Introduction to the course

BIL721: Computational Photography
Spring 2015, Lecture 1

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Animated movie still from The Royal Tenenbaums (2001)
by If We Don't, Remember Me.
Today’s Schedule

• A little about me
• A little about you
• A brief history of photographic technology
• Introduction to Computational Photography
• Course outline and logistics
About me

• Asst. Prof. Aykut Erdem
  http://web.cs.hacettepe.edu.tr/~aykut/

Hacettepe University
Faculty Member
2010-now

Ca’ Foscari University of Venice
Post-doctoral Researcher
2009-2010

Middle East Technical University
1997-2008
Ph.D., 2008
M.Sc., 2003
B.Sc., 2001

Massachusetts Institute of Technology
Visiting Student
About me

- Asst. Prof. Aykut Erdem
  http://web.cs.hacettepe.edu.tr/~aykut/

http://vision.cs.hacettepe.edu.tr/
My Research

Image smoothing

flower placed ground.
cat sitting room.
ship parked harbor.

Cross-modal multimedia retrieval

Visual Saliency Prediction

Predicted most memorable (85%)
Predicted least memorable (44%)

Image memorability
Introduce yourselves

• Who are you?
• What do you know about photography?
• Why you want to take this class?
What is Computational Photography?
What is Computational Photography?

• An emerging new research area bringing together the advancements in computer graphics, computer vision and image processing to overcome the limitations of conventional photography.

• Digital photography:
  – Simply replaces traditional sensors and recording by digital technology.
  – Involves only simple image processing.

• Computational photography:
  – More elaborate image manipulation, more computation.
  – New types of media (panorama, 3D, etc.).
  – Camera design that take computation into account.
Depicting Our World: The Beginning

Prehistoric Painting, Lascaux Cave, France
~13,000 – 5,000 B.C.

Slide credit: Alyosha Efros
The Empress Theodora with her court.
Ravenna, St. Vitale 6th c.

Slide credit: Alyosha Efros
Middle Ages

Nuns in Procession. French ms. ca. 1300.

Slide credit: Alyosha Efros
Renaissance – Perspective

North Doors (1424)  Lorenzo Ghiberti (1378-1455)  East Doors (1452)

Slide credit: Alyosha Efros
Renaissance – Perspective

Paolo Uccello,
Miracle of the Profaned Host (c.1467-9)

Slide credit: Alyosha Efros
Song Dynasty (China)

Qingming Festival by the Riverside, Zhang Zeduan ~900 AD

Slide credit: Fei-Fei Li
Edo Period (Japan)

The Great Wave off Kanagawa, part of the series Thirty-six Views of Mount Fuji, Hokusai (between 1826 and 1833)
The Ottoman army besieging Vienna, from Huner-nama ('Book of Skills'). Nakkas Osman, 1588.
Ottoman Miniatures

An Ottoman miniature from Surname-ı Vehbi, Abdulcelil Levni (1720)
Renaissance – Realism

Jan van Eyck, The Arnolfini Marriage (c.1434)

Slide credit: Alyosha Efros
Camera Obscura

• A camera-like device for automating perspective drawing
• Key elements of camera already present
  Image formation—small hole projects image into room
  Image recording—artists stands there and traces
Forming better images

- Lenses increase sharpness and brightness
Recording images automatically

- Silver halide (AgCl, AgBr, AgI) salts are light sensitive
  - absorbed photons in halide ions cause free electrons
  - electrons combine with Ag+, producing metallic silver

- Daguerre: first practical and permanent photographic plate
  - Hg vapor (yikes!) combines with Ag to produce reflective amalgam
  - Daguerrotypes were widely popular

- Indirect negative-plate processes
  - negative images on paper, glass allowed multiple copies to be printed

- Roll film: silver halide grains in gelatin on celluloid
  - introduced by Eastman in 1880s
  - portable, convenient, practical
  - sensitive (“fast”) enough for moving subjects in daylight

Slide credit: Steve Marschner
Recording images better

View from the Window at Le Gras, Joseph Nicéphore Niépce (1826)
Recording images better

Still Life, Louis Jaques Mande Daguerre, 1837

Slide credit: Alyosha Efros
First photograph including a person (on pavement at lower left), by Daguerre, 1838
ANYBODY who can wind a watch can use the Kodak Camera. It is a magazine camera, and will make one hundred pictures without reloading. The operation of taking the picture is simply to point the camera and press a button. The picture is taken instantaneously on a strip of sensitive film, which is moved into position by turning a key.

A DIVISION OF LABOR. After the one hundred pictures have been taken, the strip of film (which is wound on a spool) may be removed, and sent by mail to the factory to have the pictures finished. Any amateur can finish his own pictures, and any number of duplicates can be made of each picture. A spool of film to reload the camera for one hundred pictures costs only two dollars.

No tripod is required, no focusing, no adjustment whatever. Rapid rectilinear lens. The Kodak will photograph anything, still or moving, indoors or out.

A PICTURESQUE DIARY of your trip to Europe, to the mountains, or the sea-shore, may be obtained without trouble with a Kodak Camera, that will be worth a hundred times its cost in after years.

A BEAUTIFUL INSTRUMENT is the Kodak, covered with dark Turkey morocco, nickel and lacquered brass trimmings, enclosed in a neat sole leather carrying case with shoulder-strap—about the size of a large field-glass.

Send for a copy of the KODAK PRIMER with Kodak photograph.

THE EASTMAN DRY PLATE AND FILM CO.,
Branch: 115 Oxford St., London.
ROCHESTER, N.Y.
Motion Pictures

• Sensitive roll film enables sampling in time
• 1890s—several cameras
  – Lumière brothers’ Cinematographe
  – Edison’s Kinescope
George Méliès

Georges Méliès, A Trip to the Moon, 1902

Slide credit: Steve Marschner
Improvements in Cameras

- Size and portability
- Ease of use
- Automation
Improvements in film

• Sensitivity
  – enables photographs of faster subjects—“faster” film

• Dynamic range
  – higher quality images with detail in highlights and shadows expanded “latitude” to mess up the exposure

• Resolution
  – enables smaller format cameras
Television

- Practical around 1927 (Farnsworth)
- Camera basically the same
  - imaging lens plus planar image sensor
- Recording is electronic
  - various early schemes
  - early winner: CRT image sensors
    (Orthicon, Vidicon, ...)
- Initially seems quite different from photography/cinematography
  - ephemeral output signal—live viewing only low resolution, low dynamic range images
Imaging around 1950s–70s

• Technology improves incrementally
  – Film emulsions improve; very high quality attainable in large formats
  – Video technology improves; but standards keep resolution fixed
  – Lens designs improve, cameras become much more usable

• Usage is refined
  – Photography an established art form, widespread hobby
  – Cinematography develops as a storytelling medium
  – Television becomes dominant mass communication medium
Meanwhile...

- Invention of Charge-Coupled Device (CCD) (1969)
  - solid-state, fundamentally discrete image sensor
  - quickly established in astronomy, space
  - by mid-80s, displaces tubes in video cameras (as drop-in replacement)
- Computing and computer graphics
  - sufficient memory to store images becomes available
  - first framebuffers developed 1972–74
- Digital signal transmission and processing
  - used for audio and telephone
- These set the stage for the next revolution
Meanwhile...

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Digital imaging

• Halftone printing of images
  – halftone process around for a while
  – complex, delicate optical procedure
  – moving images from place to place requires moving film or paper

• Digital imaging
  – scan images from film or paper
  – transmit images by phone
  – do processing (e.g. halftone separation) by computing
  – print images using laser printer or laser film recorder

• Image editing
  – 1990—Adobe Photoshop 1.0

• Image compression algorithms
  – make image storage, transmission more practical
But is a photo realistic?
But is a photo realistic?
Is reality what we want?

Newlyweds

Slide credit: Derek Hoiem

http://salavon.com
Enter Computer Graphics...
Traditional Computer Graphics

3D geometry

physics

Simulation

projection

Slide credit: Alyosha Efros
State of the Art

- Amazingly real
- But so sterile, lifeless, futuristic (why?)

Slide credit: Alyosha Efros
The richness of our everyday world
Beauty in complexity
Which parts are hard to model?
People

From “Final Fantasy”

On the Tube, London

Slide credit: Alyosha Efros
Faces / Hair

From “Final Fantasy”

Slide credit: Alyosha Efros

Photo by Joaquin Rosales Gomez
Hyper-humans
Urban Scenes

Virtual LA (SGI)

Photo of LA

Slide credit: Alyosha Efros
Nature

River Cherwell, Oxford

Slide credit: Alyosha Efros
The Realism Spectrum

Computer Graphics

+ easy to create new worlds
+ easy to manipulate objects/viewpoint
- Very hard to look realistic

Computational Photography

Realism Manipulation Ease of capture

Photography

+ instantly realistic
+ easy to acquire
- very hard to manipulate objects/viewpoint

Slide credit: Alyosha Efros
The unfinished 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
Limitations of traditional photography

• Blur, camera shake, noise, damage
Limitations of traditional photography

- Limited resolution
Limitations of traditional photography

• Bad color / no color
Limitations of traditional photography

- Unwanted objects
Limitations of traditional photography

- Unfortunate expressions
Limitations of traditional photography

• Limited dynamic range
Limitations of traditional photography

• Single viewpoint, static 2D picture
Limitations of traditional photography

- Single depth of focus
Computational Photography

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

Generalized imaging
Lots of computation
Final image

Slide credit: Fredo Durand
Computational Photography

• Arbitrary computation between the optical array and the final image

• 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)
Computational Photography

• How can I use computational techniques to capture light in new ways?
• How can I use computational techniques to breathe new life into the photograph?
• How can I use computational techniques to synthesize and organize photo collections?

Slide credit: Alyosha Efros
Class Details
Logistics

• Instructor:
  – Aykut Erdem (111)
  – Office hours: By appointment

• Time and Location
  – Lectures: Tuesdays, 13:00-15:45 @ D10

• Class webpage:
Communication

• We will be using Piazza for course related discussions and announcements.

• Please enroll Piazza group by following the link:
Prerequisites

- Good programming skills (especially Matlab)
- Basic knowledge of linear algebra and calculus.
- Previous knowledge of computer graphics, computer vision or image processing will be helpful but not absolutely required.
Reference books

http://szeliski.org/Book/
Supplemental Reading Material

- Lecture notes and handouts
- Papers and journal articles
Related Conferences

- ACM SIGGRAPH
- ACM SIGGRAPH Asia
- Eurographics (EG)
- ACM Multimedia (MM)
- IEEE International Conference on Computer Vision (ICCV)
- European Conference on Computer Vision (ECCV)
- IEEE Conference on Computer Vision and Pattern Recognition (CVPR)
- British Machine Vision Conference (BMVC)
- Asian Conference of Computer Vision (ACCV)
- Advances in Neural Information Processing Systems (NIPS)
- IEEE International Conference on Computational Photography (ICCP)
- IEEE International Conference on Pattern Recognition (ICPR)
Related Journals

- ACM Transactions on Graphics (TOG)
- International Journal of Computer Vision
- IEEE Transactions on Pattern Analysis and Machine Intelligence
- Computer Vision and Image Understanding
- Pattern Recognition
- Journal of Mathematical Imaging and Vision
- Image and Vision Computing
- The Visual Computer
Grading Policy

• 20% Programming Assignments
• 20% Quizzes
• 20% Paper Presentations/Class participation
• 40% Project and final term paper
Programming Assignments

• A total of 4 programming assignments
• Related to the topics covered in the class.
• Each one will involve
  – implementing an algorithm (usually in Matlab),
  – carrying out a set of experiments, and
  – writing up a report

• All assignments have to be done individually, unless stated otherwise!
Paper presentations and Quizzes

• The students will be required to present at least one research paper either of their choice or from the suggested reading list.

• These papers should be read by every student as the quizzes about the presented papers will be given on the weeks of the presentations.
Project

• The students taking the course will be required to do a project in computational photography, which should be done individually.

• This project may be
  – An original implementation of a new or published study
  – A detailed empirical evaluation of two or more related methods not covered in the class

• March 10: Project proposals
• April 23: Project progress reports
• June 2: Project final reports

• Detailed description of the course project at
Tentative Schedule
Cameras and Sensors

• Image formation
  – How cameras work?
Image Processing Basics
Texture synthesis, video textures

• Goal: create new samples of a given texture
• Many applications: virtual environments, hole-filling, texturing surfaces

Image Retargeting, Blending

Slide credit: Rob Fergus
Compositing and Matting

- Gradient domain image manipulation
Warping and Morphing

Image deformation using moving least squares

Schaefer et al. (2006)

Face morphing

Slide credit: Svetlana Lazebnik
Panoramas and Mosaics

Panorama stitching

AutoCollage

Rother et al. (2006)

Multi-viewpoint panoramas

Agarwala et al. (2006)

Slide credit: Svetlana Lazebnik
High dynamic range imaging
Tone mapping

Before

After

Slide credit: Fredo Durand
Faces

Exploring Photobios, SIGGRAPH 2011
Ira Kemelmacher-Shlizerman, Eli Shechtman, Raul Garg, and Steven M. Seitz

Illumination-Aware Age Progression, CVPR 2014
Ira Kemelmacher-Shlizerman, Supasorn Suwajanakorn, and Steven M. Seitz
Better Photos

• What makes a great photo?

Derrière la gare de Saint-Lazare,
Cartier-Bresson (1932)
Better Photos

• Users often disappointed by BW photos
Better Photos

• Can you “transfer” some of the low-level qualities?
Better Photos

Output result

Two-scale Tone Management for Photographic Look
Soonmin Bae, Sylvain Paris, Frédo Durand, SIGGRAPH 2006
Big Visual Data: Image Completion

Slide credit: Alyosha Efros

Scene Completion using Millions of Photographs
Big Visual Data: Image Completion

Scene Completion using Millions of Photographs
Big Visual Data: Image Completion

Scene Completion using Millions of Photographs
Big Visual Data: Image Completion

Scene Completion using Millions of Photographs
Scene Completion using Millions of Photographs

Slide credit: Alyosha Efros
Big Visual Data: Hallucination for Different Times of Day

Reading Assignment

• Brian Hayes, *Computational Photography*, *American Scientist* 96, 94-99, 2008

• *100 Ideas That Changed Photography* (Brain Pickings)
Next: Cameras and Sensors

• Pinhole Optics and Lenses
• Exposure & Depth-of-field
• Aberrations
• Sensors
• Color sensing