Digital Image Processing

EE368/CS232

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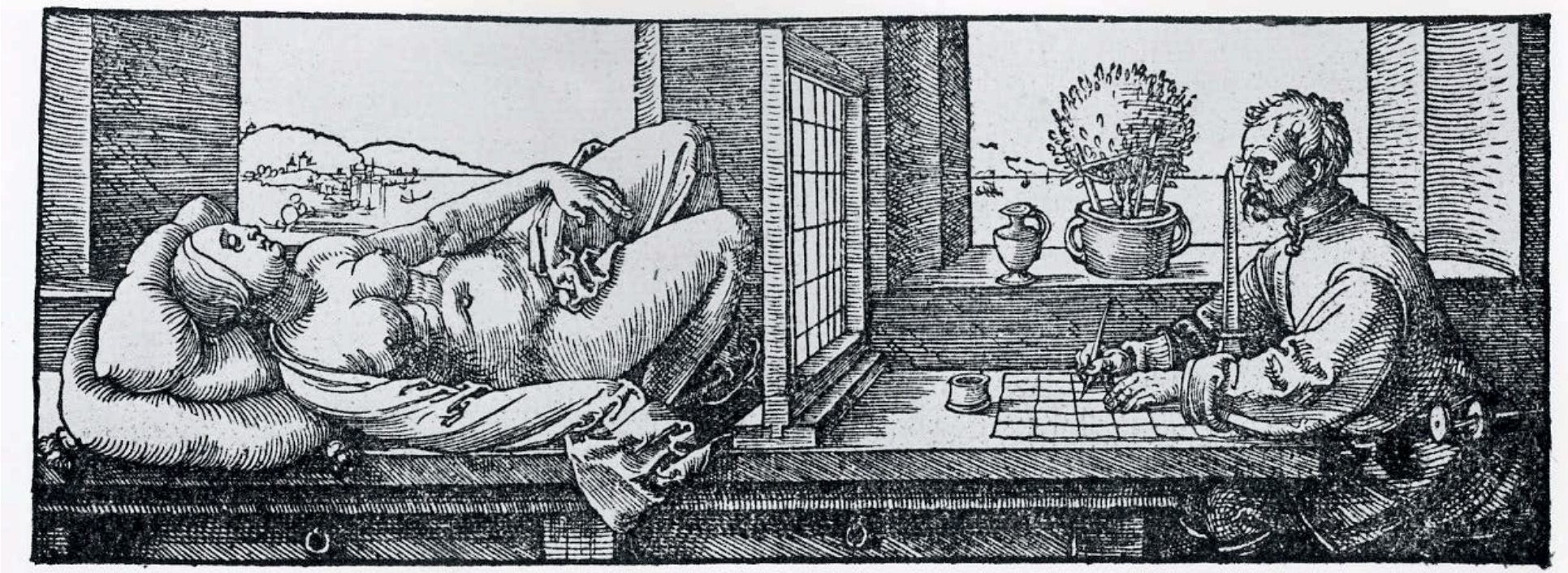
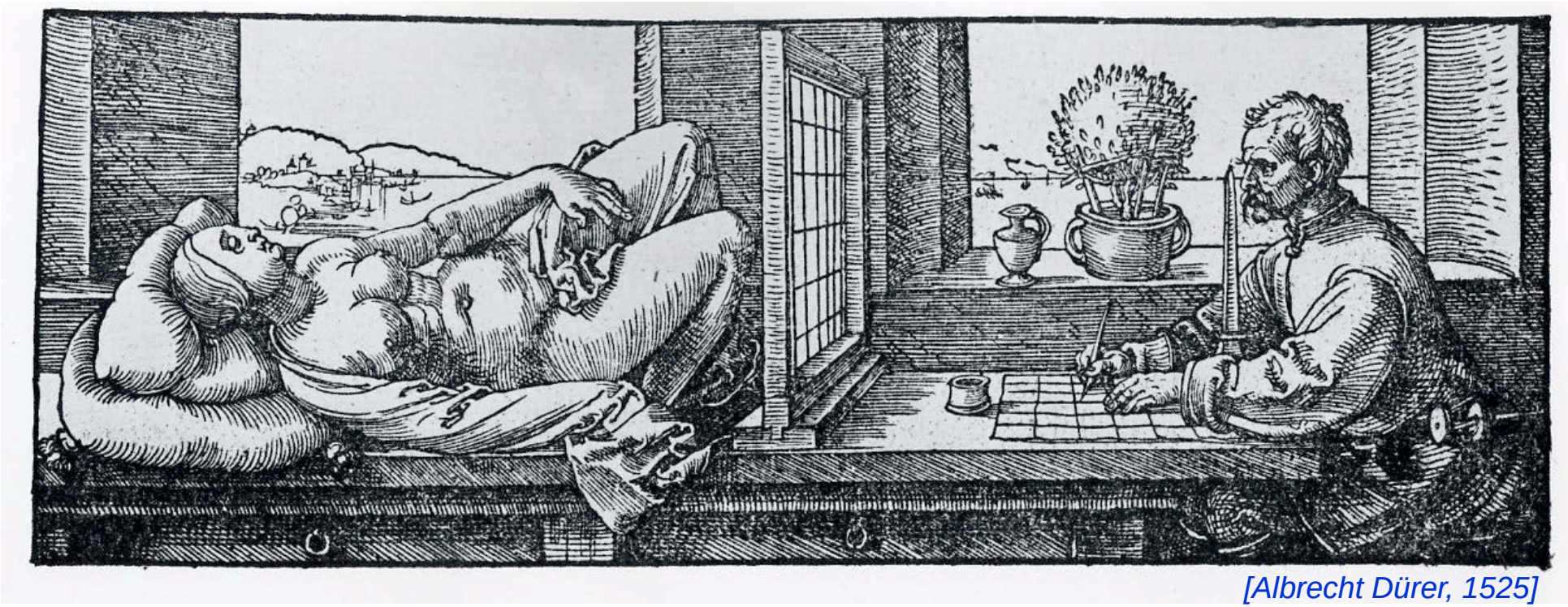
What is an image?



[Albrecht Dürer, 1525]

What is an image?



[Albrecht Dürer, 1525]

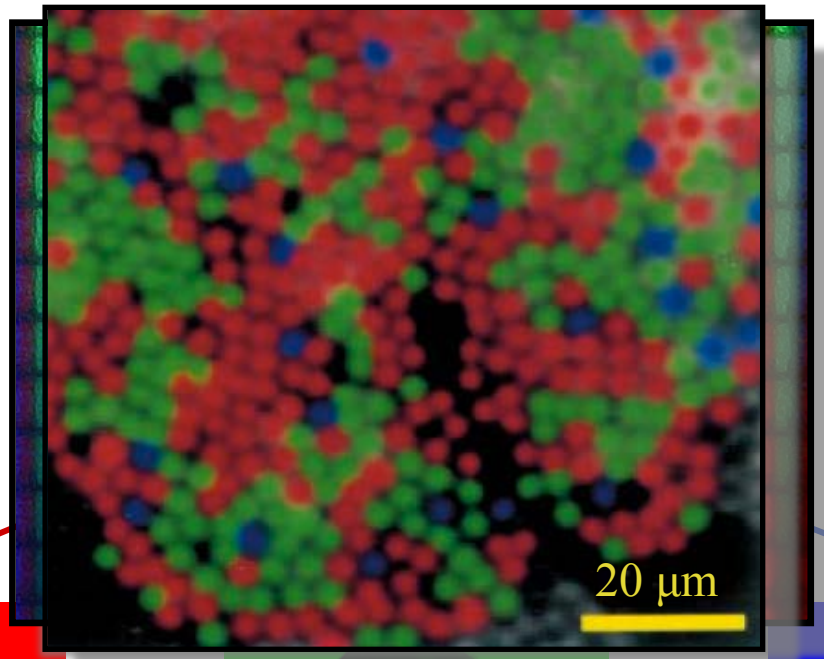
- **Image**: a visual representation in form of a function $f(x,y)$ where f is related to the brightness (or color) at point (x,y)
- Most images are defined over a rectangle
- Continuous in amplitude and space

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“)

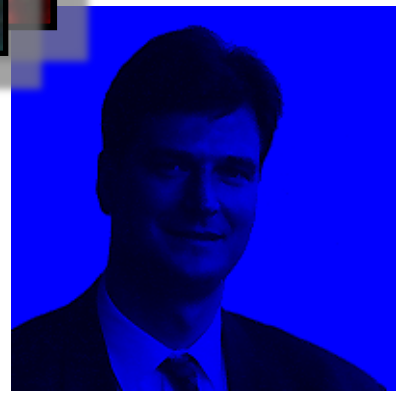
200x200 100x100 50x50 25x25

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





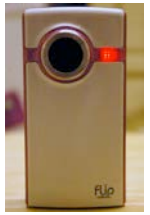
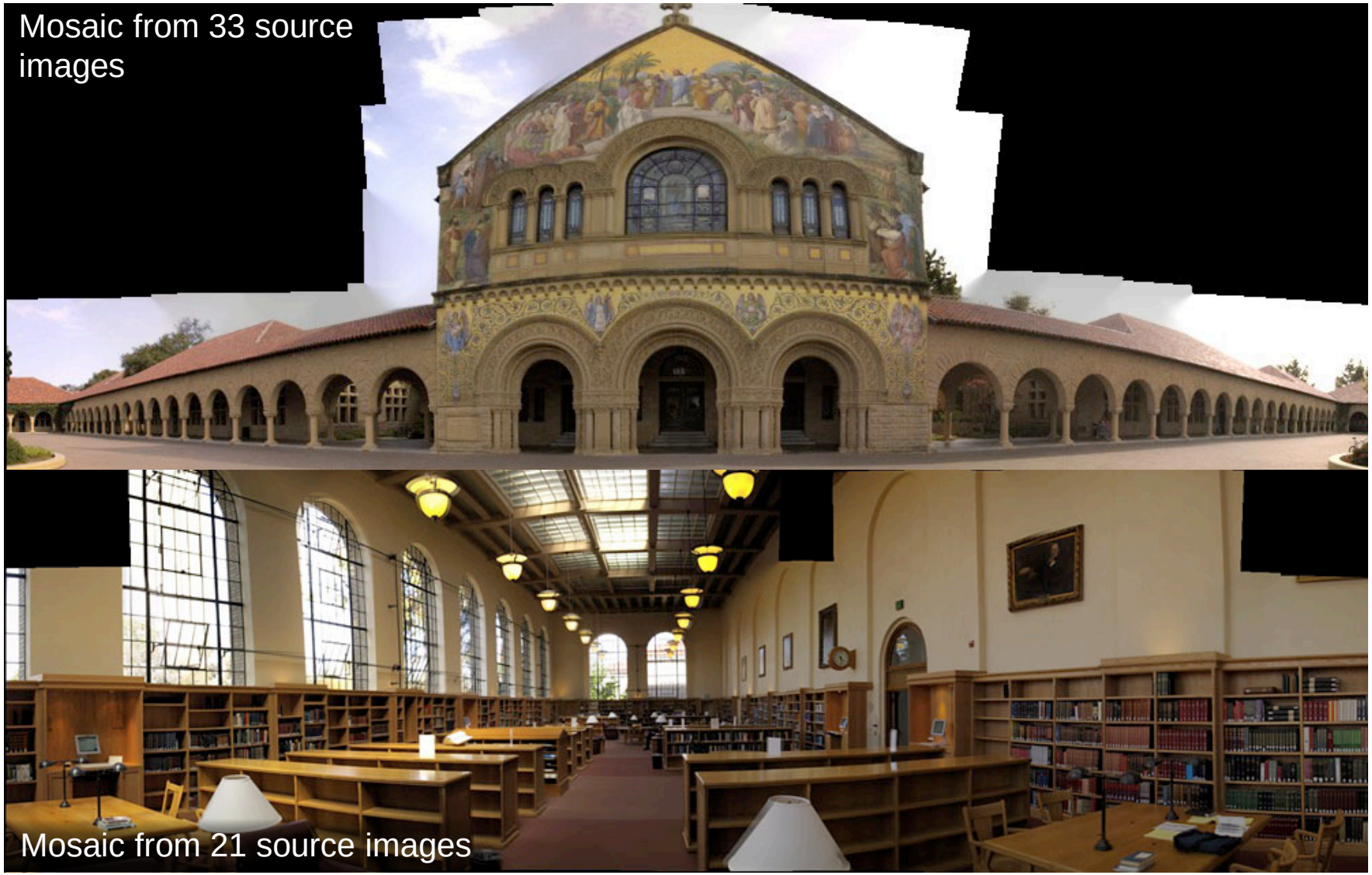



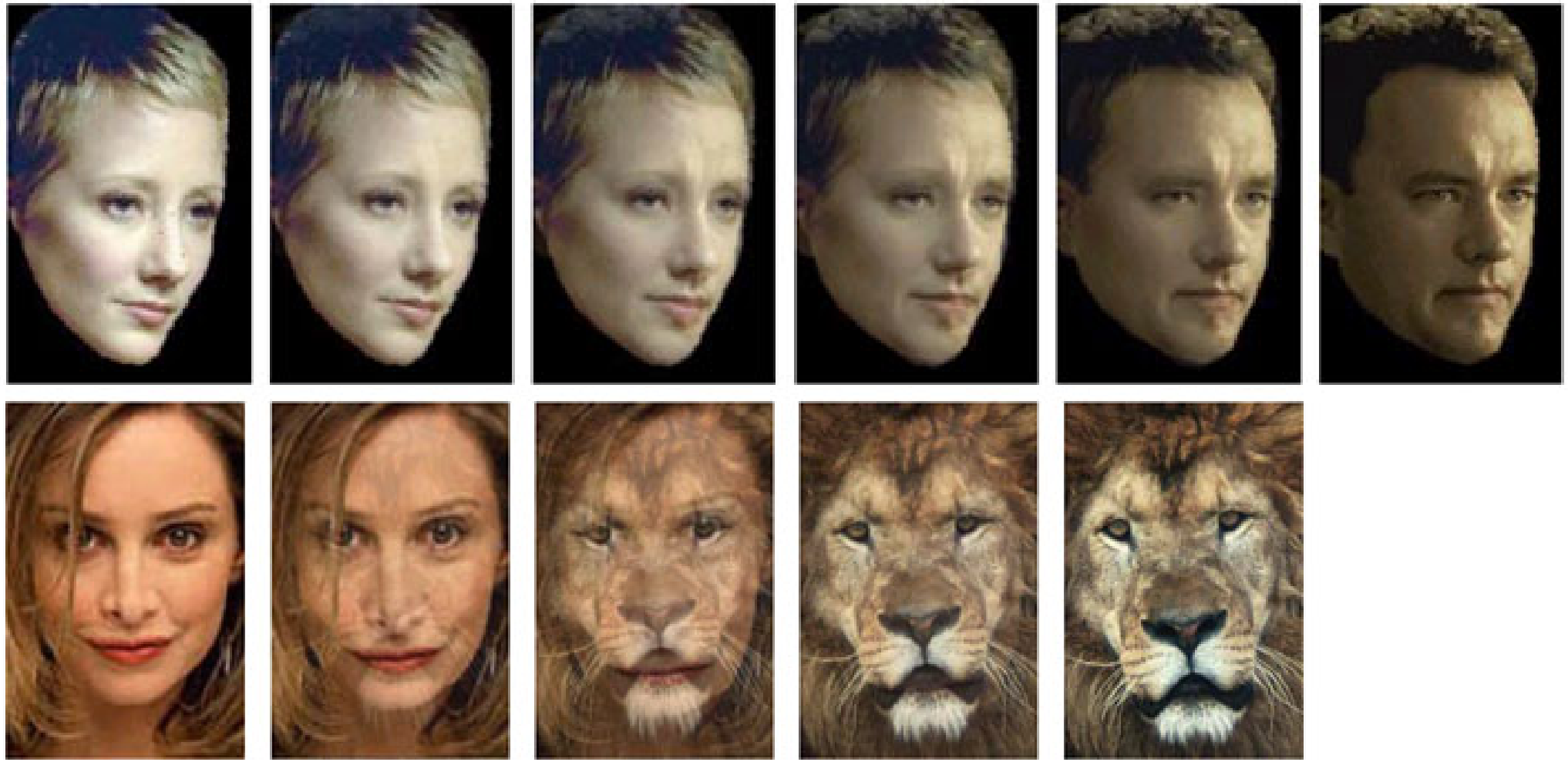

Image Processing Examples



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

Image Processing Examples

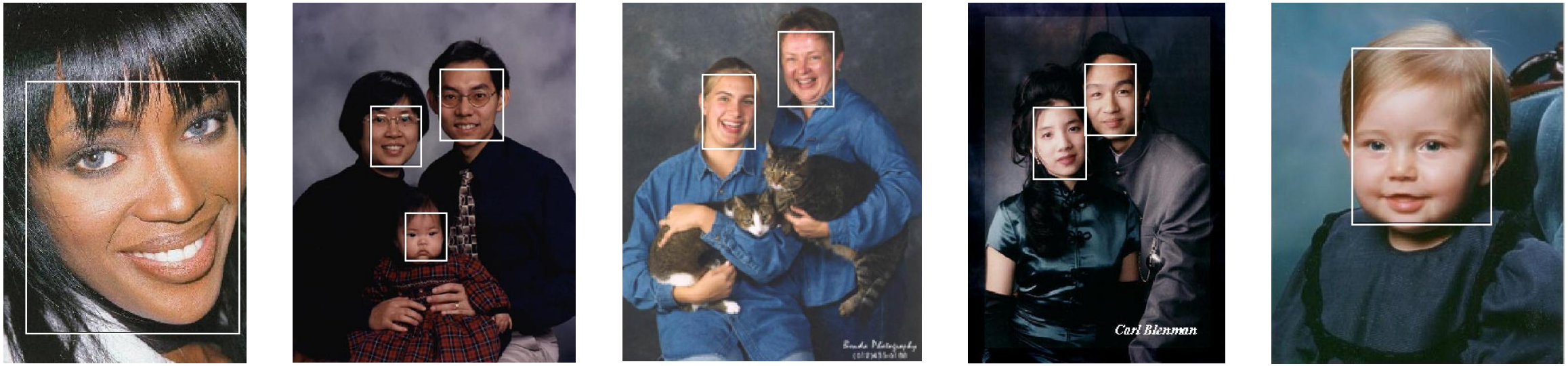
Face morphing



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

Image Processing Examples

Face Detection

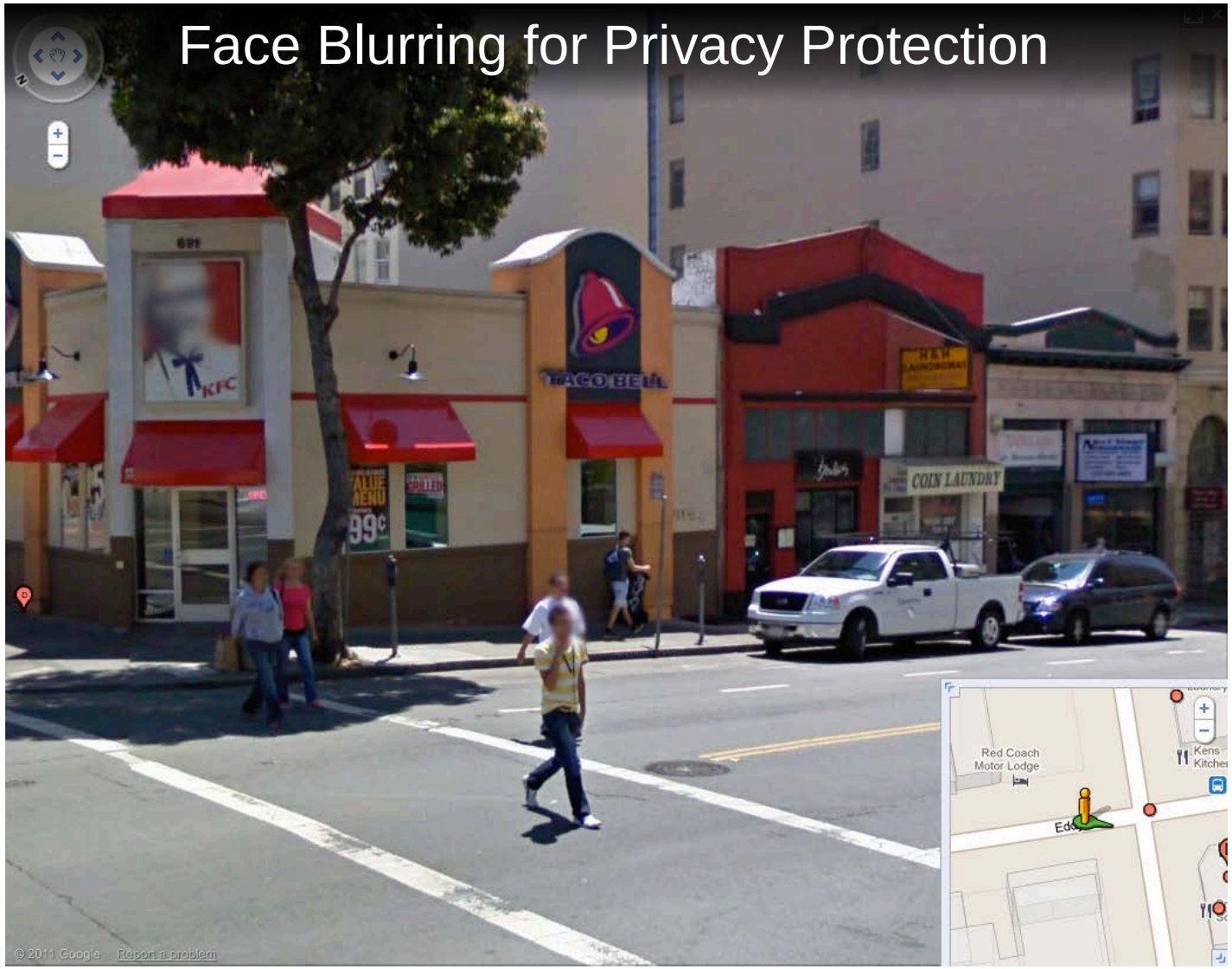


source: Henry Chang, Ulises Robles, EE368 class project, spring 2000.

Image Processing Examples

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

Image Processing Examples



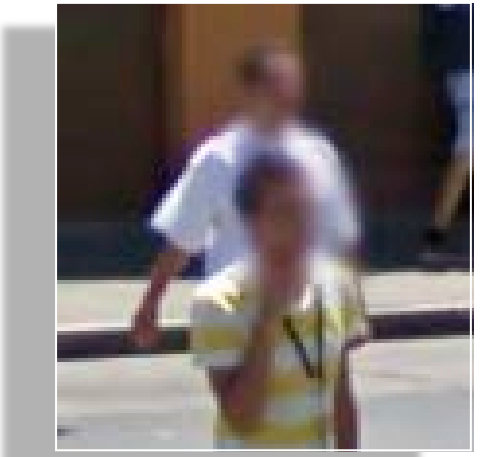
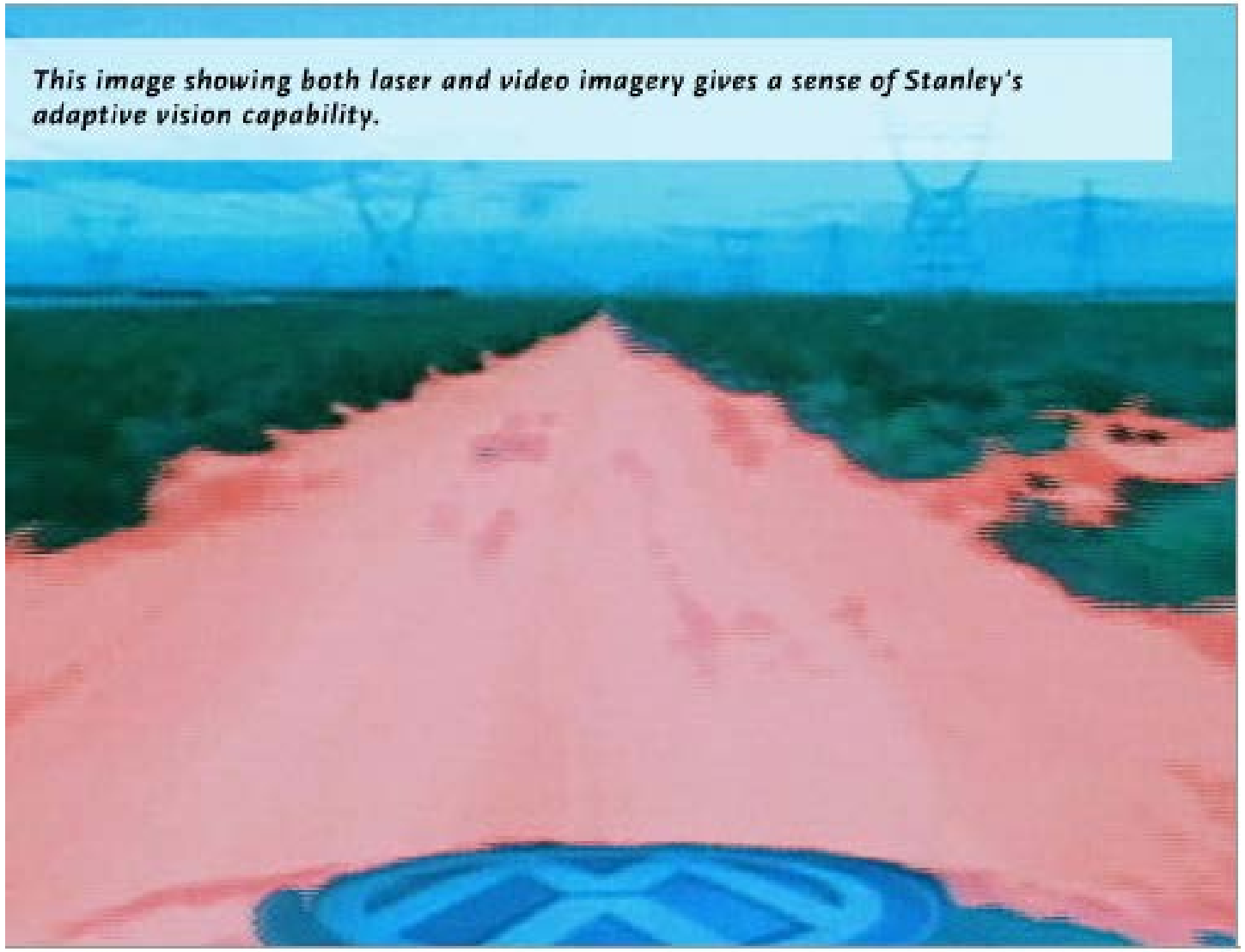
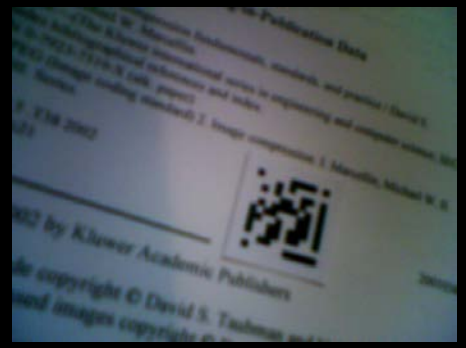


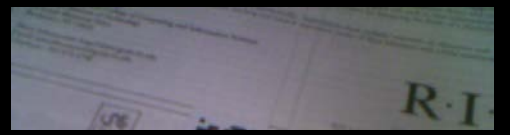
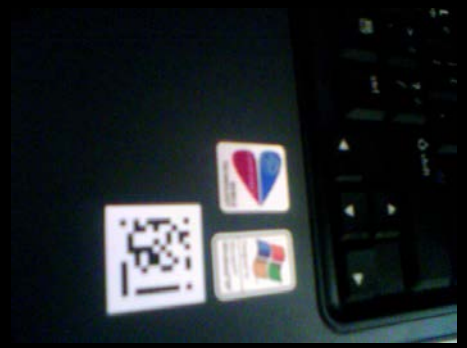
Image Processing Examples



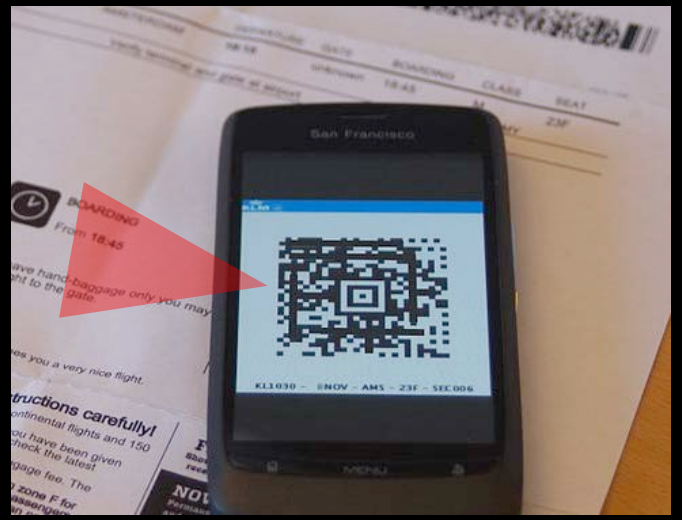
http://cs.stanford.edu/group/roadrunner/stanley.html

EE368 Spring 2006 Project:
Visual Code Marker Recognition







EE368 Spring 2007 Project: Painting Recognition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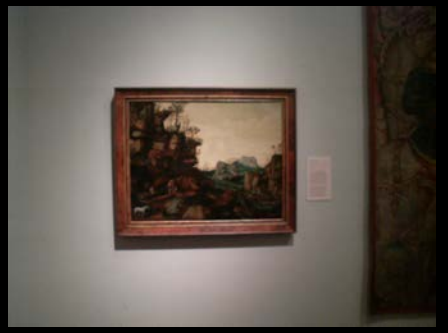
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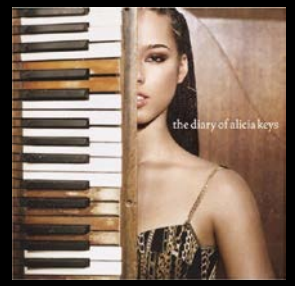
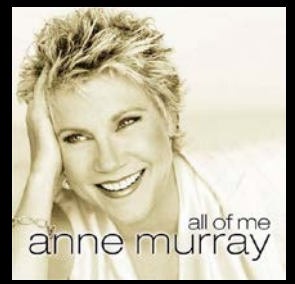
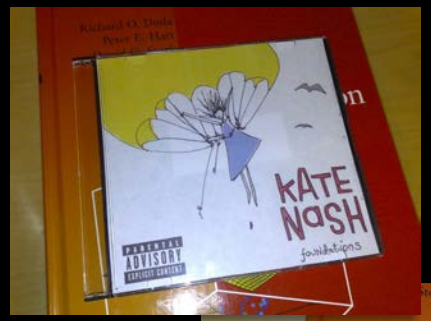
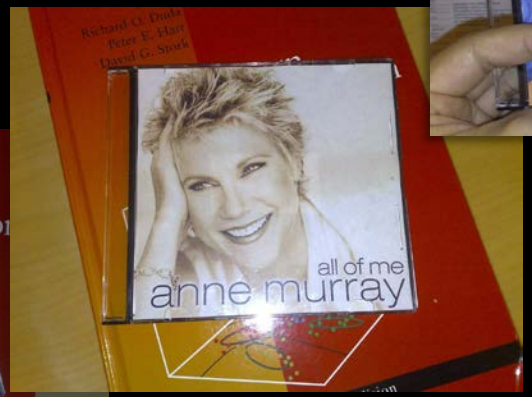
EE368 Spring 2007 Project: Painting Recognition

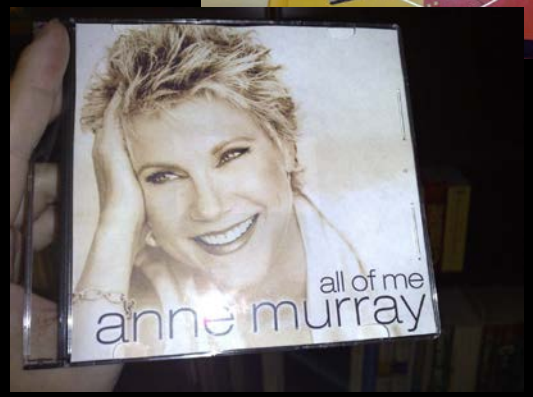
EE368 Spring 2008 Project: CD Cover Recognition

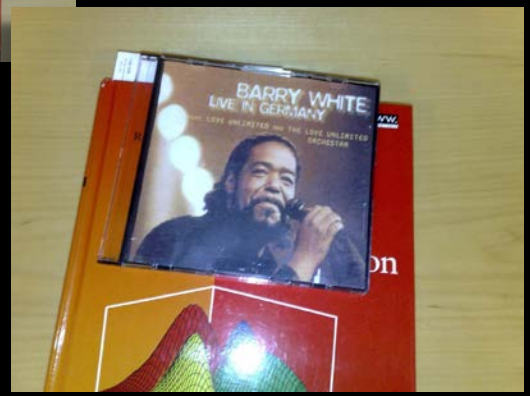










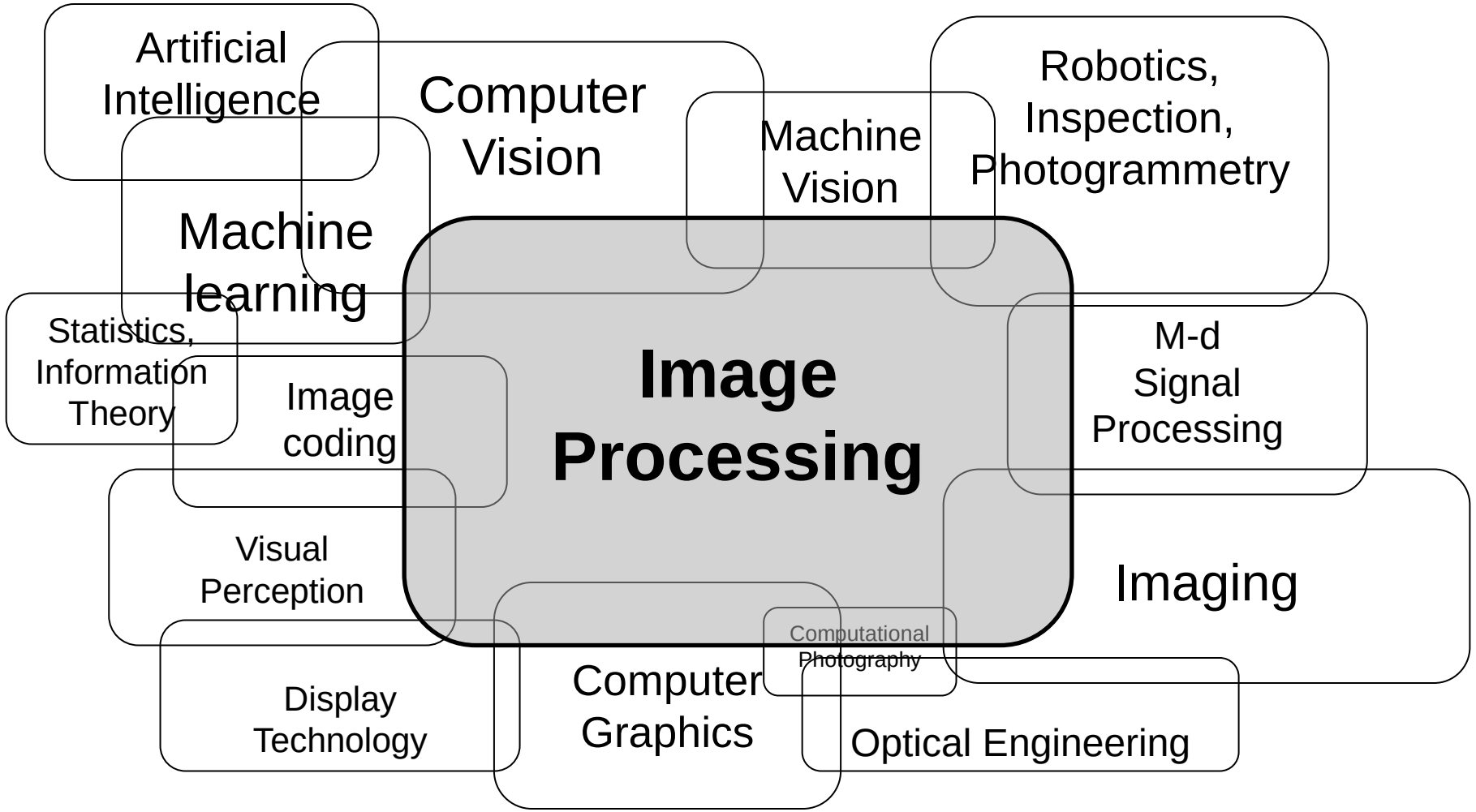


CD Cover Recognition on Cameraphone

EE368/CS232 Topics

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

Image Processing and Related Fields



EE368/CS232 Organisation

- Online course – no classroom lectures
- Not a MOOC – exclusively for Stanford students
- Weekly problem session: Th 1:15pm-2:05pm in Gates B03
- Office hours
  - David Chen, Fr 4:00-6:00 p.m., Packard 021 (SCIEN Lab)
  - Huizhong Chen, Th 4:00-6:00 p.m., Packard 021 (SCIEN Lab)
  - Bernd Girod: by appointment
- Class Piazza page:

  http://piazza.com/class#spring2014/ee368

EE368/CS232 Organisation

- Release of lecture videos with embedded quizzes, every Monday for 7 weeks
- Weekly homework assignments corresponding to video modules,
  due one week later, require computer + Matlab, solve individually
- First release on March 31 (first day of class)
- Late Midterm
  - 24-hour take-home exam
  - 3 slots, **May 21-24**

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: **April 30, 11:59 p.m.**
- Project presentation: Poster session, **June 2, 4-6:30 p.m.**
- Remote SCPD students can alternatively submit a narrated video presentation
- Submission of written report and source code:
  June 6, 11:59 p.m.

EE368/CS232 Grading

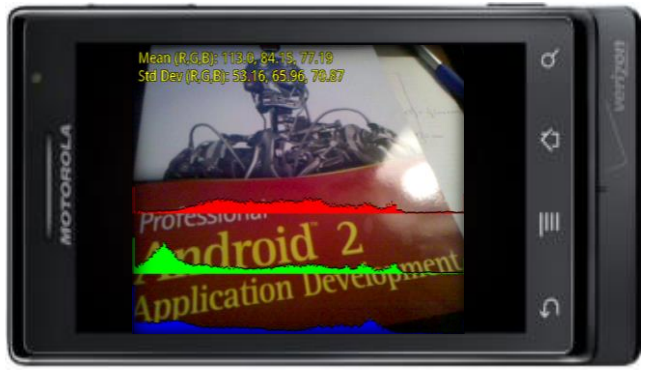
- Participation: 10%
  (Online videos, quizzes, discussion forum)
- Homeworks: 20%
- Midterm: 30%
- Final project: 40%
- No final exam.

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

Mobile image processing (optional)

- 40 Motorola DROID cameraphones available for class projects (must be returned after, sorry)
- Lectures on Android image processing in first three weeks
- Android development environment on your own computer or in SCIEN lab
- Programming in Java (C++ for OpenCV)



Reading

- Slides available as pdf files on the class website (click on  for source code and data)
  https://www.stanford.edu/ee368
- Popular text books
  - R. C. Gonzalez, R. E. Woods, „Digital Image Processing,“ 3rd edition, Prentice-Hall, 2008, $186.– ($147 on Amazon).
  - A. K. Jain, „Fundamentals of Digital Image Processing,“ Prentice-Hall, Addison-Wesley, 1989, $186.– ($141 on Amazon).
- Software-centric books
  - R. C. Gonzalez, R. E. Woods, S. L. Eddins, „Digital Image Processing using Matlab,“ 2nd edition, Pearson-Prentice-Hall, 2009, ca. $ 140.--.
  - G. Bradski, A. Kaehler, „Learning OpenCV,“ O‘Reilly Media, 2008, $ 50.00.
- Comprehensive state-of-the-art
  - Al Bovik (ed.), „The Essential Guide to Image Processing,“ Academic Press, 2009, $ 92.95.
- Journals/Conference Proceedings
  - IEEE Transactions on Image Processing
  - IEEE International Conference on Image Processing (ICIP)
  - IEEE Computer Vision and Pattern Recognition (CVPR)

EE368/CS232 Final Project

- Develop, implement and test/demonstrate image processing algorithm(s)
- May or may not use an Android device
- Important dates
  - Project proposal due: **April 30, 11:59 p.m.**
  - Project presentation: Poster session, **June 2, 4-6 p.m.**
  - Submission of written report and source code: **June 6, 11:59 p.m.**
- Posters, reports & source code will be posted online
- Project grade based on
  - Technical quality, significance, and originality 50%
  - Written report 25%
  - Poster/demo 25%

Project proposal

- Written project proposal in pdf format
- Submit by email to *ee368-spr1314-staff@lists.stanford.edu*
- Submit early for a head start, but no later than deadline
- Proposal must contain:
  - Title
  - Name(s) and email address(es) of the student(s)
  - Description of the goals of the project and the work to be carried out (200-400 words)
  - 3+ scholarly references (web pages don‘t count)
  - Indication whether you will use an Android device
- We will request a revision, if needed
- Approved proposals will be posted online

Project group and topic

- Groups of 2-3 students **strongly** encouraged
- Groups > 3 need special permission: provide compelling reason and work plan
- Use our Google Doc spreadsheet and Piazza to look for project partners – indicate general direction of interest
- Check out past proposals and projects in Final Projects section of class website
- Check journals and conference proceedings for ideas, e.g.,
  - IEEE Transactions on Image Processing
  - IEEE International Conference on Image Processing (ICIP)
  - IEEE Conference on Computer Vision and Pattern Recognition (CVPR)
- Do not be overly ambitious in your project goals!

Midterm

- 24-hour take-home exam
- 3 slots, **May 21-24, 5 pm → 5 pm**
- Typically, students spend about 5-6 hours
- Need Matlab, computer, Internet access
- Preparation: review homeworks and online quiz questions

EE368/CS232 poster session

- Poster session **June 2, 4-6 p.m., Packard Atrium**
- Put up your poster by 4 p.m., attend the entire session, take poster down after 6 p.m.
- Spend 1/3 time with your poster, 2/3 time visiting other posters
- Be prepared to give a 3-4 minute presentation/demo
- Poster boards are 3 ft wide x 2 ft tall
- Poster printing help available from course staff
- Poster template available on class website

EE368/CS232 final project submission

Due June 6, 11:59 p.m.

- Written project report, 2000 words typical, 4000 words max
- *zip* archive of all source code written
- *pdf* of the poster
- Submit everything (except videos) by email to ee368-spr1314-staff@lists.stanford.edu
- If you have a demo, we encourage you to record a video and submit through class webpage

EE368/CS232 project report

- Submit as pdf, 2000 words typical, 4000 words max., not including references.
- Use IEEE conference paper as a template
  http://www.ieee.org/conferences_events/conferences/publishing/templates.html
- Include graphs, pictures, and references
- Observe the Stanford Honor Code
  - Do not copy or paraphrase text without proper attribution
  - Do not copy or modify figures without proper attribution
  - Never, ever manipulate, suppress, or make up experimental results
- Groups submit ONE report
- Include a break-down of who did what as an appendix to the report