Special Topics:

Image-based Rendering

Computer Graphics
CMU 15-462/15-662

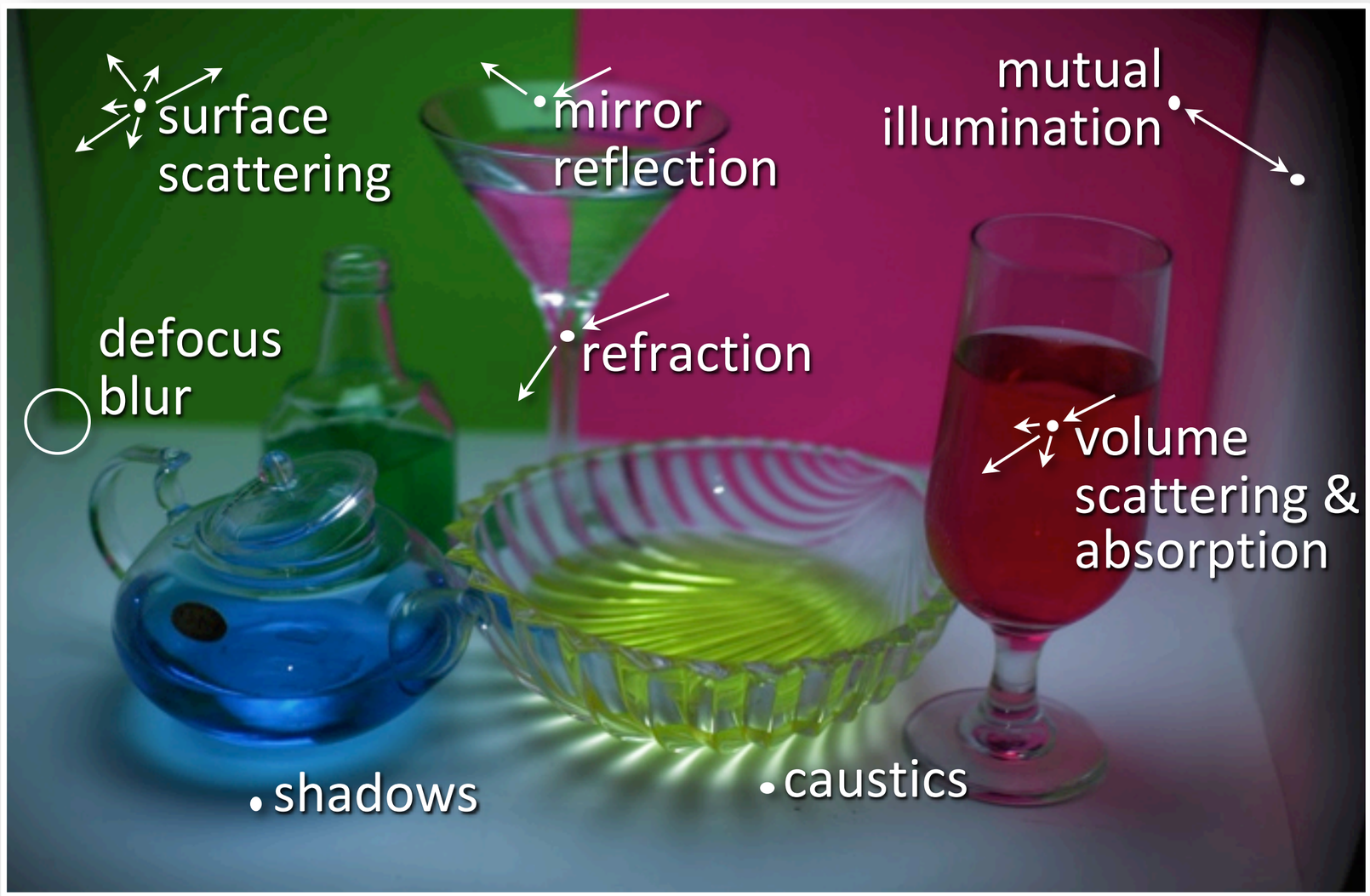
So—why haven't we "solved" graphics yet?

The “Mustache” controversy

Justice League (2017)
Budget: 300 Million USD

Graphics is still hard!

- Creating photorealistic images from scratch takes a lot of effort
- Hard to recreate complex geometry and lighting effects found in photos like this:



IDEA: What about replacing geometry and reflectance models with photos?

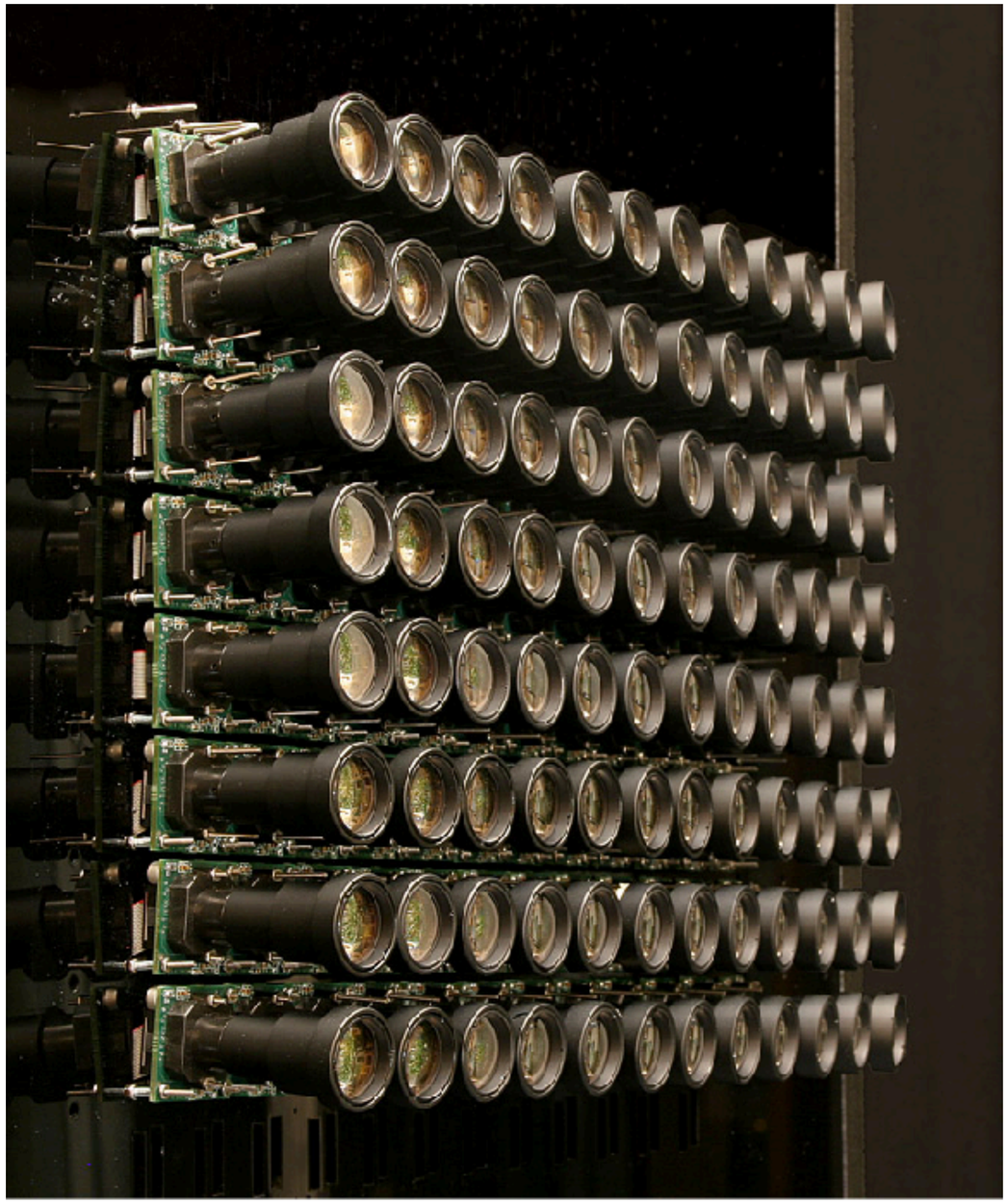
The “Bullet Time” Effect

Bullet Time Effect: Behind the Scenes

The Matrix

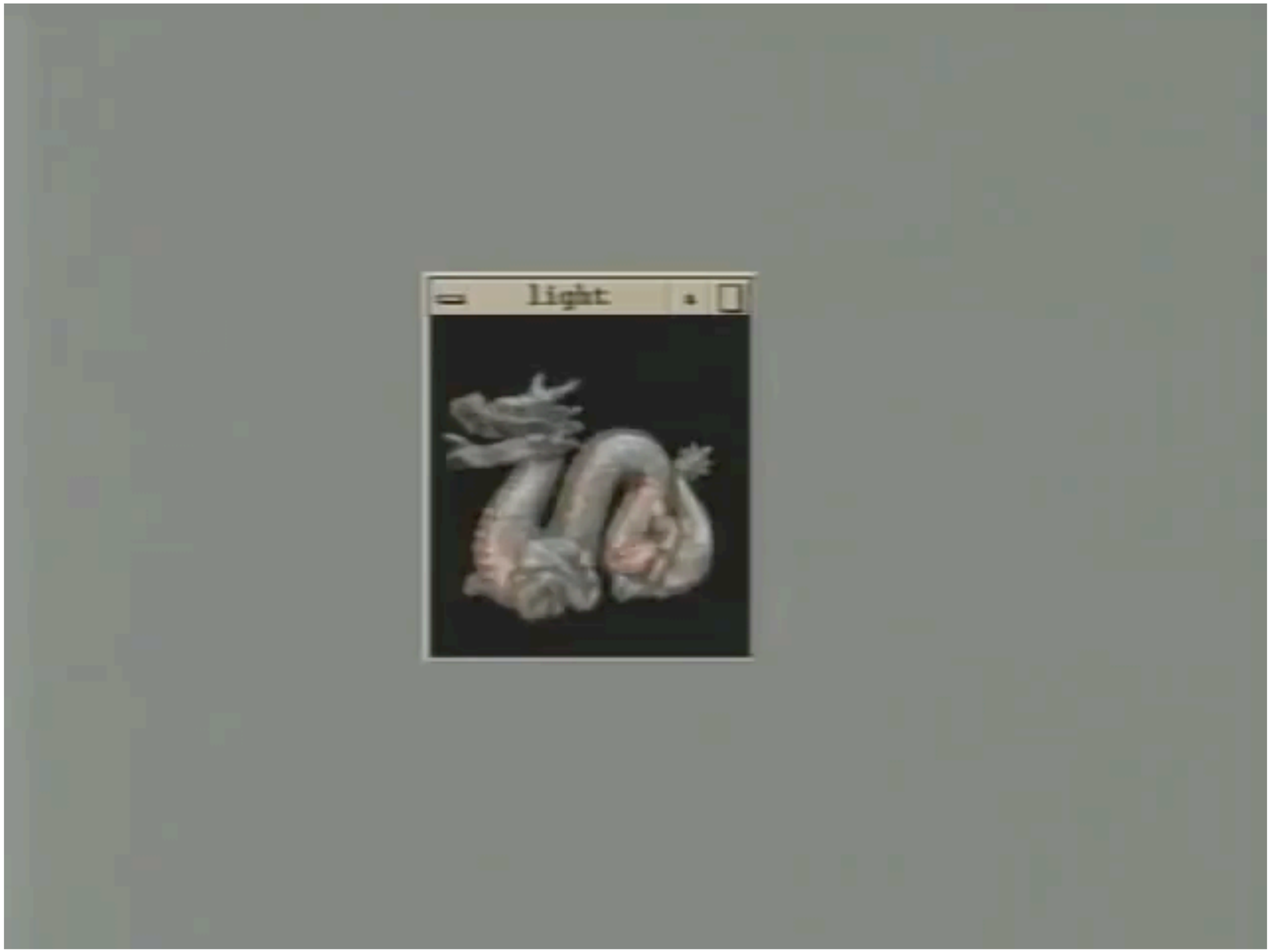
Image-based Rendering

- Skip modeling geometry and material reflectance properties
- Instead, capture sets of photos (e.g., with different viewpoints or under different illumination) that can be used to render <u>novel</u> images of a scene
  - light field rendering: *photorealistically* change camera viewpoint or other parameters (e.g., focus)
  - image-based relighting: generate *photorealistic* images under synthetic illumination conditions



http://graphics.stanford.edu/projects/lightfield/

Light Field Rendering (with synthetic images)

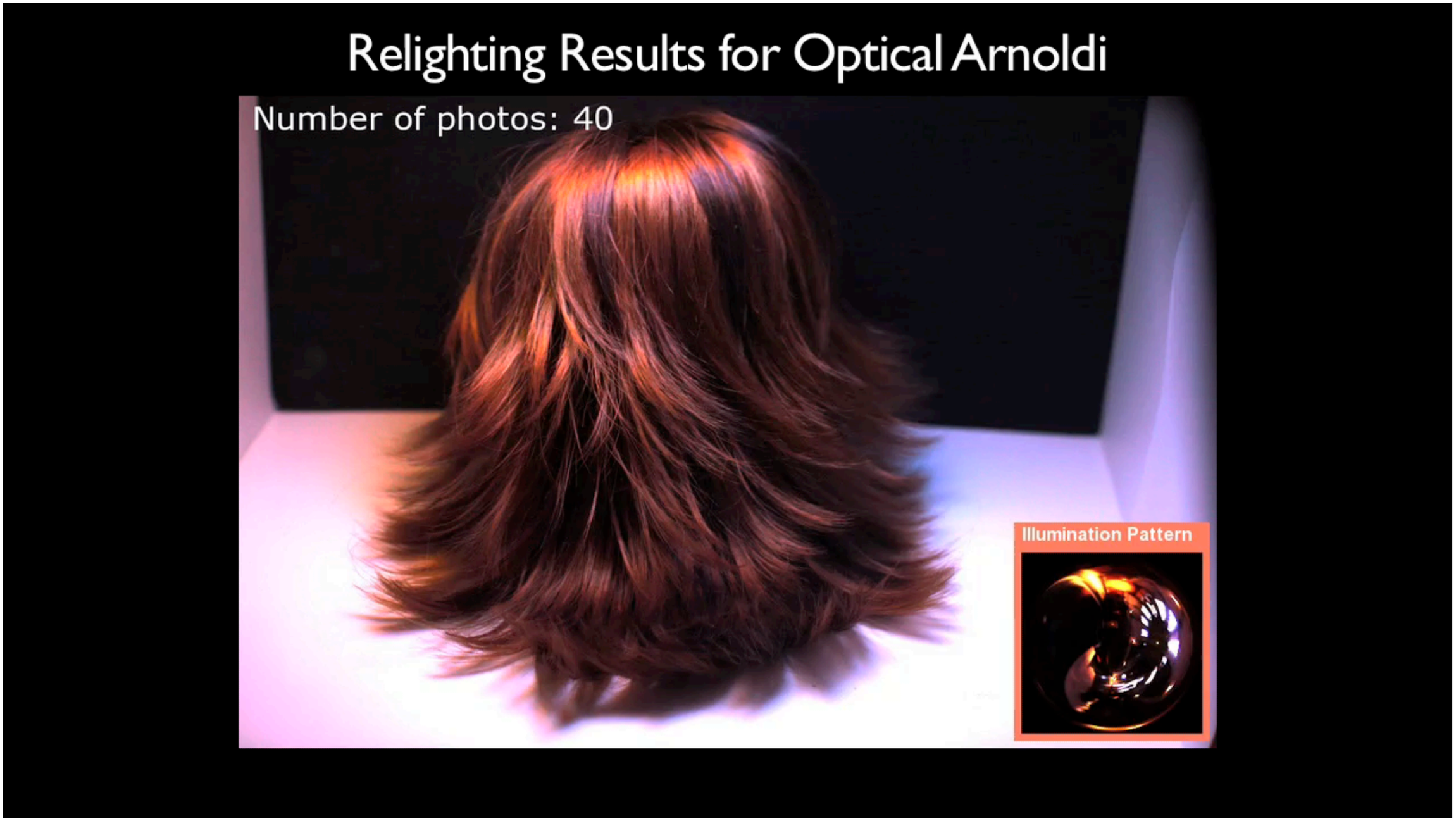


"Light Field Rendering", Mark Levoy and Pat Hanrahan

Light Field Rendering (with real images)

Lytro Illum Camera

Image-based Relighting



"Optical Computing for Fast Light Transport Analysis", O'Toole and Kutulakos

Image-based Relighting

Observation #1

= 2 x

photo taken with light source emitting a x b Watts =
a x (photo taken with light source emitting b Watts)

Image-based Relighting

Observation #2

=

+

photo taken under two light sources =
sum of photos taken under each source individually

Image-based Relighting

Observation #2

photo taken under two light sources =
sum of photos taken under each source individually

Image-based Relighting

Observation #2

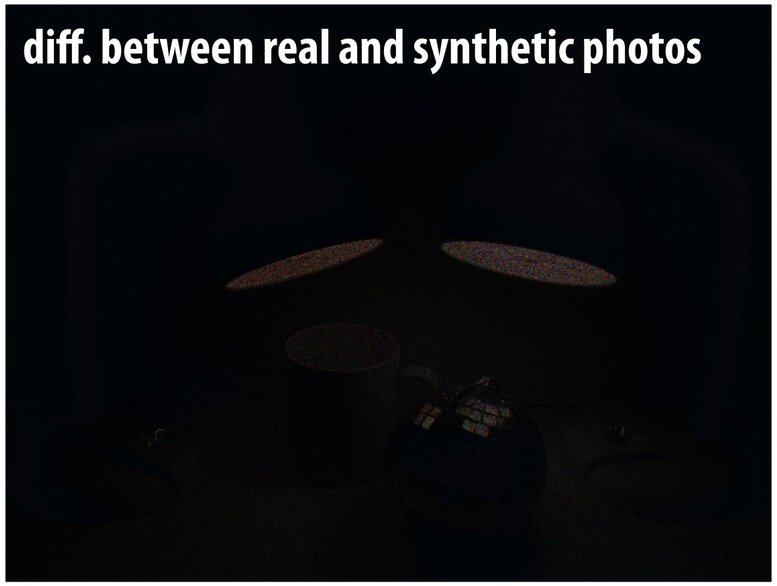


photo taken under two light sources =
sum of photos taken under each source individually

Image-based Relighting

- Simple set of rules can be used to predict the appearance of a scene based on previously-captured images:
  - photo taken with light source emitting a x b Watts = a x (photo taken with light source emitting b Watts)
  - photo taken under two light sources = sum of photos taken under each source individual
- We can come up with a complete set of "rules" for working with images u, v, and w (all lit by different light sources):

For all vectors $\mathbf{u}, \mathbf{v}, \mathbf{w}$ and scalars a, b:

- $\mathbf{u} + \mathbf{v} = \mathbf{v} + \mathbf{u}$
- $\mathbf{u} + (\mathbf{v} + \mathbf{w}) = (\mathbf{u} + \mathbf{v}) + \mathbf{w}$
- There exists a *zero vector* "$\mathbf{0}$" such that $\mathbf{v} + \mathbf{0} = \mathbf{0} + \mathbf{v} = \mathbf{v}$
- For every $\mathbf{v}$ there is a vector "$-\mathbf{v}$" such that $\mathbf{v} + (-\mathbf{v}) = \mathbf{0}$
- $1\mathbf{v} = \mathbf{v}$
- $a(b\mathbf{v}) = (ab)\mathbf{v}$
- $a(\mathbf{u} + \mathbf{v}) = a\mathbf{u} + a\mathbf{v}$
- $(a + b)\mathbf{v} = a\mathbf{v} + b\mathbf{v}$

(Looks familiar!)

Image-based Relighting

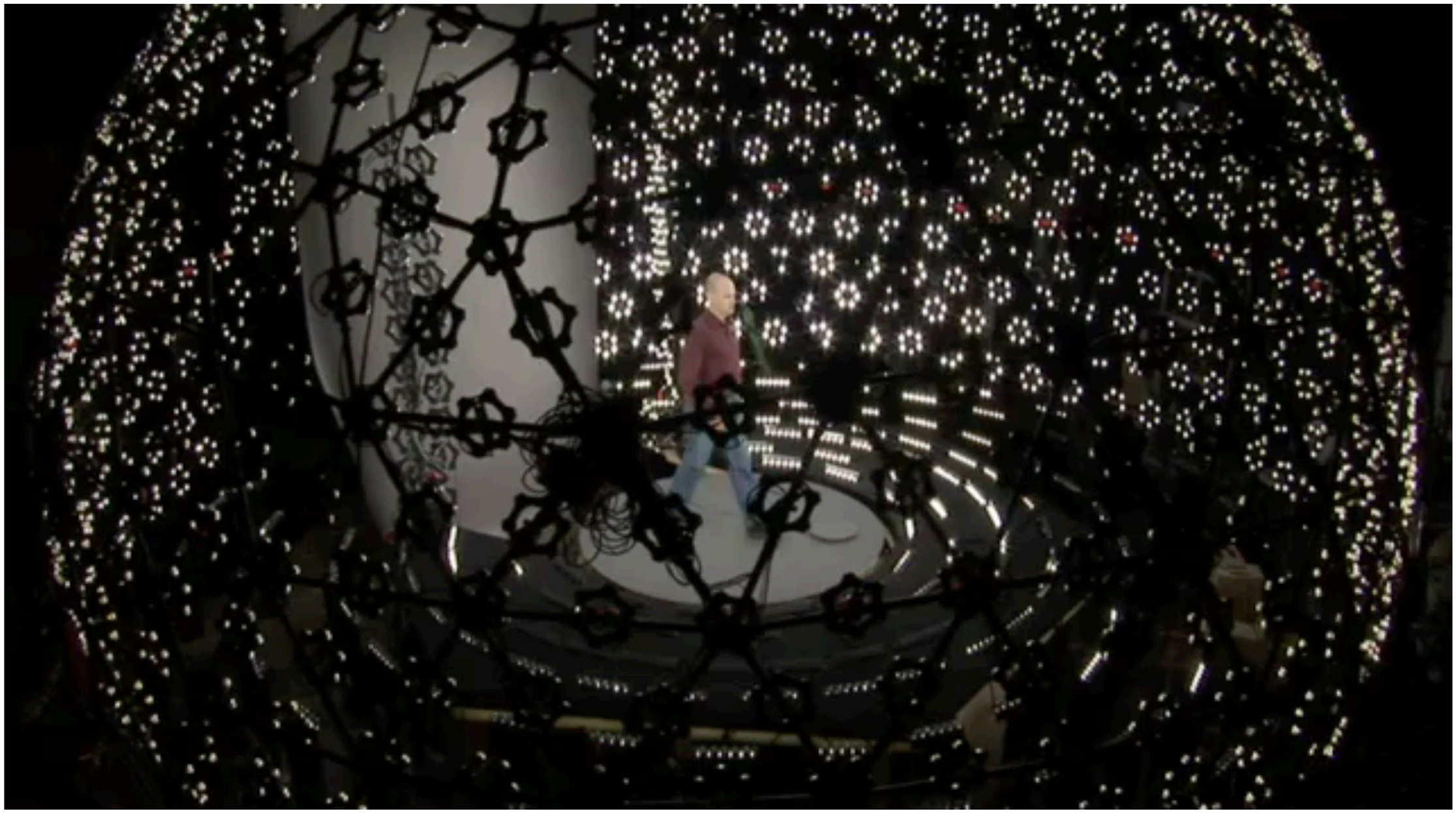
Generate new photos by computing weighted combination of images!

(e.g., adding the red channel of image 1 and the blue channel of image 2)

Light Stage 1 from USC: ICT

Source: http://www.pauldebevec.com/Research/LS/

Light Stage 6 from USC: ICT



Source: http://vgl.ict.usc.edu/Research/RHL/

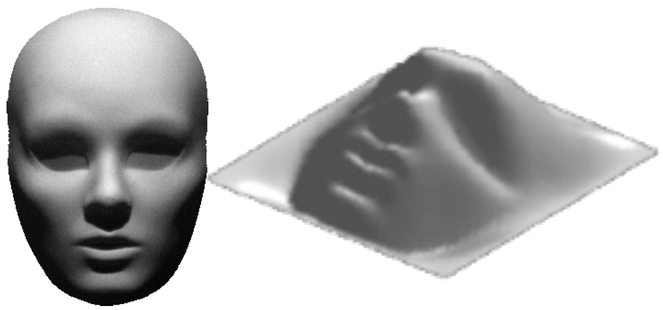
Mobile Light Stage from USC: ICT

Source: http://gl.ict.usc.edu/Research/PresidentialPortrait/

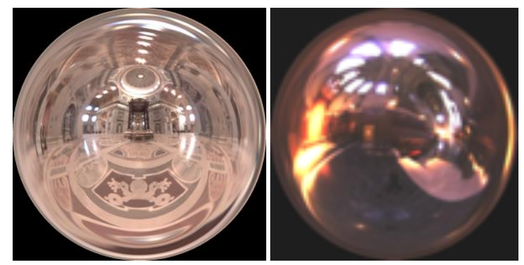
CG Avatars from Facebook Reality Labs

Want to learn more?

- **16-823: Physics-based Methods in Vision (a.k.a. Appearance Modeling**
  - **Spring 2020: Tuesdays & Thursdays, 1:30pm - 2:50pm**

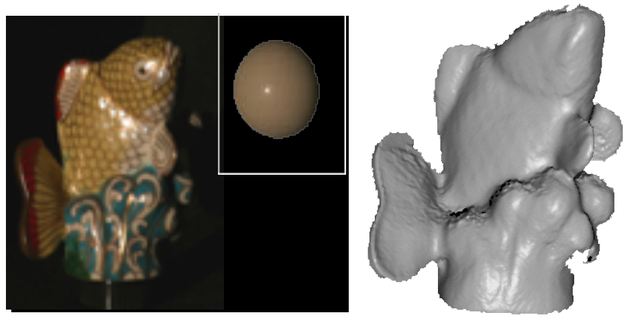


Shape from Shading



Illumination Estimation

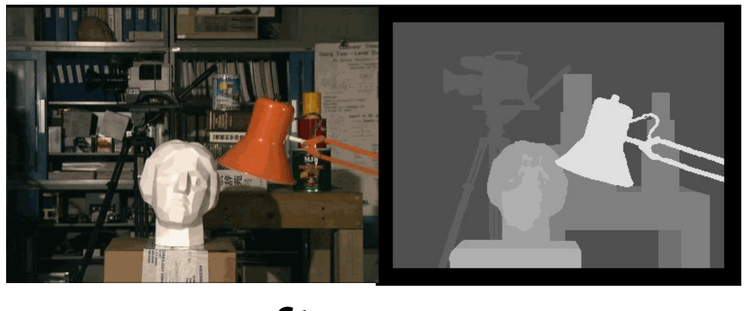
Texture Modeling



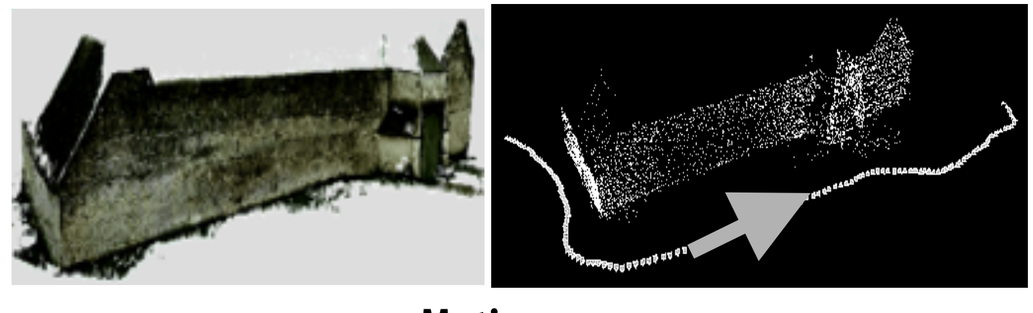
Photometric Stereo

Color Constancy

Reflection Separation



Stereo



Motion