EE 4211 Computer vision

Introduction

Semester A, 2020-2021

Outline

- Course overview
- Applications of computer vision
- Introduction

Teaching Team

- Course leader
  - Dr. Yixuan YUAN < yxyuan.ee@cityu.edu.hk >
  - Office: G6361, Green Zone, 6/F, AC1
  - Phone: 3443-7803
  - Open hour: Monday 4:00-6:00 PM

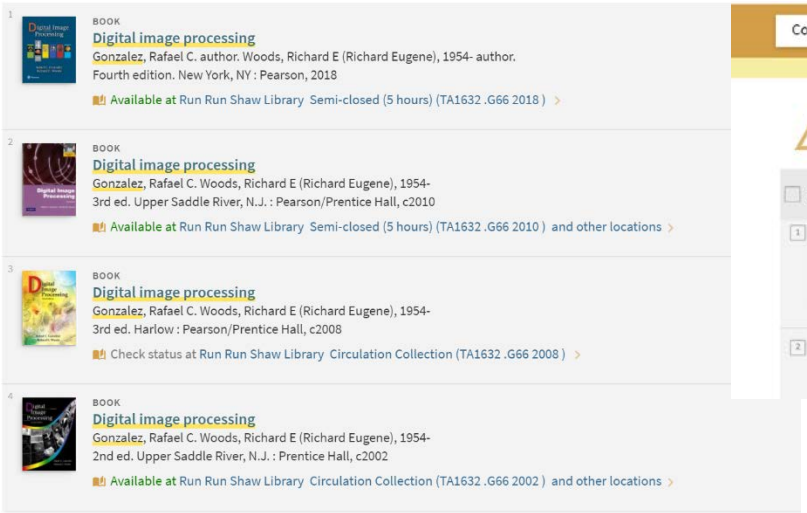
- One teaching assistant
  - Guo Xiaoqing < xiaoqiguo2-c@my.cityu.edu.hk >
  - Office: G2325, AC1
  - Open hour: Monday 1:00-7:00 PM

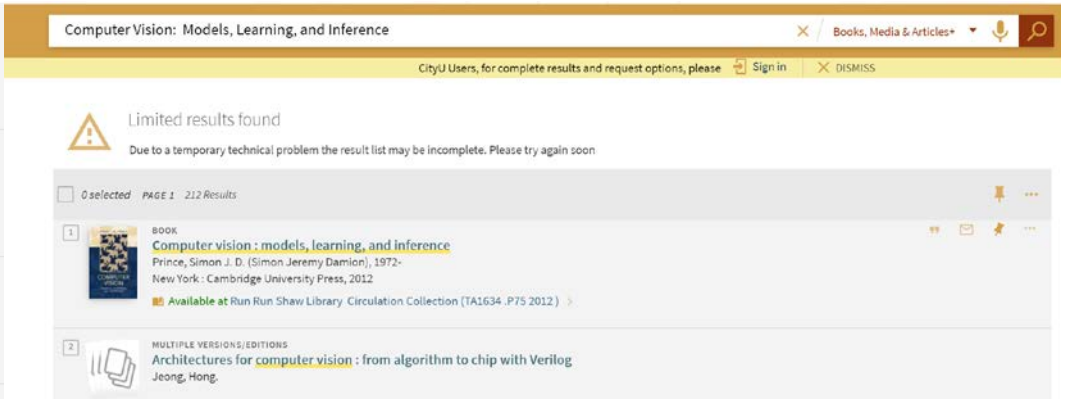
Classroom Rules

- Attendance
  - Class attendance is required and you are responsible for any materials or announcements.
- No talking during lectures
- Temporarily leaving classroom
- Mobile phones
- Foods/drinks
- HW hand-in/out via Canvas NOW

Reference

- Digital image processing (www.ImageProcessingPlace.com)
- Computer Vision: Models, Learning, and Inference (http://www.computervisionmodels.com/)
- Books (CityU library)





Couse content

- Image Processing is the study of any algorithm that takes an image as input and returns a vector or image as output.
- Computer vision is an interdisciplinary scientific field that deals with how computers can be made to gain high-level understanding from digital images or videos.
- Main topics include:
  - Image editing and manipulation (Meitu app)
  - Image enhancement
  - Image segmentation
  - Object detection in images
  - Face recognition

Schedules

Week	Date	Topics
1	Sep. 4	Introduction/Imaging
2	Sep. 11	Image enhancement in spatial domain
3	Sep. 18	Image enhancement in frequency domain (HW1 out)
4	Sep. 25	Morphological processing
5	Oct. 2	Image restoration(HW1 due)
6	Oct. 9	Image restoration
7	Oct. 16	Midterm (no tutorials this week)
8	Oct. 23	Edge detection (HW2 out, illustrate the project)
9	Oct. 30	Image segmentation (HW2 due)
10	Nov. 6	Face recognition with PCA, LDA (tutorial on deep learning framework)
11	Nov. 13	Face recognition based on deep learning Image segmentation based on deep learning (tutorial on coding)
12	Nov. 20	Object detection with traditional methods (Quiz) Object detection based on deep learning
13	Nov. 27	Project presentation
14	Dec. 4	Review and Summary

Evaluation

- Course grades
  - 2 Homework assignments (15%)
  - 1 Quiz (10%)
  - 1 Midterm (20%)
  - 1 Project (20%)
  - Final exam (35%)

- Remarks:
  - By university regulation, to pass the course, students are required to achieve at least 30% in course work and 30% in the examination.
  - Attend at least two course work, including homework assignments and quiz.

Homework

- Two HWs will be assigned
- HW will be distributed and submitted via Canvas
- Late HW will be subject to 50% deduction
- It will include calculation and coding

Quiz, Midterm Test and Final Exam

- Open-books (in the recent situation)
- Open-notes
- Durations:
  - 1 hour for quiz
  - 2 hours for midterm test
  - 2 hours for final exam
- Needed formulas will be provided
- Regular calculator is allowed

Project

- 3-4 students form a group
- Focused on one task (challenges, kaggle, will specify later)
- Related to our course (segmentation, detection, classification, recognition)
- Apply state-of-the-art models or develop novel models to deal with specific tasks
  - 10 mins presentation+5 mins Q&A (Judged by me and whole students)
  - One report per-group (specify your role), Target to publish a paper

Cheating/plagiarize

- Copying your classmate's assignments or programs, is a very serious offense! If you are found cheating, you will automatically get a F grade in this course and your act will be reported to the Department for necessary disciplinary actions.

- Please don't let others copy your assignments or programs as we don't have a way to tell who is copying who and you may be liable to the penalties.

- Paper writing examples.

EE4211
Computer Vision

An important and useful course for engineers

Image enhancement

Image restoration

Image segmentation

Object detection

Outline

- Course overview
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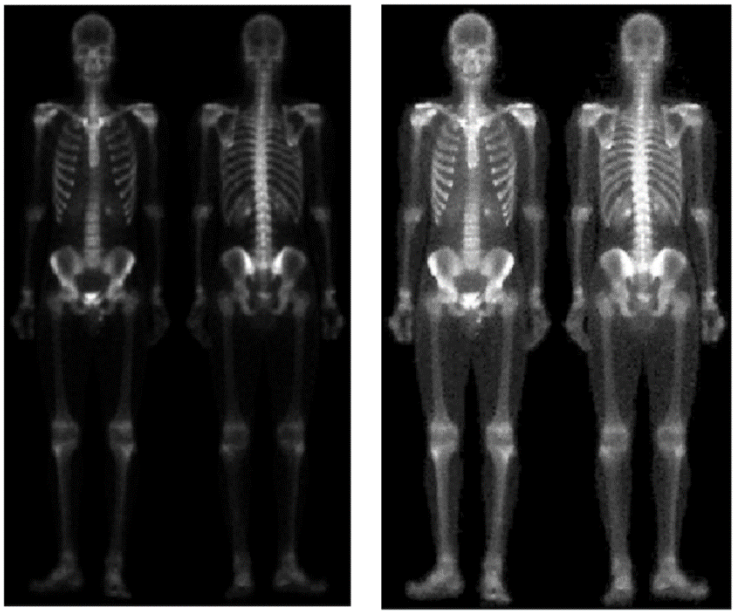
Image Enhancement

- Image enhancement: adjust digital images to make them more suitable for display or further processing.
- Image enhancement methods:
  - Spatial domain: direct manipulation of pixels in an image
  - Frequency domain: modify the Fourier transform of an image
  - Combination of these two categories

Image Enhancement

- Spatial domain: direct manipulation of pixels in an image (Lecture 2)



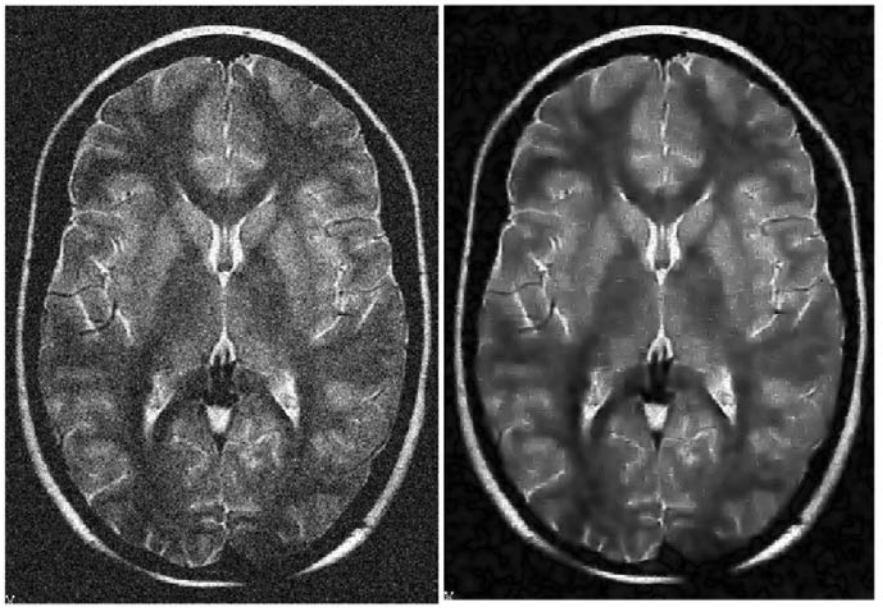
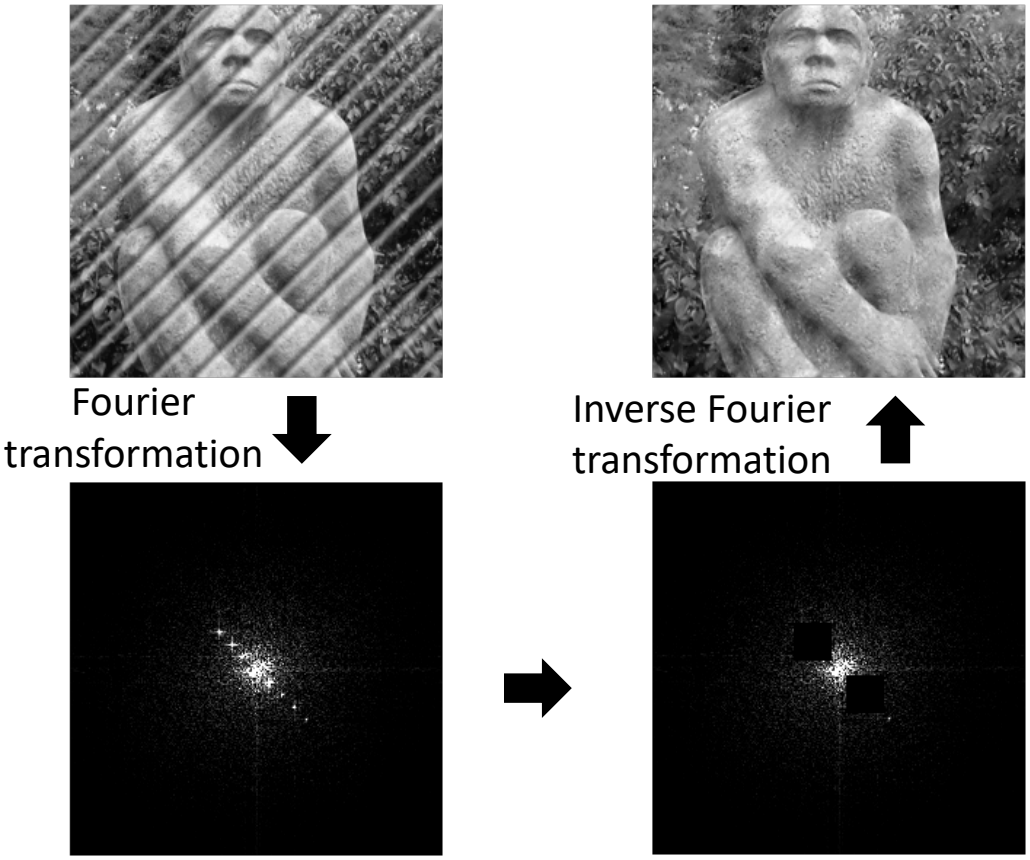


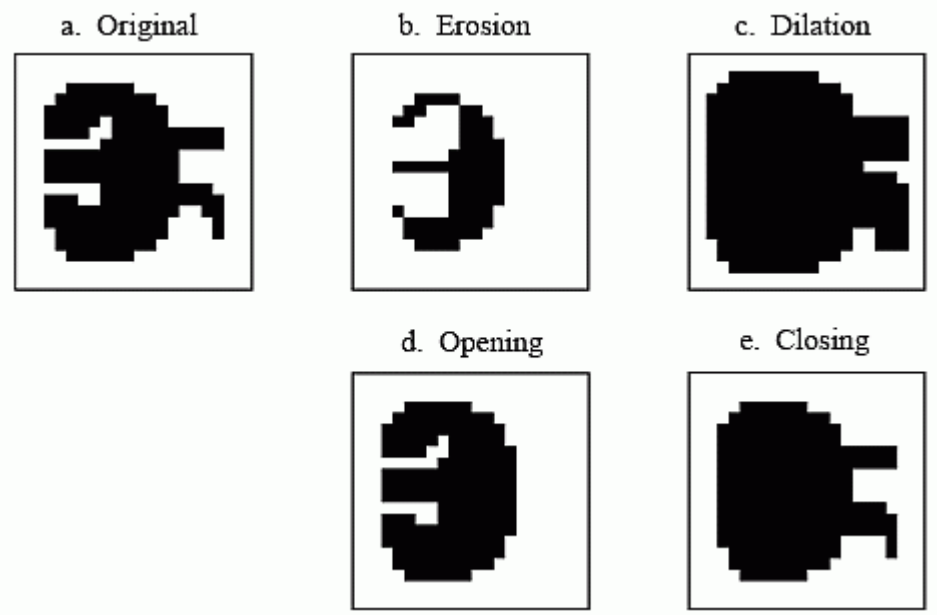
Image Enhancement

- Frequency domain: modify the Fourier transform of an image
- Combination of these two categories (Lecture 3)



Morphological processing

- The value of each pixel in the output image is based on a comparison of the corresponding pixel with its neighbors.
- By choosing the size and shape of the neighborhood, you can construct a morphological operation. (Lecture4)



Morphological processing

- Erosion (侵蝕): erodes away the boundaries of foreground object.
- Dilation (擴張): It is just opposite of erosion.

Original image

erosion

dilation

Morphological processing

- Opening: erosion followed by dilation, useful in removing noise.
- Closing: reverse of Opening, useful in closing small holes inside the foreground objects, or small black points on the object.

Open

Closing

Image Restoration

- To restore a degraded image to its original form (Lecture6)
- Similar to image enhancement, but more objective
- Identify the degradation process and attempt to reverse it
- Try to model the previous noise and remove it

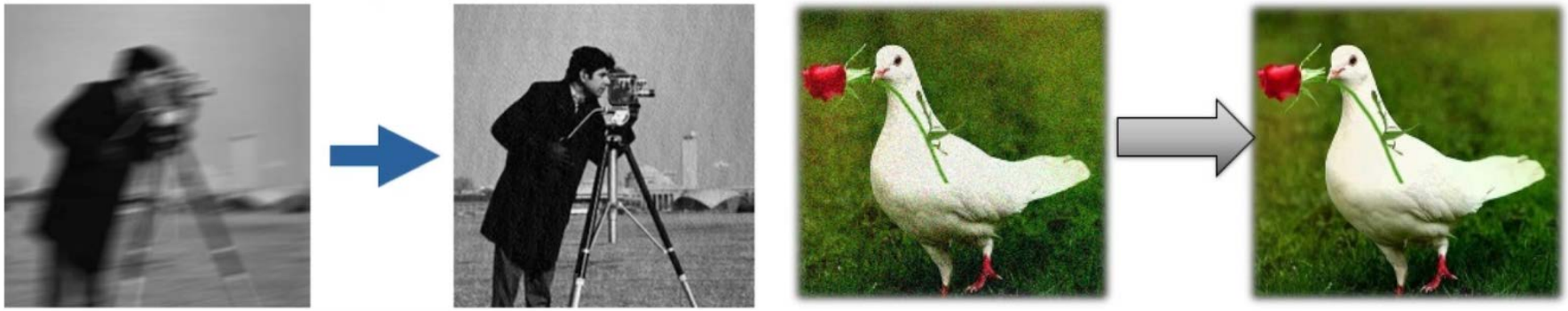
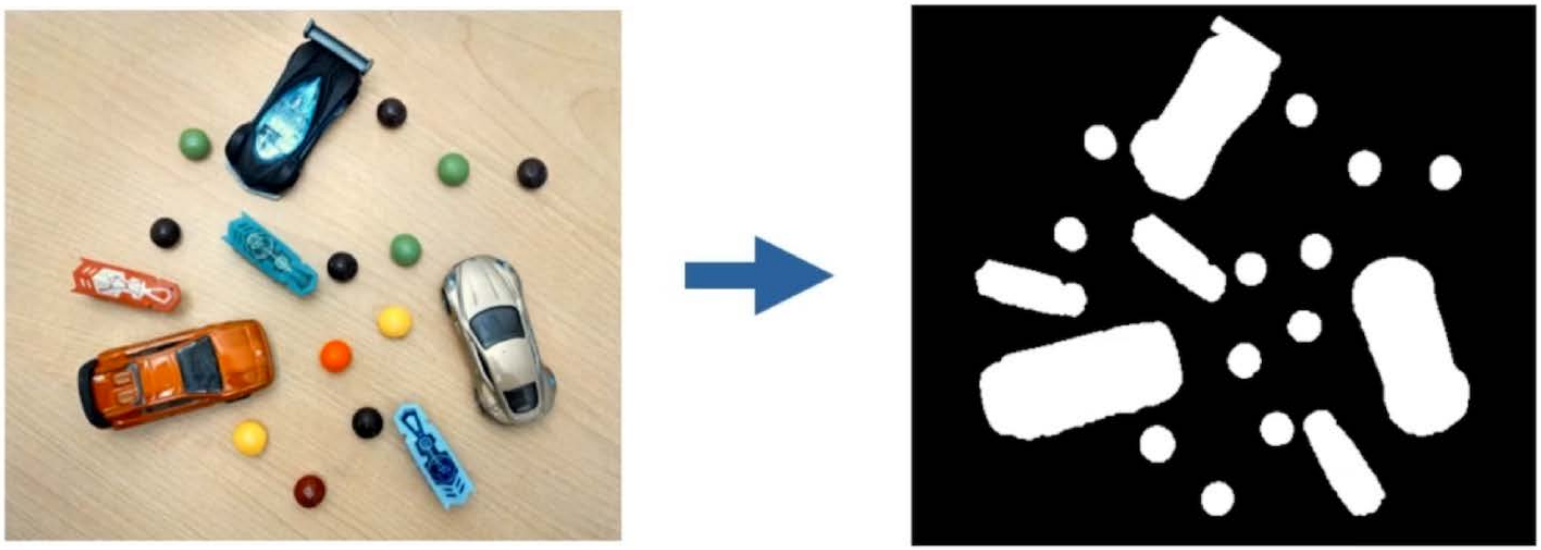


Image Segmentation

- Image segmentation: divide an image into multiple parts. This is typically used to identify objects and other relevant information within an image.

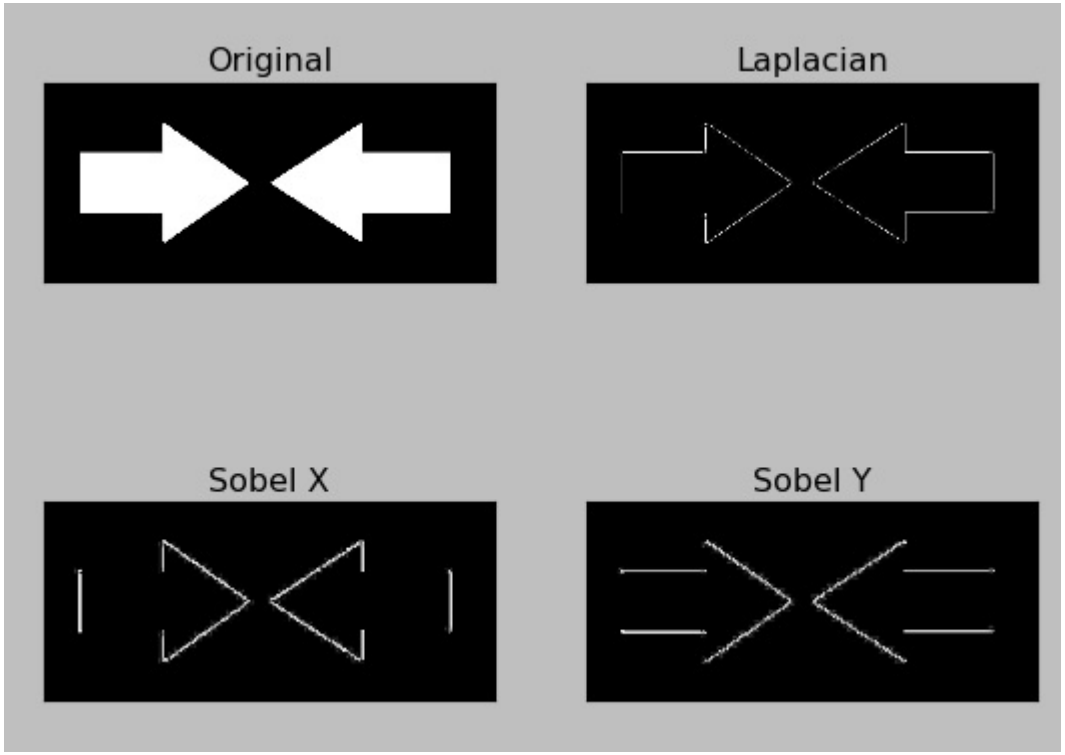


Edge detection

- Edge detection is the process of detecting the boundary of two regions. (Lecture8)

Edge detection

- Gradient change



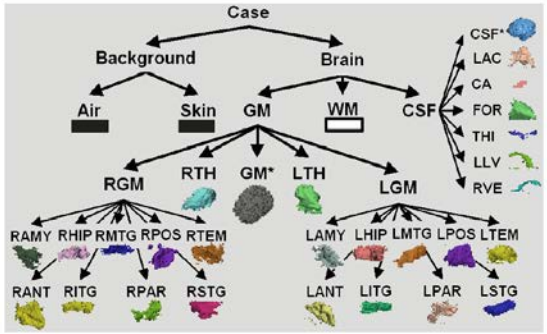
0	-1	0
-1	4	-1
0	-1	0

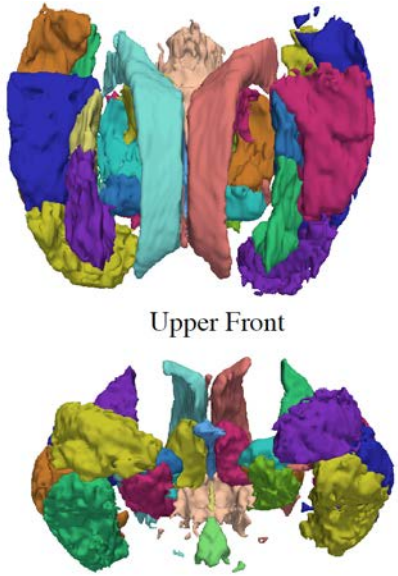
Image Segmentation

- Segmentation are based on one of two basic properties of gray scale values. (Lecture9)
  - Discontinuity: to partition an image based on abrupt changes in intensity.
  - Similarity: to partition an image into regions that are similar according to a set of predefined criteria.

Image Segmentation

- Medical image segmentation
  - To discover the brain structure information
  - To provide treatment planning (radiotherapy and chemotherapy)





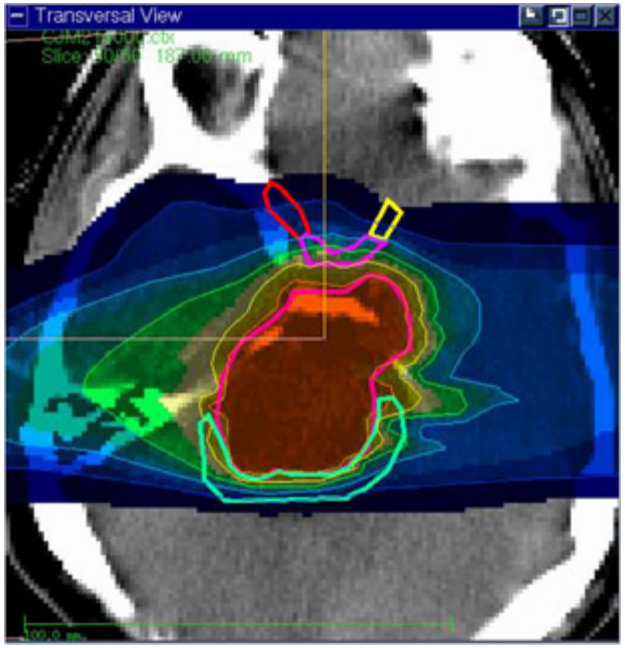
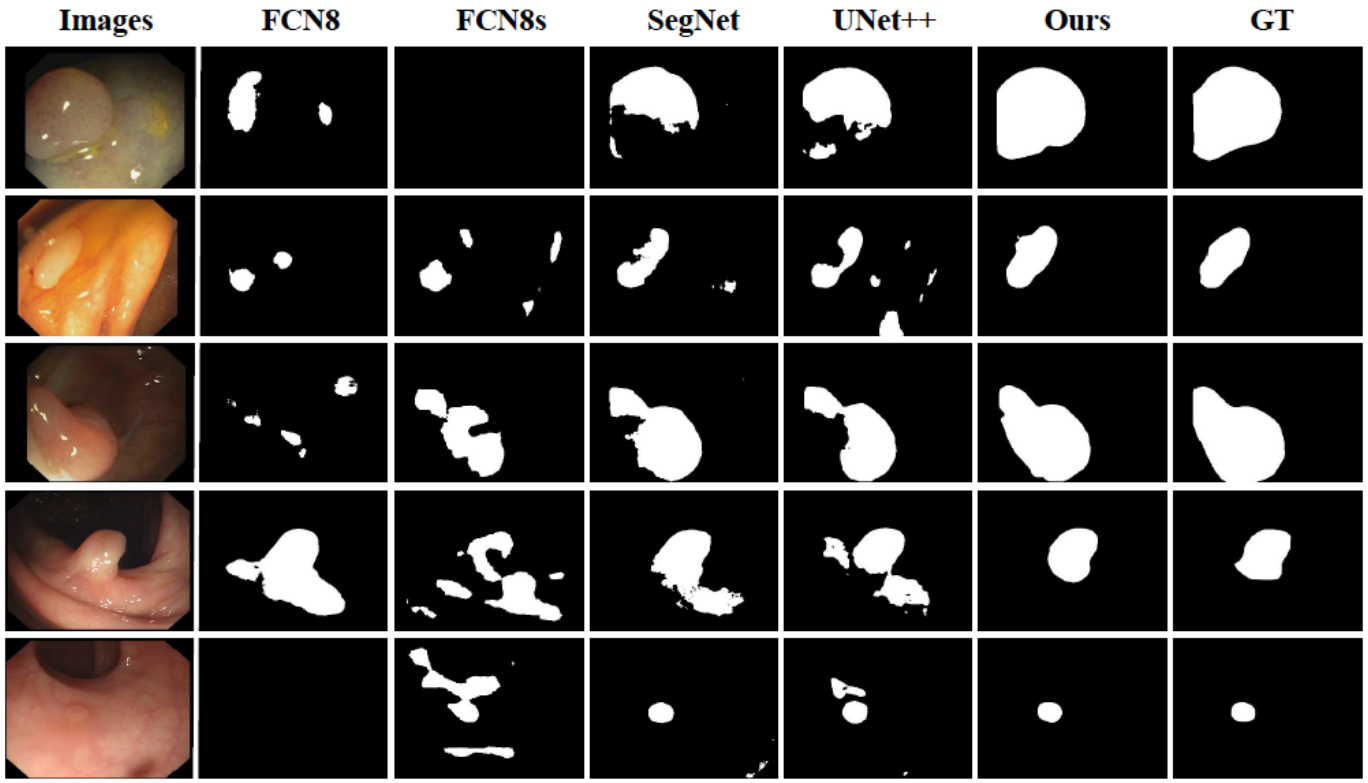


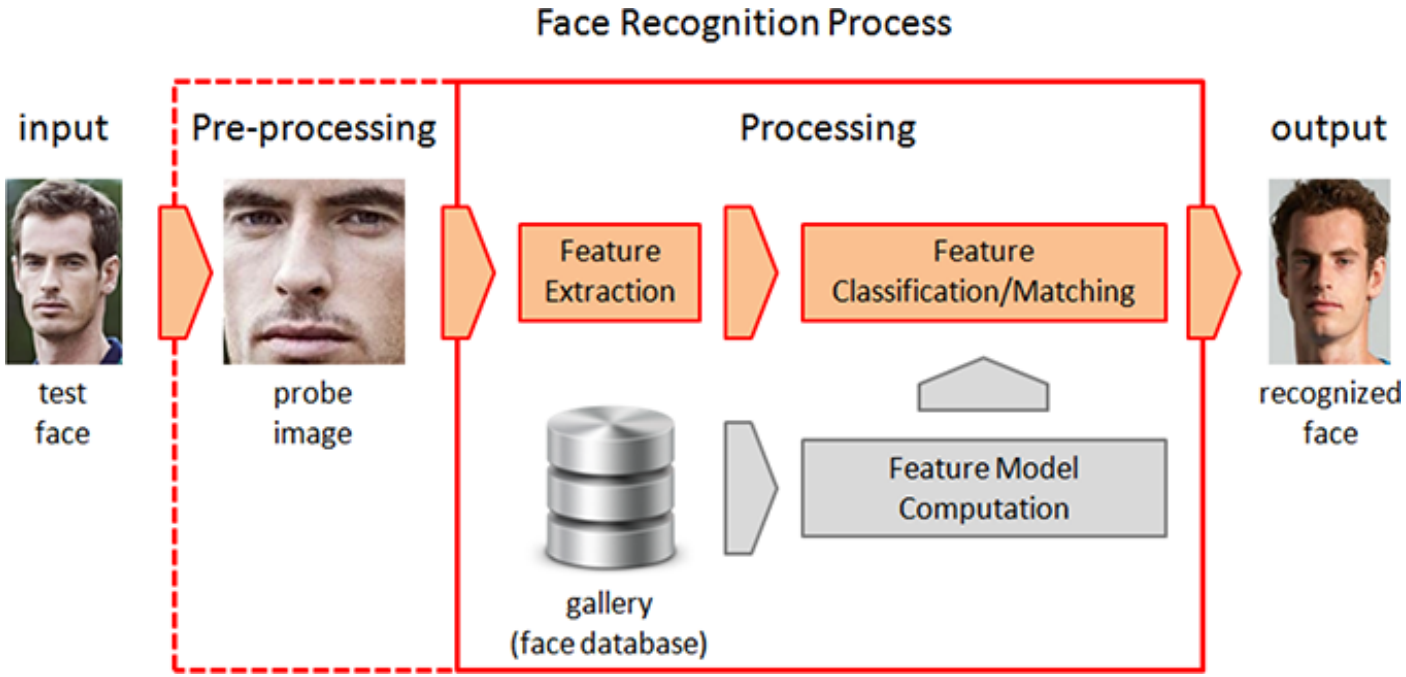
Image Segmentation

- Medical image segmentation



Face recognition

- To identify or verify a person from a digital image or a video frame from a video source. (Lecture10)
- Multiple methods in which facial recognition systems work. But in general, they work by comparing selected facial features from given image with faces within a databa.se

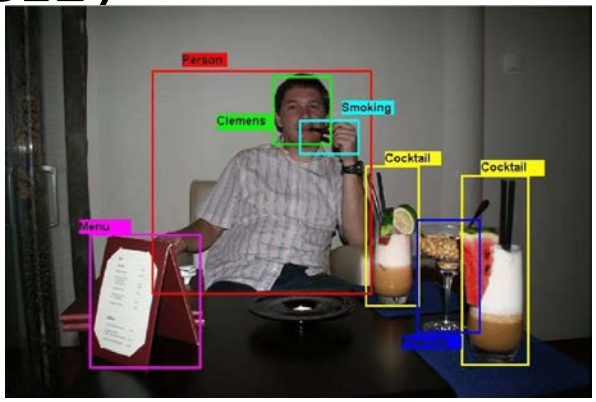


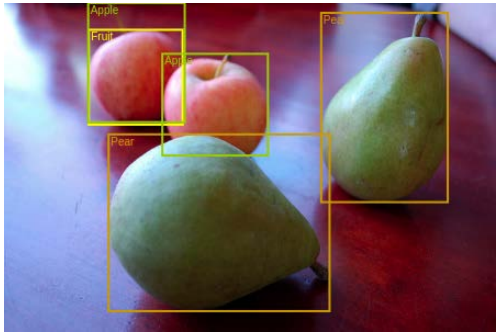
Face recognition

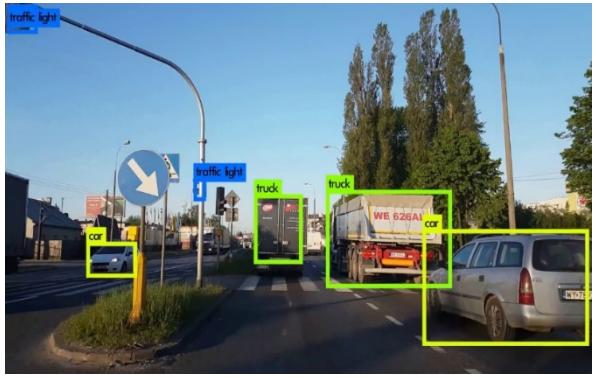
- Examples:
  - China Customs in Luo Hu
  - Detect criminals in Zhang Xueyou's vocal concert

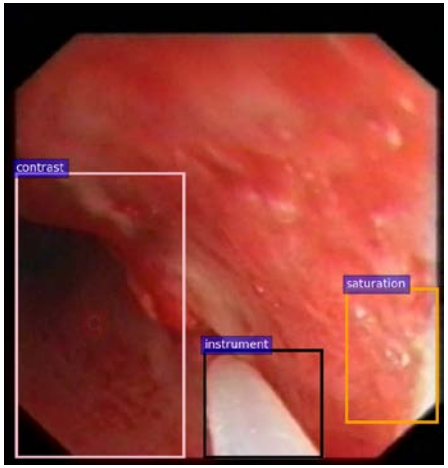
Object detection

- Examples: Self-driving automobile, abnormality detection (Lecture12)









Course Learning Outcomes

- Students are able to apply the basic image processing or computer vision principles and tools on how to manipulate digital images.
- Students are able to apply digital image processing or computer vision techniques on solving practical problems of commercial and scientific interests by implementing algorithms in Matlab/Python.

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Two Questions of this course

- **Where do digital images come from?**
  - Gamma Ray
  - X-Ray
  - Ultra-Violet light
  - Visible light
  - Infra Red, etc
- Course content

Sources of Image Data

- Normally images are formed from electromagnetic (EM) wave.
- Humans are able to see images from the visual spectrum.
- Machines can see images generated by sources that humans are not capable to see, such as infra-red (IR), ultra-sound.

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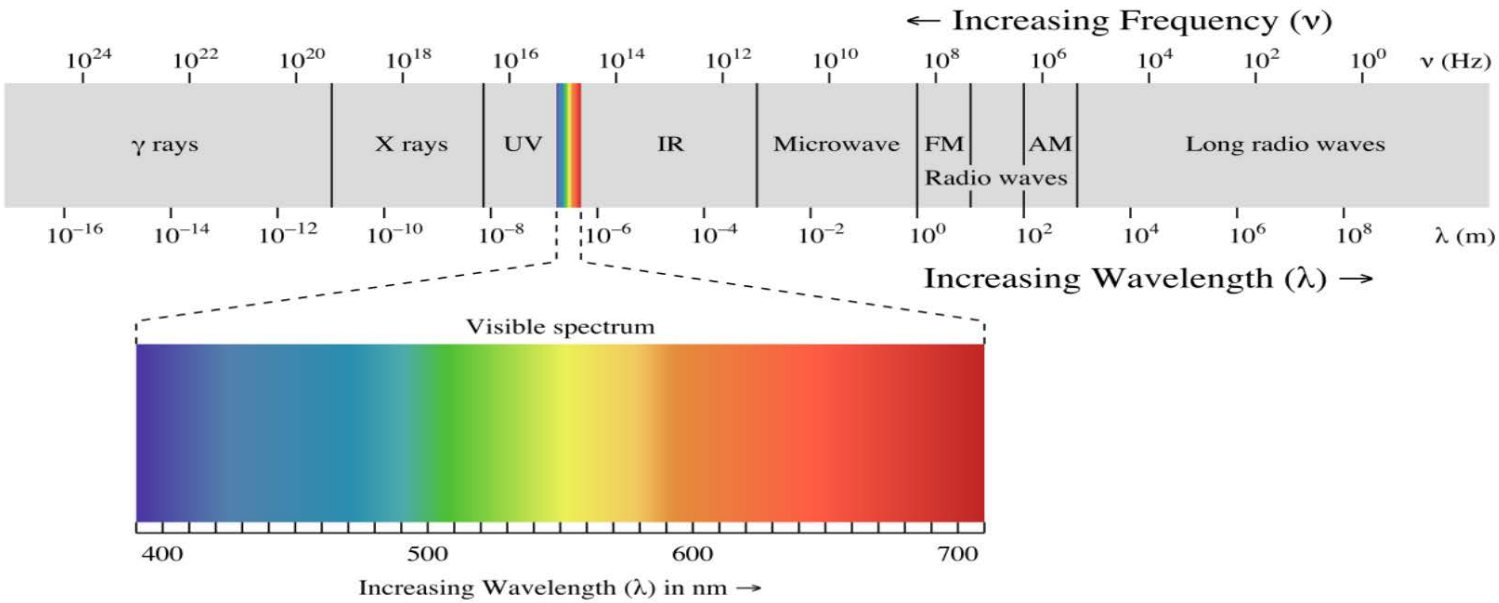
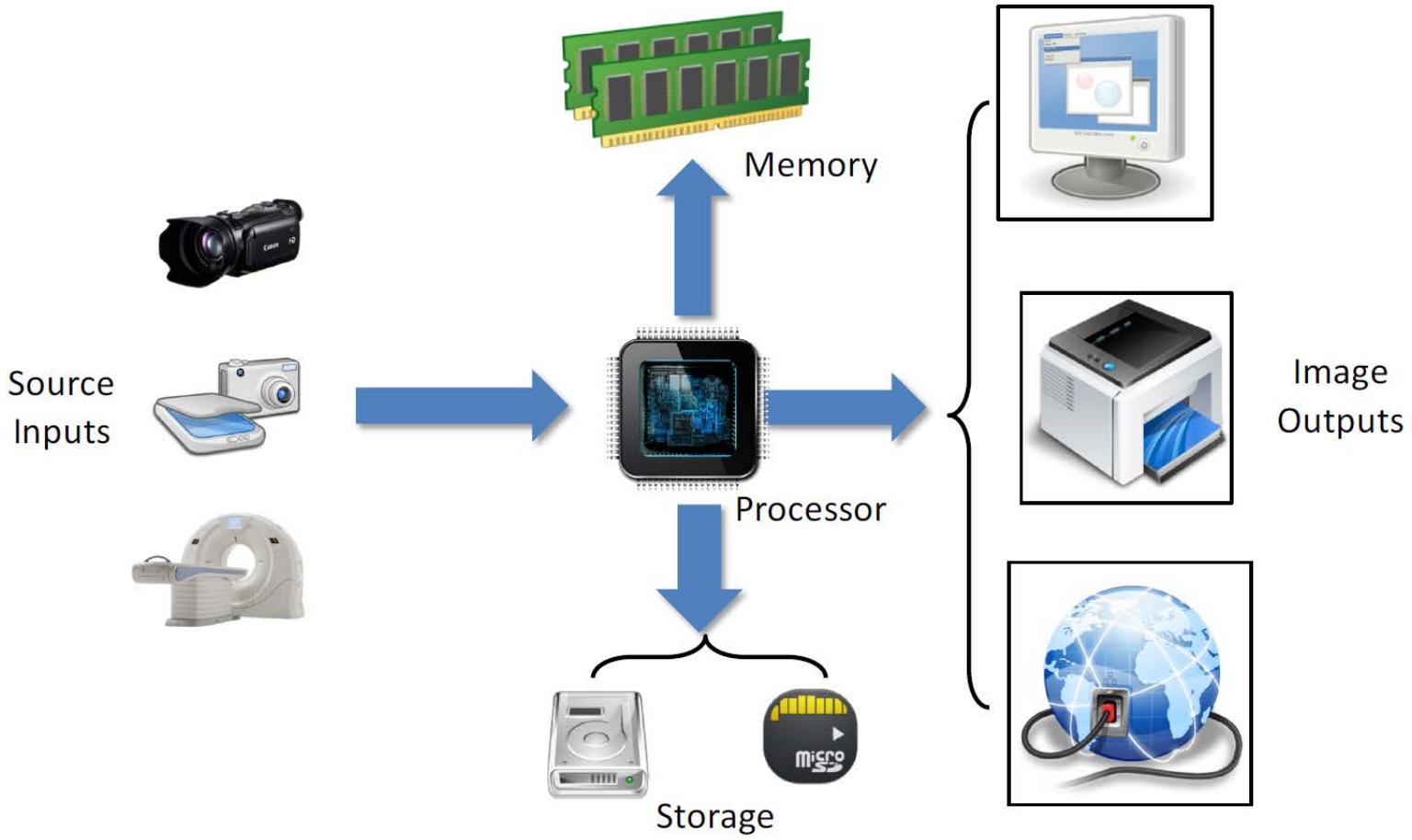
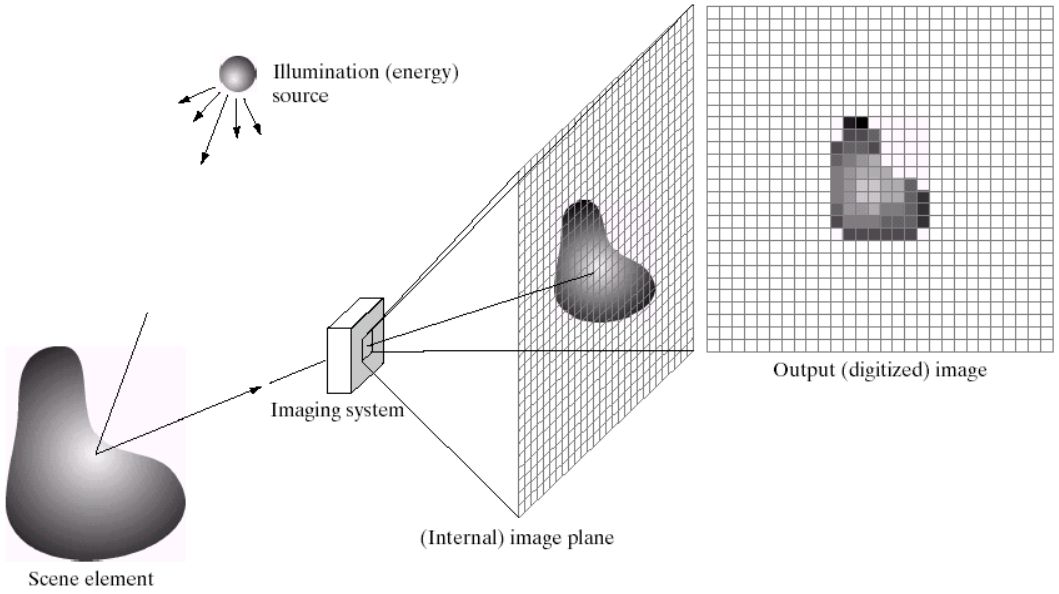


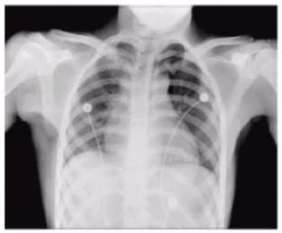
Image Processing System

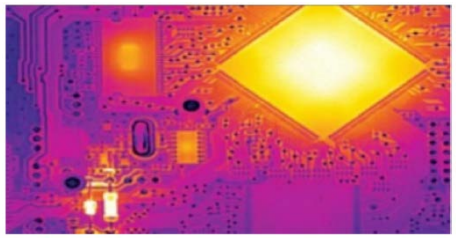


How to Visualize Light

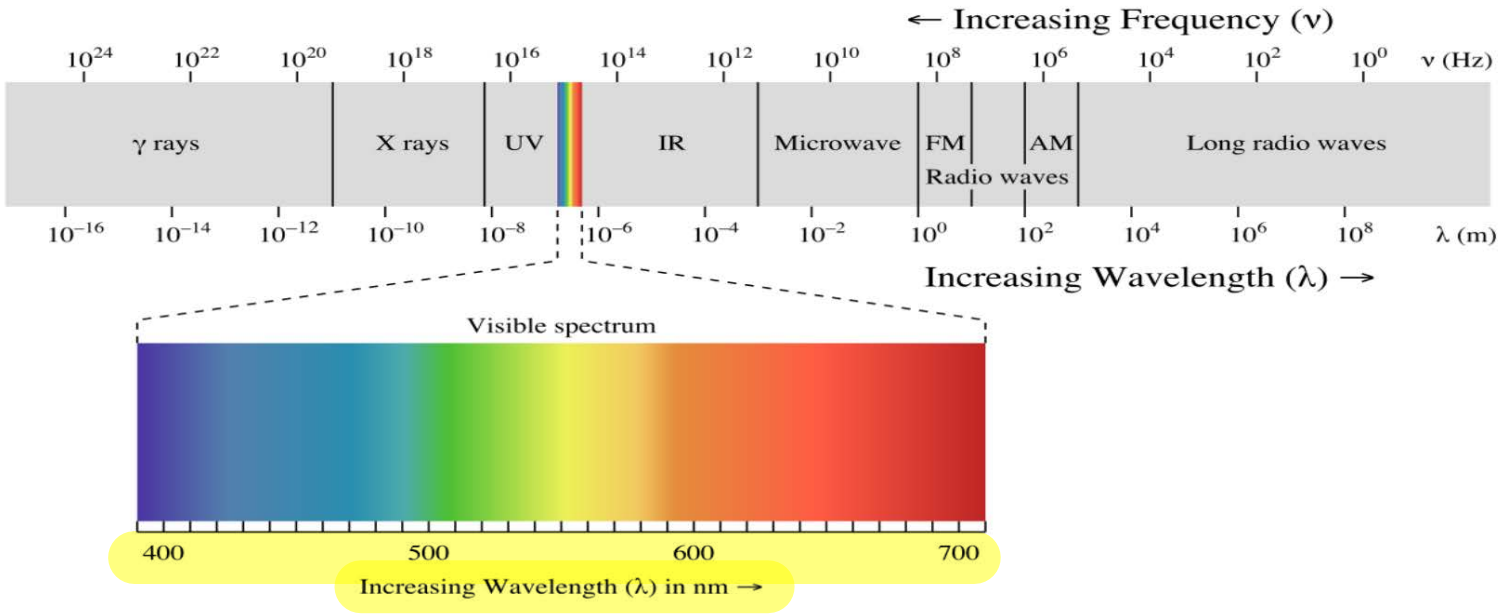
- **Reflected light**
  - Photographic images, …
- **Absorbed light**
  - X-ray image, …
- **Emitted light**
  - Infrared image, …





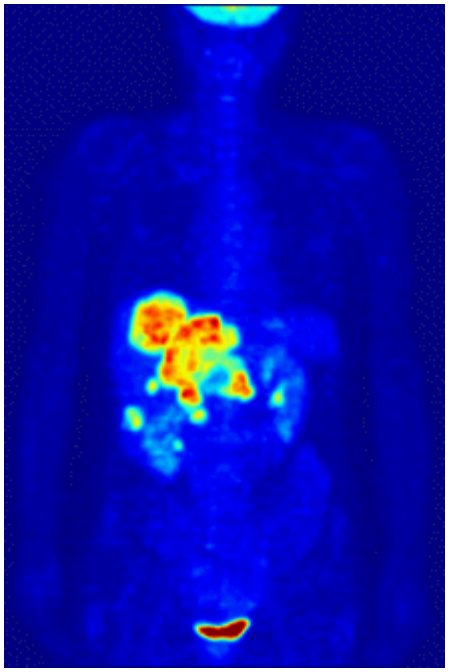


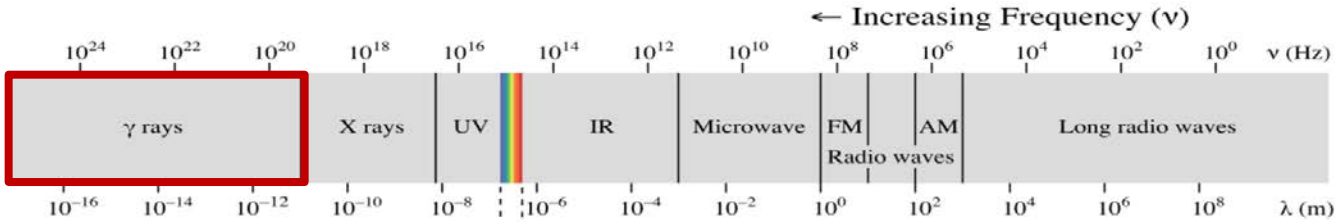
Different Imaging System



Gamma Ray Imaging

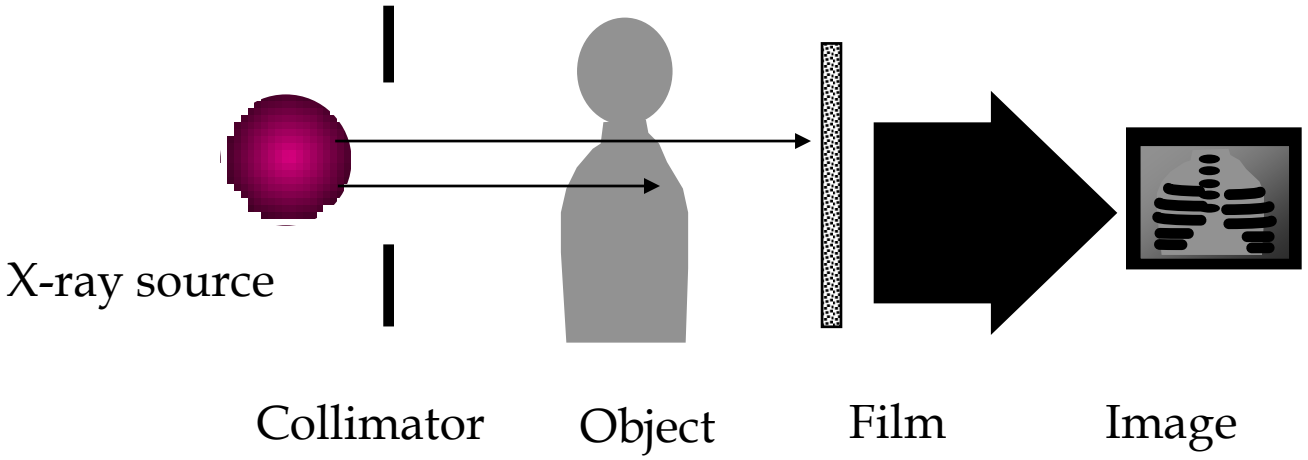
- Positron-emission tomography (PET):
  - Inject patient with isotope (同位素)
  - detects pairs of gamma rays emitted indirectly by a positron-emitting radionuclide
  - Show the structure and functional information of organs

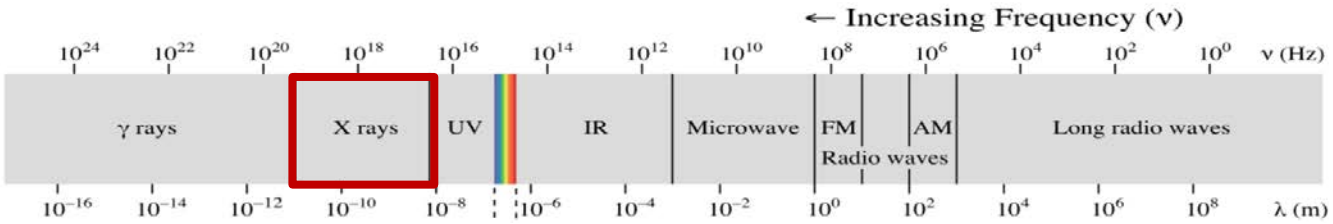




X-Ray Imaging

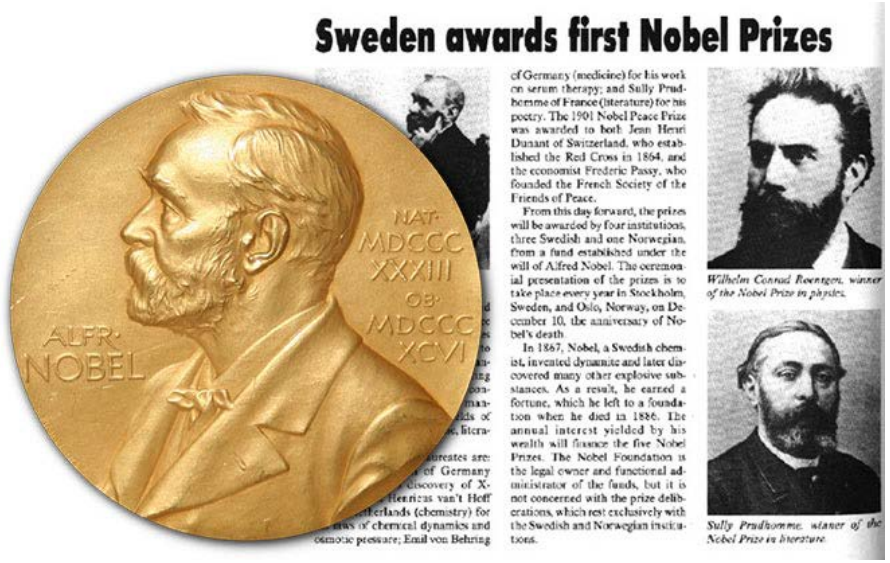
- X-rays are electromagnetic radiation
- X rays have a strong energy
  - Bone: High density, absolve more X-rays, show bright in images
  - Lung: less density, absolve less X-rays, show dark in images





X-Ray Imaging

- In 1895, while experimenting with cathode rays, physics professor Röntgen, asked his wife to set her hand on a photographic plate.



Sweden awards first Nobel Prizes

of Germany (medicine) for his work on serum therapy; and Sully Prudhomme of France (literature) for his poetry. The 1901 Nobel Peace Prize was awarded to both Jean Henri Dunant of Switzerland, who established the Red Cross in 1864, and the economist Frederic Passy, who founded the French Society of the Friends of Peace.

From this day forward, the prizes will be awarded by four institutions, three Swedish and one Norwegian, from a fund established under the will of Alfred Nobel. The ceremonial presentation of the prizes is to take place every year in Stockholm, Sweden, and Oslo, Norway, on December 10, the anniversary of Nobel's death.

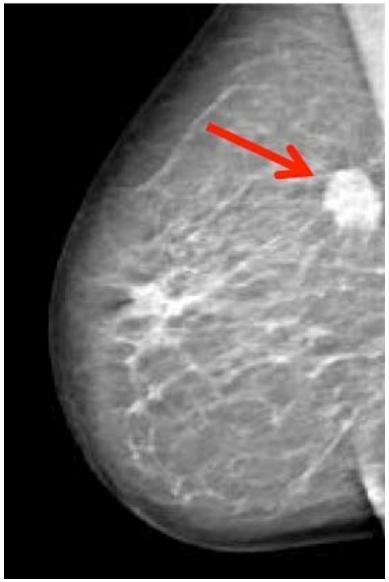
In 1867, Nobel, a Swedish chemist, invented dynamite and later discovered many other explosive substances. As a result, he earned a fortune, which he left to a foundation when he died in 1896. The annual interest yielded by his wealth will finance the five Nobel Prizes. The Nobel Foundation is the legal owner and functional administrator of the funds, but it is not concerned with the prize deliberations, which rest exclusively with the Swedish and Norwegian institutions.

Wilhelm Conrad Roentgen, winner of the Nobel Prize in physics.

Sully Prudhomme, winner of the Nobel Prize in literature.

Applications of X-Rays Imaging (1)

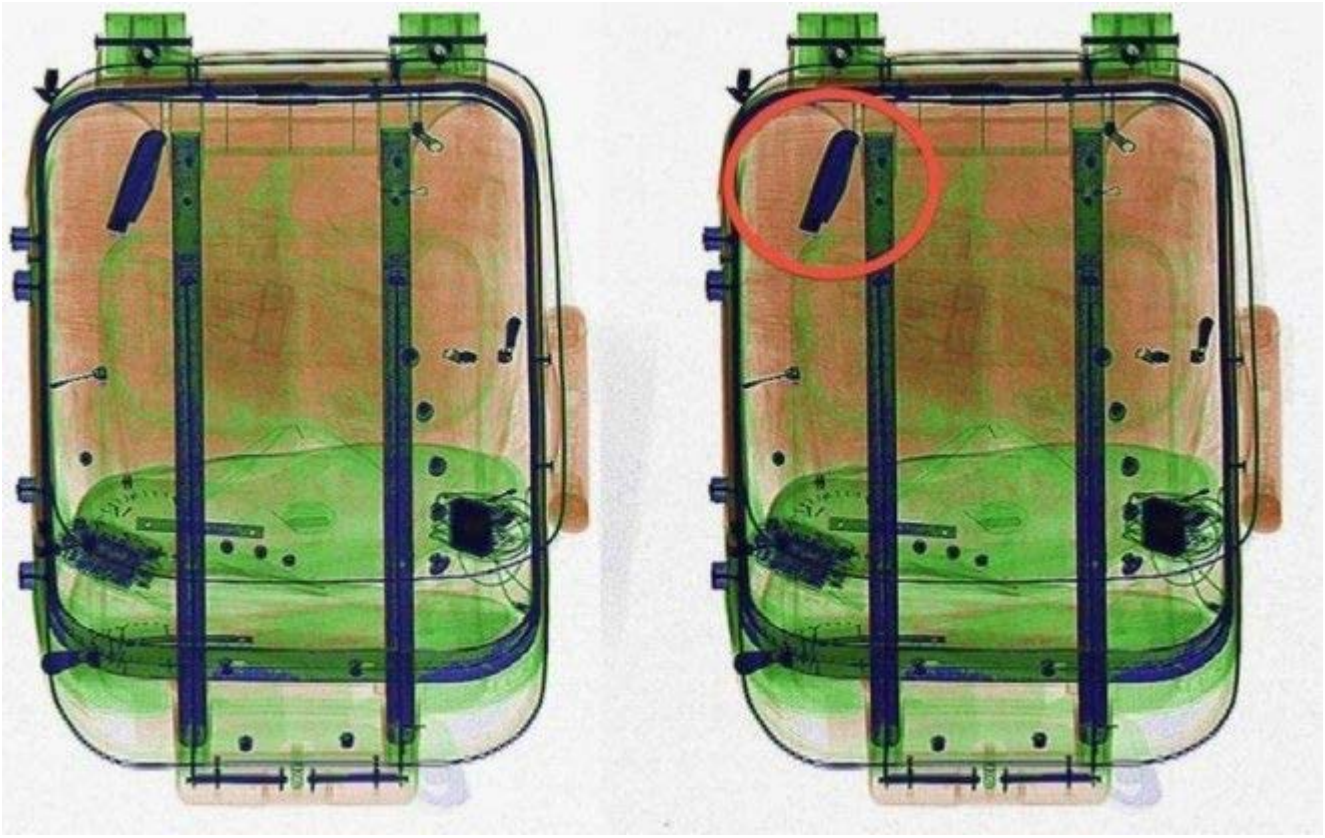
- Chest **x-**rays (Abnormalities in lungs, broken ribs)
- Mammography (Calcifications/abnormalities in breast tissues)
- Dental x-ray (Panoramagram, cavities, wisdom teeth)



The rib: higher density, absorb more X-ray information and show white in the image.

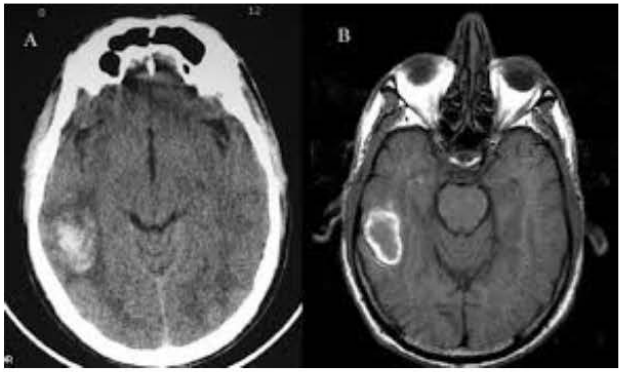
Applications of X-Rays Imaging (2)

- Airport security



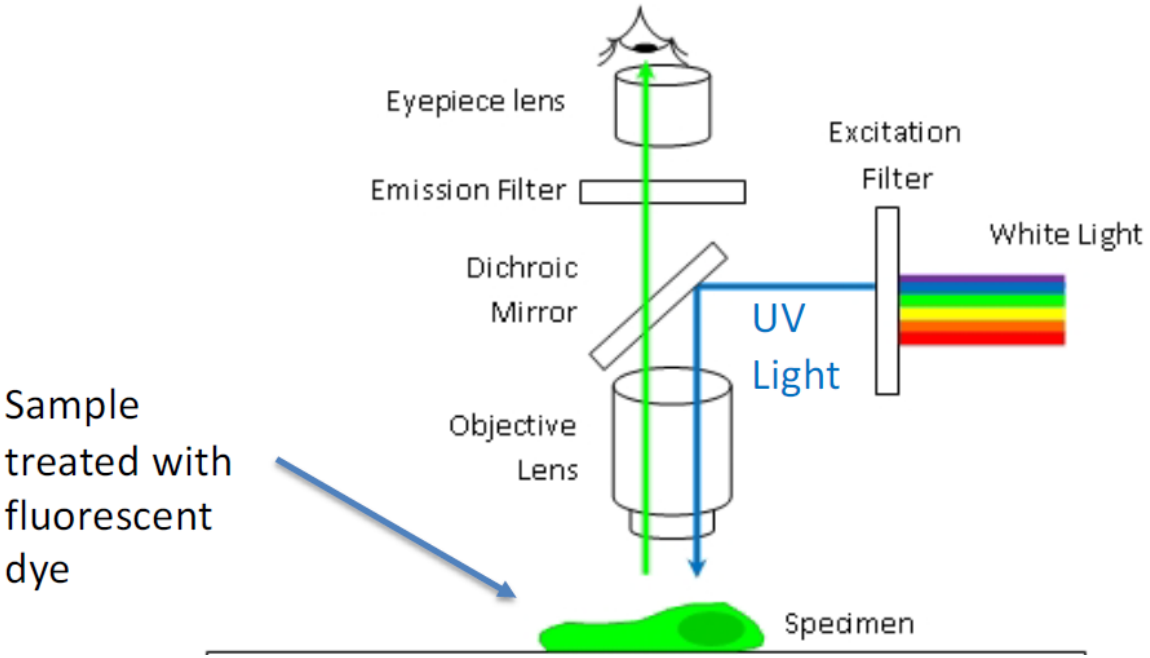
Applications of X-Rays Imaging (3)

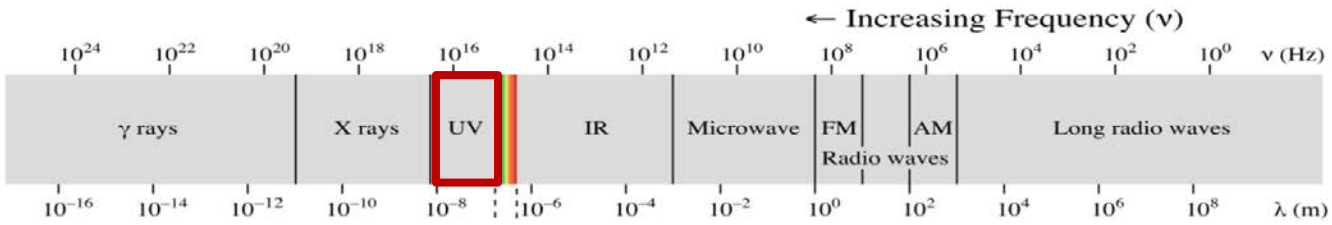
- Another important use of X-Rays is Computer Tomography (CT) scanning. It can create 3D image of object from many projections.



(紫外線) Ultraviolet Imaging

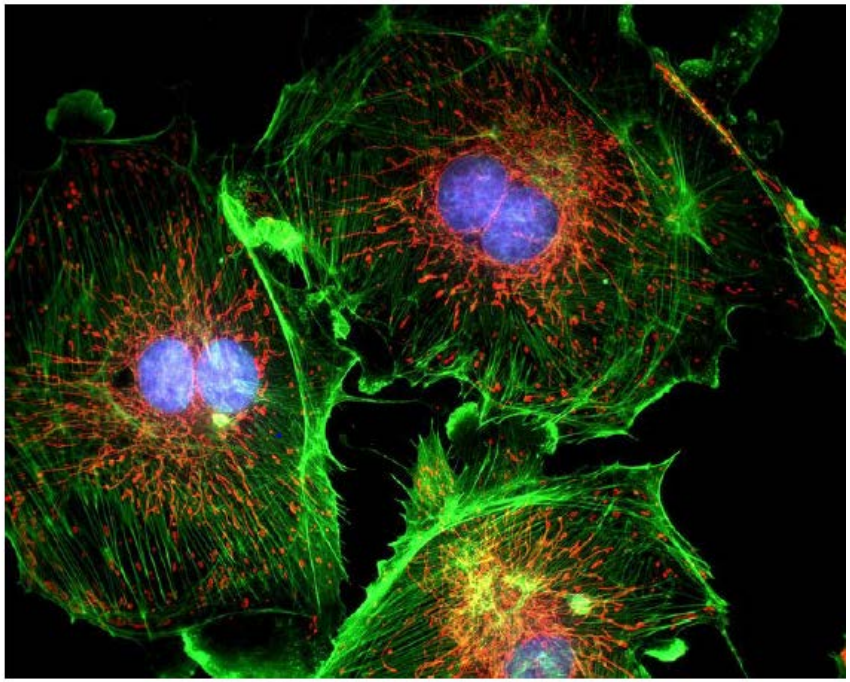
- Fluorescence Microscopy: use a much higher intensity light source which excites a fluorescent species in a sample.

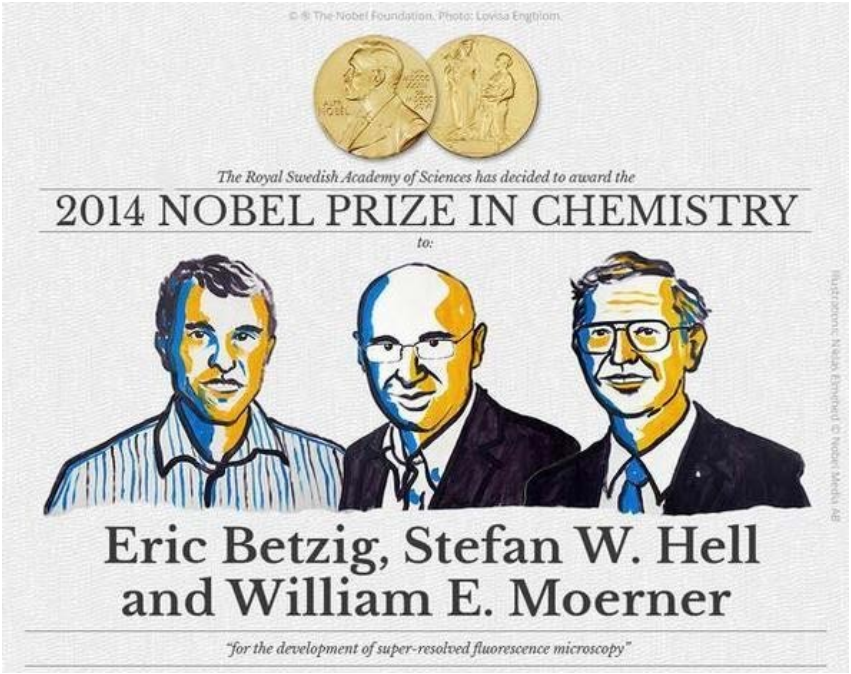




Ultraviolet Imaging

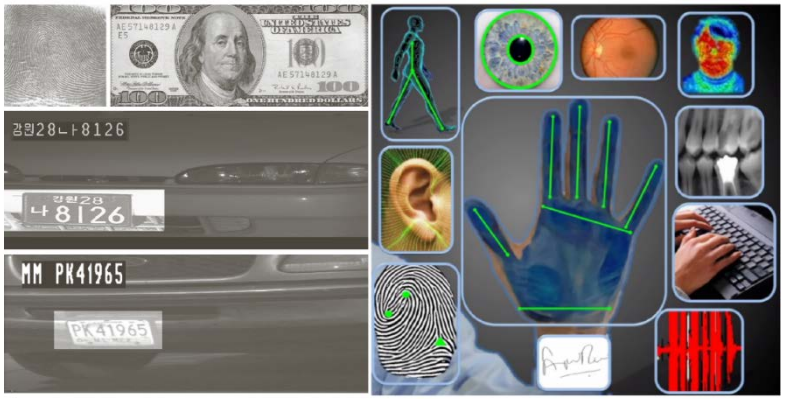
- Fluorescence Microscopy

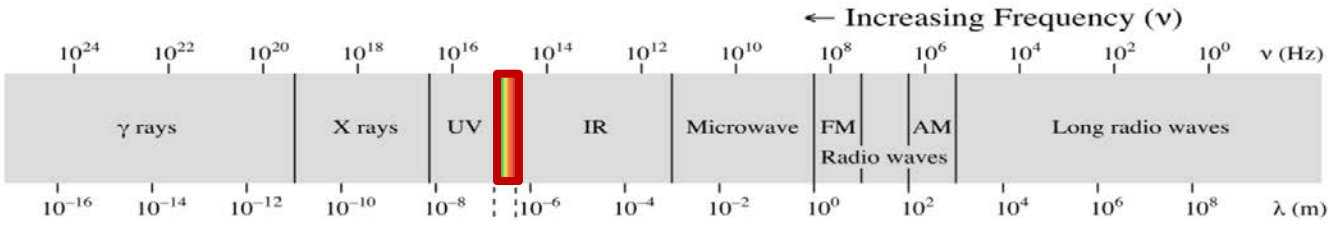




Visible-Band Imaging

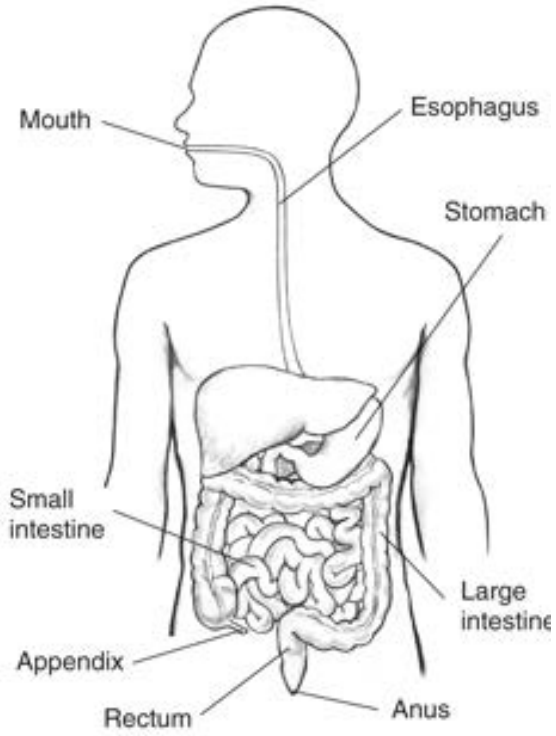
- Smartphones
- Consumer Digital Imaging
- Light Microscope
- Remote Sensing (Satellite)
- Manufacturing Inspection
- Spacecraft Imaging
- License Plate Recognition
- Biometrics

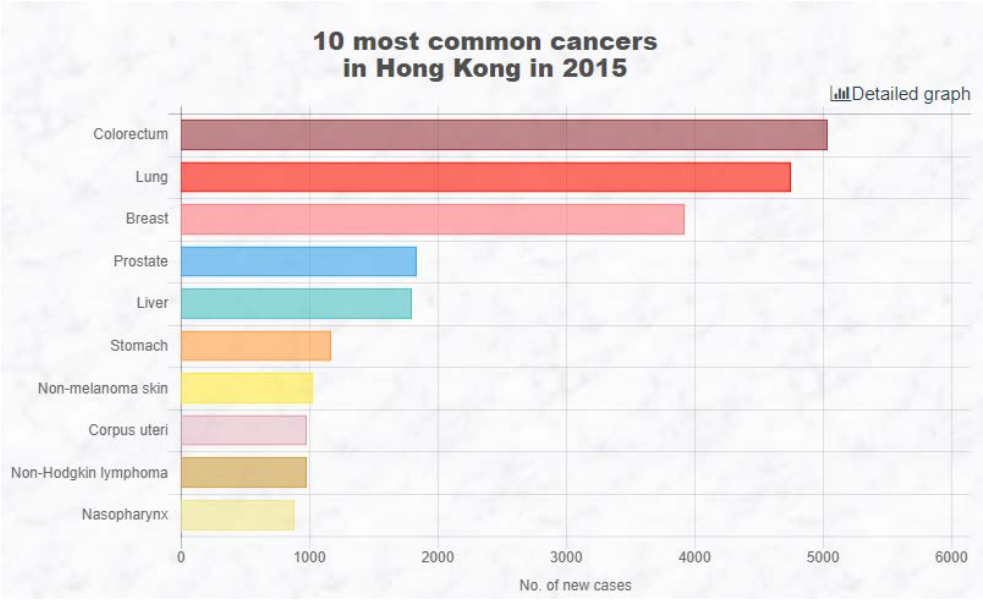




Visible-Band Imaging

- Importance
  - Gastrointestinal (GI) tract - 30 feet long structure
  - 1st common cancer





Visible-Band Imaging (endoscopy)

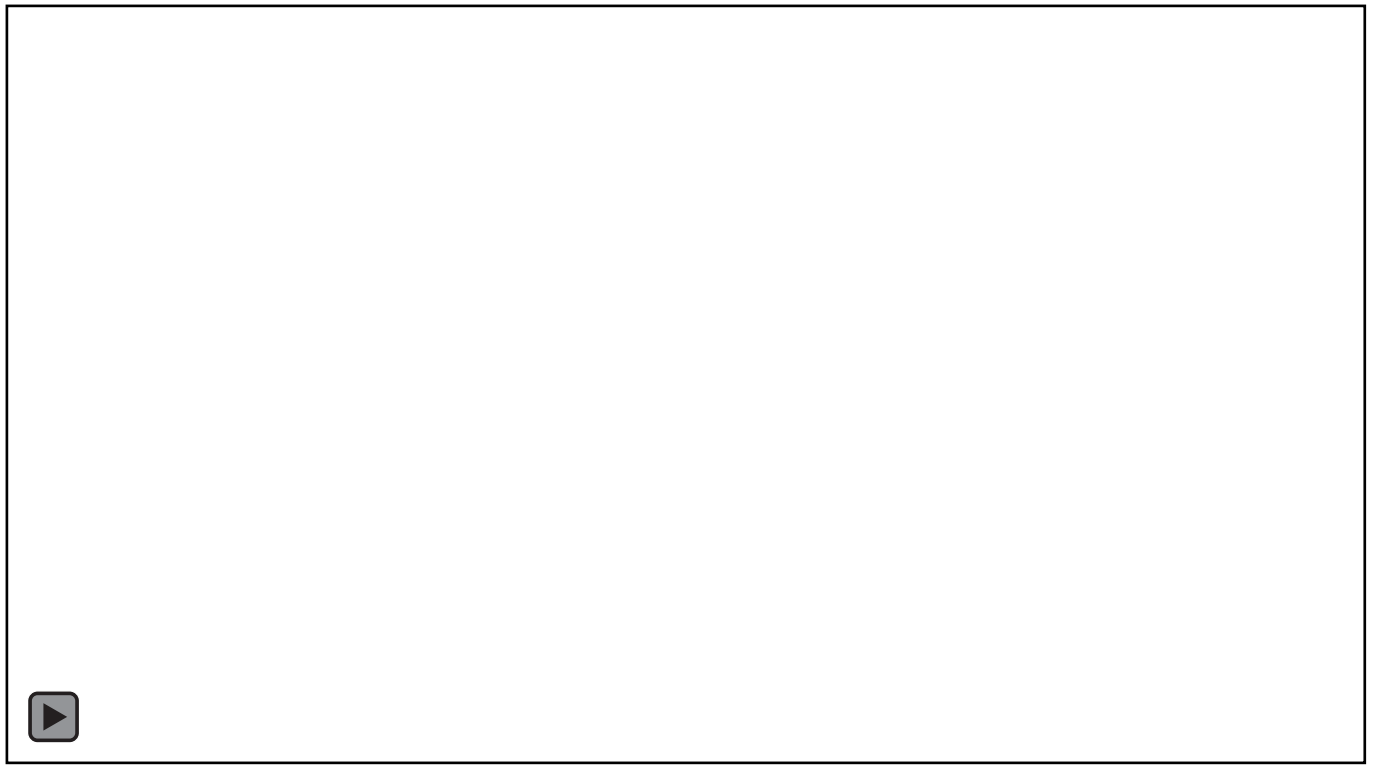
- Upper endoscopy (內窺鏡檢查)
  - visualizes the upper part of the GI tract up to the duodenom
    inserted directly into mouth
- Colonoscopy (結腸鏡檢查)
  - examination of the large bowl and the distal part of the small bowl passed through the anus
- Disadvantage
  - Invasive; Painful; Can't reach to small intestines

Visible-Band Imaging(WCE)

- Wireless capsule endoscopy
  - Introduced by Iddan et al. in 2000
  - Approved by the U.S Food & Drug Administration in 2001
  - 11x26mm

- Examination procedure
  - Swallowed by patients
  - Propelled by peristalsis
  - Send images to data-recording device
  - Downloaded for reviewing

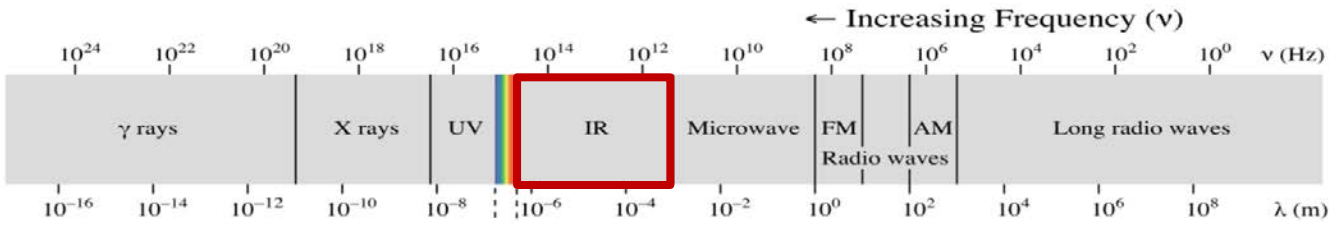
Visible-Band Imaging(WCE)



To automatically recognize abnormality for clinicians

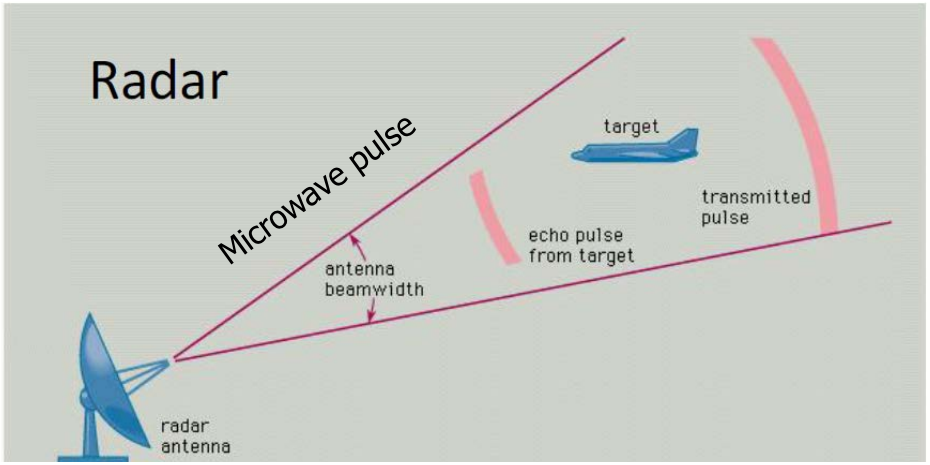
Infra-Red Imaging

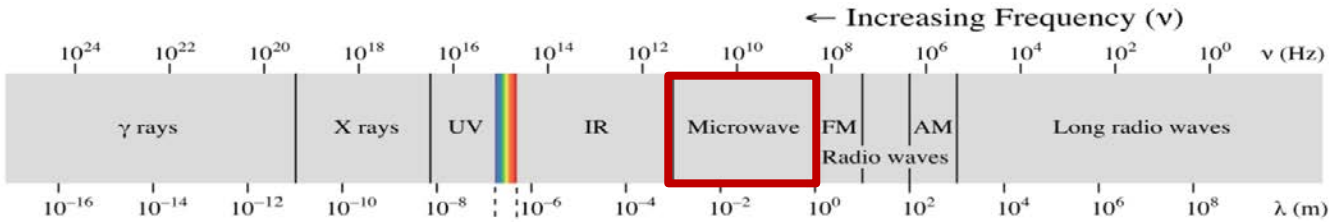
- Infrared radiation is emitted by all objects with a temperature above absolute zero.
- Thermography makes it possible to see one's environment with or without visible illumination.



Microwave Imaging

- Waves from the transmitter reflect off the object and return to the receiver, giving information about the object's location and speed.
- Bases on whether the pulses returns and the time they returns, you can infer what's up in the sky.

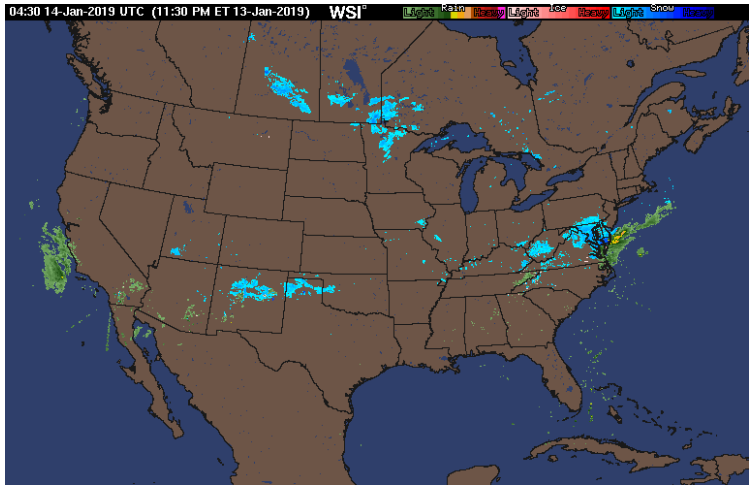


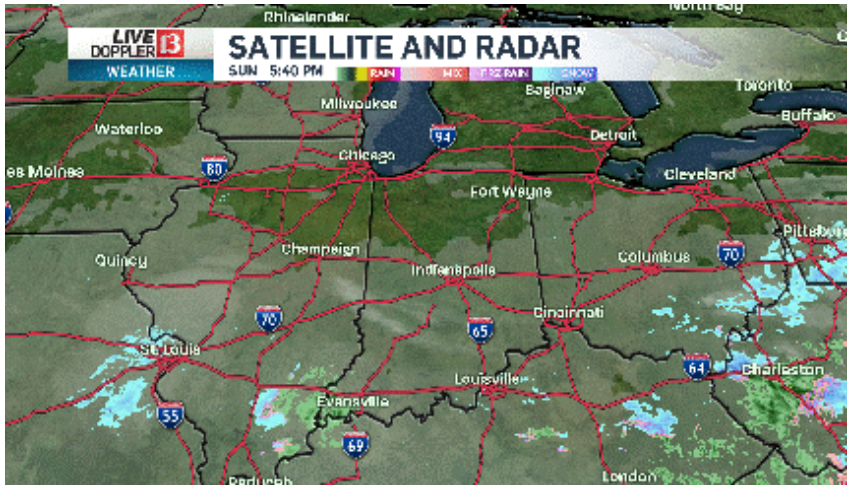


Microwave Imaging

降水

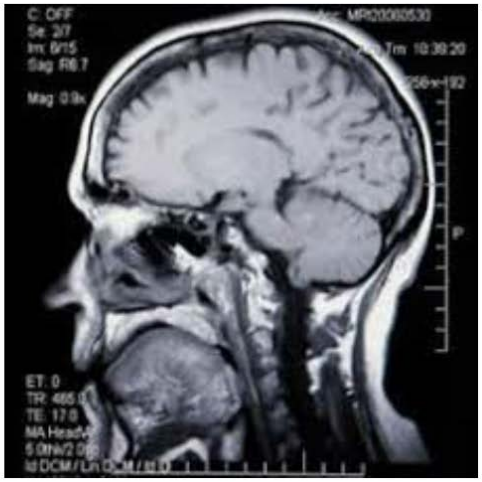
- A weather radar is used to locate precipitation, calculate its motion, estimate its type (rain, snow, hail, etc.), and forecast its future position and intensity.



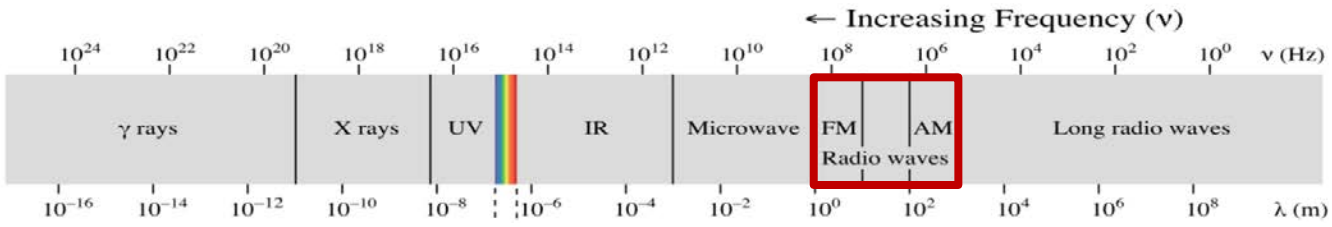


Radio-Band Imaging

- MRI (Magnetic Resonance Imaging): use strong magnetic fields, and radio waves to generate images of the organs.

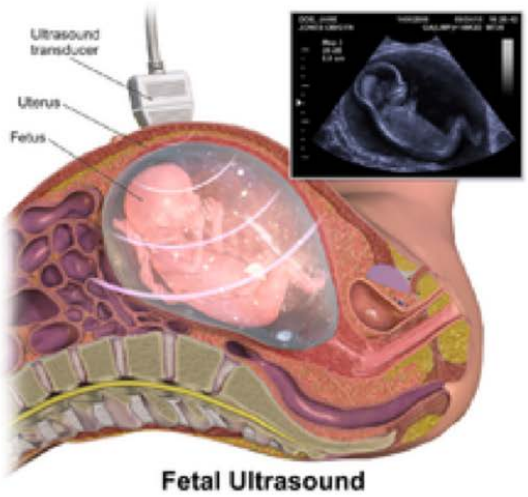


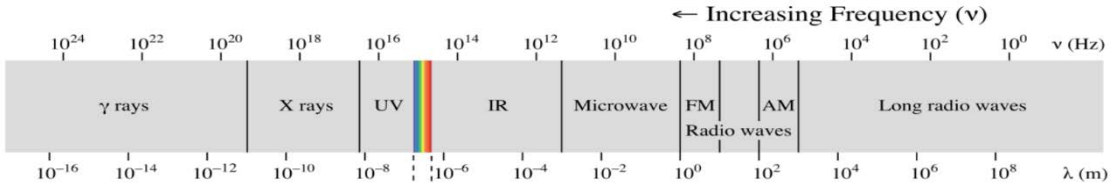
https://www.youtube.com/watch?v=kmfmGhI8l9E



Ultrasound Image (without photons)

- Ultrasound imaging: use sound waves to produce pictures of the inside of the body
- Safe, noninvasive, real time and does not use ionizing radiation

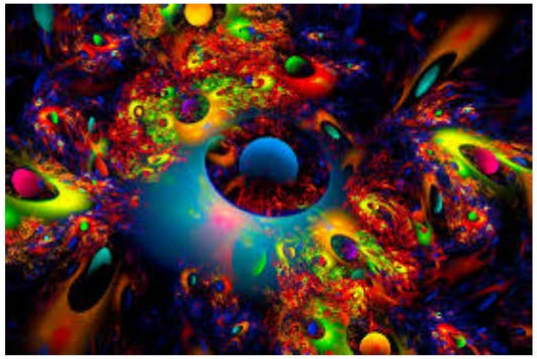


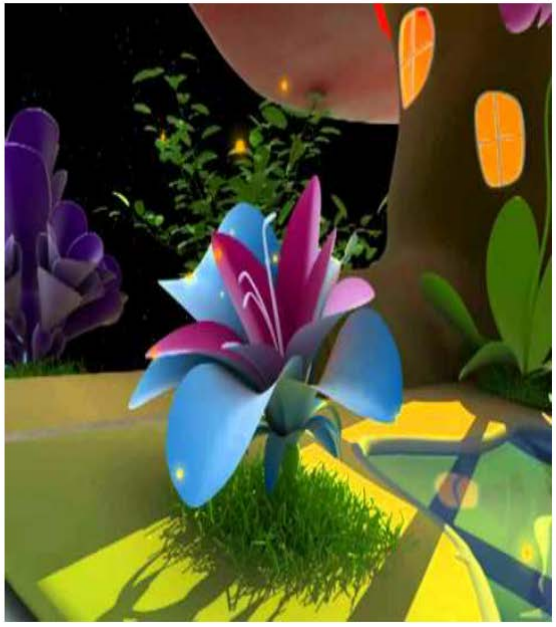


Computer Generated Images

- Very important to deal with limited data in real cases
- The GTA5 dataset has 24966 images that are rendered from the GTA5 game.
- Domain adaptation: Synthesized images->real images (autonomous vehicles)

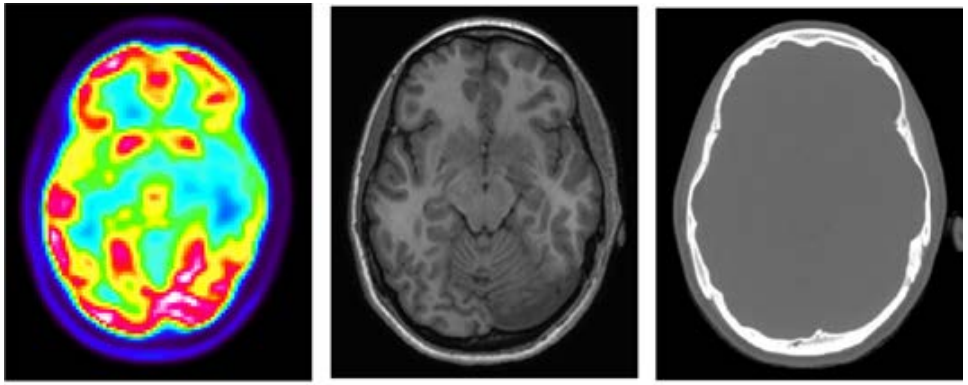
(合成圖像)



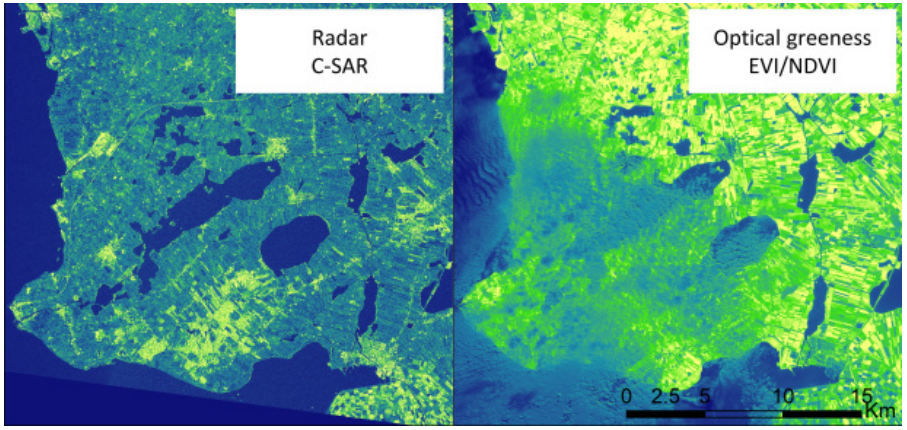


Digital Images

- Same object with different image modalities



(a) PET (b) MRI (c) CT



Two Questions of this course

- Where do digital images come from?
  - Gamma Ray
  - X-Ray
  - Ultra-Violet light
  - Visible light
  - Infra Red, etc

- **Course content?**

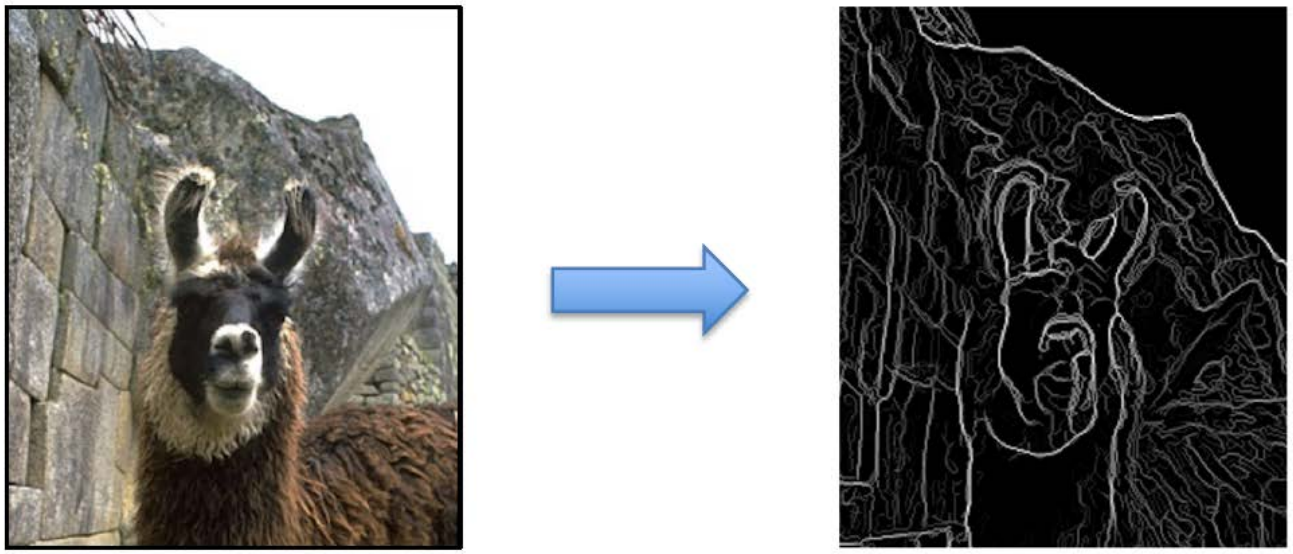
Low-level Image Processing

- Major functions: noise reduction, contrast enhancement, image sharpening, etc.
- Primitive operations where inputs and outputs are images:
  - Image ==> Image
- Example: Enhance the sharpness of an image

(a) Original Image (b) Enhanced Image

Mid-Level Image Processing

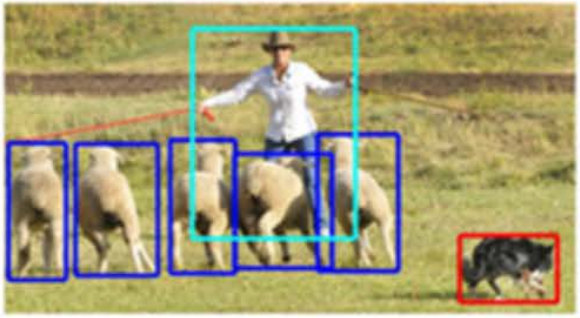
- Major functions: segmentation, edge detection
- Inputs are images, outputs are attributes
  - Image ==> Attributes (Edges, Lines, Regions)
- Example: Find the edges of the image



High-Level Image Processing

- Making sense of an image; image understanding.
- Image ==> Description
- Perform the cognitive functions normally associated with vision.

(a) classification

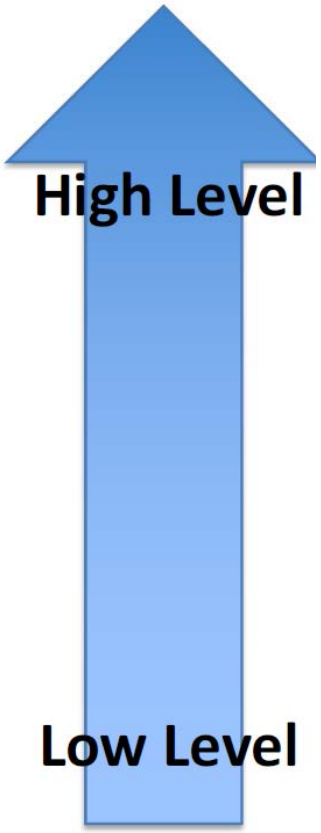

(b) detection


(c) segmentation

Relationship

- Image analysis involves extracting meaningful image from an image
  - Image segmentation
  - Image matching and comparison
  - Medical diagnosis from an image
- Computer vision strives to emulate the human visual system
  - Object recognition
  - Motion tracking

Relationship



- Computer Vision
  - Object detection, Shape analysis, tracking, use of AI and Machine learning
- Image Analysis
  - Segmentation, Image registration, Masking
- Image Processing
  - Image enhancement, noise removal, Restoration, Feature detection, Compression

Software requirement

- Matlab
  - University provides the installation of Matlab on University-owned or personally-owned computers for teaching and research.
  - https://www.cityu.edu.hk/csc/deptweb/facilities/central-sw-tah.htm
- Python