Digital Image Processing

Medical Images

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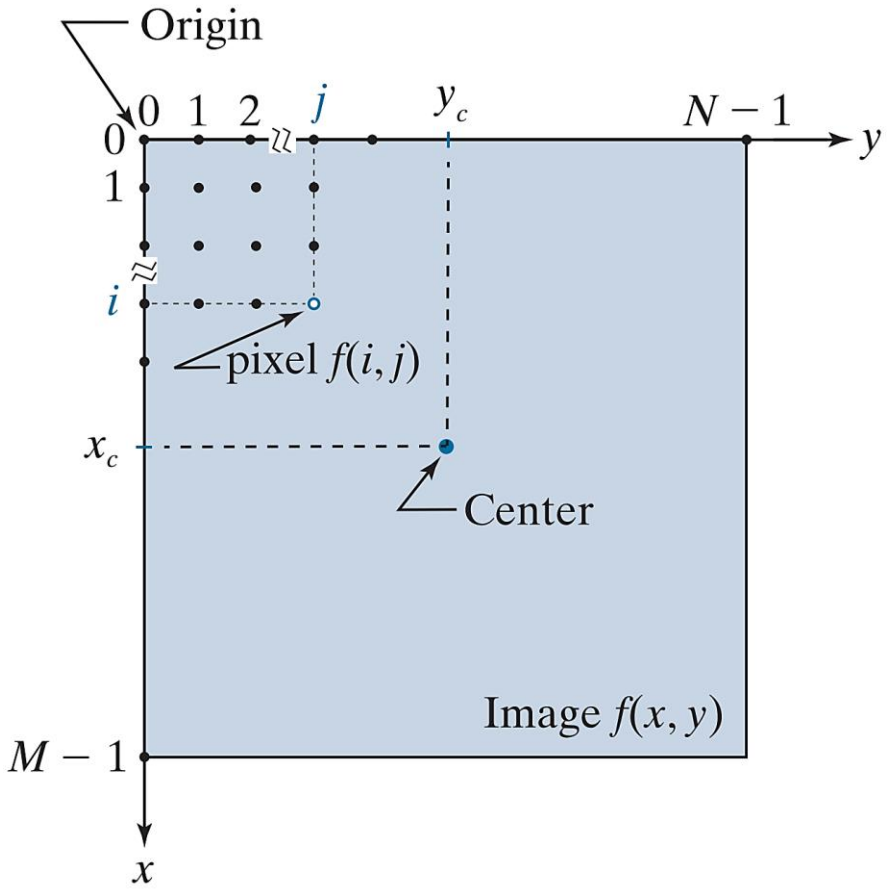
Basic Definitions

- Digital Image, Mathematical Definition:
  - $I = f(x, y)$
  - I: intensity (or color)
  - (x, y): Position or Coordination
- When (x, y) and I are finite and discrete quantities → digital image
  - Pixels, picture elements, image elements, Voxel
    - Digital Camera: Physical Pixel
    - Medical Images: Physical Voxel

Matrix Representation

› Image Representation, $f(x, y)$:



0.71	0.81	0.81	0.87	0.57	0.37	0.80
0.49	0.62	0.60	0.58	0.50	0.60	0.58
0.86	0.84	0.74	0.58	0.51	0.39	0.73
0.96	0.67	0.54	0.85	**0.48**	0.37	0.88
0.69	0.49	0.56	0.66	0.43	0.42	0.77
0.79	0.73	0.90	0.67	0.33	0.61	0.69
0.91	0.94	0.89	0.49	0.41	0.78	0.78

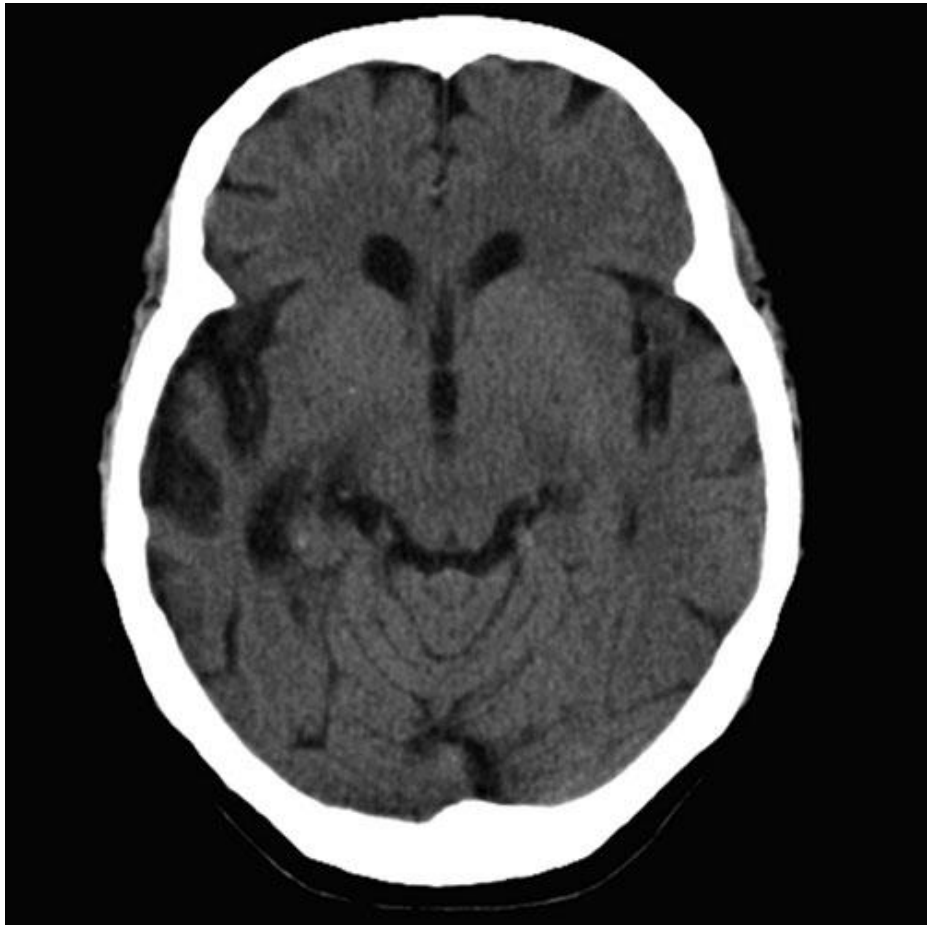
$f(3,4)=0.48$

Samples (1)

› Radiography

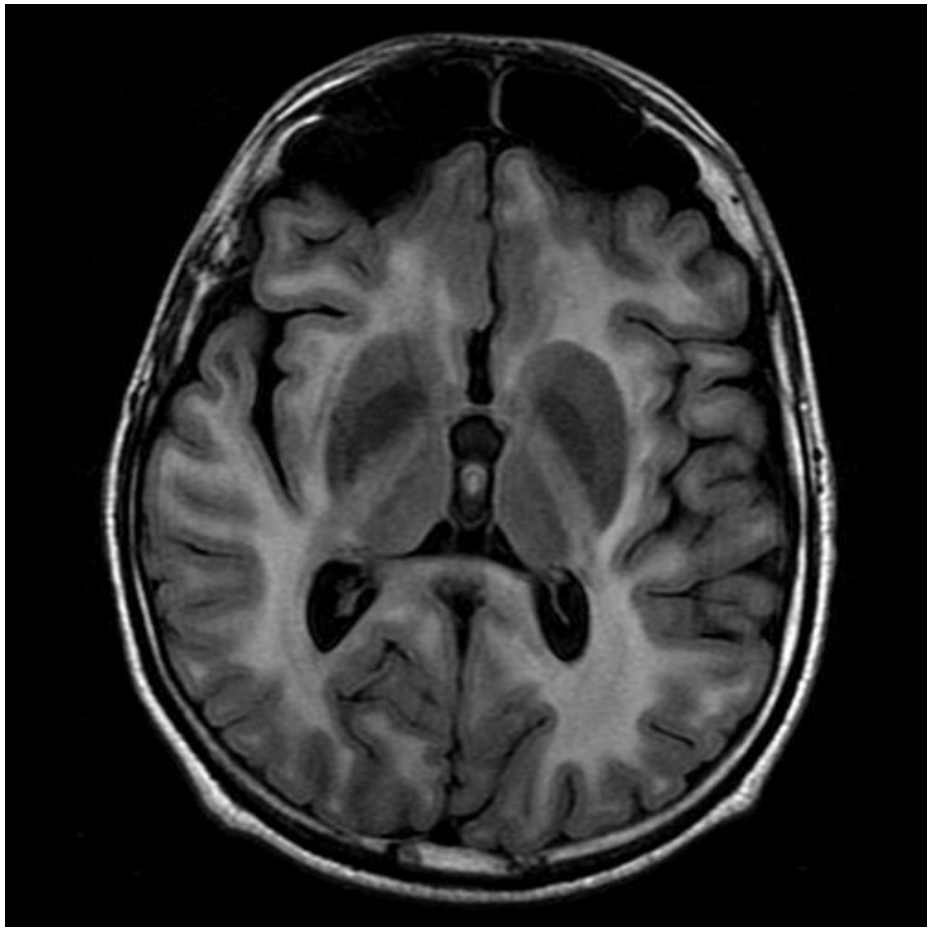
Samples (2)

› CT



Samples (3)

› MRI

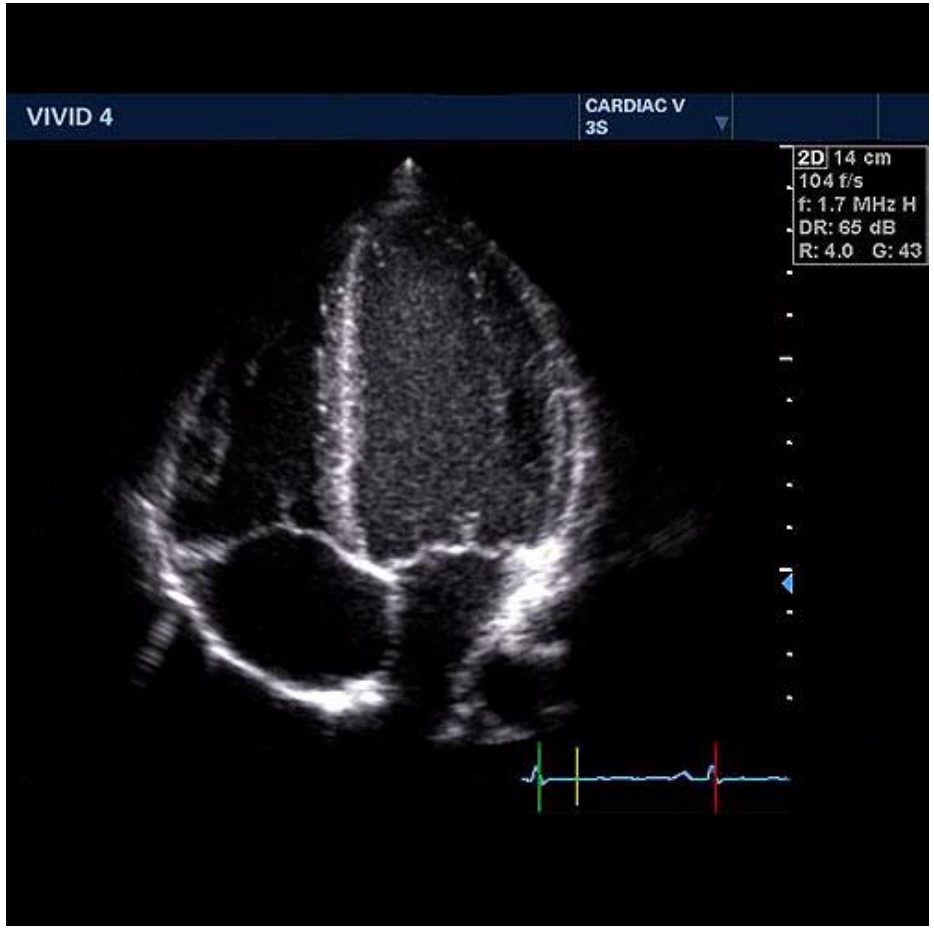


Samples (4)

› MRI

Samples (5)

› US



Samples (6)

› US

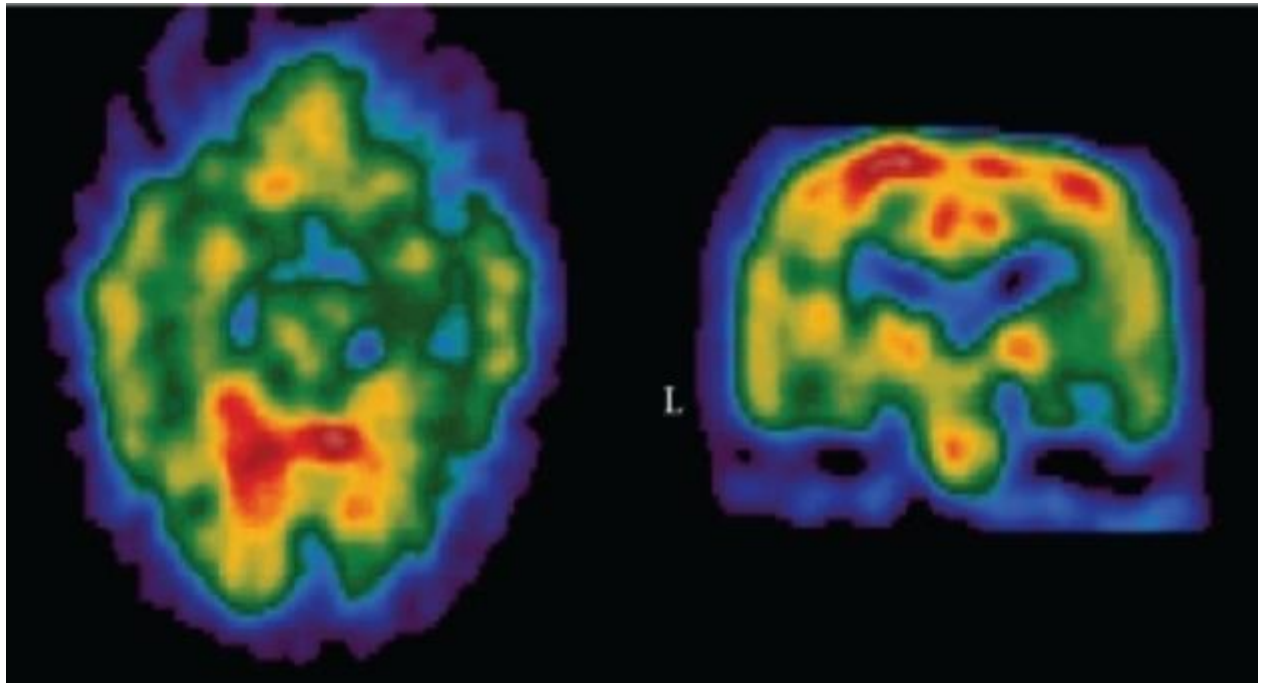
Samples (7)

› US


VIVID 4
VASCULAR
1
2D 4 cm
19 f/s
f: 10.0 MHz
DR: 70 dB
R: 4.0 G: 41
P:-2dB
TIs:1.3
MI:1.0

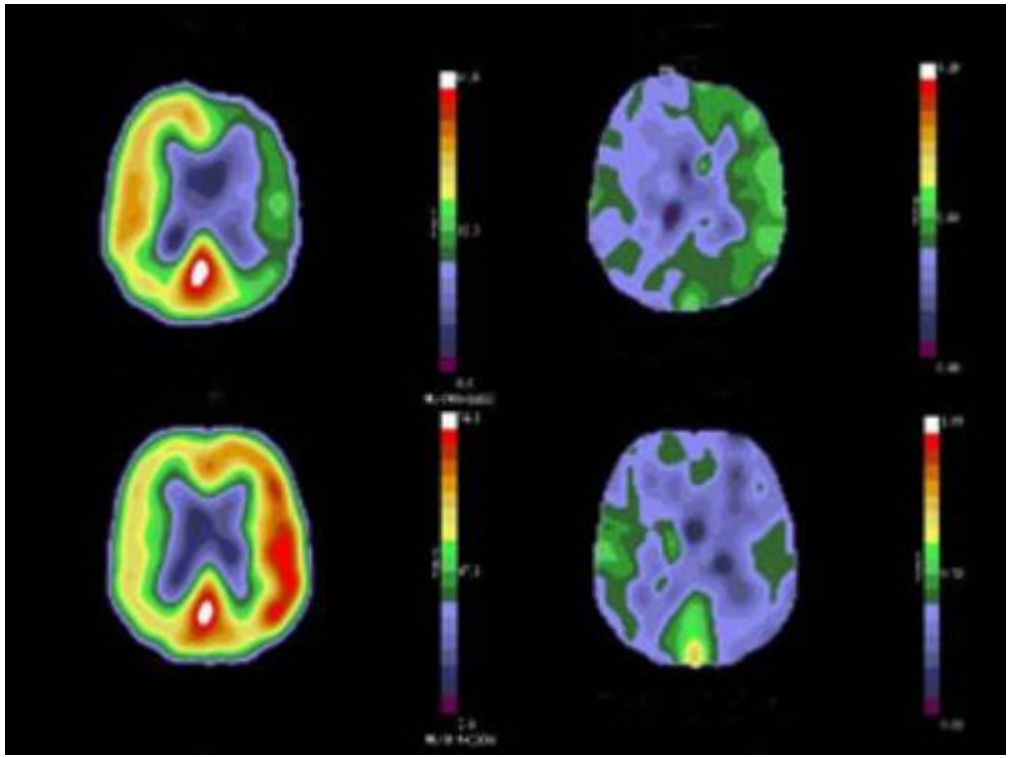
Samples (8)

› SPECT



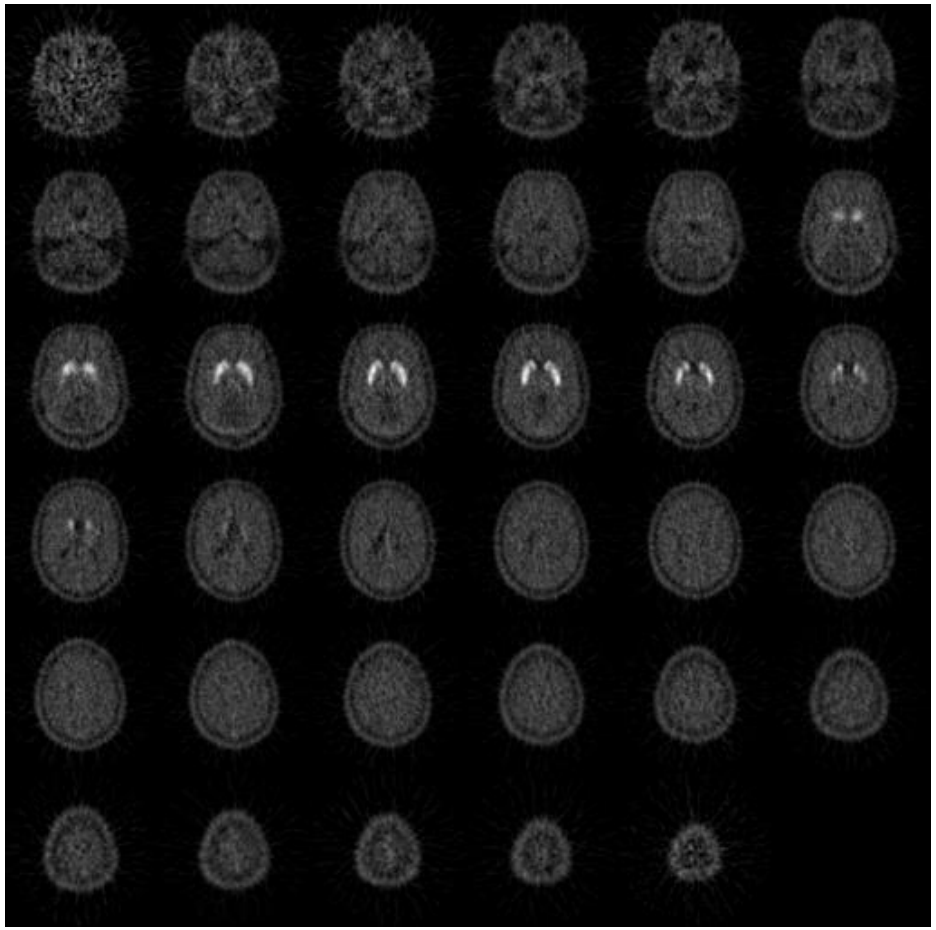
Samples (9)

› PET



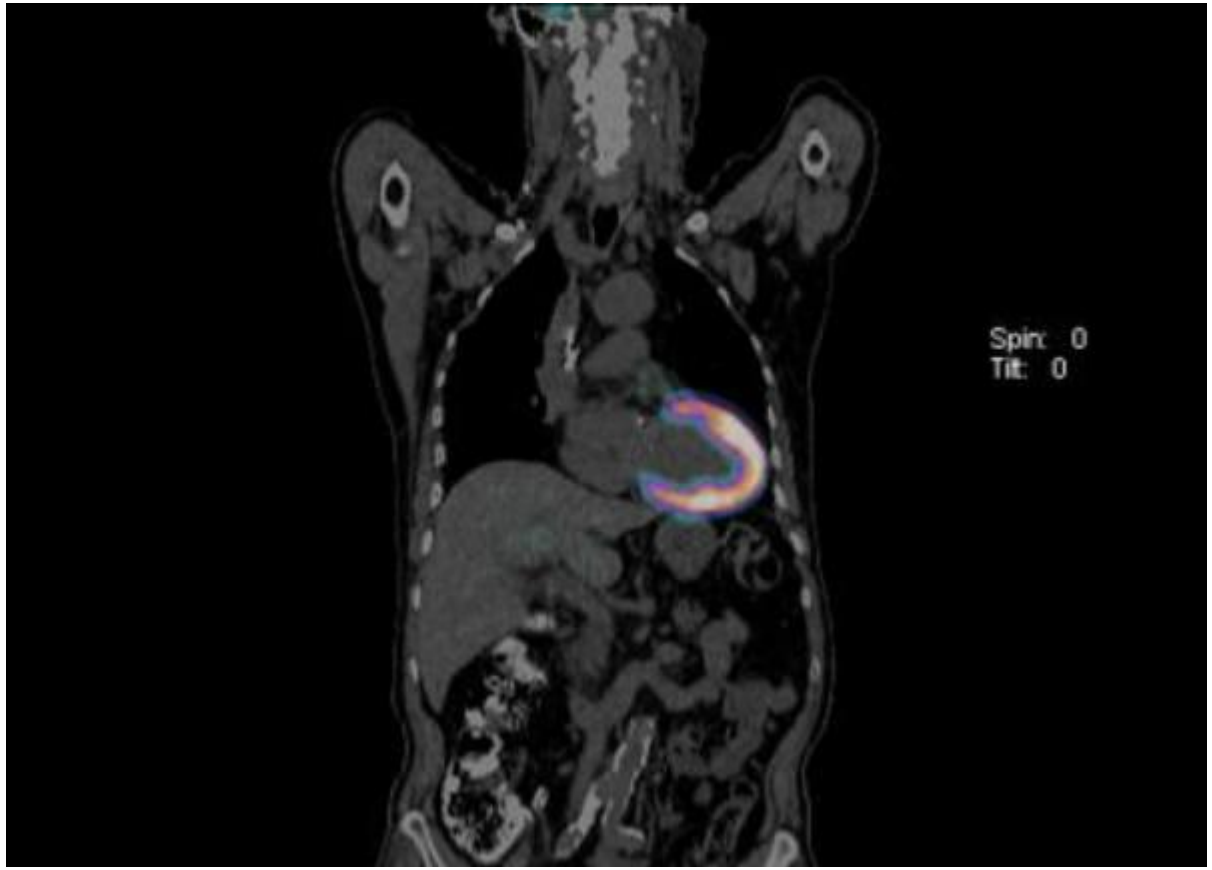
Samples (10)

› PET



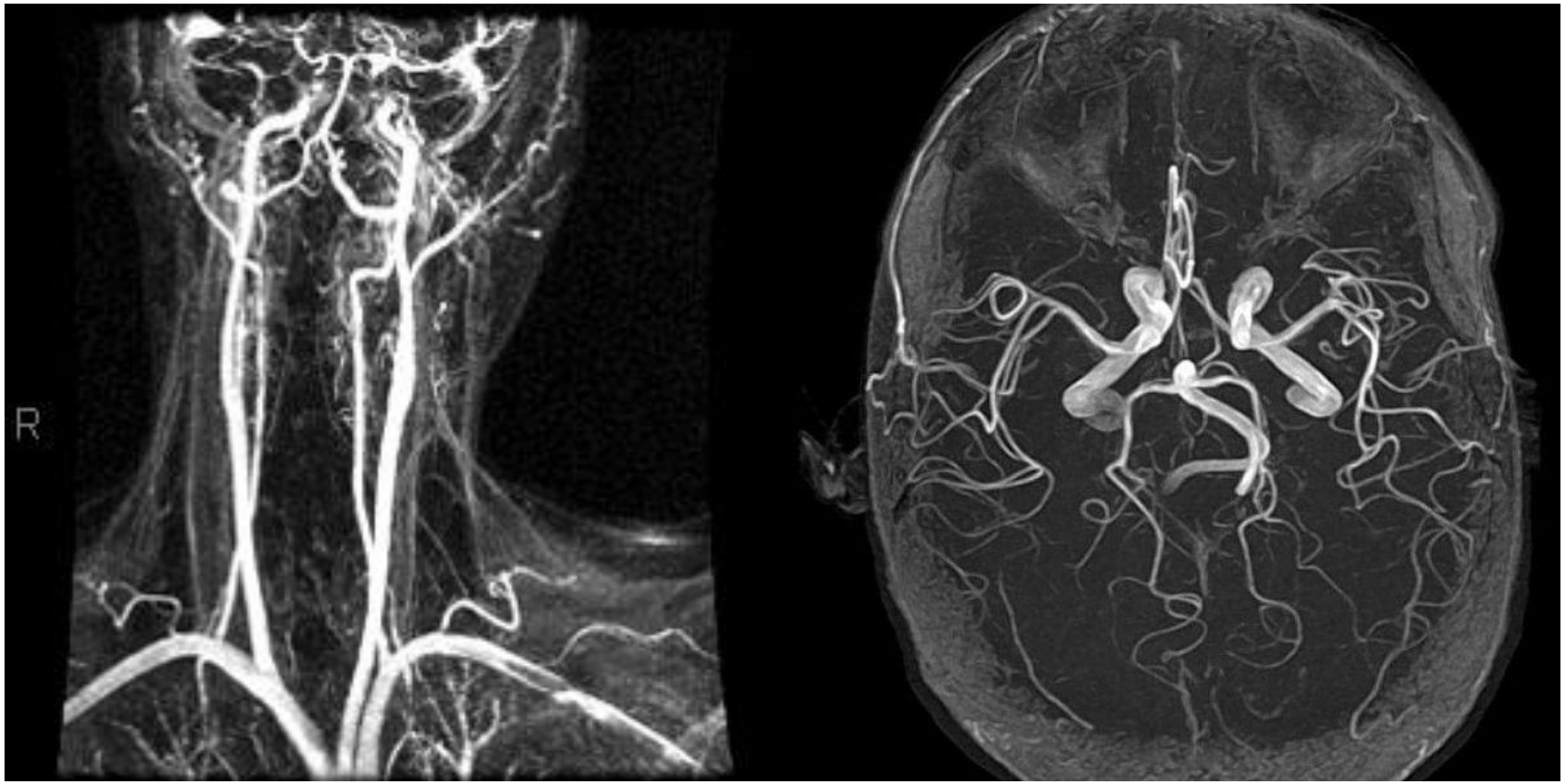
Samples (11)

› PET-CT



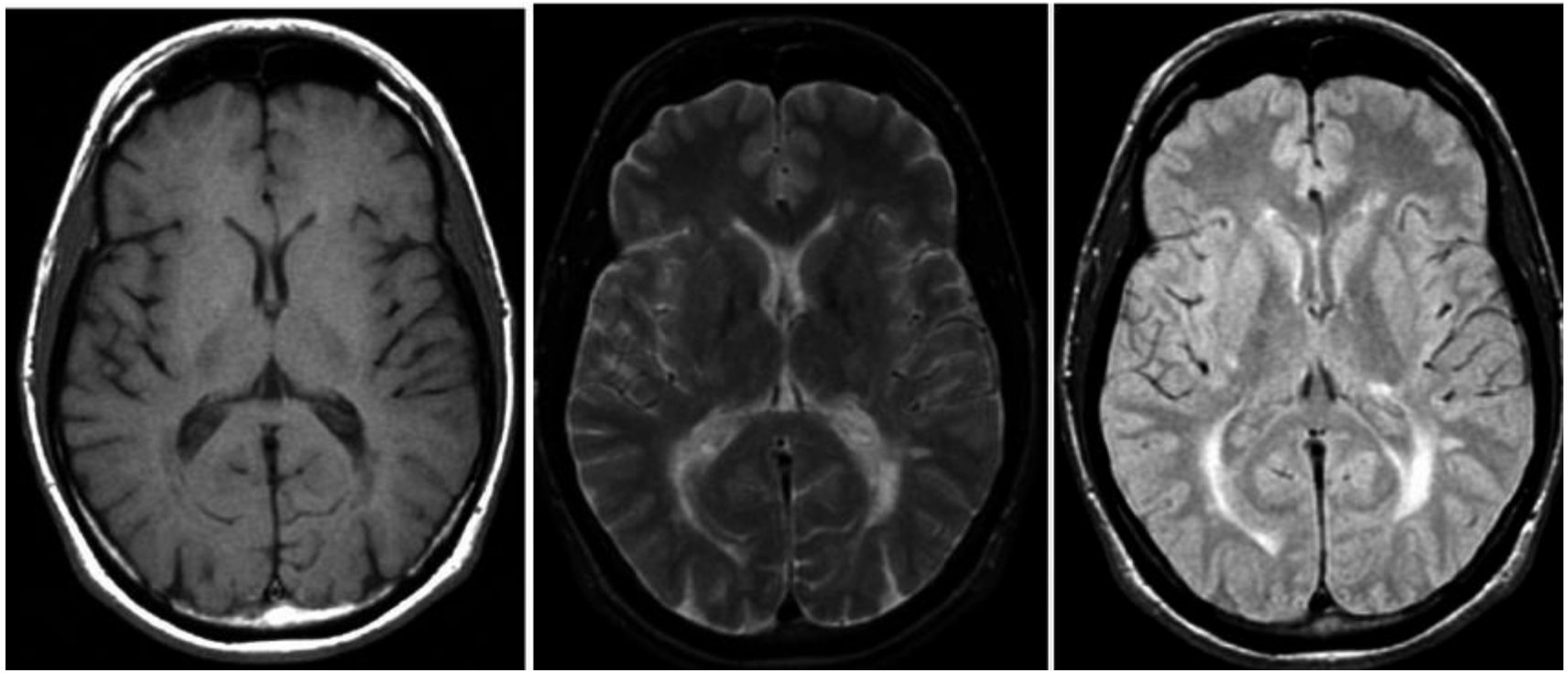
Samples (12)

› MRA



Sample (13)

› MRI as a Multi Channels imaging modalities:

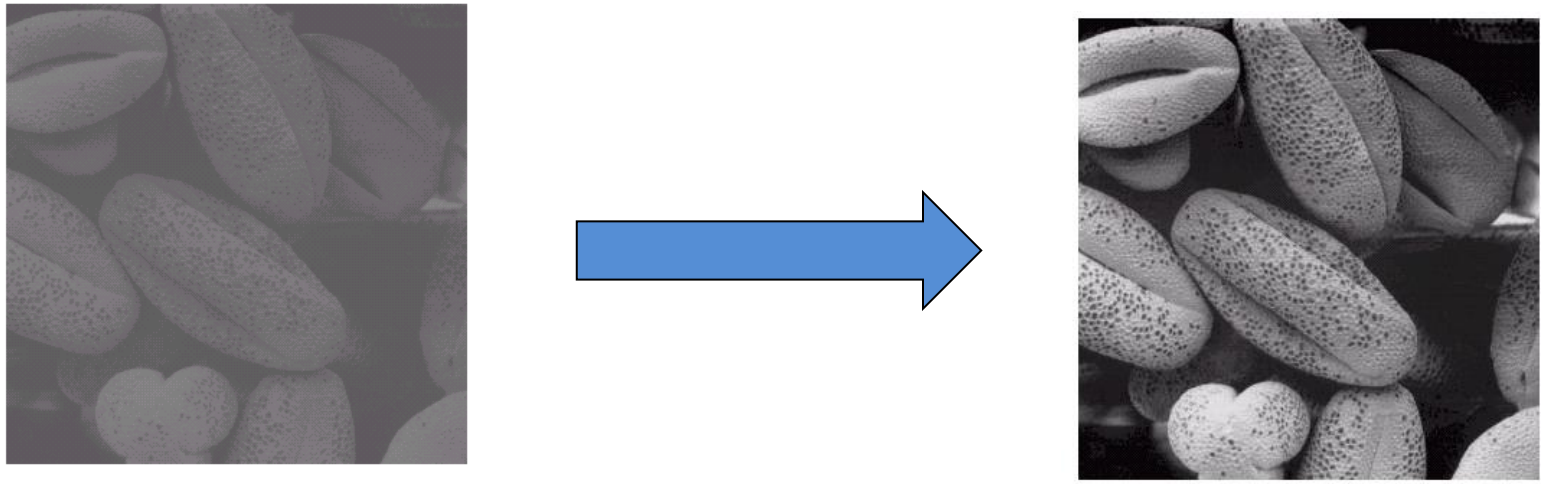


Applications (1)

- DIP applications:
  - Image Quality Enrichment
  - Data Redundancy Reduction
  - Automatic Detection
  - Machine Vision
  - Machine Recognition/Verification

Applications (2)

› An Example of Image Processing Results

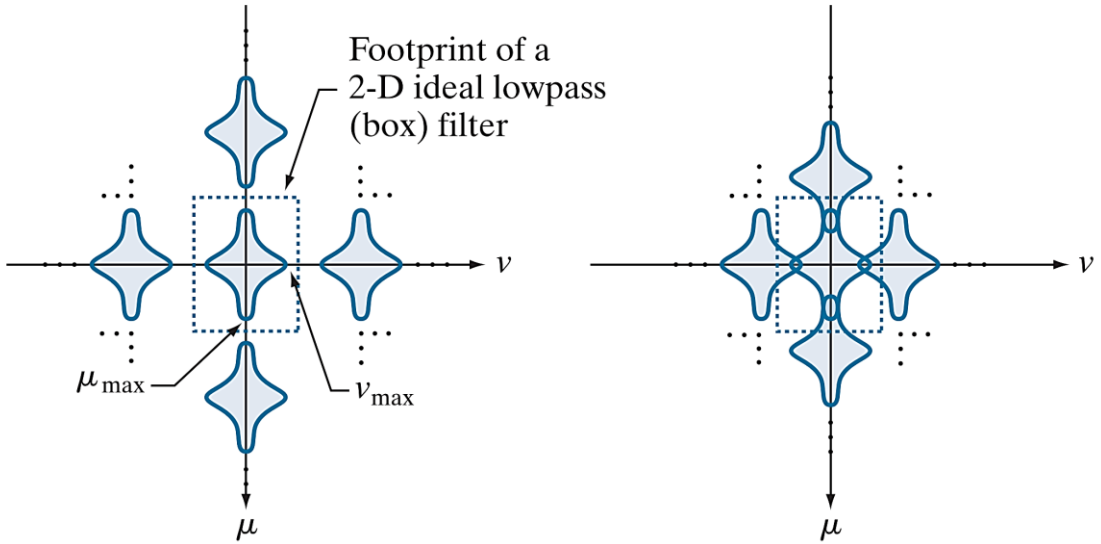


Basic Concepts (1)

› Frequency in 2D:
  – Gray level changes in any direction

Basic Concepts (2)

- Image Sampling
  - How to determine the sampling rate?
  - Nyquist sampling theorem
    - If input is a band-limited signal with maximum frequency Ω_N
    - The input can be uniquely determined if sampling rate $\Omega_S > 2\Omega_N$
      - Nyquist frequency : Ω_N
      - Nyquist rate : Ω_S

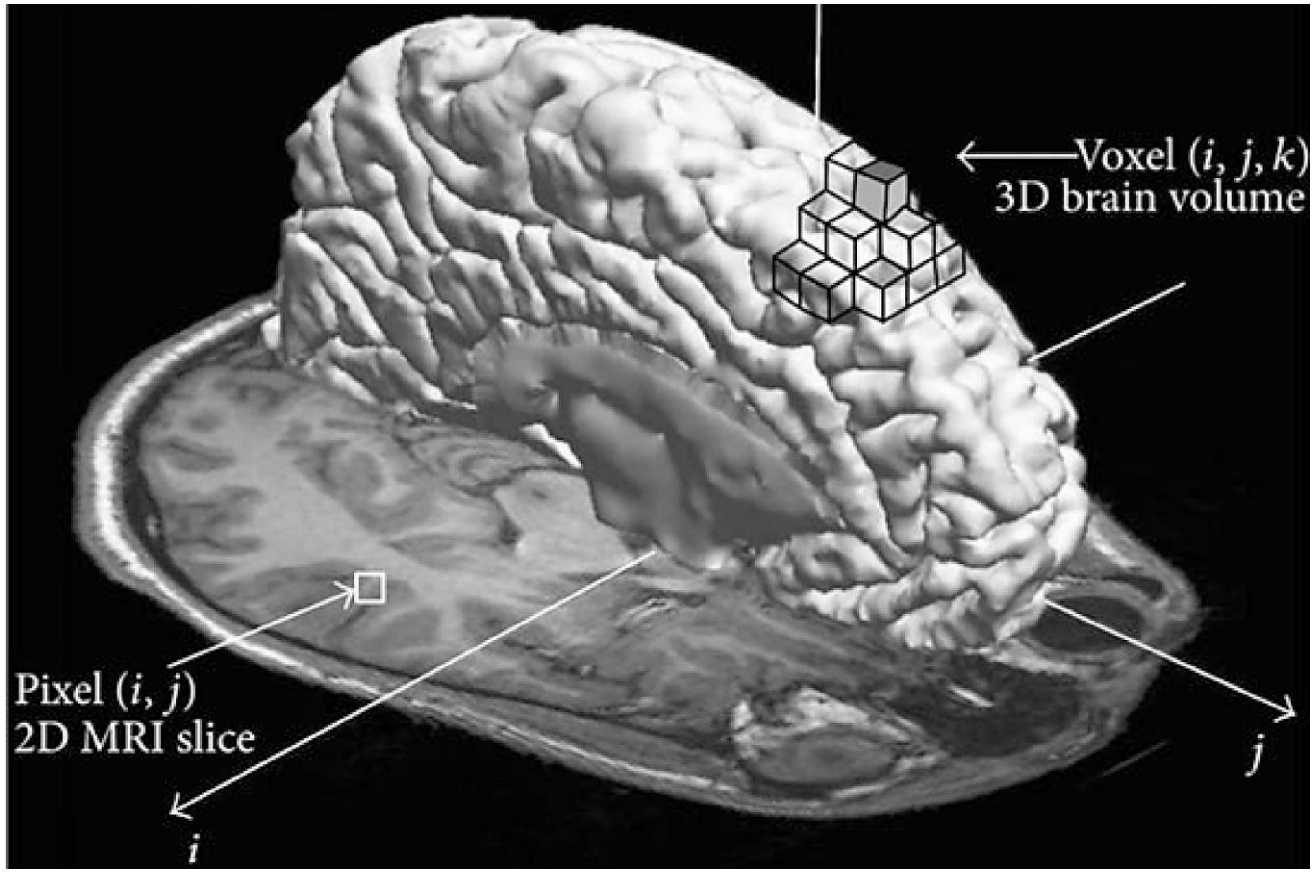


Basic Concepts (3)

- Image Quantization
  - L- level digital image of size MxN
  - Means: A digital image having:
    - A spatial resolution MxN pixels
    - A gray-level resolution of L levels (*0-L-1*)
  - Medical image standard: 16/12 bits
- Spatial resolution in real-world space
  - Pixel and Voxel dimension $(1 \times 1 \times 1) = 1mm^3$

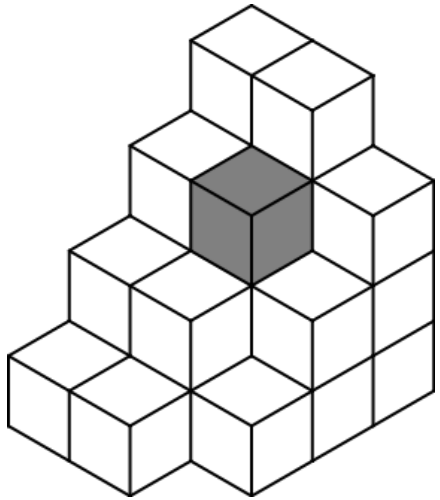
Basic Concepts (4)

› Pixel and Voxel in Medical Images:



Basic Concepts (4)

› Voxel in Medical Images:



Basic Concepts (5)

- L = 2^k gray levels, gray scales [0,…,L-1]
- The dynamic range of an image
  - [min(image) max(image)]
  - If the dynamic range of an image spans a significant portion of the gray scale → high contrast
  - Otherwise, low dynamic range results in a washed out gray look

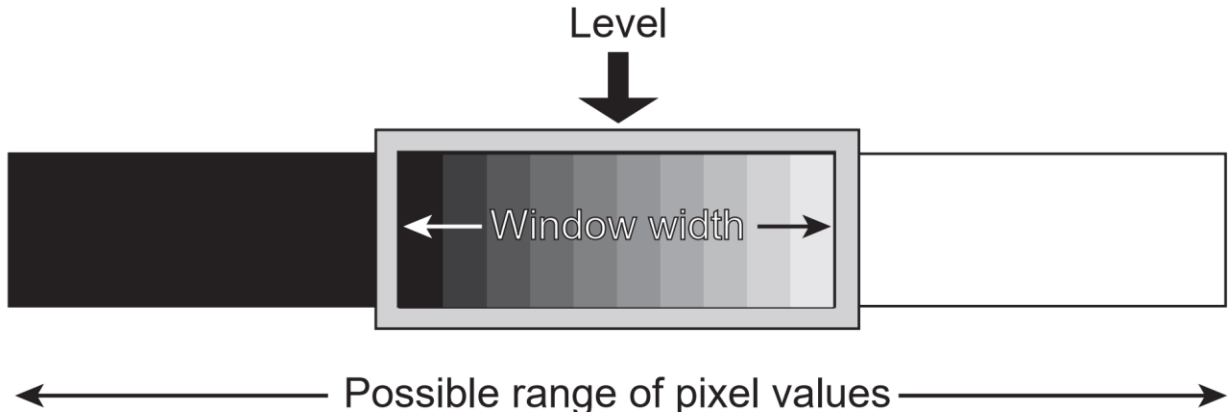
Basic Concepts (6)

- Gray Levels in CT:
  - Gray levels in CT image represent attenuation coefficient in each pixel.
  - Gray levels expressed in Hounsfield units (HU)
    - Water: 0 HU
    - Air: -1000 HU
    - Bone: 400 - 3000 HU
  - Maximum CT number is 2000-4000

$$CT = \frac{\mu - \mu_{Water}}{\mu_{Water} - \mu_{air}} \times 1000\ HU$$

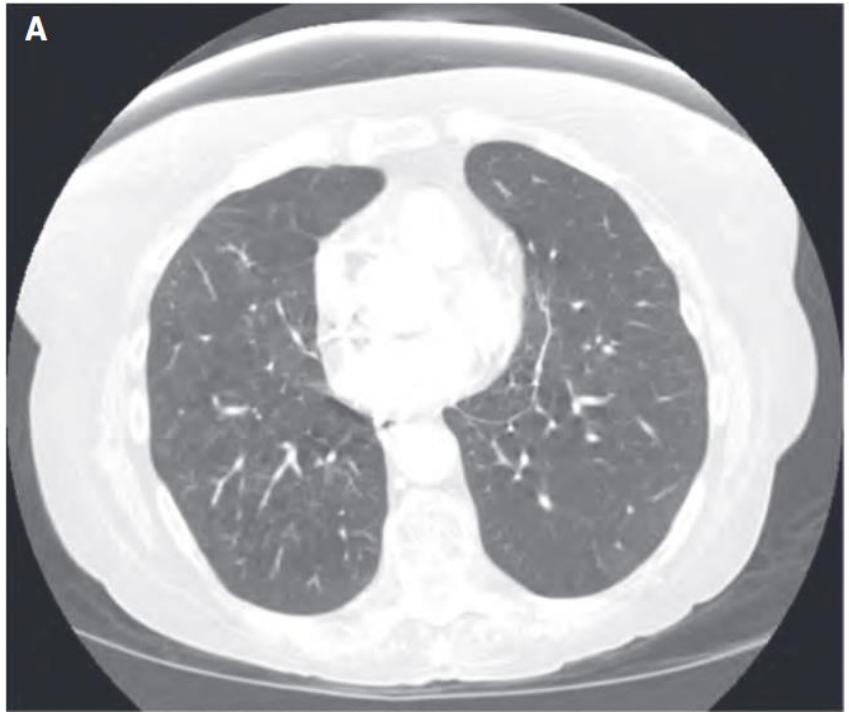
Basic Concepts (7)

- CT images displayed with suitable brightness and contrast.
  - Two important value: Window Level (WL) and Window Width (WW)
    - WL is CT number of mid-grey
    - WW is number of HU from black to white
- Choice of WW and WL dictated by clinical need
  - -1000 HU
  - 0 HU
  - 4000+ HU



Basic Concepts (8)

› WL and WW effect:



Basic Concepts (8)

- Paradigm of image processing:
  - Low-level processing
    - Inputs and outputs are images
    - Primitive operations: de-noise, enhancement, sharpening, …
  - Mid-level processing
    - Inputs are images, outputs are attributes extracted from images
    - Segmentation, classification,…
  - High-level processing
    - "Make sense" of an ensemble of recognized objects by machines

Matlab Command (1)

- Matlab Image Processing ***Read/Write***:
  - imformats
  - imfinfo, imread, imwrite
  - dicominfo, dicomread, dicomwrite
  - analyze75info, analyze75read (Mayo Clinic)
  - interfileinfo, interfileread

Matlab Command (2)

- Matlab Image Processing ***Display***:
- image, imagesc, imshow, imtool, subimage
- colorbar, montage

Matlab Command (3)

- Matlab Image Processing ***Type Conversion***:
- double, ind2gray, im2double
- uint16, uint8, gray2ind

The End

› AnY QuEsTiOn?