a dual photograph



“dual” camera
projector



“dual” light
photocell





scene



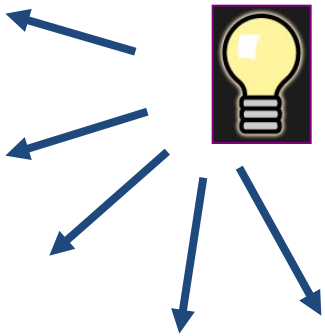
Forming a dual photograph



“dual” camera



image of scene



“dual” light



scene

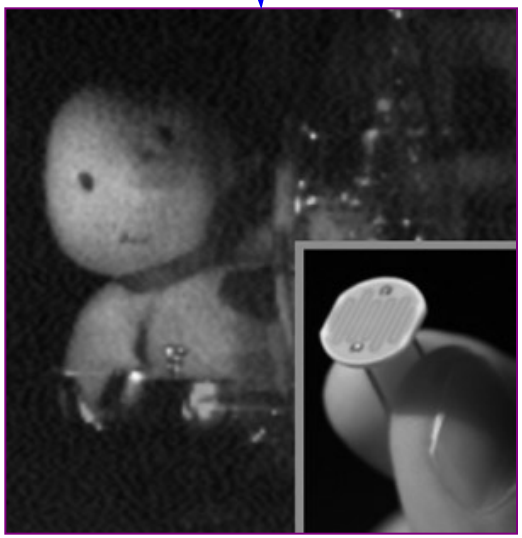


Physical demonstration

- light replaced with projector
- camera replaced with photocell
- projector scanned across the scene

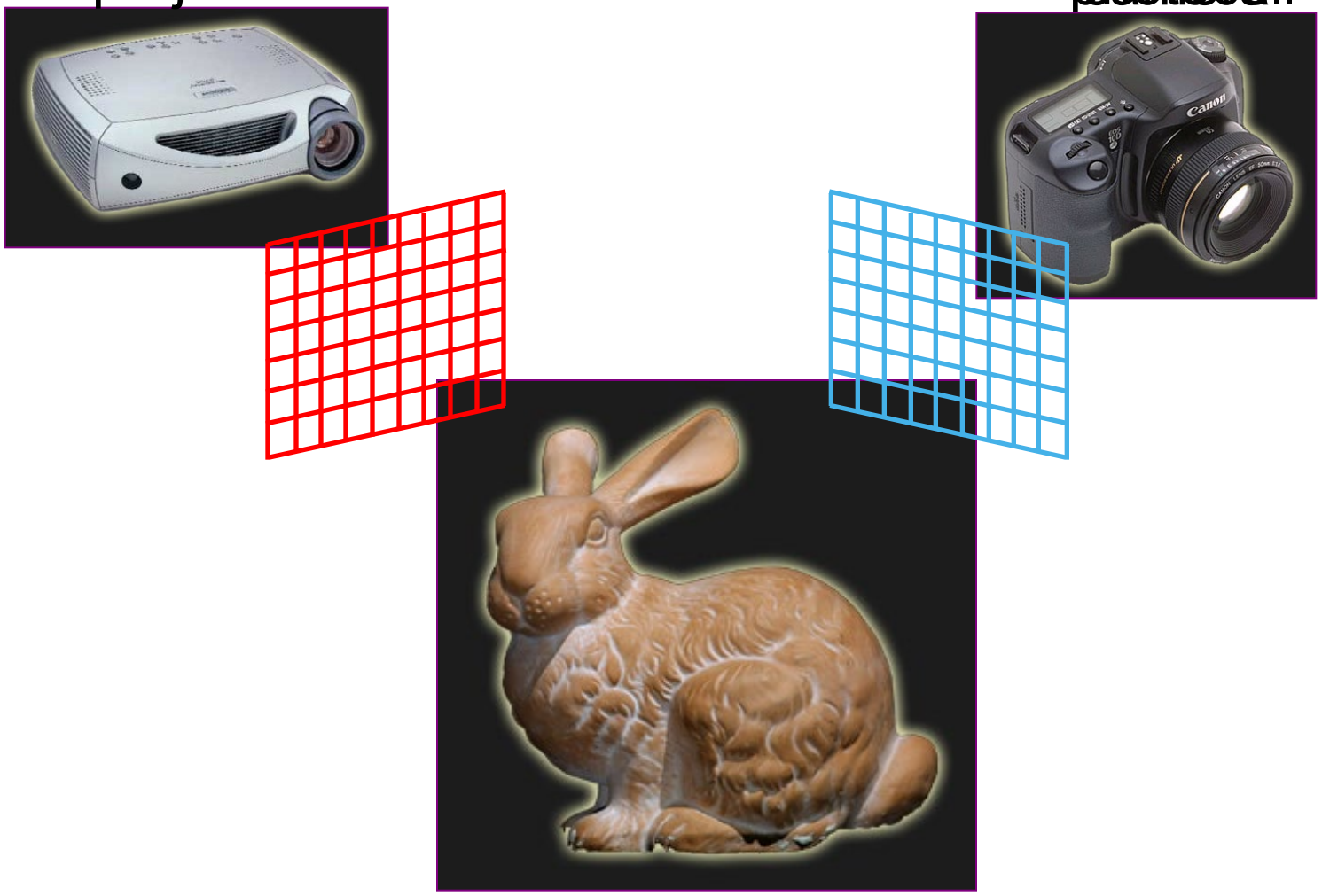


conventional photograph,
with light coming from right

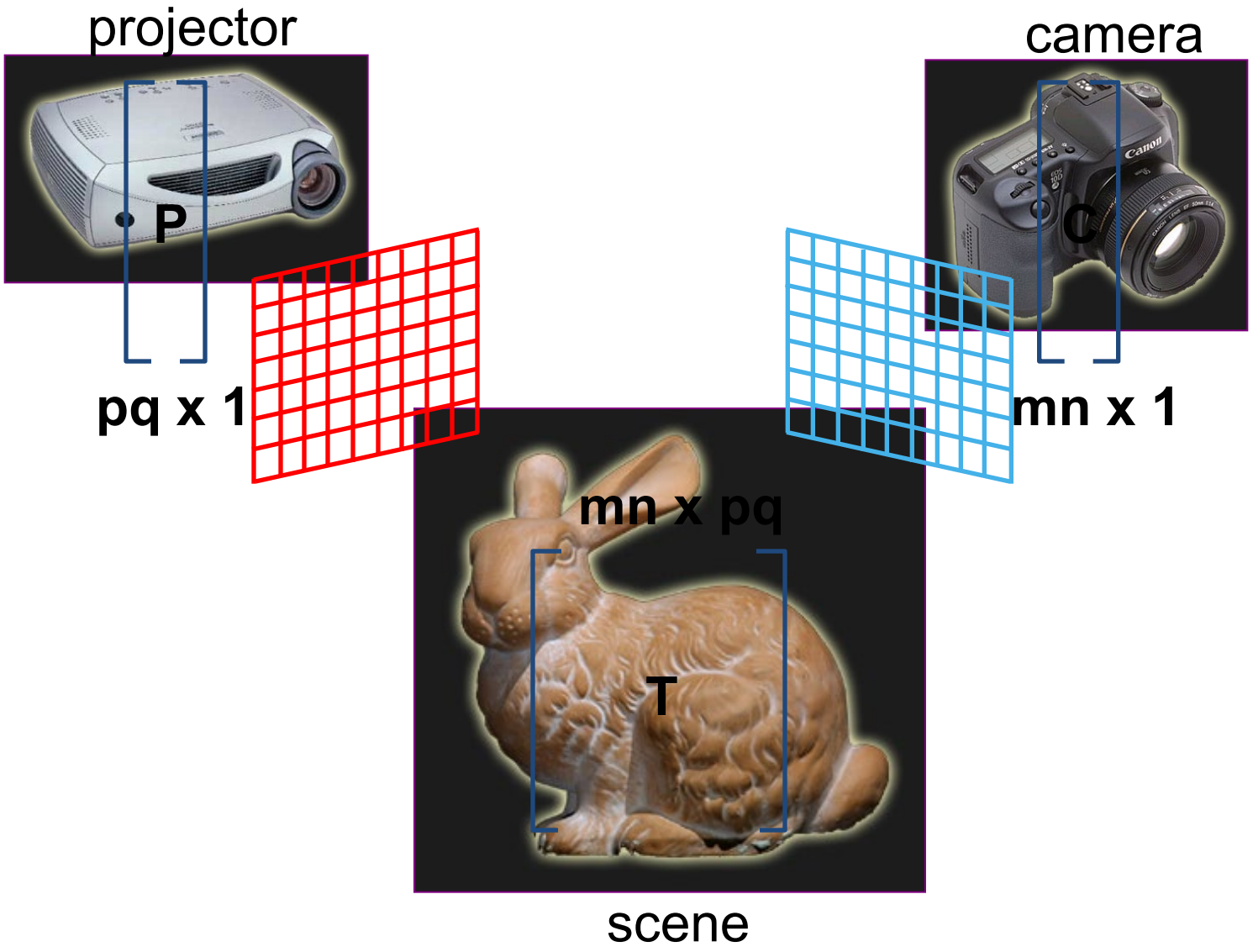


dual photograph,
as seen from projector's position
and as illuminated from photocell's position

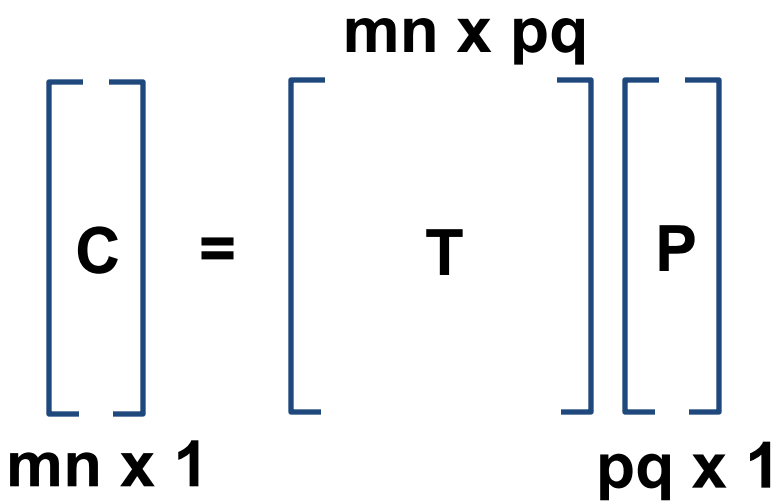
The 4D transport matrix



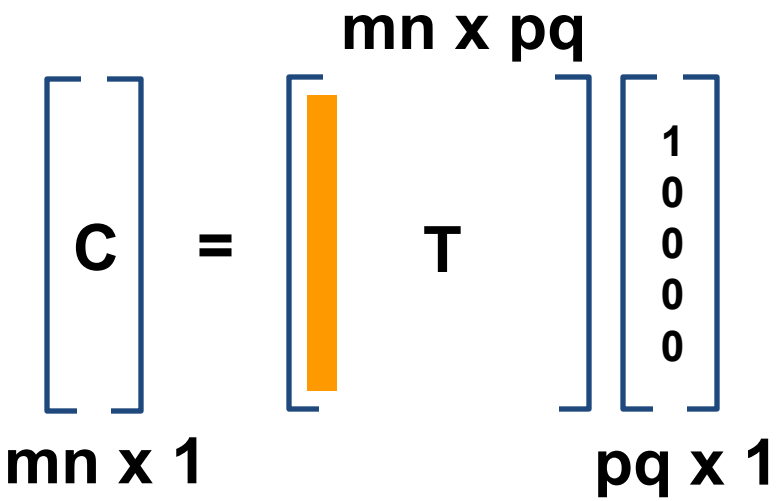
The 4D transport matrix



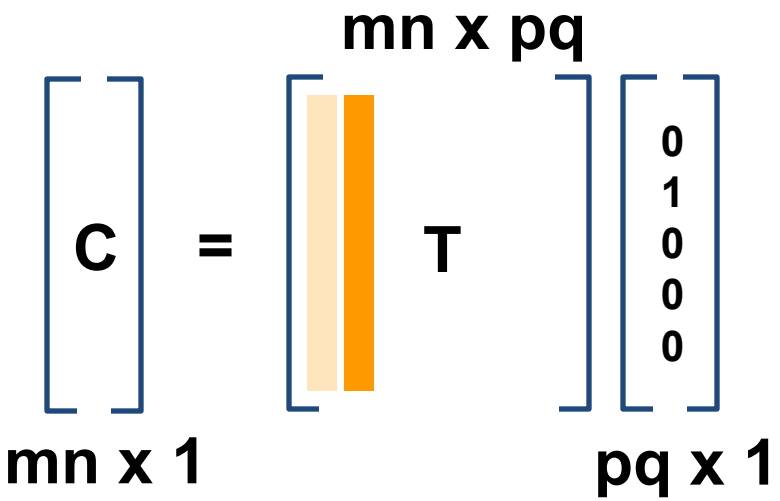
The 4D transport matrix



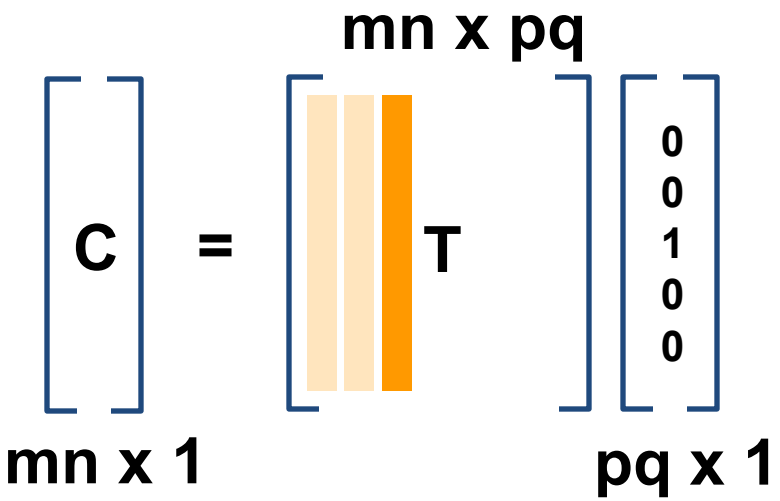
The 4D transport matrix



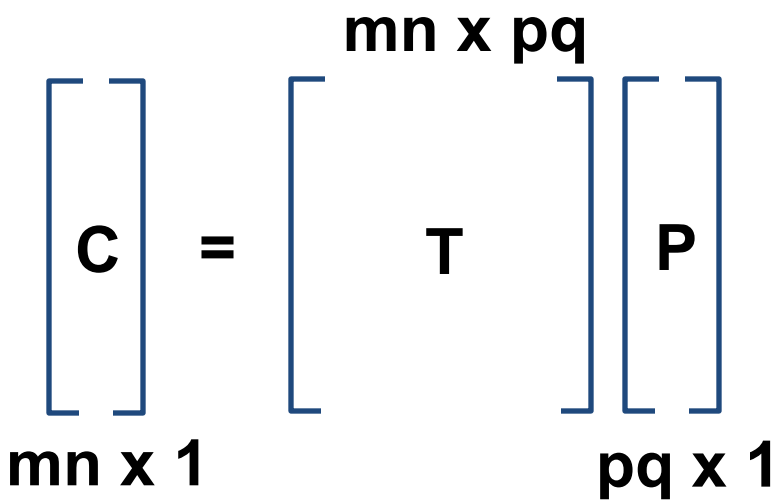
The 4D transport matrix



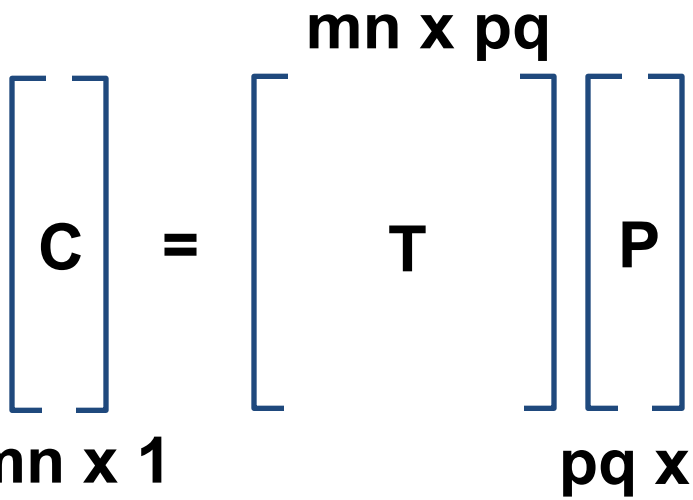
The 4D transport matrix



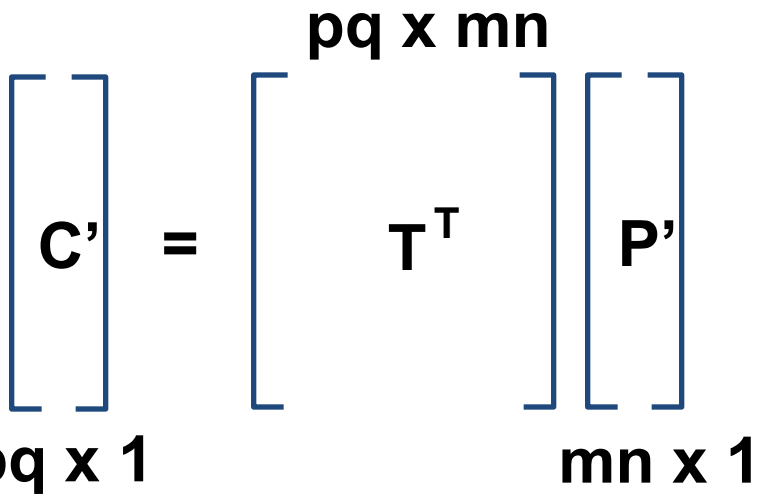
The 4D transport matrix



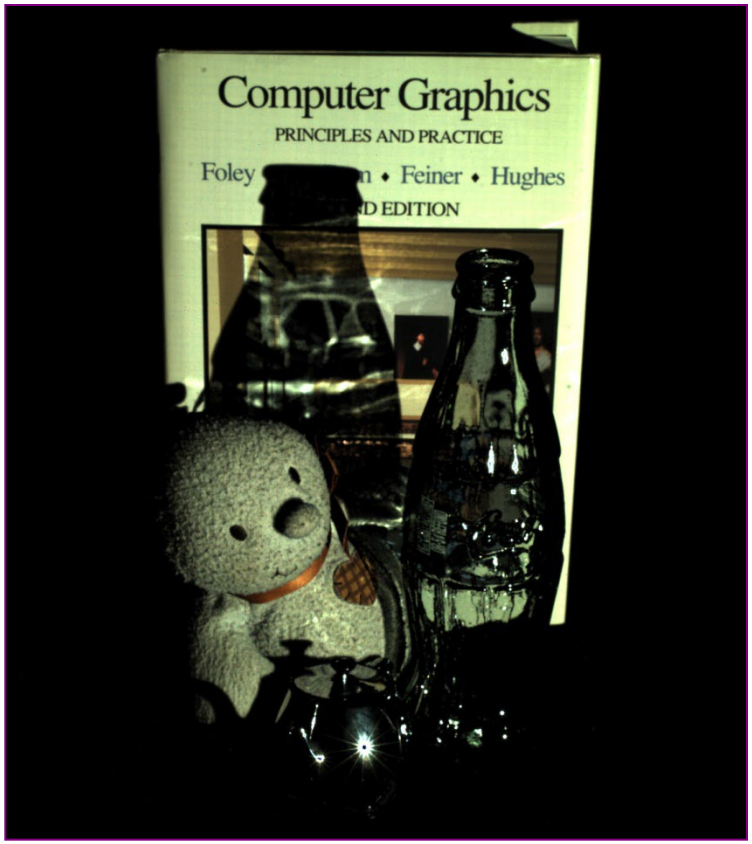
The 4D transport matrix



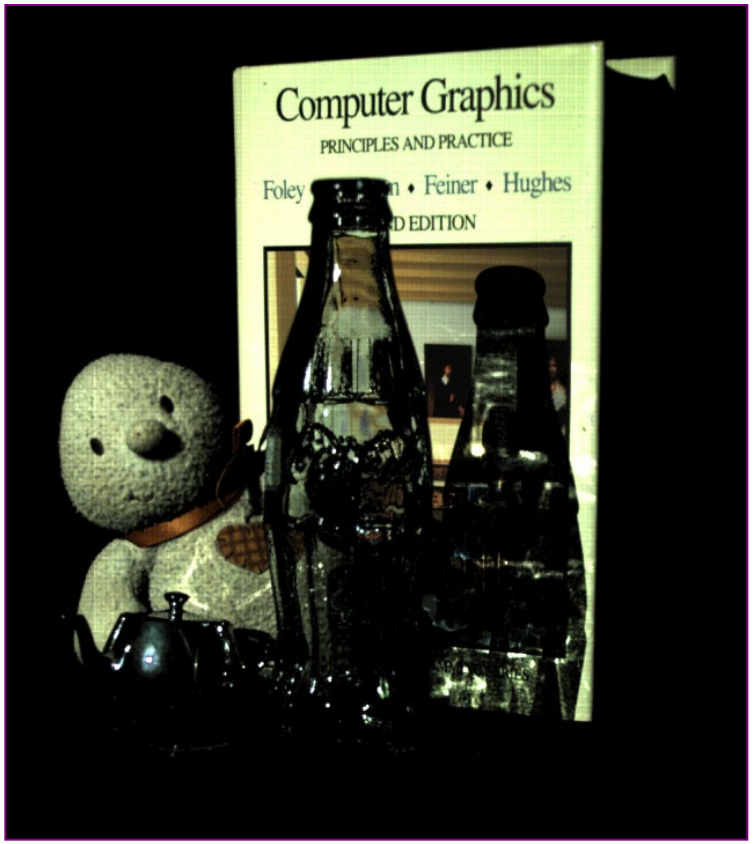
applying Helmholtz reciprocity...



Example



conventional photograph
with light coming from right



dual photograph
as seen from projector's position

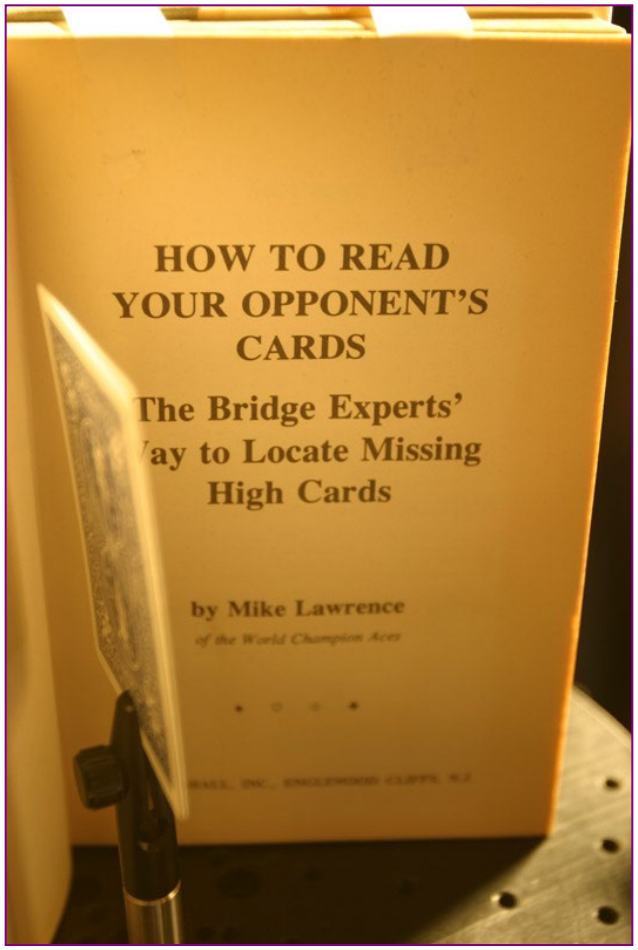
Properties of the transport matrix



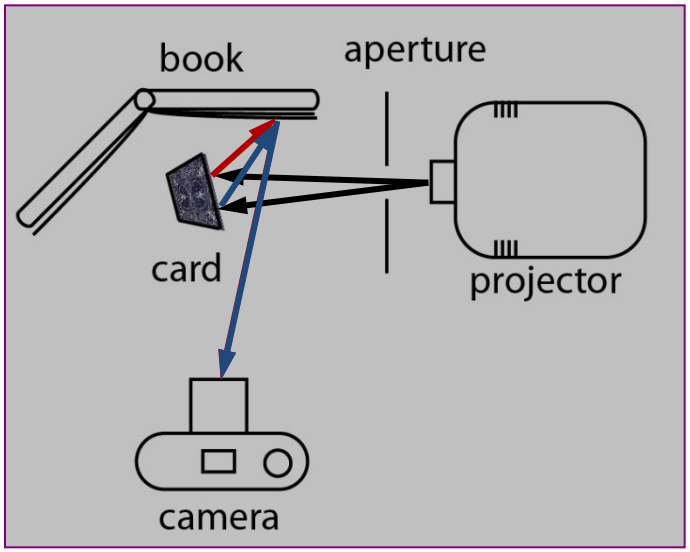
- little inter-reflection
  → sparse matrix
- many inter-reflections
  → dense matrix
- convex object
  → diagonal matrix
- concave object
  → full matrix

Can we create a dual photograph entirely from diffuse reflections?

Dual photography from diffuse reflections



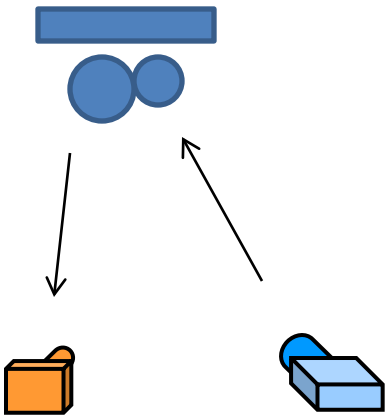
the camera's view



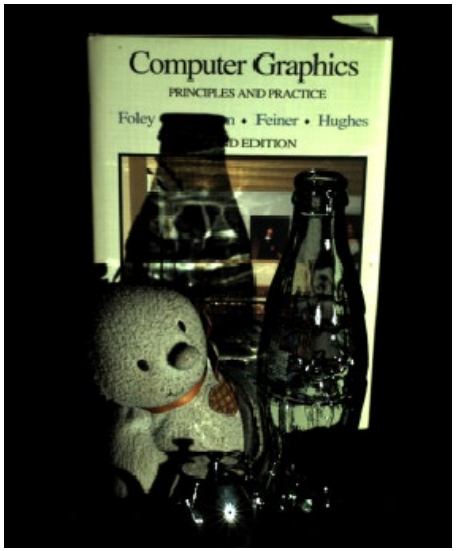


Light Transport Based Methods

- Can encode light (or projector) to camera “transport” in a large matrix T

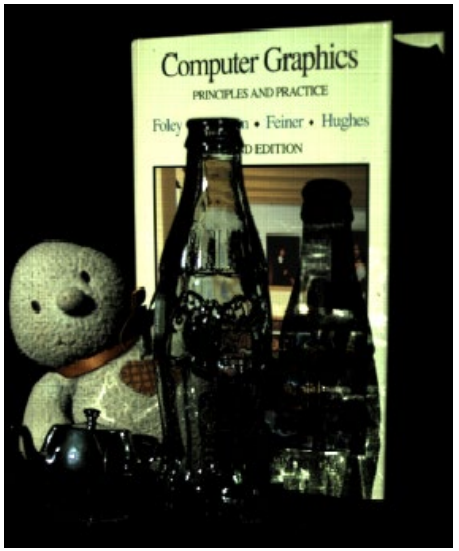


Camera c Projector p



$$\begin{bmatrix} c \end{bmatrix} = \begin{bmatrix} T \end{bmatrix} \begin{bmatrix} p \end{bmatrix}$$

As seen from camera…

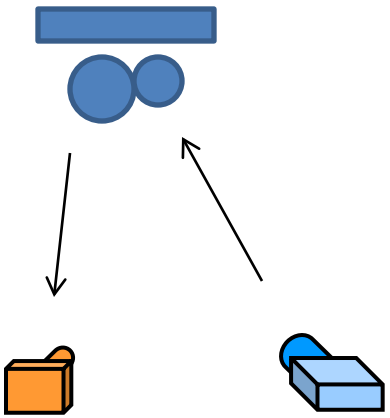


$$\begin{bmatrix} p \end{bmatrix} = \begin{bmatrix} T^t \end{bmatrix} \begin{bmatrix} c \end{bmatrix}$$

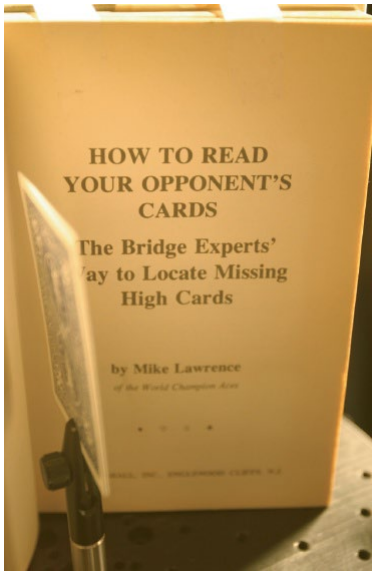
As seen from projector!!!

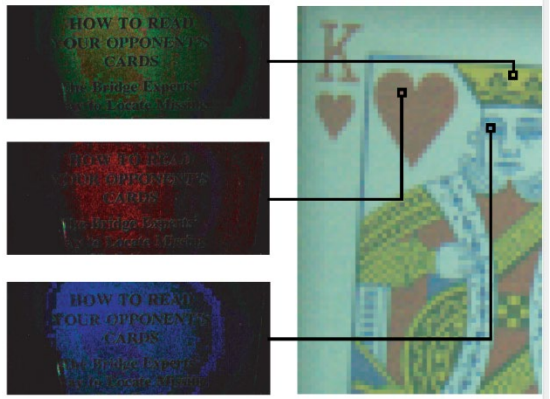
Light Transport Based Methods

- Can encode light (or projector) to camera “transport” in a large matrix T



Camera c Projector p





$$\begin{bmatrix} c \end{bmatrix} = \begin{bmatrix} T \end{bmatrix} \begin{bmatrix} p \end{bmatrix}$$

As seen from camera…

$$\begin{bmatrix} p \end{bmatrix} = \begin{bmatrix} T^t \end{bmatrix} \begin{bmatrix} c \end{bmatrix}$$

As seen from projector!!!

Relighting



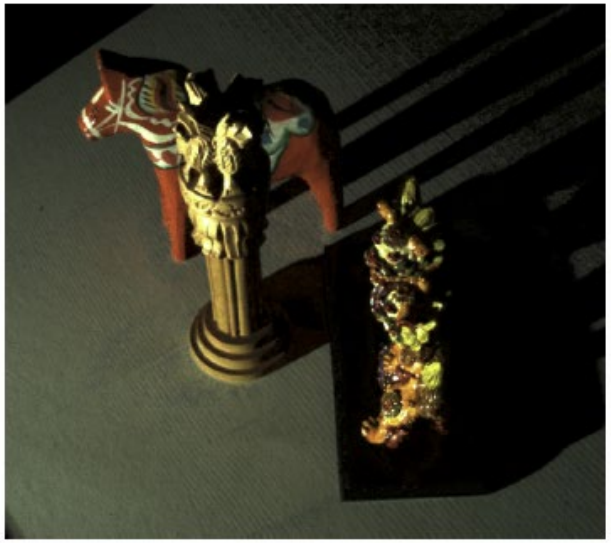


With Dual Photography…

Relighting









With Dual Photography…

Relighting



(a)



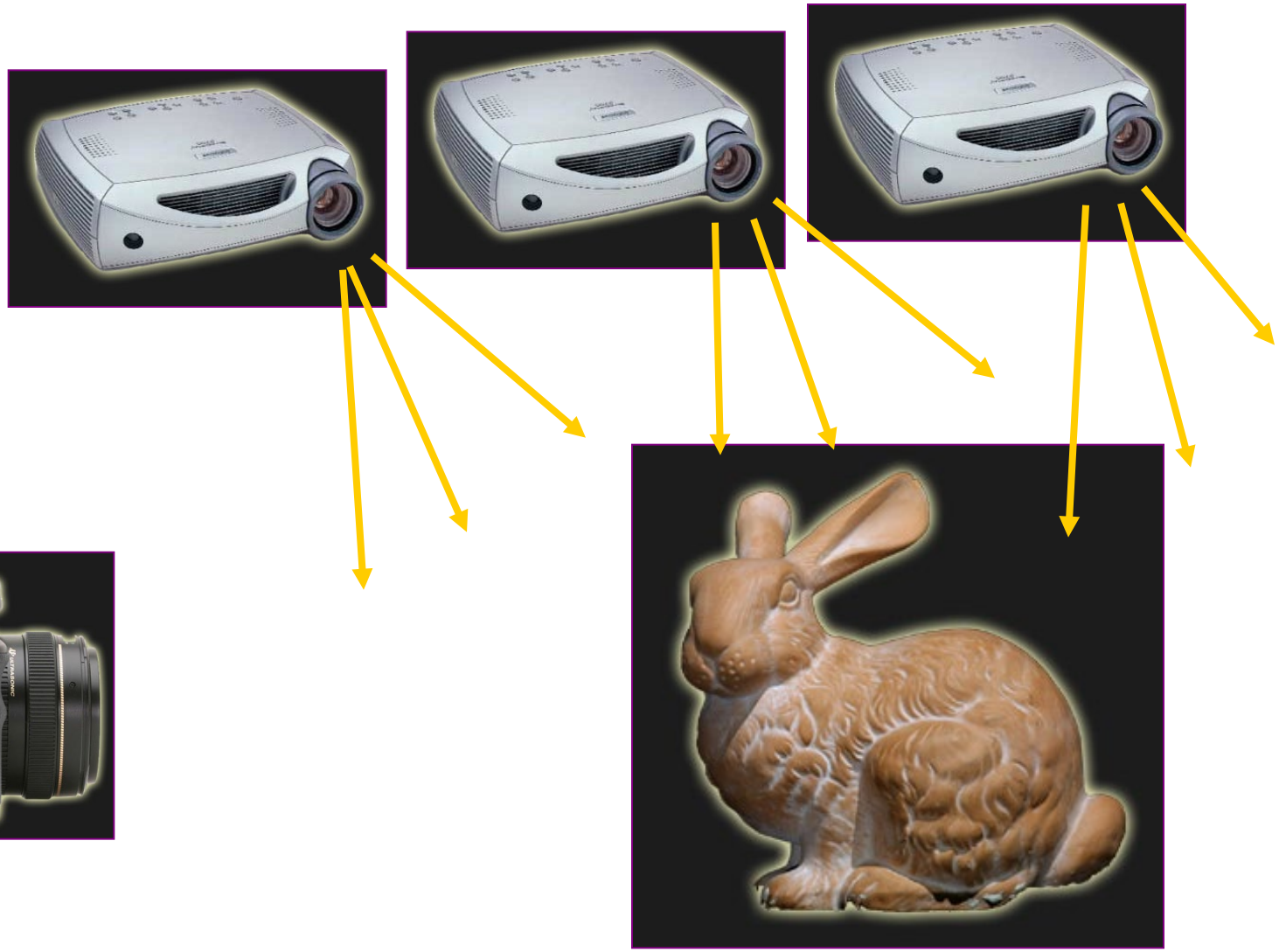
(b)





With Dual Photography…

The 6D transport matrix



The 6D transport matrix











Measuring the 6D transport matrix

projector



camera array







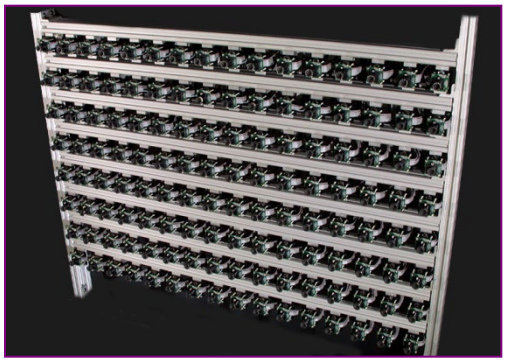
scene

Relighting with complex illumination

projector



camera array



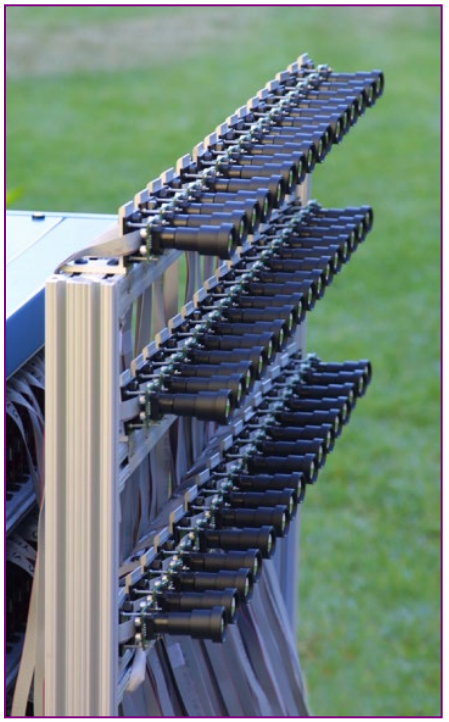


scene

pq x mn x uv

$$\begin{bmatrix} C' \end{bmatrix} = \begin{bmatrix} T^T \end{bmatrix} \begin{bmatrix} P' \end{bmatrix}$$

pq x 1 mn x uv x 1



- step 1: measure 6D transport matrix T
- step 2: capture a 4D light field
- step 3: relight scene using captured light field

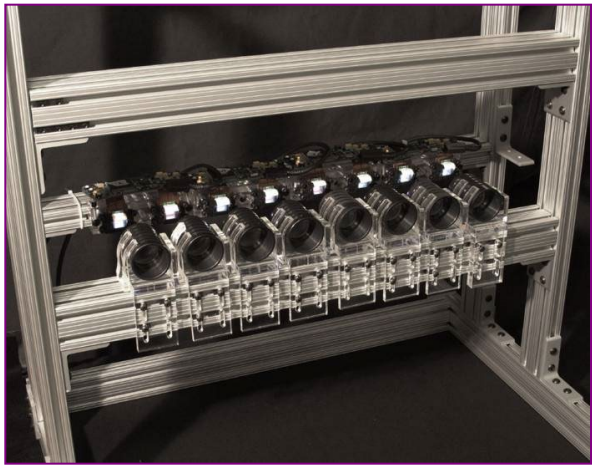
Running time



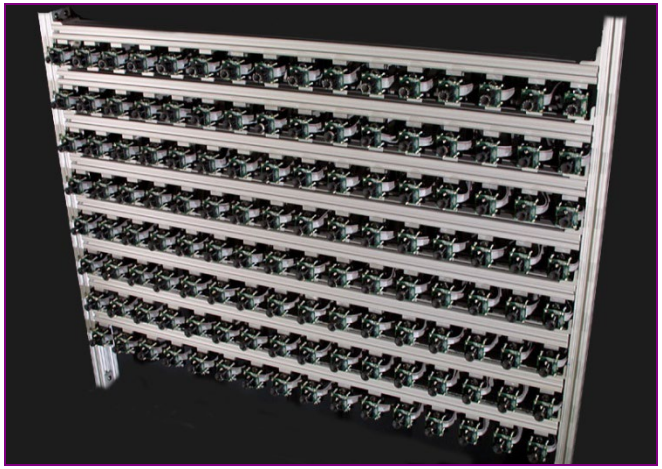
- the different rays within a projector can in fact be parallelized to some extent
- this parallelism can be discovered using a coarse-to-fine adaptive scan
- can measure a 6D transport matrix in 5 minutes

Can we measure an 8D transport matrix?

projector array



camera array





scene

Photon Cameras

- Seeing around corners
  - How to see around corners
  - Velten et al. (from MIT, Ramesh Raskar and more)
  - Uses Photon Cameras

- Here at Purdue…
  - Sotiris Nousias also does work using Photon Cameras