Computational Photography: Interactive Imaging and Graphics

A Bit About Me

- Jesus J Caban, PhD

- Who am I?
  - National Library of Medicine, NIH
  - Graduated from UMBC a year ago
  - MS in Image Processing & Computer Vision

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  - E: caban1 at cs.umbc.edu
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  - W: http://cs.umbc.edu/~caban1
CMSC 491/691: Computational Photography

- **When:** Mondays & Wednesdays
- **Time:** 5:30 – 6:45pm
- **Where:** Math & Psychology101
- **Office Hours:**
  - M & W: 5:00pm ITE 365
  - By appointment

Outline

1. Introduction to Computation Photography
   - History
   - Digital Images & Digital Image Processing
   - Computer Vision
   - Graphics & Images
2. Syllabus
   - Objectives
   - Goals
   - Schedule
3. Image Formation
Computational Photography

- Research area where image processing, computer vision, computer graphics and photography converge.

What’s Photography?

- Photography:
  - term first used in 1839
  - from two Greek (photos and graphé) that mean “writing with light” or “drawing with light”
Pinhole Camera

- About 2,500 years ago, Chinese people wrote about the general idea of a “dark room”
- A reflection is formed upside down on the opposite wall
- In the 1500s, artists started using the “camera obscura” to draw pictures

History - Cameras

- The beginning of photography was around 1826
- French scientist Niepce used a plate with asphalt for eight hours to capture the first image
- By 1837 Daguerre found a chemical compound that was more sensitive to light
Timeline

What is a Digital Image?

- A digital image is a representation of a two-dimensional image as a finite set of digital values, called picture elements or pixels.
What is a Digital Image?

- *Digitization* implies that a digital image is an *approximation* of a real scene.
- Pixels are attributes that can represent gray levels, color, heights, opacities, luminance, etc…

History of Digital Images

- One of the first applications of digital images was in the newspaper industry.
- First digitization and transmission were done in the 1920s.
- The *Bartlane* cable picture transmission service.
- Images were transferred by submarine cable between London and New York.
- Pictures were coded for cable transfer and reconstructed at the receiving end on a telegraph printer.
Digital Image Processing

• **In the 1930s:**
  - higher quality images,
  - increased number of tones in reproduced images

• **In the 1960s:** digital image processing
  - **1964:** Computers used to improve the quality of images of the moon taken by the Ranger 7 probe
  - Such techniques were used in other space missions including the Apollo landings

Digital Image Processing – Beyond Space Program

• **1970s:** Digital image processing begins to be used in medical applications

• **1979:** Sir Godfrey N. Hounsfield & Prof. Allan M. Cormack share the Nobel Prize in medicine for the invention of tomography, the technology behind Computerised Axial Tomography (CAT) scans
Digital Image Processing

- **1990**: Photoshop 1.0
- Digital image processing has grown to be everywhere

Areas of Image Processing and Analysis

- Image Processing can be broken up into three areas / levels

1. **Low Level Process**
   - **Input**: Image
   - **Output**: Image
   - **Examples**: Noise removal, image sharpening

2. **Mid Level Process**
   - **Input**: Image
   - **Output**: Attributes
   - **Examples**: Object recognition, segmentation

3. **High Level Process**
   - **Input**: Attributes
   - **Output**: Understanding
   - **Examples**: Scene understanding, autonomous navigation
Computational Photography

- Convergence of image processing, computer vision, computer graphics and photography

What’s Computer Vision

- Is a discipline that studies how to reconstruct, interpret, and understand a 3D scene from its 2D images
  1. Analyze images
     - Image properties (luminance, color, textures, etc…)
     - structures (shape, location, relationship, etc…)
  2. Perform Inference

- Combines knowledge from Machine Learning, AI, statistics, robotics, etc…
# Areas of Image Processing and Analysis

Image Processing can be broken up into three areas / levels:

## 1. Low Level Process
- **Input:** Image
- **Output:** Image
- **Examples:** Noise removal, image sharpening

## 2. Mid Level Process
- **Input:** Image
- **Output:** Attributes
- **Examples:** Object recognition, segmentation

## 3. High Level Process
- **Input:** Attributes
- **Output:** Understanding
- **Examples:** Scene understanding, autonomous navigation

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## Autonomous navigation

![Autonomous navigation image](image_url)
Stereo Reconstruction

Face / Gesture Recognition
Computer Vision in Sports

Convergence of image processing, computer vision, computer graphics and photography

Computational Photography

- Convergence of image processing, computer vision, computer graphics and photography
Computer Graphics

- Sub-field in computer science that studies methods for synthesizing and manipulating visual content.
  - CG is about making realistic and pretty computer generated pictures

- Courses:
  - CSMC 435
  - CSMC 634
  - CSMC 635

Traditional Computer Graphics

- 3D geometry
- Textures
- Physics
- Projection
- Simulation
Artistic effects are used to make images more visually appealing, to add special effects and to make composite images.
Computational Photography

- Convergence of image processing, computer vision, computer graphics and photography

What topics belong to CP?

Interactive Digital Photomontage

Agarwala et al.
Mosaics: stitching images together

virtual wide-angle camera

Debluring

Fergus et al,
Debluring

Original  Unsharp mask  Output

Fergus et al,

Think about Computational Techniques Everywhere
Calibration: Curved Display
Medical Image Analysis

[Images of medical images]

Medical Image Analysis

[Another set of medical images with annotations]

9/1/10
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   - History
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   - Graphics & Images

Syllabus
- Objectives
- Goals
- Schedule

3. Image Formation

Computational Photography
- Computational photography is an emerging research area at the intersection of computer graphics, image processing, and computer vision.

CMSC 691 will cover topics / concepts not necessarily inside the CP area.
Objectives

1. The fundamental mathematical and computational techniques that can be used to enhance digital images
2. A broad overview of the core concepts of graphics, image processing, and vision that can be used to analyze images
3. A hands-on experience of implementing techniques to analyze and enhance their own digital images
4. A place to help MS/PhD students complete their image-related research

Prerequisites

- Be able to develop software applications in modern programming languages (e.g. C/C++, Java, Python)
- Be familiar with basic concepts of linear algebra and calculus.
- Have some background in computer graphics, computer vision, or image processing is helpful.
- Undergraduates:
  - Co-requisites: CMSC 435 or consent from instructor
Textbook

- There is no required text.

- Various chapters, presentations, course notes, and papers will be made available throughout the semester.

- Optional textbooks relevant to this course:
  - *Multiple View Geometry in Computer Vision*, Hartley & Zisserman, 2004

CSMC 491 vs. 691

- Students registered in CMSC 691 will be required to do more substantial work

- Each written or programming assignment will have additional problems that graduate students must complete.

- Graduate students are expected to submit a more thorough paper as their final paper. Will be graded based on:
  - completeness of summarizing previous work
  - inclusion of formulation and theoretical analysis
  - quality of the results.
Academic Integrity

- All written homeworks, programming assignments, and presentations must be done individually unless explicitly instructed otherwise.

- Cheating and plagiarism will be dealt with in accordance with university procedures.

- You are encouraged to discuss with your peers approaches and techniques broadly.

Grading

- The course format will consist of lectures, paper presentations, student presentations, and discussions.

- The grading of this course will be based on:

  Distribution:
  - Written assignments (10%)
  - Programming assignments (40%)
  - Paper Presentation (10%)
  - Final project (30%)
  - Class attendance and participation (10%)

- Scale: Final grades will be assigned according to the following scale:
  - A: 90--100%
  - B: 80--89%
  - C: 70--79%
  - D: 55--70%
  - F: 0--54%
Written and Programming Assignments

- Written assignments will count for 10% of the final grade.
- Programming assignments will count for 40% of the final grade.
- Students can pick either C/C++, Java, or Python to implement their programming homeworks.

Late policy:

- Written assignments will be due at the beginning of class on the due date.
- Programming projects will be due at 11:59pm on the due date.
- Students may turn one homework up to 24 hours late, but must notify the instructor when the special extension is used. Failure to notify the instructor and/or any additional day will result in a 10% penalty of the assignment grade.
- Additional exceptions for emergencies and medical conditions may be given if deemed appropriate.
Syllabus

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What other topics?

- Topics and the emphasis in different areas might change over the semester

- What topics would you like to see discussed in class?
Paper presentation

- A list of suggested papers will be distributed

- Students must pick two papers that they would like to present to the class
  - Pick a paper / topic you like
  - In some cases, students might present a paper that is not within the list

- Each paper presentation should last about 20 minutes.

- Days that you are not presenting:
  - submit a question about the paper(s) of the day (at the beginning of the class)
  - questions will count for participation

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### Syllabus

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Final Project

- Draft Proposal (10%)
- Revised Proposal (10%)
- Literature survey (20%)
- Final paper (40%)
- Final presentation (20%)

How to select your project?

- Find something you like
- Try to make something related to your thesis / dissertation
- Read some of the papers / topics in advance
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