Wrap-up and discussion

15-468, 15-668, 15-868
Physics-based Rendering
Spring 2025, Lecture 18

https://graphics.cs.cmu.edu/courses/15-468

Course announcements

- Final project presentations next Thursday.
  - Logistics will be posted on Slack.

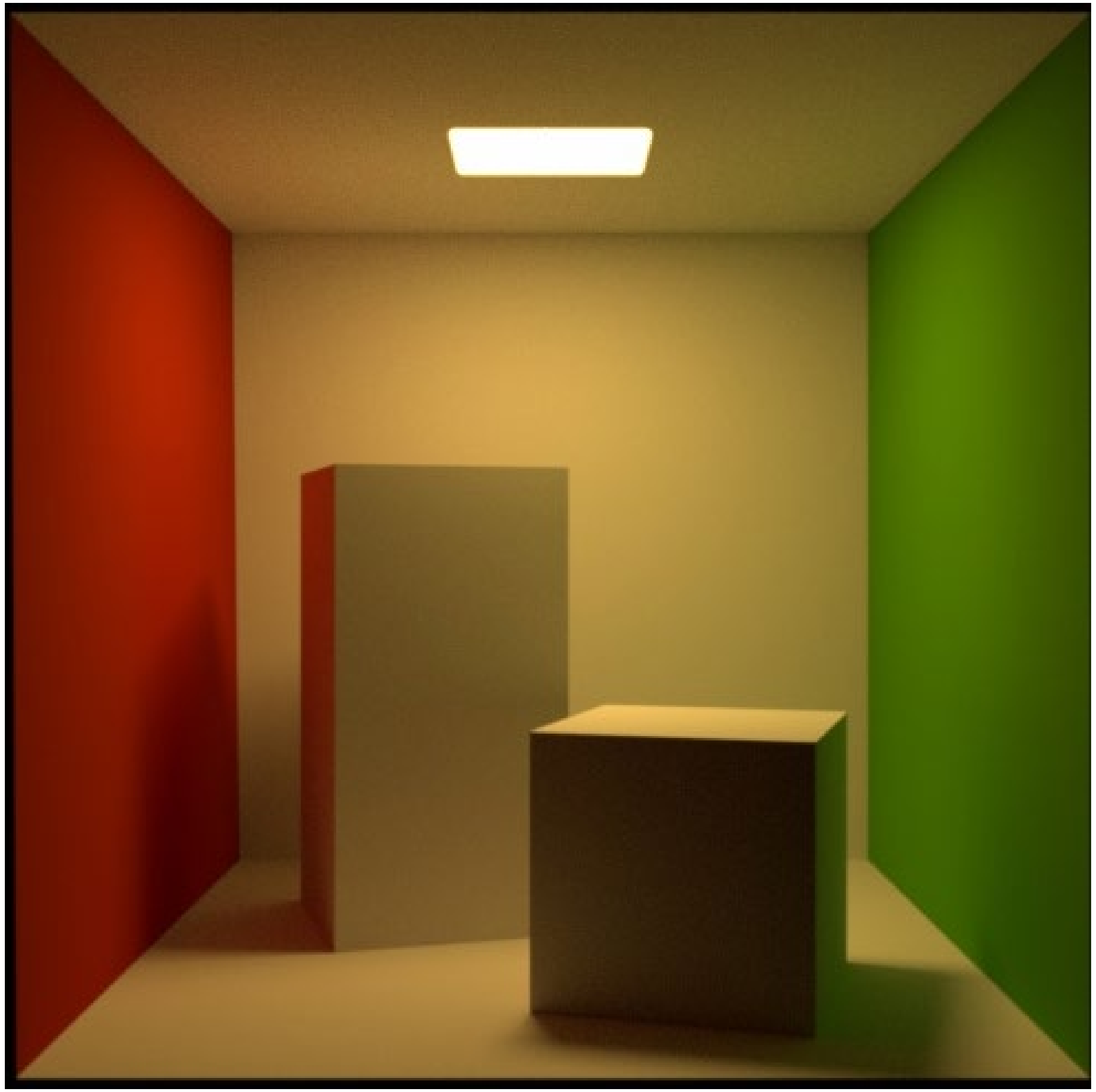
Overview of today’s lecture

- Class wrap-up and discussion.

Topics we covered

Basics of ray tracing:

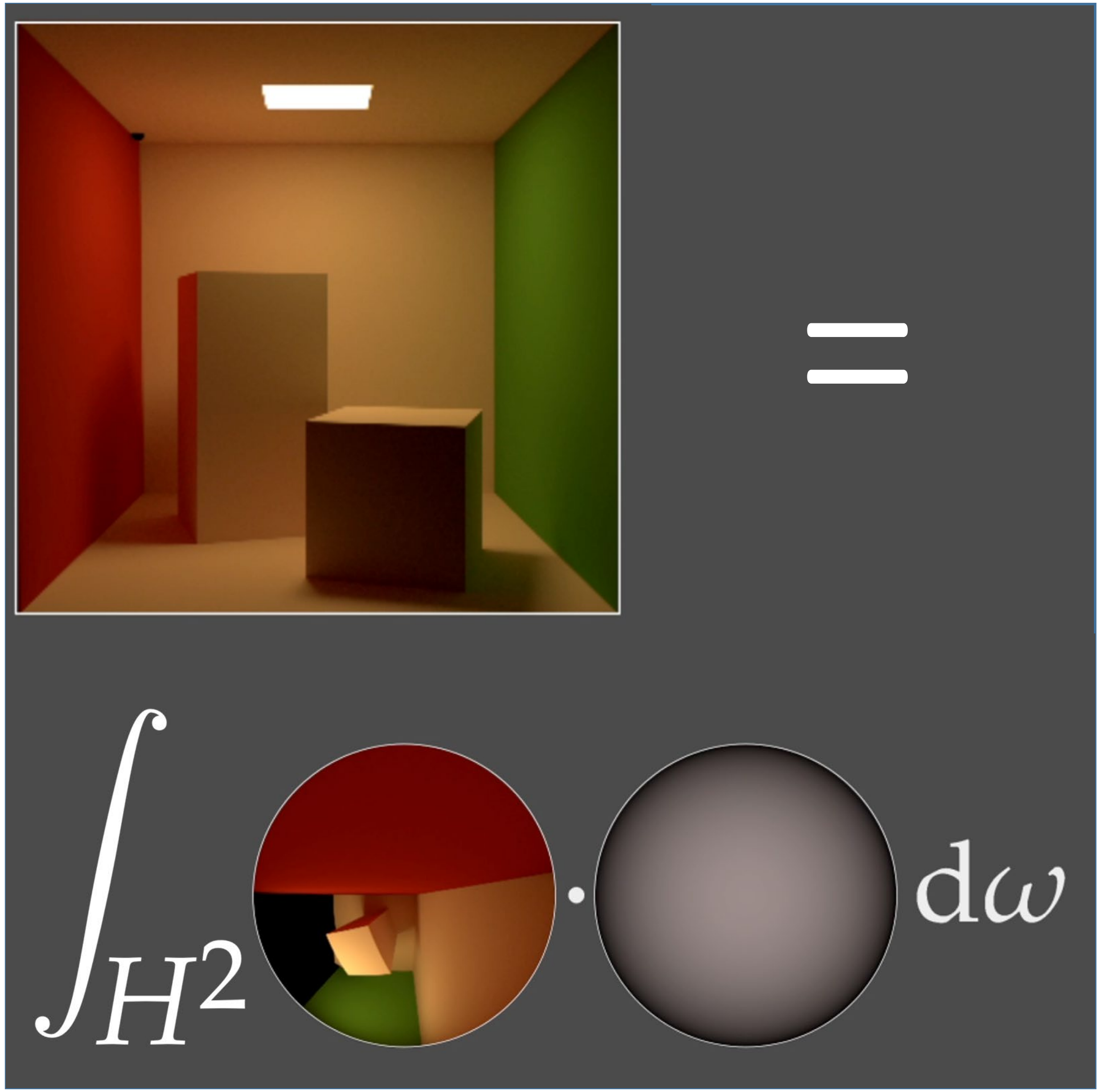
- trace-intersect recursions
- basic camera and illumination models
- shading
- intersection queries
- texture mapping



Topics we covered

Theory of light transport and materials:

- rendering equation
- radiative transfer equation
- path integral formulations
- microfacet reflectance models
- statistical scattering models



Topics we covered

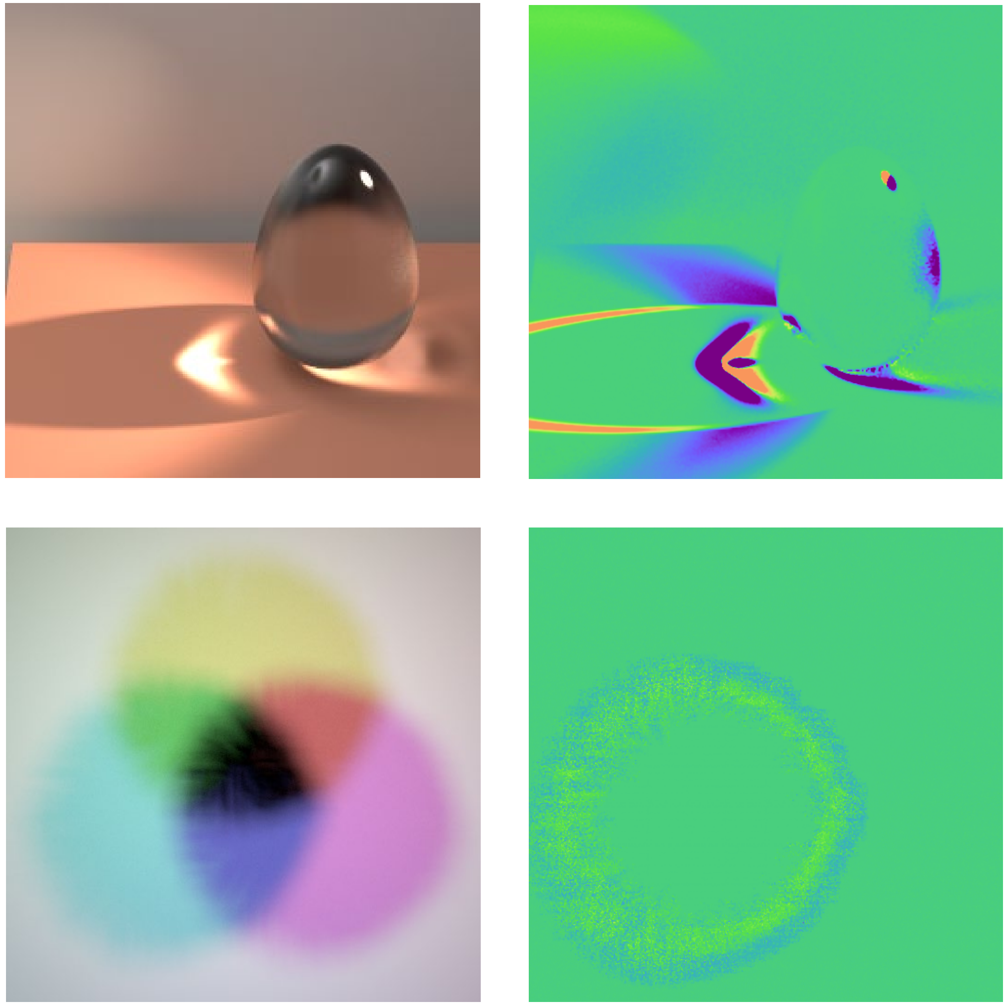
Monte Carlo rendering algorithms:

- unidirectional and bidirectional estimators
- Markov chain Monte Carlo techniques
- volumetric rendering
- photon mapping
- importance sampling techniques
- quasi-Monte Carlo techniques

Topics we covered

Advanced topics:

- differentiable and inverse rendering
- rendering wave-optics effects
- rendering specular transport effects
- rendering eikonal transport effects



Things you should know how to do

1. Implement a path tracing and volumetric path tracing pipeline.
2. Use different types of textures.
3. Implement different types of light sources.
4. Implement different types of materials.
5. Write integrators for direct illumination, ambient occlusion, and global illumination.
6. Derive complex results about radiometry and light transport.
7. Use an array of statistical techniques to solve integration problems.

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

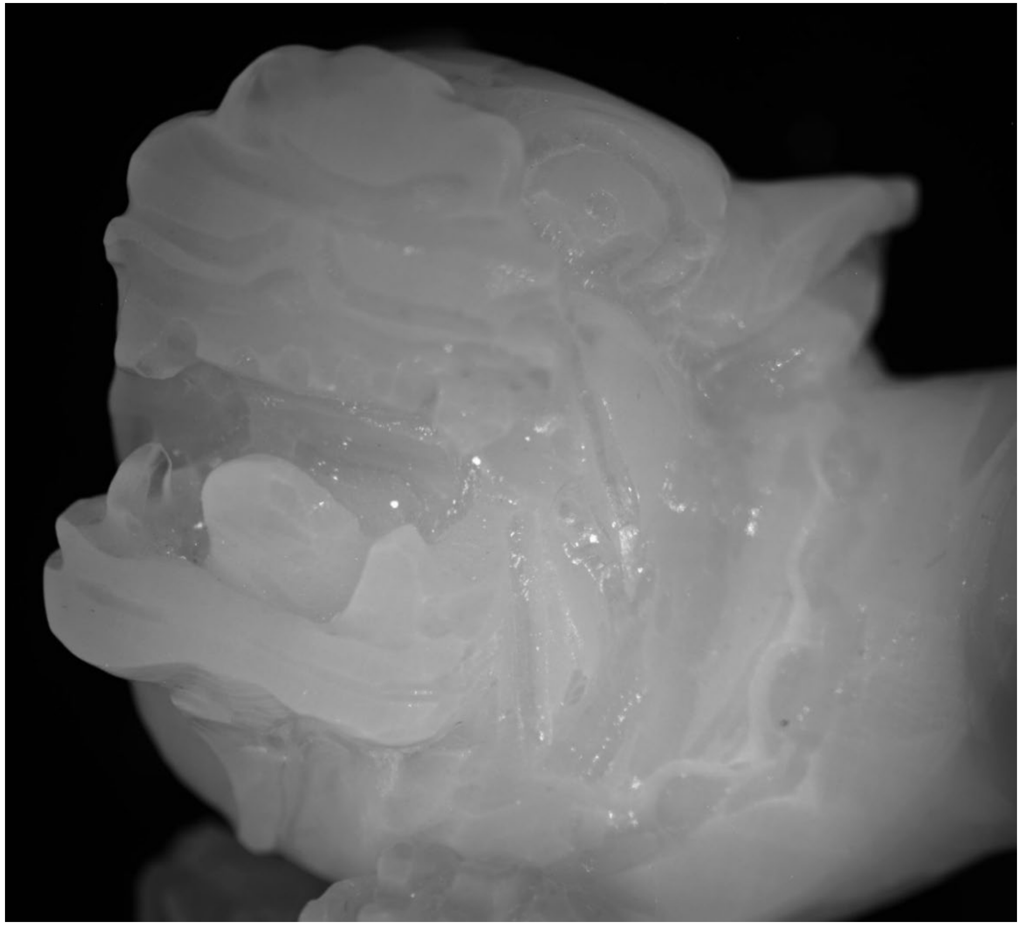
If you are an undergraduate, check out the new **graphics concentration**.

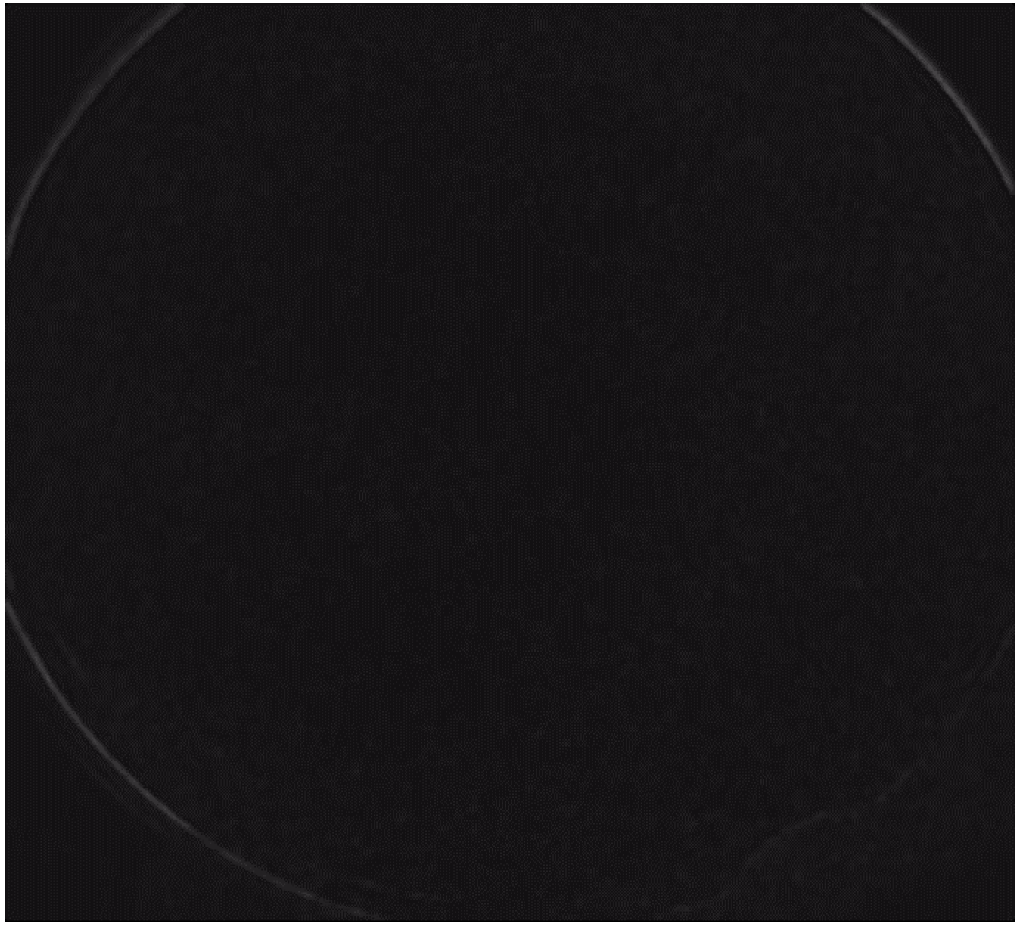
Background courses (ideally you should take both):
- 15-362 computer graphics.
- 16-385 computer vision.

More advanced graphics courses:
- 15-365 experimental animation
- 15-458 discrete differential geometry
- <u>15-463 computational photography ← Fall 2025, offered by Yannis</u>
- 15-464 technical animation
- 15-465 animation art and technology
- 15-466 computer game programming
- 15-469 algorithmic textiles design
- 15-472 real-time graphics
- 16-726 learning-based image synthesis
- 21-387, 15-327, 15-627 Monte Carlo methods and applications

More advanced vision courses:
- 16-822 geometry-based methods in vision
- 16-823 physics-based methods in vision
- 16-824 visual learning and recognition
- 16-831 statistical techniques in robotics
- 16-833 robot localization and mapping
- 16-881 deep reinforcement learning for robotics
- 16-899 learning for 3D vision

15-463, 15-663, 15-862 Computational Photography
Fall 2025





https://graphics.cs.cmu.edu/courses/15-463

Instructor: Ioannis (Yannis) Gkioulekas

Topics to be covered

Digital photography:

- optics and lenses
- color
- exposure
- aperture
- focus and depth of field
- image processing pipeline

[Photo from Gordon Wetzstein]

Topics to be covered

Image manipulation and merging:

- bilateral filtering
- edge-aware filtering
- gradient-domain image processing
- flash/no-flash photography
- high-performance image processing

[Banerjee et al., SIGGRAPH 2014]

Topics to be covered

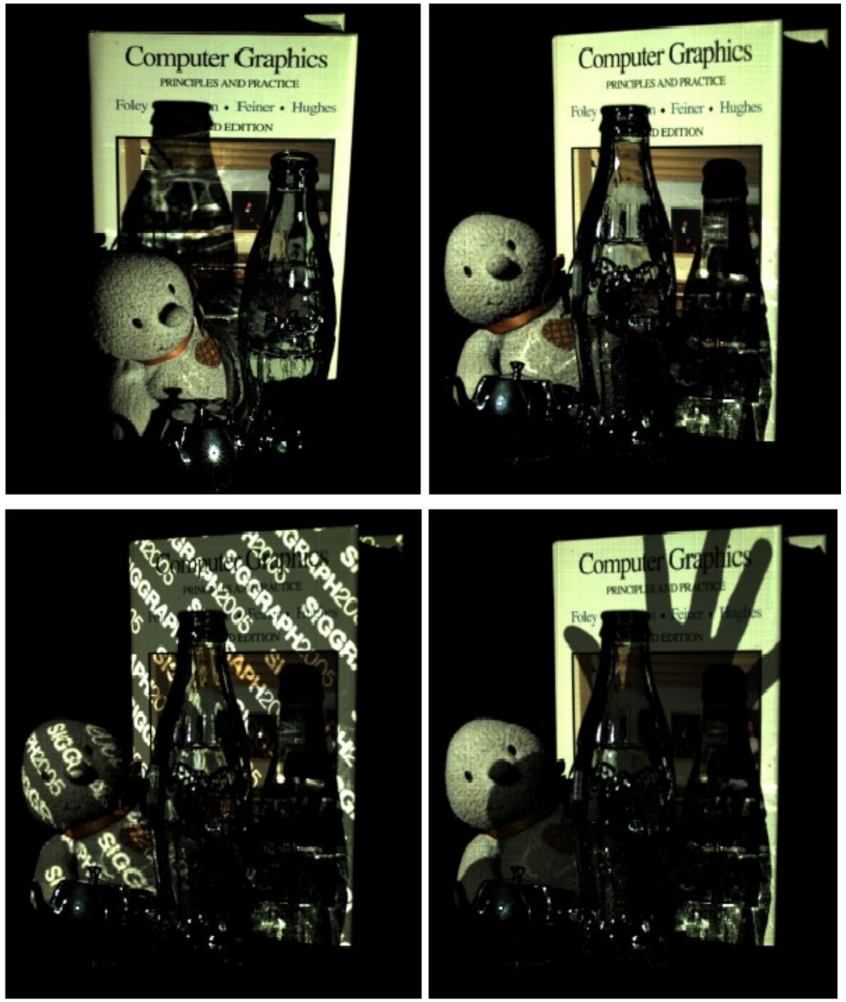
Types of cameras:

- geometric camera models
- light-field cameras
- coded cameras
- lensless cameras
- compressive cameras
- hyperspectral cameras

Topics to be covered

Active illumination and sensing:

- time-of-flight sensors
- structured light
- computational light transport
- transient imaging
- non-line-of-sight imaging
- optical computing



[Sen et al., SIGGRAPH 2005]

Evaluation

- Six homework assignments (75%):
    - programming and capturing your own photographs.
    - all programming will be in **Python**
    - first assignment will serve as a gentle introduction to Python.
    - five late days, you can use them as you want.

- Final project (20%):
    - we will provide more information near the end of September.
    - 15-663, 15-862 require more substantive project.
    - if your ideas require imaging equipment, talk to us in advance.
    - **no exam, but final project presentations are during the exam period.**

- Maybe take-home quizzes??

Do I need a camera?

- You will need to take your own photographs for assignments 1-6 (all of them):
  - Assignment 1: pinhole camera – you need a high-sensitivity camera.
  - Assignment 2: HDR – you need a camera with manual exposure controls.
  - Assignment 3: image filtering – you can use your phone camera.
  - Assignment 4: lightfields – you need a camera with manual focus control..
  - Assignment 5: photometric stereo – you need a camera with RAW support.
  - Assignment 6: structured light – you can use your phone camera.

- We have 50 Nikon D3X00 kits (camera + lens + tripod) for students.
  - If you have your own camera, please use that!

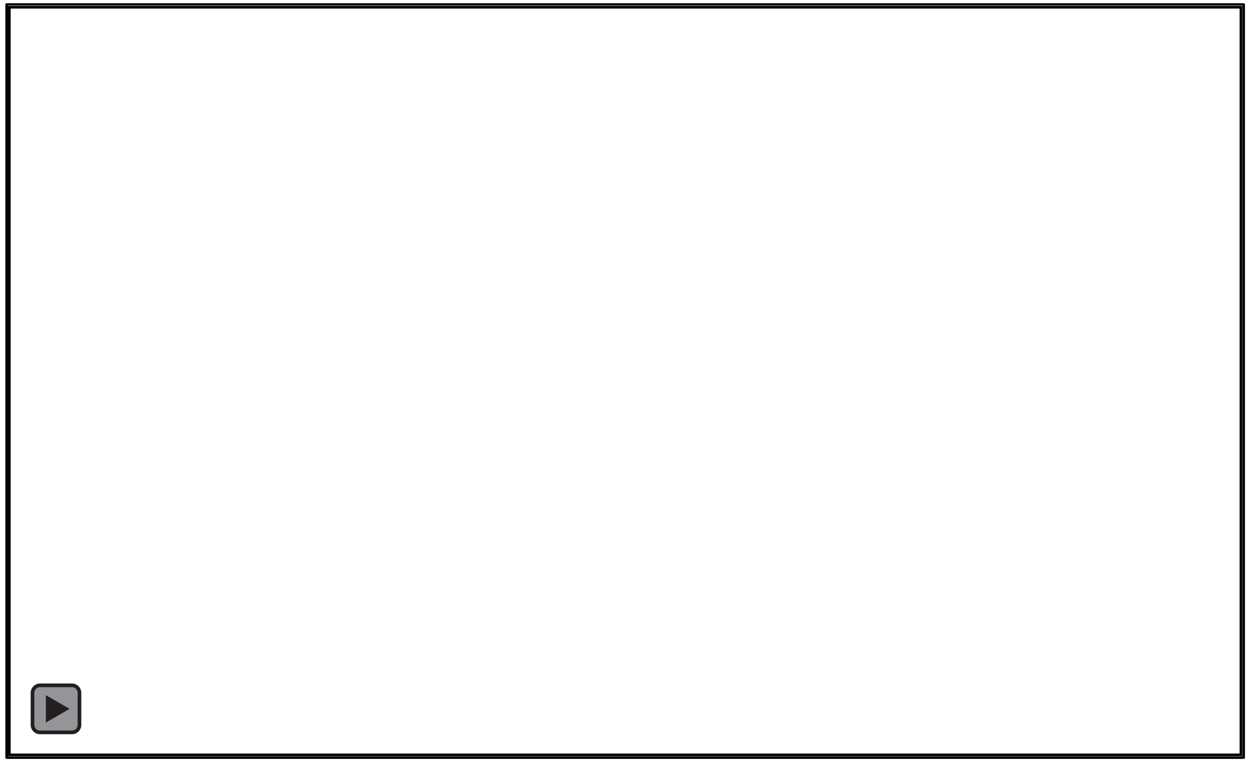
Final project competition

- At the end of the semester, we will ask other computational photography faculty at CMU (Srinivasa Narasimhan, Matthew O’Toole, Aswin Sankaranarayanan, Jun-Yan Zhu) to join the final project presentations and vote on the two best final projects.
- The two winning students will receive a **free DSLR camera kit** (same as the one provided for homework).
- Last year’s projects for inspiration: https://graphics.cs.cmu.edu/courses/15-463/final_project_competition.html

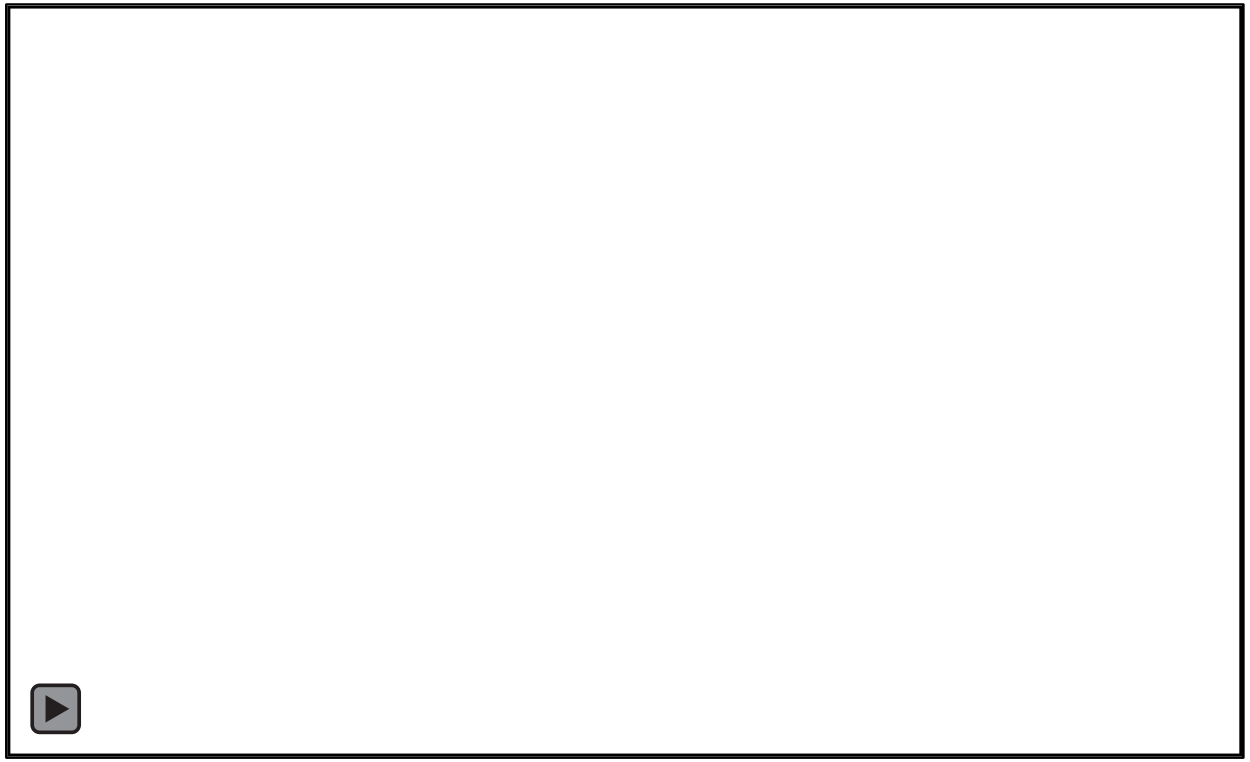
Interplay between computational imaging and physics-based rendering

- Learn about new types of cameras, optics, and light transport effects → inspiration for new rendering problems to pursue.
- Learn about computational light transport → insights into properties of light transport.
- Learn about challenging imaging problems → opportunities to use rendering to tackle them.

Separate direct and global illumination

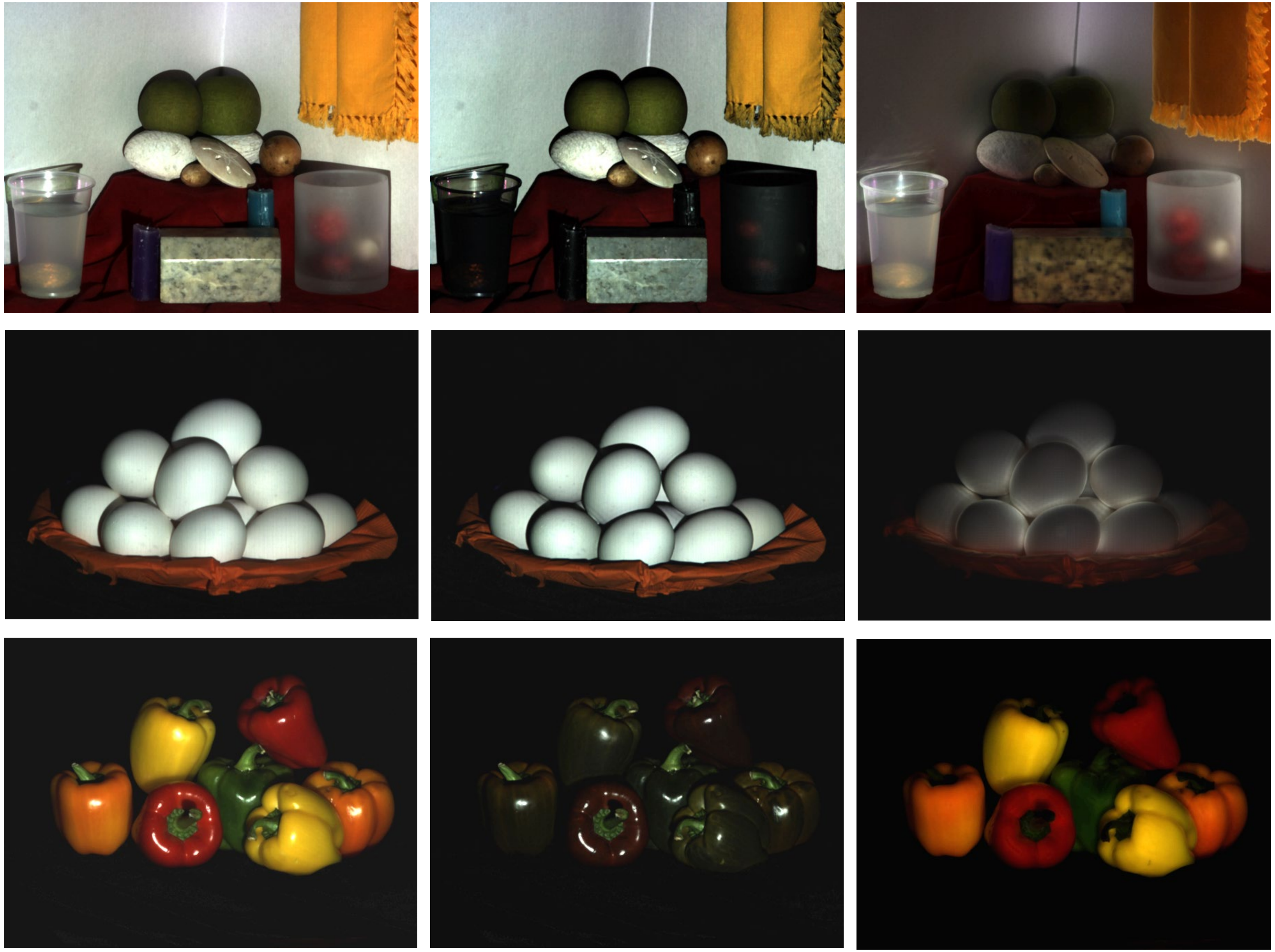


direct-only illumination

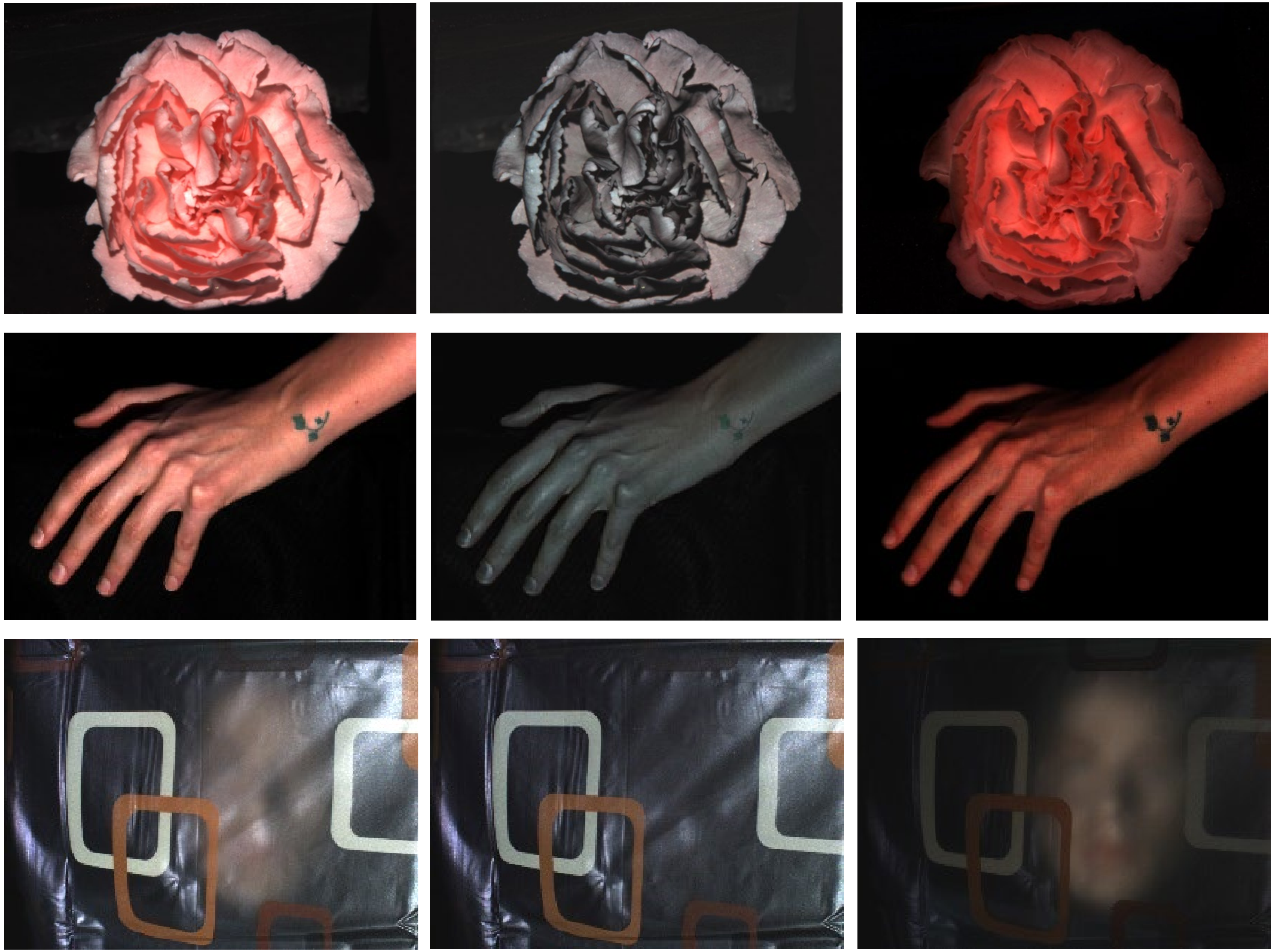


indirect-only illumination

Separate direct and indirect illumination



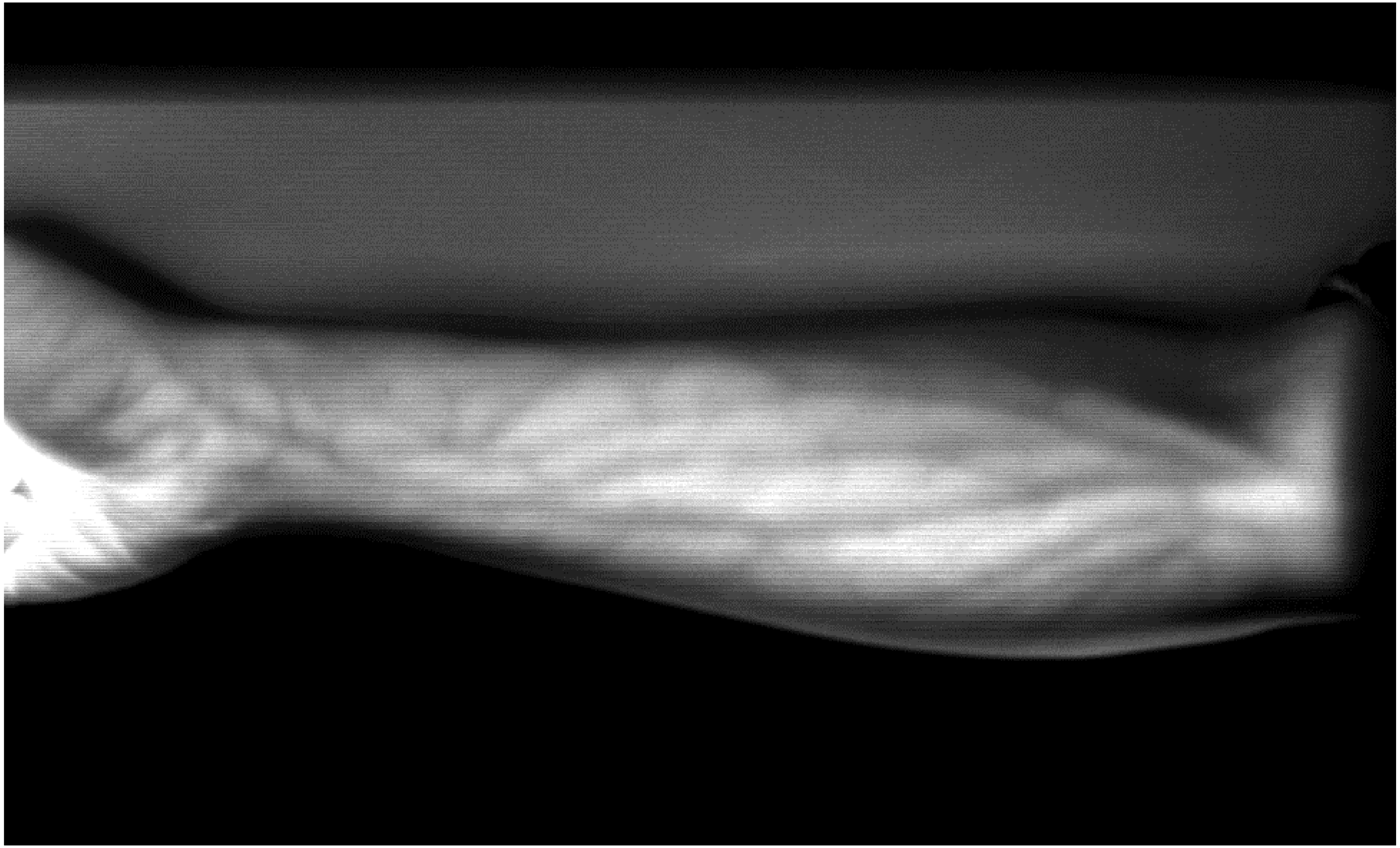
Separate direct and indirect illumination



Separating paths by length

Looking through the skin

Live vein imaging



[NSF Expedition]

Dual photography

Interested in research?

- Visit the graphics lab and imaging group websites:

  https://graphics.cs.cmu.edu/
  https://imaging.cs.cmu.edu/

- Email Yannis if you want to be added to the graphics lab mailing list and attend our weekly meetings.

- We are actively recruiting research assistants for projects relating to **rendering**, imaging, and graphics in general. Please email Yannis if interested.

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

Many, many possible projects, including:

- Projects on rendering and inverse rendering.
- Projects on theory of light transport.
- Projects on algorithms for differentiable rendering.
- 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.

Ideal background:

- Knowledge of (at least one of) graphics, vision, physics, numerical computing.
- If you’ve taken 15-468, you have the background.

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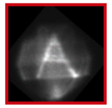
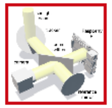


Megahertz Light Steering without Moving Parts

Adithya Pediredla, Srinivasa G. Narasimhan, Maysamreza Chamanzar, Ioannis Gkioulekas. *CVPR 2023.*



Passive Micron-scale Time-of-Flight with Sunlight Interferometry

Alankar Kotwal, Anat Levin, and Ioannis Gkioulekas. *CVPR 2023.*

Swept-Angle Synthetic Wavelength Interferometry

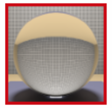
Alankar Kotwal, Anat Levin, and Ioannis Gkioulekas. *CVPR 2023.*

Neural Kaleidoscopic Space Sculpting

Byeongjoo Ahn, Michael De Zeeuw, Ioannis Gkioulekas, and Aswin C. Sankaranarayanan. *CVPR 2023.*

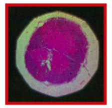
Neural Implicit Surface Reconstruction using Imaging Sonar

Mohamad Qadri, Michael Kaess, Ioannis Gkioulekas. *ICRA 2023.*



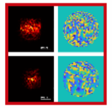
Adjoint Nonlinear Ray Tracing

Arjun Teh, Matthew O'Toole, Ioannis Gkioulekas. *ACM Transactions on Graphics (SIGGRAPH) 2022.*



Towards Mixed-State Coded Diffraction Imaging

Benjamin Attal, Matthew O'Toole. *IEEE Transactions on Pattern Analysis and Machine Intelligence (TPAMI) 2022.*



Fluorescent wavefront shaping using incoherent iterative phase conjugation

Dror Aizik, Ioannis Gkioulekas, and Anat Levin. *Optica 2022.*

https://imaging.cs.cmu.edu/

Questions?

Which parts of the course did you like the most?

Which parts of the course did you like the least?

Any topics you wanted to learn more about?

Any topics you wanted to learn less about?

How should we change the programming assignments?

Would you prefer to use a different codebase/renderer for programming assignments?

How should we change the take-home quizzes?

How does homework difficulty compare to other classes?

Any kind of homework you would have liked to see?

Any changes to final projects?