

DICOM: Digital Image Communication in Medicine
 Segmentation, Detection, Compensation (Registration)

Tools:

Viewer Software

analysis software - MevisLab, 3D Slicer

Rapid prototyping programming language → MATLAB, IDL

Software libraries - OpenCV, ITK (insight toolkit)
 2D 2D, 3D, 4D

Segmentation, Classification → analysis task would be typical

Guide to Medical Image Analysis

Digital Image Acquisition:

X-Ray, Magnetic Resonance, Ultrasound, Nuclear

Image intensifiers, TFT, analogue for X-ray (static images)

Select spatial resolution

Fluoroscopy

Angiography

movement of the organ - fluoroscopy → used for diagnosis ⇒ pacemaker

Angiography - focus on vascular system using contrast agent

Digital subtraction angiography DSA

Mammography

use molybdenum → produce monochrome X-ray with peak energies 17-19 keV

Bremstrahlung → Inverse X-ray tube efficiency 100:1 ratio mammography (TFT)

CT Computed Tomography
Project 2D images to 3D

Hounsfield Unit

$$\text{Hu} (\text{Fy}) = 1000 \cdot \frac{\mu - \mu_{\text{water}}}{\mu_{\text{water}} - \mu_{\text{air}}}$$

$$\mu_{\text{water}} = \mu_{\text{air}}$$

Contrast enhancement:

CTA : computed Tomography Angiography
requires higher exposure than X-ray

Magnetic Resonance Imaging (MRI)

Proton, neutron

^1H , $^{2\text{H}}$, ^{16}O , ^{12}C , ^{14}N

Angular momentum - spin

MRI uses response of hydrogen nucleus

MRI do not use ionizing radiation

coronal, sagittal views

1 to 3 Tesla

use high magnetic field $0.00003\text{ T} \rightarrow 0.00006\text{ T}$

Radio frequency signals are passed to spin atoms

$$\omega = \gamma B_0 \quad \text{Larmar frequency}$$

frequency encoding, filtered backpropagation

* K-space imaging (frequency space)

magnetic strength in terms of frequency

phase encoding gradient 0 to 360°

MRI VS CT : Gantry is small in MRI, image need not be 2", spin density ρ , spin lattice relaxation T_1 ,

Spin - spin relaxation T_2 determine resonance signal
No Hounsfield in MRI

MR sequences

echo spin sequence

echo time \rightarrow time b/w 90° impulse & echo impulse

repetition time \rightarrow time b/w measurement

EPI: echo planar imaging

phase encoding & frequency encoding

Phase shift gradient

RARE: Rapid Enhancement with Relaxation Enhancement

Problems: - chemical shift of proton, Ghosting, Shading,
Metal Artifacts

MR Angiography:

gadolinium

MIP: maximum intensity projection

BOLD Imaging:

Blood Oxygen Level Dependency

HB: Hemoglobin

Oxygenated hemoglobin \rightarrow diamagnetic

deoxygenated hemoglobin \rightarrow paramagnetic

fMRI - cortical activity

Perfusion Imaging:

relative net cerebral blood volume (rCBV)

relative cerebral blood flow (rCBF)

mean transit time (MT)

for tumor analysis, cardiac imaging

Ultrasonid -

Liver, gallbladder, pancreas, kidneys, spleen, heart, uterus
esophagus

Transrectal Ultrasound (TRUS) → imaging prostate

IV US : Intravascular Ultrasound → imaging organs from
within

Doppler Imaging:

→ Doppler effect

→ diagnosing effects of vessel blockage due to stenosis

FUS → focused ultrasound Imaging

→ used for thermal ablation of tumors - overheat tumor cell

→ Inducing mechanical effect (moving stone in gallbladder)

Brain, prostate,

Artifacts of US Imaging:

Sound waves are attenuated

Absorption turns wave energy into heat

Wave may be scattered or

Interference by divergence waves cause deterioration

Image Analysis of US image

→ Speed of sound in material

→ Refraction

→ Mirror echoes

Nuclear Imaging:

Radioactive tracer materials are injected in blood.

Brain activity, heart activity, Arthritis.

Images are created from measuring photon

Feb 6 - Feb 16
Ch 2 G12 - MRI (39)
MCQ - 10

Feb 7 / /

Techniques:

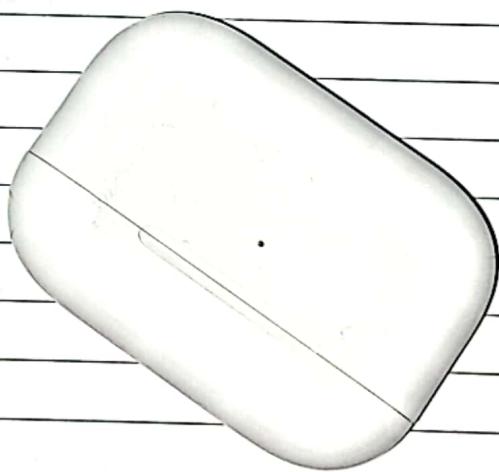
- Scintigraphy
- SPECT (Single Photon Emission Computed Tomography)
- PET (Positron Emission Tomography)

Scintigraphy:

$^{99m} \text{Tc}$ (Technetium)

collimator, scintillator crystal

Projection of bones (skull)



MRI →

Diffusion Imaging

DTI: Diffusion Tensor Imaging

for fiber tracking (neuron connectivity)

MR fractography - connectionsism

Image Analysis on MRI

better contrast for soft tissue

Shading effect

local homogeneity

Noise in MR Imaging

Ultra sound

Use sound waves, 1-2 MHz, 1500 m/s

A-scan : sends single wave

B-scan : US Scan images

Image Storage & Transfer

HL7 : Health Level 7. \approx DICOM

HIS : Hospital Information System

RIS : Radiology Information System

PACS : Picture Archiving & Communication System

HL7 - communication between clinical information system

DICOM - standardize communication of image

OSI : Open system interconnect

P,D,N,TS,P,A

RIM : Reference Information Model

DICOM Standard - preserves semantically relevant info:

- Patient Information
- Examination Information
- Technical Information
- Image

Two objects for communicating:

- Composite : Patient details + Image + Report
- Normal : report

Service for composite object

C-STOR $\ddot{\text{e}}$, C-FIND, C-GET, C-MOVE

Service for normal object

N-CREATE, N-DELETE, N-SET, N-GET, N-ACTION,
N-EVENT-NOTIFY

IOD : Information Object Description

UID : Unique Identifier

IOD:

DIMSE: DICOM Message Service Element
 SOP: Service Object Pair

DICOM classes are static

client - server paradigm

SCP - Service Class Provider - server

SCU - Service Class User - client

Application Entities (AE)

communication session b/w two components.

→ Network Image Management (NIM)

→ Network Image Interpretation Management

→ Network Print Image

→ Image Procedure management

→ off-line storage media management

NIM involves sending images b/w two devices

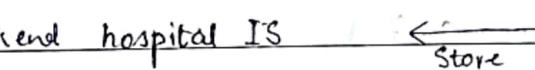
Push mode → img sent from one device to another

Pull mode → img sent to departmental workstation
or used for information exchange

two phases of pull mode: request : C-FIND, image C-GET

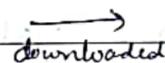
Server:

Backend hospital IS



MR Image

CT Image



Client:

Doctor's Clinic

AE ①
Active

AE ②
MR system

②

SCP DIMSE for IOD MR }
 C-STORE, { C-FIND, C-GET } } Server SCP ---- CT
 SCU DIMSE for IOD MR }
 C-STORE } Client SCU CT
 C-STORE

Network Management Service

- service, query / retrieve of storage.
- C-STORE for storage
- C-FIND, C-MOVE, C-CREATE for query

DICOM connectivity: problem statement, application entity specification, communication profile, specialization

DICOM file format: highly variable, minimal effort → tagged format
 Name of file is UID → 128 byte preamble, 4 byte identification, mandatory set of data elements

Shadow grp → odd no. grp id.

little-endian

H2NS: Host To Network

ACR: American College of Radiology

Luminance of grayscale \geq 50 foot lamberts

Compression Standard JPEG & JPEG2000

Image Enhancement

- Increase perception
- Increase quality

Measures of Image Quality

- Spatial Resolution: Structure,
- Technical Resolution: 8 bits or 24 bits (RGB)
- Contrast based Resolution: variable
- Perceived Resolution: line pairs per millimeter (lpm)

Gray Level Co-occurrence Matrix (GLCM):

Modulation Transfer Function (MTF)

Signal to Noise Ratio (SNR)

$$\text{Spatial Domain} \Leftrightarrow \text{Frequency Domain}$$

$$g(x,y) = T[f(x,y)]$$

$T \rightarrow$ Transformation

Types of IF in SD:

Single pixel method: Gray level, Arithmetic

Multiple pixel method: Spatial filtering

Gray - level transformation:

$$s = T(r)$$

$r =$ input intensity $s =$ output intensity
windowing with window size

Contrast Stretching

M - input image, I - output image. Ni - no of pixels having
in gray level i frequency table is:

I	0	1	2	3	4	5	6	7
Ni	0	0	a	b	c	d	e	0

Compute output image frequency table:

$$g(f) = \frac{(f - f_{\min})}{f_{\max} - f_{\min}} \frac{I_{\max} - I_{\min}}{I_{\max} + I_{\min}}$$

$$= \frac{(f - 2)}{6 - 2} \times 0$$

$$= \frac{(f - 2)}{4}$$

for 2a

$$= \frac{(2 - 2)}{4} \times 0 = 0$$

$$\text{for } 3b = \frac{(3 - 2)}{4} \times 0 = 1 \times 1.75 = 1.75^\circ \approx 2$$

$$\text{for } 4c = \frac{2 \times 0}{4} = 3.5 \approx 4$$

$$\text{for } 5d = 3 \times 1.75 = 5.25 \approx 5$$

$$\text{for } 6e = 4 \times 0 = 7$$

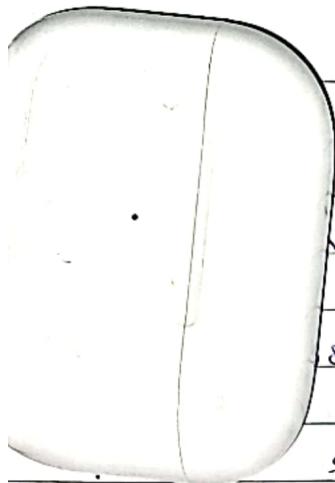
$$\text{for } 7 = -2 \times 0 = -2 \times 1.75 = -3.50$$

Output

I	0	1	2	3	4	5	6	7
Ni	a	0	b	0	c	d	0	e

I	0	1	2	3	4	5	6	7	8
Ni	28	45	0	38	98	46	70	0	0

$$g(f) = \frac{(f - 2)}{6 - 0} \times \frac{7 - 0}{6 - 0} + 0$$



$$\cancel{\frac{46 \times 7}{6}} = 52.5 \approx 53$$

$$\cancel{\frac{48 \times 7}{6}} = 44.3 \approx 44$$

$$\cancel{\frac{98 \times 7}{6}} = 114.3 \approx 114$$

$$\text{for } 5: \frac{46 \times 7}{6} = 53.6 \approx 57$$

$$\text{for } 6: \frac{70 \times 7}{6} = 81.6 \approx 82$$

I 0 1 2 3 4 5 6 7

Ni

~~for 0 : 0~~

$$\text{for } 1: \frac{7}{6} = 1.1 \approx 1$$

$$\text{for } 2: \frac{2 \times 7}{6} = 2.3 \approx 2$$

$$\text{for } 3: \frac{3 \times 7}{6} = 3.5 \approx 4$$

$$\text{for } 4: \frac{4 \times 7}{6} = 4.6 \approx 5$$

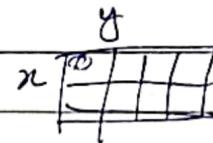
$$\text{for } 5: \frac{5 \times 7}{6} = 5.8 \approx 6$$

$$\text{for } 6: \frac{6 \times 7}{6} = 7$$

~~for 7: 0 1 2 3 4 5 6 7~~

28 45 0 0 38 98 46 70

Euclidean Distance: $\sqrt{2} = 1.414$



$$D_e(p, q) = \sqrt{(x-s)^2 + (y-t)^2}$$

City block distance:

$$D_b(p, q) = |x-s| + |y-t|$$

2		
2	1	2
2	1	0
2	1	2

Chess Board Distance

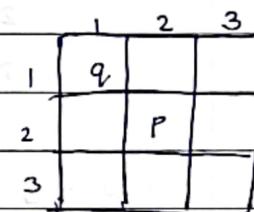
$$D_8(p, q) = \max(|x-s|, |y-t|)$$

2	2	2	2	2
2	1	1	1	2
2	1	0	1	2
2	1	1	1	2

Q. Compute Distance between two pixel

$$q: (1, 1)$$

$$p: (2, 2)$$



$$\text{Euclidean} = \sqrt{1+1} = \sqrt{2}$$

$$CB = |1| + |1| = 2$$

$$ChB = \max(1, 1) = 1$$

Q.

Use City block

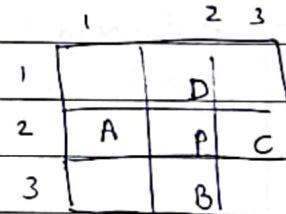
$$P(A) = (2, 1)$$

$$P(B) = (3, 2)$$

$$P(C) = (2, 3)$$

$$P(D) = (1, 2)$$

$$P(P) = (2, 2)$$



$$P(A \text{ to } P) = |0| + |1| = 1$$

$$P(P \text{ to } C) = |0| + |1| = 1$$

$$P(A \text{ to } B) = |1| + |1| = 1$$

$$P(P \text{ to } D) = |0| + |1| = 1$$

Since the dist b/w all 4 are same i.e. 1

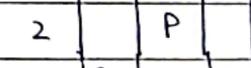
$\therefore A, B, C \& D$ are neighbouring pixel of P.

using Chess Board for ND

$$P(D) = (2, 2) \quad P(a_1) = (1, 1) \quad P(a_2) = (1, 3)$$

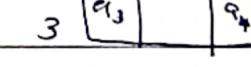


$$P(a_3) = (3, 1) \quad P(a_4) = (3, 3)$$



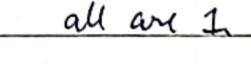
$$P(a_1, p) = \max(|1|, |1|) = 1$$

$$P(a_3, p) = 1$$



$$P(a_2, p) = \max(|1|, |1|) = 1$$

$$P(a_4, p) = 1$$



all are 1

Smoothing / averaging
 Noise removal / filter
 Edge Detection
 Contrast enhancement

					$\begin{matrix} 0 & 1 & 0 \\ 1 & 1 & 1 \\ 0 & 1 & 0 \end{matrix}$	$\Sigma =$

color value kernel

$$98 \quad 6 \quad 6 \quad -1 \quad -1 \quad -1$$

$$2 \quad 8 \quad 6 \quad -1 \quad +6 \quad -1$$

$$2 \quad 2 \quad 9 \quad -1 \quad -1 \quad -1$$

$$-8 - 6 - 6 - 2 + (6 \times 8) - 6 - 2 - 2 - 9 / 8$$

$$= 128 - 42 / 8 = 86 / 8 = 10.75 \approx 11$$

Histogram Processing

$$h(r_k) = n_k \quad k = 0, \dots, L-1$$

$$p_n(r_k) = \frac{h(r_k)}{MN} = \frac{n_k}{MN}$$

MN = size of image (MxN)

$$S_k = T(r_k) = (L-1) \sum_{j=0}^k p_n(r_j)$$

$k = 0, \dots, L-1$

n_k	n_k	$p_n(n_k) = n_k/MN$	$MN = 4096$
0	790	0.19	
1	1023	0.25	
2	850	0.21	
3	656	0.16	
4	329	0.08	
5	245	0.06	
6	122	0.03	
7	81	0.02	

$$S_0 = T(n_0) = 7 \sum_{j=0}^0 p_n(r_j) = 7 p_n(r_0) = 1.33 \rightarrow 1$$

$$S_1 = 7 \times (0.25 + 0.19) = 3.08 \approx 3$$

$$S_2 = 7 \times (0.21 + 0.25 + 0.19) = 4.55 \rightarrow 5$$

$$S_3 = 7 \times (0.19 + 0.25 + 0.21 + 0.16) = 5.67 \rightarrow 6$$

$$S_4 = 7 \times (0.19 + 0.25 + 0.21 + 0.16 + 0.08) = 6.23 \rightarrow 6$$

$$S_5 = 7 \times (0.19 + 0.25 + 0.21 + 0.16 + 0.08 + 0.06) = 6.65 \rightarrow 7$$

$$S_6 = 7 \times (0.19 + 0.25 + 0.21 + 0.16 + 0.08 + 0.06 + 0.03) = 6.86 \rightarrow 7$$

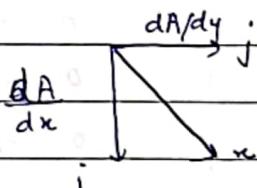
$$S_7 = 7 \times (0.19 + 0.25 + 0.21 + 0.16 + 0.08 + 0.06 + 0.03 + 0.02) = 7$$

AHE : Adaptive Histogram Equalization

CLAHE : Contrast limited adaptive histogram equalization

2D Gradient Operator

$$\Delta A = \frac{dA}{dx} i + \frac{dA}{dy} j$$



$$\text{Magnitude} = \sqrt{\left[\frac{dA}{dx}\right]^2 + \left[\frac{dA}{dy}\right]^2} \quad B_i = \begin{bmatrix} -1 \\ 1 \end{bmatrix}$$

$$B_j = \begin{bmatrix} -1 & 1 \end{bmatrix}$$

$$\text{Orientation} = \tan^{-1} \begin{bmatrix} 1 & \frac{dA/dy}{dA/dx} \\ 0 & 1 \end{bmatrix}$$

$$\Delta^2 A = A * B \quad B = \begin{bmatrix} 1 & -2 & 1 \end{bmatrix}$$

$$B = B_i + B_j$$

$$= \begin{bmatrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{bmatrix}$$

$$L = -\Delta A^2$$

$$B = \begin{bmatrix} 0 & -1 & 0 \\ -1 & 4 & -1 \\ 0 & -1 & 0 \end{bmatrix}$$

#

Laplacian filter

$$\begin{array}{ccccccccc} 0 & 1 & 0 & 0 & 10 & 10 & 10 & 10 & L-8 & -1 & -1 & -1 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & & -1 & 8 & -1 \\ 0 & 1 & 0 & 0 & 10 & 10 & 10 & 10 & & -1 & -1 & -1 \\ 0 & 1 & 0 & 0 & 10 & 10 & 10 & 10 & & & & \\ 0 & 1 & 0 & 0 & 10 & 10 & 10 & 10 & & & & \\ 0 & 1 & 0 & 0 & 10 & 10 & 10 & 10 & L-4 & 0 & -1 & 0 \\ 1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & & -1 & 4 & -1 \\ 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & & 0 & -1 & 0 \end{array}$$

for $L-4$ Substitute 0

Substitute 1

$$\begin{array}{ccccccccc} 0 & -10 & 20 & 10 & 20 & & & & -2 \\ 0 & -10 & 10 & 0 & 10 & & & & -1 \\ 0 & -10 & 10 & 0 & 10 & & & & -1 \\ 0 & -10 & 10 & 0 & 10 & & & & 19 \\ 0 & -10 & 20 & 10 & 20 & & & & -12 \end{array}$$

for
exam
purposes

$L-4$

0 1 0

$L-8$

1 1 1

1 -4 1

1 -8 1

Actual
output

0 1 0

1 1 1

$$\begin{array}{ccccc}
 -2 & -11 & 19 & 9 & 18 \\
 -1 & -10 & 10 & 0 & 9 \\
 -1 & -10 & 10 & 0 & 9 \\
 -1 & -10 & 10 & 0 & 9 \\
 -2 & -11 & 19 & 9 & 18
 \end{array}$$

Substitute '1'

Substitute boundary value for L-4

$$\begin{array}{ccccc}
 0 & -10 & 10 & 0 & 0 \\
 0 & -10 & 10 & 0 & 0 \\
 0 & -10 & 10 & 0 & 0 \\
 0 & -10 & 10 & 0 & 0 \\
 0 & -10 & 10 & 0 & 0
 \end{array}$$

Resolution Enhancement

Interpolation → zooming, shrinking, rotating, geometrically
correcting digital image

Bilinear interpolation → 4 nearest neighbour

$$V(x,y) = ax + by + cxy + d$$

Shape-based interpolation

Sobel filter

$$y_x = \begin{bmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{bmatrix} * A \quad y_y = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} * A$$

A is original source image
x increase in right direction & y increase in
down direction

$$y = \sqrt{y_x^2 + y_y^2}$$

gradient direction

$$\theta = \arctan \left[\frac{y_y}{y_x} \right] = \tan^{-1} \left[\frac{y_y}{y_x} \right]$$

$$0 \ 0 \ 0 \ 10 \ 10 \ 10 \ 0 \ 0 \ 10$$

$$0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 10$$

$$0 \ 0 \ 0 \ -10 \ 10 \ 10 \ 0 \ 10$$

$$0 \ 0 \ 0 \ 10 \ 10 \ 10 \ 0 \ 10 \ h_x = 1 \ 0 \ -1$$

$$0 \ 0 \ 0 \ 10 \ 10 \ 10 \ 0 \ 10 \ 2 \ 0 \ -2$$

$$0 \ 0 \ 0 \ 10 \ 10 \ 10 \ 0 \ 10 \ 1 \ 0 \ -1$$

$$0 \ 0 \ 0 \ 10 \ 10 \ 10 \ 0 \ 10$$

$$0 \ 0 \ 0 \ 10 \ 10 \ 10 \ 0 \ 10 \ h_y = -1 \ -2 \ -1$$

$$0 \ 0 \ 0 \ 10 \ 10 \ 10 \ 0 \ 10 \ 0 \ 0 \ 0$$

$$1 \ 2 \ 1$$

zero padding

$$y_x = \begin{matrix} 0 & -30 & -30 & 0 & 30 \\ 0 & -40 & -40 & 0 & 40 \\ 0 & -40 & -40 & 0 & 40 \\ 0 & -40 & -40 & 0 & 40 \\ 0 & -30 & -30 & 0 & 30 \end{matrix}$$

border value

$$y_x = \begin{matrix} 0 & -40 & -40 & 0 & 0 \\ 0 & -40 & -40 & 0 & 0 \\ 0 & -40 & -40 & 0 & 0 \\ 0 & -40 & -40 & 0 & 0 \\ 0 & -40 & -40 & 0 & 0 \end{matrix}$$

zero padding $y_y =$

$$\begin{matrix} 0 & -10 & -30 & -40 & -30 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & -10 & -30 & -40 & -30 \end{matrix}$$

border value $y_y =$

$$\begin{matrix} 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{matrix}$$

Zero padding $y =$

$$\begin{matrix} 0 & 10\sqrt{10} & 30\sqrt{2} & 40 & 30\sqrt{2} \\ 0 & 40 & 40 & 0 & 40 \\ 0 & 40 & 40 & 0 & 40 \\ 0 & 40 & 40 & 0 & 40 \\ 0 & 10\sqrt{10} & 30\sqrt{2} & 40 & 30\sqrt{2} \end{matrix}$$

Border value $y =$

$$\begin{matrix} 0 & 40 & 40 & 0 & 0 \\ 0 & 40 & 40 & 0 & 0 \\ 0 & 40 & 40 & 0 & 0 \\ 0 & 40 & 40 & 0 & 0 \end{matrix}$$

Laplacian of Gaussian [LOG] (Mexican hat filter)

$$G_{\sigma}(\pi) =$$

$$D_{\text{gauss}, x} = \frac{\partial f_{\text{gauss}}(x,y)}{\partial x}$$

Gaussian kernel:

$\frac{1}{16}$	$\frac{1}{8}$	$\frac{1}{16}$	0	20	20	30	40	50	60
$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{8}$	25	25	25	35	45	55	65
$\frac{1}{16}$	$\frac{1}{8}$	$\frac{1}{16}$	30	30	30	40	50	60	70
			35	35	35	45	55	65	75
3	5	3	40	40	40	50	60	70	80
5	9	5	40	40	40	50	60	70	80
3	5	3							

[2 3 7 5]

24 5

28 24 33

output:	24	28	33	43	53	58
	30	30	35	45	55	60
	35	40	50	60	65	
	40	45	55	65	70	
	43	48	58	68	73	

Gaussian kernel applied to smooth image

56	34	16	-4	-24	28	28	33
52	32	12	-8	-28	28	28	33
40	20	0	-20	-40	30	30	35
32	12	-8	-28	-40			
16	-4	-24	-44	-64			

5x5 Laplacian of Gaussian mask

$$\begin{matrix} 0 & 0 & -1 & 0 & 0 \\ 0 & -1 & -2 & -1 & 0 \\ -1 & -2 & 16 & -2 & -1 \\ 0 & -1 & -2 & -1 & 0 \\ 0 & 0 & -1 & 0 & 0 \end{matrix}$$

Gabor filter

Respond to edge & texture changes

$$g_{\sigma, \kappa, \gamma, \lambda, \Psi}(x, y) = \exp\left(-\frac{s^2 + yt^2}{2\sigma^2}\right) \cos\left(2\pi \frac{s}{\lambda} + \Psi\right)$$

$$s = x \sin \alpha + y \cos \alpha \quad t = x \cos \alpha - y \sin \alpha$$

Types of Noise

Gaussian Noise

Salt & Pepper Noise

Speckle Noise

Noise is usually modeled as stationary, additive & with zero mean

$$g = f + n$$

Noise reduction scheme:

Linear filtering

Median filtering

Diffusion filtering

Bayesian image

$$\text{Mean, } s = \frac{1}{S^2} \begin{bmatrix} \text{image} \end{bmatrix}$$

$S = 3$ 5×5 matrix image size

Binomial filter

$$c_{\text{binom}, b}^{\text{ID}} = \frac{1}{2^b} C_{\text{binom}, 1}^{\text{ID}}$$

$$\begin{aligned} [b^0] &= [1] & b^1 &= [1, 1] & b^2 &= [1, 2, 1] \\ b^3 &= [1, 3, 3, 1] & b^4 &= [1, 4, 6, 4, 1] \end{aligned}$$

$$C_{\text{Butterworth}, \omega_{\max}}(u, v) = \frac{1}{1 + ((u^2 + v^2) / \omega_{\max}^2)^k}$$

Hanning & Hann

$$G_{\text{Hann}, \omega_{\max}}(uv) = \begin{cases} \alpha - (1-\alpha) \cos\left(\frac{\sqrt{u^2+v^2}}{\omega_{\max}} \pi\right) & u^2 + v^2 < \omega_{\max}^2 \\ 0 & \text{otherwise} \end{cases}$$

$$\alpha = 0.53836 \rightarrow \text{Hanning window} \quad \alpha = 0.5 \rightarrow \text{Hann window}$$

Order Statistic filter

→ Median filter

$$\hat{f}(n, y) = \underset{(n, c) \in S_{xy}}{\text{median}} \{g(n, c)\}$$

→ Max & Min filter

0	1	-	0	-	6	7
2	1	0	-	1	6	5
1	1	-	7	-	5	6
1	0	-	6	-	6	5
2	5	-	6	-	7	6

Mean filter:

$$\begin{matrix} 0 & 1 & 6 \\ 1 & 7 & 5 \\ 0 & 6 & 6 \end{matrix}$$

$$\frac{1+6+7+1+5+6+6}{9} = \frac{32}{9} = 3.55 \approx 4$$

filter:

$$\text{Median} = 5$$

$$0 \ 0 \ 11 \ 5 \ 6 \ 6 \ 6 \ 7$$

↑

$$\text{Max} : 7$$

$$\text{Min} : 0$$

$$\begin{matrix} 0 & 1 & 6 \\ 1 & 5 & 5 \\ 0 & 6 & 6 \end{matrix}$$

$$\frac{30}{9} = \frac{10}{3} = 3.33 \approx 3$$

$$\begin{matrix} 0 & 1 & 6 & 15 & 5 & 0 & 6 & 6 \\ 0 & 0 & 11 & 55 & 66 & 6 \end{matrix}$$

↑

$$\text{Median} : 5$$

$$\text{Median:}$$

$$\begin{matrix} 1 & 1 & 6 \\ 1 & 5 & 6 \\ 2 & 6 & 6 \end{matrix}$$

$$\text{Min:}$$

$$\begin{matrix} 0 & 0 & 0 \\ 0 & 0 & 1 \\ 0 & 0 & 5 \end{matrix}$$

#

Diffusion filtering

Median filter does not reduce noise by right alter the edge.

→ homogeneous diffusion

→ inhomogeneous diffusion

→ anisotropic diffusion

↑ incr
decr.

Gradient Adaptive Smoothing Bilateral filtering

Feature Detection

Canny edge detector

Edge Model \rightarrow template

Contour Model \rightarrow set of open & closed contour are searched
in top-down fashion

Hough transformation

input img \rightarrow compare with edge model

voting scheme \rightarrow find straight line in images

Harris corner detector

$$H(x_0, y_0) = \sum_{n=x_0-K}^{x_0+K} \sum_{y=y_0-K}^{y_0+K} \omega(n, y) \begin{bmatrix} \left(\frac{\partial I}{\partial x}\right)^2 & \left(\frac{\partial I}{\partial x}\right)\left(\frac{\partial I}{\partial y}\right) \\ \left(\frac{\partial I}{\partial x}\right)\left(\frac{\partial I}{\partial y}\right) & \left(\frac{\partial I}{\partial y}\right)^2 \end{bmatrix}$$

corner: K_1 & K_2 are large

edge: either K_1 or K_2 is large

homogeneous: K_1 & K_2 will be low

Texture:

kind of microstructure in a structured world

\rightarrow Repetition of pattern

Deterministic texture pattern \rightarrow manufactured object
Visible texture

Orientation, Periodicity, complexity

Texture measure:

→ Haralick's feature: Gray level co-occurrence matrix [GLCM]

→ Spatial feature (Sobel)

→ Laplace filter

Feature Detection

Agglomeration → cluster

↓ Purpose of image segmentation → to generate pixel agglomeration, delineation of specific feature
data knowledge & domain knowledge

Segmentation Strategies

→ Foreground Segmentation → focuses on single object in image

→ Hierarchical Segmentation → applies multi-resolution concept for gradual refinement

→ Multi-layer Segmentation → carried out at different scale producing layer of segment.

Data Knowledge

Continuity in time & continuity in space.

Homogeneity of intensity.

Gaussian with zero mean value