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# Digital Image Processing (CSE405)

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## Introduction

Md. Ferdous

Lecturer, Dept. of CSE, BSMRSTU

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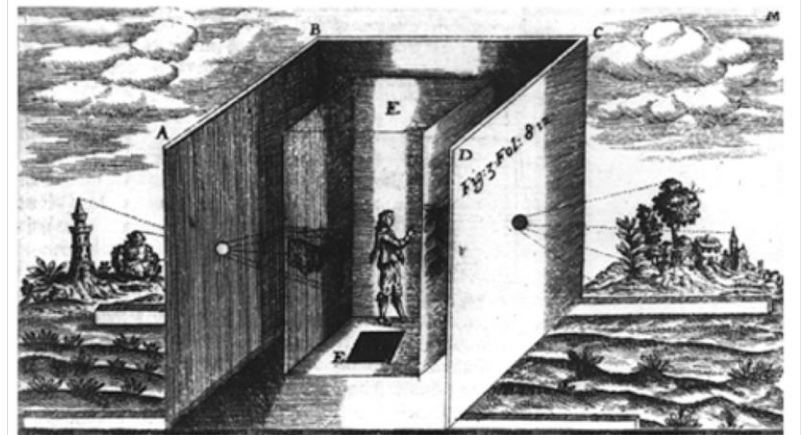
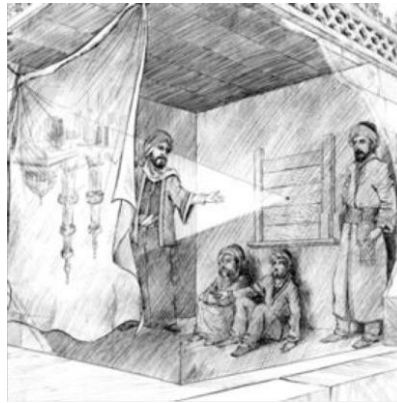
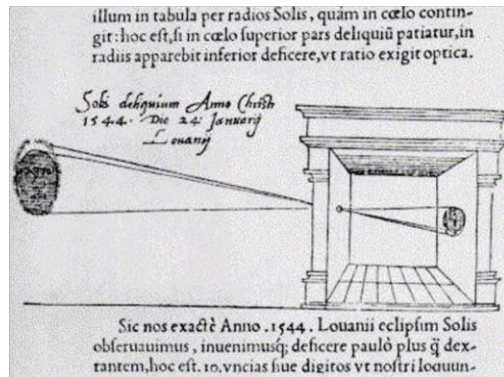
# Imaging



[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  $(x,y)$
- Most images are defined over a rectangle
- Continuous in amplitude and space

# Analog Image

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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?

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We can think of an **image** as a function,  $f$ , from  $\mathbb{R}^2$  to  $\mathbb{R}$ :

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

A color image is just three functions pasted together.

We can write this as a “vector-valued” function:

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

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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”)



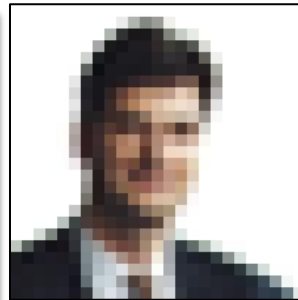
200x200



100x100

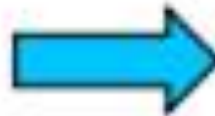
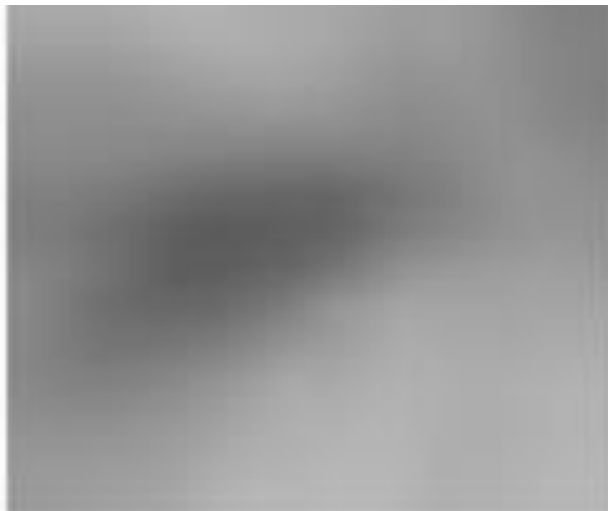


50x50



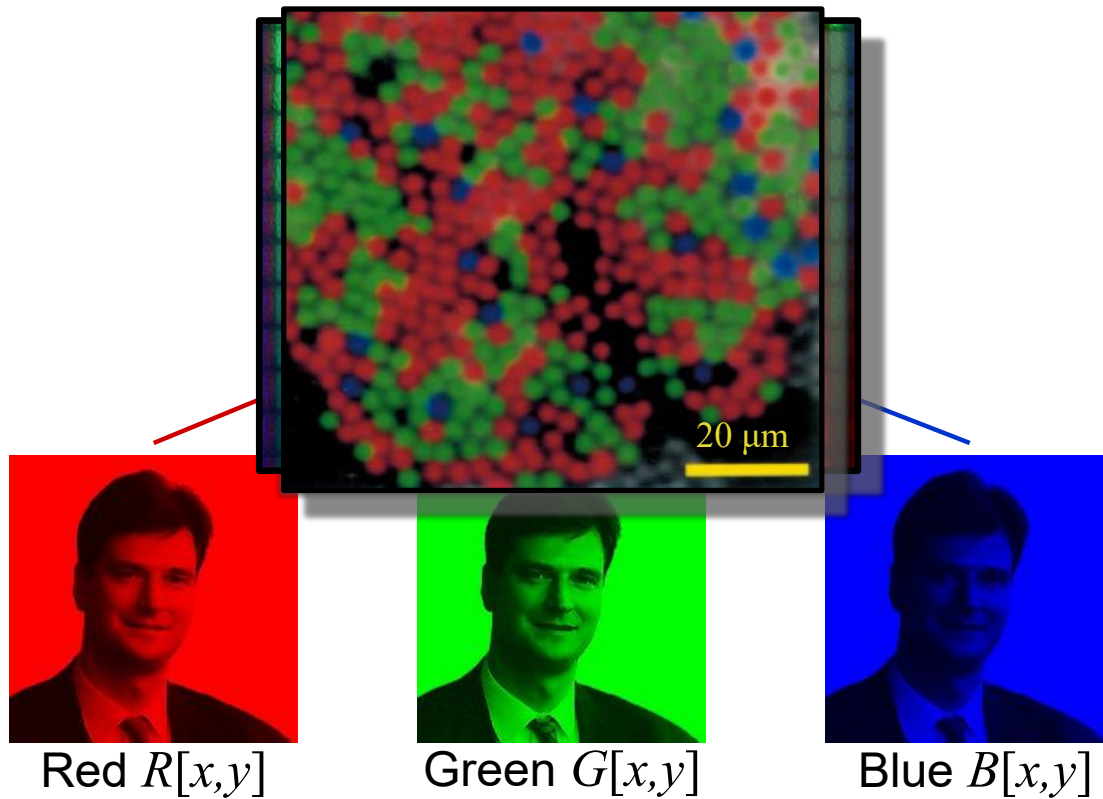
25x25

1. *Journal of Management Studies*, 1997, 34, 1, 1-14.



121 145 136 126 151 149 151 154 156 163 163 163 159 151  
140 140 140 140 140 110 140 140 140 140 140 140 140 140  
160 140 141 140 140 140 141 136 136 136 136 136 136 133  
111 121 129 119 120 124 140 140 140 136 136 136 126 120  
139 111 108 108 104 116 120 160 107 140 144 141 129 123  
117 160 000 000 004 004 160 130 125 136 161 147 147 145  
126 124 136 100 000 000 160 167 116 121 141 147 180 180  
182 182 187 124 113 168 169 160 127 128 138 160 187 186  
189 157 157 158 135 123 120 120 111 136 136 147 150 163  
185 185 183 163 163 166 136 131 135 136 146 140 154 163  
166 160 170 160 166 166 170 173 140 140 147 140 182 186  
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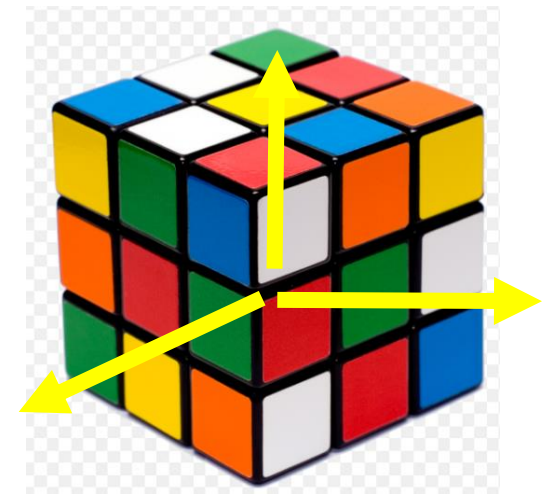
# Color Components



Monochrome image



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



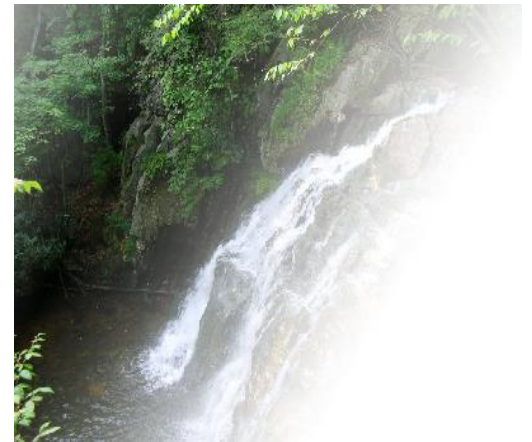


# What is a Digital Image? (cont...)

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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)



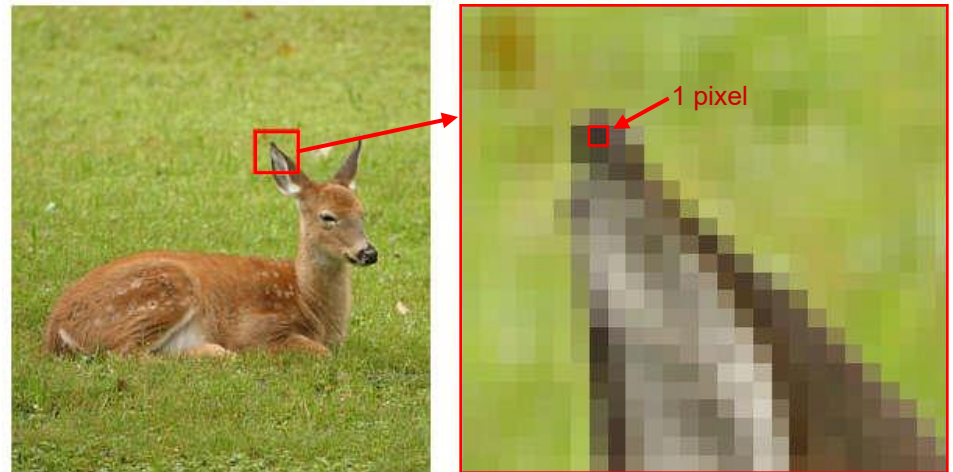
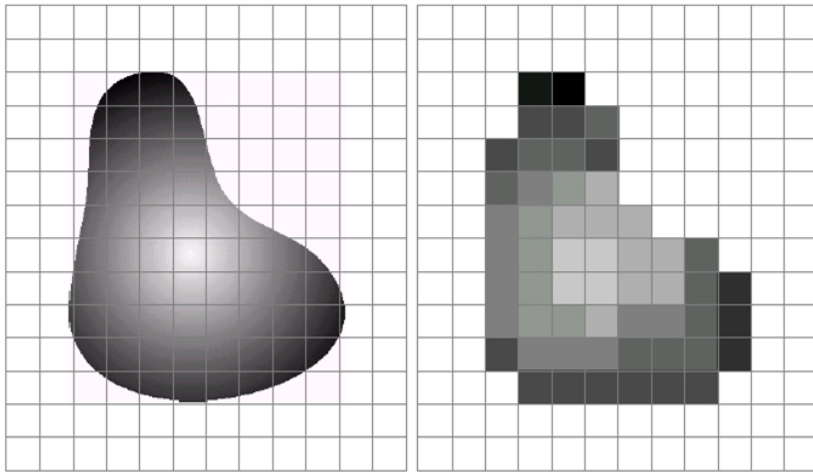
For most of this course we will focus on grey-scale images

# What is a Digital Image? (cont...)

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

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



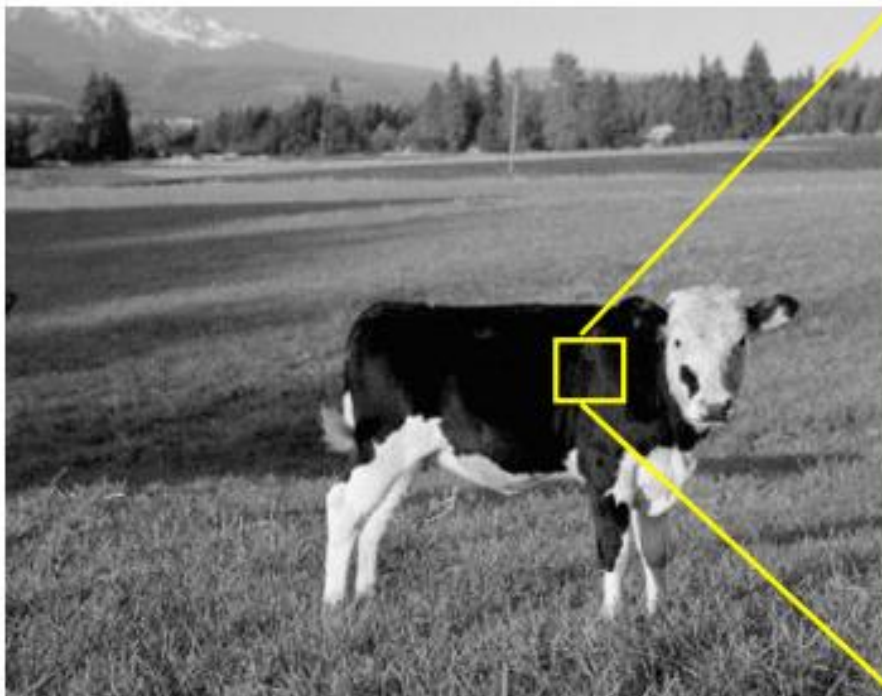
# Visualizing Image

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Recall two ways of visualizing an image

Intensity pattern

2d array of numbers



Putdata: /home/camps/cowgray.jpg									
File									
146	161	165	159	165	177	166	142	143	141
149	154	152	149	158	171	164	147	144	141
147	146	145	148	157	160	151	139	140	138
147	149	157	167	167	155	139	129	133	132
148	154	167	176	169	150	135	131	131	131
139	144	152	155	149	139	133	133	133	134
131	132	132	131	132	133	131	127	130	132
133	132	129	127	134	141	134	122	125	127
129	127	126	128	131	132	130	127	129	127
129	127	126	128	131	132	130	128	130	129

We “see it” at this level

Computer works at this level

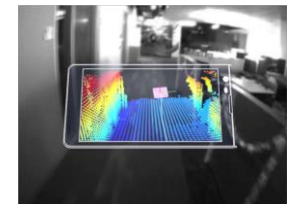
# What is Digital Image Processing?

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- 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?

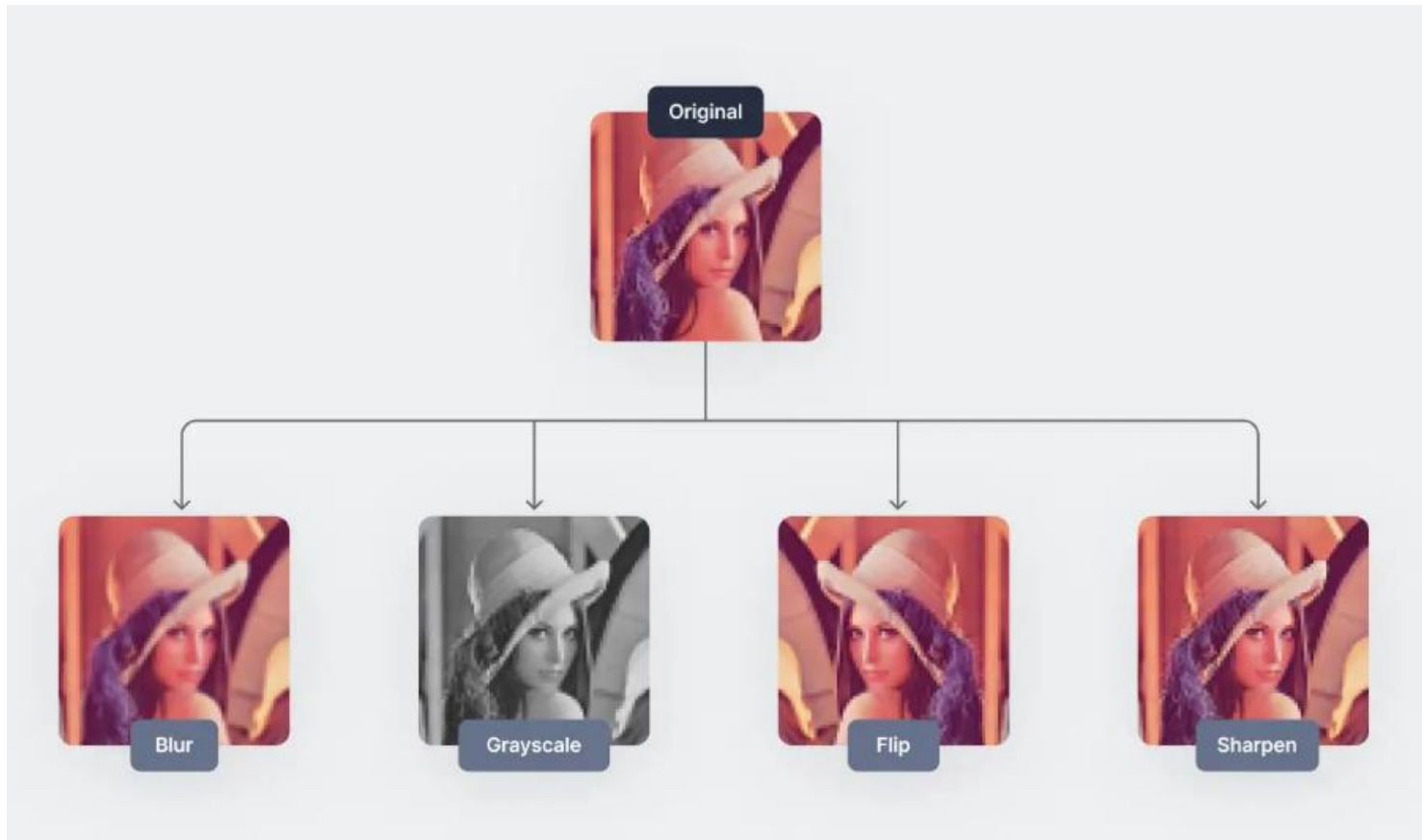
- Acquire an image
  - *Correct aperture and color balance*
  - *Reconstruct image from projections*
- Prepare for display or printing
  - *Adjust image size*
  - *Color mapping, gamma-correction, halftoning*
- Facilitate picture storage and transmission
  - *Efficiently store an image in a digital camera*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

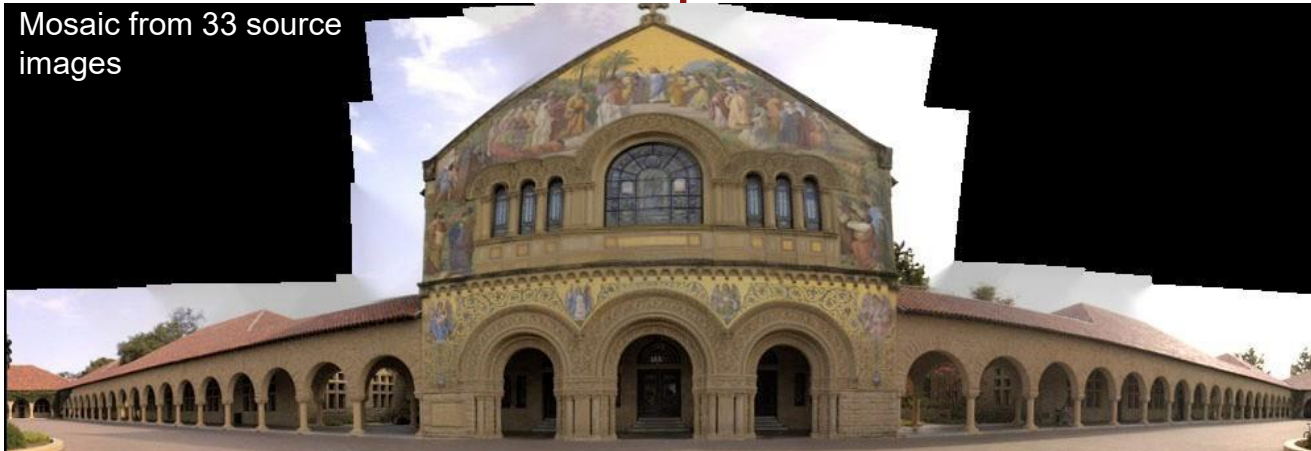
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Examples of typical image processing operations

# Image Processing Examples

Mosaic from 33 source  
images



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



Google Jump



facebook 360



light.co

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# Image Processing Examples

## Face morphing



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

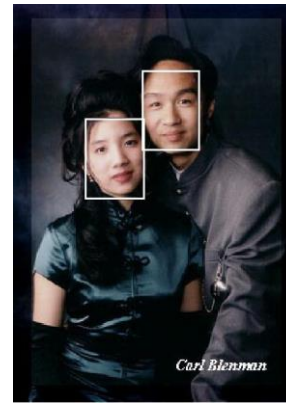
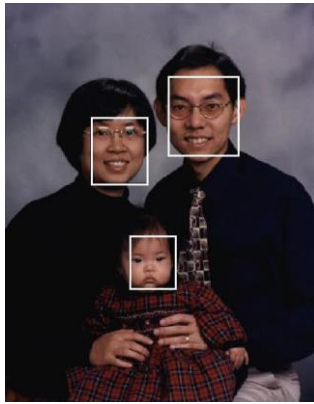
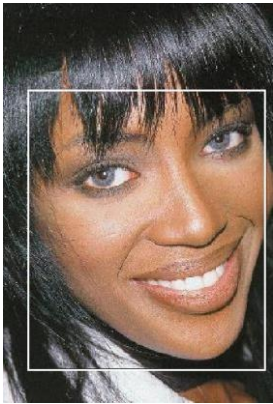




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# Image Processing Examples

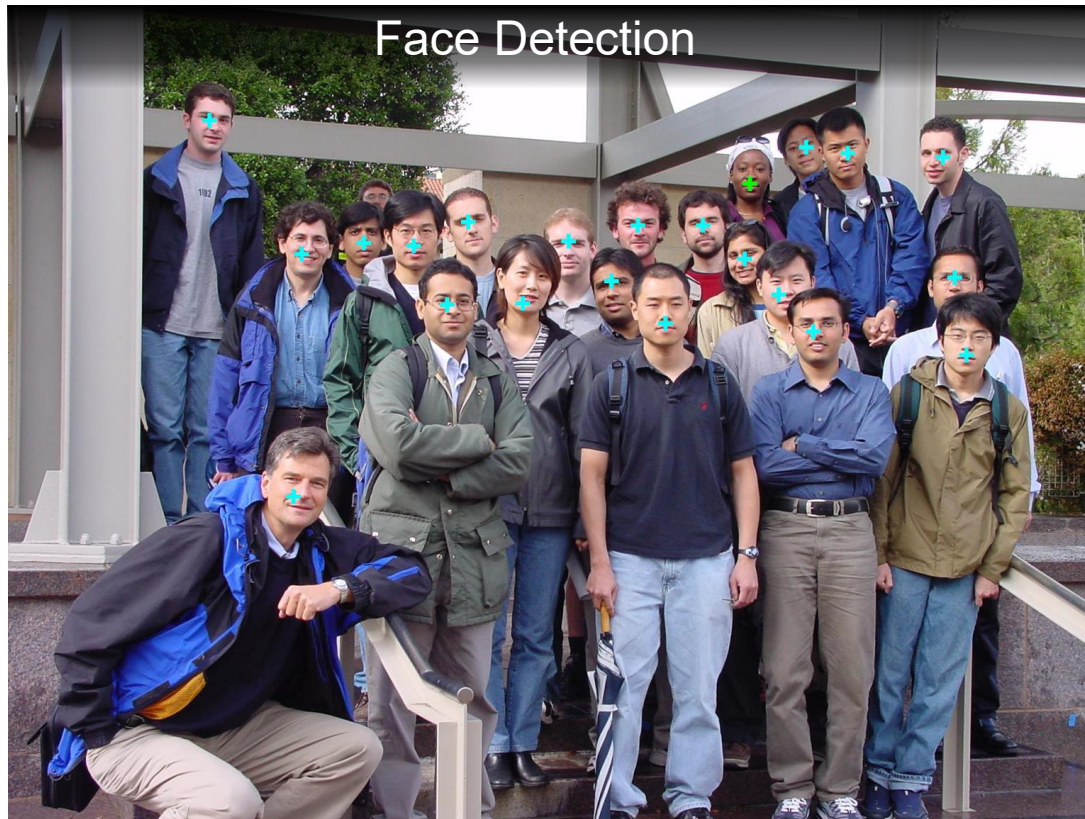
## Face Detection



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

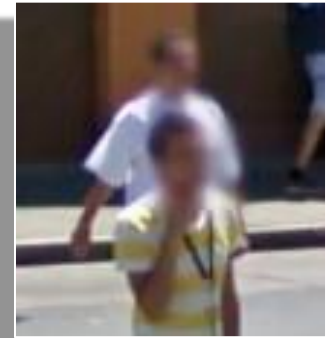
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# Image Processing Examples



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

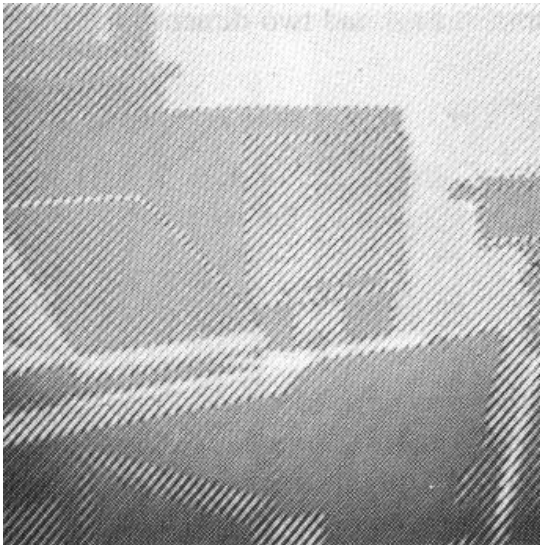
# Image Processing Examples



# Operations in Frequency Domain

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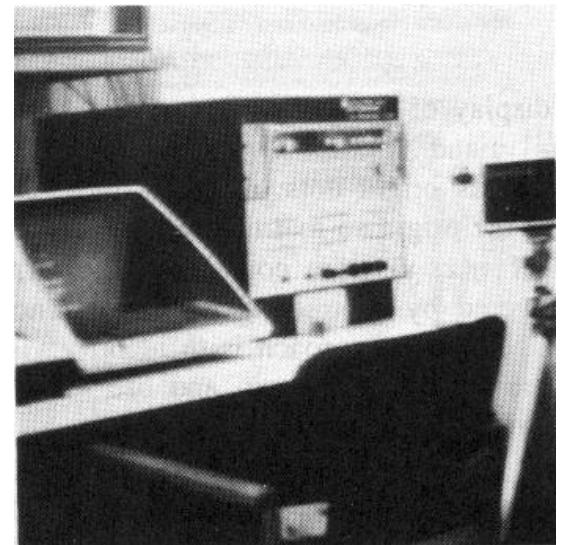
Original Noisy image



Fourier Spectrum



Filtered image





# Image Inpainting 1

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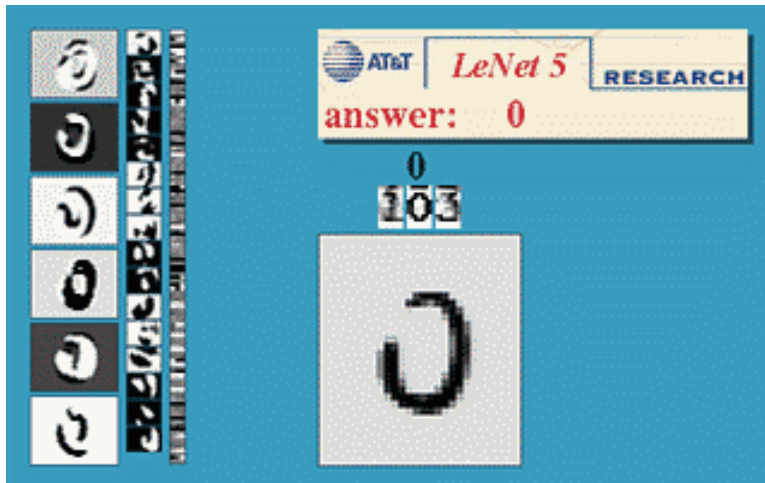


# Optical character recognition (OCR)

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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](http://en.wikipedia.org/wiki/Automatic_number_plate_recognition)

# Login without a password...

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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

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*Sportvision* first down line  
Nice [explanation](http://www.howstuffworks.com) on [www.howstuffworks.com](http://www.howstuffworks.com)

# Smart cars

Slide content courtesy of Amnon Shashua

[▶▶ manufacturer products](#)[consumer products ◀◀](#)

## Our Vision. Your Safety.



rear looking camera

forward looking camera

side looking camera

### EyeQ Vision on a Chip

[▶ read more](#)

### Vision Applications



Road, Vehicle, Pedestrian Protection and more

[▶ read more](#)

### AWS Advance Warning System

[▶ read more](#)

### News

- ▶ [Mobileye Advanced Technologies Power Volvo Cars World First Collision Warning With Auto Brake System](#)
- ▶ [Volvo: New Collision Warning with Auto Brake Helps Prevent Rear-end](#)

[▶ all news](#)

### Events

- ▶ [Mobileye at Equip Auto, Paris, France](#)
- ▶ [Mobileye at SEMA, Las Vegas, NV](#)

[▶ read more](#)

## Mobileye

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

# Challenges: viewpoint variation

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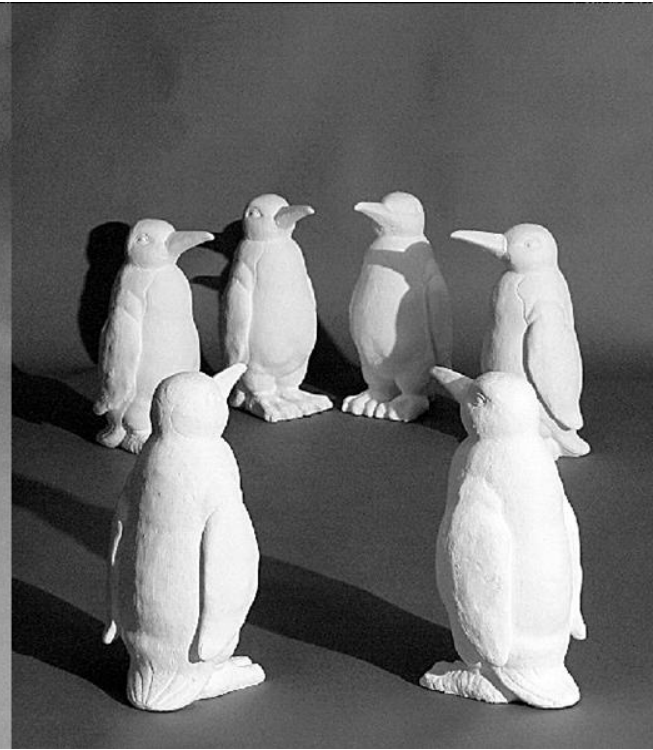
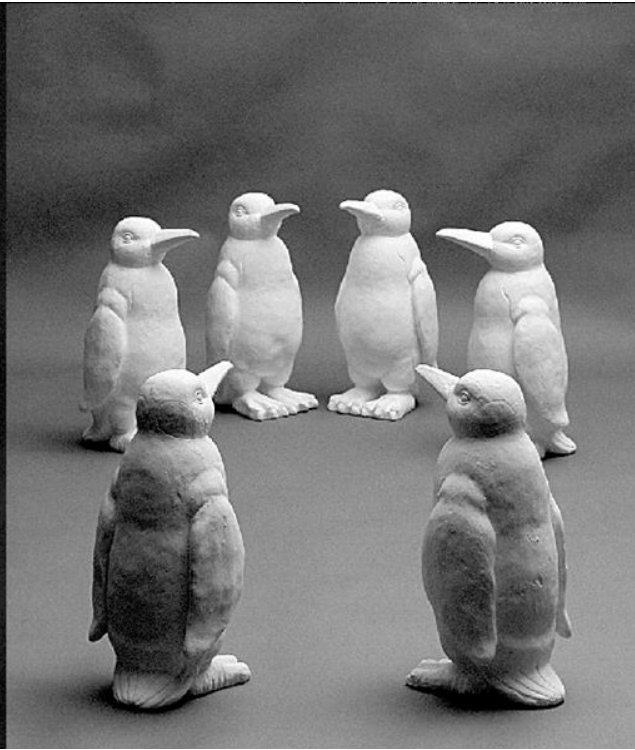
Michelangelo

slide credit: Fei-



# Challenges: illumination

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# Challenges: scale

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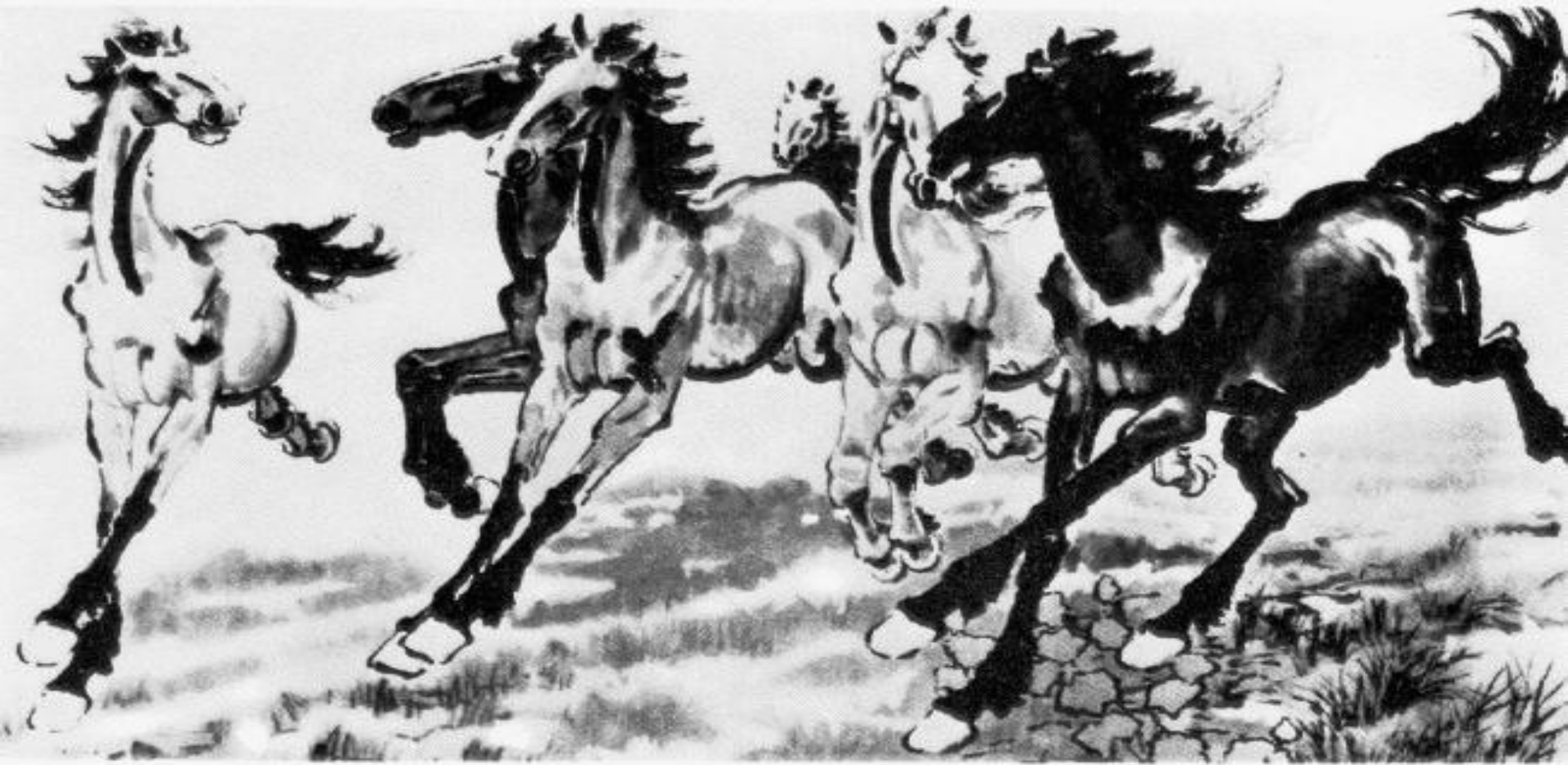
and small things  
from Apple.  
(Actual size)



slide credit: Fei-

# Challenges: deformation

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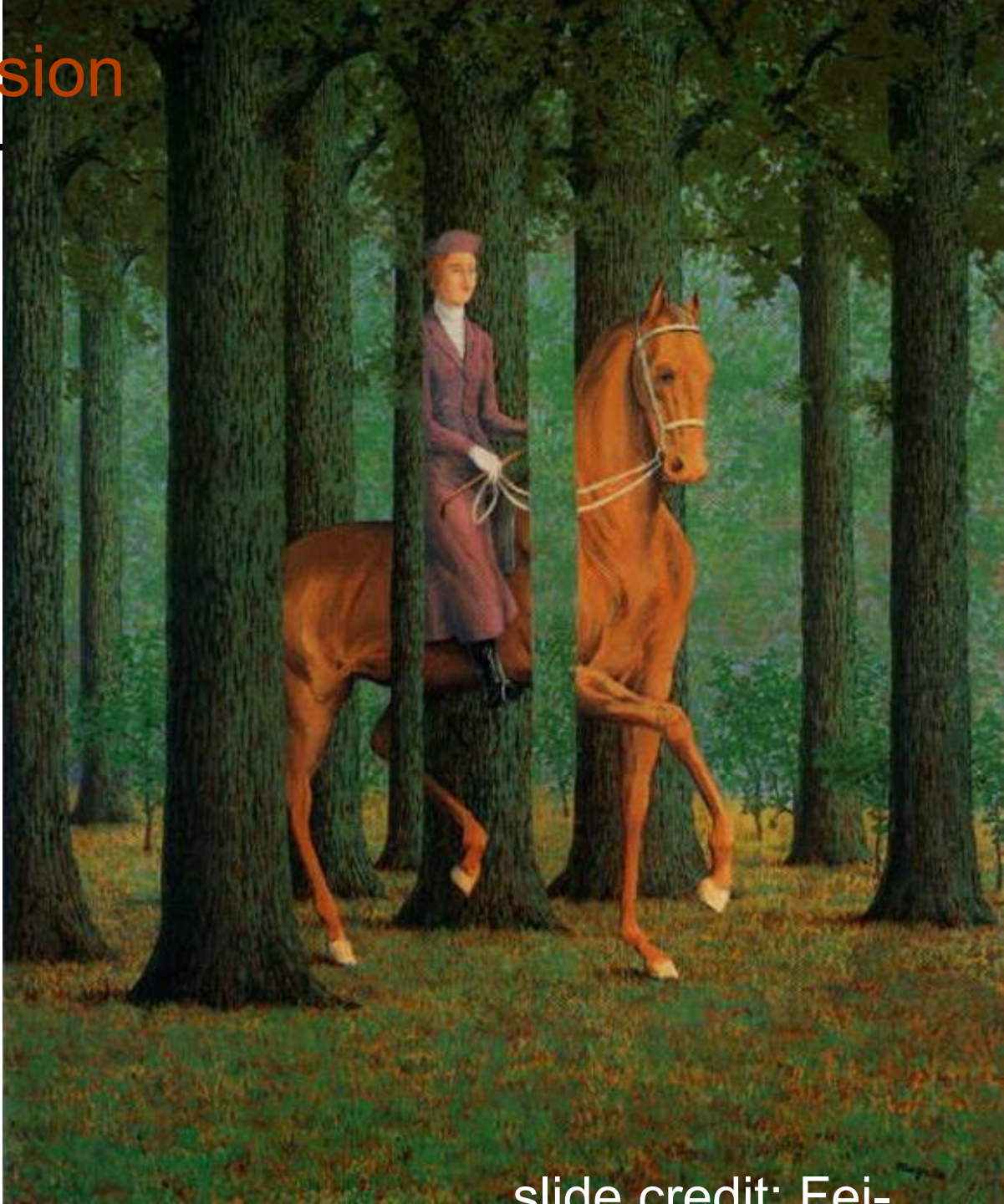
Xu, Beihong  
1943

slide credit: Fei-



# Challenges: occlusion

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Magritte,

slide credit: Fei-



# Challenges: background clutter

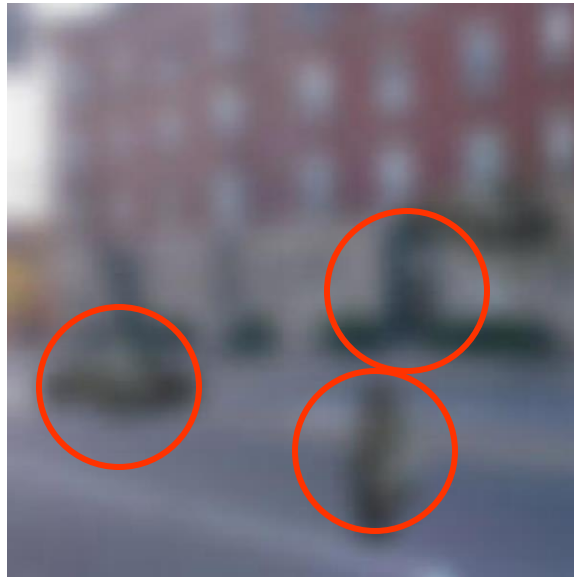
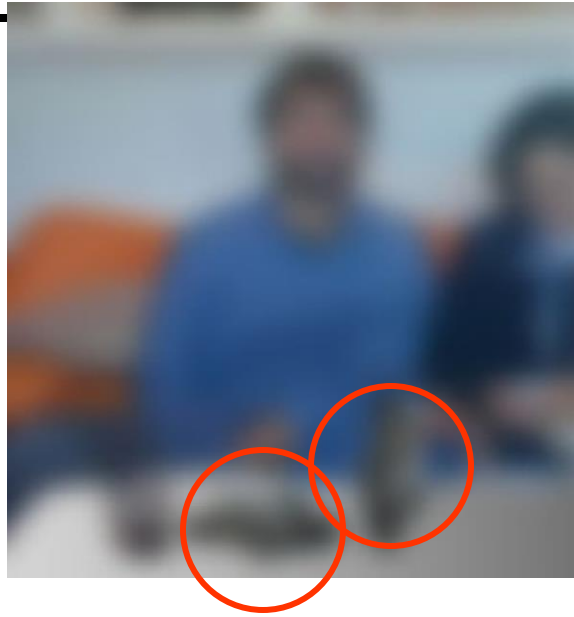


Emperor shrimp and commensal crab on a sea cucumber in Fiji  
Photograph by Tim Laman



# Challenges: local ambiguity

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slide credit: Fei-

# Challenges or opportunities?

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



# Bottom line

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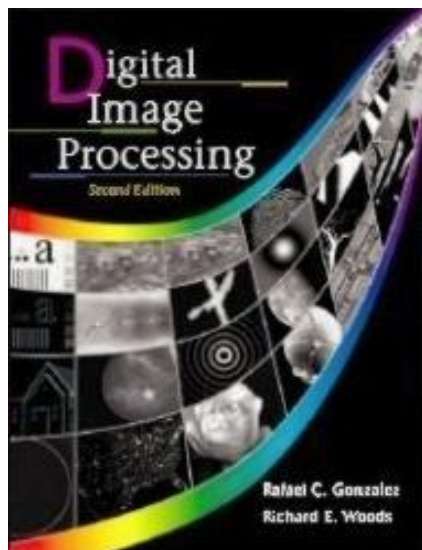
- Perception is an inherently ambiguous problem
  - Many different 3D scenes could have given rise to a particular 2D picture



- 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

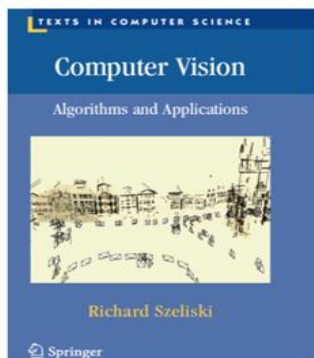
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“Digital Image Processing”,  
Rafael C. Gonzalez & Richard E. Woods,

## Computer Vision: Algorithms and Applications

© 2010 [Richard Szeliski](#), Microsoft Research



<http://szeliski.org/Book/>

# Important links

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1. [https://bioimagebook.github.io/chapters/1-concepts/1-images\\_and\\_pixels/images\\_and\\_pixels.html](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

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