

Introduction and Overview

Computational Photography

CSE 273

Lecture 1

CSE 273: Computational Photography

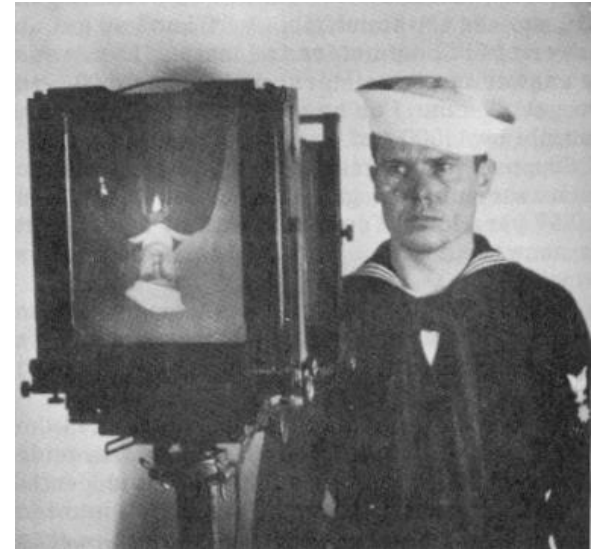
- Today
 - Course overview
 - Logistics

What is computational photography?

- To answer this question, let's first answer the follow prerequisite question
- What traditional photography?

Traditional photography

- The acquisition of images by recording light (or other electromagnetic radiation) either electronically (using an image sensor) or chemically (using film)
- Typically, a lens is used to focus the light reflected or emitted from objects in the scene being imaged into an image on the light sensitive surface inside a camera during a timed exposure



Computational photography

- An interdisciplinary field that deals with overcoming the limitations of traditional photography using computational techniques from *image processing*, *computer vision*, and *computer graphics*
- Practical techniques used to overcome traditional photography limitations (e.g., image resolution, dynamic range, and defocus and motion blur) and those used to produce images (and more) that are not possible with traditional photography (e.g., computational illumination and novel optical elements such as those used in light field cameras)

Image processing

- A discipline in which both the input and output of a process are images
 - There are usually other input parameters to the process

Computer vision

- An interdisciplinary field that deals with how computers can be made to gain high-level understanding from digital images or videos
- Engineering perspective
 - Computer vision seeks to automate tasks that the human visual system can do

Computer graphics

- The manipulation of visual and geometric information using computational techniques that focus on the mathematical and computational foundations of image generation

Common rudiments

- Probability
- Statistics
- Linear algebra
- Geometry
- Projective geometry
- Optimization
- Optics
- Fourier analysis
- Sampling
- Algorithms
- Photometry
- Physics of color
- Human vision
- Psychophysics
- Performance evaluation

Computational photography

- Computer vision and/or computer graphics?
 - Although computational photography is currently most popular in computer graphics, most computational photography techniques first appeared in computer vision

Deep learning in computational photography

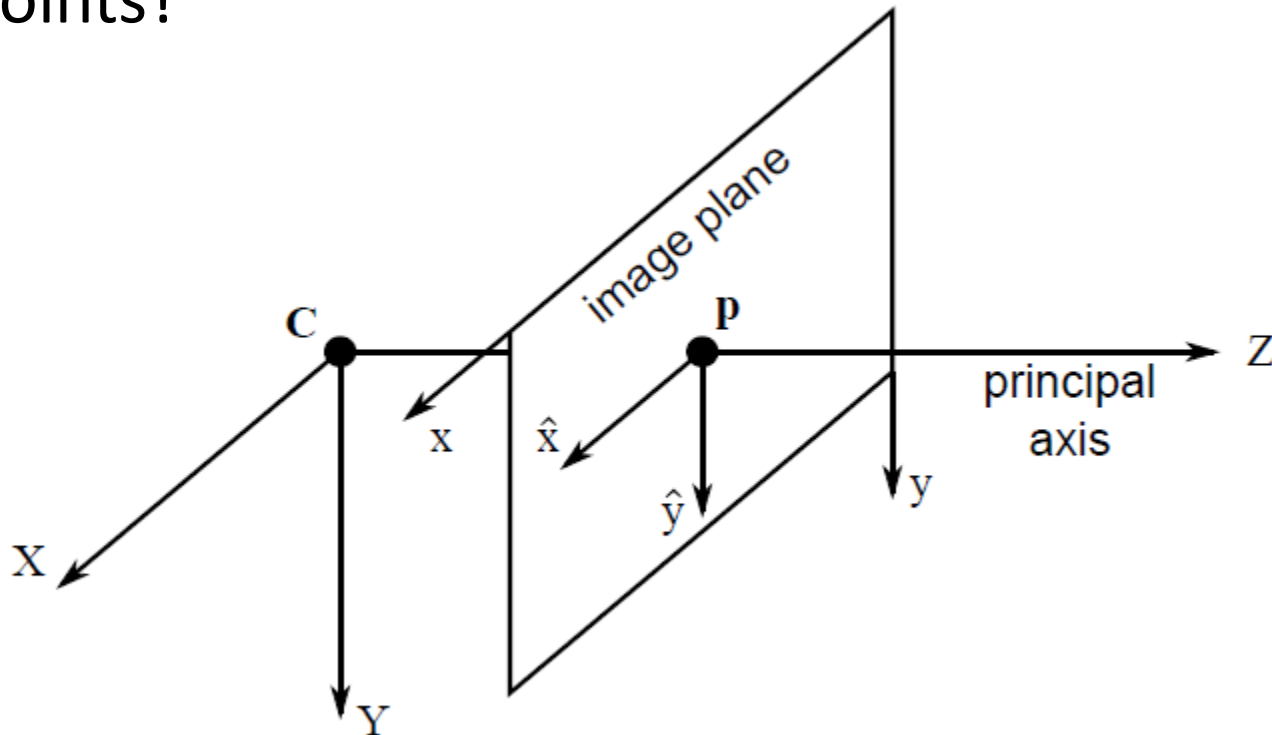
- First, understand the physics of the problem, then be wise about whether to use deep learning
 - If not, then you may “learn the bitter lesson that building in how we think we think does not work in the long run” and “general methods that leverage computation are ultimately the most effective, and by a large margin”
 - Richard Sutton, “The Bitter Lesson”
 - On the other hand, you may learn “we have to take into account the total cost of any solution, and that so far they have all required substantial amounts of human ingenuity”
 - Rodney Brooks, “The Better Lesson”

CSE 273 topics

- Cameras and image formation
- Image processing
- Burst photography
- Computational imaging
- Camera and image motion
- Camera arrays
- Light field photography
- Computational illumination

Cameras

- Geometric image formation
 - How do 3D world points project to 2D image points?



Cameras

- Photometric image formation
 - What color is the projected point?

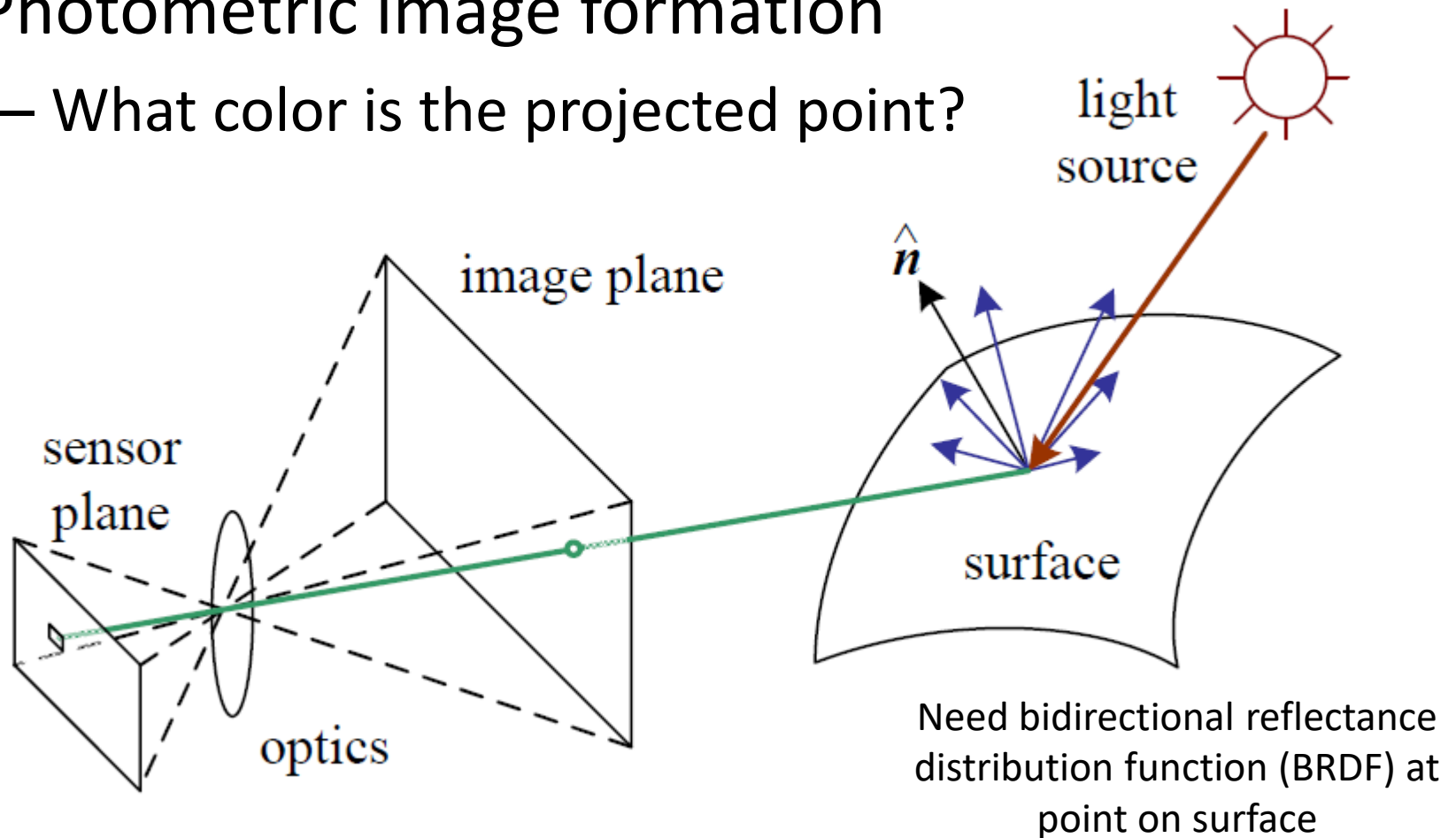


Image processing

- Demosaicing
- Color spaces

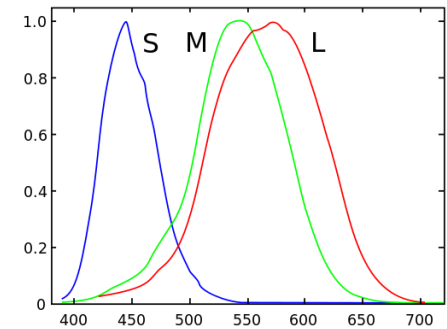
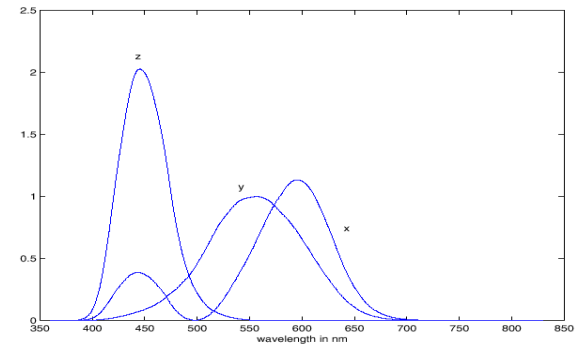
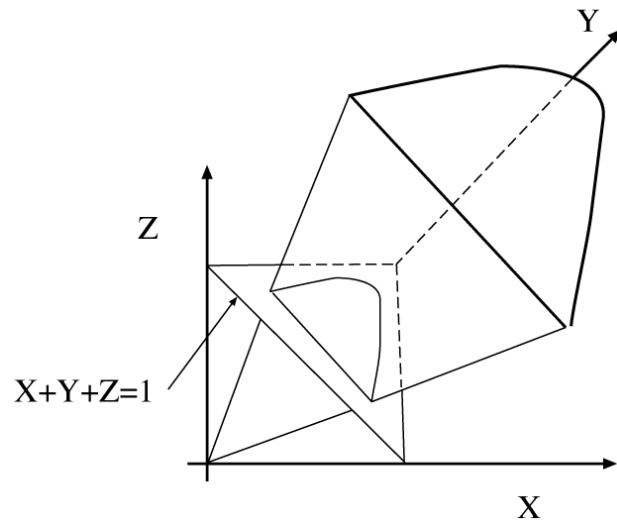
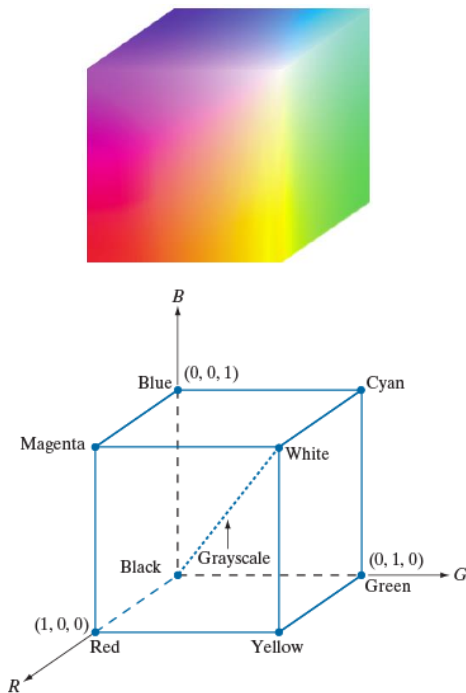
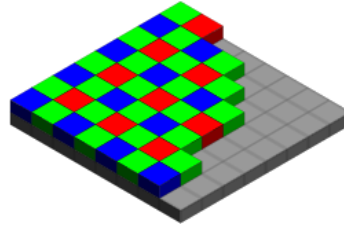
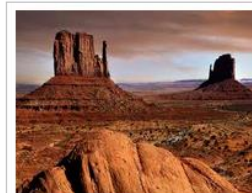
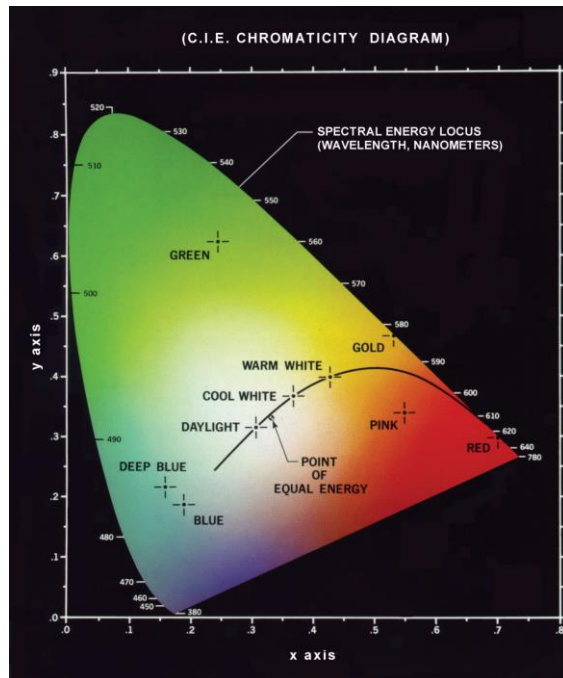
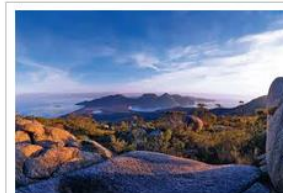


Image processing

- Gamut mapping
- White balancing and color balancing



Source



Target



Source mapped to target

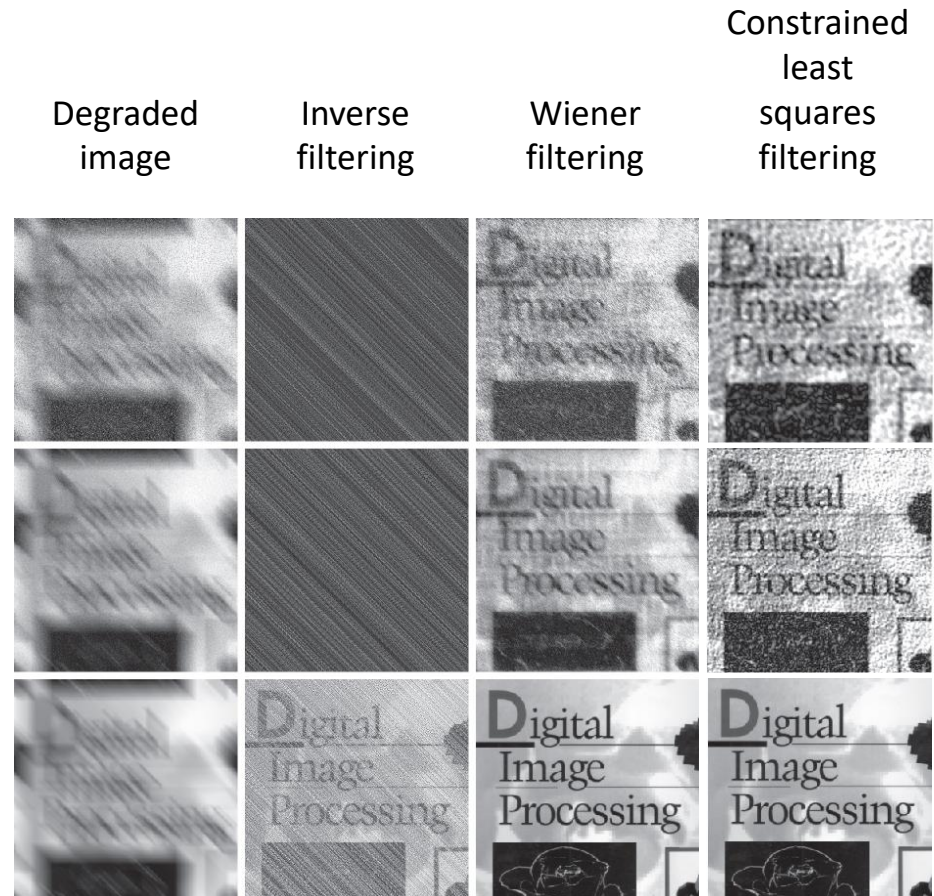
Image processing

- Dehazing
- Denoising
- Deconvolution

Motion blur
and
additive noise

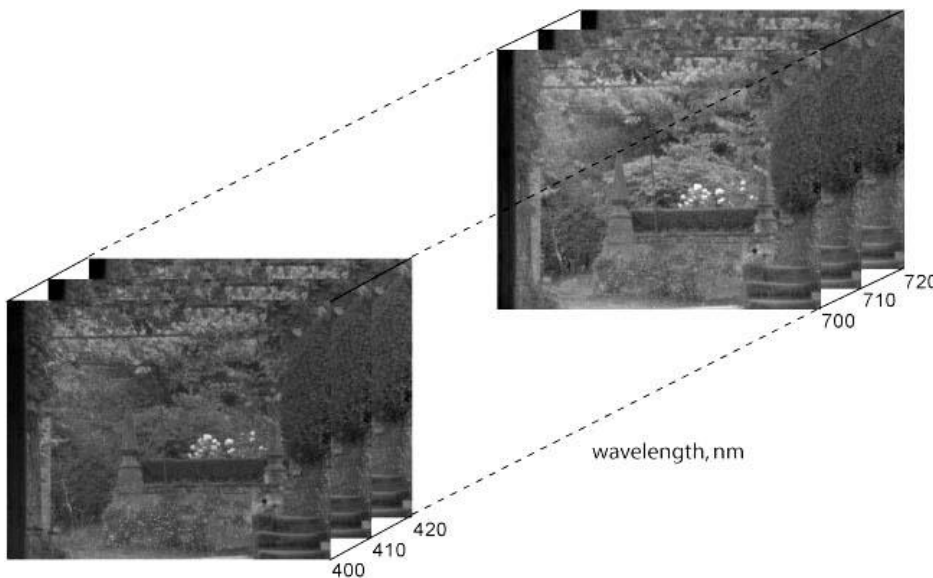
Less noise

Much less noise



Burst photography

- Hyperspectral image (HSI) set to RGB image



Hyperspectral image



RGB image

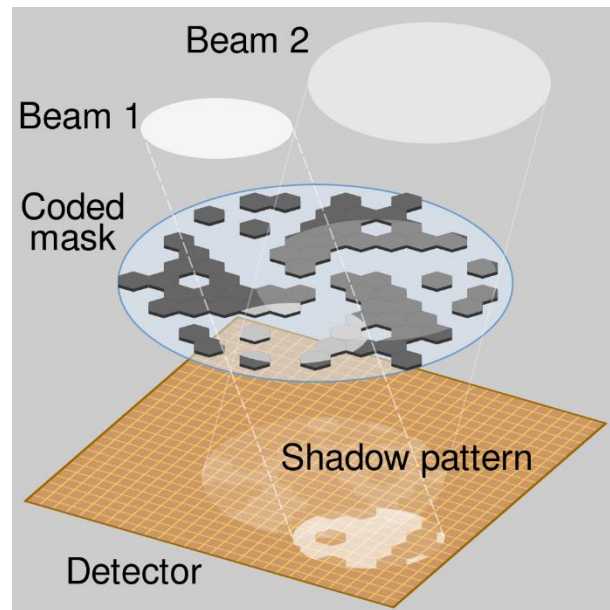
Burst photography

- Set of standard dynamic range (SDR) images to a high dynamic range (HDR) image
- Super resolution

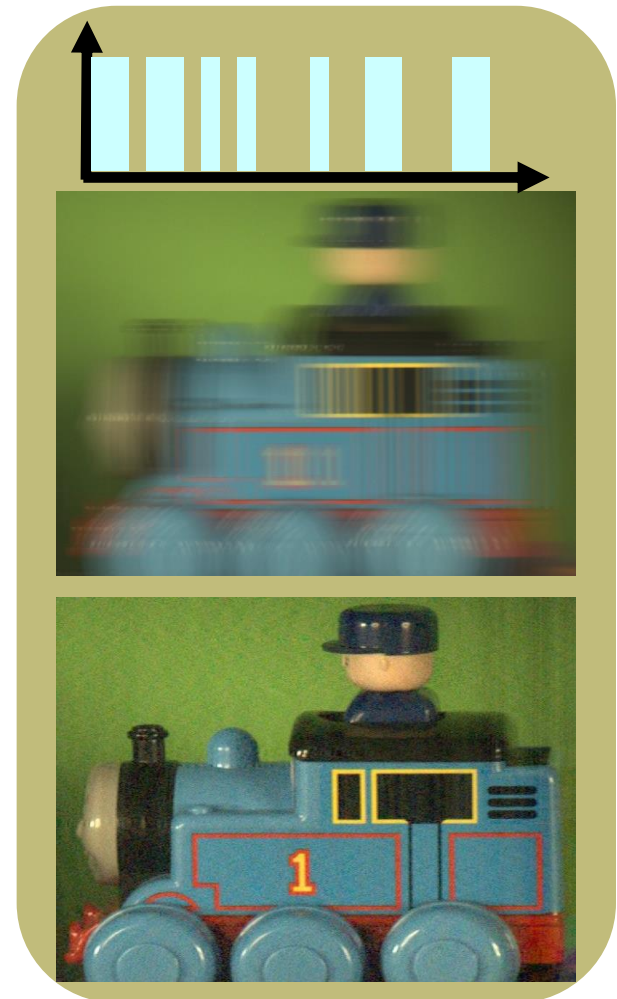


Computational imaging

- Coded photography
- Compressive imaging



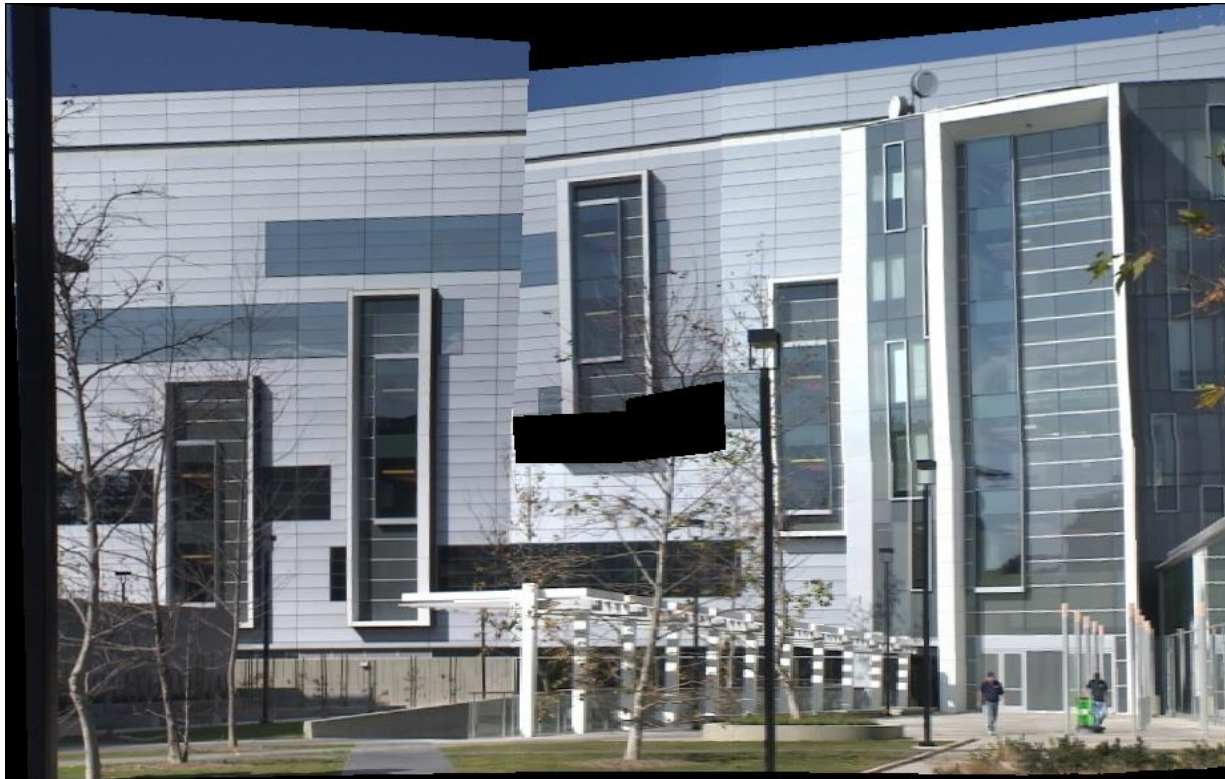
Coded aperture



Coded exposure

Camera and image motion

- Mosaic construction from video or a set of images



Camera and image motion

- Video stabilization



Original video

Stabilized video

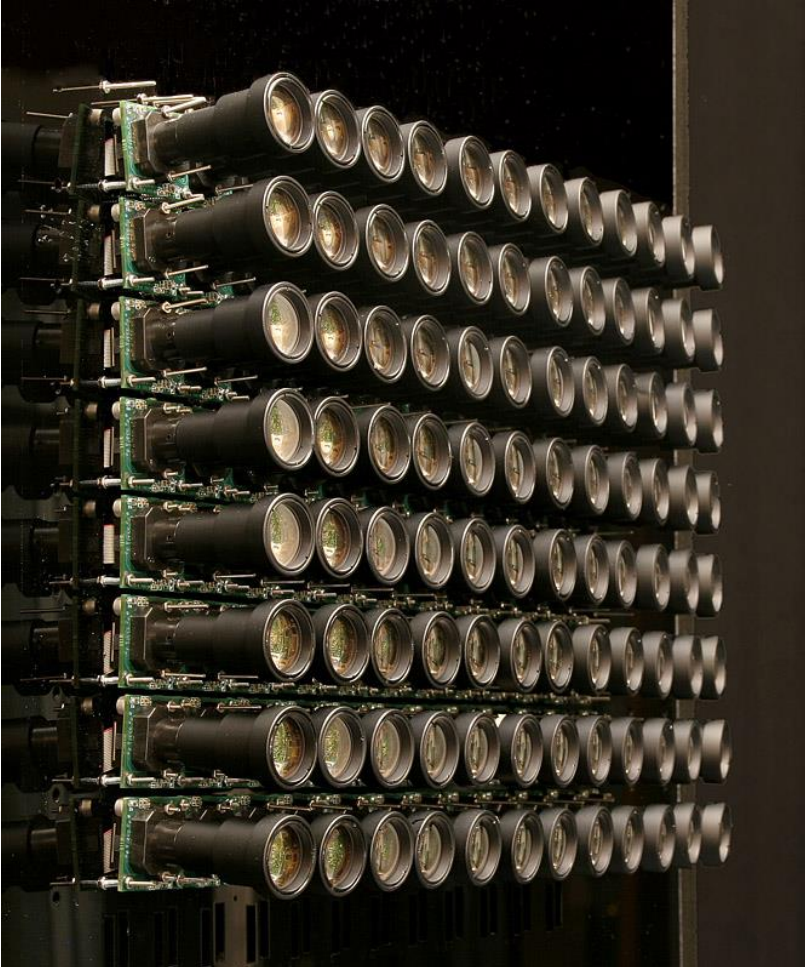
Camera arrays



The Matrix
(bullet time)

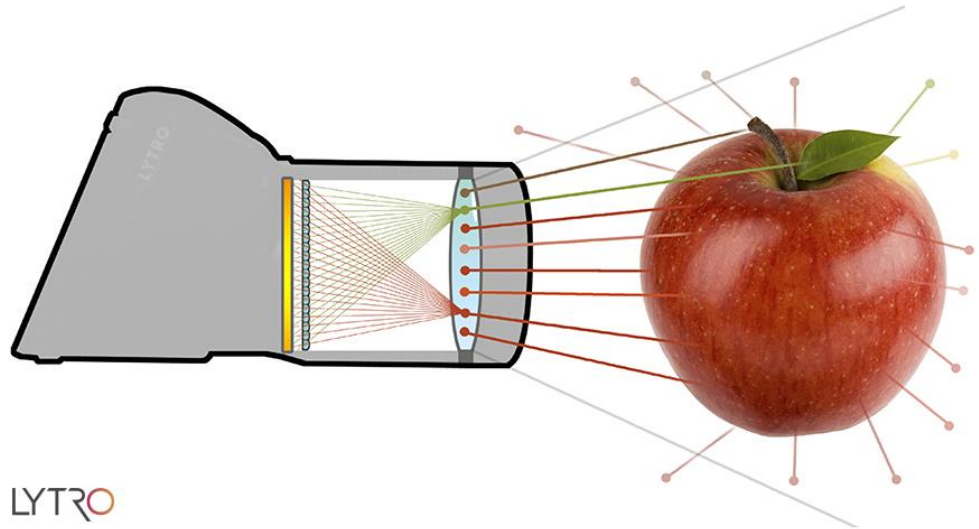
Application:
view synthesis

Camera arrays



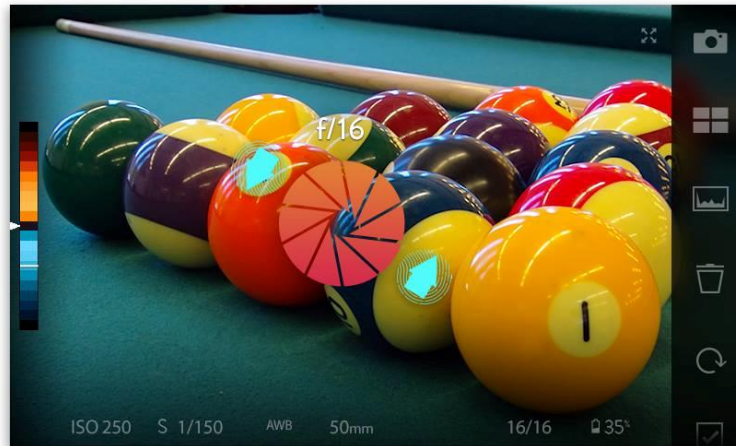
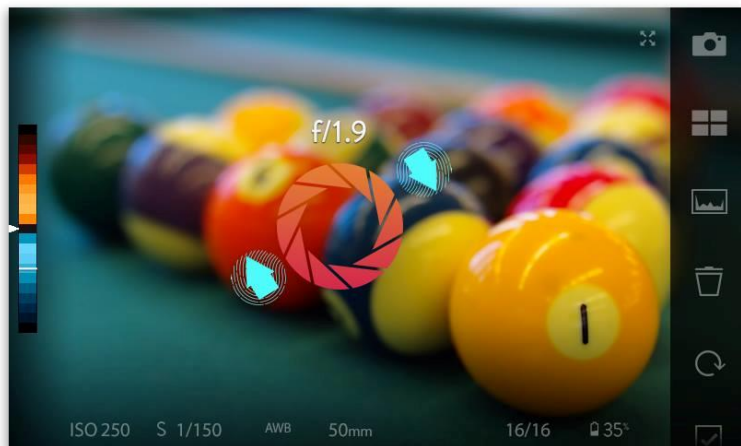
Application: synthetic focus

Light field photography



LYTRO

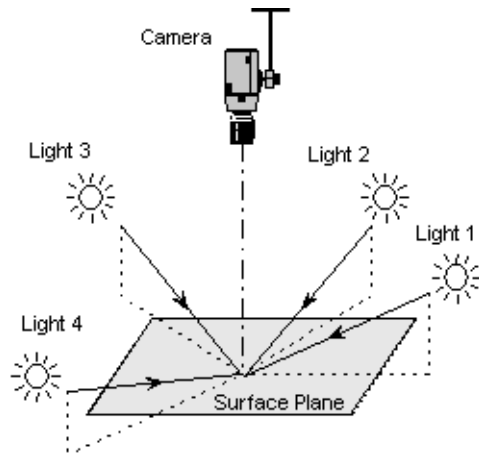
The Microlens Array in the Lytro ILLUM gathers bundles of light rays and distributes those bundles to specific pixels on the sensor to capture the rays' angularity, color and intensity. Proportions not to scale.



Application:
refocus

Computational illumination

- Photometric stereo



surface
(albedo texture map)

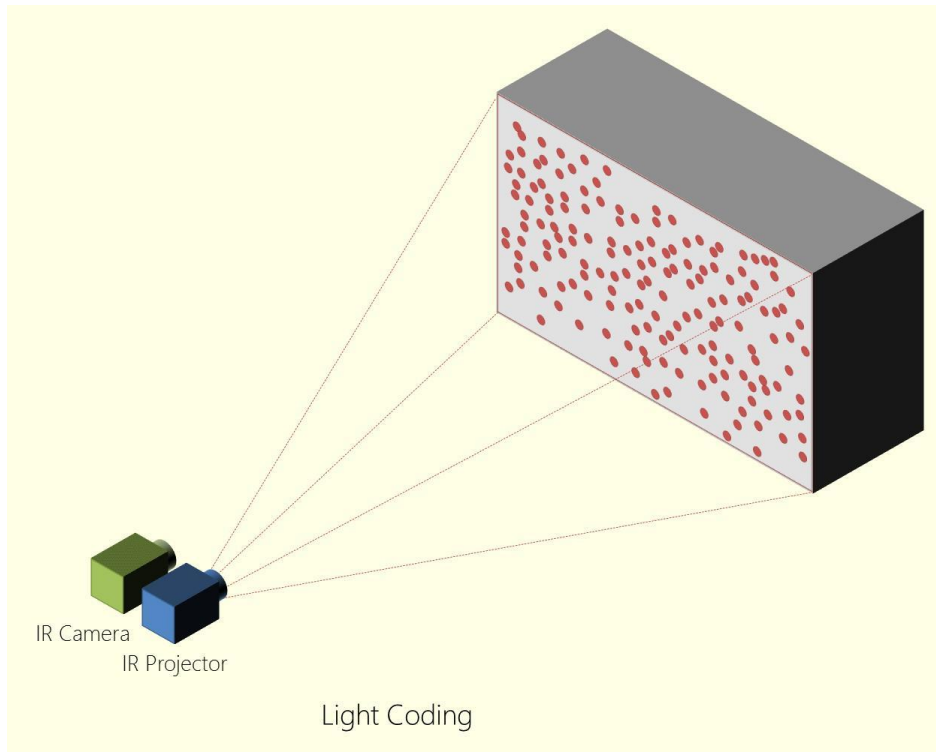


albedo

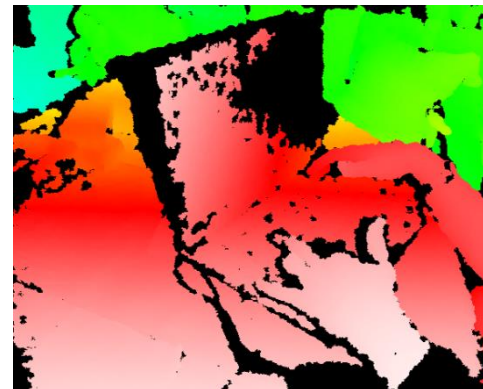
+ surface normals

Computational illumination

- Structured illumination (e.g., Kinect 1)



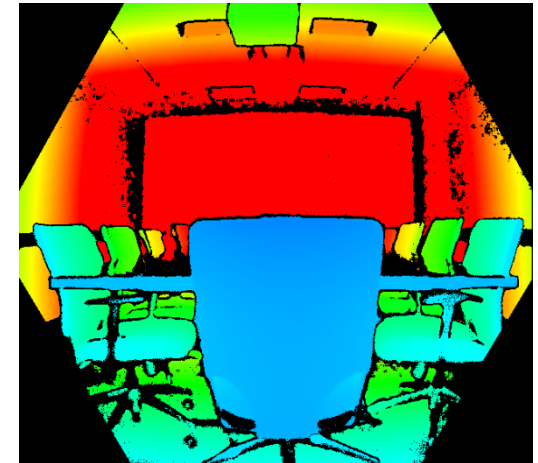
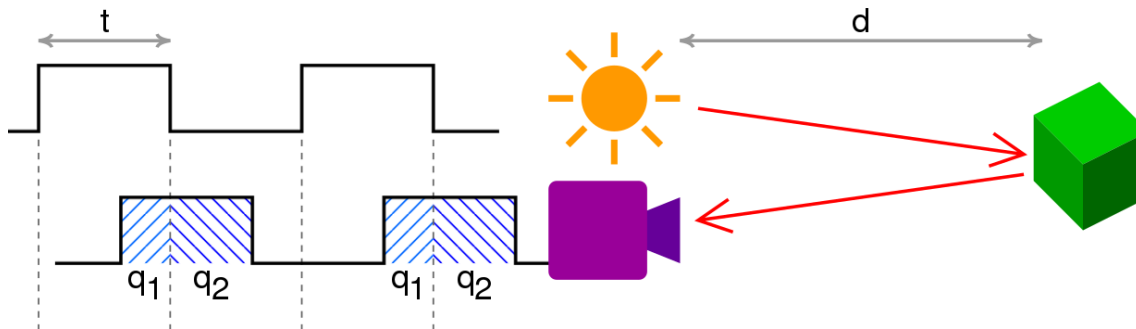
IR image



Depth image

Computational illumination

- Time of flight (e.g., Kinect 2, Azure Kinect DK)



Depth image

Syllabus

- Instructor: Ben Ochoa
- TA: Karan Santhosh
- Public course website
 - <https://cseweb.ucsd.edu/classes/wi24/cse273-a/>
- Course is on Canvas
 - **Piazza** for discussion
 - **Gradescope** for submitting assignments
- 18 lecture meetings
 - 2 university holidays (Jan 15 and Feb 19)

CSE 273 schedule

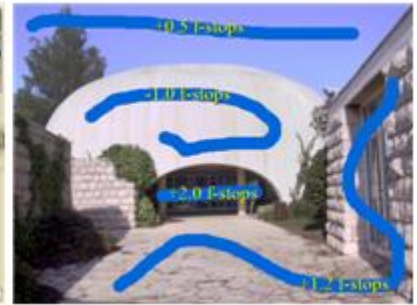
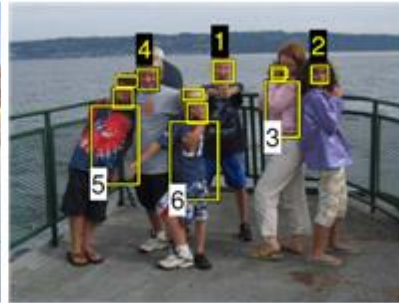
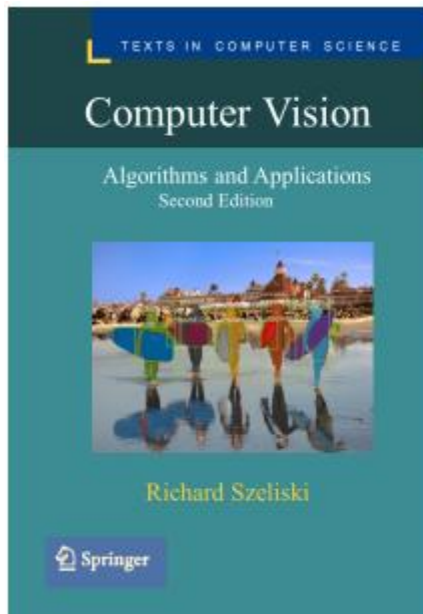
- Weeks 1-5
 - Typical lectures and homework assignments
- Weeks 6 and 7
 - Work on project proposals (and projects)
- Week 8
 - Initial project presentations and work on projects
- Weeks 9 and 10
 - Work on projects
- Finals week
 - Final project presentations

Syllabus

- Grading
 - 4 homework assignments (40% of grade)
 - Programming (using language of your choice) and report (e.g., prepared using Markdown or LaTeX; not handwritten)
 - Late policy: 15% grade reduction for each 12 hours late
 - Will not be accepted 72 hours after the due date
 - Project (60% of grade)
 - Project proposal and initial project presentation (20% of grade)
 - Project report and final project presentation (40% of grade)
 - **Late submissions will not be accepted**
 - No midterm or final exams
 - Piazza
 - Extensive, nontrivial participation could raise your grade (e.g., raise a B+ to an A-)

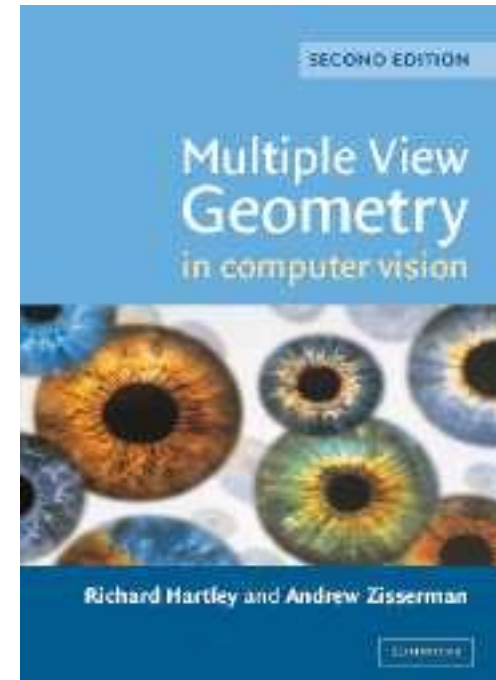
Helpful textbooks

- Computer Vision: Algorithms and Applications, 2nd edition
 - Richard Szeliski
 - <http://szeliski.org/book>



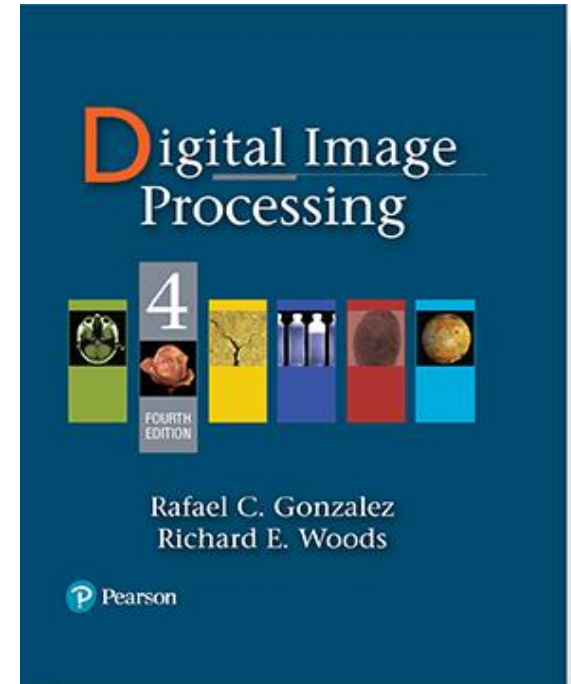
Helpful textbooks

- Multiple View Geometry in Computer Vision, 2nd edition
 - Richard Hartley and Andrew Zisserman
- Download the corrections and errata



Helpful textbooks

- Digital Image Processing, 4th edition
 - Rafael C. Gonzalez and Richard E. Woods
- See book website
 - Corrections and clarifications



Collaboration Policy

- Ask and answer questions on Piazza, not email
- Post **publicly** (optionally anonymously)
 - Conceptual questions and high-level questions about assignments
- All other posts must be **private** to “Instructors” (includes instructor and instructional assistants)
 - Low-level, detailed assignment questions (e.g., implementation details)
 - Assignment-specific code
 - Results (intermediate or final; e.g., numerical values, images, figures)
 - **Posting such items publicly is an academic integrity violation**
- If you are unsure, then post privately to “Instructors”
 - If suitable, then it will be changed to a public post
- Piazza is the official, University-sanctioned discussion forum
 - **Do not use Piazza to solicit others to an alternative forum**

Collaboration policy

It is expected that you complete your academic assignments on your own and in your own words and code. The assignments have been developed by the instructor to facilitate your learning and to provide a method for fairly evaluating your knowledge and abilities (not the knowledge and abilities of others). So, to facilitate learning, you are authorized to discuss assignments with others; however, to ensure fair evaluations, you are not authorized to use the answers developed by another, copy the work completed by others in the past or present, or write your academic assignments in collaboration with another person.

Academic integrity policy

Integrity of scholarship is essential for an academic community. The University expects that both faculty and students will honor this principle and in so doing protect the validity of University intellectual work. For students, this means that all academic work will be done by the individual to whom it is assigned, without unauthorized aid of any kind.

Academic integrity violation

If the work you submit is determined to be other than your own, you will be reported to the Academic Integrity Office for violating UC San Diego's Policy on Integrity of Scholarship. In accordance with the CSE department academic integrity guidelines, ***students found committing an academic integrity violation will receive an F in the course.***

Student conduct policy

UC San Diego strives to maintain a climate of fairness, cooperation, and professionalism. It is expected that you practice basic principles, including, but not limited to, mutual respect, civility, and decency, towards maintaining an atmosphere free of abusive or demeaning treatment. Non-academic student misconduct will be reported to the Center for Student Accountability, Growth, and Education for violating UC San Diego's Principles of Community.

Wait list

- Number of enrolled students is limited by
 - Size of room
 - Number of instructional assistants
- General advice
 - Wait for as long as you can
- UCSD policy: Extension (e.g., concurrent enrollment, UPS) students have lowest priority

Certification of commencement of academic activity

- Every course at UC San Diego, per the US Department of Education, is required to certify whether students have commenced academic activity for a class to be counted towards eligibility for Title IV federal financial aid. This certification must be completed during the first two weeks of instruction.
- For this course, the requirement will be fulfilled via an ungraded prior knowledge quiz, which will assist the instructional team by providing information about your background coming into the course
 - In Canvas (<https://canvas.ucsd.edu>), go to the course and navigate to Quizzes, then click on **First Day Survey: Prior Knowledge #FinAid**

Next lecture

- Cameras and color