Digital Image Processing
(CSE405)

Introduction

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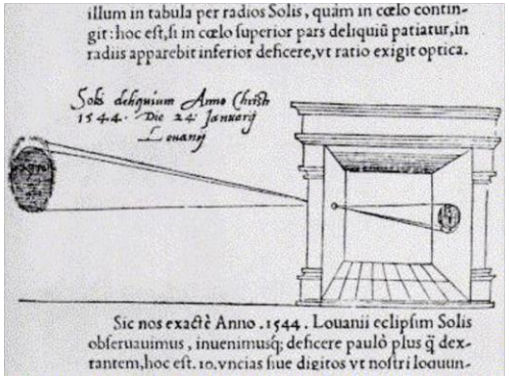
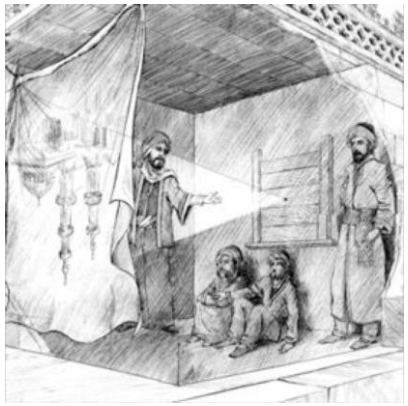
Imaging

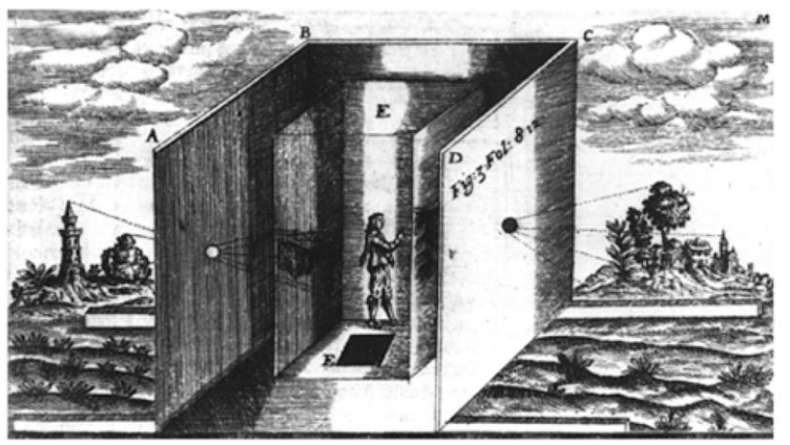
[Albrecht Dürer, 1525]

- **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







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)
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Analog Image

An image can be understood as a 2D light intensity function f(x,y) where:

- x and y are spatial coordinates
- The value of f at any point (x, y) is proportional to the brightness or gray value of the image at that point

Cannot be stored as such on a digital computer.

What is an image?

We can think of an **image** as a function, *f*, from R^2 to R:

- $f(x, y)$ gives the **intensity** at position (x, y)
- Realistically, we expect the image only to be defined over a rectangle, with a finite range:
  - f: $[a,b]\mathrm{x}[c,d] \rightarrow [0,1]$

A color image is just three functions pasted together. We can write this as a "vector-valued" function:

$$f(x,y) = \begin{bmatrix} r(x,y) \\ g(x,y) \\ b(x,y) \end{bmatrix}$$

Digital Images and Pixels

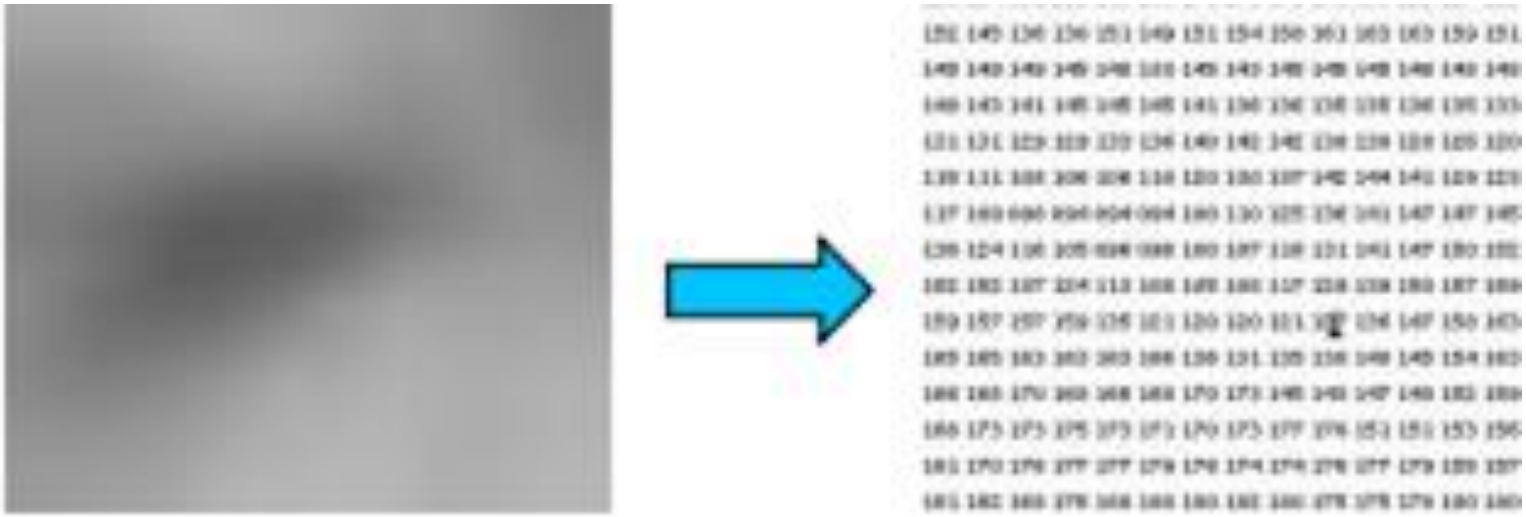
- **Digital image**: discrete samples $f[x,y]$ representing continuous image $f(x,y)$
- Each element of the 2-d array $f[x,y]$ is called a **pixel** or **pel** (from “picture element“)

200x200 100x100 50x50 25x25

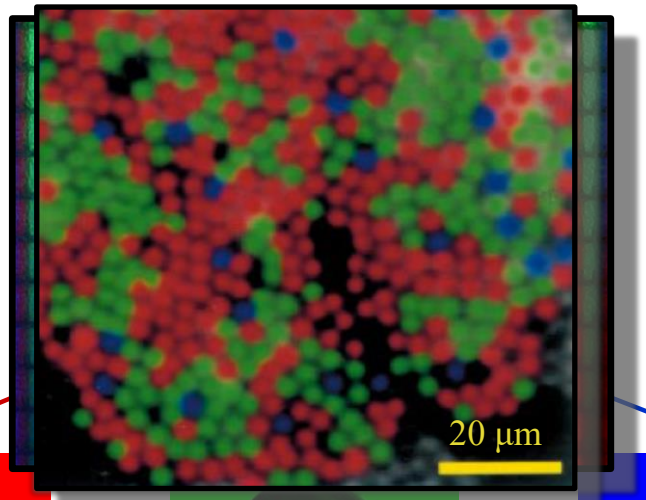
Digital Image

A digitized image is one in which:

- Spatial and grayscale values have been made discrete.
- Intensities measured across a regularly spaced grid in x and y directions are sampled to
  - 8 bits (256 values) per point for black and white,
  - 3x8 bits per point for color images.
- Stored as a 2D arrays of gray-level values. The array elements are called pixels and identified by their x, y coordinates.



Color Components



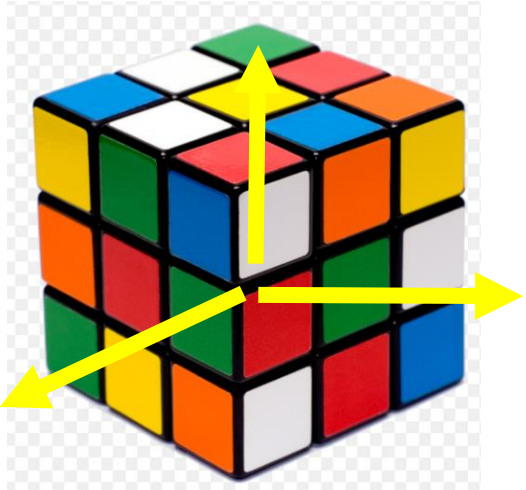
Red $R[x,y]$

Green $G[x,y]$

Blue $B[x,y]$

Monochrome image

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



What is a Digital Image? (cont…)

Common image formats include:

- 1 sample per point (B&W or Grayscale)
- 3 samples per point (Red, Green, and Blue)
- 4 samples per point (Red, Green, Blue, and “Alpha”, a.k.a. Opacity)

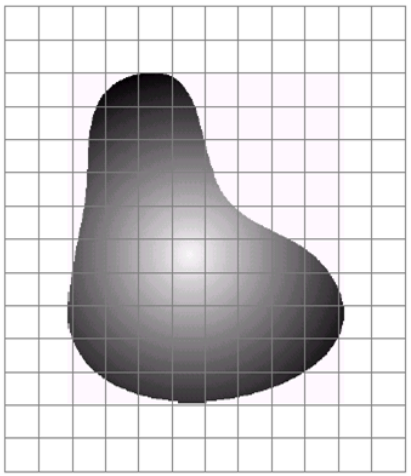


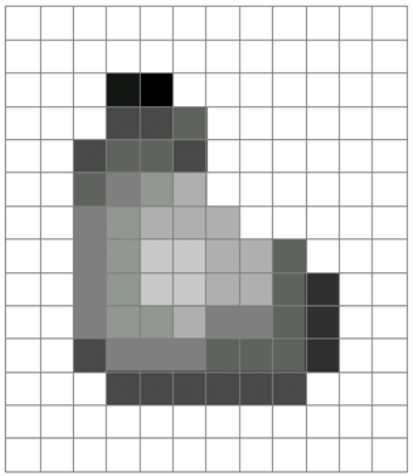
For most of this course we will focus on grey-scale images

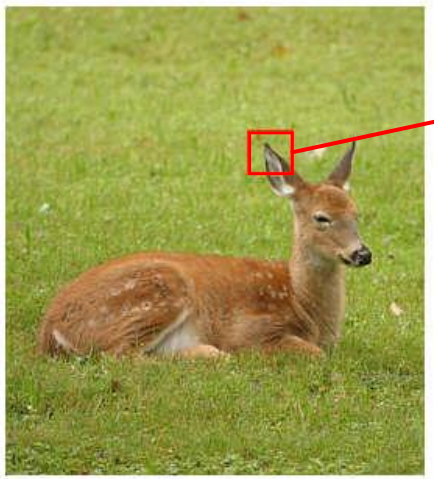
What is a Digital Image? (cont…)

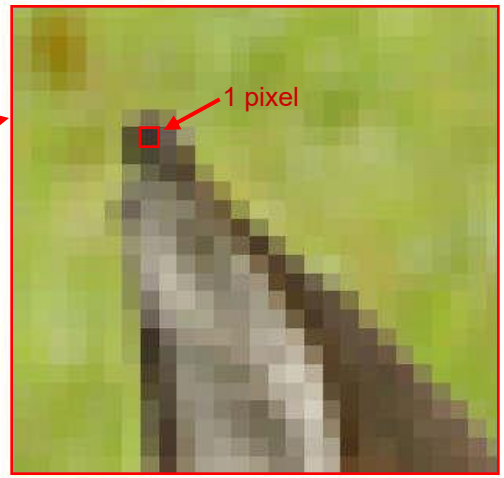
Pixel values typically represent gray levels, colours, heights, opacities etc

Remember *digitization* implies that a digital image is an *approximation* of a real scene







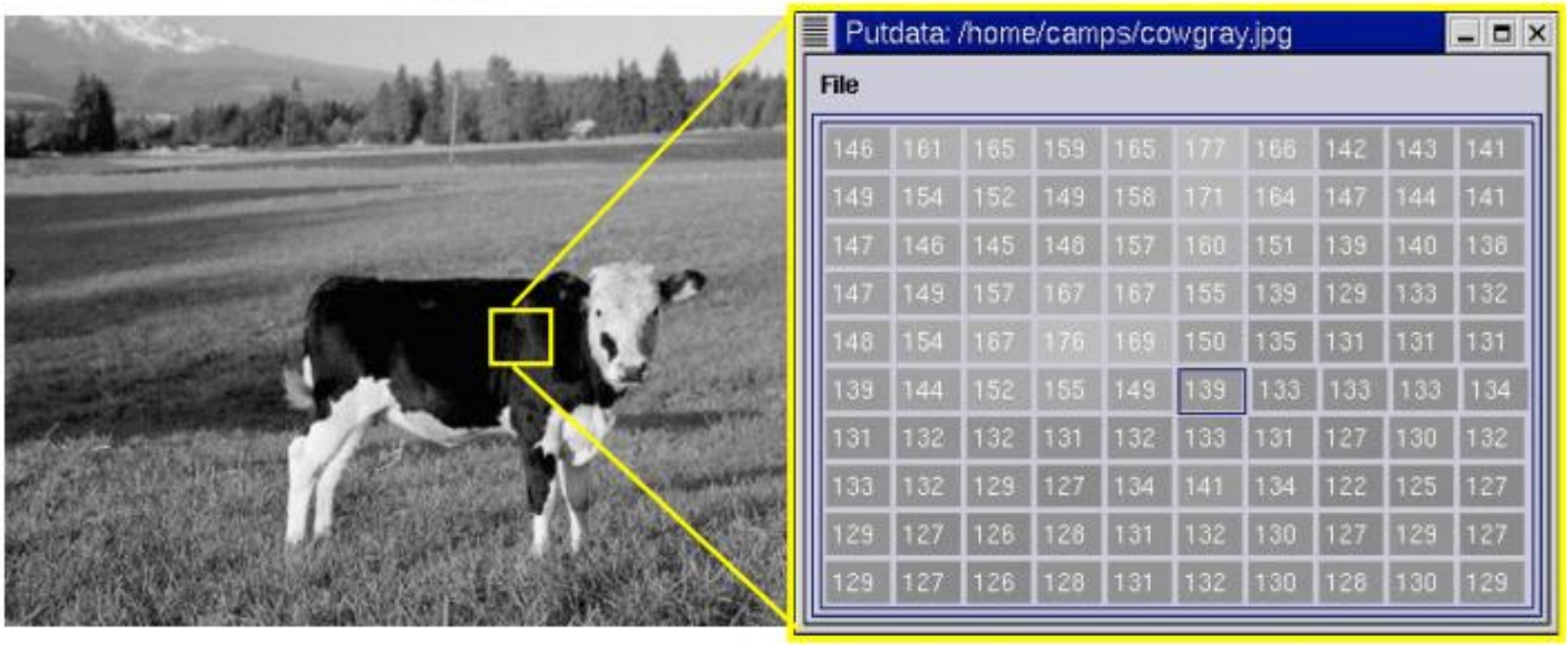


Visualizing Image

Recall two ways of visualizing an image

Intensity pattern

2d array of numbers



We “see it” at this level

Computer works at this level

What is Digital Image Processing?

- Digital image processing focuses on two major tasks
  - Improvement of pictorial information for human interpretation
  - Processing of image data for storage, transmission and representation for autonomous machine perception
- Some argument about where image processing ends and fields such as image analysis and computer vision start

Why do we process images?

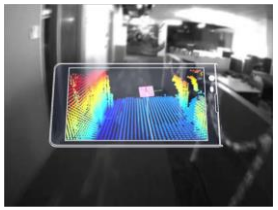
- Acquire an image
  - *Correct aperture and color balance*
  - *Reconstruct image from projections*
- Prepare for display or printing
  - *Adjust image size*
  - *Color mapping, gamma-correction, halftoning*
- Facilitate picture storage and transmission
  - *Efficiently store an image in a digital camera*
  - *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



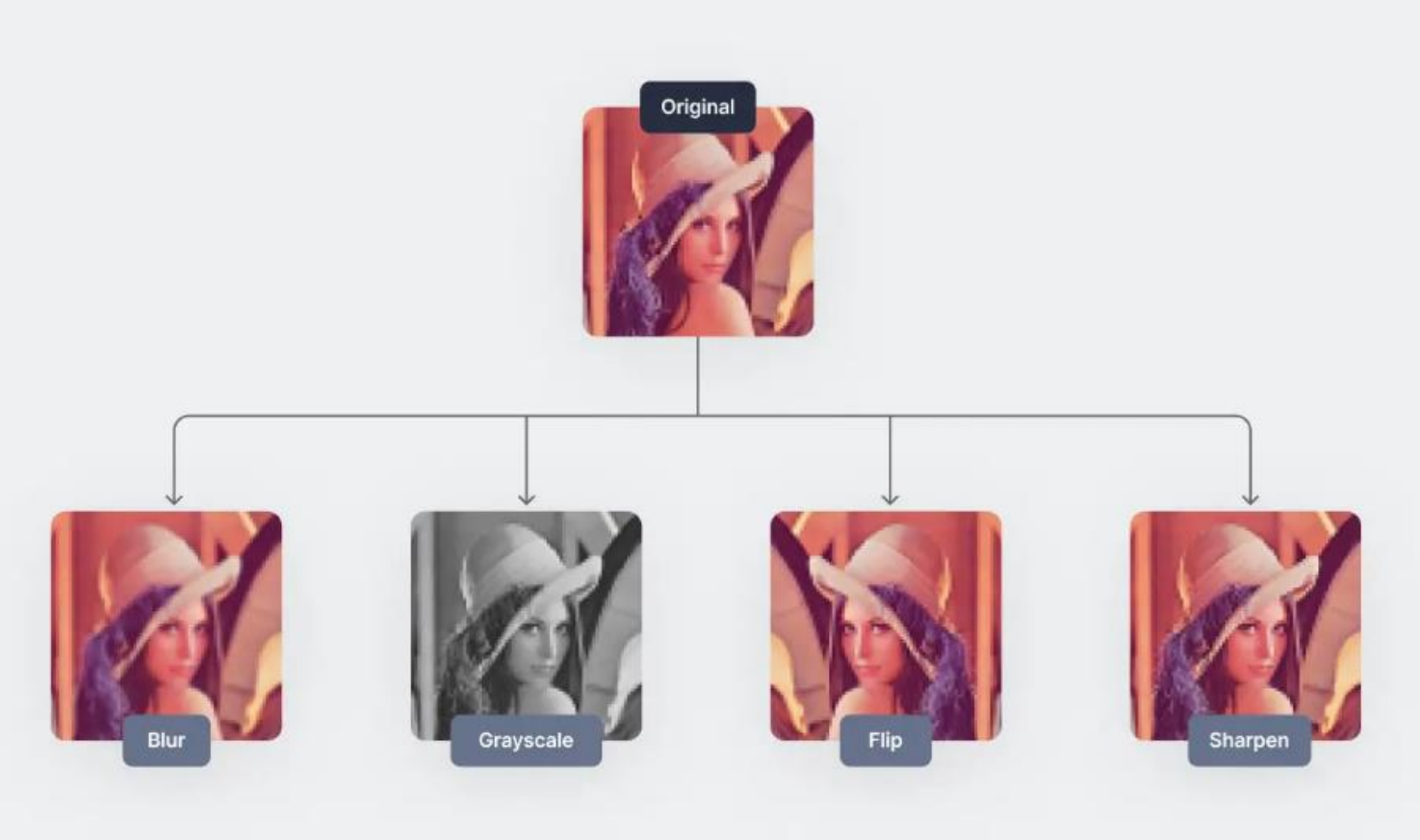






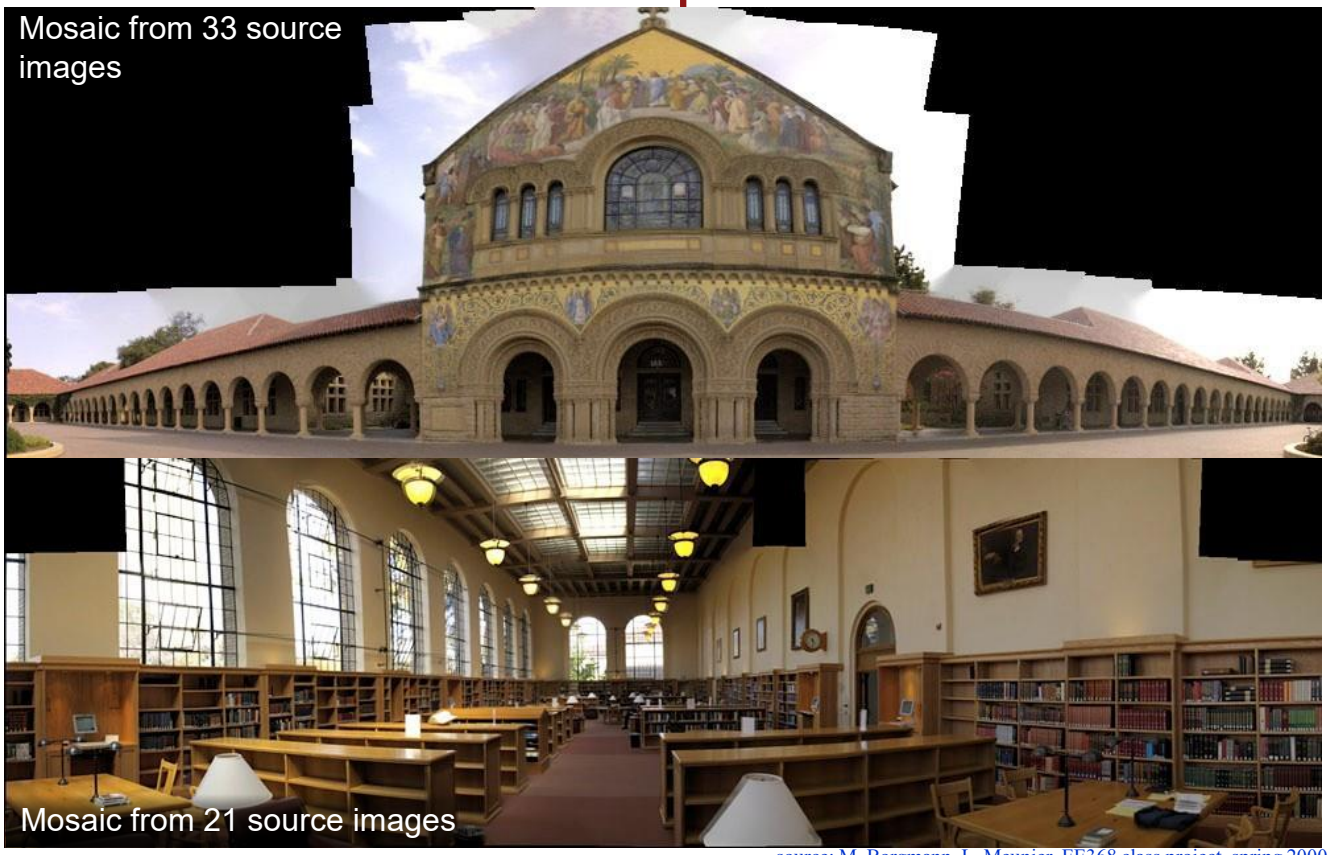



Have you done it?



Examples of typical image processing operations

Image Processing Examples



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

Google Jump

facebook 360

light.co

Image Processing Examples

Face morphing

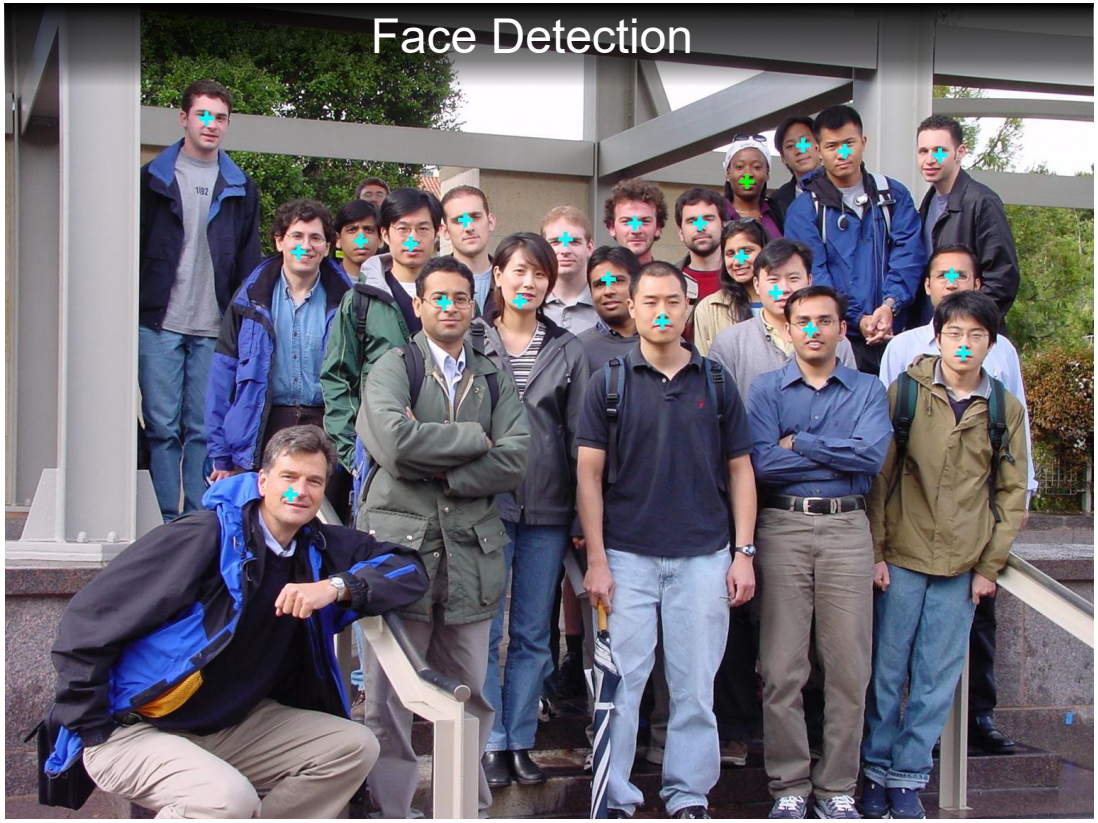
Source: Yi-Wen Liu and Yu-Li Hsueh, EE368 class project, spring 2000.

Image Processing Examples

Face Detection

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

Image Processing Examples

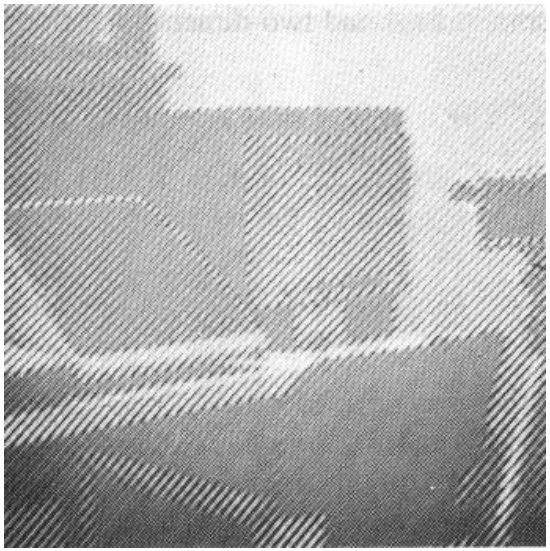


source: Michael Bax, Chunlei Liu, and Ping Li, EE368 class project, spring 2003.

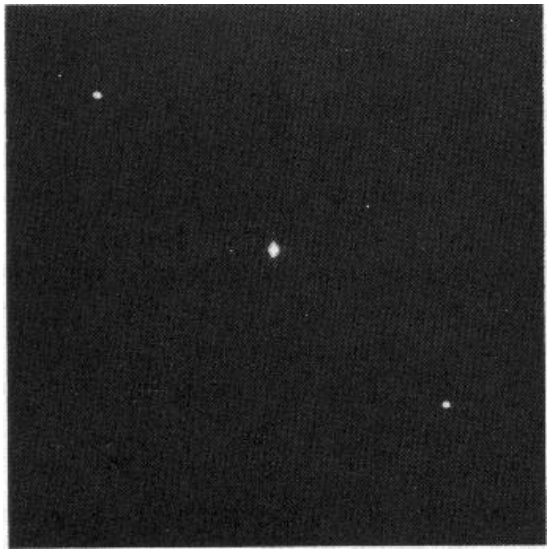
Image Processing Examples

Operations in Frequency Domain

Original Noisy image



Fourier Spectrum



Filtered image

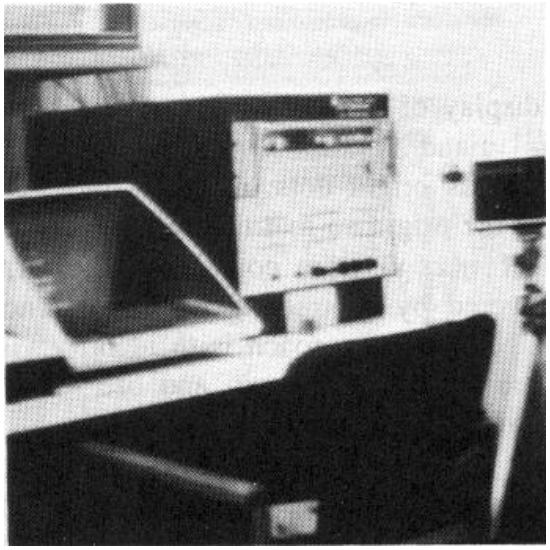
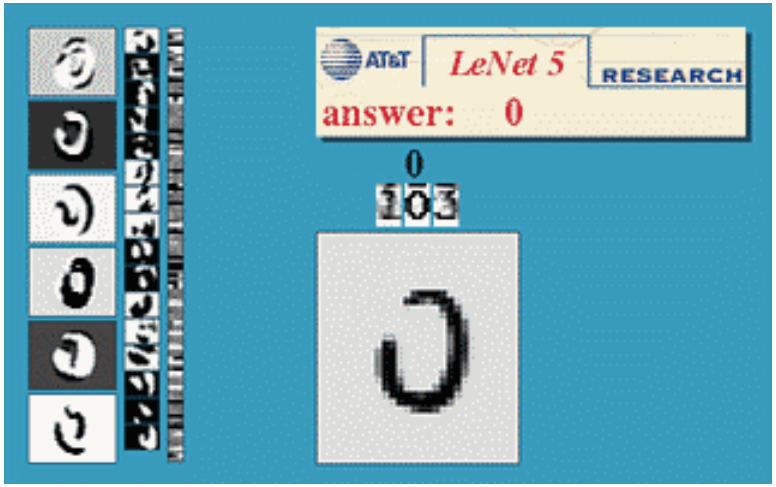


Image Inpainting 1

Optical character recognition (OCR)

Technology to convert scanned docs to text

- If you have a scanner, it probably came with OCR software



Digit recognition, AT&T labs
http://www.research.att.com/~yann/

License plate readers
http://en.wikipedia.org/wiki/Automatic_number_plate_recognition

Login without a password…

Fingerprint scanners on many new laptops, other devices

Face recognition systems now beginning to appear more widely
http://www.sensiblevision.com/

Object recognition (in mobile phones)

This is becoming real:

- Lincoln Microsoft Research
- Point & Find, Nokia

Sports

Sportvision first down line
Nice explanation on www.howstuffworks.com

Smart cars

Slide content courtesy of Amnon Shashua

Mobileye

- Vision systems currently in high-end BMW, GM, Volvo models
- By 2010: 70% of car manufacturers.
- Video demo

Challenges: viewpoint variation

Michelangelo

slide credit: Fei-

Challenges: illumination

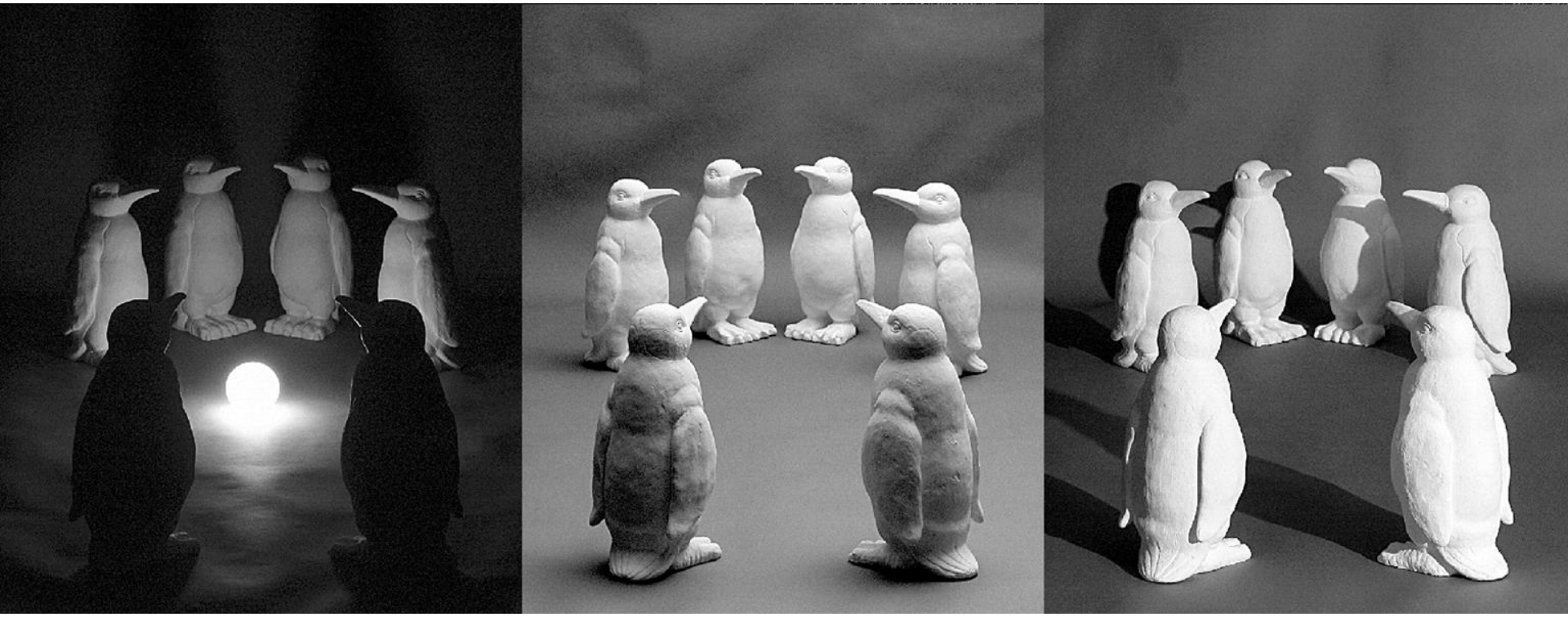
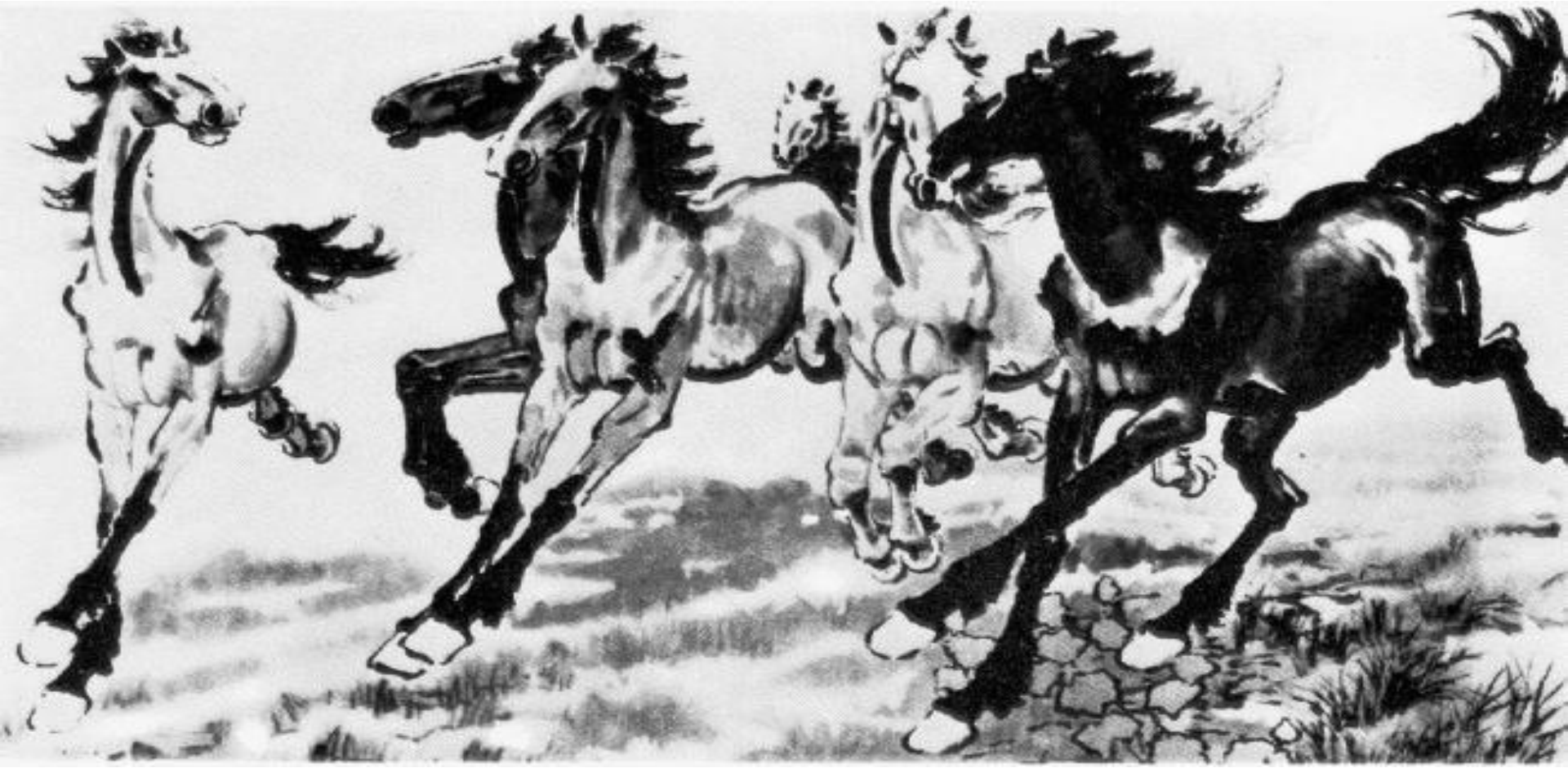


image credit:

Challenges: scale

slide credit: Fei-

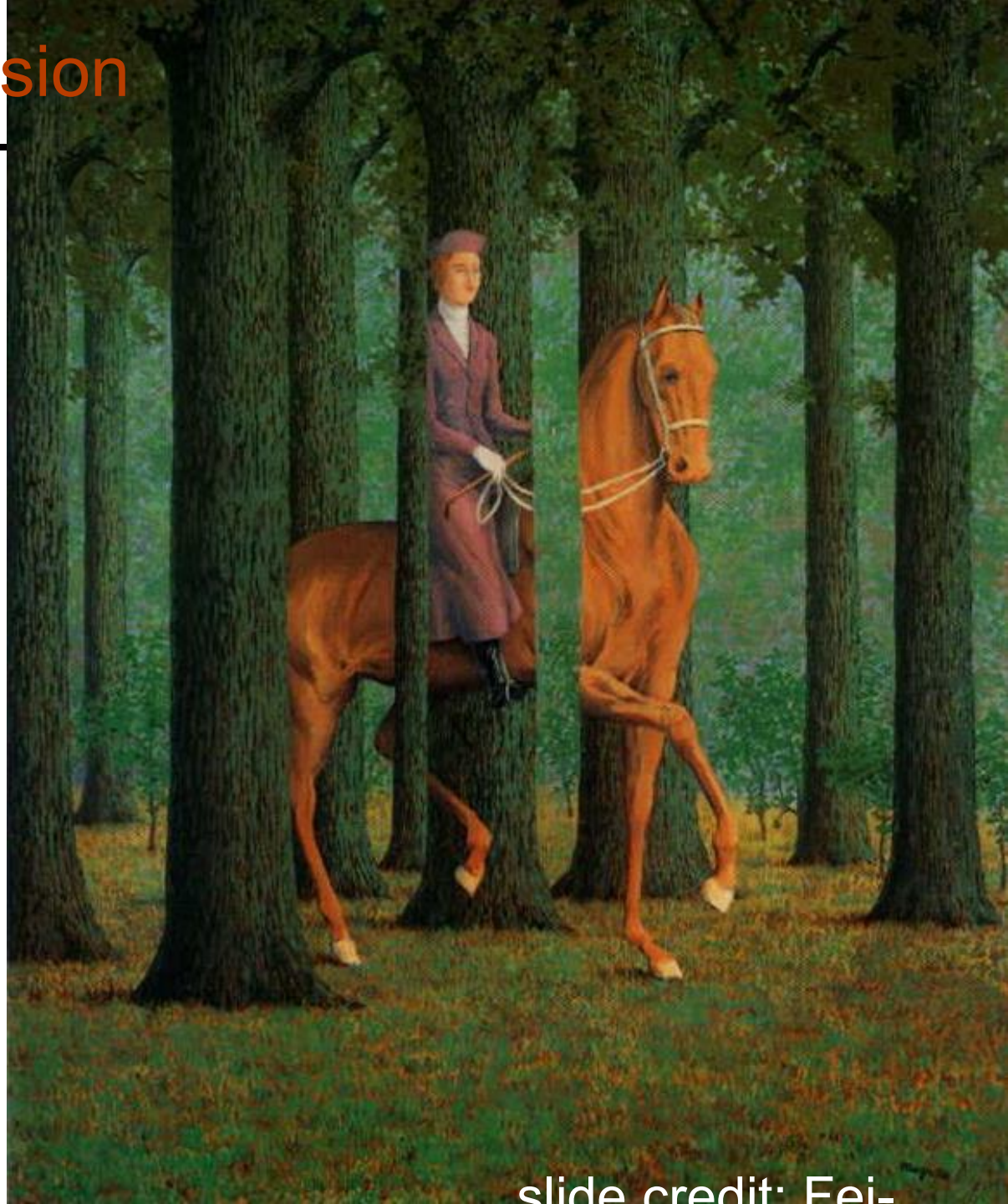
Challenges: deformation



Xu, Beihong
1943

slide credit: Fei-

Challenges: occlusion

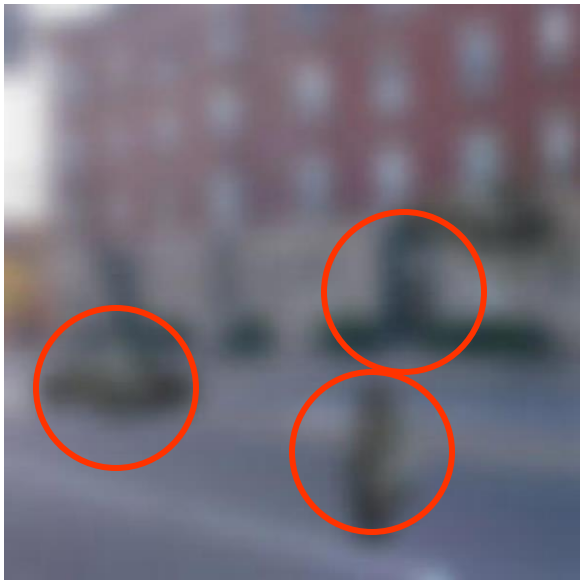


Magritte,

slide credit: Fei-

Challenges: background clutter

Challenges: local ambiguity



slide credit: Fei-

Challenges or opportunities?

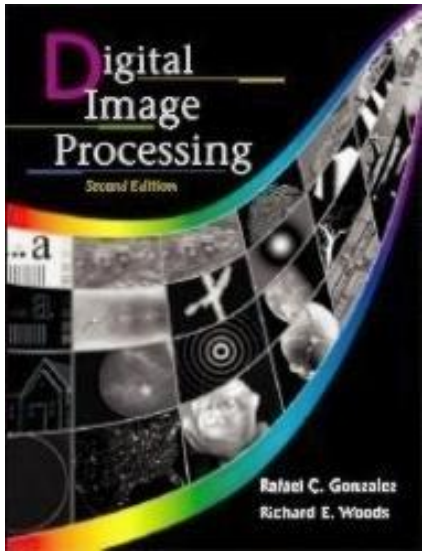
- Images are confusing, but they also reveal the structure of the world through numerous cues
- Our job is to interpret the cues!

Bottom line

- Perception is an inherently ambiguous problem
  - Many different 3D scenes could have given rise to a particular 2D picture

- Possible solutions
  - Bring in more constraints (or more images)
  - Use prior knowledge about the structure of the world
- Need both exact measurements and statistical inference!

Textbook



"Digital Image Processing",

Rafael C. Gonzalez & Richard E. Woods,

Computer Vision: Algorithms and Applications

© 2010 Richard Szeliski, Microsoft Research

http://szeliski.org/Book/

Important links

1. https://bioimagebook.github.io/chapters/1-concepts/1-images_and_pixels/images_and_pixels.html
2. https://www.oreilly.com/library/view/practical-computer-vision/9781449337865/ch04.html

Recommended books:

1. Digital Image Processing- Rafael C.Gonzalez and Richard Eugene Woods

What are you looking for