BBM 444 – Fundamentals of Computational Photography

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Today

• Introduction to Computational Photography
• Course Overview
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 -- 15,000 B.C.

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

Slide credit: Alyosha Efros
Depicting Our World: Middle Ages

*Nuns in Procession*. French ms. ca. 1300.

Slide credit: Alyosha Efros
Depicting Our World: Renaissance

North Doors (1424)

Lorenzo Ghiberti (1378-1455)

East Doors (1452)
Depicting Our World: Renaissance

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

Slide credit: Alyosha Efros
Depicting Our World: Song Dynasty (China)

Qingming Festival by the Riverside, Zhang Zeduan ~900 AD

Slide credit: Fei-Fei Li
Depicting Our World: *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.
Depicting Our World: Ottoman Miniatures

An Ottoman miniature from *Surname-i Vehbi*, Abdulcelil Levni (1720)
Depicting Our World: Toward Perfection

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

Slide credit: Alyosha Efros
Depicting Our World: *Toward Perfection*

Lens Based Camera Obscura, 1568

Slide credit: Alyosha Efros
Depicting Our World: Perfection!

View from the Window at Le Gras, Joseph Nicéphore Niépce (1826)
Depicting Our World: *Perfection!*

*Still Life*, Louis Jaques Mande Daguerre, 1837

Slide credit: Alyosha Efros
After realism...

Monet,

*La rue Montorgueil*

Slide credit: Alyosha Efros
Depicting Our World: Ongoing Quest

Pablo Picasso

David Hockney

Slide credit: Alyosha Efros
Better than realism?

David Hockney, *Place Furstenberg*, (1985)

Slide credit: Alyosha Efros
Which one is right?

Multiple viewpoints

Single viewpoint

David Hockney,
Place Furstenberg, 1985

Alyosha Efros
Place Furstenberg, 2009

Slide credit: Alyosha Efros
Depicting Our World: Ongoing Quest

Enter Computer Graphics...
Traditional Computer Graphics

3D geometry

physics

Simulation

projection

GRAPHICS

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

Photo by Svetlana Lazebnik

Slide credit: Alyosha Efros
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”
Hyper-humans
Urban Scenes

Virtual LA (SGI)

Photo of 1 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**

**Photography**

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

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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

Slide credit: Fredo Durand
Limitations of traditional photography

- Blur, camera shake, noise, damage

Slide credit: Svetlana Lazebnik
Limitations of traditional photography

• Limited resolution
Limitations of traditional photography

- Bad color / no color

Slide credit: Svetlana Lazebnik
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
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
Welcome to BBM 444!
Course Information

Instructor: Aykut Erdem (111)
TA: Levent Karacan (CVL)

Lectures (BBM 444): Fridays, 13:00-15:45 @ D9
Practicum (BBM 446): Mondays, 13:00-15:45 @ D9
Office hours: By appointment

Class webpage:
http://web.cs.hacettepe.edu.tr/~aykut/classes/spring2013/bbm444/
Communication

• The course webpage will be updated regularly throughout the semester with lecture notes, programming and reading assignments and important deadlines.
  http://web.cs.hacettepe.edu.tr/~aykut/spring2013/bbm444

• All other communications will be carried out through Piazza. Please enroll it by following the link:
  https://piazza.com/hacettepe.edu.tr/spring2013/bbm444
Prerequisites

• Good math (calculus, linear algebra, statistics) and programming skills.
• An introductory course in image processing (BBM 413) is highly recommended.
Reference books

http://szeliski.org/Book/
Grading Policy

• BBM 444
  – A set of written assignments (15%)
  – A midterm exam (35%)
  – A final exam (45%)
  – Class participation (5%)

• BBM 446
  – 4 programming assignments
Programming Assignments

• 4 assignments related to the topics covered in the class.

• Each assignment will involve implementing an algorithm, carrying out a set of experiments to evaluate it, and writing up a report on the experimental results.

• All assignments have to be done individually, unless stated otherwise.
Important Dates

• PA 1 15 March 2013
• PA 2 5 April 2013
• PA 3 3 May 2013
• PA 4 24 May 2013

• Midterm exam 26 April 2013

• Final exam To be announced later
Syllabus
Cameras and Image Formation

• Image formation
  – How cameras work?

Slide credit: Rob Fergus
Image Processing
Blending and Compositing

• Gradient domain image manipulation
Image Resizing

Slide credit: Rob Fergus
Warping and Morphing

Image deformation using moving least squares

Schaefer et al. (2006)

Face morphing

Slide credit: Svetlana Lazebnik
Data-driven texture synthesis

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

Super resolution
Panoramas and Collages

Panorama stitching

AutoCollage

Rother et al. (2006)

Multi-viewpoint panoramas

Agarwala et al. (2006)

Slide credit: Svetlana Lazebnik
Denoising

Slide credit: Rob Fergus
Image Completion

Scene Completion using Millions of Photographs
Image Completion

Scene Completion using Millions of Photographs
Image Completion

Scene Completion using Millions of Photographs
Image Completion

Scene Completion using Millions of Photographs
Image Completion

Scene Completion using Millions of Photographs
High dynamic range imaging
Tone mapping

• Users often disappointed by BW photos
Tone mapping

- Can you “transfer” some of the low-level qualities?
Tone mapping

Slide credit: Fredo Durand

Output result

Two-scale Tone Management for Photographic Look
Soonmin Bae, Sylvain Paris, Frédo Durand, Siggraph 2006
Photo quality assessment

• What makes a great photo?

*Derrière la gare de Saint-Lazare*,
Cartier-Bresson (1932)
Non-photorealistic rendering

Karacan, L., Erdem, A. and Erdem, E., *work in progress*
Reading Assignment

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