Digital Image Processing

Imaging

[Albrecht Dürer, 1525]

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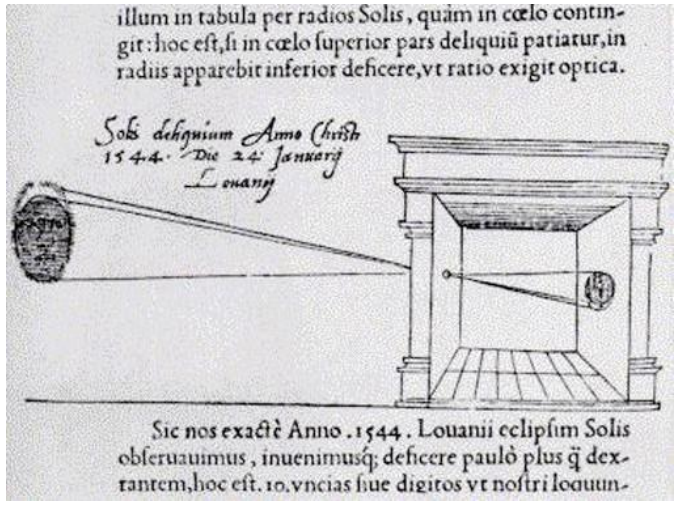
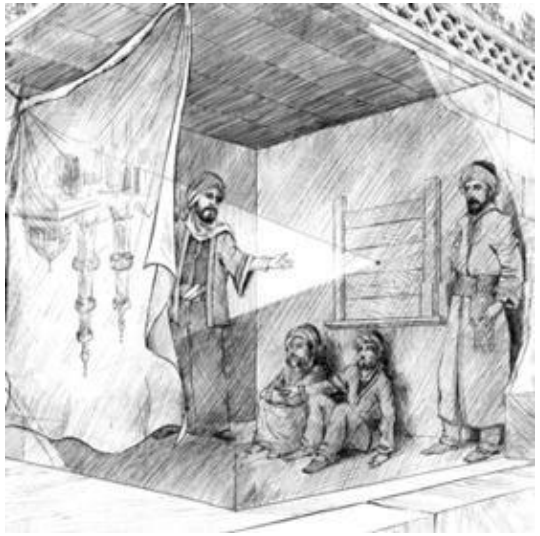
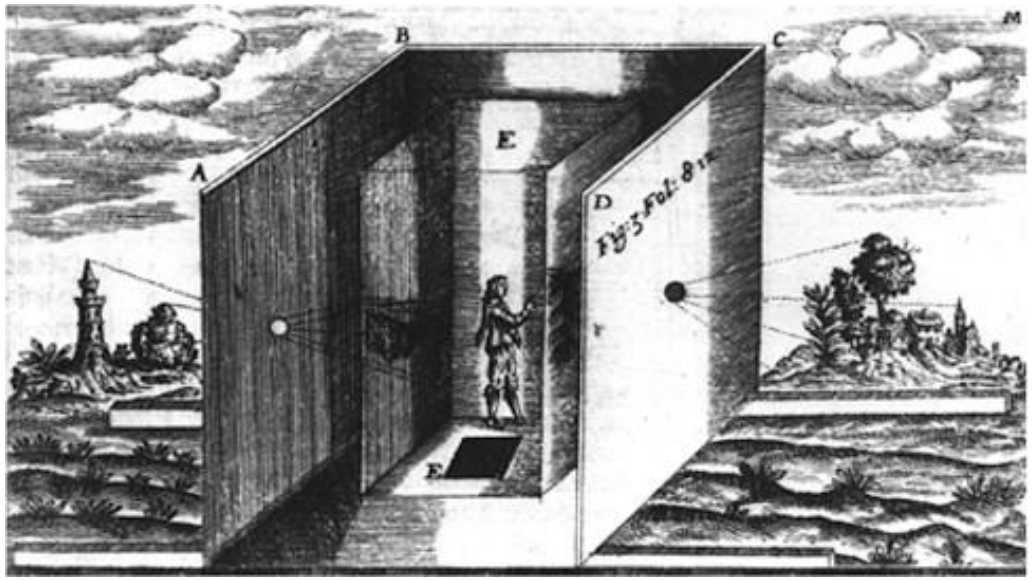
- **Image**: a visual representation in form of a function $f(x,y)$ where f is related to the brightness (or color) at point (x,y)
- Most images are defined over a rectangl
- Continuous in amplitude and space

Imaging



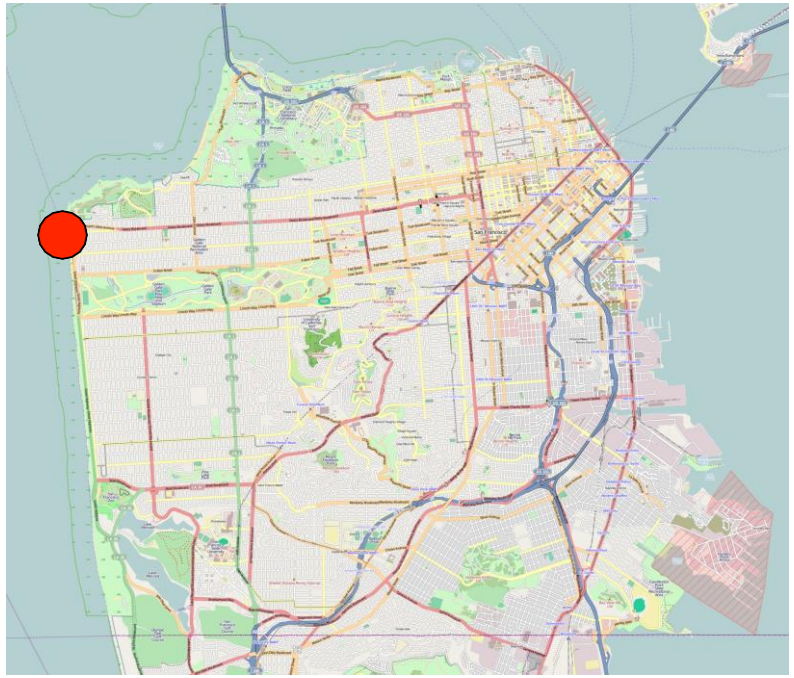




Dark chamber with lenses *[Kircher 1646]*

- **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 rectangl
- Continuous in amplitude and space

Camera Obscura in San Francisco

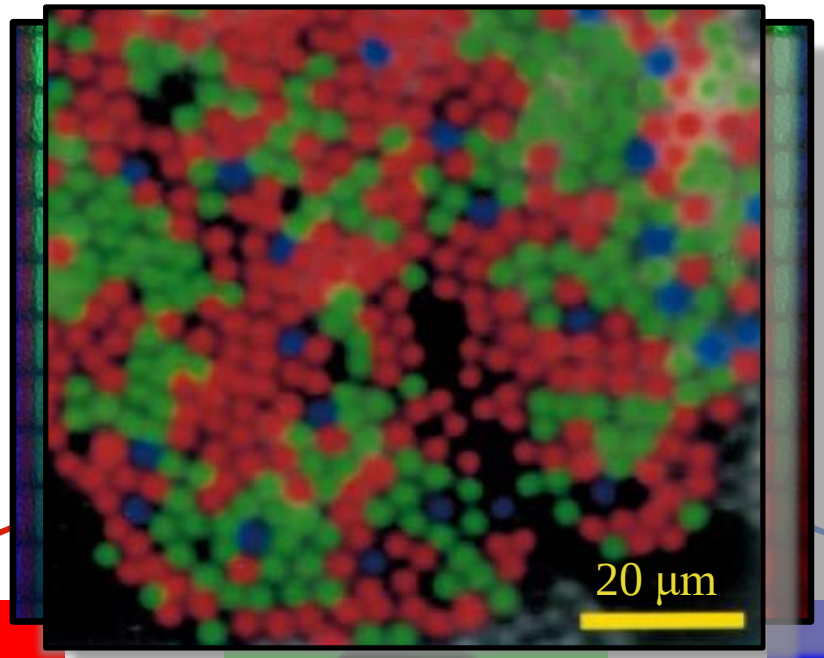


Digital Images and Pixels

- **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









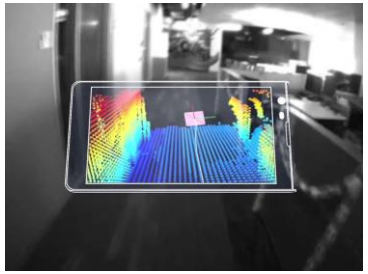
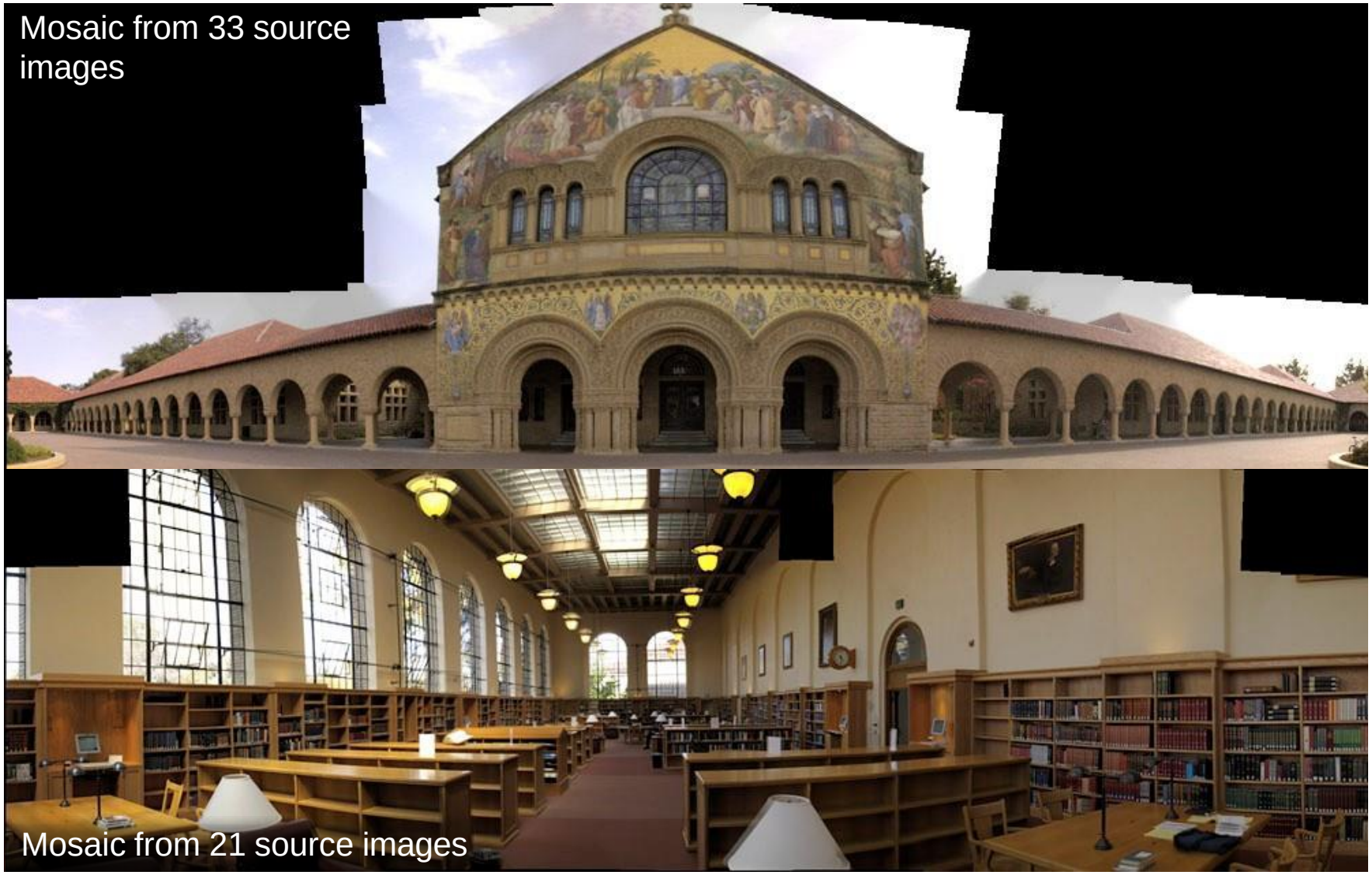



Image Processing Examples



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

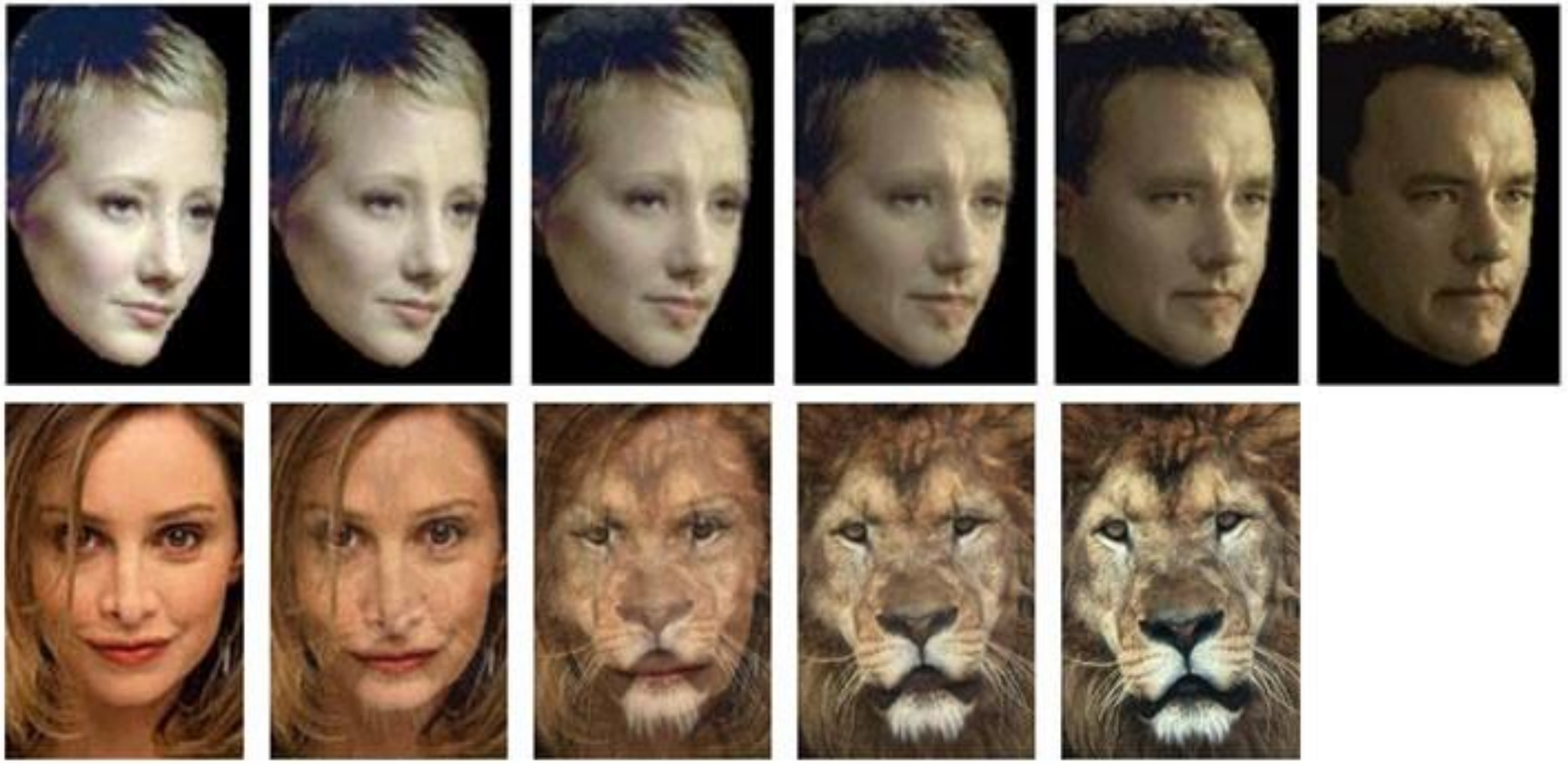
Google Jump

facebook 360

light.co

Image Processing Examples

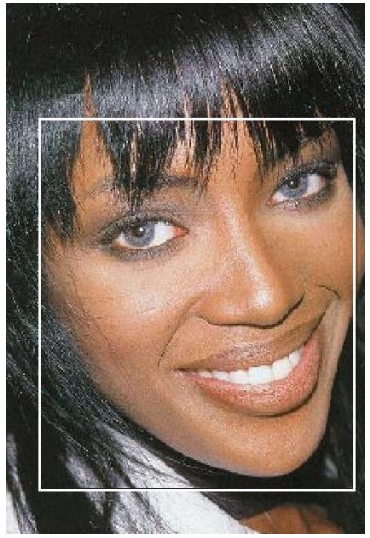
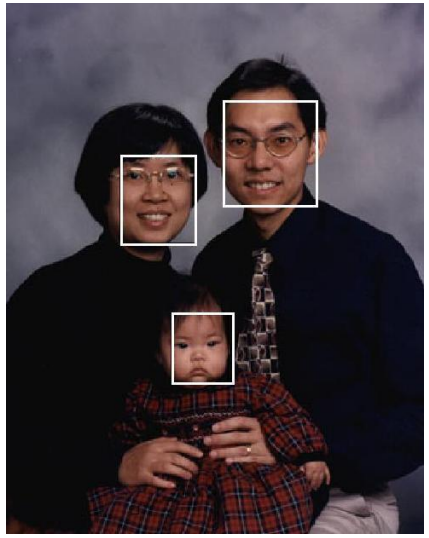
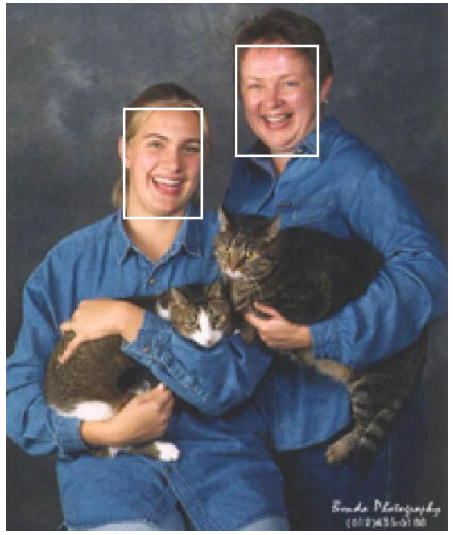
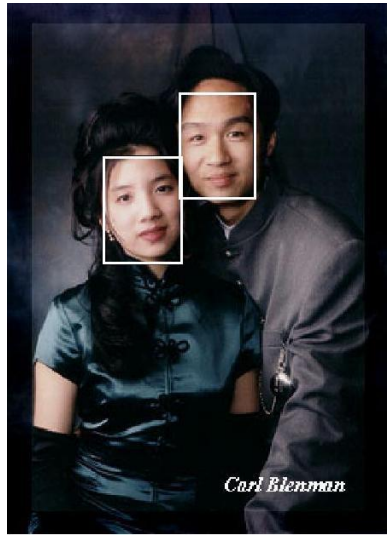
Face morphing



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

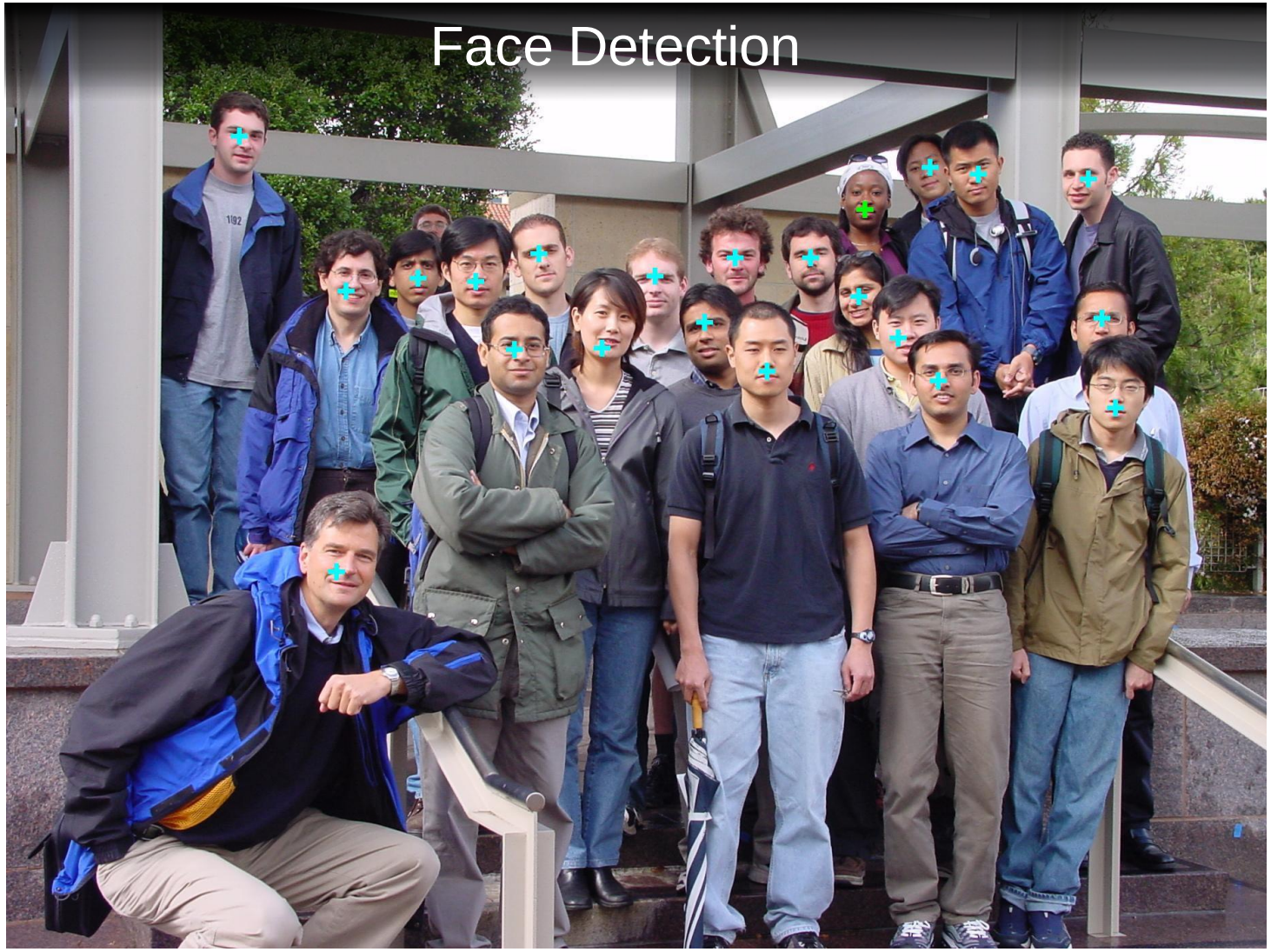
Image Processing Examples

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

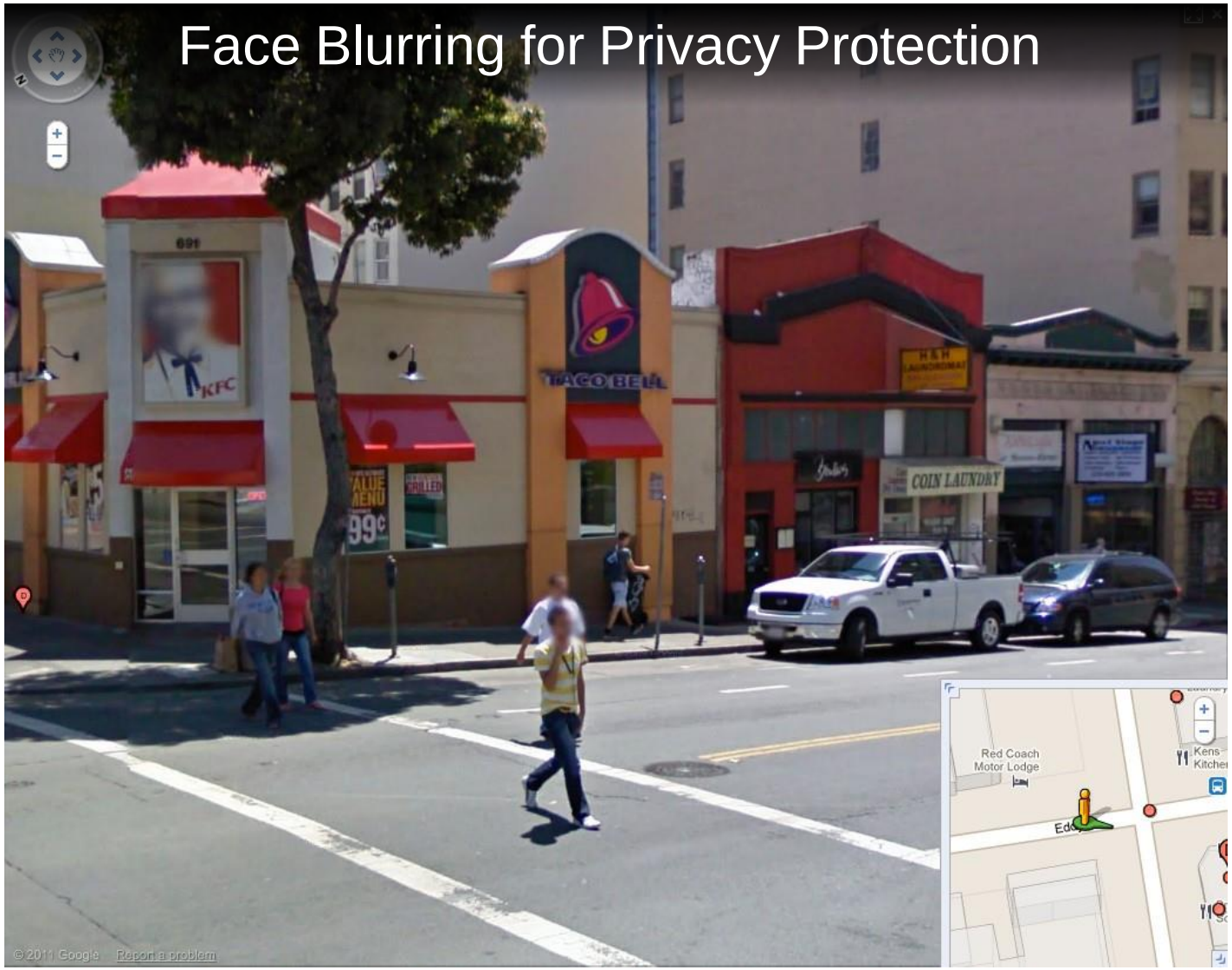
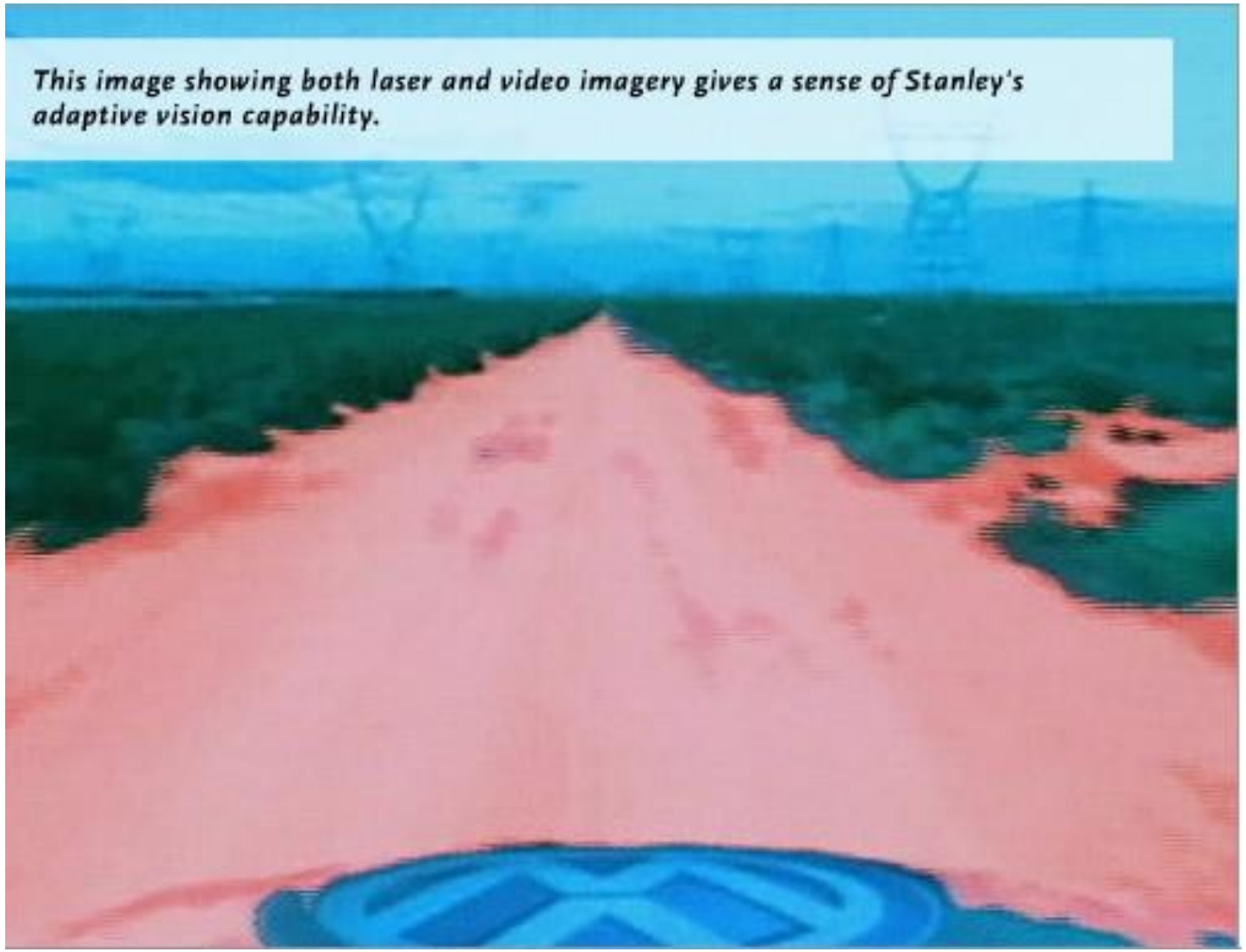
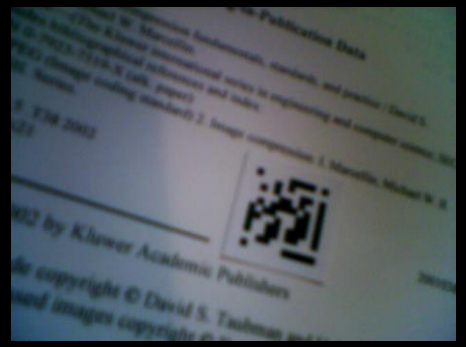


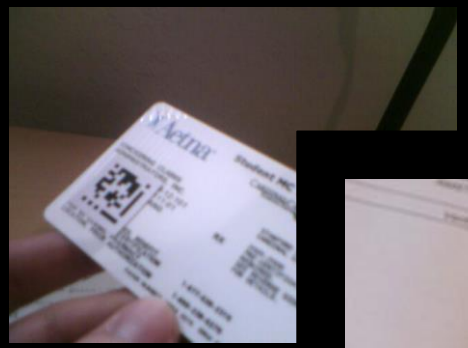
Image Processing Examples

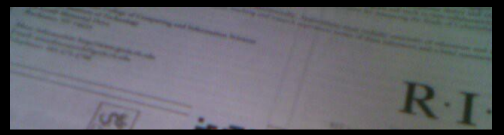


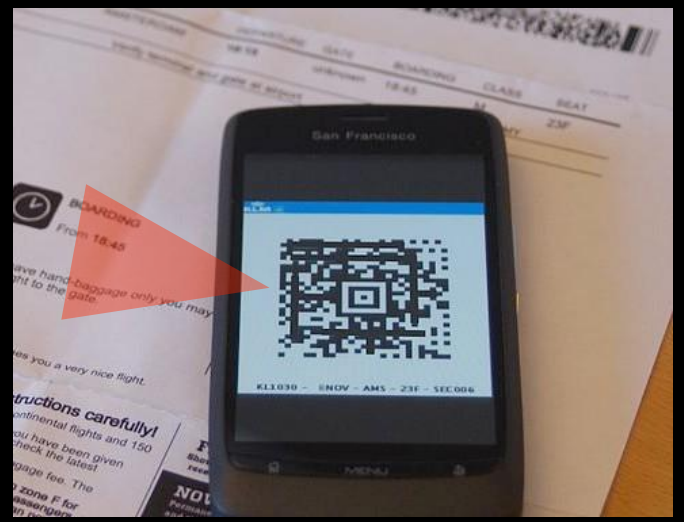
http://cs.stanford.edu/group/roadrunner/stanley.html

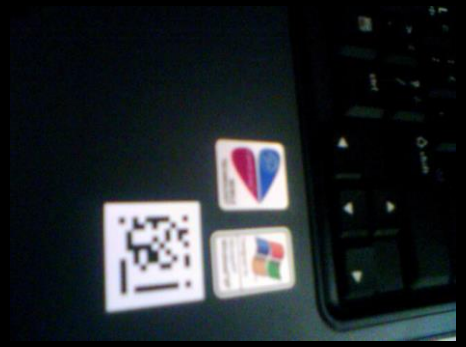
Image Processing Examples
Visual Code Marker Recognition

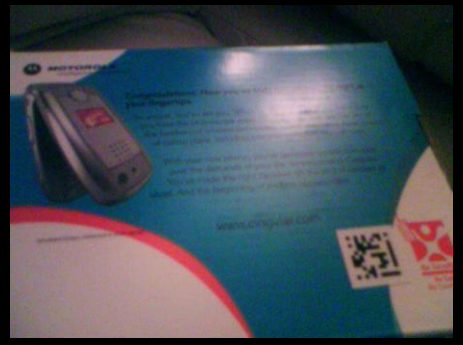












EE368 Spring 2006 Project

Image Processing Examples
Painting Recognition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EE368 Spring 2007 Project

Image Processing Examples
Painting Recognition

EE368 Spring 2007 Project

Painting Recognition for Augmented Reality

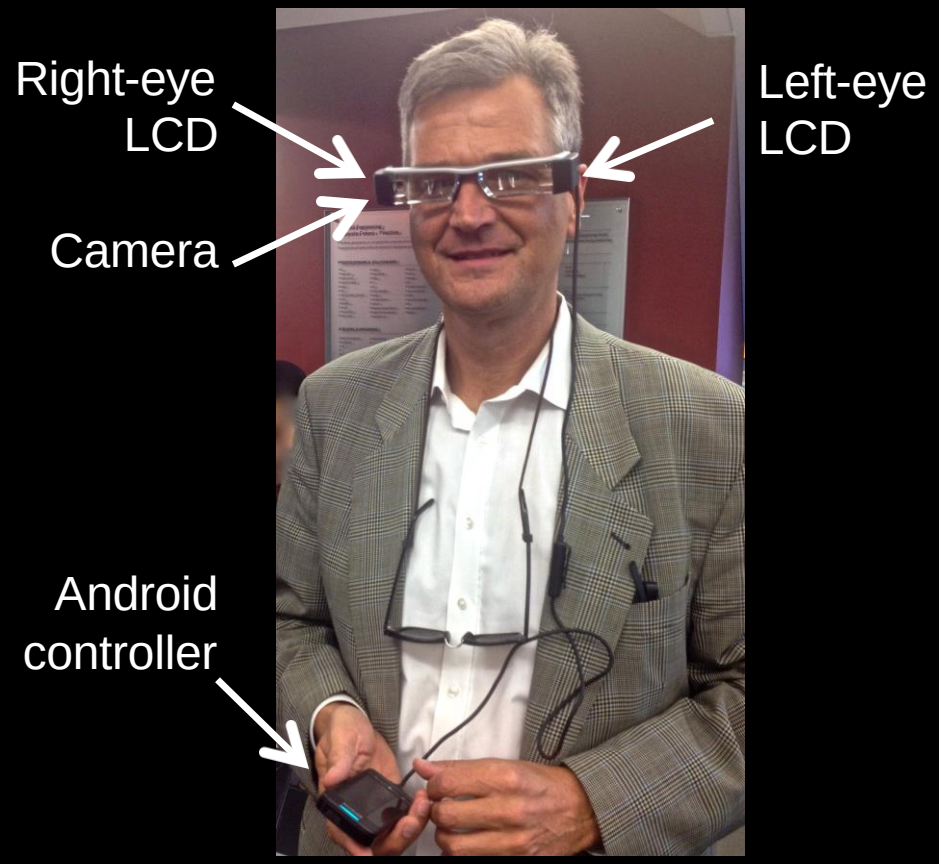
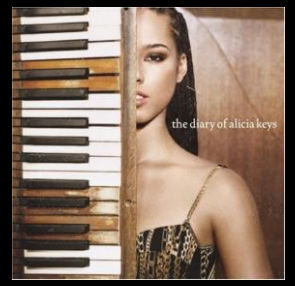
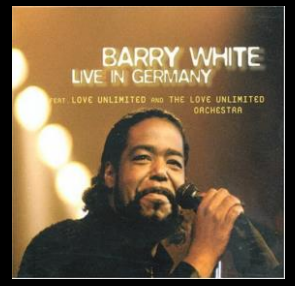
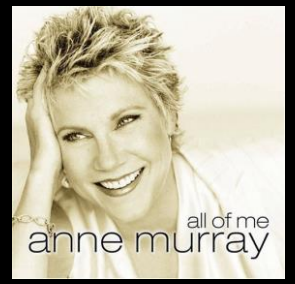
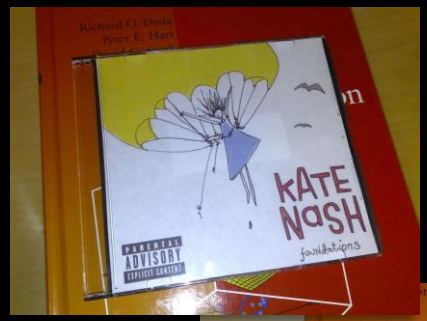


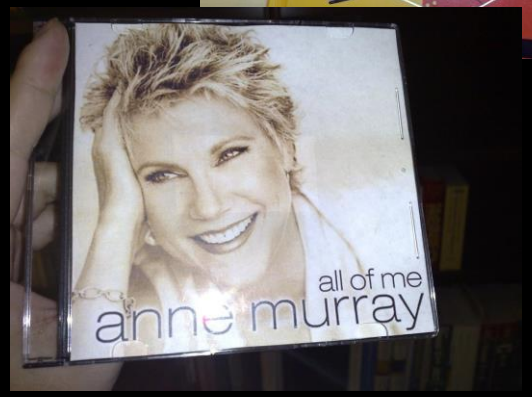
Image Processing Examples
CD Cover Recognition

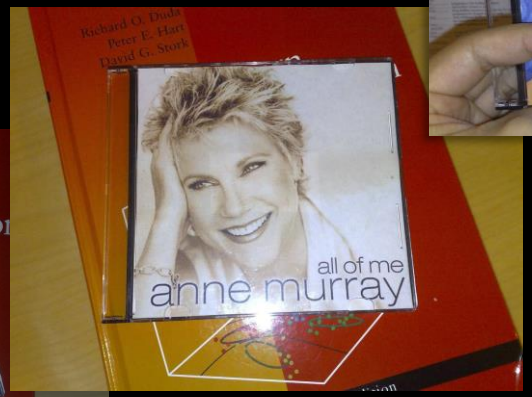


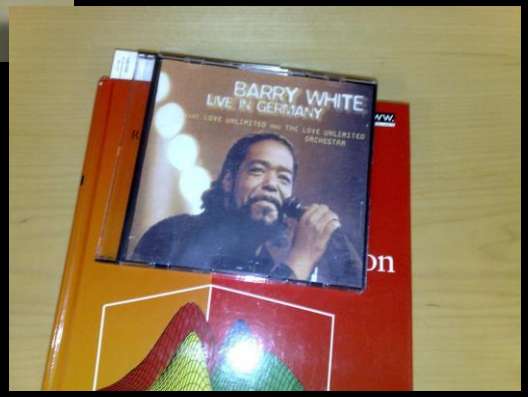








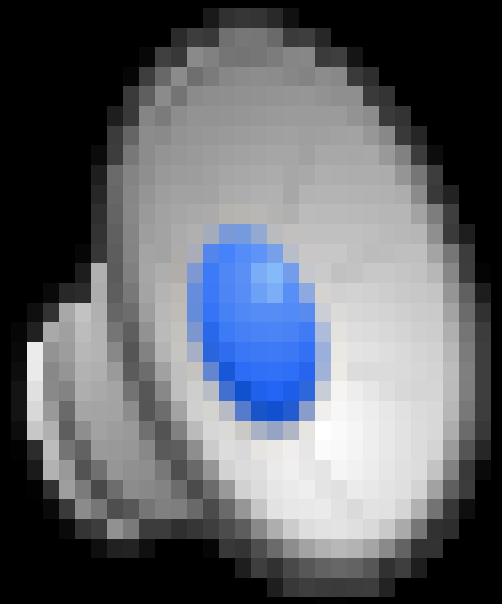




EE368 Spring 2007 Project

CD Cover Recognition on Cameraphone

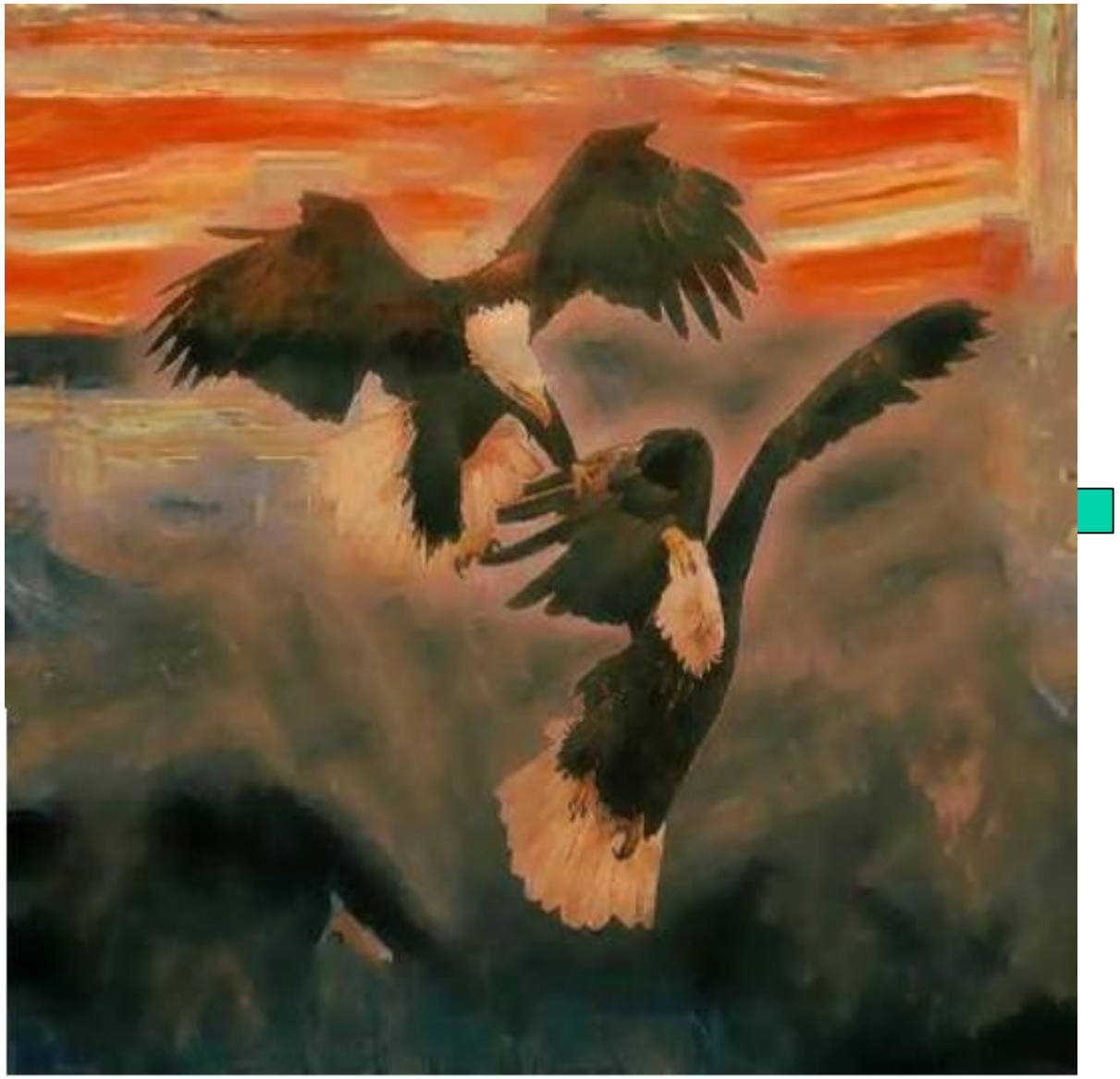
Video See-through Augmented Reality on the Phone



Hershed Tilak & Robert Mahieu EE368, 2015/16

Image Processing Examples: Style Transfer

Original photos



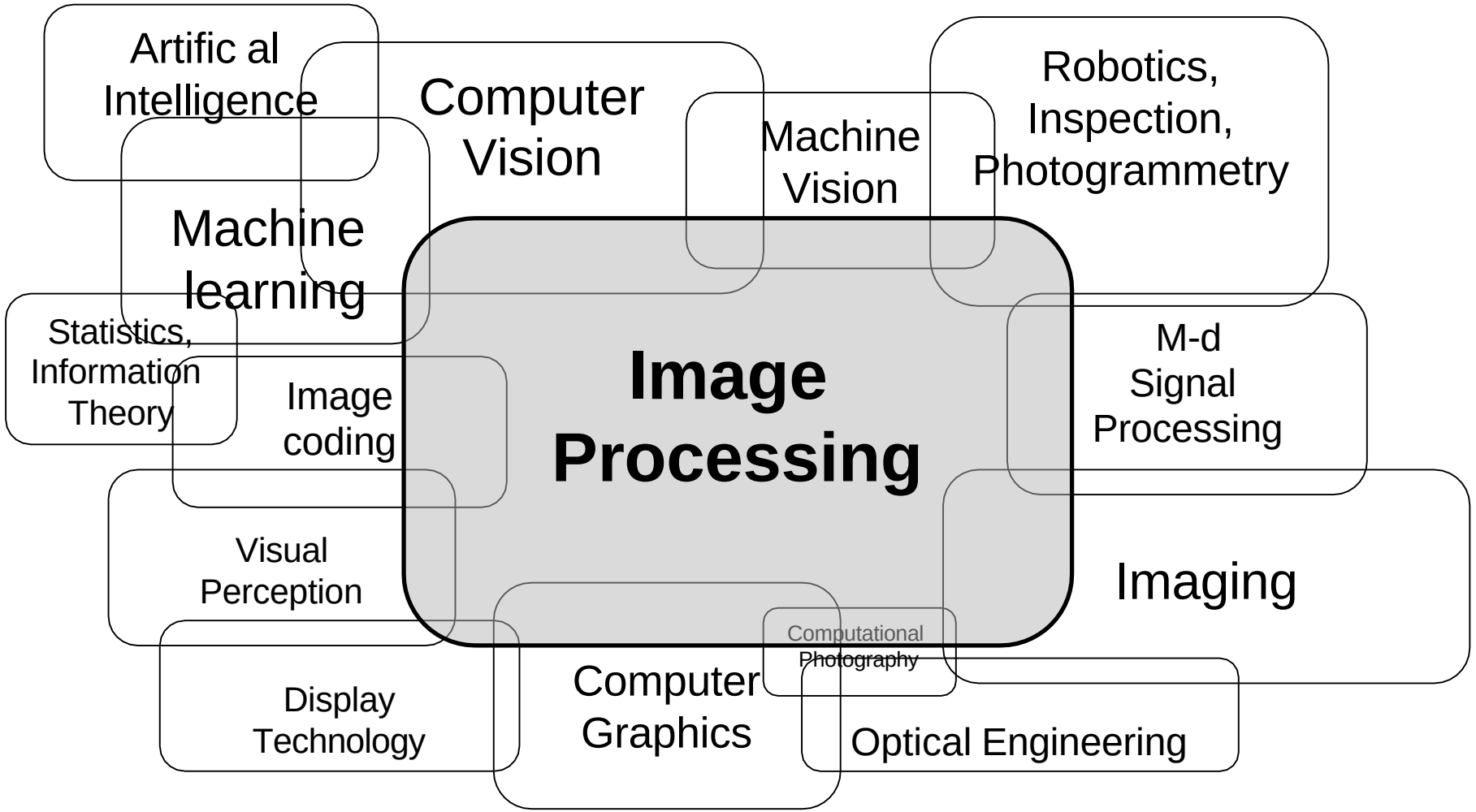
Style examples

Elias Wang, Nicholas Tan, EE368, 2016/17

Topics

- Image sensing and acquisition, sampling, quantization
- Spatial transformations, filtering in space domain and frequency domain.
- Restoration, enhancement, reconstruction; computed tomography
- Wavelets and multi-resolution processing
- Image and video compression and communication; watermarking
- Morphological Image processing
- Color processing
- Edge detection; feature extraction; SIFT, MSER
- Image segmentation
- Neural networks and deep learning
- 3D image processing
- Applications to augmented reality and virtual reality

Image Processing and Related Fields



Reading

 for source code and data)

- 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)
  - ....