Overview

Computational Photography
CSE 291
Lecture 1
CSE 291: Computational Photography

• Today
  – Course overview
  – Logistics
What is computational photography?

• To answer this question, let’s first answer the 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
What is 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
CSE 291 topics

• Cameras and image formation
• Image processing
• Burst photography
• Camera and image motion
• Computational illumination
• Camera arrays
• Light field photography
• Computational imaging
• Additional topics if time permits
Cameras

• Geometric image formation
  – How do 3D world points project to 2D image points?
Cameras

• Photometric image formation
  – What color is the projected point?

Need bidirectional reflectance distribution function (BRDF) at point on surface
Image processing

- Demosaicing
- Color spaces
Image processing

• Gamut mapping
• White balancing and color balancing
Image processing

• Dehazing
• Denoising
  – Bilateral filtering
• Deconvolution

Motion blur and additive noise

Degraded image  Inverse filtering  Wiener filtering  Constrained least squares filtering
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

SDR images

<table>
<thead>
<tr>
<th>SDR images</th>
<th>HDR image (mapped to 8 bits per sample)</th>
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sRGB version
Camera and image motion

- Mosaic construction from video or a set of images
Camera and image motion

• Video stabilization

Original video

Stabilized video
Computational illumination

• Photometric stereo

Surface (albedo texture map) + surface normals

Albedo
Computational illumination

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

• Time of flight (e.g., Kinect 2, Azure Kinect DK)
Camera arrays

The Matrix (bullet time)

Application: view synthesis
Camera arrays

Application: synthetic focus
Light field photography

Application: refocus

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.
Computational imaging

- Coded photography
- Compressive imaging

Coded aperture

Coded exposure
Additional topics (if time permits)

• Event based cameras
• Image fusion
Syllabus

• Instructor: Ben Ochoa
• TA: Karen Lucknavalai
• Course is on Canvas
• Course website
  – https://cseweb.ucsd.edu/classes/sp20/cse291-f/
• 19 lecture meetings (recorded)
  – 1 university holiday (Monday, May 25)
• Class discussion
  – Piazza
CSE 291 schedule (tentative)

• Weeks 1-5
  – Typical lectures and homework assignments
• Week 6
  – Work on project proposals
• Week 7
  – Initial project presentations
    • 10 minutes each!
• Weeks 8-9
  – Work on projects
• Week 10
  – Final project presentations
    • 10 minutes each!
Syllabus

• Grading
  – 4 homework assignments (50% of grade)
    • Programming and report prepared using Markdown or LaTeX
    • Late policy: 15% grade reduction for each 12 hours late
      – Will not be accepted 72 hours after the due date
  – Project (50% of grade)
    • Initial project presentation (10% of grade)
    • Final project presentation (10% of grade)
    • Project report (30% of grade)
    • Late submission will not be accepted
  – No midterm or final exams
  – Piazza
    • Ask (and answer) questions using Piazza, not email
    • Good participation could raise your grade (e.g., raise a B+ to an A-)
Helpful textbooks

• Computer Vision: Algorithms and Applications
  – Richard Szeliski
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
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.
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 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 UCSD'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.*
Wait list

• Number of enrolled students is limited by
  – Size of room
  – Number of instructional assistants (TAs and tutors)

• General advice
  – Wait for as long as you can

• UCSD policy: concurrent enrollment (Extension) students have lowest priority