Digital Image Processing
EE368/CS232

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Imaging

[Albrecht Dürer, 1525]
- **Image**: a visual representation in form of a function $f(x,y)$ where $f$ is related to the brightness (or color) at point $(x,y)$
- Most images are defined over a rectangle
- Continuous in amplitude and space
**Imaging**

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Camera Obscura in San Francisco
Digital Images and Pixels

- **Digital image**: discrete samples $f[x,y]$ representing continuous image $f(x,y)$
- Each element of the 2-d array $f[x,y]$ is called a **pixel** or **pel** (from “picture element“)

![Images with different resolutions: 200x200, 100x100, 50x50, 25x25]
Color Components

Monochrome image

\[ R[x,y] = G[x,y] = B[x,y] \]

Red \( R[x,y] \)
Green \( G[x,y] \)
Blue \( B[x,y] \)
Why do we process images?

- Acquire an image
  - Correct aperture and color balance
  - Reconstruct image from projections

- Prepare for display or printing
  - Adjust image size
  - Color mapping, gamma-correction, halftoning

- Facilitate picture storage and transmission
  - Efficiently store an image in a digital camera
  - Send an image from space

- Enhance and restore images
  - Touch up personal photos
  - Color enhancement for security screening

- Extract information from images
  - Read 2-d bar codes
  - Character recognition
  - Depth estimation

- Many more ... image processing is ubiquitous
Image Processing Examples

Mosaic from 33 source images

Mosaic from 21 source images

source: M. Borgmann, L. Meunier, EE368 class project, spring 2000.
Image Processing Examples

Face morphing

Source: Yi-Wen Liu and Yu-Li Hsueh, EE368 class project, spring 2000.
Image Processing Examples

Face Detection

source: Henry Chang, Ulises Robles, EE368 class project, spring 2000.
Image Processing Examples

Face Detection

source: Michael Bax, Chunlei Liu, and Ping Li, EE368 class project, spring 2003.
Image Processing Examples

Face Blurring for Privacy Protection
Image Processing Examples

This image showing both laser and video imagery gives a sense of Stanley's adaptive vision capability.

http://cs.stanford.edu/group/roadrunner/stanley.html
Image Processing Examples
Visual Code Marker Recognition
Image Processing Examples
Painting Recognition

EE368 Spring 2007 Project
Image Processing Examples
Painting Recognition

EE368 Spring 2007 Project
Painting Recognition for Augmented Reality
Image Processing Examples
CD Cover Recognition
CD Cover Recognition on Cameraphone
Video See-through Augmented Reality on the Phone

Hershed Tilak & Robert Mahieu EE368, 2015/16
Image Processing Examples: Style Transfer

Original photos

Elias Wang, Nicholas Tan, EE368, 2016/17
EE368/CS232 Topics

- Point operations/combining images/histograms
- Color science
- Image thresholding/segmentation
- Morphological image processing
- Image filtering, deconvolution, template matching
- Eigenimages, Fisherimages
- Edge detection, keypoint detection
- Scale-space image processing
- Image matching, image registration
EE368/CS232 Organisation

- **Lectures**
  - MWF 1:30 pm – 2:50 pm in Gates B03 for 5+2 weeks (1/7 – 2/11; 2/27 – 3/6)
  - Attendance highly recommended.
  - Lecture videos on [https://suclass.stanford.edu](https://suclass.stanford.edu): view after class, or before, or not at all.

- **Problem sessions**: Fr 4:30 pm – 5:20 pm in Gates B03 for 5+1 weeks

- **Office hours**
  - Bernd Girod: We 3 pm – 4:15 pm (after class), Packard 373, no office hours 2/13, 2/20
  - Jean-Baptiste Boin: Mo 5-7 pm, Packard 312

- **Class Piazza page**:
  
EE368/CS232 Weekly Assignments

- Weekly problem sets
  - Handed out Mondays, correspond to the lectures of that particular week
  - About 8-12 hours of work, requires computer + Matlab
  - Discussions among students encouraged, however, individual solution must be submitted
  - Due 9 days later (Wednesday 1:30 pm).
  - Late submission: 30% penalty if submitted by Friday 1:30 pm. No credit afterwards.
  - Submit 5 out of 6 assignments for credit (worst out of 6 is discarded)

- Problem set submission:
  - Electronic online submission via Gradescope.
  - Enrollment: http://www.gradescope.com - create an account, then use entry code M8EB78

- First assignment released on January 7 (first day of class), due January 16
EE368/CS232 Weekly Assignments (cont.)

- Weekly lecture review and online quizzes
  - Multiple choice questions covering the lectures on [https://suclass.stanford.edu](https://suclass.stanford.edu)
  - Review the corresponding module, if you are uncertain about your answer
  - Graded, solve individually, due Wednesdays 1:30 pm, no credit for late submission
  - Must get 90% correct (across ~7 weeks of quizzes) for full credit

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EE368/CS232 Midterm

- 24-hour take-home exam
- Problems similar to weekly assignments
- Typically requires 5-6 hours of work
- 3 slots, **February 13 – 16**
EE368/CS232 Term Project

- Group project, teams of typically 2-3 students. Larger teams (up to 5) can be approved. Single-person-projects strongly discouraged.
- Plan for about 50-60 hours per person
- Develop, implement and test/demonstrate an image processing algorithm
- Presentation #1 (proposal + initial results): February 25
- Presentation #2: (preliminary results), March 8 and 11
- Remote SCPD students can alternatively submit a narrated video presentation
- Submission of written report and source code: March 15, 11:59 p.m.
EE368/CS232 Grading

- Online quizzes: 10%
- Homework problems: 20%
- Midterm: 30%
- Term project: 40%
- No final exam.
SCIEN Laboratory

- SCIEN = Stanford Center for Image Systems Engineering (http://scien.stanford.edu)
- Exclusively a teaching laboratory (shared this quarter with EE367)
- Location: Packard room 001, card access
- 20 Linux PCs
  - Matlab with Image Processing Toolbox
  - Android development environment
- Account on SCIEN machines for all enrolled in class

Remote login details:
PC Name: rm021-x.stanford.edu, x=1, 2, ..., 20
Username: win\<SUNet ID>
Password: SUNet password
Mobile image processing (optional)

- Up-to-date tutorials on Android image processing online
- Android development environment on your own computer or in SCIEN lab
- Programming in Java (C++ for OpenCV)
- Limited number of loaner tablets for students who don’t have their own device
Reading

- Slides available as pdf files on the class website (click on for source code and data)
  http://www.stanford.edu/class/ee368/handouts.html
- Popular text books
- Software-centric books
- Journals/Conference Proceedings
  - IEEE Transactions on Image Processing
  - IEEE International Conference on Image Processing (ICIP)
  - IEEE Computer Vision and Pattern Recognition (CVPR)
  - ....