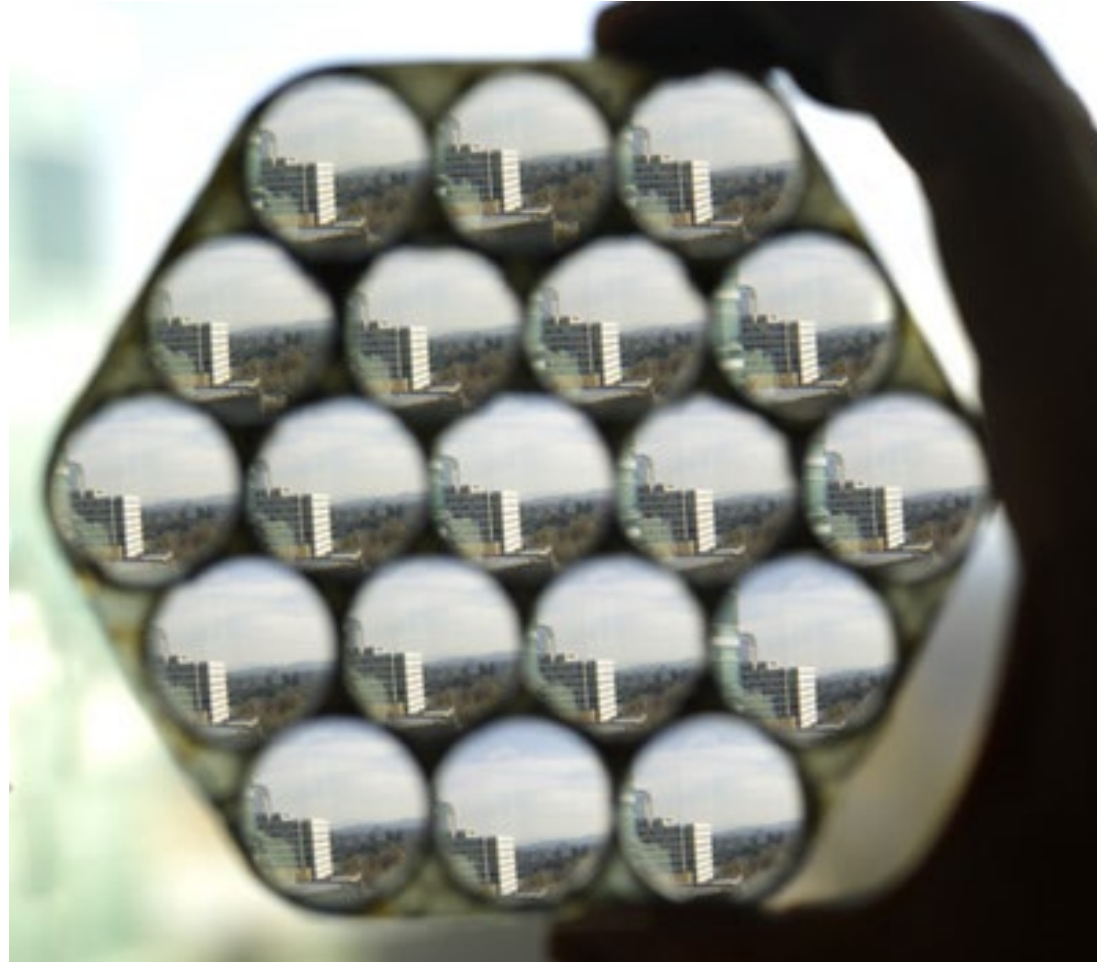


Wrap-up and discussion



15-463, 15-663, 15-862
Computational Photography
Fall 2023, Lecture 20

Course overview

- | | | |
|---------------------------------------|---|-------------------|
| 1. Photographic optics and pipeline. | ← | Lectures 2 – 4. |
| 2. Exposure, HDR, and noise. | ← | Lectures 5 – 7. |
| 3. Color and image editing. | ← | Lectures 8 – 10. |
| 4. Focus and coded photography. | ← | Lectures 11 – 13. |
| 5. Radiometry and photometric stereo. | ← | Lectures 14 – 15. |
| 6. Geometry and stereo. | ← | Lectures 16 – 18. |
| 7. Computational light transport. | ← | Lectures 19 – 21. |

Photographic optics and pipeline

- pinhole and lens cameras
- lenses and other optical elements
- paraxial optics
- aperture
- image processing pipeline



Exposure, HDR, and noise

- exposure control
- high-dynamic-range imaging
- radiometric calibration
- noise modeling
- noise calibration



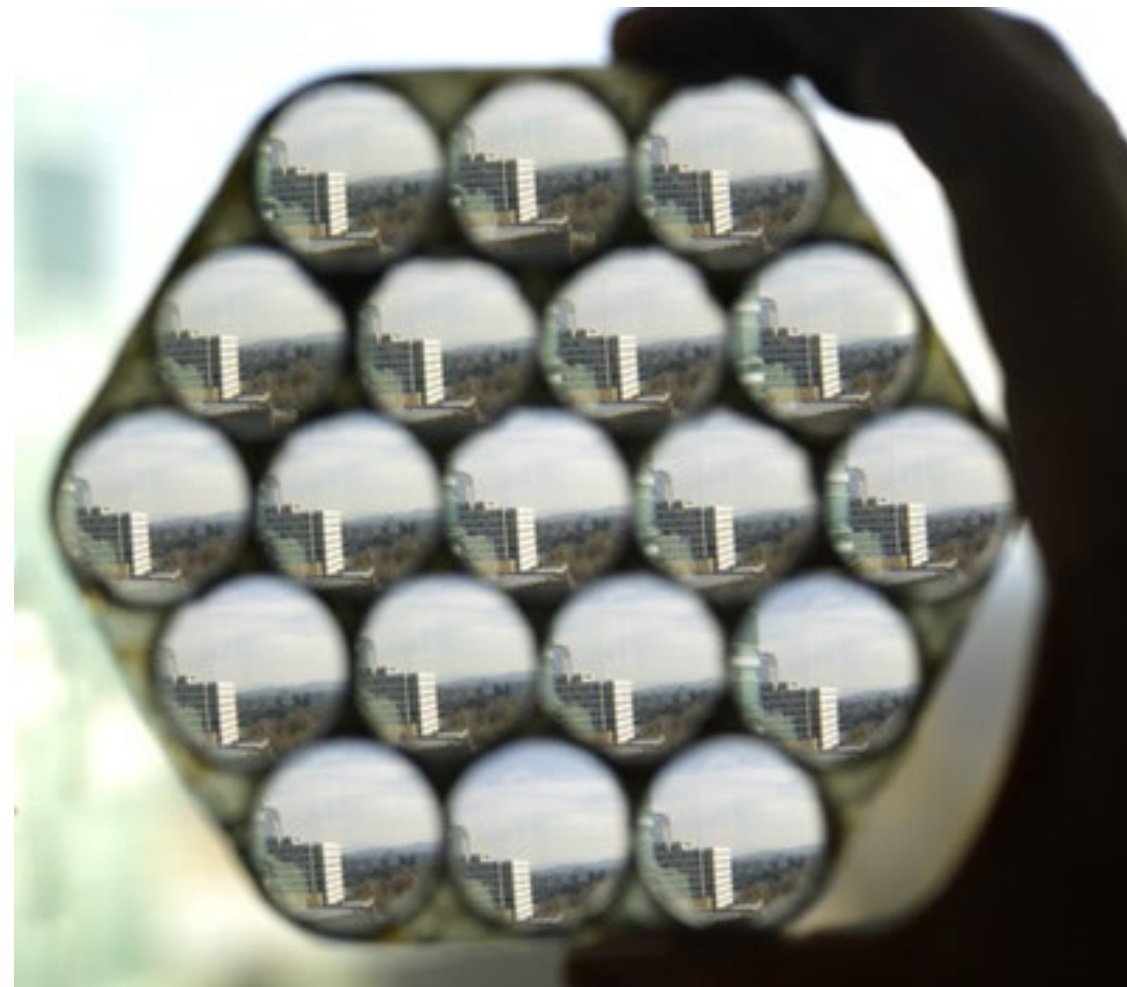
Color and image editing

- tonemapping
- color processing
- color calibration
- edge-aware and bilateral filtering
- gradient-domain processing
- Poisson integration



Focus and coded photography

- focal stacks
- depth from (de)focus and confocal stereo
- lightfields and lightfield processing
- plenoptic camera
- deconvolution and motion deblurring
- coded aperture
- coded exposure



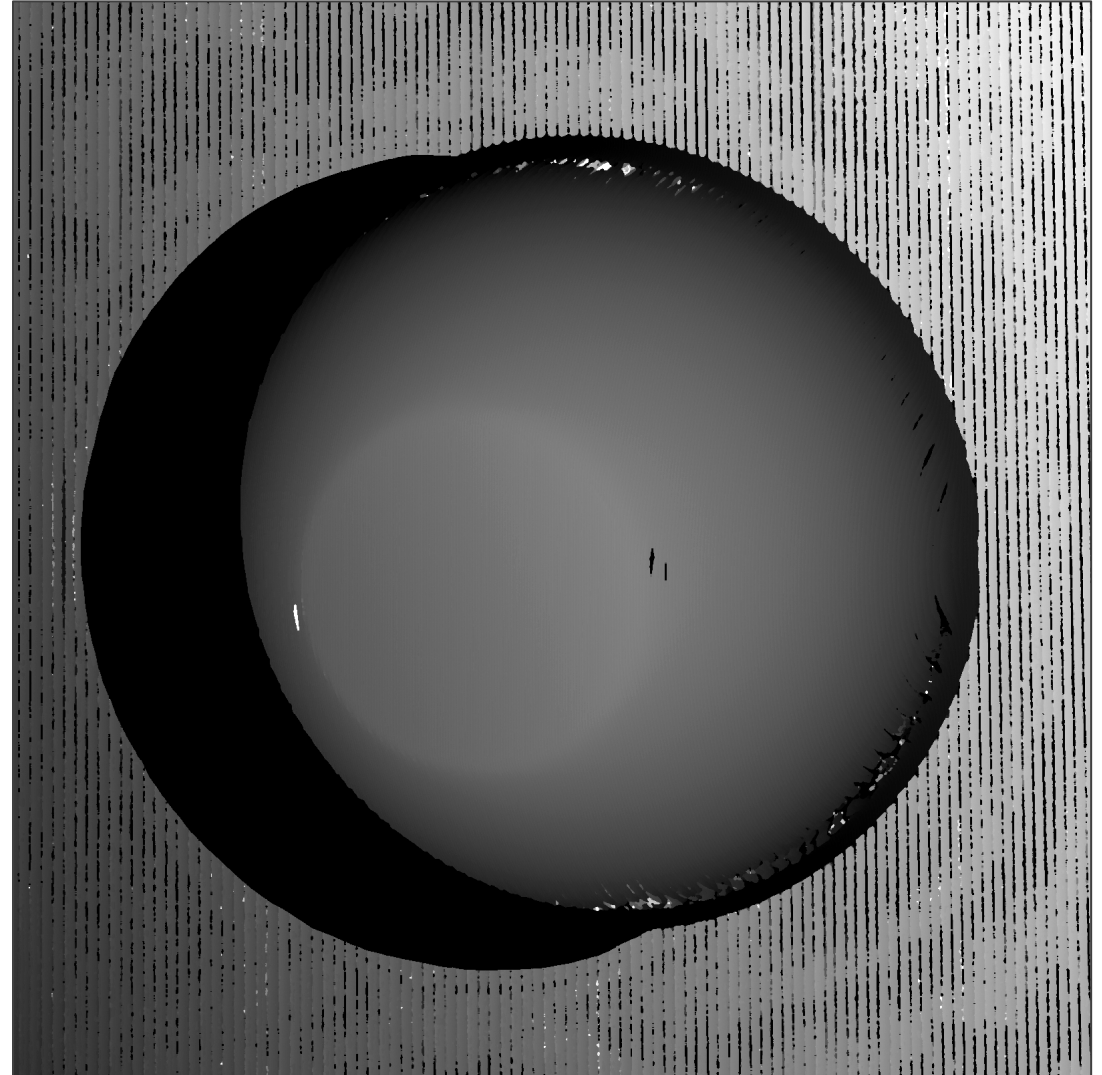
Radiometry and photometric stereo

- radiometry
- reflectance equation
- BRDF models
- illumination models
- calibrated photometric stereo
- uncalibrated photometric stereo



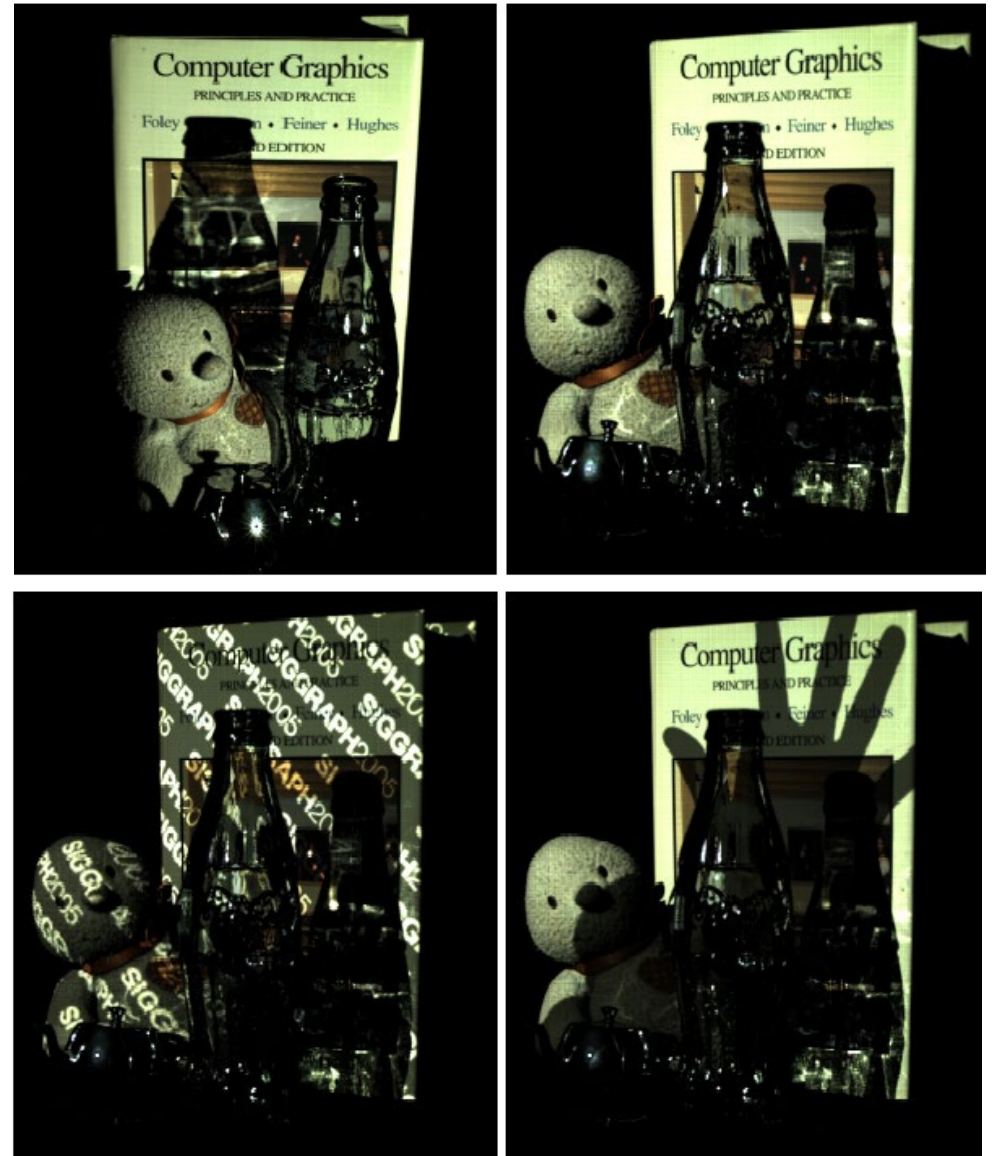
Geometry and stereo

- geometric camera models
- geometric camera calibration
- triangulation
- epipolar geometry
- stereo and disparity
- depth from lightfields
- structured light scanning



Computational light transport

- time-of-flight imaging
- direct and global illumination
- light transport matrices
- dual photography
- optical computing
- probing and epipolar imaging



Things you should know how to do

1. Build simple pinhole cameras, use DSLR cameras and modern lenses.
2. Write your own LDR and HDR image processing pipelines.
3. Calibrate the radiometric, color, noise, and geometric properties of a camera.
4. Fuse images and perform flash/no-flash photography.
5. Use bilateral and gradient-domain filtering for image editing tasks.
6. Capture and refocus your own lightfields and focal stacks.
7. Build three different types of depth and shape sensing systems: depth-from-defocus, photometric stereo, structured light.

Do you plan on taking any other vision/graphics courses?

If you are an undergraduate, check out the **graphics concentration**.

Background courses (ideally you should take both):

- 15-462/662 computer graphics.
- 16-385/16-720 computer vision.

More advanced courses directly relevant for computational photography and imaging:

- **15-468 physics-based rendering – modeling, simulating, and inverting light transport. ← Spring 2024, offered by Yannis**
- 15-458 discrete differential geometry – background for 3D geometry processing and geometric optics.
- 16-822 geometry-based methods in vision – all about epipolar geometry.
- 16-726 learning-based image synthesis – learning-based variants of computational photography algorithms.
- 16-722 sensing and sensors – background on vision and other sensors and noise modeling.
- 16-866 sensor systems – similar to above, background on vision and other sensors and noise modeling.
- 33-353 intermediate optics – wave optics, hands-on experience with optical components.
- 18-416 nano-bio-photonics – modern photonics systems and applications to biology.

More general vision (left) and graphics (right):

- | | |
|---|---------------------------------------|
| • 16-824 visual learning and recognition | • 15-365 experimental animation |
| • 10-703 deep reinforcement learning | • 15-464 technical animation |
| • 16-831 statistical techniques in robotics | • 15-465 animation art and technology |
| • 16-833 robot localization and mapping | • 15-466 computer game programming |
| • 16-881 deep reinforcement learning for robotics | • 15-469 algorithmic textiles design |

Interested in doing research in computational imaging or rendering? Talk to me!

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Many, many possible projects, including:

- Projects on rendering and inverse rendering.
- Projects on theory of light transport.
- Projects on coherent imaging and optical coherence tomography.
- Projects on material inference (reflectance, scattering, refractive fields, particle sizing).
- Projects on tissue imaging.
- Projects on non-line-of-sight imaging.
- Projects on combining physics (rendering) and deep learning.
- Projects on data-driven optimization of imaging systems.
- Projects derived from your final project for a paper publication.

Many 15-463/663/862 alumni have worked on various research projects in my group.

Ideal background:

- Knowledge of (at least one of) graphics, vision, physics, numerical computing.
- If you've taken 15-463, you have the background.



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Convolutional Approximations to the General Non-Line-of-Sight Imaging Operator

Byeongjoo Ahn, Akshat Dave, Ashok Veeraghavan, Ioannis Gkioulekas, and Aswin C. Sankaranarayanan. *ICCV 2019*.



A Differential Theory of Radiative Transfer

Cheng Zhang, Lifan Wu, Changxi Zheng, Ioannis Gkioulekas, Ravi Ramamoorthi, and Shuang Zhao. *ACM SIGGRAPH Asia 2019*.



Ellipsoidal Path Connections for Time-gated Rendering

Adithya Pediredla, Ashok Veeraghavan, and Ioannis Gkioulekas. *ACM SIGGRAPH 2019*.



Wave-based Non-Line-of-Sight Imaging using Fast f-k Migration

David B. Lindell, Gordon Wetzstein, Matthew O'Toole. *ACM SIGGRAPH 2019*.



A Monte Carlo Framework for Rendering Speckle Statistics in Scattering Media

Chen Bar, Marina Alterman, Ioannis Gkioulekas, Anat Levin. *ACM SIGGRAPH 2019*.



A Theory of Fermat Paths for Non-Line-of-Sight Shape Reconstruction

Shumian Xin, Sotiris Nousias, Kiriakos N. Kutulakos, Aswin C. Sankaranarayanan, Srinivasa G. Narasimhan, and Ioannis Gkioulekas. *CVPR 2019*.



Multispectral Imaging for Fine-Grained Recognition of Powders on Complex Backgrounds

Tiancheng Zhi, Bernardo R. Pires, Martial Hebert, Srinivasa G. Narasimhan. *CVPR 2019*.



Beyond Volumetric Albedo—A Surface Optimization Framework for Non-Line-of-Sight Imaging

Chia-Yin Tsai, Aswin C. Sankaranarayanan, Ioannis Gkioulekas. *CVPR 2019*.



Non-Line-of-Sight Imaging with Partial Occluders and Surface Normals

Felix Heide, Matthew O'Toole, Kai Zang, David B. Lindell, Steven Diamond, Gordon Wetzstein. *ACM Trans. on Graphics 2019*.



Towards Multifocal Displays with Dense Focal Stacks

Rick Chang, Vijaya Kumar, Aswin C. Sankaranarayanan. *ACM SIGGRAPH Asia 2018*.