Digital Image Processing
EE368/CS232

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(previously taught by Prof. Bernd Girod)
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Imaging

[Albrecht Dürer, 1525]

Imaging

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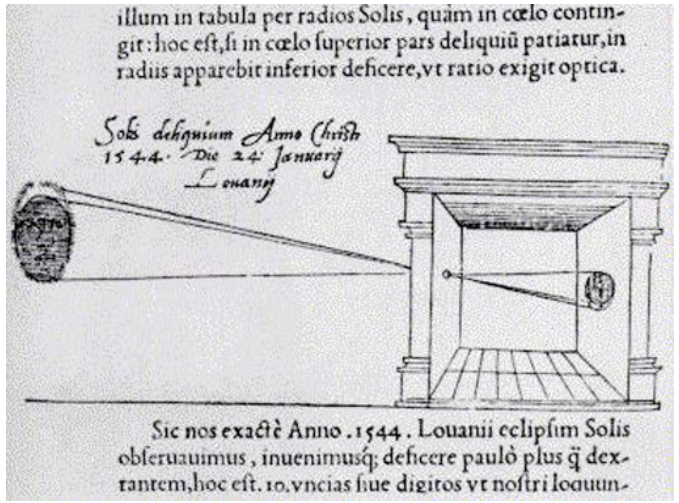
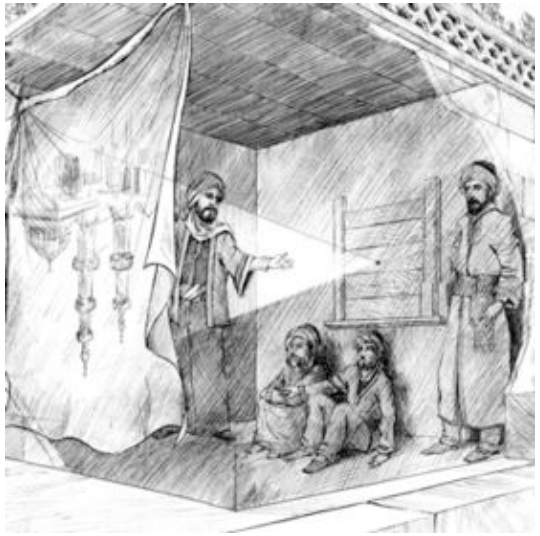
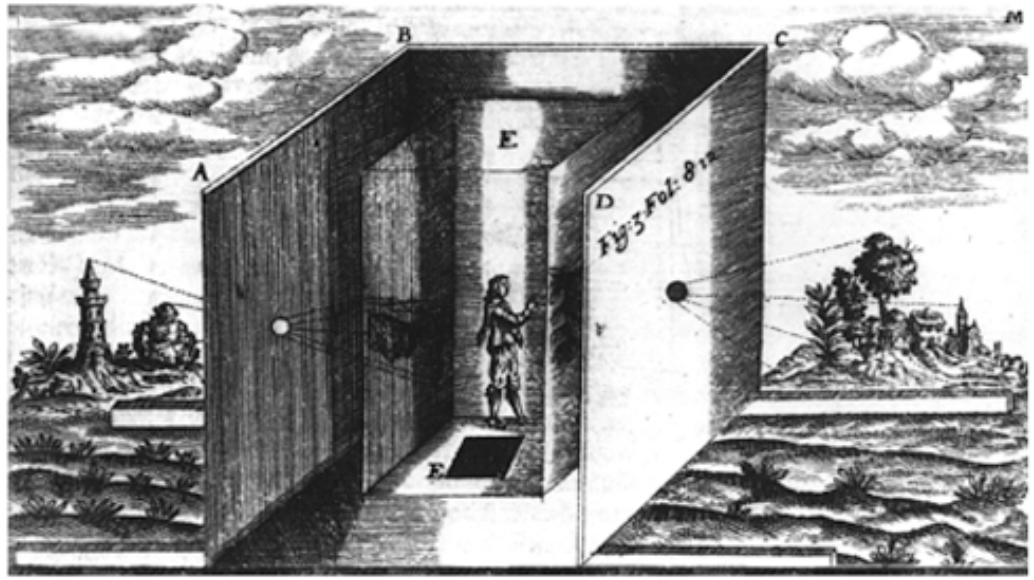
- **Image**: a visual representation in form of a function $f(x,y)$ where f is related to the brightness (or color) at point (x,y)
- Most images are defined over a rectangle
- Continuous in amplitude and space

Imaging







Dark chamber with lenses *[Kircher 1646]*

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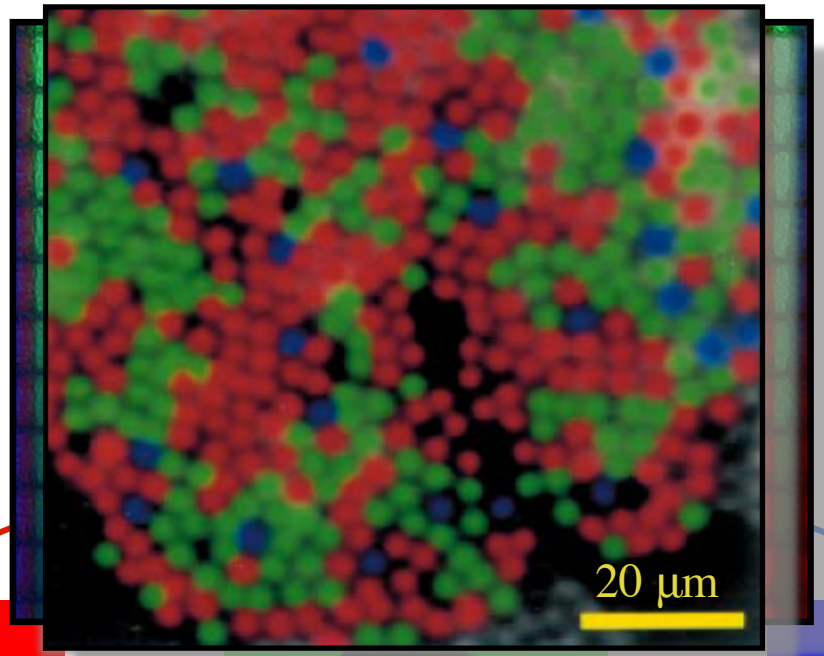
Digital Images and Pixels

- **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“)

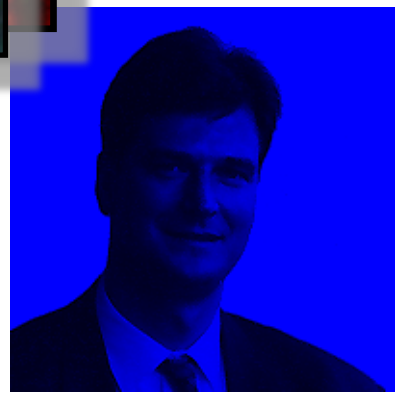
200x200 100x100 50x50 25x25

Color Components



Red $R[x,y]$

Green $G[x,y]$



Blue $B[x,y]$

Monochrome image

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

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*
- Many more ... image processing is ubiquitous







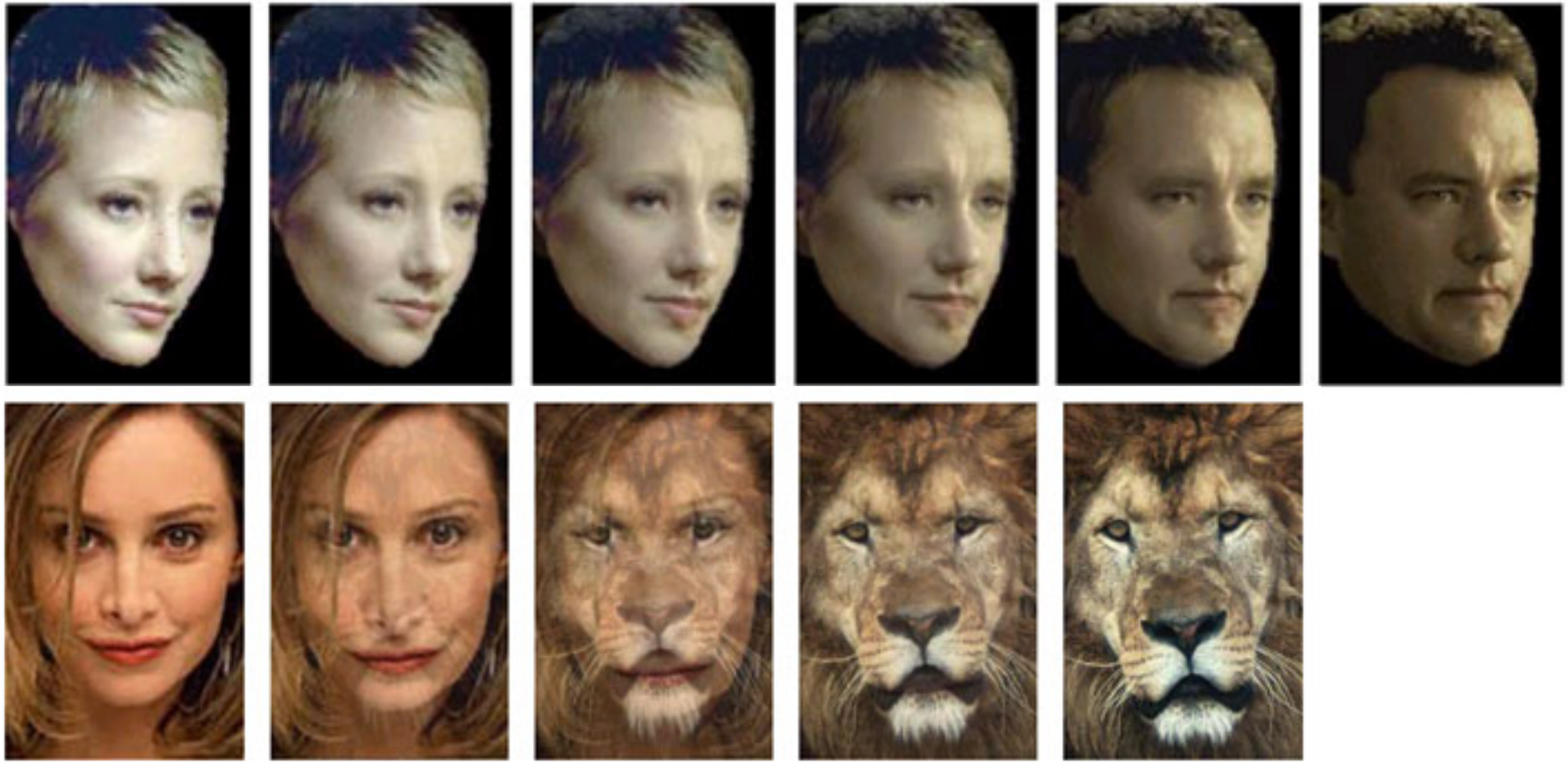


Image Processing Examples

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

Image Processing Examples

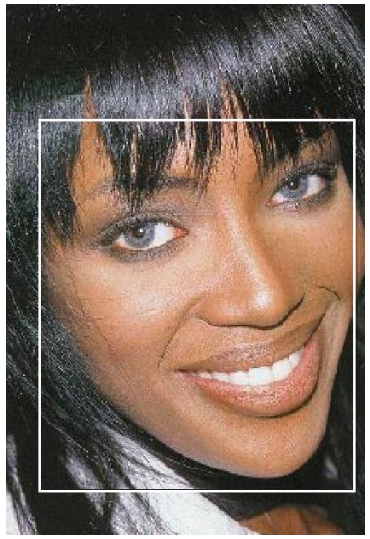
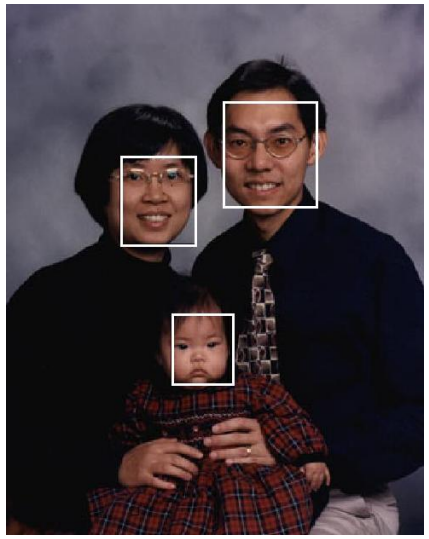
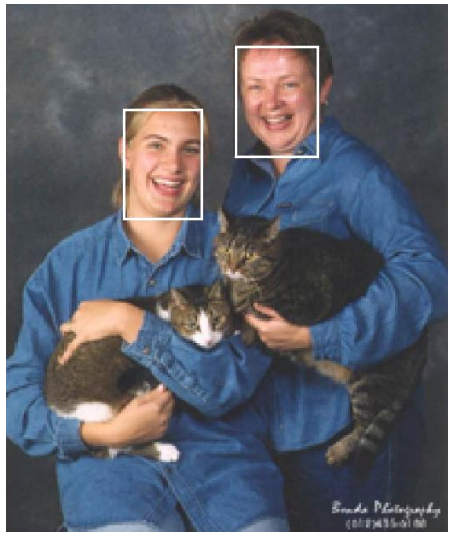
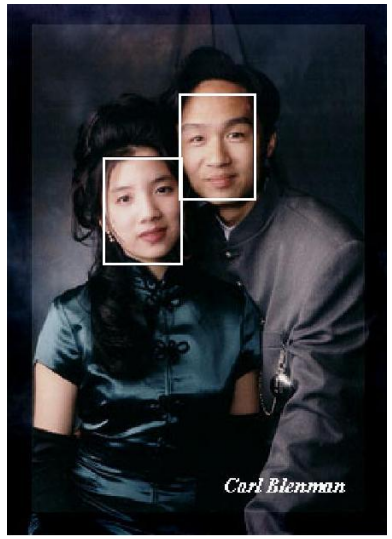
Face morphing



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

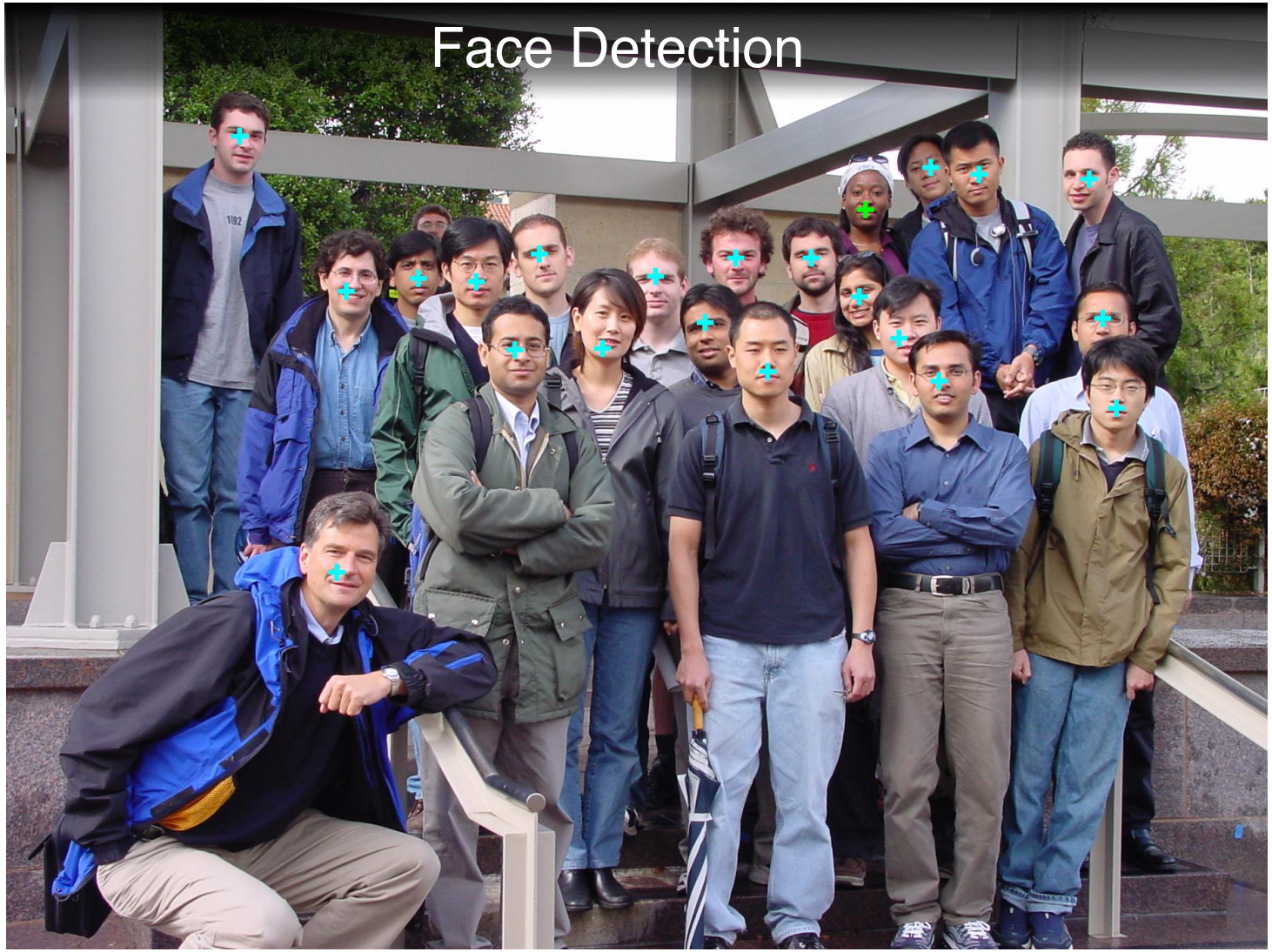
Image Processing Examples

Face Detection

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

Image Processing Examples



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

Image Processing Examples

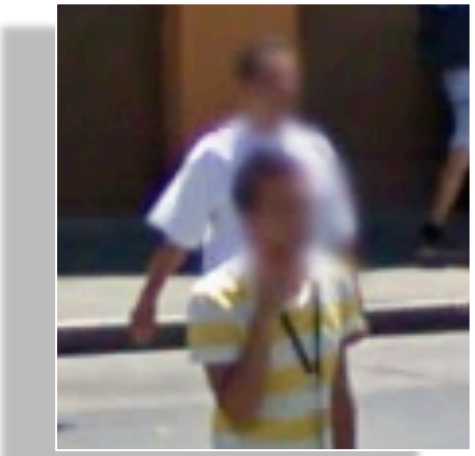
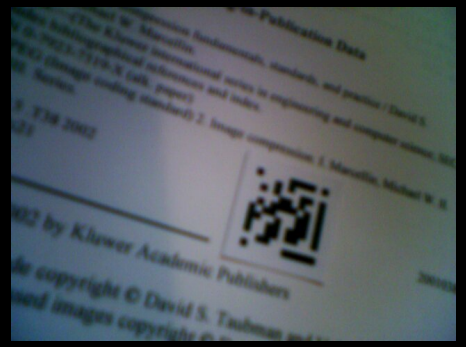
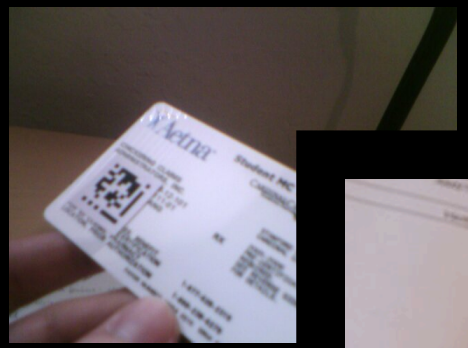
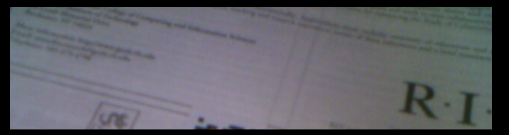
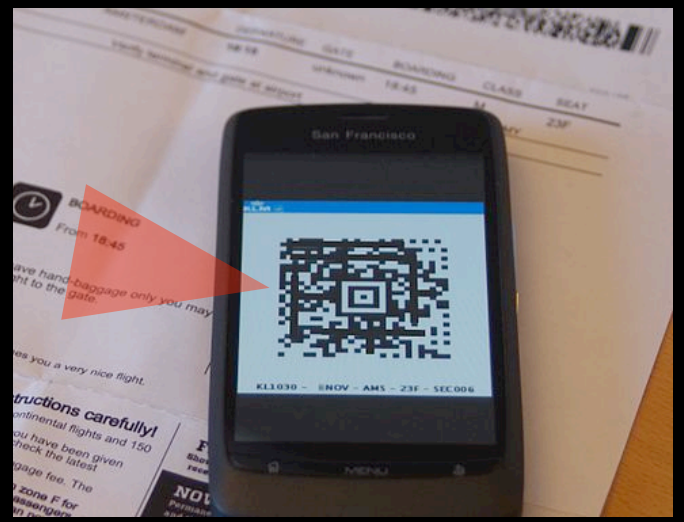


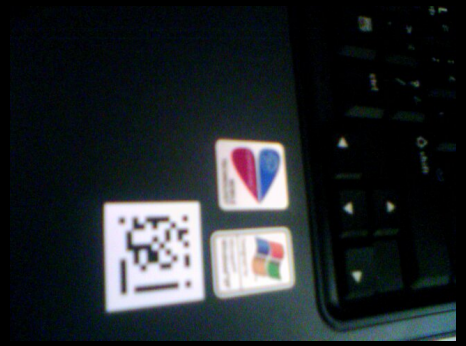
Image Processing Examples

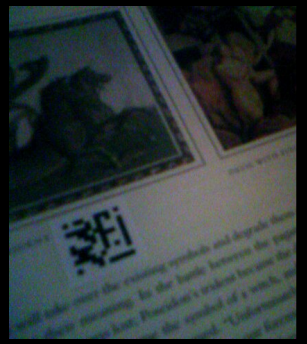
http://cs.stanford.edu/group/roadrunner/stanley.html

EE368 Spring 2006 Project:
Visual Code Marker Recognition

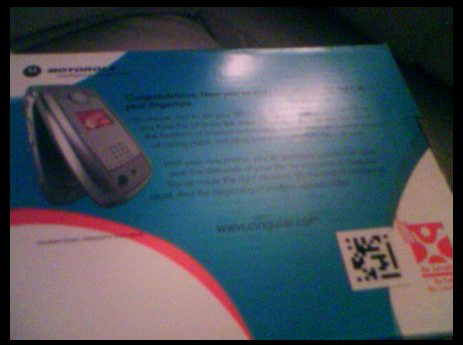










EE368 Spring 2007 Project: Painting Recognition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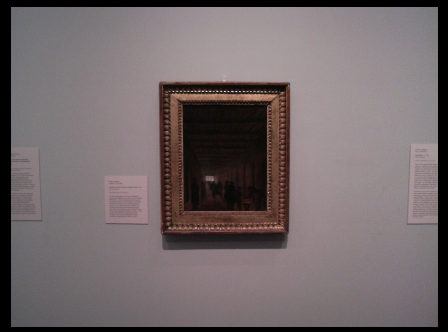
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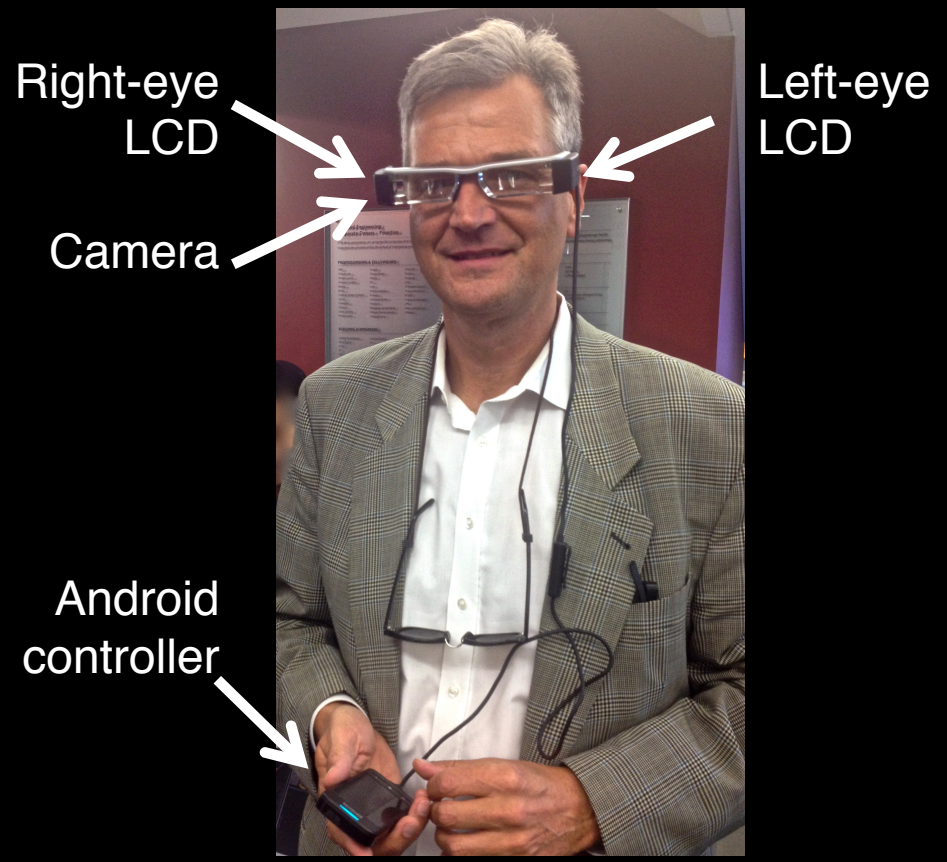
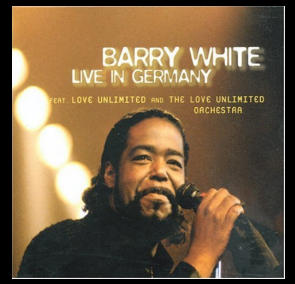
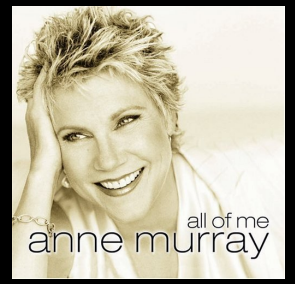
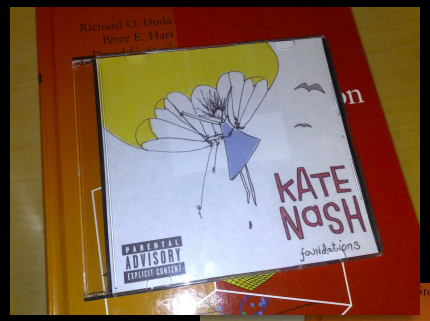
Painting Recognition for Augmented Reality

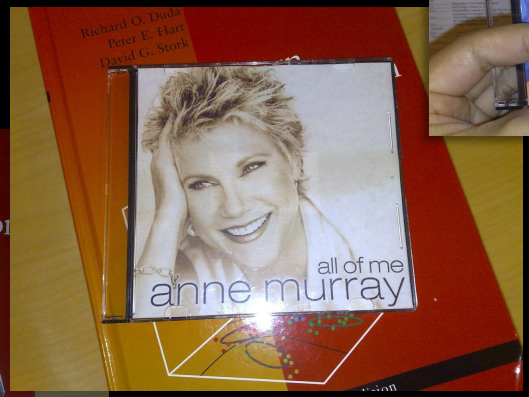


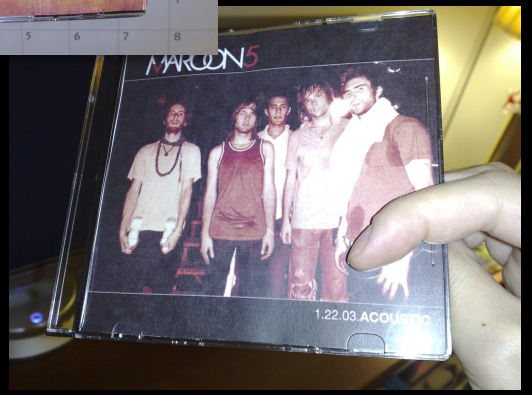
EE368 Spring 2008 Project:
CD Cover Recognition

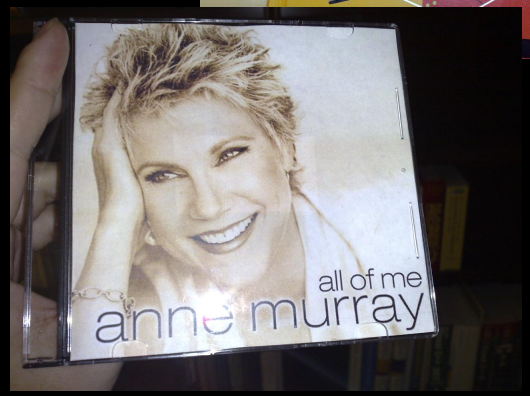


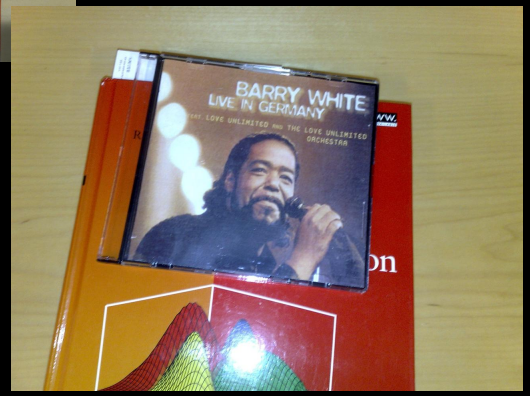










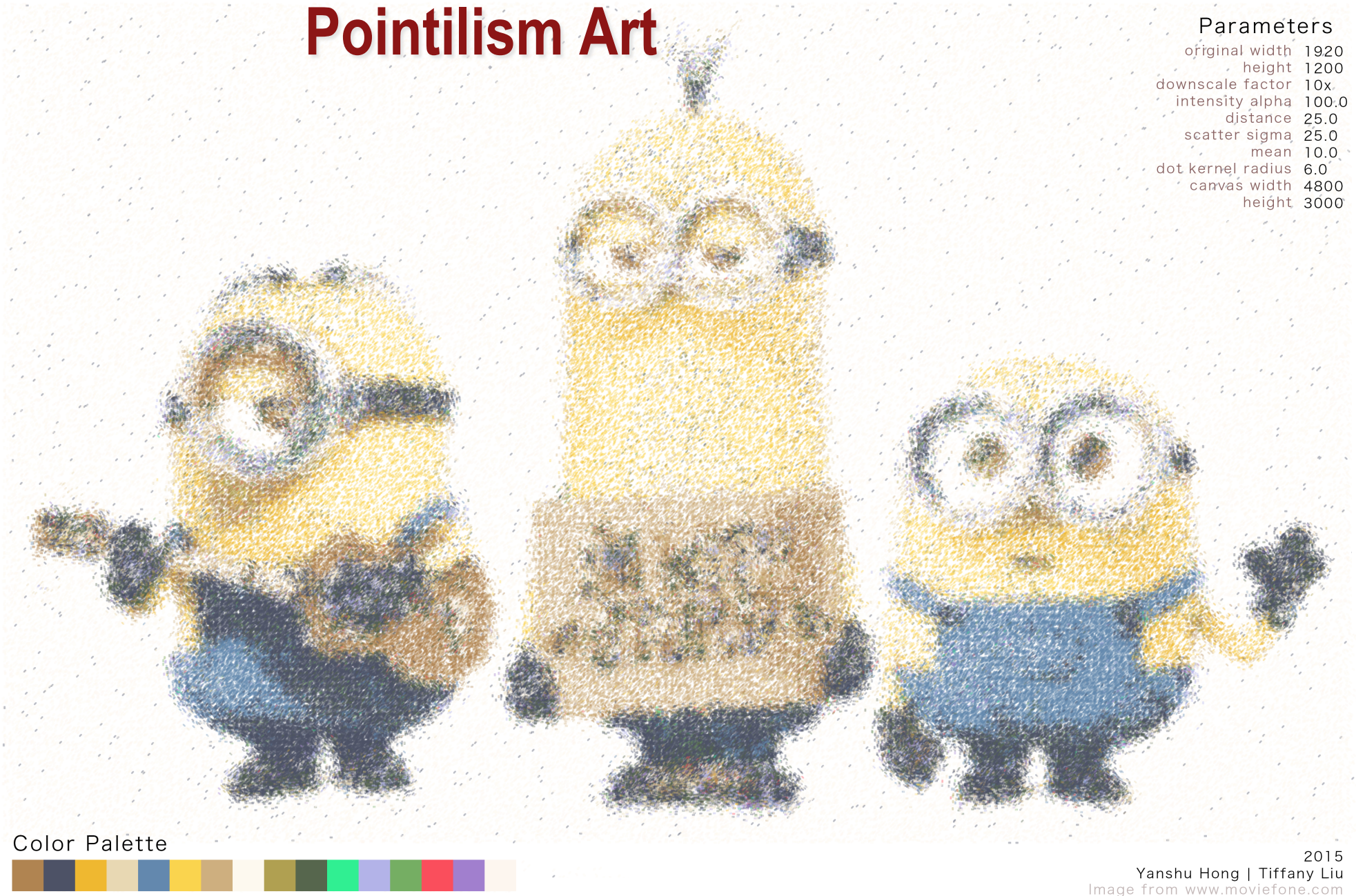


CD Cover Recognition on Cameraphone

Video See-through Augmented Reality on the Phone

Hershed Tilak & Robert Mahieu 2015

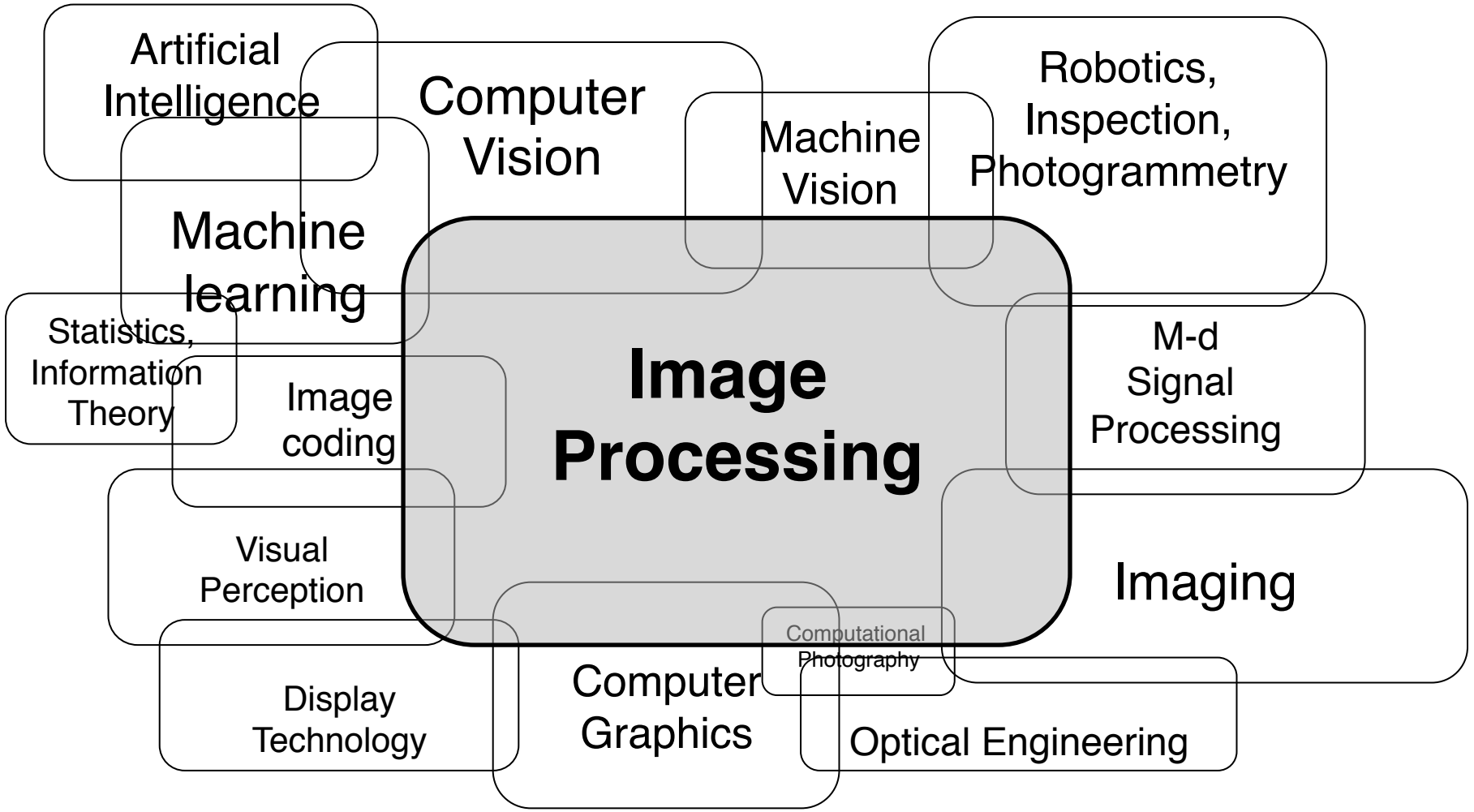
Pointilism Art



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

Image Processing and Related Fields



Other Courses

- How does the course relate to computer vision classes?

CS131 – Foundations

CS231M - Mobile

CS231A - Introduction

CS231B – Cutting Edge

EE368 / CS232

CS231n – Conv Net

CS431 – High-level

CS331 – Reading

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CS431 – High-level

EE368 / CS232

CS231A - Introduction

CS231n – Conv Net

CS331 – Reading

- CS 148: Introduction to Computer Graphics and Imaging
- PSYCH 221: Applied Vision and Image Systems Engineering
- EE 367 / CS 448I: Computational Imaging and Display
- EE 267: Virtual Reality

- CS 178: Digital Photography
- CS 448A: Computational Photography

not actively taught, but archived!

EE368/CS232 Organisation

- Lectures
  - MWF 1:30 pm – 2:50 pm in Gates B03 for 7 weeks
  - Attendance highly recommended.
  - Lecture videos (recordings from previous years) on OpenEdX: view after class, or before, or not at all.
- Problem session: Fridays 4:30-5:20 pm in Gates B03 for 7 weeks
- Office hours
  - Gordon Wetzstein: Wed 3 pm – 4 pm (after class), Packard 236 (come to discuss projects, …)
  - TAs: Mo 4:30-6:30 pm, Packard 312 (come to discuss homeworks and lecture content)
- Class Piazza page:

  https://piazza.com/stanford/fall2016/ee368

EE368/CS232 Organisation

- Class website:
  - http://web.stanford.edu/class/ee368/

EE368/CS232 Weekly Assignments

- Weekly problem assignments
  - 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 pm).
- Homework submission:
  - Electronic online submission via Gradescope!
  - Enrollment link: http://www.gradescope.com - create an account, then use entry code M55W8M
- Weekly lecture review and online quizzes
  - Multiple choice questions covering the lectures on OpenEdX (https://suclass.stanford.edu)
  - Review the corresponding module, if you are uncertain about your answer
  - Graded, solve individually, due at the same time as corresponding problem assigments
  - same deadline as homeworks
- First assignment handed out on September 26 (first day of class)

EE368/CS232 Midterm

- 24-hour take-home exam
- Problems similar to weekly assignments
- Typically requires 5-6 hours of work
- 3 slots one week (pick 1) after the last lecture, **November 16-18 2016**

EE368/CS232 Final Project

- Individual or group project, plan for about 50-60 hours per person
- Develop, implement and test/demonstrate an image processing algorithm
- Project proposal due: **October 21, 11:59 p.m.**
- Project presentation: Poster session, **December 7, 2016, 4-6:30 p.m.**
- Remote SCPD students can alternatively submit a narrated video presentation
- Submission of written report and source code:
  December 9, 2016, 11:59 p.m.

EE368/CS232 Grading

- Online quizzes: 5%
- Homework problems: 30%
- Midterm: 25%
- Final project: 40%
- No final exam.

In-class Discussions and Socrative

- Brief in-class quizzes integrated into the lectures
- socrative allows you to share your answers instantaneously and anonymously.
- It's o.k. to make mistakes; you will not be graded
- socrative.com, room: ee368

SCIEN Laboratory

- SCIEN = Stanford Center for Image Systems Engineering (http://scien.stanford.edu)
- Exclusively a teaching laboratory
- Location: Packard room 021
- 20 Linux PCs, scanners, printers etc.
  - Matlab with Image Processing Toolbox
  - Android development environment
- Access:
  - Door combination for lab entry will be provided by TA
  - Account on SCIEN machines will be provided to all enrolled in class
  - Remote access possible – see website and talk to TA

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
  - William K. Pratt, „Introduction to Digital Image Processing," CRC Press, 2013.
  - R. C. Gonzalez, R. E. Woods, „Digital Image Processing," 3rd edition, Prentice-Hall, 2008.
  - A. K. Jain, „Fundamentals of Digital Image Processing," Prentice-Hall, Addison-Wesley, 1989.
- Software-centric books
  - R. C. Gonzalez, R. E. Woods, S. L. Eddins, „Digital Image Processing using Matlab," 2nd edition, Pearson-Prentice-Hall, 2009.
  - G. Bradski, A. Kaehler, „Learning OpenCV," O'Reilly Media, 2008.
- Comprehensive state-of-the-art
  - Al Bovik (ed.), „The Essential Guide to Image Processing," Academic Press, 2009.
- Journals/Conference Proceedings
  - IEEE Transactions on Image Processing
  - IEEE International Conference on Image Processing (ICIP)
  - IEEE Computer Vision and Pattern Recognition (CVPR)
  - ....