Digital Image Processing
EE368/CS232

Bernd Girod
Department of Electrical Engineering
Stanford University

Imaging

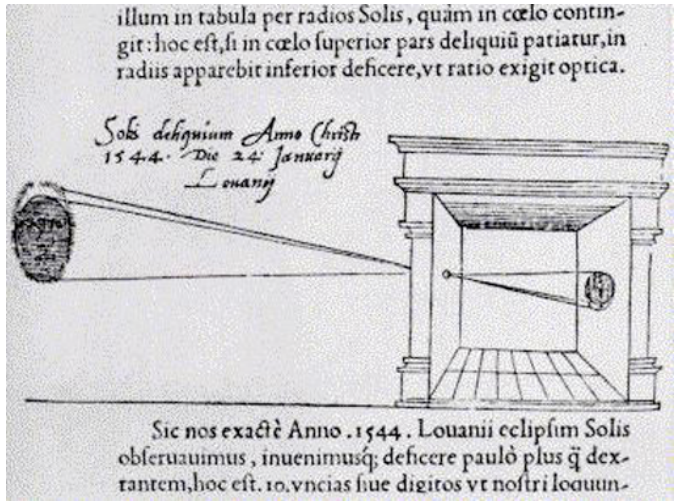
[Albrecht Dürer, 1525]

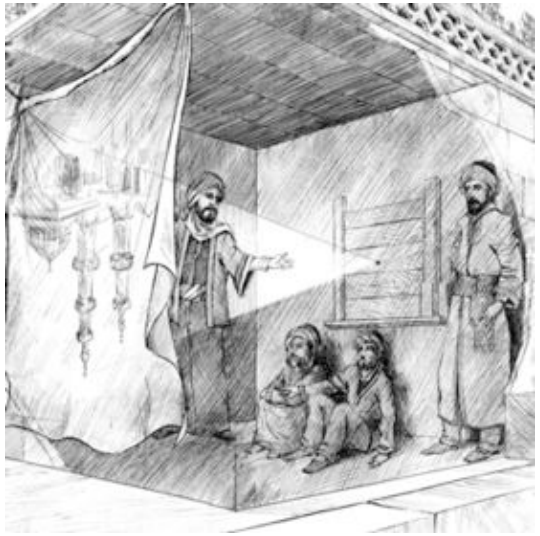
Imaging

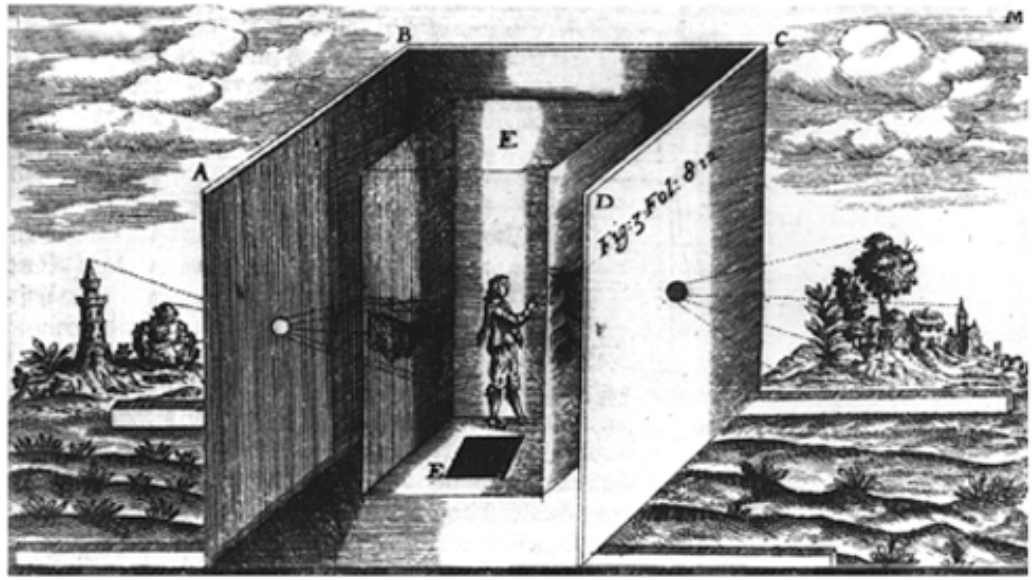
[Albrecht Dürer, 1525]

- **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



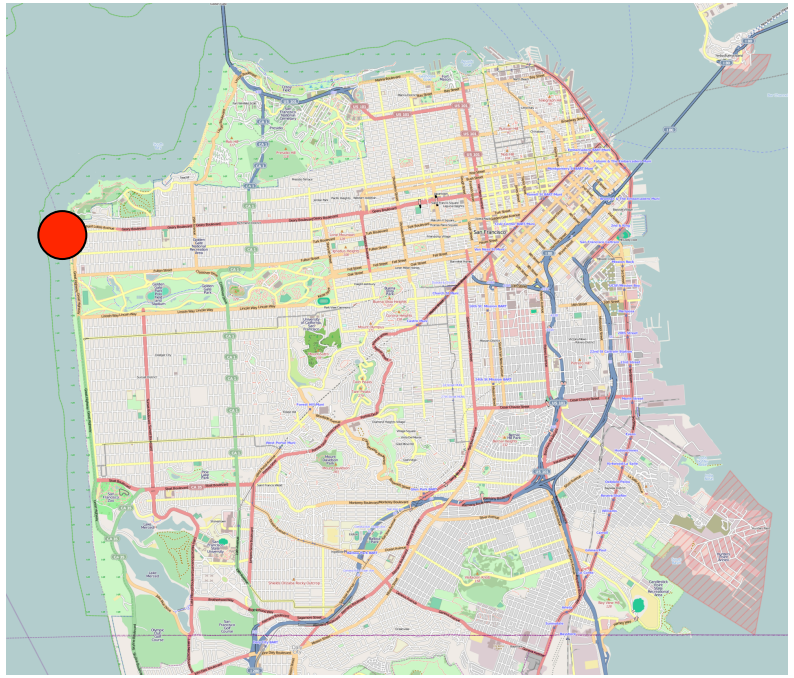




Dark chamber with lenses *[Kircher 1646]*

- **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

Camera Obscura in San Francisco

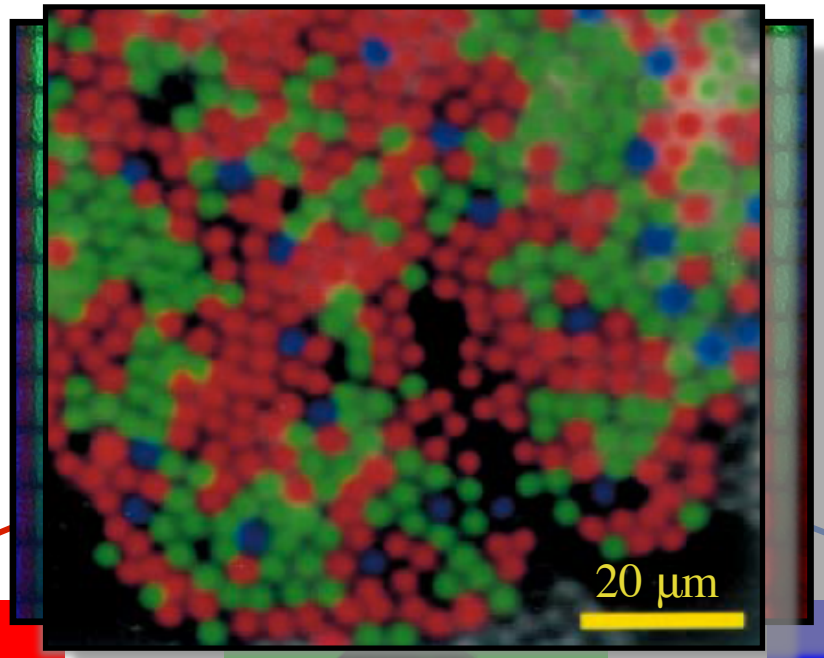


Digital Images and Pixels

- **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“)

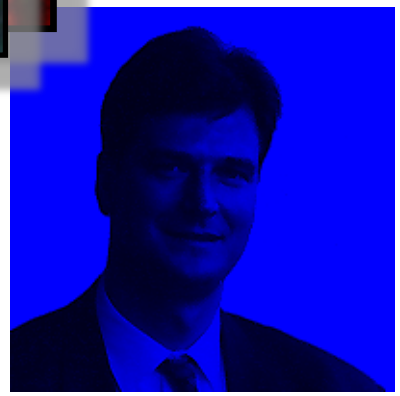
200x200 100x100 50x50 25x25

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*
  - *Depth estimation*
- Many more ... image processing is ubiquitous









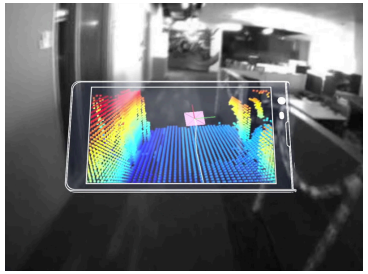



Image Processing Examples

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

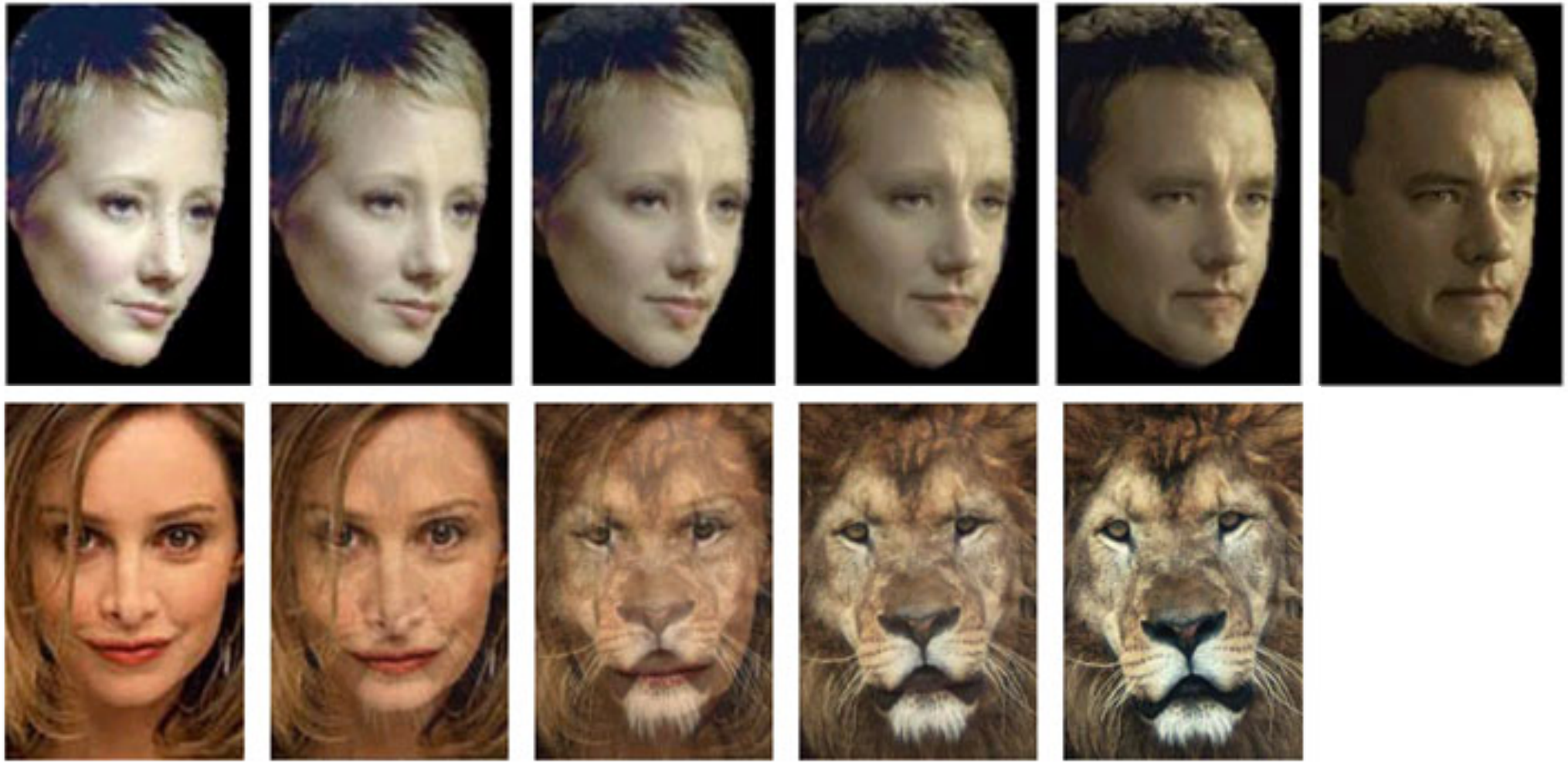
Google Jump

facebook 360

light.co

Image Processing Examples

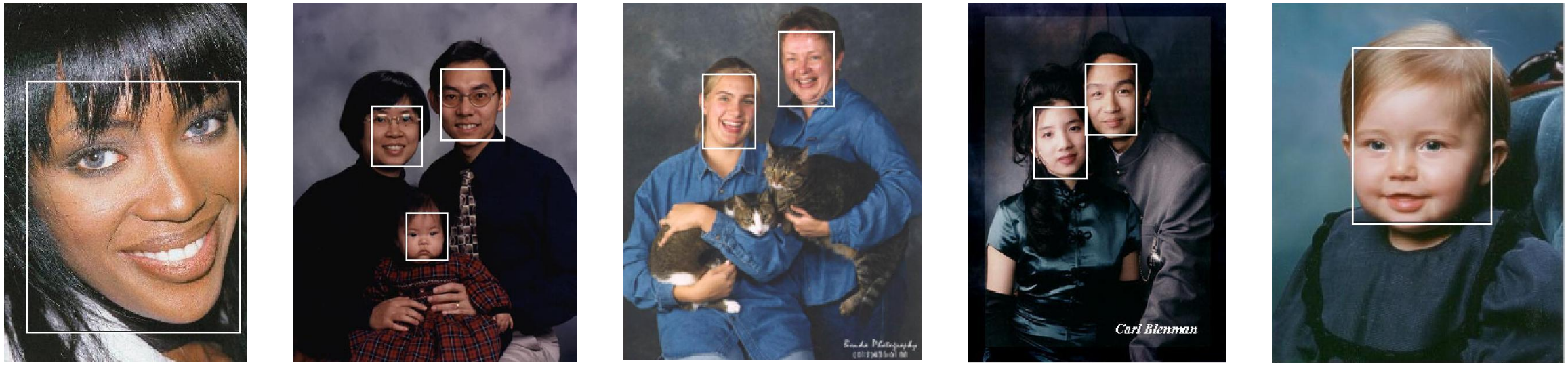
Face morphing



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

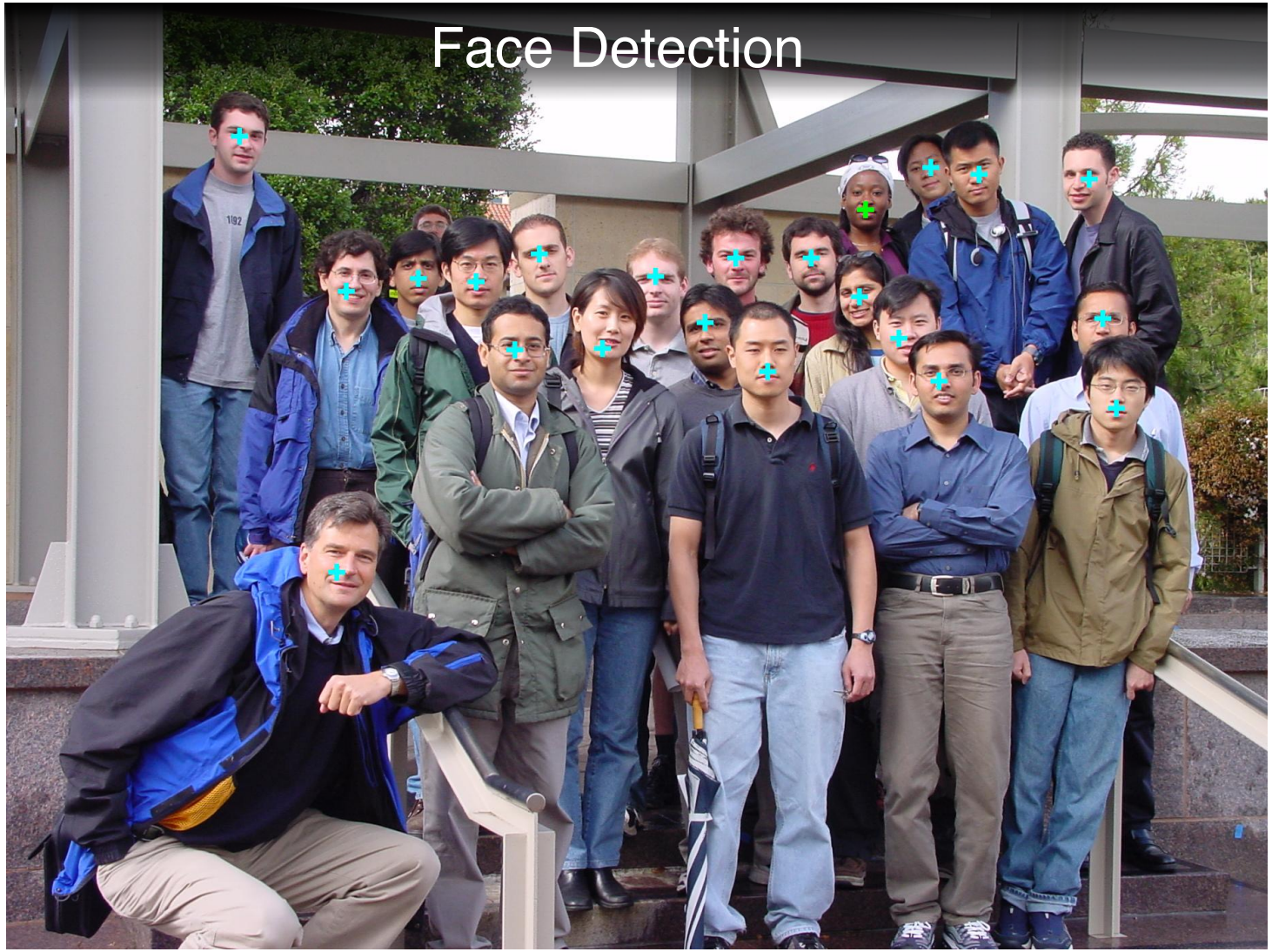
Image Processing Examples

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

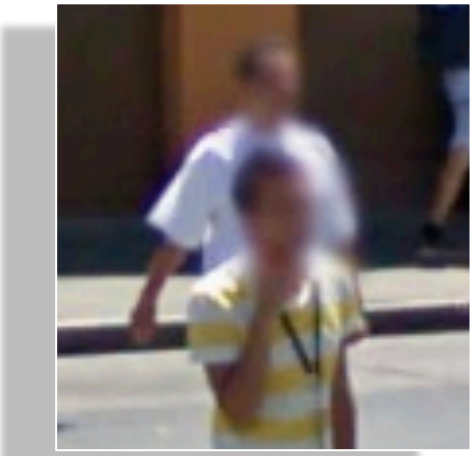
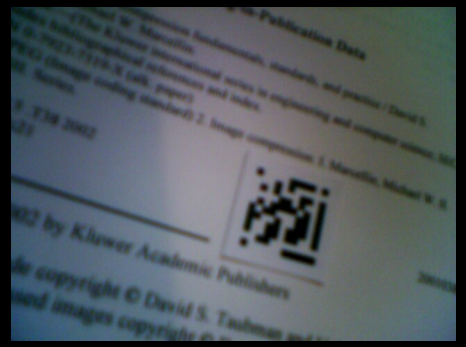
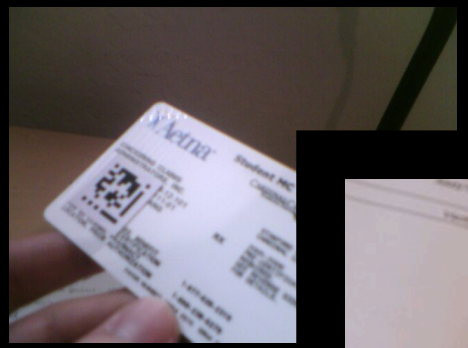
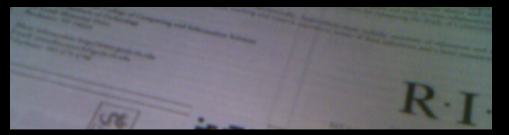
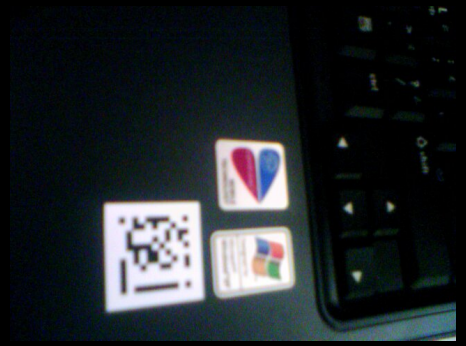


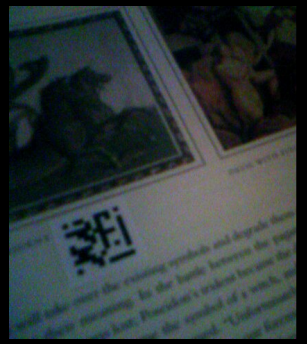
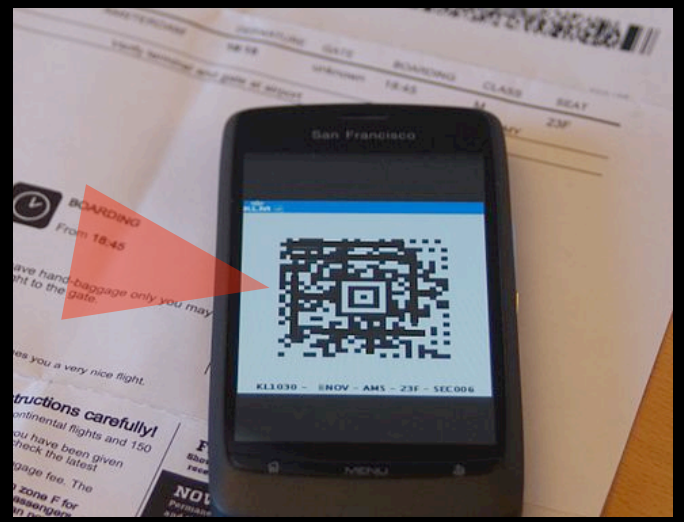
Image Processing Examples

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

Image Processing Examples
Visual Code Marker Recognition

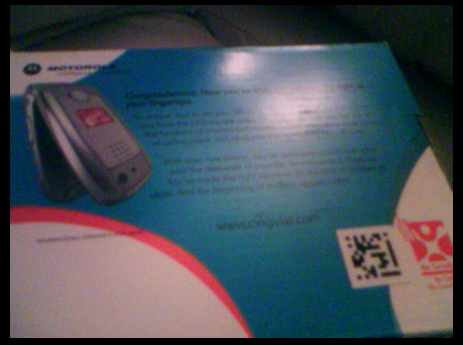




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Image Processing Examples
Painting Recognition


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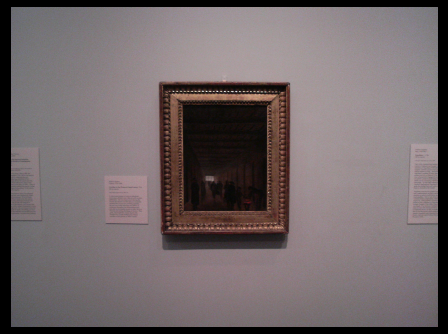
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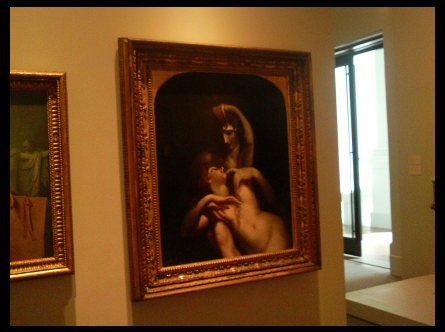
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EE368 Spring 2007 Project

Image Processing Examples
Painting Recognition

EE368 Spring 2007 Project

Painting Recognition for Augmented Reality

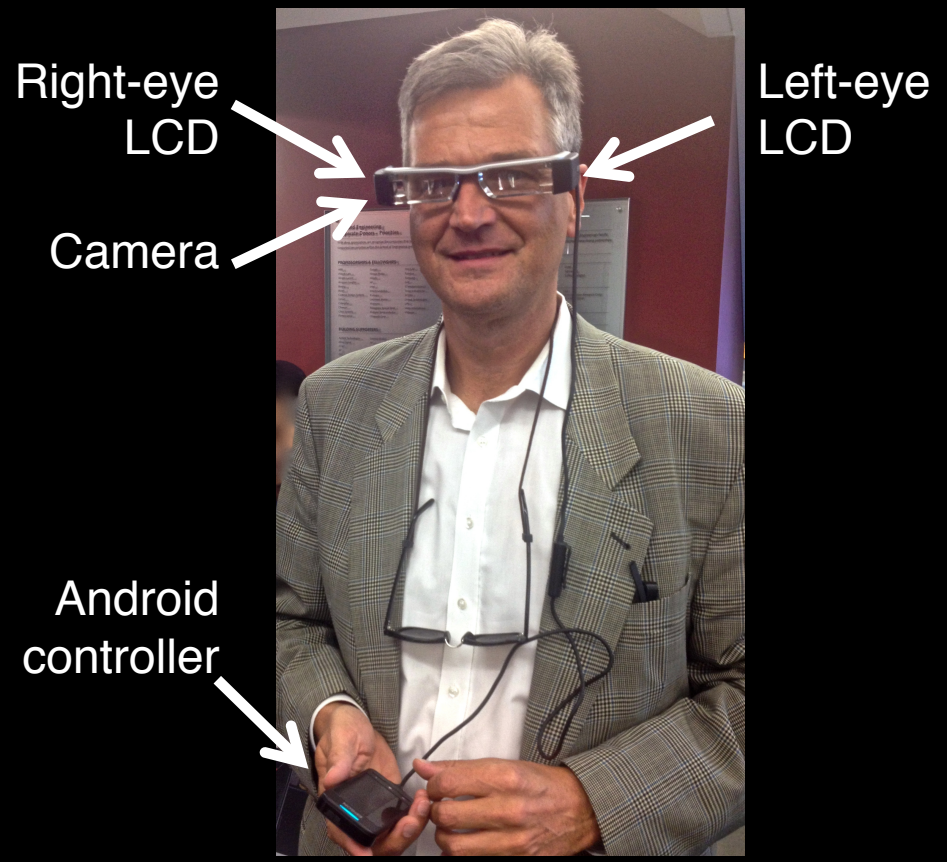
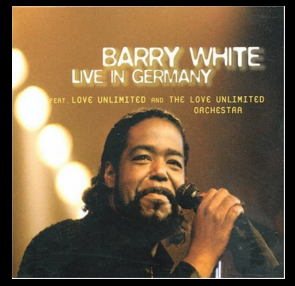
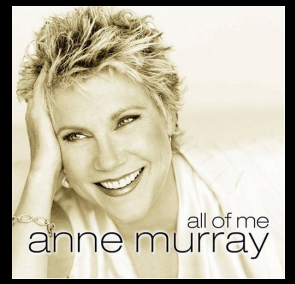
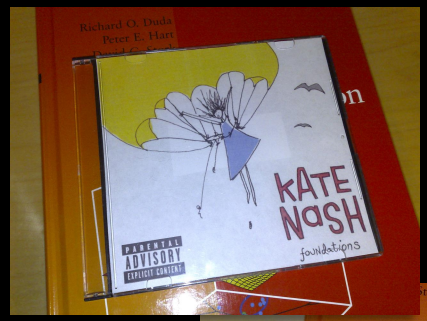
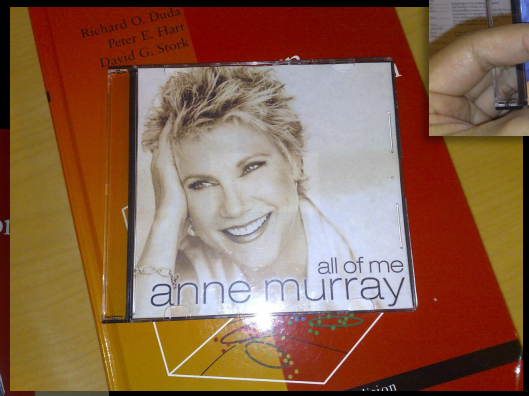


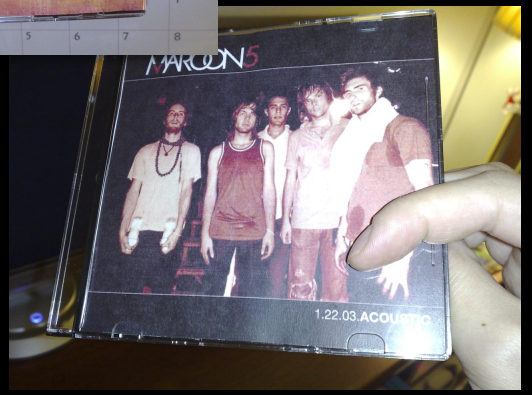
Image Processing Examples
CD Cover Recognition

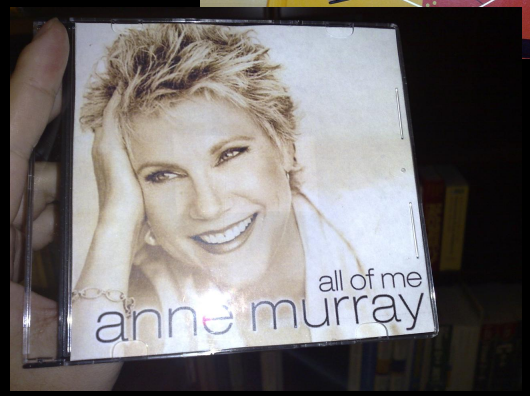


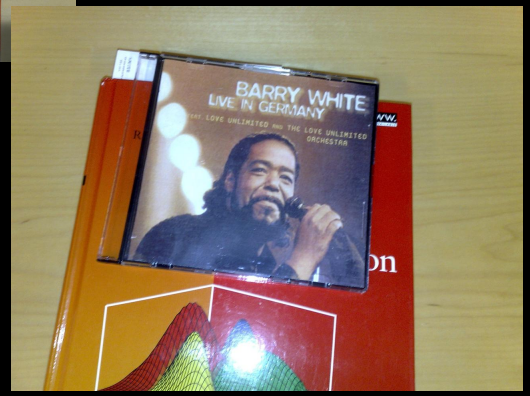












EE368 Spring 2007 Project

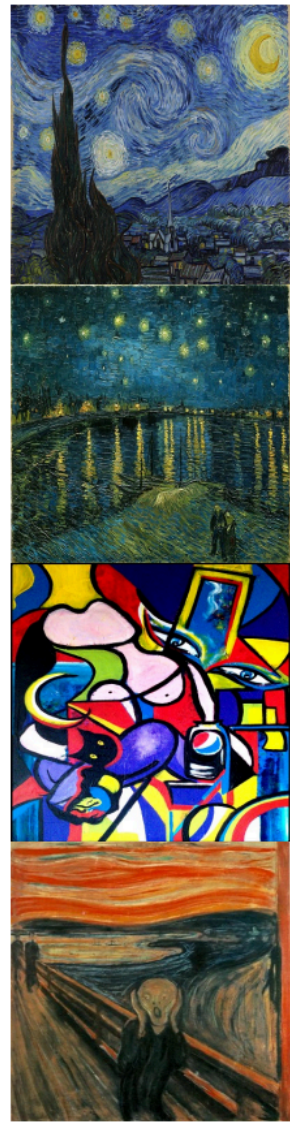
CD Cover Recognition on Cameraphone

Video See-through Augmented Reality on the Phone

Hershed Tilak & Robert Mahieu EE368, 2015/16

Image Processing Examples: Style Transfer

Original photos



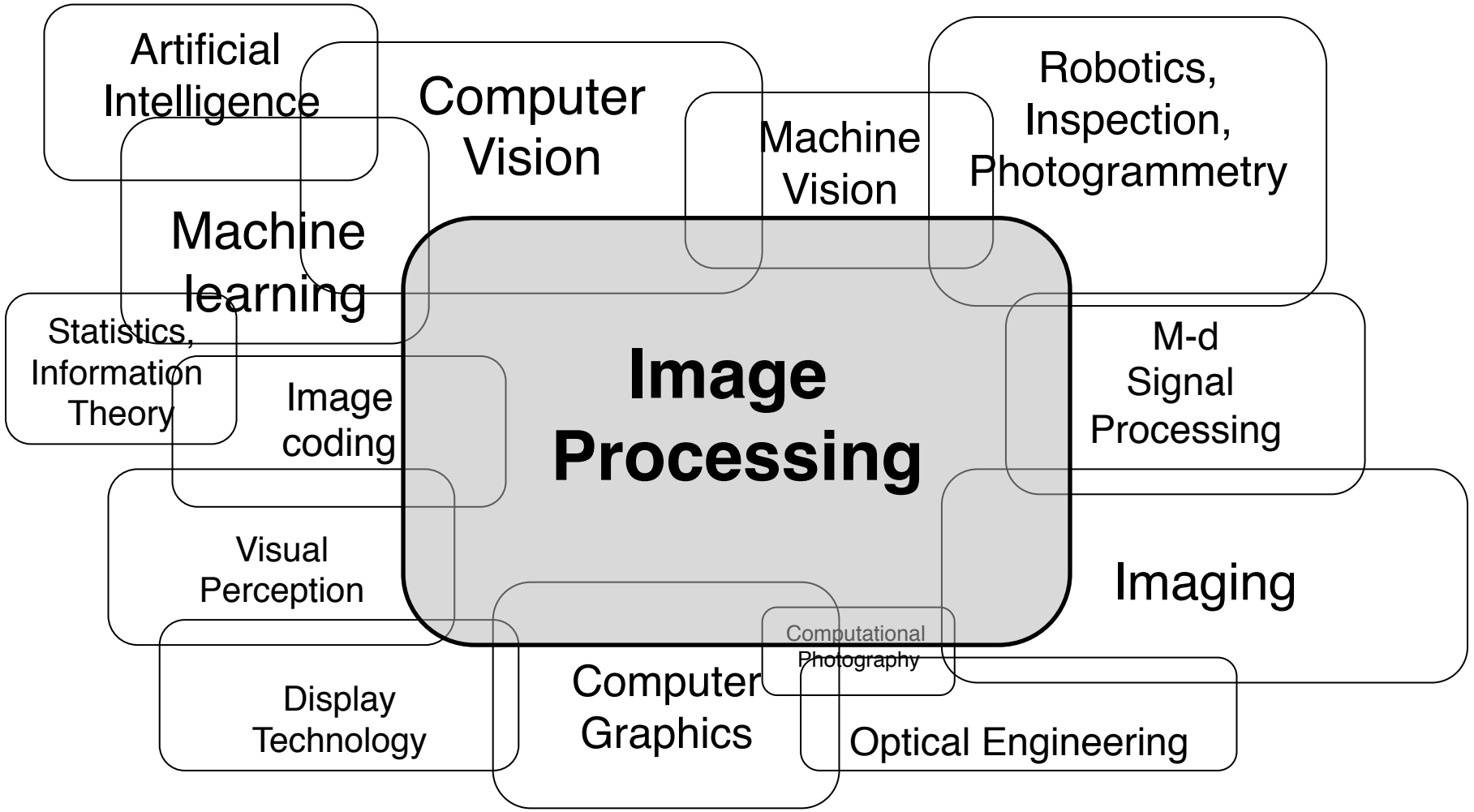
Style examples

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

Image Processing and Related Fields



EE368/CS232 Organisation

- Lectures
  - MWF 1:30 pm – 2:50 pm in Gates B03 for 7 weeks
  - Attendance highly recommended.
  - Lecture videos on https://suclass.stanford.edu: view after class, or before, or not at all.
- Problem sessions: Friday 4:30 pm – 5:20 pm, Gates B03, for 7 weeks
- Office hours
  - Bernd Girod: We 3 pm – 4:15 pm (after class), Packard 373, no office hours 2/28
    Jean-Baptiste Boin: Mo 5-7 pm, Packard 312
  - Jayant Thatte: Mo 4-6 pm, Packard 312
- Class Piazza page:

    https://piazza.com/stanford/winter2018/ee368cs232

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.
- Homework submission:
  - Electronic online submission via Gradescope.
  - Enrollment: http://www.gradescope.com - create an account, then use entry code 94P687.
- Weekly lecture review and online quizzes
  - Multiple choice questions covering the lectures on Lagunita (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
- First assignment handed out on January 8 (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 during week after the last lecture, **February 28 – March 3**

EE368/CS232 Final Project

- Group project, teams of 3-5 students, exceptions possible.
- Plan for about 50-60 hours per person
- Develop, implement and test/demonstrate an image processing algorithm
- Project proposal due: **February 12, 11:59 p.m.**
- Project presentation: Poster session, **March 14, 4:30-6:30 p.m.**
- Remote SCPD students can alternatively submit a narrated video presentation
- Submission of written report and source code: **March 16, 11:59 p.m.**

EE368/CS232 Grading

- Online quizzes: 10%
- Homework problems: 20%
- Midterm: 30%
- 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

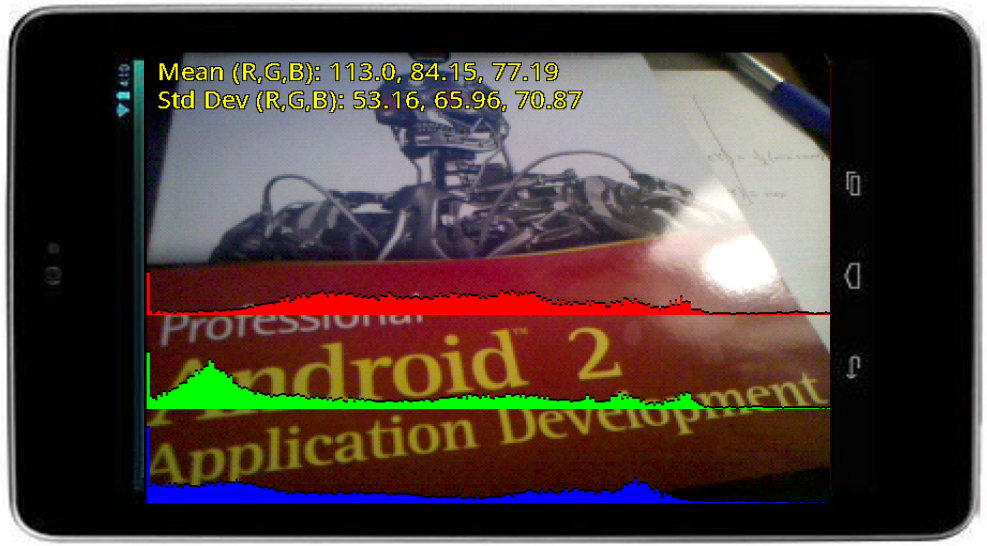
SCIEN Laboratory

- SCIEN = Stanford Center for Image Systems Engineering (http://scien.stanford.edu)
- Exclusively a teaching laboratory (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
  - William K. Pratt, „Introduction to Digital Image Processing," CRC Press, 2013.
  - R. C. Gonzalez, R. E. Woods, „Digital Image Processing," 4th edition, Pearson, 2018.
  - A. K. Jain, „Fundamentals of Digital Image Processing," Addison-Wesley, 1989. (older, more mathematical)
- Software-centric books
  - R. C. Gonzalez, R. E. Woods, S. L. Eddins, „Digital Image Processing using Matlab," 2nd edition, Gatesmark Publishing, 2009.
  - G. Bradski, A. Kaehler, „Learning OpenCV," O'Reilly Media, 2008.
- Comprehensive state-of-the-art compendium
  - 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)
  - ....