6.815 Digital and Computational Photography
6.865 Advanced Computational Photography

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Today's plan

• Introduction of Computational Photography
• Course facts
• Syllabus
• History
The unfinished digital photography revolution

- Traditional photography:
  - optics focuses optical array onto sensor
  - chemistry records final image

- Digital photography
  - optics focuses optical array onto sensor
  - digital sensor records final image
Computational Photography

- Arbitrary computation between the optical array and the final image
- Data recorded by sensor is not the final image
Computational Photography

Arbitrary computation between optical array and final image (or final product)

- Post-process after traditional imaging
  - a.k.a. image processing (maybe more interactive)
  - But also combine multiple images to overcome limits of traditional imaging (HDR, panorama)

- Design imaging architecture together with computation
  - Computational cameras, computational illumination, coded imaging, data-rich imaging

- Extract more than just 2D images
- New media (panorama, photo tourism)
Quick demos

Computational Photography @ MIT

•
Tone mapping

• One of your assignments!
Black and white digital

- with Soonmin Bae and Sylvain Paris [Siggraph 06]
- Users often disappointed by BW photos
High-quality black and white

- Can we “transfer” some of the low-level qualities?
- with Soonmin Bae & Sylvain Paris [Siggraph 06]
With Bae & Paris [Siggraph 06]

Our result based on Adams' example
Motion magnification

✦ with Liu, Torralba, Freeman & Adelson [Siggraph 2005]
✦ Analyze motion in video (robust to occlusion)
✦ Magnify motion that is hard to see
Motion magnification

✦ with Liu, Torralba, Freeman & Adelson [Siggraph 2005]
✦ Analyze motion in video (robust to occlusion)
✦ Magnify motion that is hard to see
Modeling virtual scenes from images

A former student, Max Chen, went to ILM (LucasFilm) to implement technology developed for his Master’s. He received a technical Oscar for it.
Image and Depth from a Conventional Camera with a Coded Aperture

With Anat Levin, Rob Fergus, Bill Freeman [Siggraph 2007]
RGB & coarse depth from single image
Defocus & depth

- Objects at focusing distance are sharp
Defocus & depth

- Objects far from focusing distance are blurrier
Defocus & depth

- Objects far from focusing distance are blurrier
Defocus & depth

- Objects far from focusing distance are blurrier
- By inferring blur, we can infer depth
Build your own coded aperture
Open the lens
Open the lens
Open the lens
Open the lens
Open the lens
Open the lens
Open the lens
Now the critical part
Cardboard mask
Cardboard mask
Cardboard mask
Cardboard mask
Cardboard mask
Cardboard mask

careful use of scotch tape
Close it up
Close it up
Close it up
Close it up
Close it up
Close it up
Voilà!
Input
Deconvolved (all-focus)
Close up

Original image

All-focus image
Depth
Refocusing (from single image!)
Refocusing (from single image!)
Refocusing (from single image!)
Refocusing (from single image!)
Results
Refocusing (from single image!)
Refocusing (from single image!)
Refocusing (from single image!)
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Administrivia

- Staff
  - Frédo Durand fredo@mit.edu
  - Soonmin BAe green@csail.mit.edu
  - 6815-students@lists.csail.mit.edu -- announcements
  - 6815-staff@lists.csail.mit.edu --to reach fredo and Soonmin
  - 6815-discuss@lists.csail.mit.edu -- student discussion
  - http://lists.csail.mit.edu

- Prereq: 18.06 & 6.003
  - or equivalent level

  - Lecture notes will be posted
Grading policy

• Assignments 72%
• Final project 28%
• 6.865
  – Additional questions compared to 6.815
  – Paper review
    • Read and write a review (Siggraph form) for a paper from the literature
Assignment

- Every week
- Mostly programming
- Camera?
  - Not required, but can help. Can be borrowed from us.
- Matlab
  - Soonmin will give an intro
  - Or see Xiaoxu Ma's slides:
  - Or read the matlab tutorial, or google
- Turn in code and results
- Final project
  - Proposal due with PSet 8
  - Individual or teams of 2
Policies

• **Collaboration**
  – You are welcome and encouraged to chat about assignments
  – Code must be written on your own

• **Late**
  – Homework must be submitted on time
  – A dean note is required to get an extension for medical reasons
  – Special circumstances: ask one week in advance
Textbook

• No textbook required
• Lots of resources on the net
• Siggraph course notes
  – http://www.merl.com/people/raskar/photo/
• Will post lectures slides
• Links to articles in slides
Questions?
Introductions

• Who are you?
• What do you know about photography?
• Why you want to take this class?
What do you think you will learn?
What the class is not about

• Little about art, photographers
• Little about EE (sensors, A/D, etc)
• Not a lot about optics
  – but some cool stuff such as wavefront coding
• Not how to use Photoshop
  – But how its coolest tools work
• Not much about 3D imaging
• Not too much fundamentals of signal processing
• Not much computational imaging, no tomography, no radar, no microscopy
• Not much computer vision, computer graphics
  – We avoided overlap with 6.837 and 6.801/6.866
What the class is about

• **Software aspects of computational photography**
  – but a bit of hardware as well, lens technology, new camera designs

• **Basic tools**
  – Linear & non-linear image processing, color

• **Emphasis on applications**
  – High-dynamic range photography, photomontage, panoramas, foreground extraction, inpainting, morphing

• **Emphasis on recent research results**
Skills you will acquire

• Implementation of basic tools
  – Color demosaicing
  – Seam carving
  – Matting
  – Bilateral filter, tone mapping
  – Gradient reconstruction
  – Panorama stitching

• General approaches to computational photography

• Important problems in computational photography
Non-photo motivation

• It's about any kind of data!
  – Speech, motion, geometry, etc.
  – Example:
    • Music
    • Motion graphs
    • Poisson mesh editing
    • BTF shop

• Lots of fundamental numerical tools
Questions?
Today's plan

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Syllabus

• Color and color perception

• Demosaicing
Syllabus

• High Dynamic Range Imaging
• Bilateral filtering and HDR display
• Matting
Syllabus

• Gradient image manipulation
Syllabus

- Tampering detection
Syllabus

• Panoramic imaging

• Image and video registration

• Spatial warping operations
Improved Seam Carving for Video Resizing

Michael Rubinstein
Mitsubishi Electric Research Lab

Ariel Shamir
The InterDisciplinary Center

Shai Avidan
Adobe Systems Inc.
Syllabus

• Active flash methods
• Lens technology
• Depth and defocus
Syllabus

• Future cameras
• Plenoptic function and light fields
Questions?
Assignment 0

• Matlab Warmup
• Spanish Castle illusion
Questions?
Quick equipment discussion

• If you’re wondering how to get serious about photography

• Ask me for more advice if needed.
• I can do an SLR initiation session if requested
Equipment

- Do get an SLR (compacts are way too limited)
- Don't worry about brand
- Don't worry about the body, get the cheapest one
- Worry about lenses
  - Zooms are convenient but quality can be a problem
    - avoid the basic zoom, but the one above is usually great
    - Avoid large focal range (18-300: yuck!)
    - Maximum aperture matters (the smaller the number, the better)
      - Get a 50mm f/1.8
        (cheap, high quality, wide aperture)
- Get a tripod
- Get an external flash if you want to take “event” pictures
  - And orient towards wall/ceiling
  - Good flash photography is very difficult
- Count ~1k for camera+standard zoom+50mm
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Quiz (0.001% of grade)

- When was photography invented?
- By whom?
  - Exposure time?
Quiz

• When was photography invented? 1826
• By whom? Niepce
  – Exposure time? 8 hours

• William Henry Fox Talbot invents the *calotype* in 1834 which pretty much invents the negative
First production camera?
First production camera?

- 1839. Daguerrotype
Beginning of hobby photography?

• 1900 Kodak Brownie
Quiz

• Who did the first color photography?

• When?
Quiz

• Who did the first color photography?
  – Maxwell
    (yes, the same from the EM equations)

• When? 1861
Quiz

Prokudin-Gorskii

- Digital restoration

http://www.loc.gov/exhibits/empire/
Prokudin-Gorskii
Instant photography?
Instant photography?

- 1947, Edwin Land (Polaroid founder)
First TV?

Transmission of moving images
First TV?

Transmission of moving images

• 1884 - Paul Nipkow
  – Using rotating disk with raster spiral
  – But amplification problems
Electronic photography?

- A. A. CAMPBELL SWINTON AND ELECTRONIC PHOTOGRAPHY - 1908
- 25 images per second
Television (II)

• PHILO T. FARNSWORTH TELEVISION - 1932

PHILO T. FARNSWORTH TELEVISION - 1932. A Utah-born Idaho farm boy, Philo T. Farnsworth helped create television as we know it today. At fourteen, he visualized trapping light in an empty jar and transmitting it one line at a time onto a magnetically deflected beam of electrons. By the time Farnsworth was 21 he had developed the first all-electronic system of television. A 1922 sketch by Farnsworth shown to his high school physics and chemistry teacher illustrated how an image might be electronically transmitted through the air to a receiver by breaking the image up into a number of horizontal slices. This image process which we now call a raster image occurred to Farnsworth when as a fourteen-year old boy he looked across the rows of a field he was plowing. Besides his contributions to television, Farnsworth patented more than 130 inventions during his lifetime.

1922 Farnsworth High School Sketch of His TV Camera Tube and First Farnsworth TV Camera
Color TV
Color TV

- First broadcast in 1951, CBS
Autofocus
Auto Focus

• 1978, Konica

• 1981 Pentax ME-F.

• Canon T80 1985
  – Canon AL1 had focus assist but no actuator

• Minolta Maxxum 1985 (AF in body)
Japanese take over camera market?
Japanese take over camera market?

• 1959 Nikon F
  – First motorized SLR
  – First 100% viewfinder
  – Mirror lockup

• Lots of pros switched from Leica to Nikon
First scanned photo?
First scanned photo?

• 1957, Russell A. Kirsch of the National Bureau of Standards, 176x176
CCD technology?
CCD technology?

• 1969, Willard S. Boyle and George E. Smith, Bell Laboratories
Computer Graphics?

Computers to create image
Computer Graphics?

Computers to create image

• Sketchpad, 1961, Ivan Sutherland’s MIT PhD thesis (advised by??)
Computer Graphics?

Computers to create image

- Sketchpad, 1961, Ivan Sutherland’s MIT PhD thesis (advised by Claude Shannon)
Paint program
Paint program

• Dick Shoup: SuperPaint [1972-73]
  – 8 bits

• Alvy Ray Smith (Pixar co-founder): Paint [1975-77]
  – 8 bits then 24 bits
  – http://www.alvyray.com/Awards/AwardsMain.htm

• Tom Porter: Paint
Photoshop
Photoshop

- Thomas Knoll and John Knoll began development in 1987
- Version 1.0 on Mac: 1990
- [http://en.wikipedia.org/wiki/Photoshop#Development](http://en.wikipedia.org/wiki/Photoshop#Development)
Internet photo browsing

• (Web browser that can display photos)
Internet photo browsing

- (Web browser that can display photos)
- Mosaics, NCSA, Urbana Champaign, 1992
First digital camera?
First digital camera?

• 1975, Steve Sasson, Kodak
• Uses ccd from Fairchild semiconductor, A/D from Motorola, .01 megapixels, 23 second exposure, recorded on digital cassette
Still video camera

- Sony Mavica 1981
  - Electronic but analog
Completely Digital Commercial camera

http://www.g4tv.com/l
Completely Digital Commercial camera

- 1991 first completely digital Logitech Dycam 376x240
Digital

- 1994 Apple quicktake, first mass-market color digital camera, 640 x 480 (commercial failure)

http://www-users.mat.uni.torun.pl/~olka/l
First megapixel sensor

• Of reasonable size?
First megapixel sensor

- Of reasonable size?
- (Kodak) Videk 1987, 1.4MPixels
Digital SLR?
Digital SLR?

- 1992 Kodak DCS 200, 1.5 Mpixels, based on Nikon body
Pros adopt digital?
Pros adopt digital?

- Nikon D1 1999, 2.7MPixels
Consumer digital SLR?
Consumer digital SLR?

- Canon D30, 2000 3MPixels
Camera phone?
Camera phone?

- In November 2000 Sharp and J-Phone introduced the first camera-phone in Japan
Traditional Photography

• XVIth century (drawing by da Vinci) Camera Obscura
• XVIIth century Robert Boyle finds that silver chloride darkens under exposure, but he believes it's due to air.
• Angelo de Sala figures out it's the sun
• early nineteenth century, Thomas Wedgwood captures silhouettes but they disappear
• 1825, Niepce makes first photo (8 hour exposure!)
• Daguerre reduces this to half an hour (development) Daguerreotype, public in 1839. Impossible to reproduce.
• William Henry Fox Talbot invents the calotype in 1834 which pretty much invents the negative
• Frederick Scott Archer in 1851 reduces exposure to a couple seconds
• 1855 beginning of stereo mania
• 1861 Maxwell shows the fist color photograph
• 1877 Edweard Muybridge photographs running horses
• 1893 Flash bulb, invented for underwater photography
• 1906 Panchromatic film that truly enable color photography
• 1924 Leica 35mm interchangable camera
• 1930 flash bulb (Paul Vierkotter)
• 1936 Kodak SLR camera
• 1948 Pentax introduces automatic diaphragm
• 1949 Zeiss developes the Contax, the first SLR with pentaprism for uninversed image
• 1963: Polaroid instant film
• 1964 Pentax TTL (through the lens) metering
• 1981 Pentax autofocus camera
Refs

- http://www.digicamhistory.com/
- http://www.photo.net/history/timeline
- http://www.loc.gov/exhibits/empire/
- http://www.spartacus.schoolnet.co.uk/USAphotographers.htm
- http://www.eyeconart.net/history/photography.htm
- http://www.g4tv.com/callforhelparchive/features/44534/Witness_to_History_The_Digital_Camera.html
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- http://www-users.mat.uni.torun.pl/~olka/
- http://inventors.about.com/od/pstartinventions/a/Photography.htm
- http://accad.osu.edu/~waynec/history/timeline.html