211651 DIGITAL IMAGE PROCESSING

Punnarai Siricharoen, Ph.D.

LECTURE 01
INTRODUCTION

Punnarai Siricharoen, Ph.D.

LECTURE 01 - OBJECTIVES

1. To introduce Digital Imaging and Image processing overview
2. To describe the example fields areas of digital imaging and applications
3. To use python for read/write/show an image

LECTURE 01 - OUTLINE

1. About this course (Syllabus)
2. Introduce Digital Imaging, applications and Challenges
3. Principal areas of digital imaging and applications
4. Python Exercises for read/write/show an image

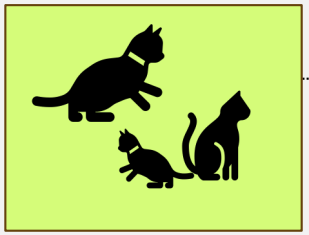
ABOUT THE COURSE

COMMUNICATIONS

- Onsite Lecture (Online sometimes) at 17-02 (Sec1), 18-16 (Sec5)
- MCV course number : 2110651
- password : 2110651 for course materials
- Discord : https://discord.gg/Wg3nhjCh

WHAT **TOPICS / IDEAS** ARE YOU WANT TO LEARN IN THIS CLASS?

IMAGE PROCESSING / DIGITAL IMAGING



cat

Image Generation

Caption: There are three cats in the image.

Image Captioning

How many cat in the image?

Visual Question Answering

Storage

Compression

Printing/display

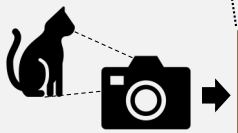


Image Acquisition

Image Improvement

- Enhancement
- Superresolution
- Restoration

Image Understanding

- Feature Extraction
- Object detection
- Object Recognition
- Image Segmentation
- Interpretation/Analysis

Challenges?????

Medical imaging

Image from Factory

Entertainment

Not to mention image processing in terms of computer graphics which is another topic.

TENTATIVE SCHEDULE (2110651)

Week / Date Sec 1,5	Topic	Assignment HW (2 weeks due)
1 –7,9/8	Introduction to image processing and software preparation, Examples of fields using digital image processing	
2 – 14,16/8	Image Acquisition / Sampling and Quantization / Arithmetic Operations	
3 – 21,23/8	Histogram and Spatial Filtering	HW #1 Spatial Domain
4 – 28,30/8	Frequency Domain & Filtering in FD	
5 – 4,6/9	Wavelet and Multiresolution Processing	
6 – 11,13/9	Image Restoration	HW #2 Frequency & Research paper
7- 18,20/9	Image Compression	
8	Midterm exam (1 A4 paper, writing) Sat 27/9/2568 9-12	
9- 2,4/10	Fundamental Image Segmentation I	In-class discussion
10 – 9,11/10	Research discussion / Morphology Feature Extraction and Analysis	**Project Assignment**
11-16,18/10	Object Recognition (traditional /modern)	
12-25/10	Object Recognition II (23 Oct Holiday, watch video from 25 Oct) - **Hybrid**	HW #3 Segmentation + Image Augmentation
13-30,1/11	Image Segmentation II	Paper review presentation for project
14-6,8/11	Object Detection : Paper discussion & applications	
15-13,15/11	Image Generative Adversarial and other Imaging Applications – discussion (read and discuss)	
16-22/11	Invited Speaker (20 Nov no class, join a talk on 22 Nov)	
17	- **Final exam** Sat 6/12/2568 9-12 - **Project Presentation** - Thu 11/12/2568 18 – 21	

IMPORTANT DATES (2110651)

- Midterm – SAT 27/9/2568 @9-12
- Final exam – SAT 6/12/2568 @9-12
- Project presentation – SAT 11/12/2568 @18 – 21

You cannot take the exam outside the predefined date & time!

TEACHING METHODS

- Lecture (+ in-class Lab) : Wednesday 13:00 – 16:00

- Research discussion
- Projects

2110651 DIGITAL IMAGING

- **Textbook:**

  - Rafael C. Gonzalez and Richard E. Woods, Digital Image Processing, Addison-Wesley

- **Grading Policy**
  - In-class Exercises: **5% (0.5 each class + bonus)**
  - Homework = **10%**
  - Project + presentation : **25%**
  - Midterm Exam : **30%**
  - Final Exam : **30%**

Score	Grade
>= 85	A
>= 75	B+
>= 70	B
>= 65	C+
>= 60	C
>= 55	D+
>= 50	D
< 50	F

CONTACT ME

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Email: punnarai.s@chula.ac.th

TAs:

TA Print

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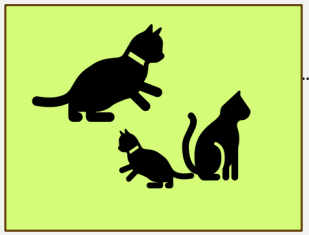
WHAT IS DIGITAL IMAGING / IMAGE PROCESSING FOR YOU?

Write a description / draw a picture
in a paper

IMAGE PROCESSING / DIGITAL IMAGING



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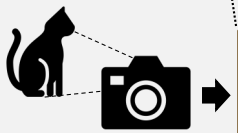

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DIGITAL IMAGE

170	172	171	174	178	183	185	183	182	181
170	172	171	173	178	182	184	182	182	181
170	171	171	172	177	182	184	182	182	182
170	170	171	172	176	182	183	182	183	182
170	169	171	171	175	182	182	183	183	182
169	167	171	170	175	183	182	183	183	182
168	166	170	169	174	183	181	183	183	182
168	165	170	168	173	183	181	183	182	182
171	168	169	172	176	180	181	184	181	179
168	170	172	170	174	182	183	181	181	179

What we see

What a computer sees

An image is denoted by two-dimensional function of the form: $f(x, y)$

f – amplitude at the spatial dimension (x,y)

DIGITAL IMAGE

What we see

183	185	184	185	189	193	193	191	189	188
183	185	184	184	189	192	192	190	189	188
183	184	184	183	188	192	192	190	189	189
183	183	184	183	187	192	191	190	190	189
183	182	184	182	186	192	190	191	190	189
182	180	184	181	186	193	190	191	190	189
181	179	183	180	185	193	189	191	190	189
181	178	183	179	184	193	189	191	189	189
184	181	182	183	187	190	189	192	188	186
181	183	185	181	185	192	191	189	188	186

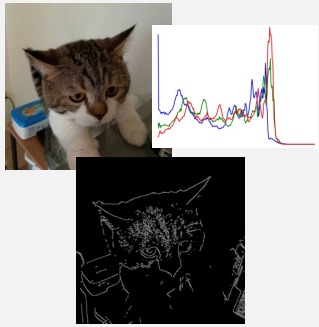
What a computer sees

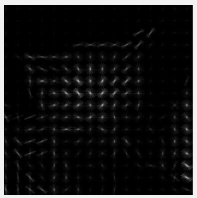
EVOLUTION

1980s

Rule-based

Edge, Threshold, Template





HOG

2000s

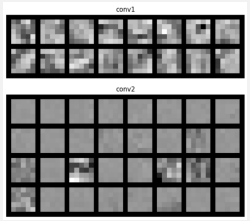
Feature-based

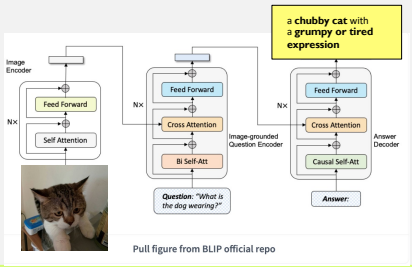
Haar, HOG, SIFT

2012+

Deep Learning

CNN, ResNet, YOLO





Pull figure from BLIP official repo

2020+

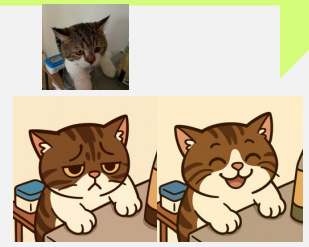
Multimodal / Vision + Language

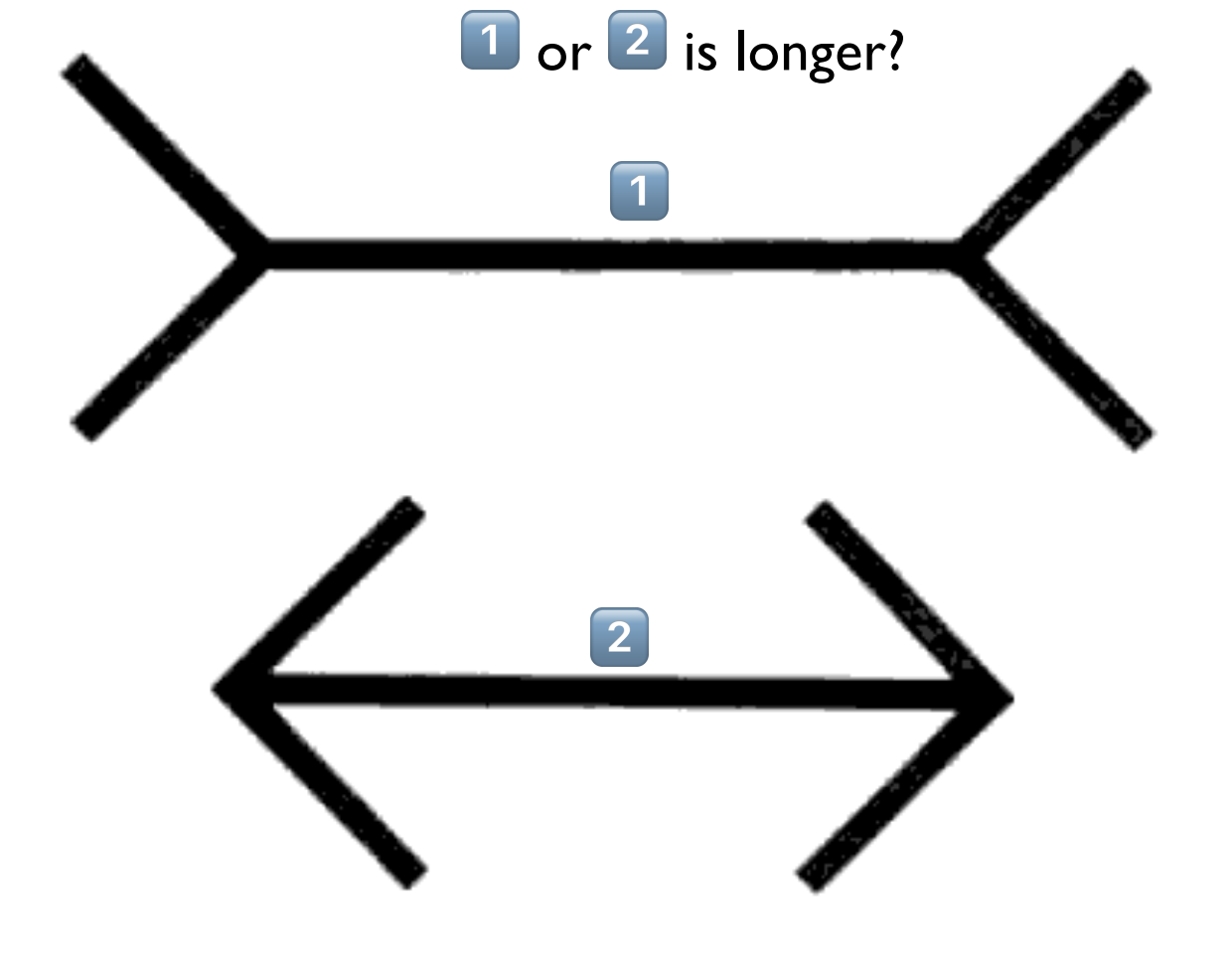
CLIP, BLIP, Flamingo, GPT-4o

2023+

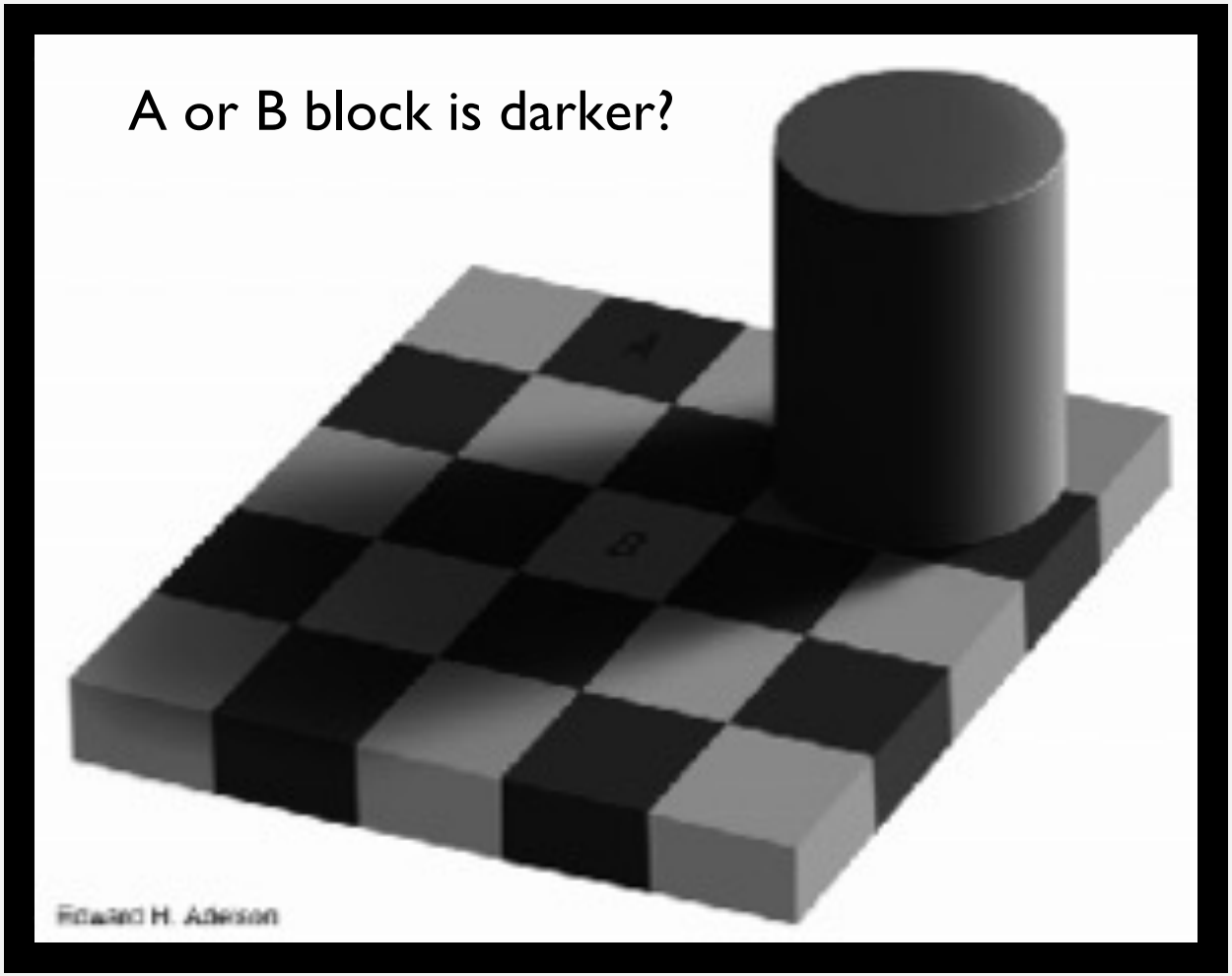
Vision + Generation + Action

DALL·E, SAM, Robotics with vision





Müller-Lyer illusion



Checker Shadow Illusion by Edward Adelson

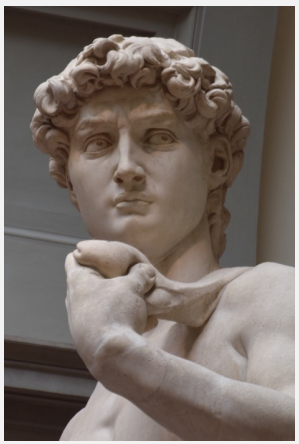
How many red X?

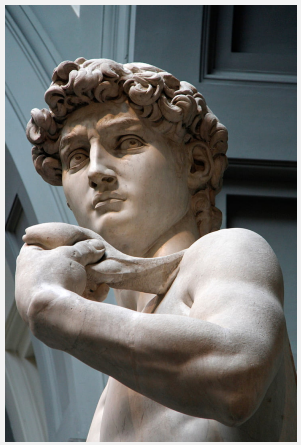
How many red X?

WHAT ARE CHALLENGES FOR COMPUTER TO SEE THINGS???

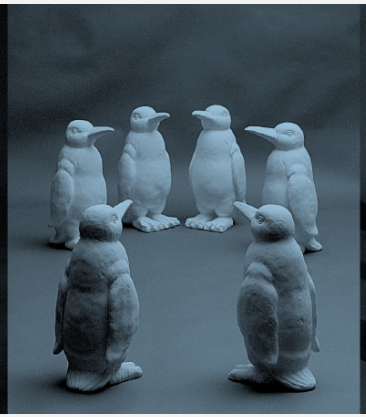
CHALLENGES

- Point of View





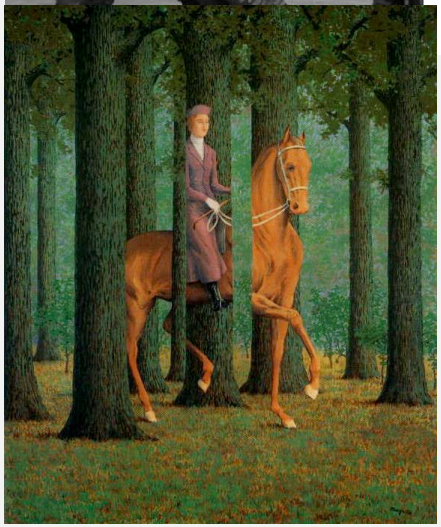
- Illumination

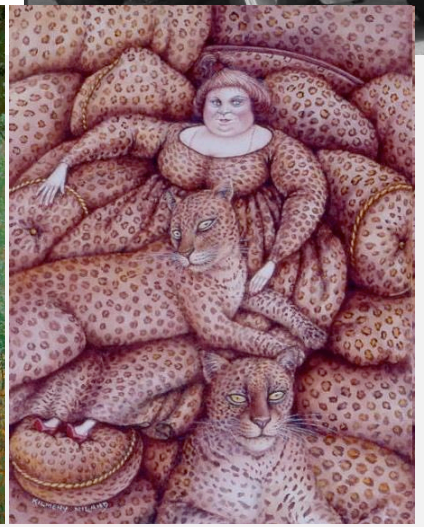




Wikipedia, Academic Gallery, Pinterest
slide credit: Fei-Fei, Fergus & Torralba

CHALLENGES

- Scale
- Deformation
- Occlusion
- Background Clutter

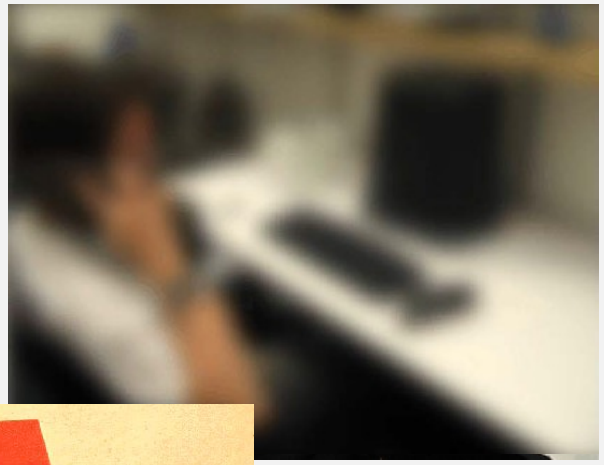




slide credit: Fei-Fei, Fergus & Torralba

CHALLENGES

- Ambiguity
- Motion
- In-class Variations

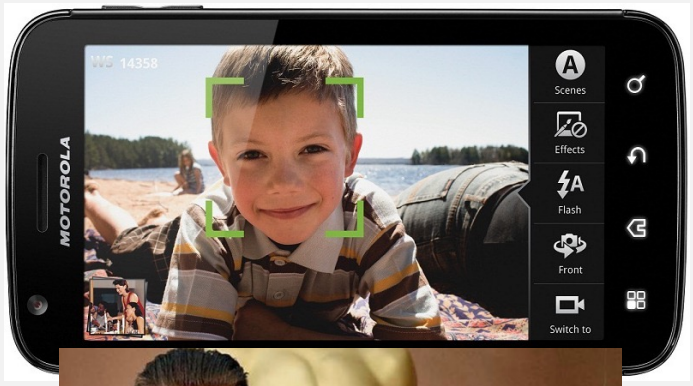


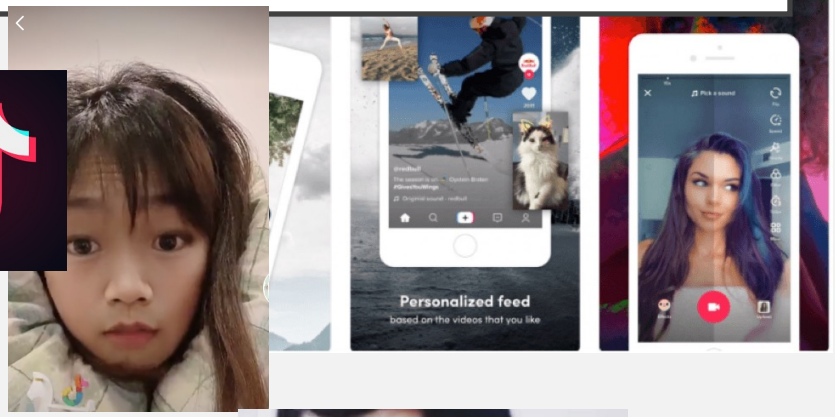
slide credit: Fei-Fei, Fergus & Torralba

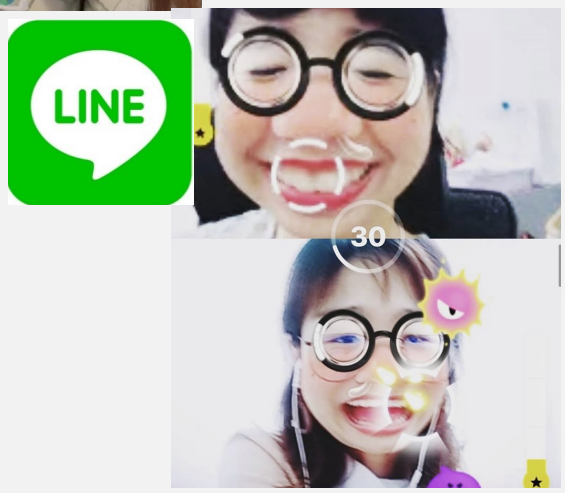
HAVE YOU EXPERIENCED IMAGE PROCESSING IN YOUR DAILY LIFE?

FACE DETECTION

- Imaging applications in Daily Life
  - Face Detection

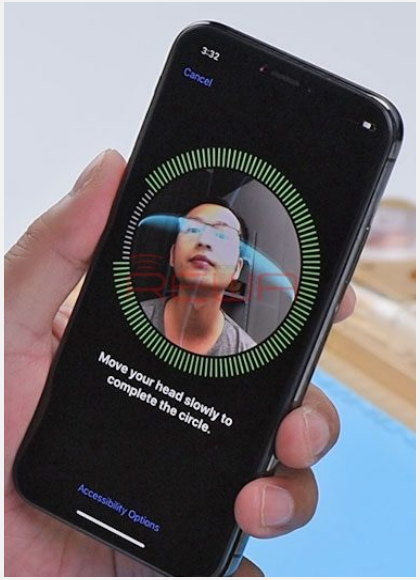






BIOMETRICS APPLICATIONS

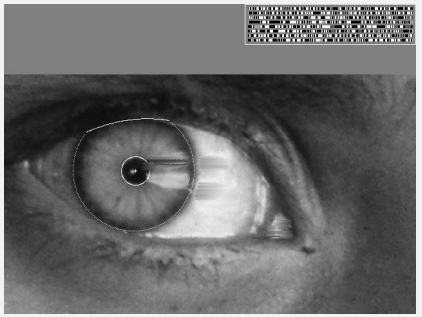
- Imaging applications in Daily Life
  - Biometrics

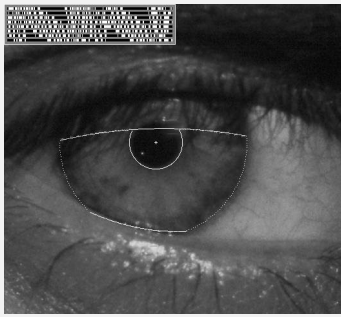


https://blog.rewatechnology.com/fix-iphone-x-face-id-not-working/

1984 2002

"*How the Afghan Girl was Identified by Her Iris Patterns*" https://www.cl.cam.ac.uk/~jgd1000/afghan.html





HANDS-FREE SELFIE

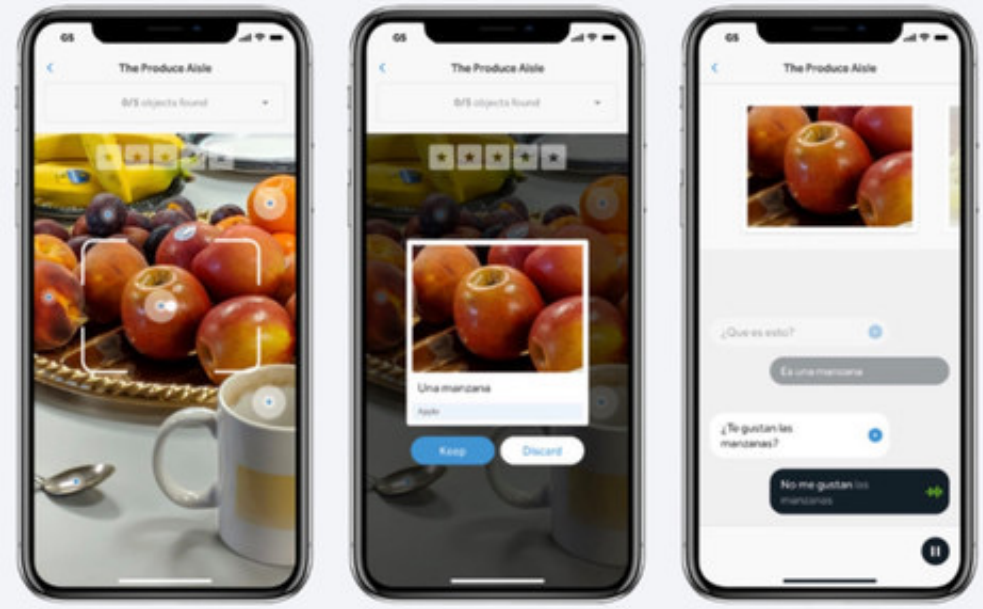
Handsome guy photo created by cookie_studio - www.freepik.com

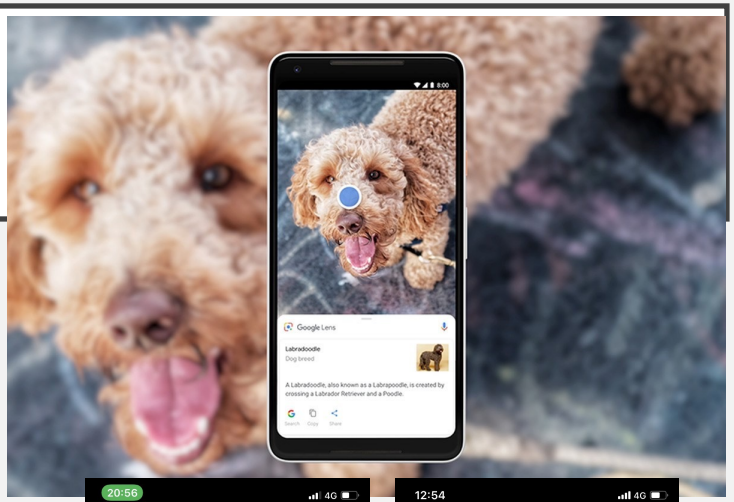
Take a HANDS-FREE selfie: App snaps photos from up to 10ft away using a simple swipe of the arm

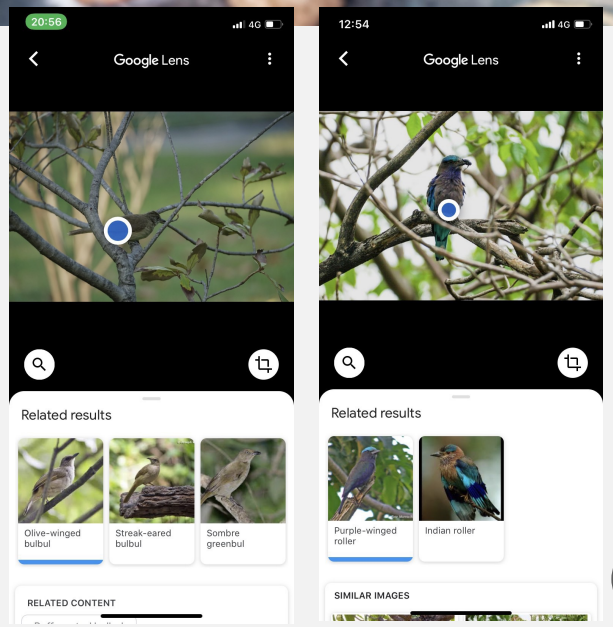
https://www.dailymail.co.uk/sciencetech/article-2674946/Take-HANDS-FREE-selfie-App-snaps-photos-10ft-away-using-simple-swipe-arm.html

OBJECT CLASSIFICATION

- Imaging applications in Daily Life
  - Object Recognition on your mobile phones







OCR – OPTICAL CHARACTER RECOGNITION

อาจารย์คณะวิศวฯ จุฬาฯ นำเทคโนโลยี AI Deep Tech พัฒนาโปรแกรมสแกนเอกสารและรูปภาพเป็นข้อความ (OCR) อ่านภาษาไทยแม่นยำกว่า 90% UTC จุฬาฯ พร้อม spin-off สู่ตลาดในนามบริษัท Eikonnex AI จำกัด

Assoc. Prof. Dr. Thanarat Chalidabhonges

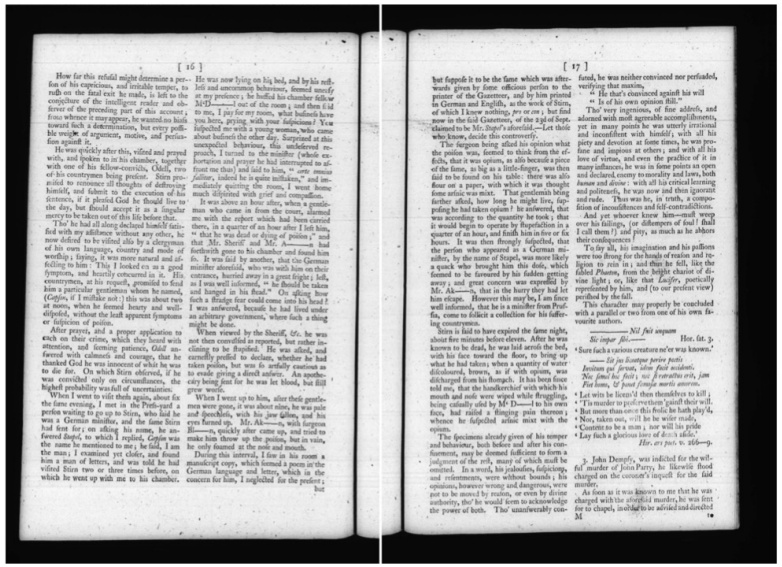
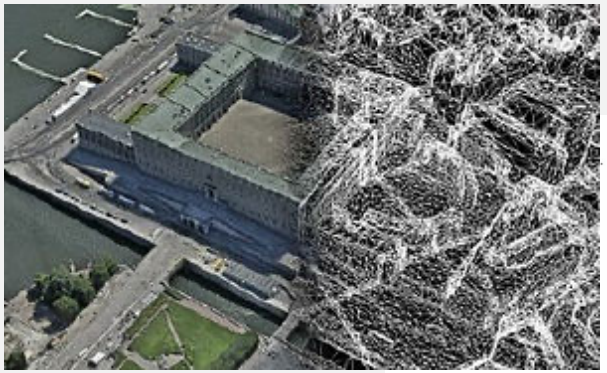


Figure 2: Ordinary's Accounts September 15, 1760 (# 3421-2)
Character Error Rate **Left: AWS 73.97%; Azure 35.26%; GCP 76.64%**
Right: AWS 75.90%; Azure 12.17%; GCP 77.36%

The Old Bailey and OCR: Benchmarking AWS, Azure, and GCP with 180,000 Page Images, William Ughetta, Brian W. Kernighan, Proceedings of the ACM Symposium on Document Engineering 2020

3D FROM IMAGES



https://grail.cs.washington.edu/rome/
Building Rome in a Day: Agarwal et al. 2009

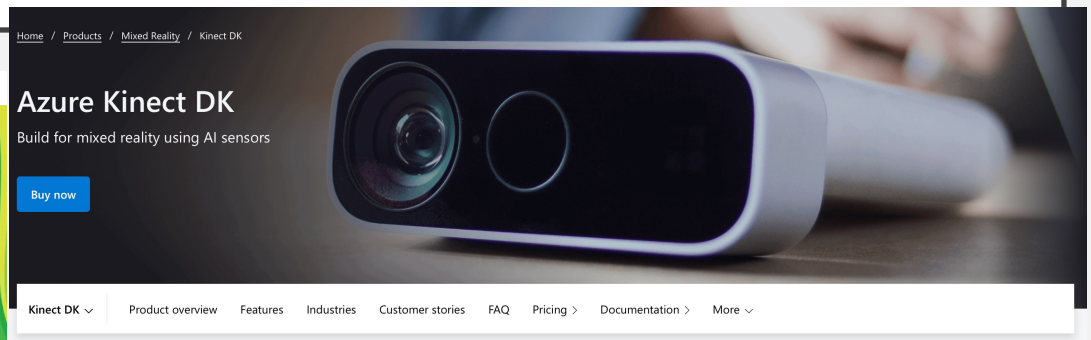
KINECT

Xbox 360 Kinect claims a Guinness World Record for the fastest-selling cor
after selling eight million units in its first 60 days.

Release timeline

2006	PrimeSense technology shown at GDC
2007	
2008	
2009	"Project Natal" announced
2010	**Kinect for Xbox 360** released
2011	Non-commercial SDK released Commercial SDK released
2012	**Kinect for Windows** released
2013	**Kinect for Xbox One** released with console
2014	**Kinect 2 for Windows** released
2015	
2016	
2017	Discontinuation of Kinect for Xbox hardware
2018	
2019	**Azure Kinect** released

https://news.microsoft.com/en-gb/announcement/xbox-360-kinect-launched/



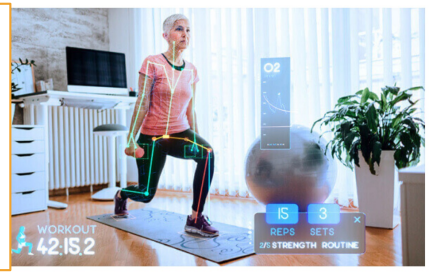
Kinect with spatial data

Azure Kinect is a cutting-edge spatial computing developer kit with sophisticated computer vision and speech models, advanced AI sensors, and a range of powerful SDKs that can be connected to Azure cognitive services.

Using Azure Kinect, manufacturing, retail, healthcare, and media enterprises are leveraging spatial data and context to enhance operational safety, increase performance, improve outcomes, and revolutionize the customer experience.

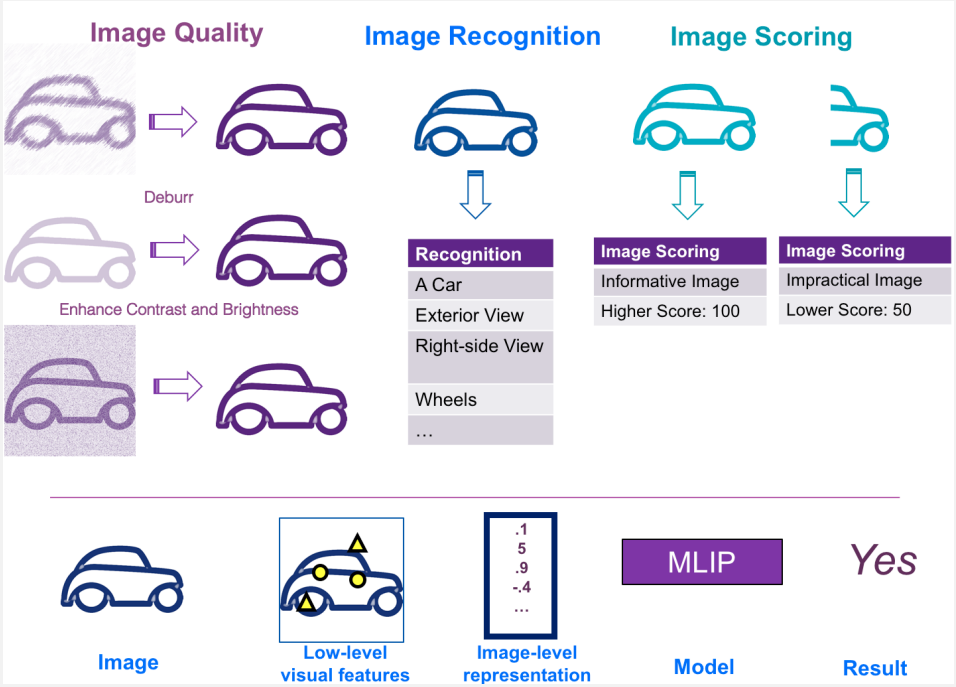
Health | Manufacturing | Media | Retail | Robotics

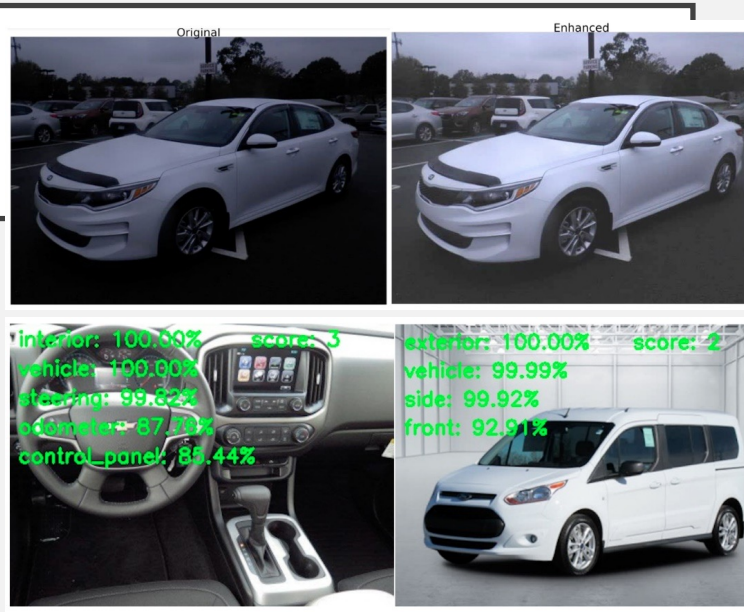
- 1-MP depth sensor
- 7-microphone array
- 12-MP RGB video camera
- Accelerometer and gyroscope (IMU) (Orientation & spatial tracking)
- External sync pins



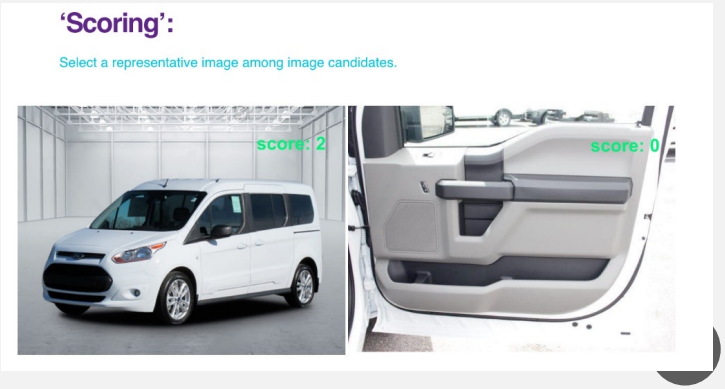
https://azure.microsoft.com/en-us/services/kinect-dk/#industries

DIGITAL MARKETING





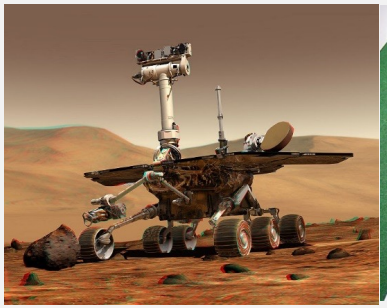
How to choose the most representative one among these image candidates needs a strategic image scoring schema

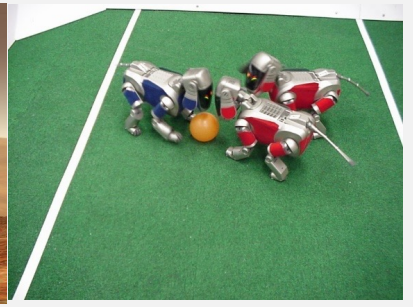


https://tech.cars.com/applications-of-machine-learning-image-processing-in-digital-marketing-982ee296dc8a

OTHERS

- Other Applications
  - Augmented Reality And Virtual Reality
  - Mobile Robots
  - Industrial Robots
  - Autocars –Tesla / Uber Bought Cmu's Lab
  - Medical Imaging





NASA's Mars Spirit Rover
http://en.wikipedia.org/wiki/Spirit_rover
http://www.robocup.org/

Vision-guided robots position nut runners on wheels

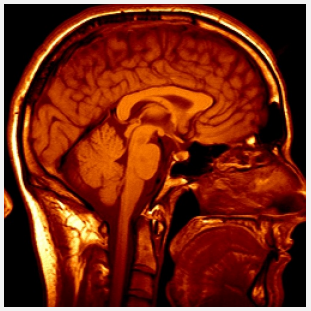
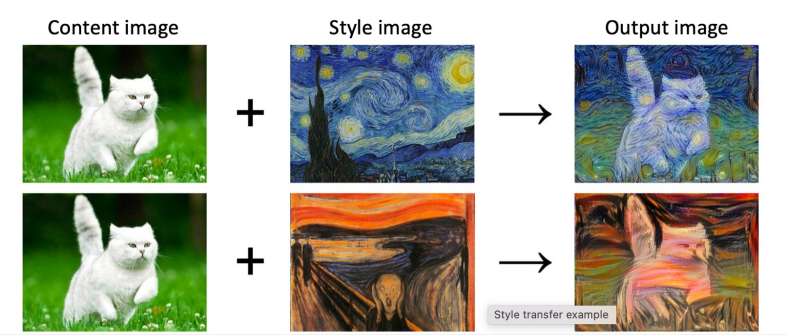
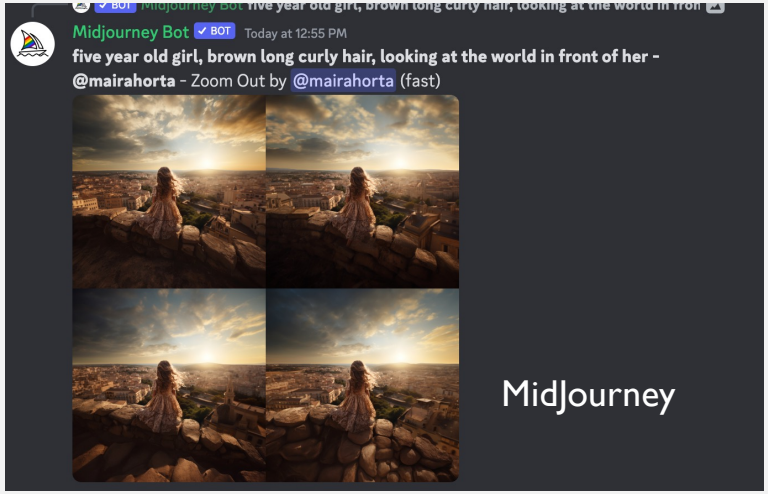
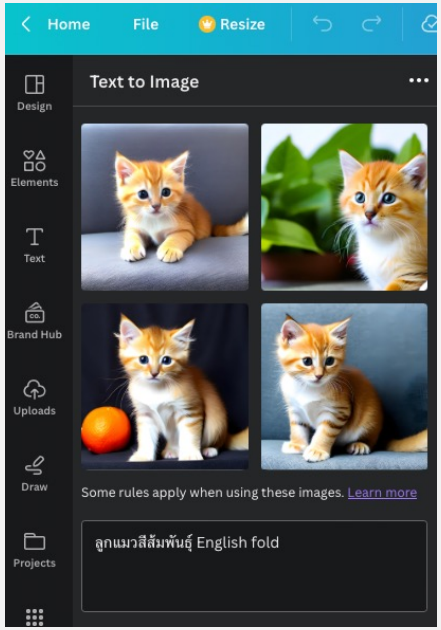


Image guided surgery Grimson et al., MIT
3D imaging MRI, CT

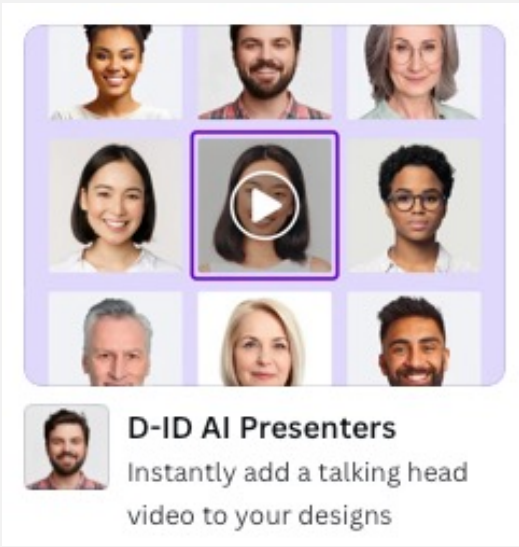
IMAGE GENERATIVE AI







Canva

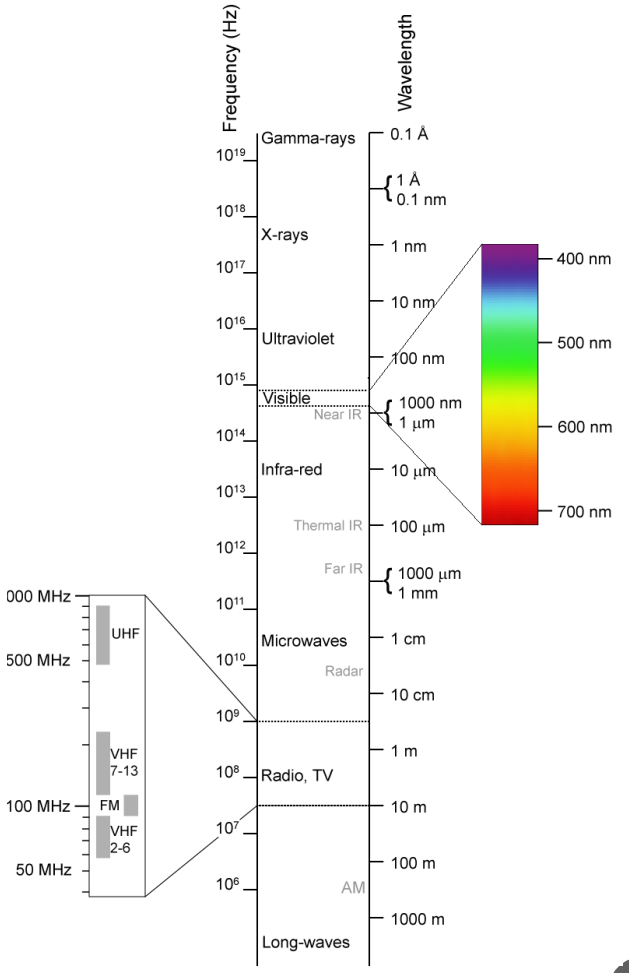


Canva/Heygen

EXAMPLES OF FIELDS THAT USE DIGITAL IMAGE PROCESSING

EXAMPLES OF FIELDS THAT USE DIGITAL IMAGE PROCESSING

- To categorize by the sources of the image
  - Electromagnetic Energy Spectrum → X-ray and visual bands
  - Others: Acoustic, ultrasonic and electronic (electron beams used in microscopy)
  - Synthetic images for modeling and visualization



Images from Gonzalez & Woods, Digital Image Processing, second edition

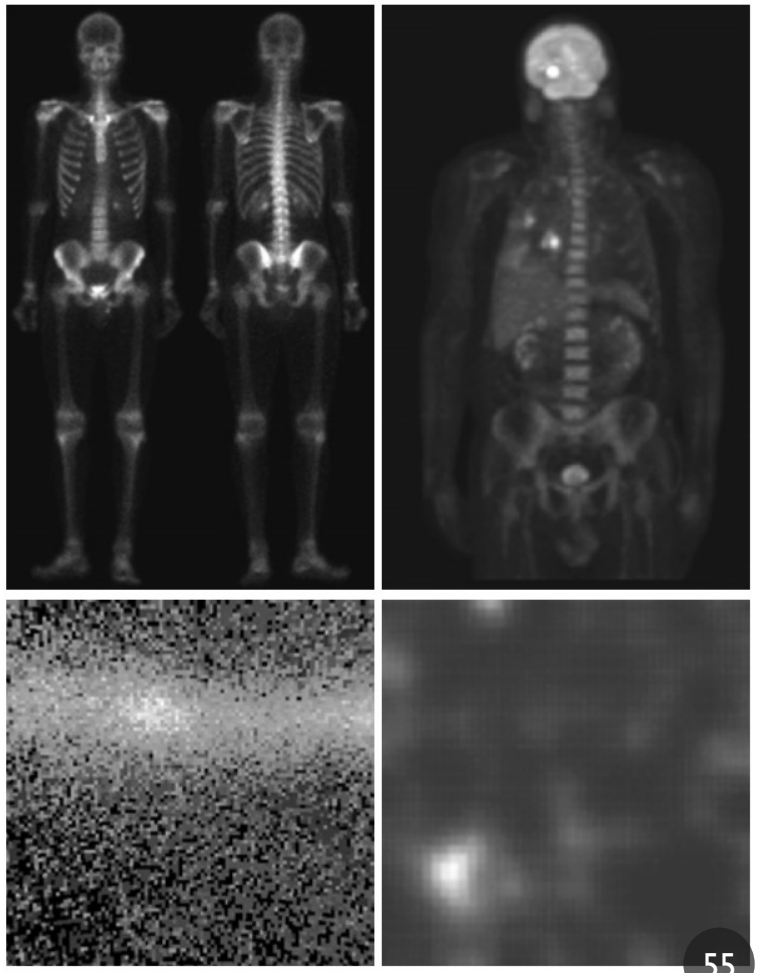
GAMMA-RAY IMAGING

- Nuclear medicine and astronomical observations
  - (a) Locate bone pathology, such as infections, tumors
  - (b) Positron emission tomography (PET) using radioactive isotope
  - (c) Cygnus Loop in gamma ray bands
  - (d) gamma radiation from a valve in a nuclear reactor

PET scan machine from https://www.healthline.com/health/pet-scan

a b
c d

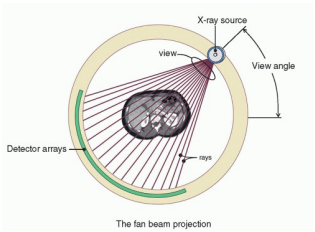
FIGURE 1.6 Examples of gamma-ray imaging. (a) Bone scan. (b) PET image. (c) Cygnus Loop. (d) Gamma radiation (bright spot) from a reactor valve. (Images courtesy of (a) G.E. Medical Systems, (b) Dr. Michael E. Casey, CTI PET Systems, (c) NASA, (d) Professors Zhong He and David K. Wehe, University of Michigan.)

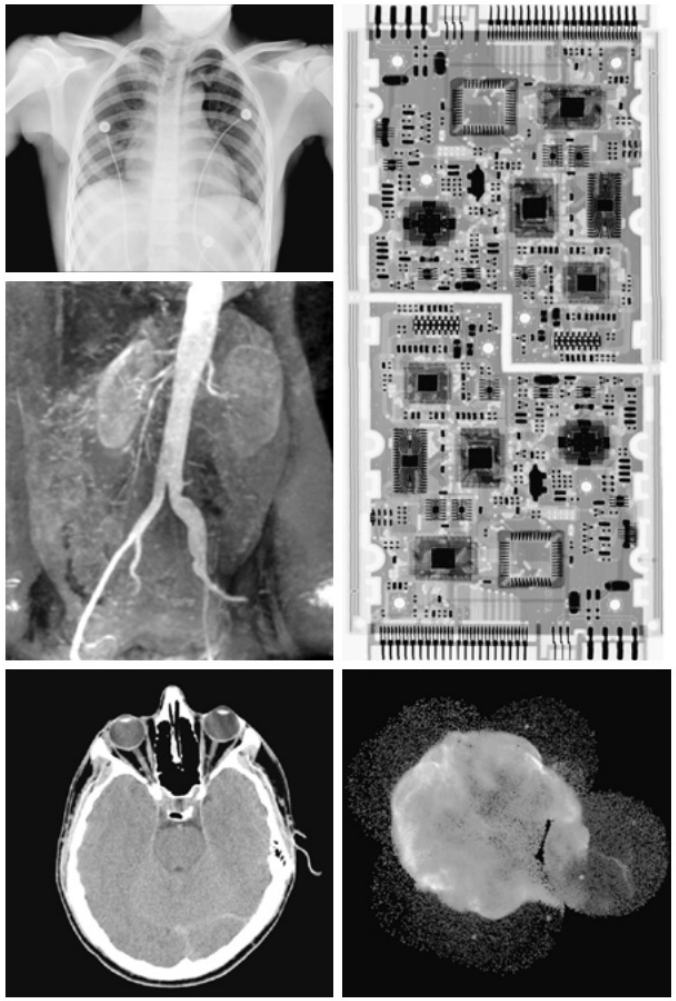


Images from Gonzalez & Woods, Digital Image Processing, second edition

X-RAY IMAGING

- Medical diagnostics, astronomy, industrial imaging
- X-ray generated by replacing patient between X-ray source and a film (phosphor screen) sensitive to X-ray energy
- Angiography (Contrast enhancement of blood vessels)
- Computerized axial tomography (CAT) – slice taken perpendicularly through the patient -> 3D rendition





a d
b
c e

FIGURE 1.7 Examples of X-ray imaging. (a) Chest X-ray. (b) Aortic angiogram. (c) Head CT. (d) Circuit boards. (e) Cygnus Loop. (Images courtesy of (a) and (c) Dr. David R. Pickens, Dept. of Radiology & Radiological Sciences, Vanderbilt University Medical Center, (b) Dr. Thomas R. Gest, Division of Anatomical Sciences, University of Michigan Medical School, (d) Mr. Joseph E. Pascente, Lixi, Inc., and (e) NASA.)

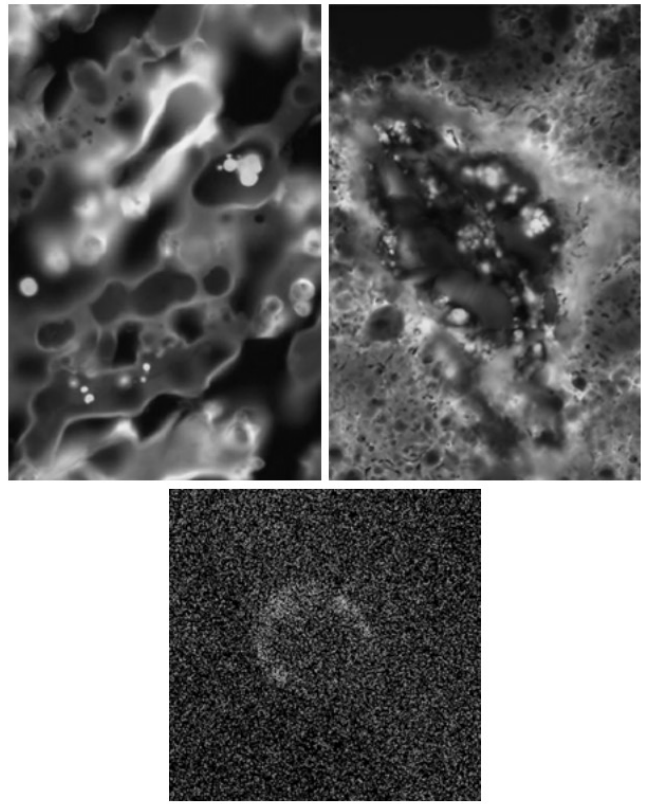
Images from Gonzalez & Woods, Digital Image Processing, second edition
https://en.wikipedia.org/wiki/CT_scan
https://radiologykey.com/computed-tomography-15/

IMAGING IN ULTRAVIOLET BAND

- Industrial inspection, microscopy, lasers, biological imaging, astronomical observations
- Fluorescent Microscopy – studying materials, such as corn smut (disease of the corn)
- Cygnus Loop again in Ultraviolet band

a b
c

FIGURE 1.8
Examples of ultraviolet imaging.
(a) Normal corn.
(b) Smut corn.
(c) Cygnus Loop.
(Images courtesy of (a) and (b) Dr. Michael W. Davidson, Florida State University, (c) NASA.)

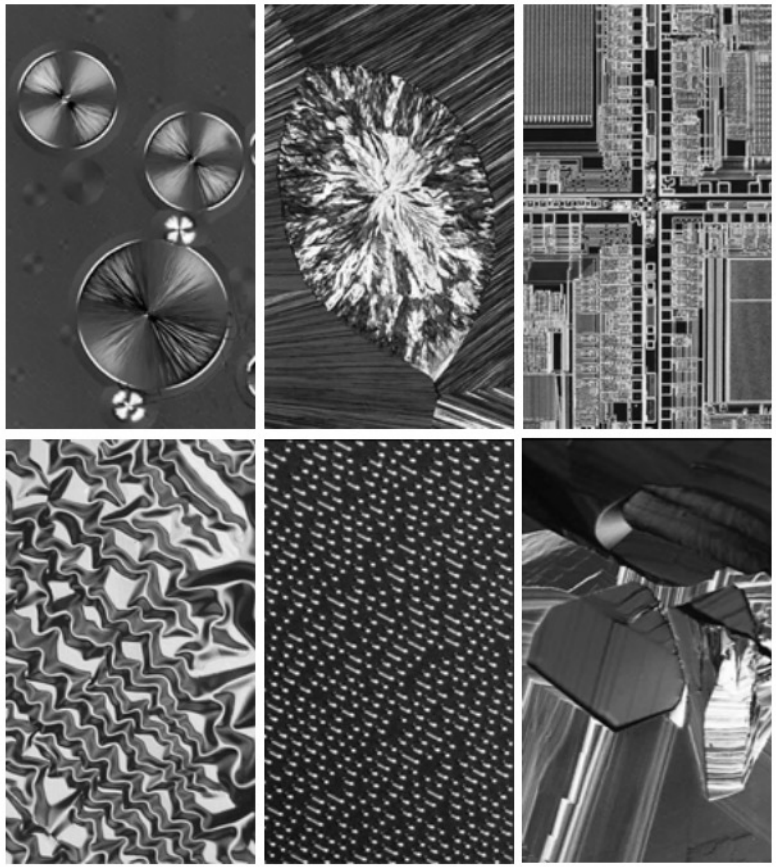


Images from Gonzalez & Woods, Digital Image Processing, second edition

IMAGING IN VISIBLE AND INFRARED BANDS

- Light microscopy imaging
  - Phamaceuticals and microinspection to materials characterization

https://www.carlroth.com



a b c
d e f

FIGURE 1.9 Examples of light microscopy images. (a) Taxol (anticancer agent), magnified 250×. (b) Cholesterol—40×. (c) Microprocessor—60×. (d) Nickel oxide thin film—600×. (e) Surface of audio CD—1750×. (f) Organic superconductor—450×. (Images courtesy of Dr. Michael W. Davidson, Florida State University.)

Images from Gonzalez & Woods, Digital Image Processing, second edition

IMAGING IN VISIBLE AND INFRARED BANDS

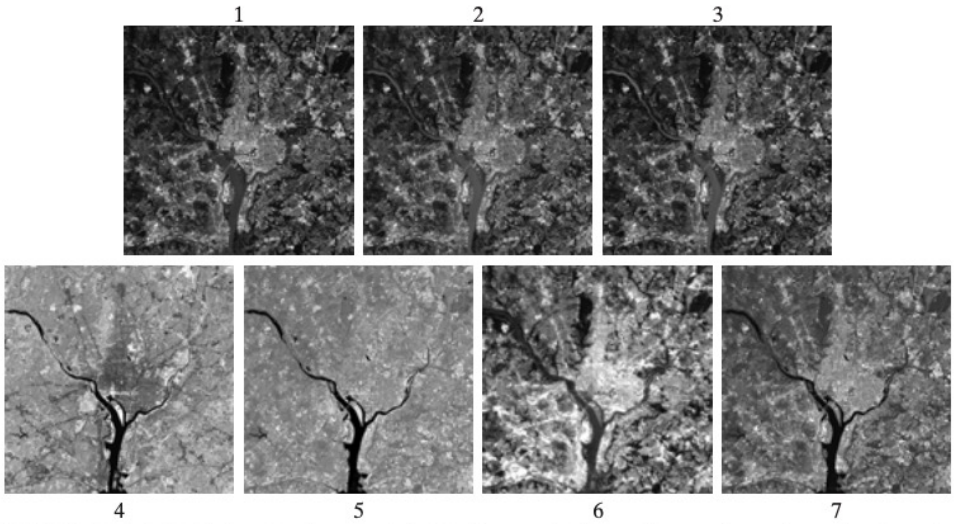


FIGURE 1.10 LANDSAT satellite images of the Washington, D.C. area. The numbers refer to the thematic bands in Table 1.1. (Images courtesy of NASA.)

Images from Gonzalez & Woods, Digital Image Processing, second edition

- Remote sensing – Thematic bands in NASA's LANDSAT satellite
  - Multispectrum imaging

Thematic bands of NASA are as LANDSAT satellite.

Band No.	Name	Wavelength (μm)	Characteristics and use
1	Visible blue	0.45–0.52	Maximum water penetration
2	Visible green	0.52–0.60	Good for measuring plant vigor
3	Visible blue	0.63–0.69	Vegetation discrimination
4	Near infrared	0.76–0.90	Biomass and shoreline mapping
5	Middle infrared	1.55–1.75	Moisture content of soil
6	Thermal infrared	10.4–12.5	Soil moisture, thermal mapping
7	Middle infrared	2.08–2.35	Mineral mapping

IMAGING IN VISIBLE AND INFRARED BANDS

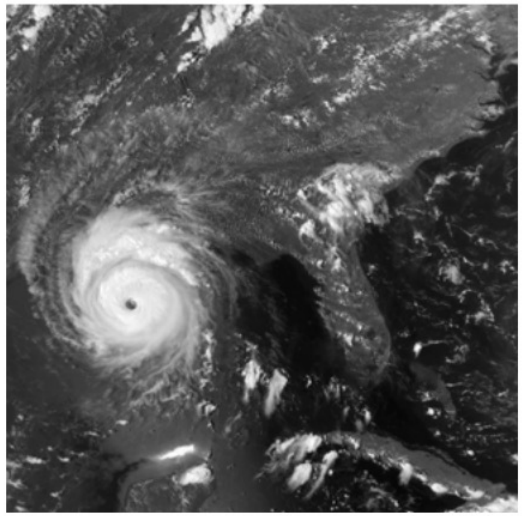


FIGURE 1.11 Multispectral image of Hurricane Andrew taken by NOAA GEOS (Geostationary Environmental Operational Satellite) sensors. (Courtesy of NOAA.)

Images from Gonzalez & Woods, Digital Image Processing, second edition

- Weather observation – multispectral imaging
  - Sensors in visible and infrared bands
- Nighttime lights of the world dataset (next page)

IMAGING IN VISIBLE AND INFRARED BANDS

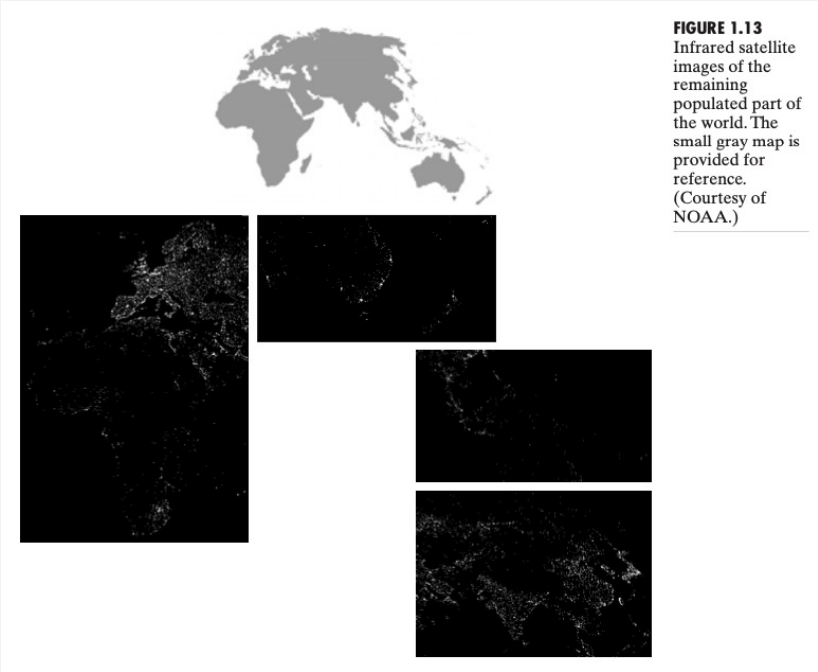


FIGURE 1.13 Infrared satellite images of the remaining populated part of the world. The small gray map is provided for reference. (Courtesy of NOAA.)

Part of the *Nighttime Lights of the World* dataset

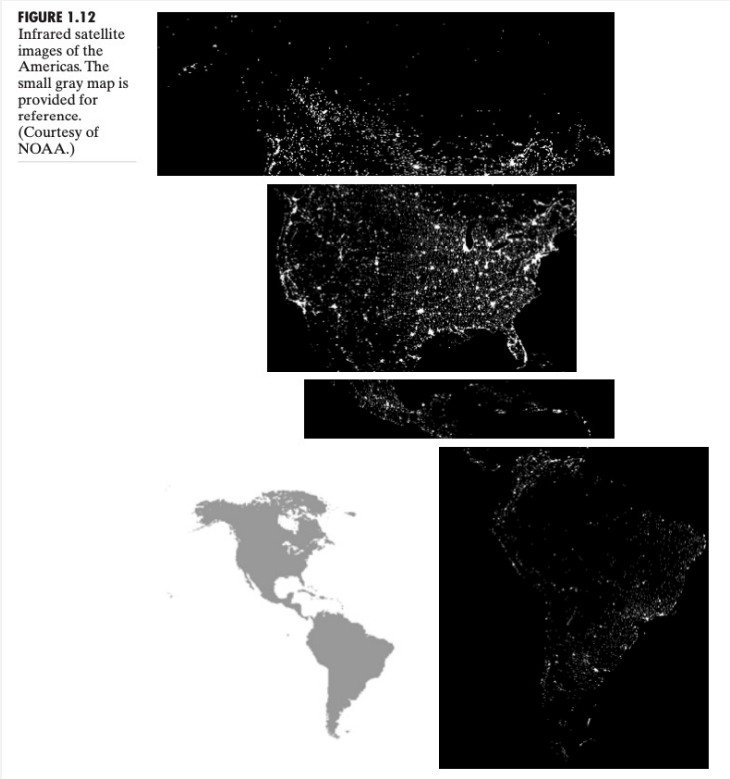


FIGURE 1.12 Infrared satellite images of the Americas. The small gray map is provided for reference. (Courtesy of NOAA.)

Images from Gonzalez & Woods, Digital Image Processing, second edition

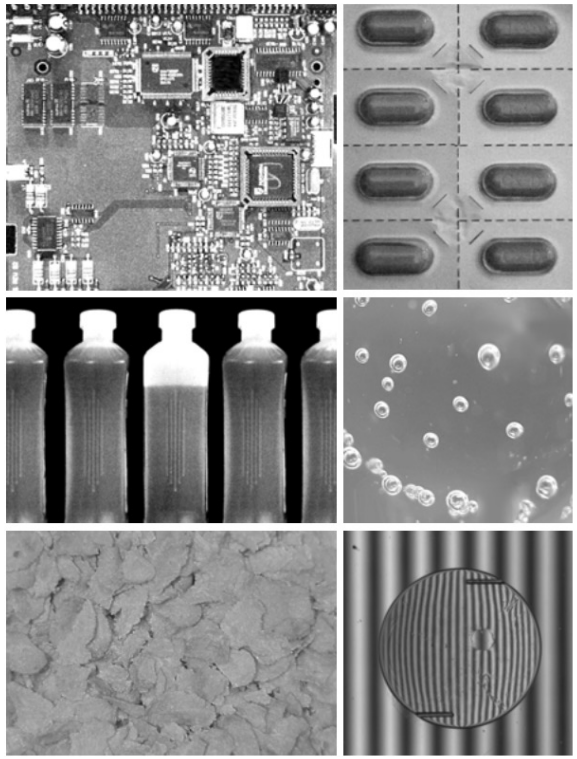
IMAGING IN VISIBLE AND INFRARED BANDS

a b
c
d

FIGURE 1.15
Some additional examples of imaging in the visual spectrum. (a) Thumb print. (b) Paper currency. (c) and (d). Automated license plate reading. (Figure (a) courtesy of the National Institute of Standards and Technology. Figures (c) and (d) courtesy of Dr. Juan Herrera, Perceptics Corporation.)

a b
c d
e f

FIGURE 1.14
Some examples of manufactured goods often checked using digital image processing. (a) A circuit board controller. (b) Packaged pills. (c) Bottles. (d) Bubbles in clear-plastic product. (e) Cereal. (f) Image of intraocular implant. (Fig. (f) courtesy of Mr. Pete Sites, Perceptics Corporation.)



Images from Gonzalez & Woods, Digital Image Processing, second edition

MICROWAVE BAND

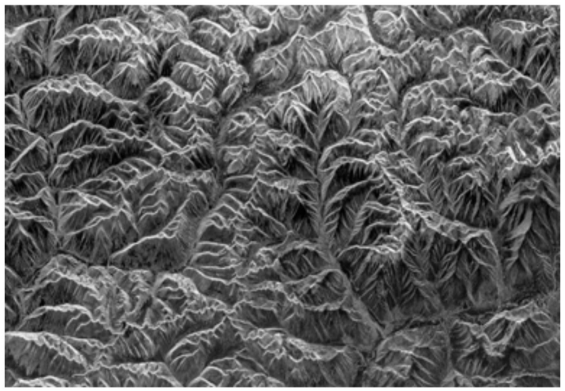
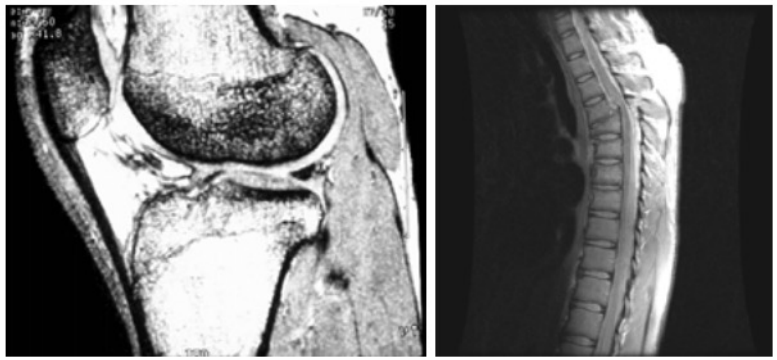


FIGURE 1.16 Spaceborne radar image of mountains in southeast Tibet. (Courtesy of NASA.)

- Radar – to collect data over virtually any region anytime regardless of weather lighting conditions
- See through vegetation, ice and dry sand
- Explore inaccessible regions of Earth's surface

Images from Gonzalez & Woods, Digital Image Processing, second edition

IMAGING IN RADIO BAND



a b

FIGURE 1.17 MRI images of a human (a) knee, and (b) spine. (Image (a) courtesy of Dr. Thomas R. Gest, Division of Anatomical Sciences, University of Michigan Medical School, and (b) Dr. David R. Pickens, Department of Radiology and Radiological Sciences, Vanderbilt University Medical Center.)

- Magnetic Resonance Imaging (MRI) – placing a patient in a powerful magnet and passes radio waves through his/her body in short pulses

Images from Gonzalez & Woods, Digital Image Processing, second edition

IMAGING IN OTHER MODALITIES

- Imaging using sound – geological exploration, industry and medicine

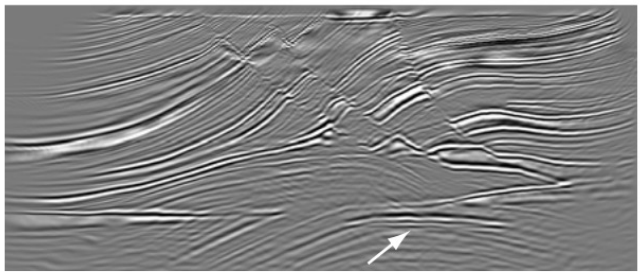
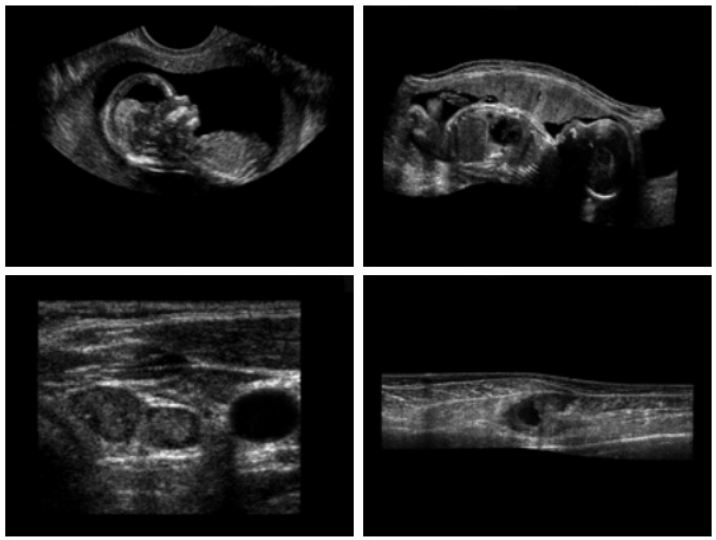


FIGURE 1.19 Cross-sectional image of a seismic model. The arrow points to a hydrocarbon (oil and/or gas) trap. (Courtesy of Dr. Curtis Ober, Sandia National Laboratories.)



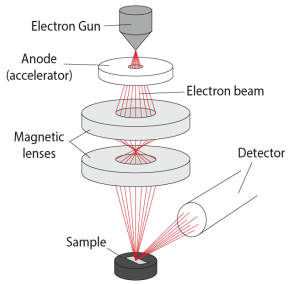
a b
c d

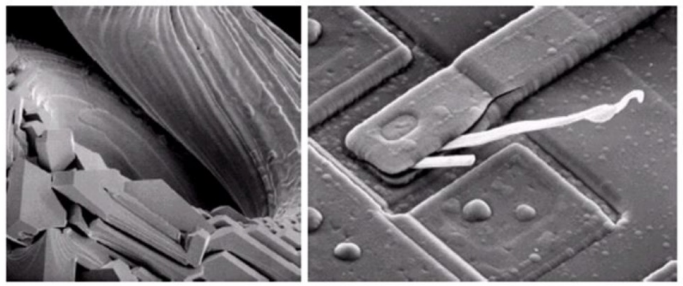
FIGURE 1.20 Examples of ultrasound imaging. (a) Baby. (2) Another view of baby. (c) Thyroids. (d) Muscle layers showing lesion. (Courtesy of Siemens Medical Systems, Inc., Ultrasound Group.)

Images from Gonzalez & Woods, Digital Image Processing, second edition

OTHER IMAGING MODALITIES

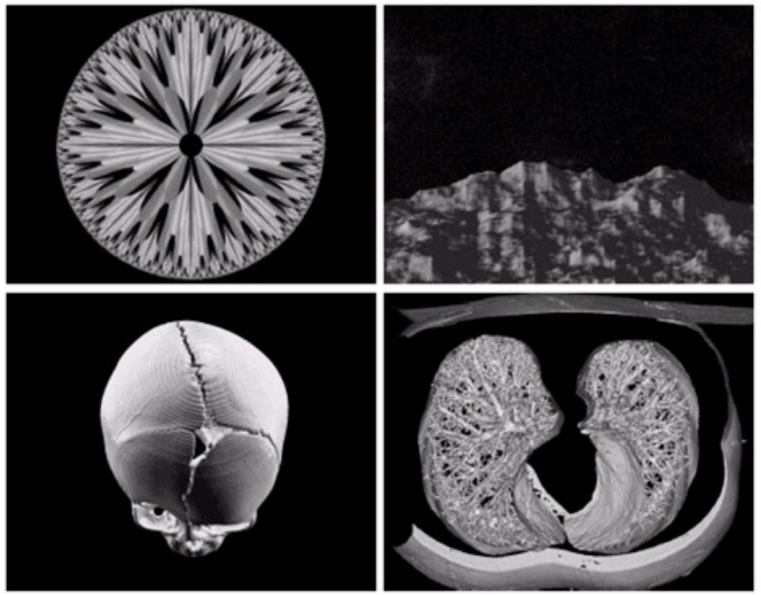
- Electron microscopy
- Computer-generated image





a b

FIGURE 1.21 (a) 250× SEM image of a tungsten filament following thermal failure. (b) 2500× SEM image of damaged integrated circuit. The white fibers are oxides resulting from thermal destruction. (Figure (a) courtesy of Mr. Michael Shaffer, Department of Geological Sciences, University of Oregon, Eugene; (b) courtesy of Dr. J. M. Hudak, McMaster University, Hamilton, Ontario, Canada.)



a b
c d

FIGURE 1.22
(a) and (b) Fractal images. (c) and (d) Images generated from 3-D computer models of the objects shown. (Figures (a) and (b) courtesy of Ms. Melissa D. Binde, Swarthmore College, (c) and (d) courtesy of NASA.)

Images from - Gonzalez & Woods, Digital Image Processing, second edition
- https://www.eng-atoms.msm.cam.ac.uk/RoyalSocDemos/SEM

REFERENCES

- Chapter 1, Rafael C. Gonzalez and Richard E. Woods, Digital Image Processing, Addison- Wesley

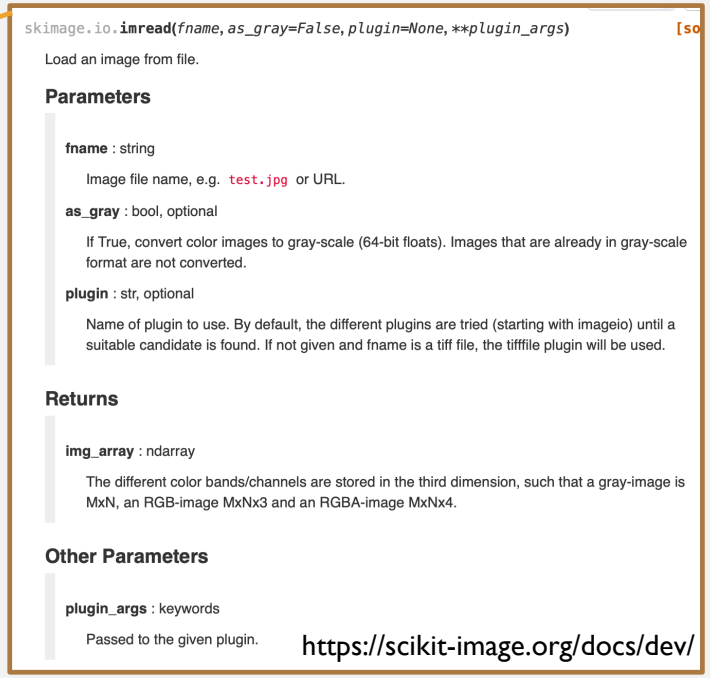
EXAMPLE #1: READ AND SHOW IMAGE

Warm up!

- Read and show an image
  - ***scikit-image*** is a collection of algorithms for image processing.

```
from skimage import io
img = io.imread("kitty.jpg")
io.imshow(img)
io.show()

import matplotlib.pyplot as plt
plt.imshow(img)
plt.show()
```



skimage.io.**imread**(*fname*, *as_gray=False*, *plugin=None*, ***plugin_args*) [so

Load an image from file.

Parameters

fname : string

Image file name, e.g. `test.jpg` or URL.

as_gray : bool, optional

If True, convert color images to gray-scale (64-bit floats). Images that are already in gray-scale format are not converted.

plugin : str, optional

Name of plugin to use. By default, the different plugins are tried (starting with imageio) until a suitable candidate is found. If not given and fname is a tiff file, the tifffile plugin will be used.

Returns

img_array : ndarray

The different color bands/channels are stored in the third dimension, such that a gray-image is MxN, an RGB-image MxNx3 and an RGBA-image MxNx4.

Other Parameters

plugin_args : keywords

Passed to the given plugin.

https://scikit-image.org/docs/dev/

GET PIXEL VALUES

```
from skimage import io
import numpy as np

img = io.imread("kitty.png")

img[0,0]
array([184, 169, 148], dtype=uint8)

img[0,0,0:2]
array([184, 169], dtype=uint8)
```

NumPy is the fundamental package for scientific computing in Python.
At the core of the ***NumPy*** package, is the ***ndarray*** object.
http://numpy.org

Matplotlib is a comprehensive library for creating static, animated, and interactive visualizations in Python.
https://matplotlib.org

matplotlib.pyplot.imshow

`matplotlib.pyplot.`imshow(*X*, *cmap=None*, *norm=None*, *aspect=None*, *interpolation=None*, *alpha=None*, *vmin=None*, *vmax=None*, *origin=None*, *extent=None*, ***, *filternorm=True*, *filterrad=4.0*, *resample=None*, *url=None*, *data=None*, ***kwargs*) [source]

Display data as an image, i.e., on a 2D regular raster.

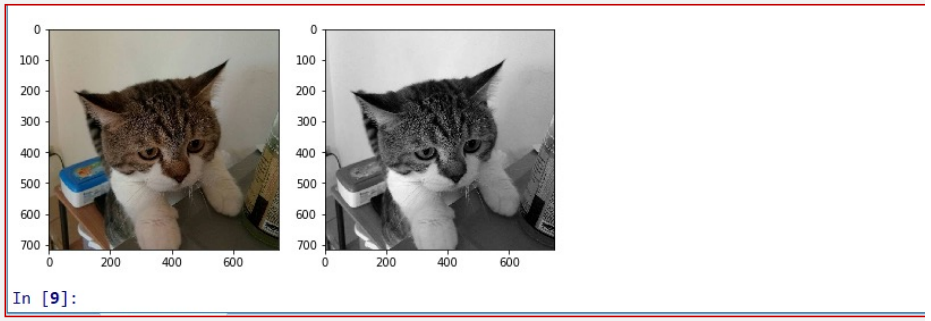
EXERCISE #1 READ AND SHOW IMAGE

Diary #1

- Compared RGB image and gray image

```
from skimage import io, color
import matplotlib.pyplot as plt
img = io.imread("kitty.png")
gray = color.rgb2gray(_____________)

fig = plt.figure(figsize=(8,4))
fig.add_subplot(1,2,1)
plt.imshow(img)
fig.add_subplot(1,2,2)
plt.imshow(_____________________________)
io.show()
```



rgb2gray

skimage.color.**rgb2gray**(*rgb*, *, *channel_axis=- 1*) [source]

Compute luminance of an RGB image.

Parameters

rgb : (…, 3, …) array_like

The image in RGB format. By default, the final dimension denotes channels.

Returns

out : ndarray

The luminance image - an array which is the same size as the input array, but with the channel dimension removed.

Raises

ValueError

If *rgb* is not at least 2-D with shape (…, 3, …).

https://scikit-image.org/docs/dev/

QUESTIONS

- What is your image size?
- What is your image data type?
- What is value at `kitty image at [50,50,2]`?
- Which one is Red/Green/blue?
- What is the maximum value of each RGB and what color is that?
- What is the minimum value of each RGB and what color is that?

EXERCISE #2 READ AND SHOW IMAGE USING CV2

- Read an image using opencv

```
import cv2
image2 = cv2.imread("kitty.jpg")

plt.imshow(image2)
plt.show()
```

- What do you see?
- Add this code:

```
image2 = cv2.cvtColor(image2,cv2.COLOR_BGR2RGB)
```

EXAMPLE #3 DICOM FILE

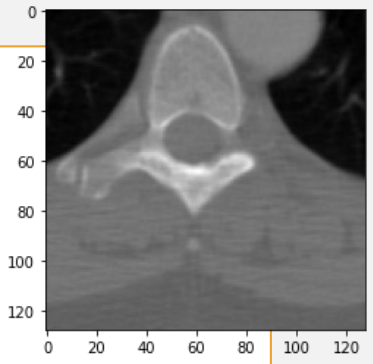
- Digital Imaging and Communications in Medicine (DICOM) format
  - Image and patient's data

```python
import matplotlib.pyplot as plt
from pydicom import dcmread
from pydicom.data import get_testdata_file

fpath = get_testdata_file('CT_small.dcm')
ds = dcmread(fpath)

print(f"Patient's Name...: {ds.PatientName}")
print(f"Patient ID.......: {ds.PatientID}")
print(f"Modality.........: {ds.Modality}")
print(f"Study Date.......: {ds.StudyDate}")
print(f"Image size.......: {ds.Rows} x {ds.Columns}")
print(f"Pixel Spacing....: {ds.PixelSpacing}")

# plot the image using matplotlib
plt.imshow(ds.pixel_array, cmap=plt.cm.gray)
plt.show()
```



pydicom

https://pydicom.github.io/pydicom/stable/auto_examples/index.html

- What is the image size?
- What is the datatype of pixel_array ?
- Min/max?
- Try with "MR_small.dcm"

clear - clear console
who – get current variables
%reset – clear all variables

Python For Data Science *Cheat Sheet*

NumPy Basics

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NumPy

The **NumPy** library is the core library for scientific computing in Python. It provides a high-performance multidimensional array object, and tools for working with these arrays.

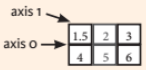
Use the following import convention:

```
>>> import numpy as np
```

NumPy Arrays

1D array

2D array



3D array

Creating Arrays

```
>>> a = np.array([1,2,3])
>>> b = np.array([(1.5,2,3), (4,5,6)], dtype = float)
>>> c = np.array([[(1.5,2,3), (4,5,6)], [(3,2,1), (4,5,6)]],
                 dtype = float)
```

Initial Placeholders

```
>>> np.zeros((3,4))                  Create an array of zeros
>>> np.ones((2,3,4),dtype=np.int16)  Create an array of ones
>>> d = np.arange(10,25,5)           Create an array of evenly
                                     spaced values (step value)
>>> np.linspace(0,2,9)               Create an array of evenly
                                     spaced values (number of samples)
>>> e = np.full((2,2),7)             Create a constant array
>>> f = np.eye(2)                    Create a 2X2 identity matrix
>>> np.random.random((2,2))          Create an array with random values
>>> np.empty((3,2))                  Create an empty array
```

I/O

Saving & Loading On Disk

```
>>> np.save('my_array', a)
>>> np.savez('array.npz', a, b)
>>> np.load('my_array.npy')
```

Saving & Loading Text Files

```
>>> np.loadtxt("myfile.txt")
>>> np.genfromtxt("my_file.csv", delimiter=',')
>>> np.savetxt("myarray.txt", a, delimiter=" ")
```

Data Types

```
>>> np.int64       Signed 64-bit integer types
>>> np.float32     Standard double-precision floating point
>>> np.complex     Complex numbers represented by 128 floats
>>> np.bool        Boolean type storing TRUE and FALSE values
>>> np.object      Python object type
>>> np.string_     Fixed-length string type
>>> np.unicode_    Fixed-length unicode type
```

Inspecting Your Array

```
>>> a.shape         Array dimensions
>>> len(a)          Length of array
>>> b.ndim          Number of array dimensions
>>> e.size          Number of array elements
>>> b.dtype         Data type of array elements
>>> b.dtype.name    Name of data type
>>> b.astype(int)   Convert an array to a different type
```

Asking For Help

```
>>> np.info(np.ndarray.dtype)
```

Array Mathematics

Arithmetic Operations

```
>>> g = a - b                        Subtraction
  array([[-0.5,  0. ,  0. ],
         [-3. , -3. , -3. ]])
>>> np.subtract(a,b)                 Subtraction
>>> b + a                            Addition
  array([[ 2.5,  4. ,  6. ],
         [ 5. ,  7. ,  9. ]])
>>> np.add(b,a)                      Addition
>>> a / b                            Division
  array([[ 0.66666667,  1.        ,  1.        ],
         [ 0.25      ,  0.4       ,  0.5       ]])
>>> np.divide(a,b)                   Division
>>> a * b                            Multiplication
  array([[  1.5,   4. ,   9. ],
         [  4. ,  10. ,  18. ]])
>>> np.multiply(a,b)                 Multiplication
>>> np.exp(b)                        Exponentiation
>>> np.sqrt(b)                       Square root
>>> np.sin(a)                        Print sines of an array
>>> np.cos(b)                        Element-wise cosine
>>> np.log(a)                        Element-wise natural logarithm
>>> e.dot(f)                         Dot product
  array([[ 7.,  7.],
         [ 7.,  7.]])
```

Comparison

```
>>> a == b                           Element-wise comparison
  array([[False,  True,  True],
         [False, False, False]], dtype=bool)
>>> a < 2                            Element-wise comparison
  array([True, False, False], dtype=bool)
>>> np.array_equal(a, b)             Array-wise comparison
```

Aggregate Functions

```
>>> a.sum()                          Array-wise sum
>>> a.min()                          Array-wise minimum value
>>> b.max(axis=0)                    Maximum value of an array row
>>> b.cumsum(axis=1)                 Cumulative sum of the elements
>>> a.mean()                         Mean
>>> b.median()                       Median
>>> a.corrcoef()                     Correlation coefficient
>>> np.std(b)                        Standard deviation
```

Copying Arrays

```
>>> h = a.view()     Create a view of the array with the same data
>>> np.copy(a)       Create a copy of the array
>>> h = a.copy()     Create a deep copy of the array
```

Sorting Arrays

```
>>> a.sort()         Sort an array
>>> c.sort(axis=0)   Sort the elements of an array's axis
```

Subsetting, Slicing, Indexing

Also see Lists

Subsetting

```
>>> a[2]
  3
```
Select the element at the 2nd index

```
>>> b[1,2]
  6.0
```
Select the element at row 1 column 2 (equivalent to `b[1][2]`)

Slicing

```
>>> a[0:2]
  array([1, 2])
```
Select items at index 0 and 1

```
>>> b[0:2,1]
  array([ 2.,  5.])
```
Select items at rows 0 and 1 in column 1

```
>>> b[:1]
  array([[1.5, 2., 3.]])
```
Select all items at row 0 (equivalent to `b[0:1, :]`)

```
>>> c[1,...]
  array([[[ 3.,  2.,  1.],
          [ 4.,  5.,  6.]]])
```
Same as `[1,:,:]`

```
>>> a[ : :-1]
  array([3,  2,  1])
```
Reversed array `a`

Boolean Indexing

```
>>> a[a<2]
  array([1])
```
Select elements from `a` less than 2

Fancy Indexing

```
>>> b[[1, 0, 1, 0],[0, 1, 2, 0]]
  array([ 4. ,  2. ,  6. ,  1.5])
```
Select elements `(1,0)`, `(0,1)`, `(1,2)` and `(0,0)`

```
>>> b[[1, 0, 1, 0]][:,[0,1,2,0]]
  array([[ 4. ,  5. ,  6. ,  4. ],
         [ 1.5,  2. ,  3. ,  1.5],
         [ 4. ,  5. ,  6. ,  4. ],
         [ 1.5,  2. ,  3. ,  1.5]])
```
Select a subset of the matrix's rows and columns

Array Manipulation

Transposing Array

```
>>> i = np.transpose(b)     Permute array dimensions
>>> i.T                     Permute array dimensions
```

Changing Array Shape

```
>>> b.ravel()               Flatten the array
>>> g.reshape(3,-2)         Reshape, but don't change data
```

Adding/Removing Elements

```
>>> h.resize((2,6))         Return a new array with shape (2,6)
>>> np.append(h,g)          Append items to an array
>>> np.insert(a, 1, 5)      Insert items in an array
>>> np.delete(a,[1])        Delete items from an array
```

Combining Arrays

```
>>> np.concatenate((a,d),axis=0)     Concatenate arrays
  array([ 1,  2,  3, 10, 15, 20])
>>> np.vstack((a,b))                 Stack arrays vertically (row-wise)
  array([[ 1. ,  2. ,  3. ],
         [ 1.5,  2. ,  3. ],
         [ 4. ,  5. ,  6. ]])
>>> np.r_[e,f]                       Stack arrays vertically (row-wise)
>>> np.hstack((e,f))                 Stack arrays horizontally (column-wise)
  array([[ 7.,  7.,  1.,  0.],
         [ 7.,  7.,  0.,  1.]])
>>> np.column_stack((a,d))           Create stacked column-wise arrays
  array([[ 1, 10],
         [ 2, 15],
         [ 3, 20]])
>>> np.c_[a,d]                       Create stacked column-wise arrays
```

Splitting Arrays

```
>>> np.hsplit(a,3)                   Split the array horizontally at the 3rd index
  [array([1]),array([2]),array([3])]
>>> np.vsplit(c,2)                   Split the array vertically at the 2nd index
[array([[[ 1.5,  2. ,  1. ],
         [ 4. ,  5. ,  6. ]]]),
 array([[[ 3.,  2.,  3.],
         [ 4.,  5.,  6.]]])]
```

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NUMPY

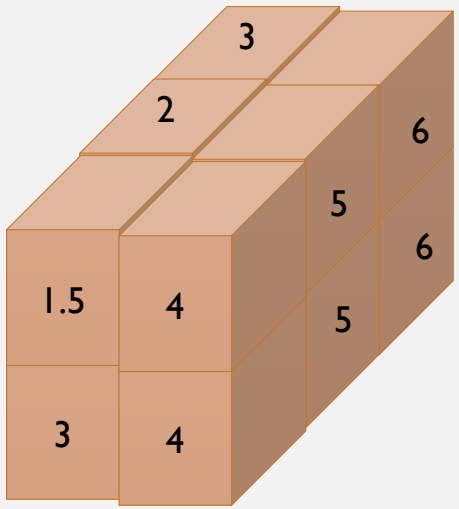
Warm up!

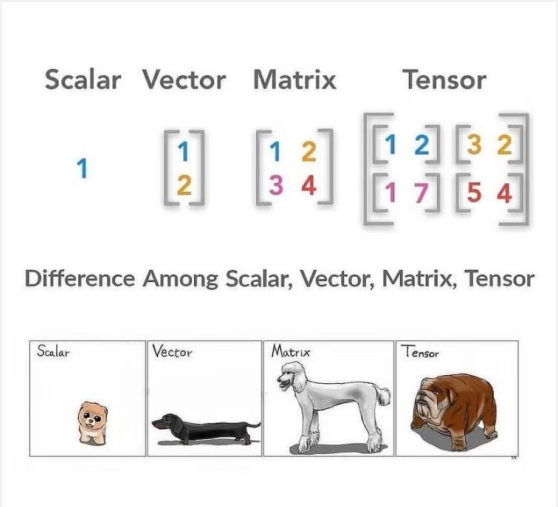
```
c = np.array([[(1.5,2,3), (4,5,6)], [(3,2,1), (4,5,6)]], dtype = float)
array([[[ 1.5,  2. ,  3. ],
        [ 4. ,  5. ,  6. ]],

       [[ 3. ,  2. ,  1. ],
        [ 4. ,  5. ,  6. ]]])

c[0,0]
Out[31]: array([ 1.5,  2. ,  3. ])

c[0,1]
Out[32]: array([ 4.,  5.,  6.])
```





EXERCISE #4

- Create 150 x 150 black image

```
import numpy as np
import matplotlib.pyplot as plt

a = np.zeros((150,150),dtype=int)
plt.imshow(a,cmap='gray')
plt.show()
```

- Create an image of 100x100 which has red color on the half left and cyan color on the half right and display the image