Peningkatan Mutu Citra
(Image Enhancement)
pada Domain Spasial

Kuliah ke-3
Program Studi S1 Reguler
Departemen Teknik Elektro, FTUI
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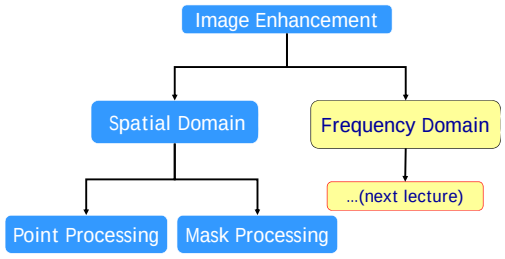
Tujuan Peningkatan Mutu Citra
(image enhancement)

- Tujuan: melakukan pemrosesan terhadap citra agar hasilnya dapat lebih *baik* dari citra awal untuk aplikasi tertentu
- Kriteria *baik* tergantung pada aplikasi dan problem:
  - Secara visual
  - Secara otomatis (untuk aplikasi selanjutnya)

Our topics



Point Processing

- Cara paling mudah
- Pemrosesan hanya melibatkan satu piksel saja (tidak menggunakan jendela ketetanggaan)
- Contoh: contrast stretching, histogram manipulation, etc.

Mask Processing - 1

- Operasi terhadap suatu jendela ketetanggaan pada citra
- Konvolusi suatu mask terhadap jendela tersebut
- Mask ini sering disebut filter

Mask Processing - 2

1	2	3
8	x	4
7	6	5

Contoh:
Jendela ketetanggan 3 × 3,
Nilai piksel pada posisi X dipengaruhi oleh nilai 8 tetangganya

→ Perbedaan dengan point processing: pada point processing, nilai suatu piksel tidak dipengaruhi oleh nilai tetangga-tetangganya

Mask Processing - 3

W_1	W_2	W_3
W_4	W_5	W_6
W_7	W_8	W_9

Mask/filter berukuran 3 × 3.
Filter ini akan diterapkan/dikonvolusikan pada setiap jendela ketetanggaan 3 × 3 pada citra

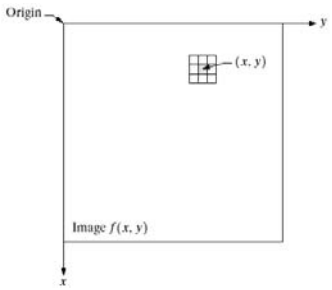
G_{11}	G_{12}	G_{13}	G_{14}	G_{15}
G21	G_{22}	G_{23}	G_{24}	G_{25}
G_{31}	G_{32}	G_{33}	G_{34}	G_{35}
G_{41}	G_{42}	G_{43}	G_{44}	G_{45}
G_{51}	G_{52}	G_{53}	G_{54}	G_{55}

$G_{22}' = w_1 G_{11} + w_2 G_{12} + w_3 G_{13} + w_4 G_{21} + w_5 G_{22} + w_6 G_{23} + w_7 G_{31} + w_8 G_{32} + w_9 G_{33}$

Jenis-jenis filter spasial

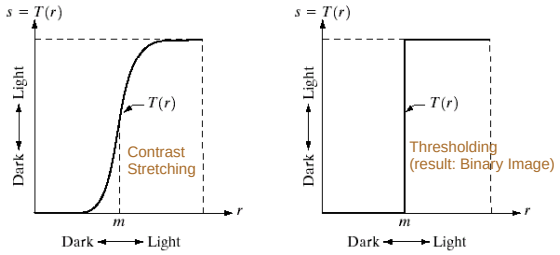
- Smoothing filters:
  - Lowpass filter (mengambil nilai rata-rata)
  - Median filter (mengambil median dari setiap jendela ketetanggaan)
- Sharpening filters:
  - Roberts, Prewitt, Sobel (edge detection)
  - Highpass filter

Neighborhood Concept (3×3)



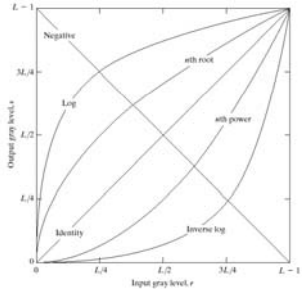
Grey Level Transformation
(contrast enhancement)

Transformation function $s = T(r)$
For point processing (mask 1×1 *)*

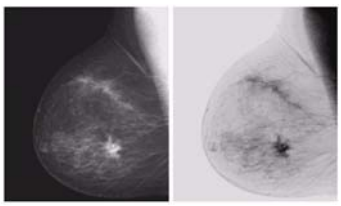


Several Transformation Functions
(image enhancement)

Transformation function: $s = T(r)$



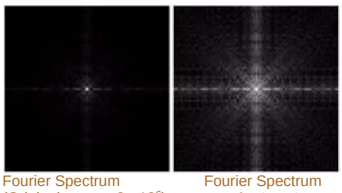
Example of Negative Transformation



Digital Mammogram (original)

Negative Transform
$s = L - 1 - r$

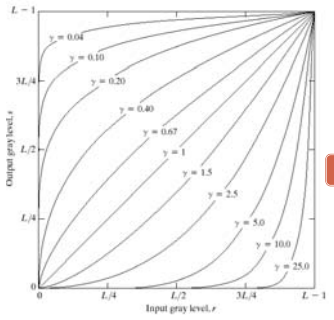
Log Transformation



Fourier Spectrum
(Original, range=0 - 10^6)

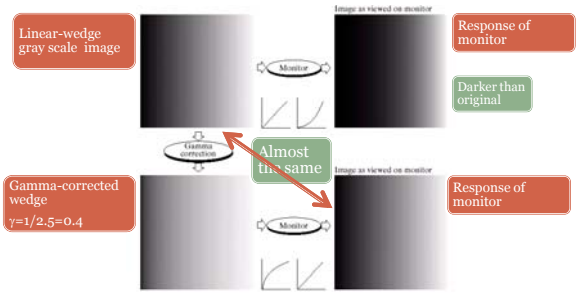
Fourier Spectrum
$s = c\ log(1 + r)$, $c=1$
Range= 0 - 6.2

Gamma Transformation

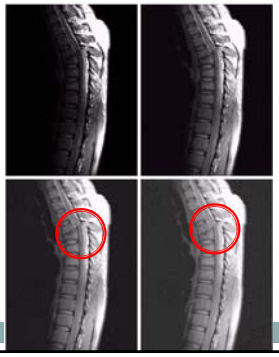


$s=cr^{\gamma}$

Gamma Correction on CRT



Another Example of Gamma Correction



Gamma-corrected
γ=0.6

Gamma-corrected
γ=0.4

Gamma-corrected
γ=0.3

Another Example of Gamma Correction

FIGURE 3.9
(a) Aerial image. (b)–(d) Results of applying the transformation in Eq. (3.2-3) with $c = 1$ and $\gamma = 3.0$, 4.0, and 5.0, respectively. (Original image for this example courtesy of NASA.)

Piecewise Linear Transformation

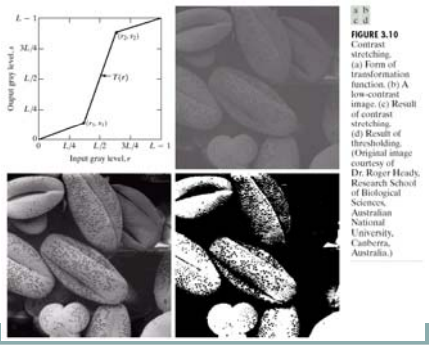


FIGURE 3.10
Contrast stretching. (a) Form of transformation function. (b) A low-contrast image. (c) Result of contrast stretching. (d) Result of thresholding. (Original image courtesy of Dr. Roger Heady, Research School of Biological Sciences, Australian National University, Canberra, Australia.)

Grey Level Slicing

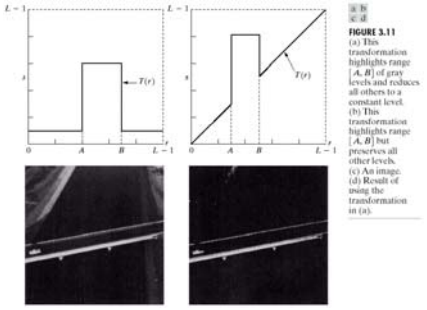
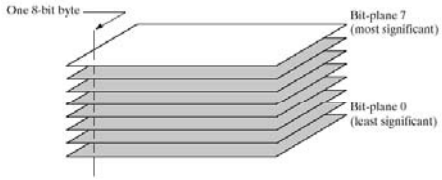


FIGURE 3.11 (a) This transformation highlights range $[A, B]$ of gray levels and reduces all others to a constant level. (b) This transformation highlights range $[A, B]$ but preserves all other levels. (c) An image. (d) Result of using the transformation in (a).

Bit Plane



Example: 8-bit fractal image

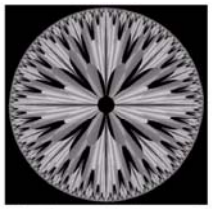
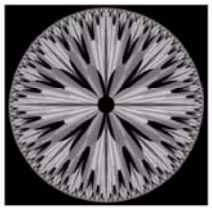
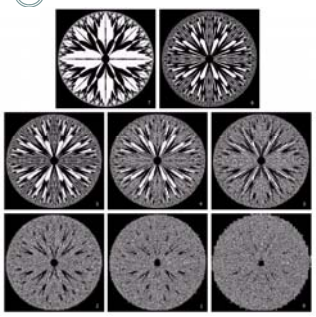


FIGURE 3.13 An 8-bit fractal image. (A fractal is an image generated from mathematical expressions). (Courtesy of Ms. Melissa D. Binde, Swarthmore College, Swarthmore, PA.)

Bit Plane Slicing



Original Image



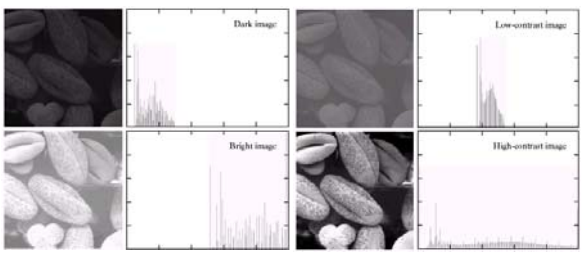
Bit plane 7,6,5, …0

Histogram Processing

- Histogram: diagram yang menunjukkan jumlah kemunculan grey level (0-255) pada suatu citra
- Histogram processing:
  - Gambar gelap: histogram cenderung ke sebelah kiri
  - Gambar terang: histogram cenderung ke sebelah kanan
  - Gambar low contrast: histogram mengumpul di suatu tempat
  - Gambar high contrast: histogram merata di semua tempat

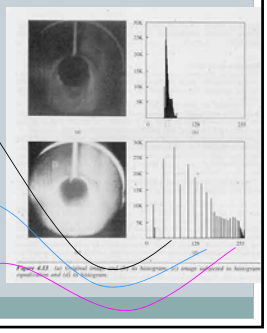
→ Histogram processing: mengubah bentuk histogram agar pemetaan gray level pada citra juga berubah

Four Basic Image Types – Histogram



Histogram Equalization

- Ide: mengubah pemetaan greylevel agar sebarannya (kontrasnya) lebih menyebar pada kisaran 0-255 (untuk citra 8 – bit)
- Sifat:
  - Grey level yang sering muncul lebih dijarangkan jaraknya dengan grey level sebelumnya
  - Grey level yang jarang muncul bisa lebih dirapatkan jaraknya dengan grey level sebelumnya
  - Histogram baru pasti mencapai nilai maksimal keabuan (contoh: 255)



Transformation Function

$$s_k = T(r_k) = \sum_{j=0}^{k} \frac{n_j}{n} = \sum_{j=0}^{k} p(r_j)$$

$$0 \le r_k \le 1 \quad dan \quad k = 0,1,\ldots..,L-1$$

Example

Example Image: An image with 0 – 10 grey level values

Original Image

3 5 5 5 4
5 4 5 4 4
5 3 4 4 4
4 5 6 6 3

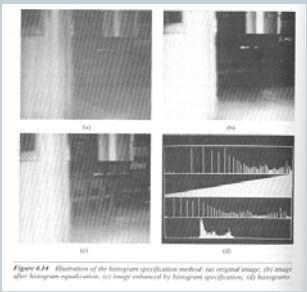
Histeq Image

1 9 9 9 5
9 5 9 5 5
9 1 5 5 5
5 9 10 10 1

Grey Level	0	1	2	3	4	5	6	7	8	9	10
Number of occurence	0	0	0	3	8	7	2	0	0	0	0
Probability of Occurence	0	0	0	0.15	0.40	0.35	0.1	0	0	0	0
Sk	0	0	0	0.15	0.55	0.90	1	1	1	1	1
Sk * 10	0	0	0	1.5	5.5	9	10	10	10	10	10
New Grey Level	0	0	0	1	5	9	10	10	10	10	10

Histogram Specification

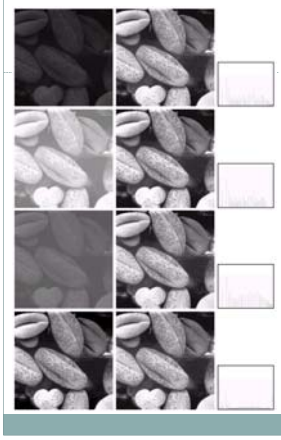
- Equalization tidak dilakukan pada seluruh bagian histogram tapi hanya pada bagian tertentu saja



Local Enhancement

- Histogram equalization hanya dilakukan pada bagian tertentu dari citra

Histeq Examples



Four basic images

- Dark
- Light
- Low contrast
- High contrast

Transformation Functions of Histeq

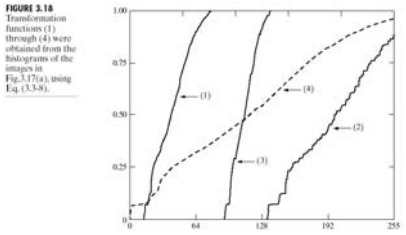
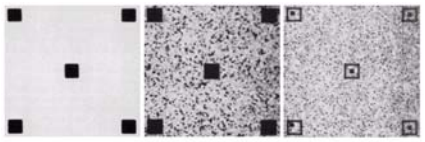


FIGURE 3.18 Transformation functions (1) through (4) were obtained from the histograms of the images in Fig. 3.17(a), using Eq. (3.3-8).

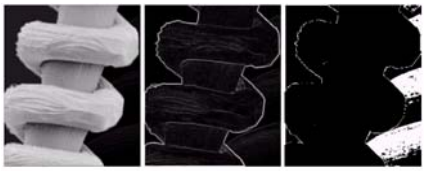
Local Enhancement (masking)



a b c

FIGURE 3.23 (a) Original image. (b) Result of global histogram equalization. (c) Result of local histogram equalization using a 7 × 7 neighborhood about each pixel.

Local Enhancement



a b c

FIGURE 3.25 (a) Image formed from all local means obtained from Fig. 3.24 using Eq. (3.3-21). (b) Image formed from all local standard deviations obtained from Fig. 3.24 using Eq. (3.3-22). (c) Image formed from all multiplication constants used to produce the enhanced image shown in Fig. 3.26.

Local mean $m_{S_{xy}} = \sum_{(s,t)\in S_{xy}} r_{s,t} p(r_{s,t})$

Local std. dev. $\sigma^2_{S_{xy}} = \sum_{(s,t)\in S_{xy}} [r_{s,t} - m_{S_{xy}}]^2 p(r_{s,t})$

Transformation Result

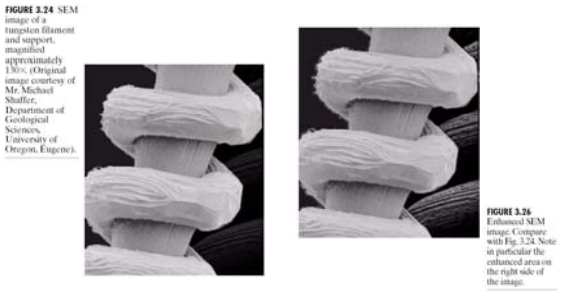


FIGURE 3.24 SEM image of a tungsten filament and support, magnified approximately 130×. (Original image courtesy of Mr. Michael Shaffer, Department of Geological Sciences, University of Oregon, Eugene).

FIGURE 3.26 Enhanced SEM image. Compare with Fig. 3.24. Note in particular the enhanced area on the right side of the image.

Arithmatic/Logic Operation: AND, OR

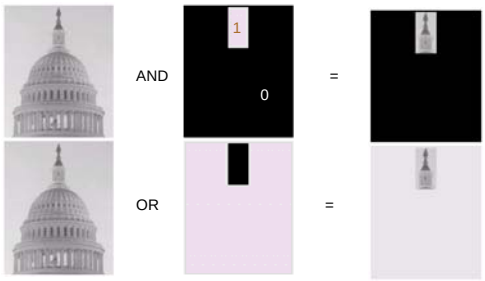


Image Difference

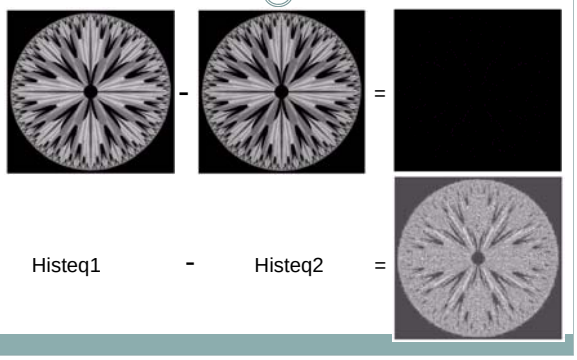


Image Substraction

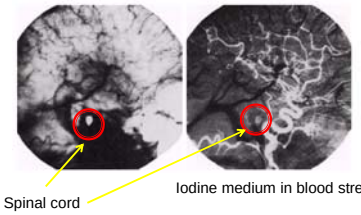


FIGURE 3.29 Enhancement by image subtraction. (a) Mask image. (b) An image (taken after injection of a contrast medium into the bloodstream) with mask subtracted out.

Spinal cord

Iodine medium in blood stream

Noisy Image – Averaging

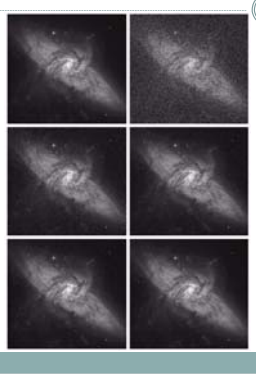


FIGURE 3.30 (a) Image of Galaxy Pair NGC3314. (b) Image corrupted by additive Gaussian noise with zero mean and a standard deviation of 64 gray levels. (c)–(f) Results of averaging $K = 8$, 16, 64, and 128 noisy images. (Original image courtesy of NASA.)

Image Differences

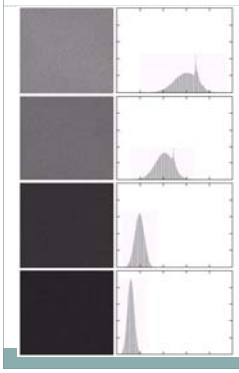


FIGURE 3.31 (a) From top to bottom: Difference images between Fig. 3.30(a) and the four images in Figs. 3.30(c) through (f), respectively. (b) Corresponding histograms.

Spatial Filtering using Mask

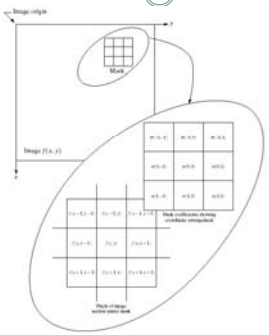


FIGURE 3.32 The mechanics of spatial filtering. The magnified drawing shows a 3×3 mask and the image section directly under it; the image section is shown displaced out from under the mask for ease of readability.

Spatial Filter Mask Representation (3×3)

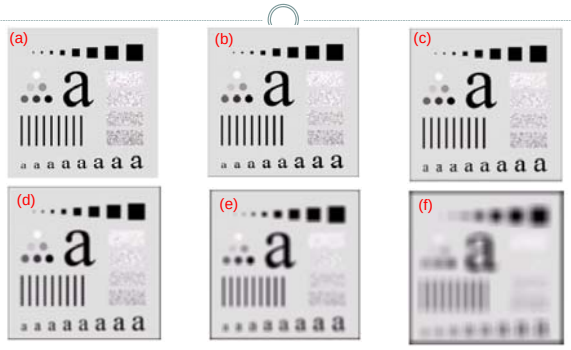
w_1	w_2	w_3
w_4	w_5	w_6
w_7	w_8	w_9

A 3×3 Smoothing Filters

$$\frac{1}{9} \times \begin{array}{|c|c|c|}\hline 1 & 1 & 1 \\ \hline 1 & 1 & 1 \\ \hline 1 & 1 & 1 \\ \hline \end{array} \qquad \frac{1}{16} \times \begin{array}{|c|c|c|}\hline 1 & 2 & 1 \\ \hline 2 & 4 & 2 \\ \hline 1 & 2 & 1 \\ \hline \end{array}$$

Filtering Results

(a) Original image; (b)-(f) Filter mask with 3,5,9,15 and 35 of size

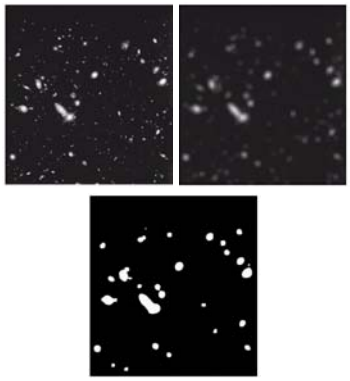


Smoothing & Thresholding

(a) Citra teleskop Hubble

(b) Smoothing 15×15

(c) Thresholding

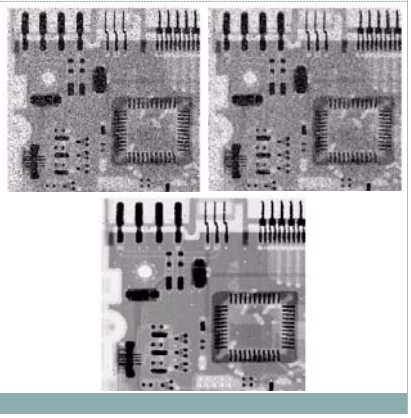


Noise Reduction by Filtering

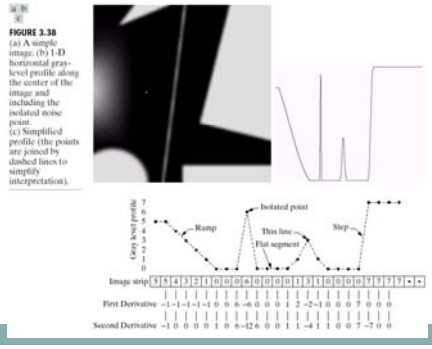
(a) X-ray corrupted by salt-and-pepper noise

(b) Noise reduction with a 3×3 averaging mask

(c) Noise reduction with a 3×3 median filter → better



Intensity Profile and Derivation Concept



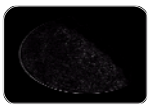
Laplacian Filters

- Extension to diagonal neighbors
- Two other implementation

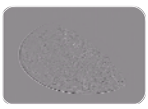
Digital Laplacian	$\nabla^2 f = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2}$	0 1 0 / 1 −4 1 / 0 1 0 ; 1 1 1 / 1 −8 1 / 1 1 1
x-direction	$\frac{\partial^2 f}{\partial x^2} = f(x+1,y) + f(x-1,y) - 2f(x,y)$	
y-direction	$\frac{\partial^2 f}{\partial y^2} = f(x,y+1) + f(x,y-1) - 2f(x,y)$	0 −1 0 / −1 4 −1 / 0 −1 0 ; −1 −1 −1 / −1 8 −1 / −1 −1 −1
Both-direction	$\nabla^2 f = [f(x+1,y) + f(x-1,y) + f(x,y+1) + f(x,y-1)] - 4f(x,y)$	(3.7-4)

Laplacian Filter

Image of North Pole of the Moon



Laplacian filtered-image



Scaled for displaying

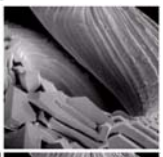
Enhanced

$$g(x,y) = \begin{cases} f(x,y) - \nabla^2 f(x,y) & \text{if the center coefficient of the Laplacian mask is negative} \\ f(x,y) + \nabla^2 f(x,y) & \text{if the center coefficient of the Laplacian mask is positive.} \end{cases}$$

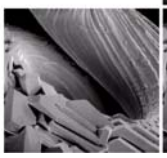
Laplacian Filter

Composite Laplacian mask

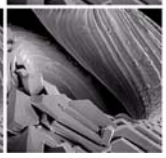
2nd composite Laplacian mask



Original Image



Filtering result using CLM



Filtering result using 2nd CLM (sharper)

High Boost Filter

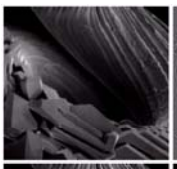
0	−1	0
−1	$A+4$	−1
0	−1	0

−1	−1	−1
−1	$A+8$	−1
−1	−1	−1

- High boost filters type 1
- High boost filters type 2
- A ≥1

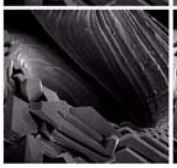
Laplacian Filters (contd.)

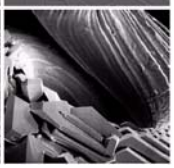
Original Image, but darker



Masking result using High Boost Filter type 2 (A=0)

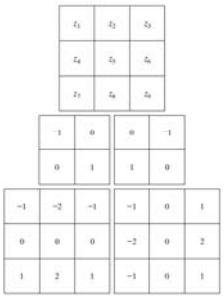
Masking result using High Boost Filter type 2 (A=1)





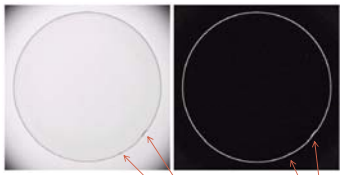
Masking result using High Boost Filter type 2 (A=1.7)

Derivative Filters



- 3×3 region of image
- Masks used to compute gradient/derivative at z_5
- All mask coeff. sum to 0
- Derivative operator qualification

Sobel Gradient



Defects seen visually

Clearer defects

Combined Filters

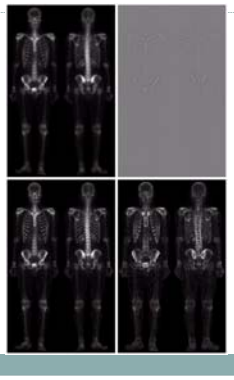


FIGURE 3.46
(a) Image of whole body bone scan. (b) Laplacian of (a). (c) Sharpened image obtained by adding (a) and (b). (d) Sobel of (a).

Combined Filters (contd.)

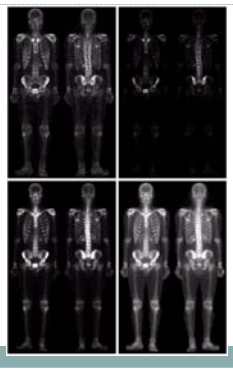


FIGURE 3.46 *(Continued)* (e) Sobel image smoothed with a 5 × 5 averaging filter. (f) Mask image formed by the product of (c) and (e). (g) Sharpened image obtained by the sum of (a) and (f). (h) Final result obtained by applying a power-law transformation to (g). Compare (g) and (h) with (a). (Original image courtesy of G.E. Medical Systems.)

Video's Time

Video today

BMW, the large vehicle manufacturer used various technology in building a new 3-series

You can see the process fully automated and only a small portion manufactured manually by human

This is one of example in image processing application (e.g. painting QC, welding QC, etc.)

MATLAB® Time

FOR YOUR OWN GOOD, START LEARNING FROM NOW!

Matlab: Noise reduction

- Cari menu untuk filtering
- Untuk berbagai jenis noise, gunakan filter:
  - Median
  - Adaptive
  - Averaging
  - Histogram processing
  - Low pass, high pass, boost-up, etc.
- Coba berbagai ukuran filter neighborhood (window)
  - 3×3, 5×5, 7×7, etc.
  - Gunakan nilai variable A yang berbeda (mis. pada Laplacian)
- Gunakan kombinasi beberapa jenis filter, bandingkan hasilnya