Introduction, Overview, Fast Forward

EE367/CS448I: Computational Imaging and Display
stanford.edu/class/ee367
Lecture 1

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What is Computational Imaging?

Computational Displays + computation + optics & electronics + human visual system = Computational Imaging

- optics
- sensing
- computation
What is Computational Imaging?

1. optically encode scene information
2. computationally recover information

• new optics
• new sensors
• new illumination
• new algorithms
What is Light?

- E&M
- Wave Optics
- Geometric Optics
- Modern Signal Processing and Optimization
What is Light?

- light as rays
- unit: (spectral) radiance
- properties: wavelength, polarization, direction, ...
- ignore diffraction
Examples
Femto Photography
Femto Photography
Femto Photography
Looking Around Corners

2nd Bounce

1st Bounce

3rd Bounce
Doppler Time-of-Flight

RGB Video

Velocity

[Image of a hand waving a white sheet with a corresponding velocity map on the right.]
Doppler Time-of-Flight

RGB Video

Velocity

Depth
Vision-correcting Display
Vision-correcting Display

printed transparency

iPod Touch prototype
300 dpi or higher

prototype construction
conventional display

vision-correcting display
Light Field Cameras

Light Field Stereoscope

SIGGRAPH 2015
Fast Forward
The Human Visual System

- anatomy of the eye
- acuity, color, 3D vision
- contrast sensitivity
- conflicts in displays
- refractive errors
Digital Photography

• optics
• aperture
• depth of field
• field of view
• exposure
• noise
• color filter arrays
• imaging processing pipeline
Computational Photography

- high dynamic range
- super-resolution
- noisy / blurry
- burst photography
Computational Illumination

- time of flight
- structured illumination
- photometric stereo
- multi-flash photography
- microsoft kinect
- leap motion
Light Fields and The Plenoptic Function

- camera arrays
- integral imaging
- coded masks
- refocus
- fourier slice photography
Coded Computational Photography

- extended depth of field
- motion invariance
- flutter shutter
Compressive Imaging

• single pixel camera
• compressive hyperspectral imaging
• compressive light field imaging
Computational Light Transport

- direct / global separation
- optical computing
- time-resolved light transport
Computational Microscopy

- confocal, light sheet, 2 photon microscopy
- light field microscopy
- computational phase-contrast microscopy
Digital Displays

- liquid crystal displays
- spatial light modulators
- gamut mapping
- stereo displays
- light field displays
Computational Displays

- HDR displays
- projection displays
- volumetric displays
- vision-correcting displays
Wearable Displays

- AR & VR
- overview
Compressive Displays

- compressive light field displays
- compressive HDR displays
- compressive super-resolution
Class Details
(no formal) Prerequisites (but …)

- basic signal processing (EE 261 or equivalent)
- linear systems / algebra (EE 263 or equivalent)
- basic computer graphics or computer vision
- strong programming skills (Matlab, Octave, Python, …)
Related, Possibly Helpful Classes

Active Stanford Classes:

- EE 267: Virtual Reality (DIY HMD)
- CS 148: Introduction to Computer Graphics and Imaging
- PSYCH 221: Applied Vision and Image Systems Engineering
- EE 364A: Convex Optimization I
- EE 368: Digital Imaging Processing

Archived Classes:

- CS 178: Digital Photography
- CS 448A: Computational Photography
Related, Possibly Helpful Classes

Also helpful

• CS 131: Computer Vision: Foundations and Applications
• CS 231A: Computer Vision: From 3D Reconstruction to Recognition
• other computer vision courses:
  EE 231B, CS 231M, CS 328, CS 331A, CS 331B, CS 431
• graphics courses: CS 248, CS 348B, CS 448
Imaging-related Activities at Stanford

• SCI – Stanford Computational Imaging Group
  • www.computationalimaging.org

• SCIEN - weekly colloquium, info here: scien.stanford.edu
  • lots of interesting talks & interesting people
  • free food & drinks
  • every Wed, 4:15-5:15 pm in Packard 101
  • sign up for the mailing list!
Requirements and Grading

• 6 assignments: 35%
• class and piazza participation: 5%
• in-class midterm: 15%
• major final project (teams of ≤ 3): 45%
  • discuss project ideas with TA & instructor!
  • project proposal presentation (02/8) – Novelty, Impact, Feasibility
  • final presentation: Friday 03/11, location TBA
  • reports due: Monday 03/14, midnight
Resources (see course website!)

- website:  stanford.edu/class/ee367
- contact:  ee367-win1516-staff@lists.stanford.edu
- office hours (TA): Mon 1-2 pm (after class), Packard 106
- office hours (Instructor, for projects): Thu 10-11am, Packard 236
- piazza:  piazza.com/stanford/winter2016/ee367
- teaching lab:  Packard 001 (access provided by TA)
Tentative Schedule

http://stanford.edu/class/ee367/
What we don’t discuss

• no medical imaging, but concept may apply – medical imaging projects are encouraged!

• only outlook on diffractive / interferroometric imaging
Lectures and Problem sessions

• 2 lectures per week: Mo & Wed 11:30am - 12:50pm in Huang 18

• 1 problem session: Fri 11:30am - 12:30pm in Huang 18

• attendance recommended, but everything is recorded
Assignments

- 6 assignments: mix of theory, hands-on building, and programming
- out every Wed after the lecture (starting this week), due Wed after at 11am
- no late days!
- you can submit until that Fri 11am with 30% penalty on the full score
- discussion among students encouraged, but must submit own solution and acknowledge others that you discussed this with
- submission via www.gradescope.com - create account, use entry code 9PY76M

- Orly will do weekly problem session (attendance highly recommended): Fridays 11:30-12:30pm, Huang Room 18 (here)
Midterm

- Feb 22: 80 minute, in-class midterm
- open book: you can use internet, lecture material, etc.
- bring laptop!
- writing small Matlab scripts may be helpful but not required – definitely bring a calculator!
Course Projects & Proposal

• individual or teams of up to 3 people
• 45% of your grade – plan on ~50-60 h per person!

• Feb 2: short project proposal = 1-2 pages with
  • motivation
  • related work
  • project overview
  • milestones, timeline & goals
  • at least 3 scientific references
  • we may ask you to revise the proposal, will assign a mentor to your team
Course Projects

• **Mar 11**: project poster + demo session
  • see poster template on website (will be there later)
  • celebrate your work and connect with students, faculty, and industry!
  • will invite many people from industry: Intel, Nvidia, Olympus, Canon, Google, Oculus / Facebook, …

• SCPD students only: can submit narrated video presentation
Course Projects

• **Mar 14**: report + source code due (at midnight)

• report = conference paper format ~6 pages with
  • abstract
  • introduction
  • related work
  • theory
  • analysis
  • results
  • discussion and conclusion
  • references
  • see latex template on website (will be there)
Course Projects

• must also submit source code along with report!

• proposals, reports, source will be available on course website
  • only use non-copyrighted material
  • especially SCPD students: no projects that require NDA or company secrets
  • may request that source code / report may not be public – contact staff
Project Ideas – Available Equipment

- Olympus Air
- Lytro Illum
- Oculus Rift DK2
- Project Tango?
- eyetribe gaze tracker
- TI LightCrafter
- SLRs
- Time of Flight Cam
- Intel RealSense
- Casio 400 or 1000 fps
Possible Course Projects

• be experimental!

• (stereo) panorama with Olympus
• light field (panorama) stitching with Lyto Illum
• simulate refractive errors of HVS with Lytro
• fuse small f-number + higher f-number stereo images from Olympus
• Eyetribe gaze tracker – do something interesting with that
• hyperspectral photometric stereo
• spatio-spectral structured illumination
Possible Course Projects

http://stanford.edu/class/ee367/projects2015.htm
Next Class: The Human Visual System

- anatomy of the eye
- acuity, color, 3D vision
- contrast sensitivity
- conflicts in displays
- refractive errors