CS63500
Capturing, Modeling, and Rendering 3D Structures

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Purdue University

Who?

- Daniel G. Aliaga

  http://www.cs.purdue.edu/~aliaga and aliaga@cs.purdue.edu
  Associate Professor of CS doing Graphics
  Doctorate in Graphics
  Master's in Graphics
  Bachelors in Graphics
  High School Degree doing graphics/robots/science
  1980 (TRS80 Model I)

  Then: http://www.youtube.com/watch?v=3yuqdC8Id48)
  http://thinkingscifi.files.wordpress.com/2012/12/starwars-graphics.png
  Now: http://www.youtube.com/watch?v=QAEkuVgt6Aw

- CGVLAB

  http://www.cs.purdue.edu/cgvlab

- You?

http://www.cs.purdue.edu/homes/aliaga

- Topic:
  - Covers fundamental problems and challenges encountered when capturing, modeling, and rendering 3D structures and objects.
  - Covers material in computer graphics, computer vision, and deep visual computing (*aka subsets of computational imaging, computational cameras, computational displays*)
- Goal:
  - To bring students up to speed in latest methods (research)
  - To enable students to develop new and improved approaches

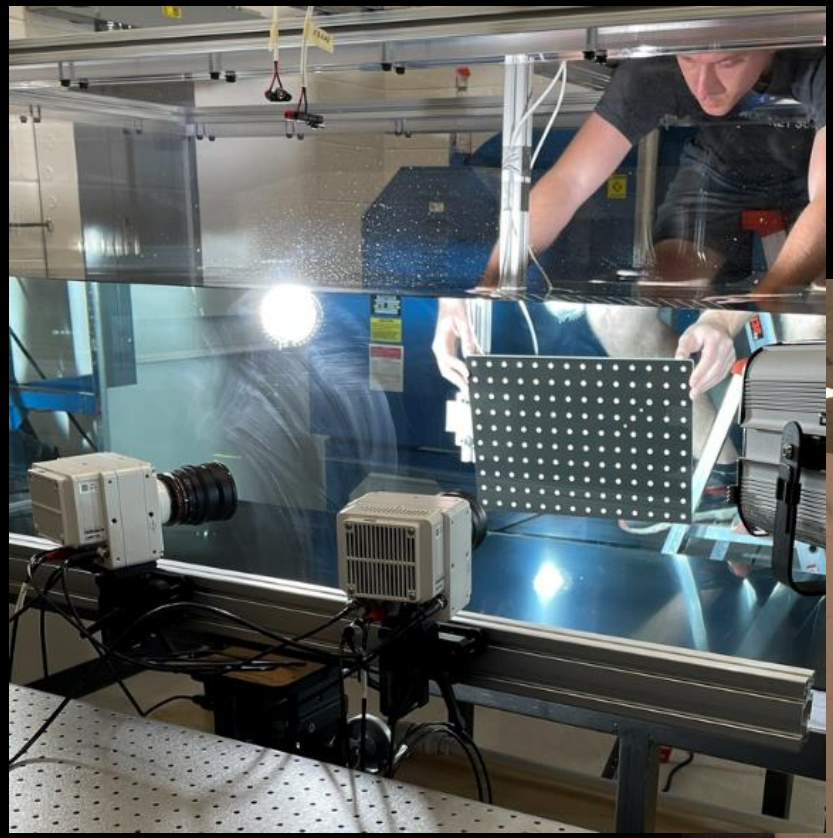
Syllabus

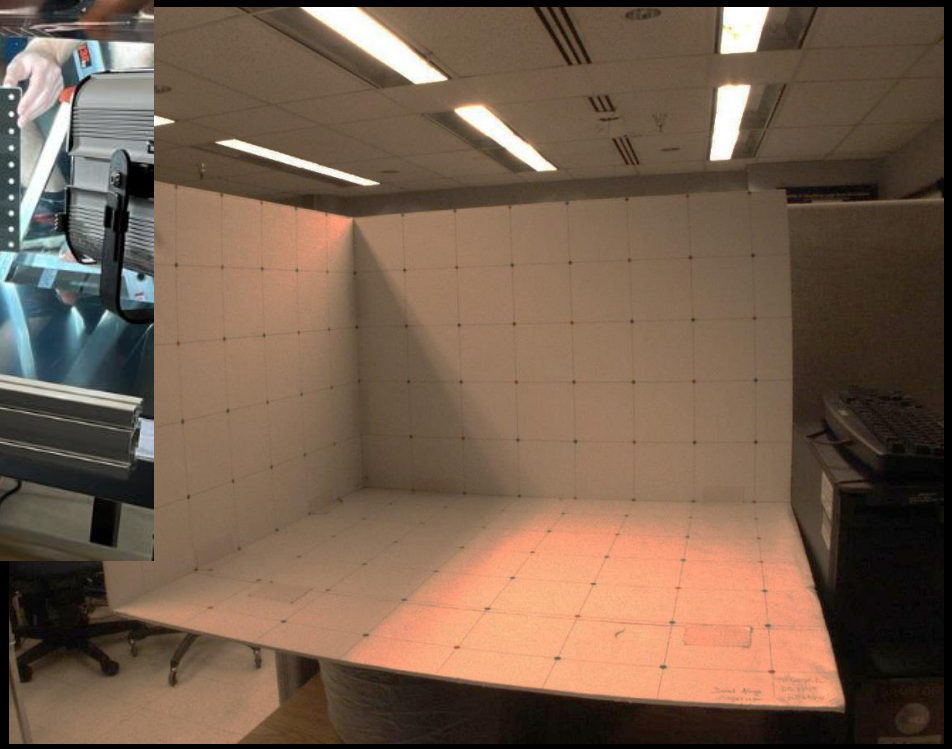
- Toolbox
  - Images, optimization/minimization, stochastic, HC, DL
- Camera Calibration
  - e.g.,g Tsai, Zhang, Bouguet's methods
- Passive Acquisition
  - e.g., stereo, self-calibration, pose-free
- Active Acquisition
  - e.g., photometric, structured light, time of flight, lasers, SPAD
- Light-Transport based Methods
  - e.g., Lightfields, Inverse Transport, NeRFs, 3DGS
- Computational Images and Cameras
  - e.g., single-image reconstruction, re-illumination, coded aperture
- Computational Displays /Optics
  - e.g., 3D displays, spatial augmented reality, inverse optics, inverse blur
- Deep Visual Computing
  - diffusion models, GANS for content generation

Workload

- 3 “short warm-up” assignments
- In-class presentations (lit. review, mid-project)
- Final project (demo/presentation)
  - Suitable for conference or journal submission…

Camera Calibration





Stereo

Photometric Acquisition

- Given three pictures from same camera viewpoint but three illumination directions…

Photometric Acquisition

- Can reconstruct normal and from normal the geometry…

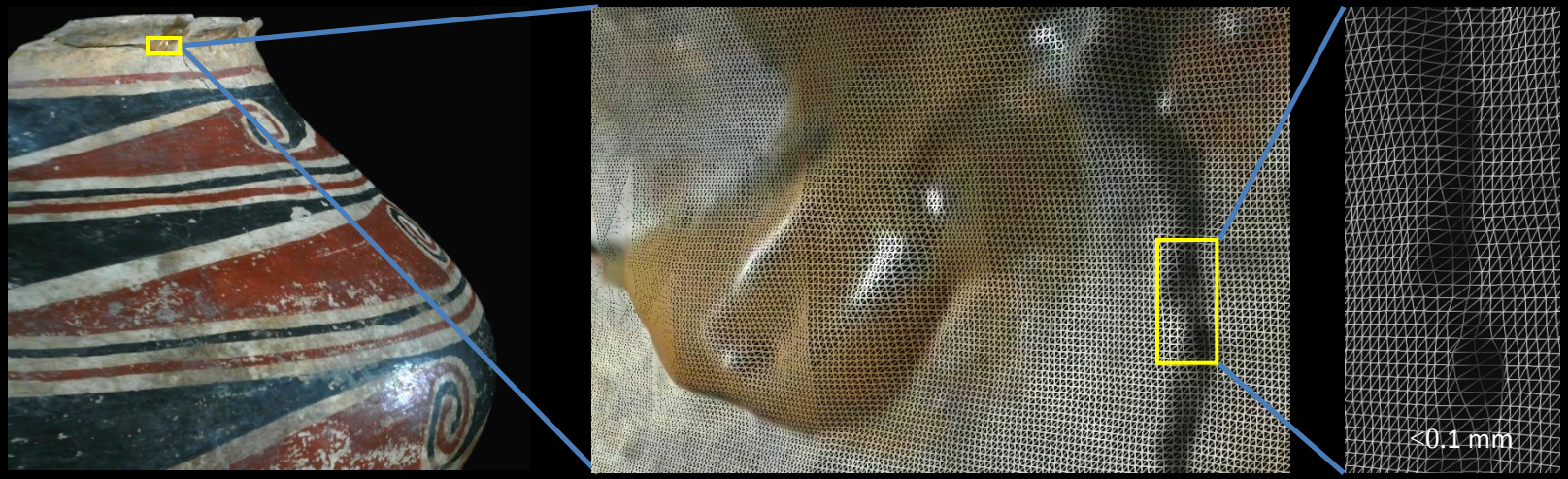
Photometric Acquisition

- Can reconstruct normal and from normal the geometry…**kinda works…**

Active/Passive Reconstruction

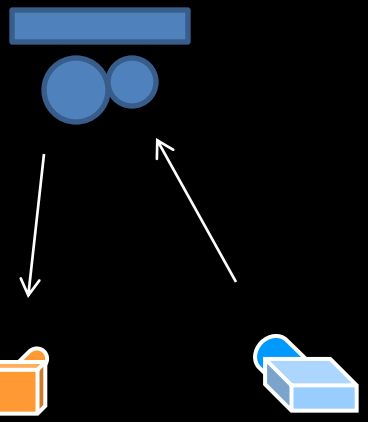
Photogeometric Acquisition

To provide an easy-to-use and high-resolution acquisition platform for deployment



Light Transport Based Methods

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



Camera c Projector p

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

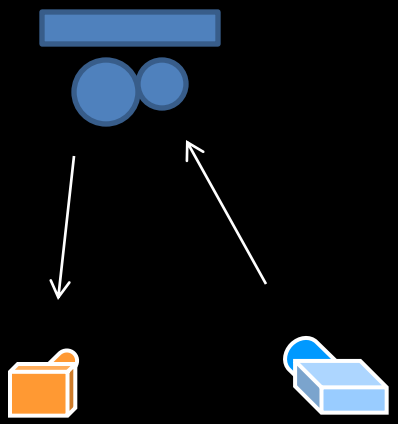
As seen from camera…

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

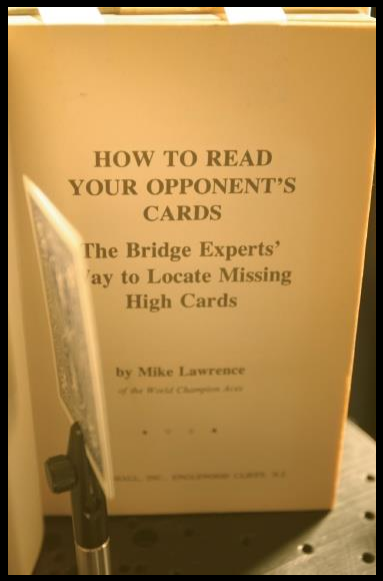
As seen from projector!!!

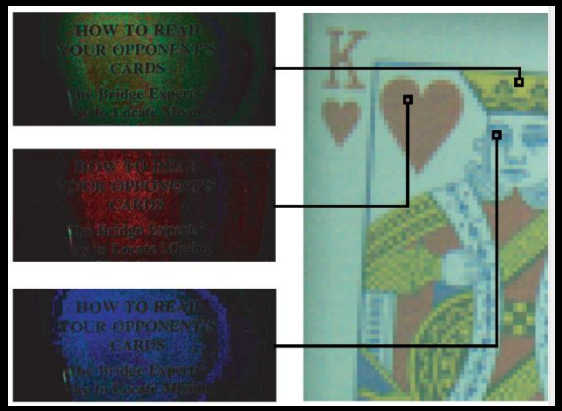
Light Transport Based Methods

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



Camera c Projector p





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As seen from camera…

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

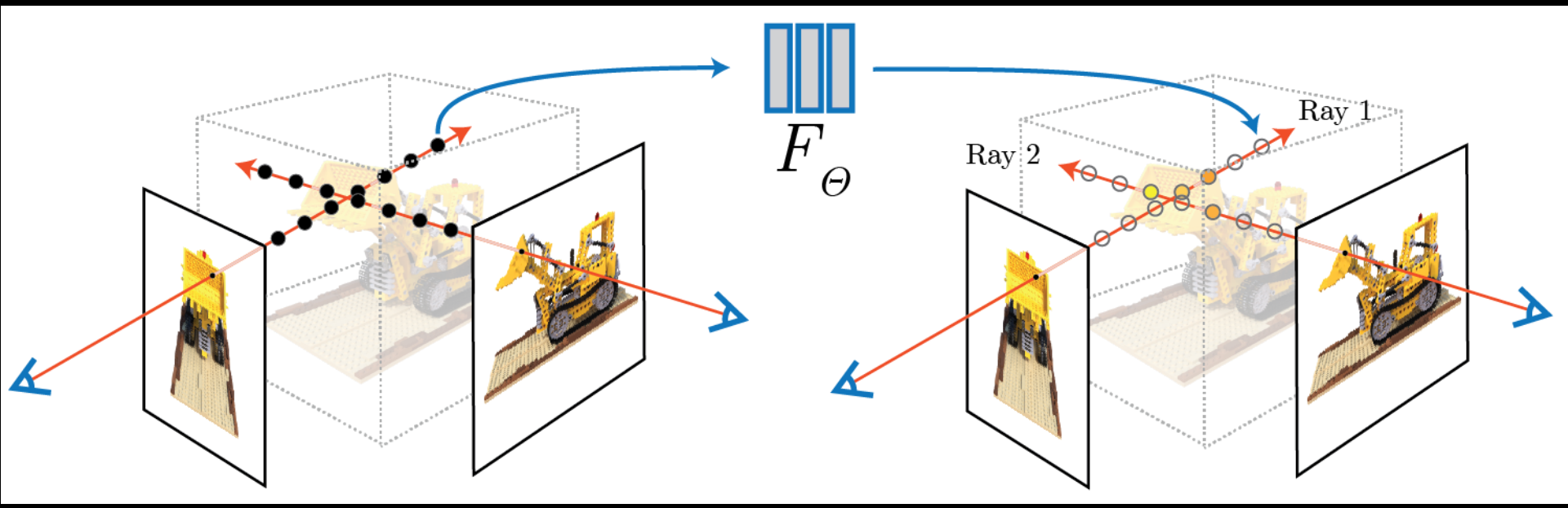
As seen from projector!!!

Light in Slow Motion

- https://www.youtube.com/watch?v=Y_9vd4HWIVA

NERF

- Neural Radiance Field
  - Deep learning version of lightfields



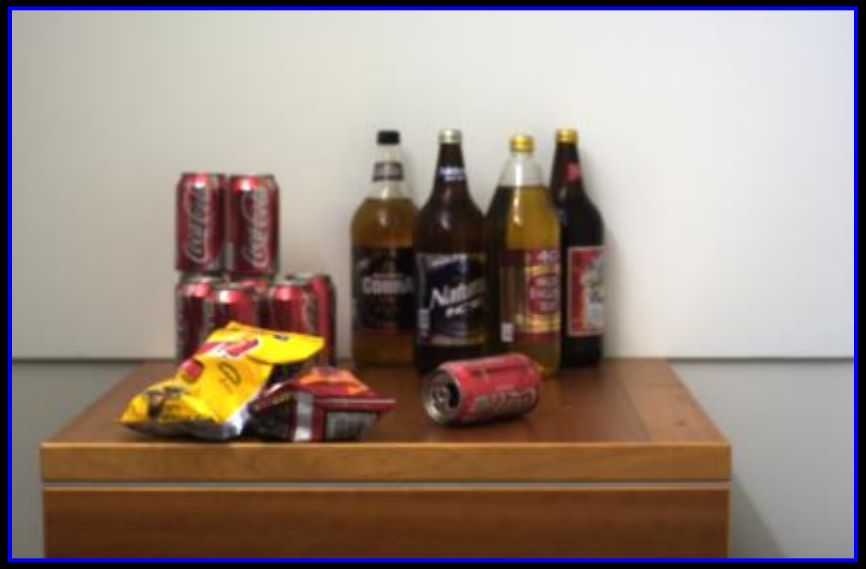
Computational Imaging/Cameras

Voila!

Coded Aperture Deblurring

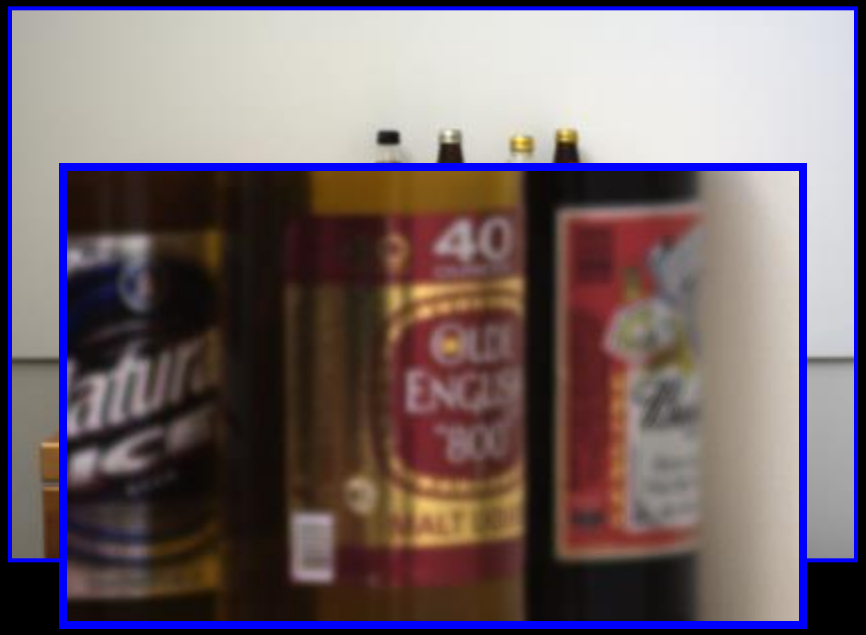
Output #1: Depth map

Single input image:

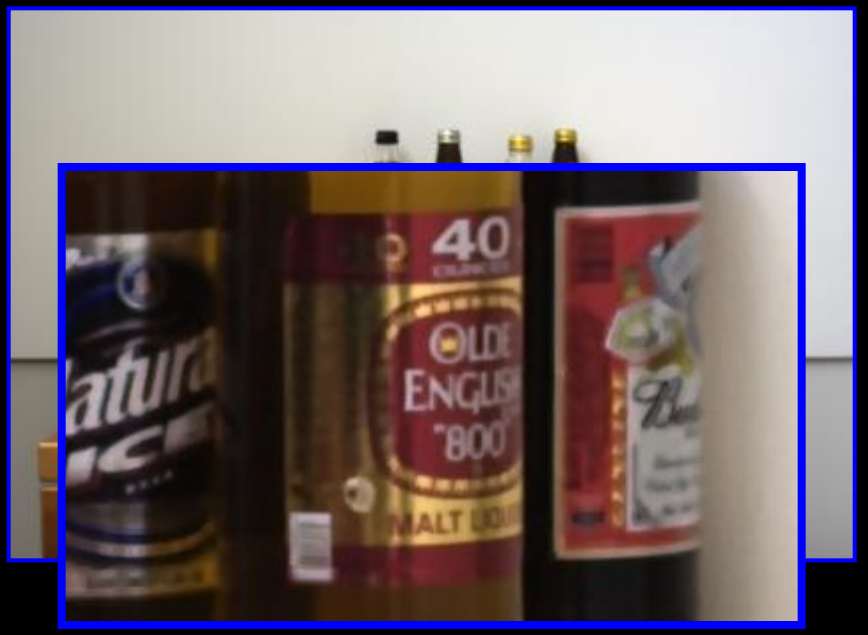


Output #1: Depth map

Single input image:



Output #2: All-focused image

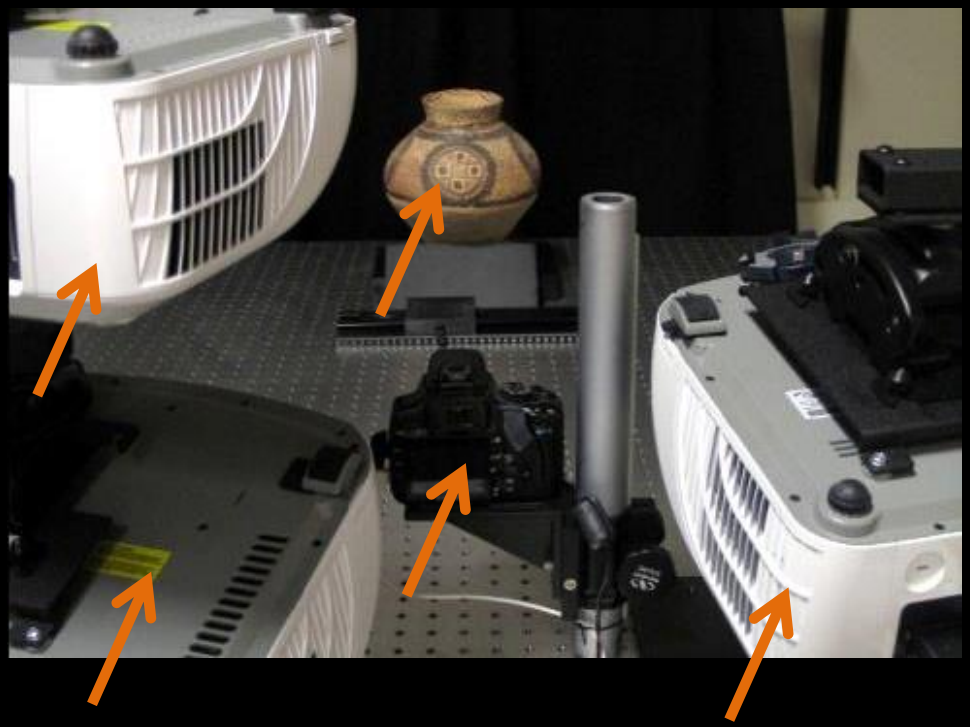


Rectified Crop

Deblurred Result

Computational Displays: Spatial Augmented Reality

- Optoma EP910 projectors
- Canon Digital Rebel XTi 10MP camera
- Object
- 3.0 GHz multicore PC



Computational Displays: Spatial Augmented Reality

- Enable visual restoration of damaged and historically significant objects without needing to touch or alter them

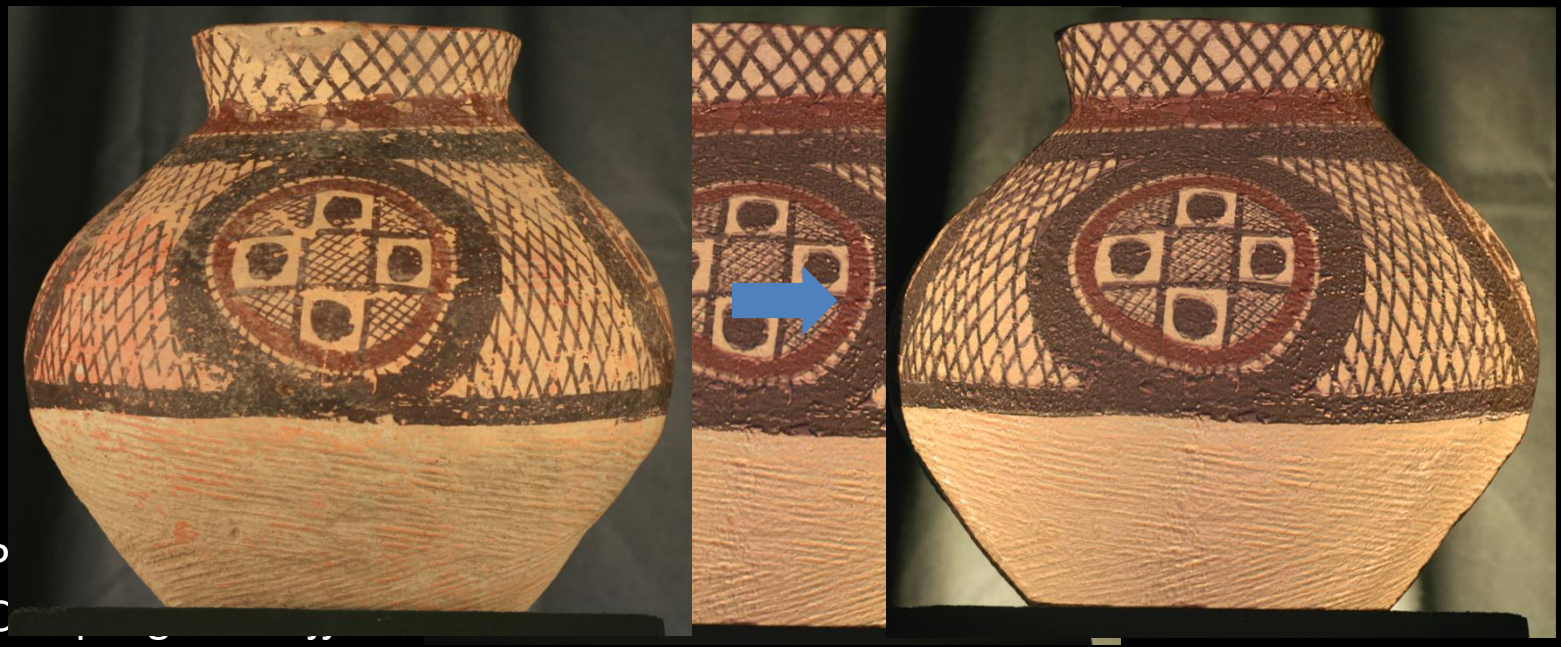


Photo Before Restoration

Photo After Restoration

Computational Displays: Spatial Augmented Reality

- Mexican pot (genuine) from the Casas Grandes Cultural Region (1200-1425 A.D.)

photo of original object

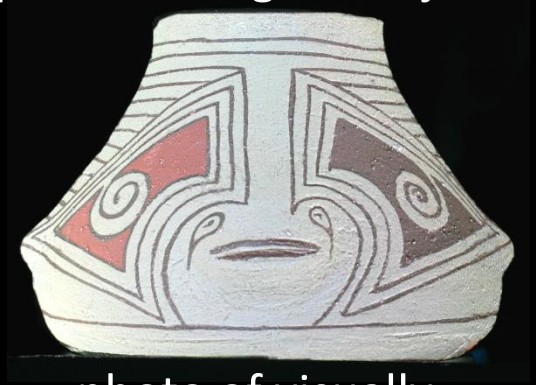


photo of visually compensated object

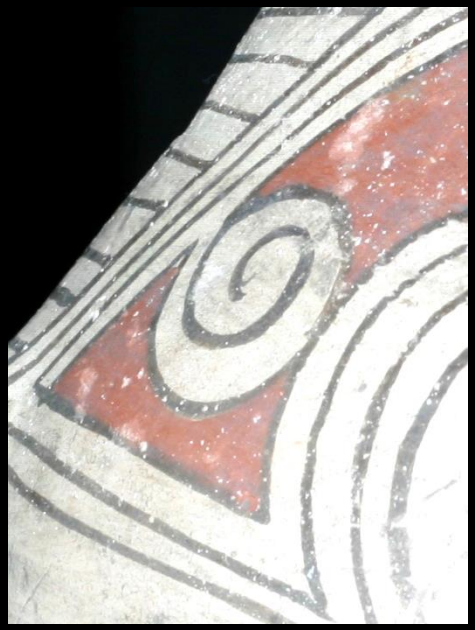


photo of original object

photo of visually compensated object

Computational Displays: Spatial Augmented Reality

Computational Displays

- http://gl.ict.usc.edu/Research/3DDisplay/

Inverse/Computational Optics

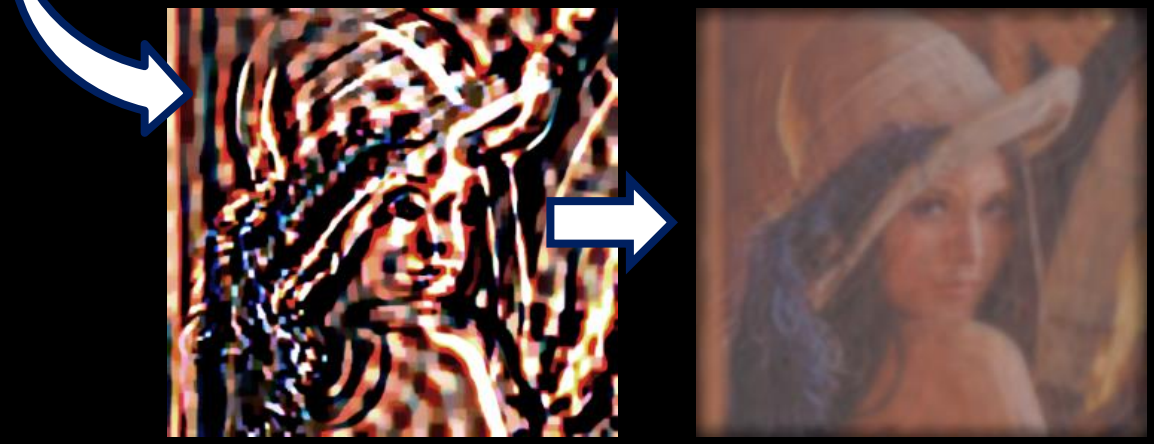
- Some deblurring approaches:
  - Inverse Filter
  - Wiener Filter
  - Lucy Richardson
  - And more!

Inverse/Computational Optics

- Family of methods that “prevent” blurring…

Original

Captured Original



Precorrected

Captured Precorrected

Inverse/Computational Optics

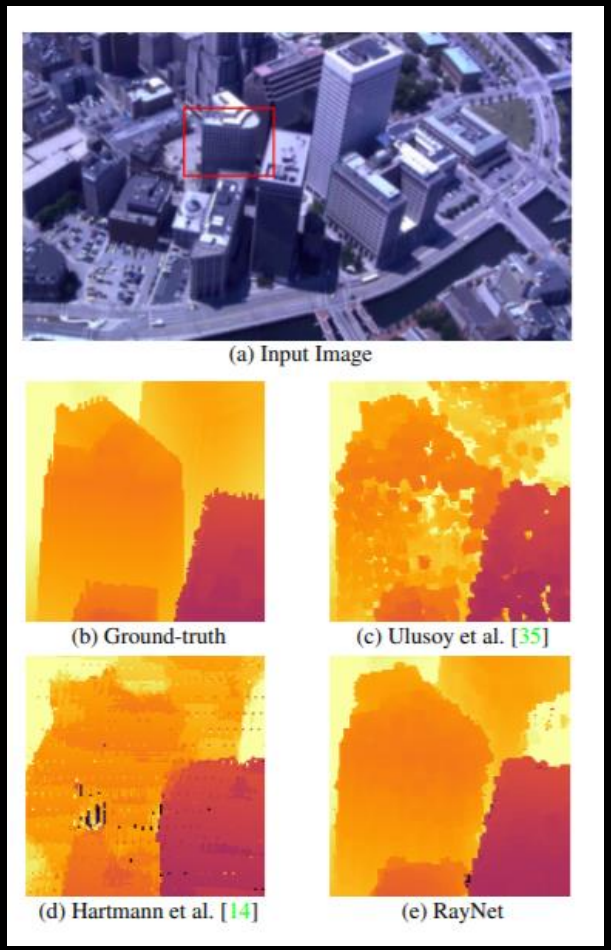
- Family of methods that “prevent” blurring…
  - Defocus blur
  - Motion blur
  - Projector blur
  - Question:
    - Are two superimposed blurry images better than one blurry?

Deep Learning and Graphics

- Fundamentals of these and use in graphics/vision
  - CNN
  - GAN
  - RNN
  - GNN
  - Diffusion Models

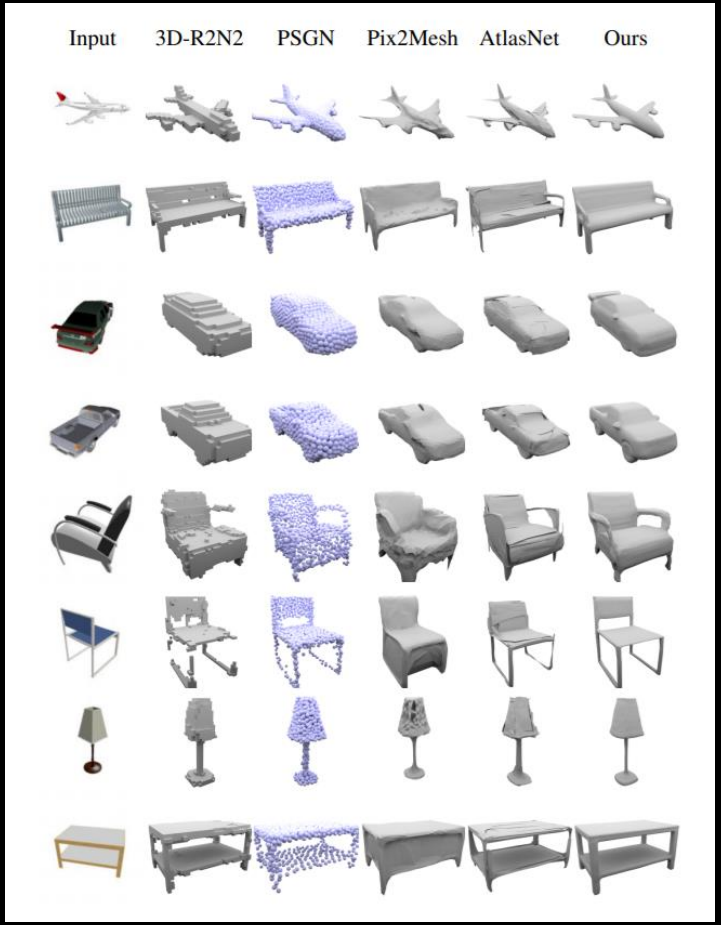
Deep Learning and Graphics

- RayNet: volumetric 3D reconstruction



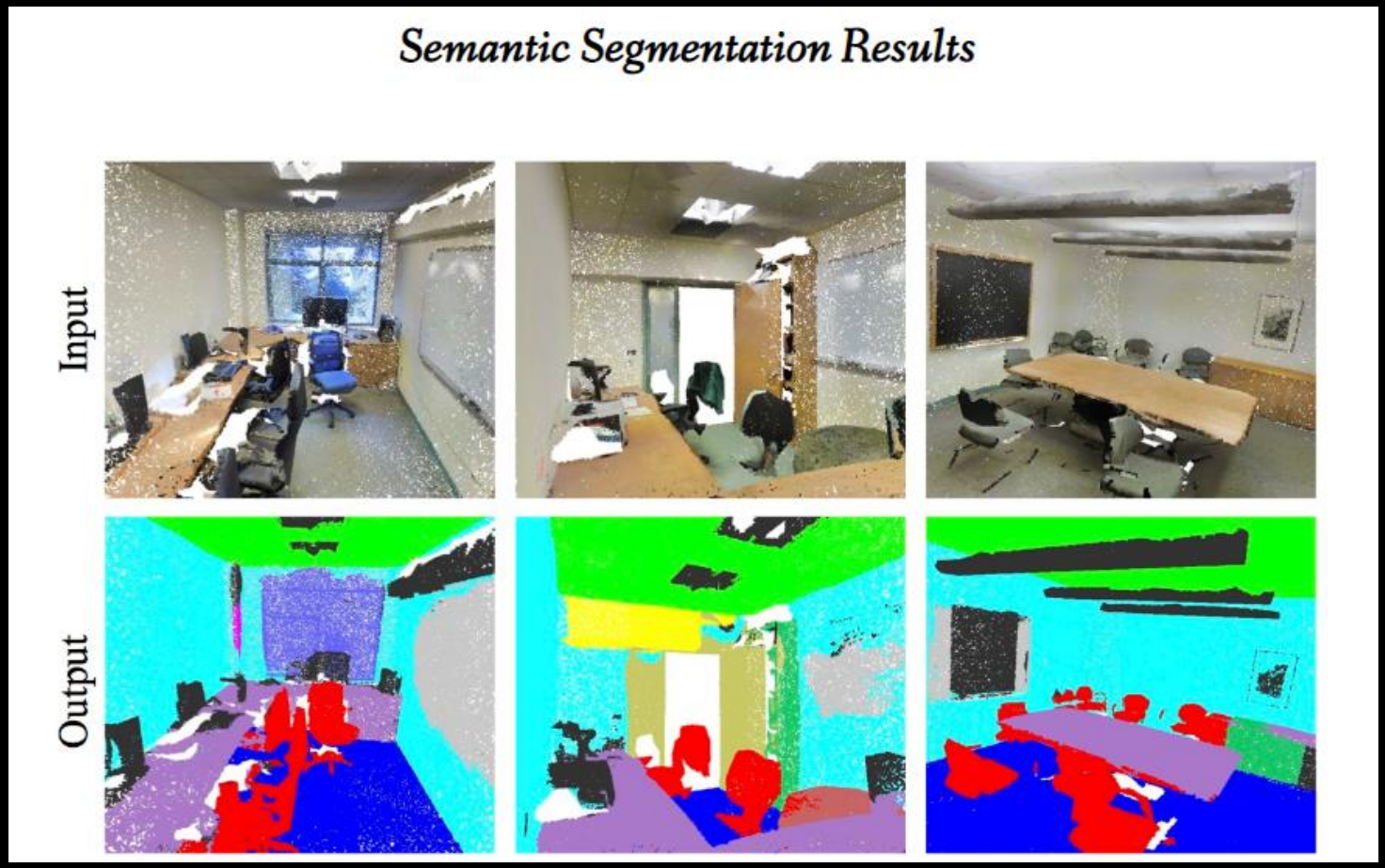
Deep Learning and 3D Reconstruction

- OccNet: occupancy-based reconstruction



Deep Learning and 3D Reconstruction

- Semantic Segmentation



Questions?