Image Processing in the Spatial Domain 1

Pengolahan Citra

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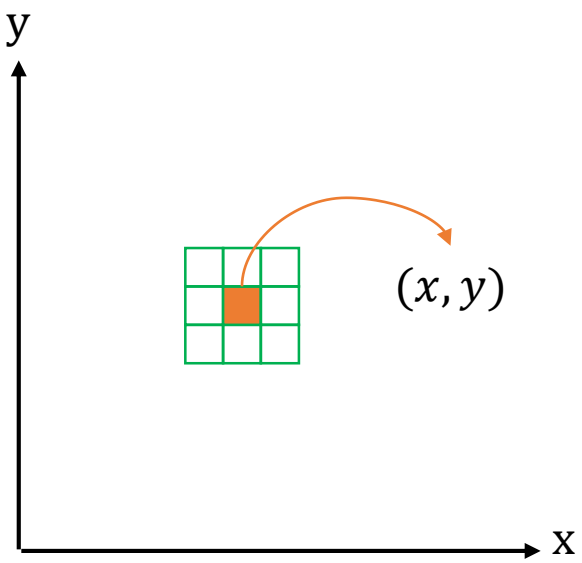
The Basics of Intensity Transformation

- Spatial transformation can be denoted as:

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

- The function T is applied to the *neighborhood* of point (x, y)
  - Can be the pixel itself
  - Can be an area surrounding the pixel
    - Typically the area is rectangular, centered on (x, y), and much smaller than the image



Spatial Transformation

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

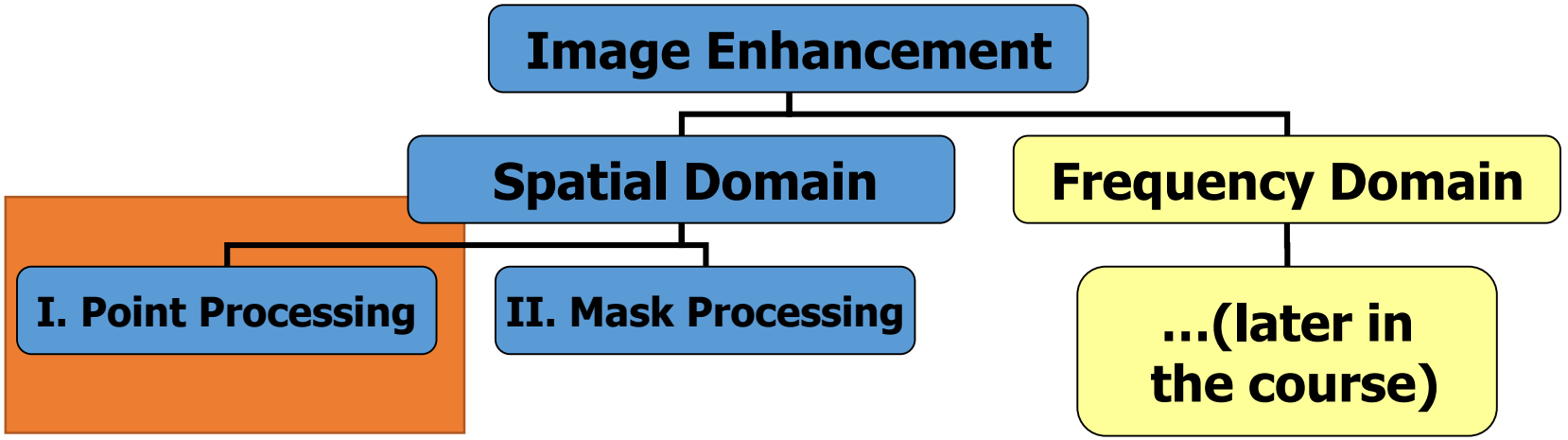
- What possible operations fulfill this formula?

We will focus for the meantime on *image enhancement*

Image Enhancement

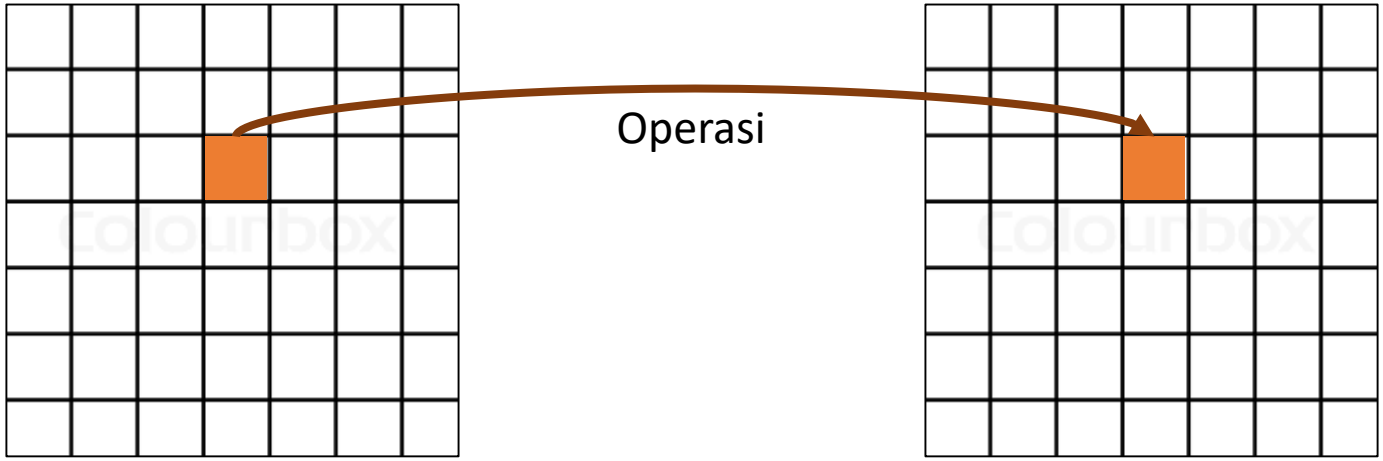
- Tujuan dari teknik peningkatan mutu/kualitas citra (*image enhancement*) :
  - Agar citra yang digunakan mempunyai kualitas lebih baik dari citra awal, dan hasil interpretasinya akan lebih baik pula
  - Kata **baik** disini sifatnya relatif tergantung pada jenis aplikasi dan problem yang dihadapi.
- Pendekatan image enhancement
  - Domain spasial
    - Termasuk warna dan intensitas
  - Domain frekuensi

Lingkup Pembahasan



Point Processing

- Pemrosesan citra yang operasinya hanya melibatkan satu piksel saja



Some Basic Intensity Transformations

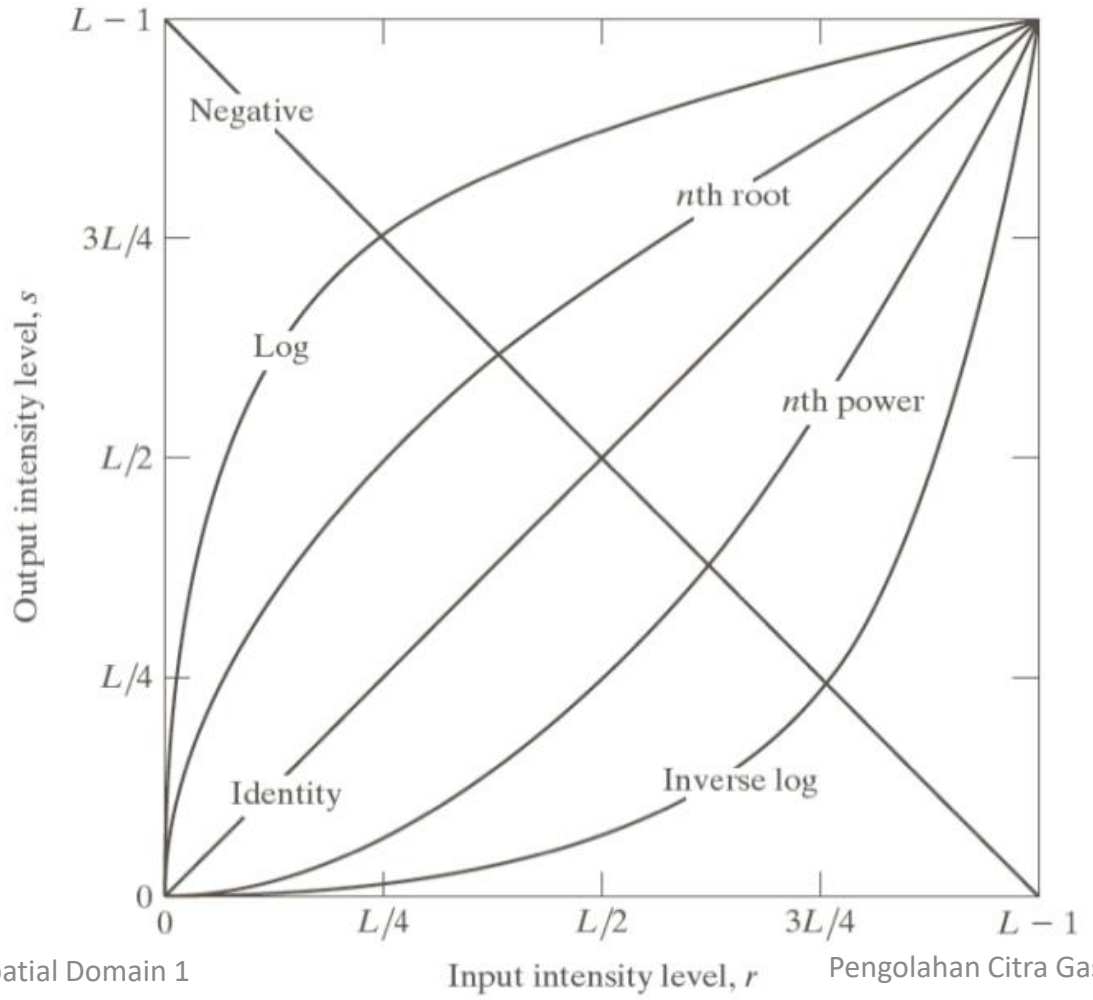
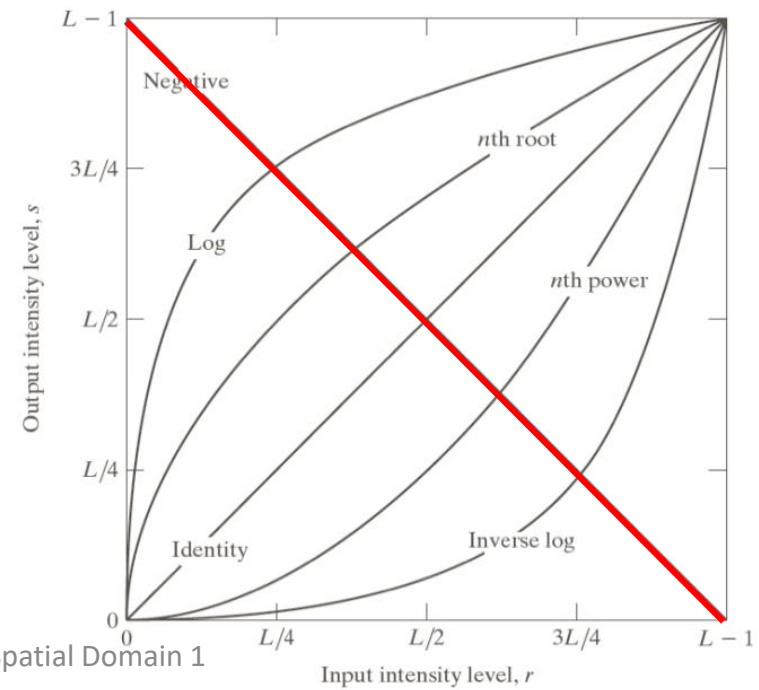


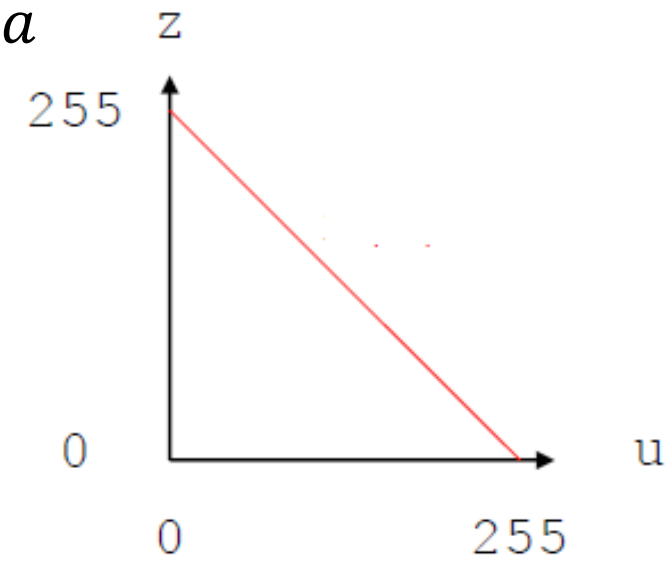
Image Negative

- Mengubah nilai grey-level piksel citra input dengan:

$$G_{baru} = 255 - Glama$$

- Recall

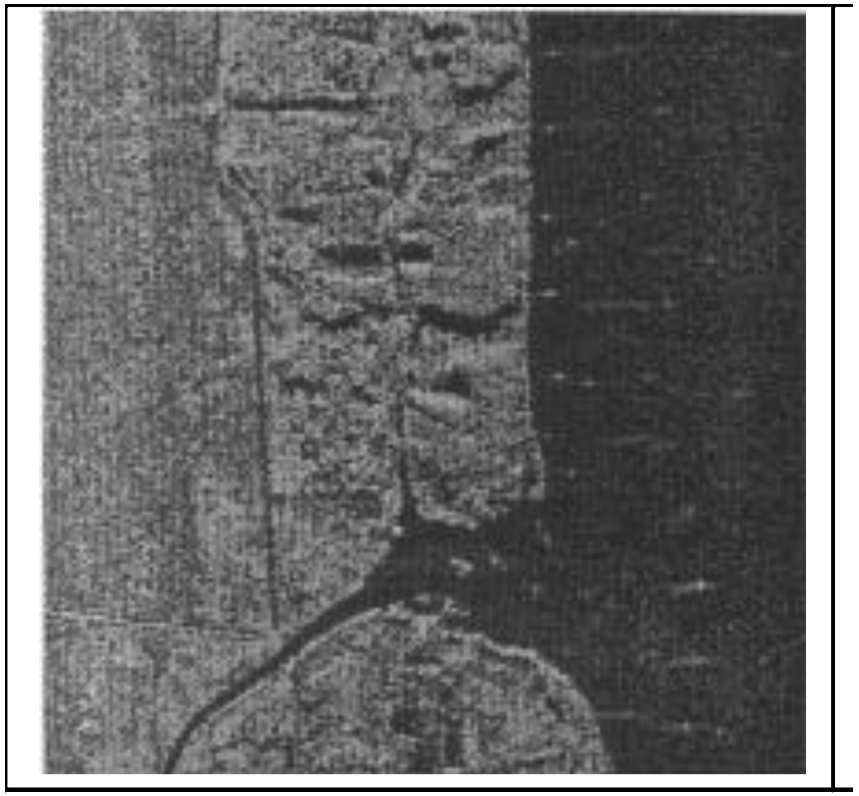




Example of Image Negative

- Hasilnya seperti klise foto

Aplikasi Penginderaan Jarak Jauh
(Sumber: Murni, 1997)



Citra Optik sering dianggap sebagai negatif dari citra SAR
(Source: Bakosurtanal RI)

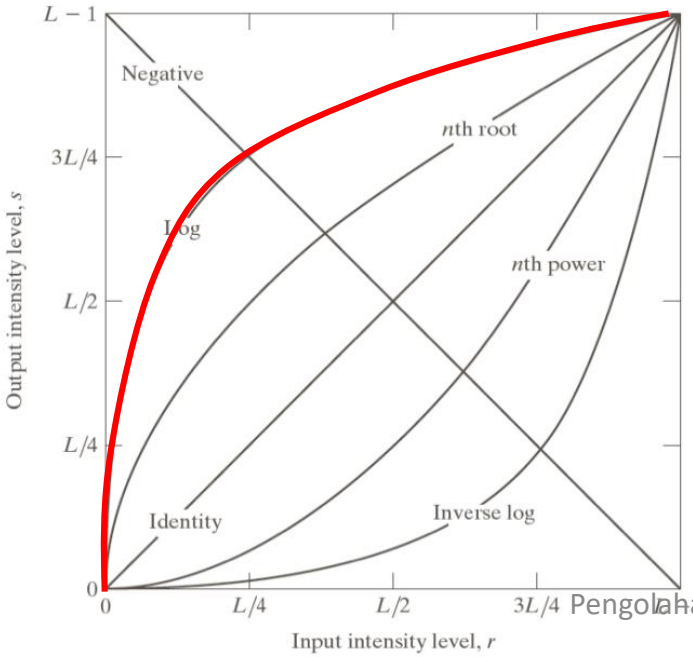
Log Transformation

- Bentuk umum dari transformasi logaritma adalah

$$s = c\ \log(1 + r)$$

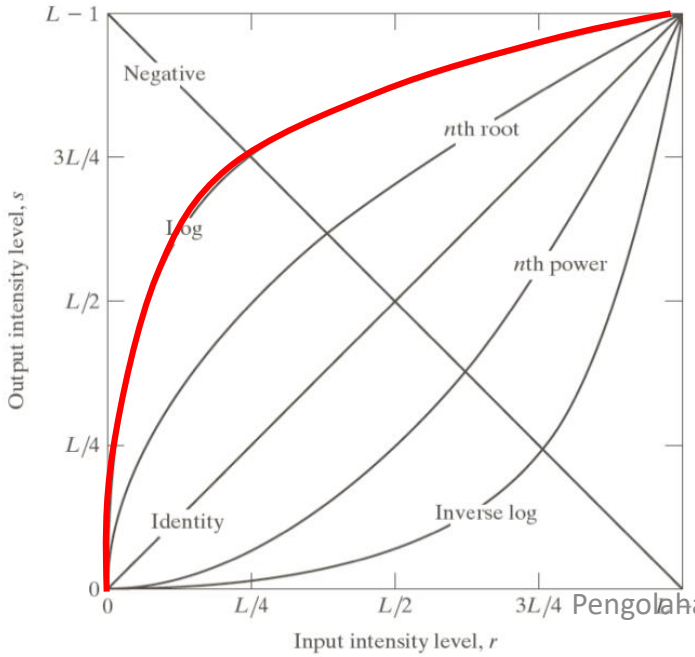
  - Untuk input r dan output s, dimana c itu konstan dan r≥0

- Recall



Log Transformation (2)

- Mapping a narrow range of low intensity values to a wider range of high intensity values, and a wide range of high intensity values to a narrower range of low intensity values.
- Tujuannya untuk ekspansi nilai pixel gelap dan kompresi nilai pixel terang→ membatasi dynamic range



Example

- Limiting the dynamic range
  - (Ex) For display purposes

Input image

Its log transform c=1

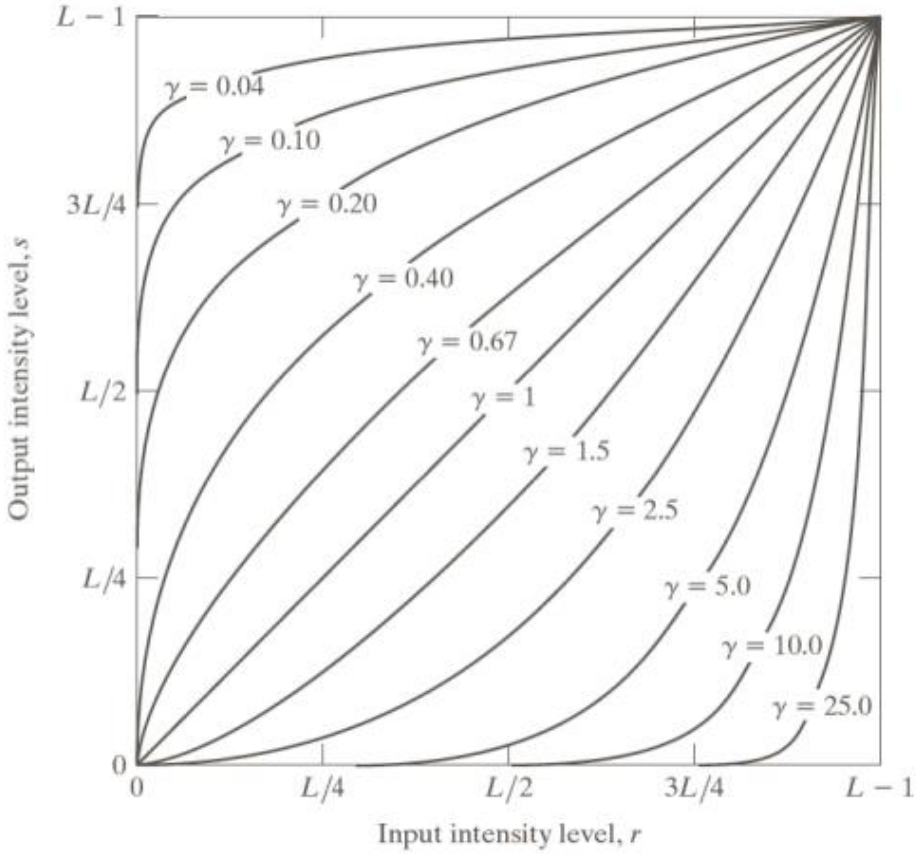
Image from Hamid Laga, Telecom Lille 1

Gamma (Power) Transformations

- Bentuk umum:

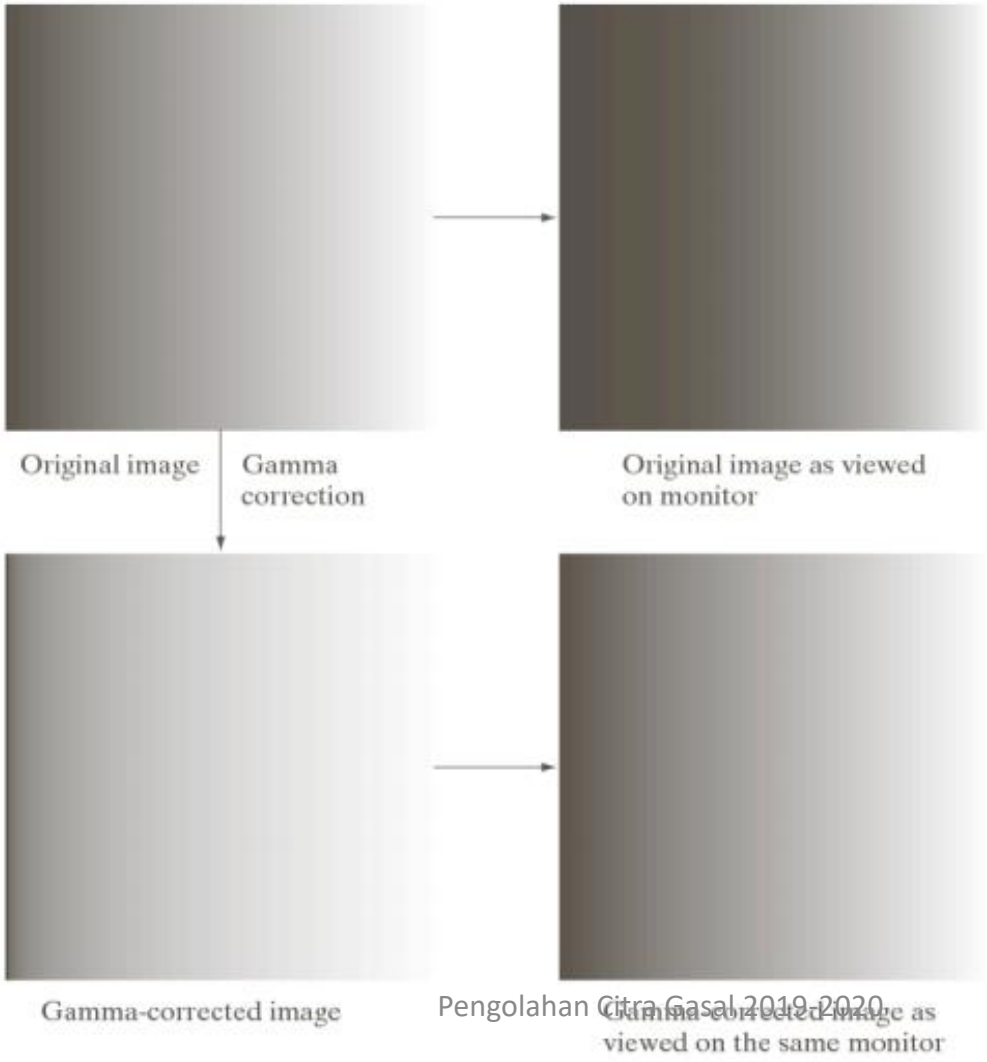
$$s = cr^{\gamma}$$

  - Untuk input r dan output s, c dan γ adalah konstan
- Similar to log transform
  - Possible transformations just by varying γ
  - $\gamma < 1$
  - $\gamma > 1$
  - $\gamma = 1$



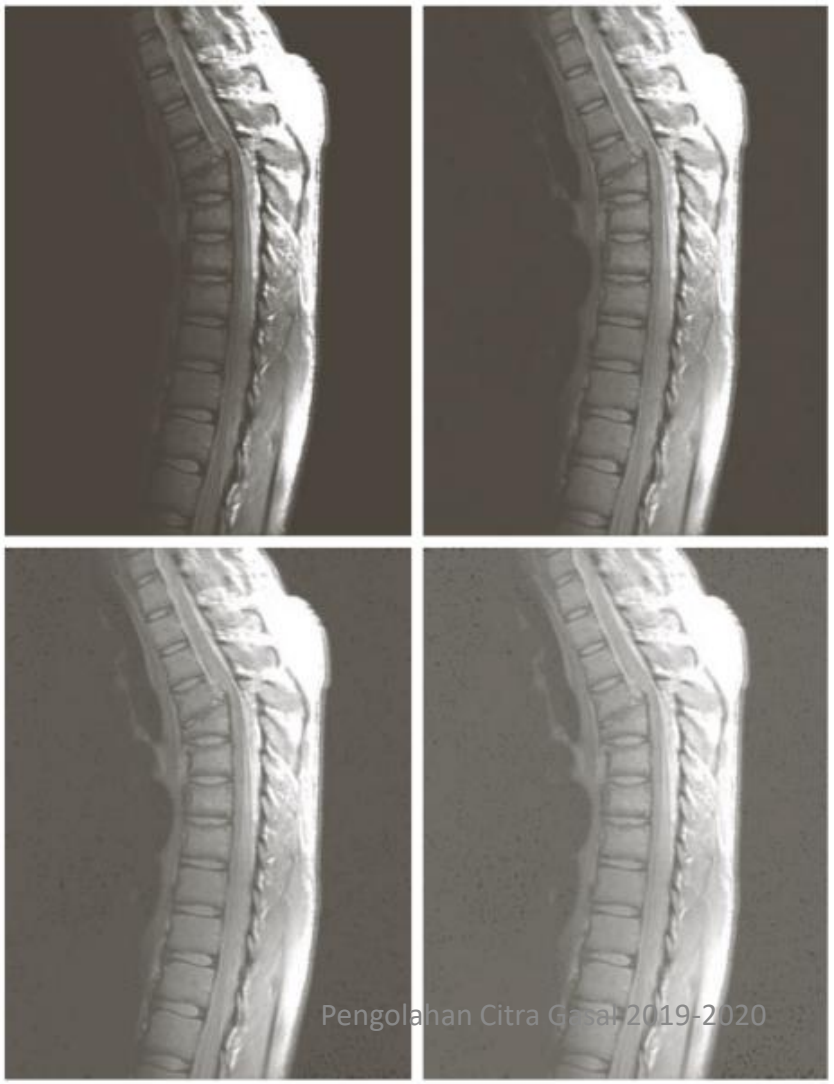
Example of Gamma Transformations

- Gamma correction for displays
- Important for *contrast*



Example of Gamma Transformations (2)

- Gamma correction for displays
- Important for *contrast*

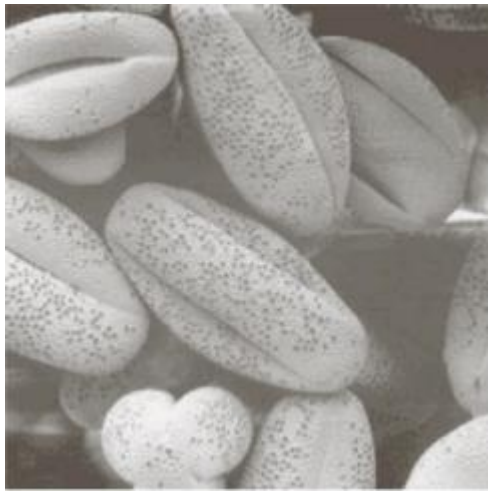


Images from Department of Radiology and Radiological Sciences, Vanderbilt University

Contrast Stretching

- Contrast stretching mengembangkan *range* level intensitas pixel yang tadinya terbatas sehingga memiliki *range* intensitas penuh.

Citra asli dengan level intensitas yang terbatas (0-100 pada image 8 bit)



Citra setelah *contrast stretching* dengan nilai intensitas 0-255 (8 bit)

Examples of Contrast Stretching

Contrast Stretching

- Fungsi lain yang baik digunakan adalah:

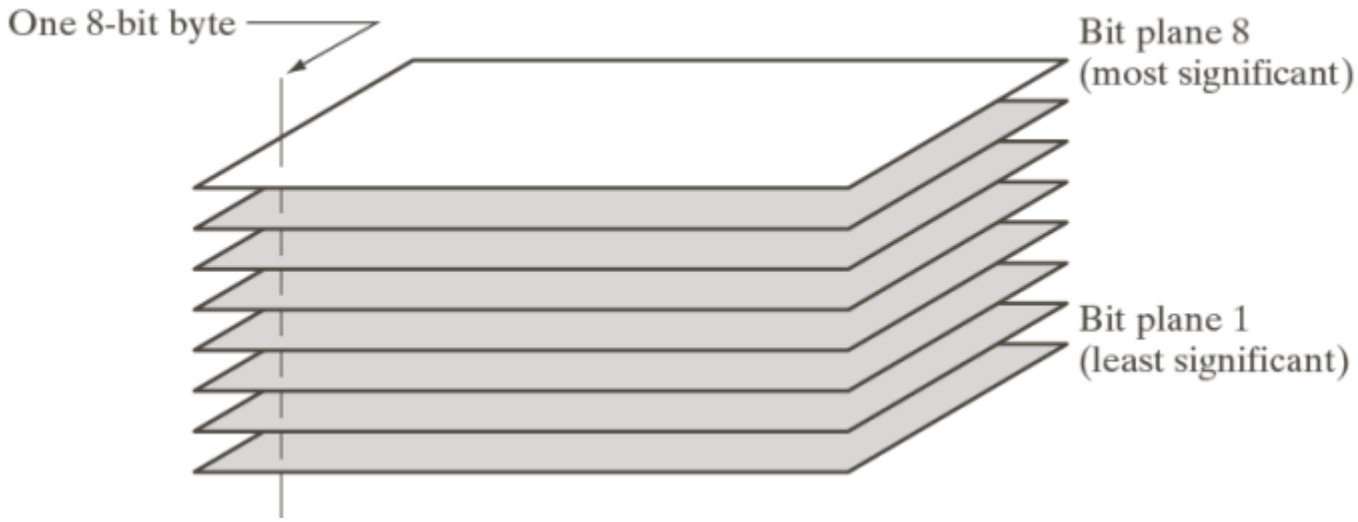
$$f_{out} = (fin - a) * b$$

  - Di mana $a = \min(fin)$, dan $b = 255/(\max(fin) - \min(fin))$

- Citra masukan yang grey level nya tidak penuh dari 0 – 255 (low constrast) diubah menjadi citra yang grey level nya berkisar dari 0 – 255 (high contrast)

Bit-Plane Slicing

- Each pixel consists of 8 bits (assuming 8-bit images)
- Instead of considering the intensity *values*, we can consider the contribution of each bit



Bit-Plane Slicing (2)

- Representation of each bit of an image of a 100-dollar bill

- Apa yang bisa disimpulkan tentang representasi ini?

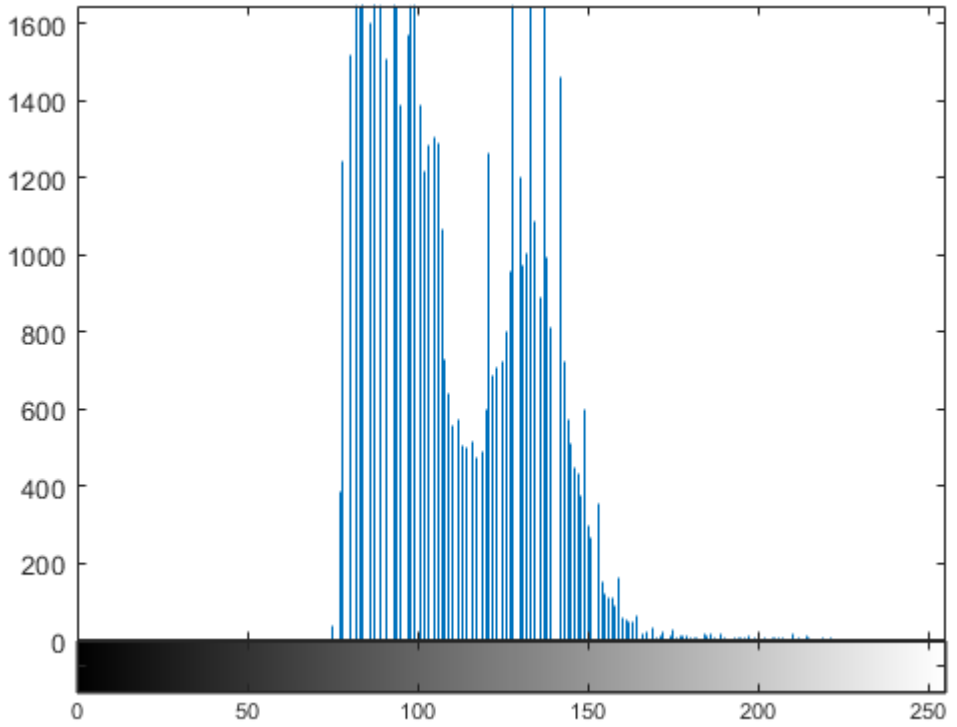
Brainstorming

- Potential usages of bit-plane slicing?

Image Histograms

- For an image with intensity levels $[0, L-1]$, its histogram is $$h(r_k) = n_k$$
  - Where r_k is the k-th intensity value and n_k is the number of pixels with intensity r_k
- The histogram plots the distribution of intensity values throughout the image

Image Histograms (2)



- 8-bit image have 256 bins by default

Image Histograms (3)

- What can we deduce from the image from their histograms?

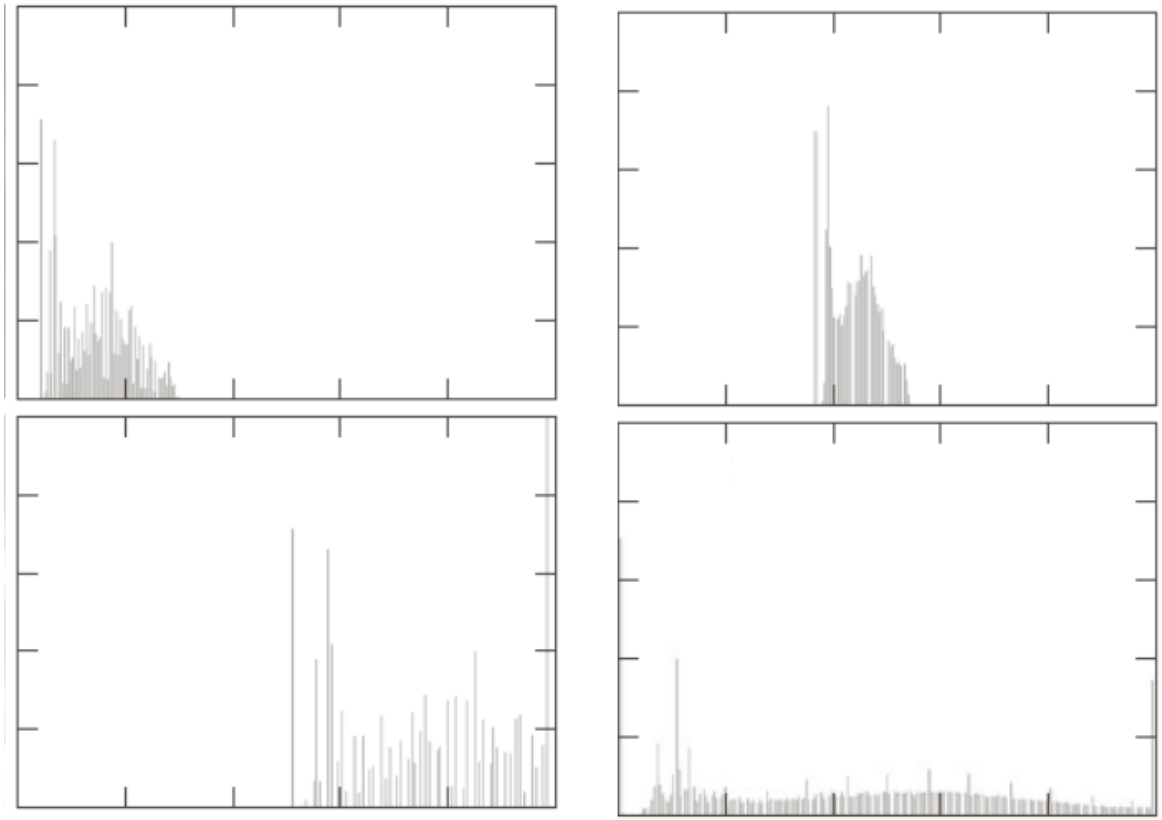


Image Histograms (4)

- What can we deduce from the image from their histograms?

Dark image

Low contrast

Bright image

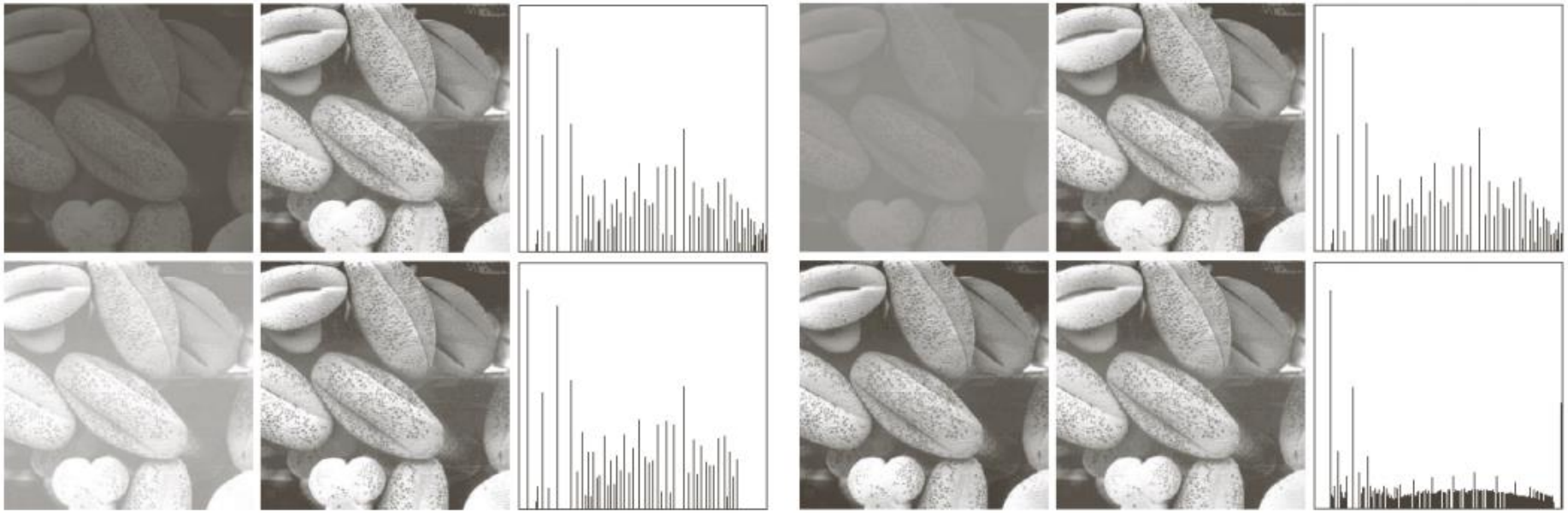
High contrast

Histogram Equalization

- Histogram processing: mengubah bentuk histogram agar pemetaan gray level pada citra juga berubah
- Ide: mengubah pemetaan greylevel agar kontrasnya lebih menyebar pada kisaran 0-255
- 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)

Histogram Equalization (Results)

- The method to generate a processed image that has a pre-defined histogram.



Histogram Equalization in all grey level and all area

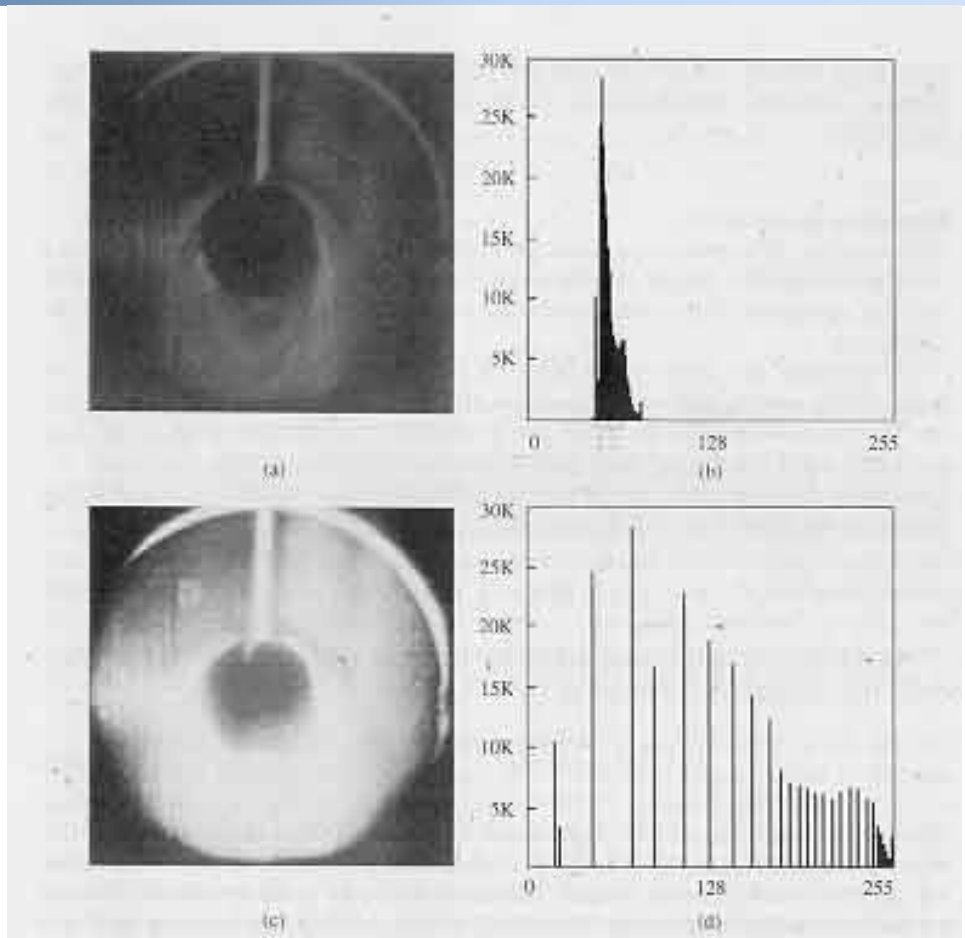


Figure 4.13 *(a) Original image and (b) its histogram; (c) image subjected to histogram equalization and (d) its histogram.*

Histogram Equalization in all grey level and all area (2)

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

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

L adalah grey level maksimal yang ada pada citra

Histogram Equalization in a Specific area (local enhancement)

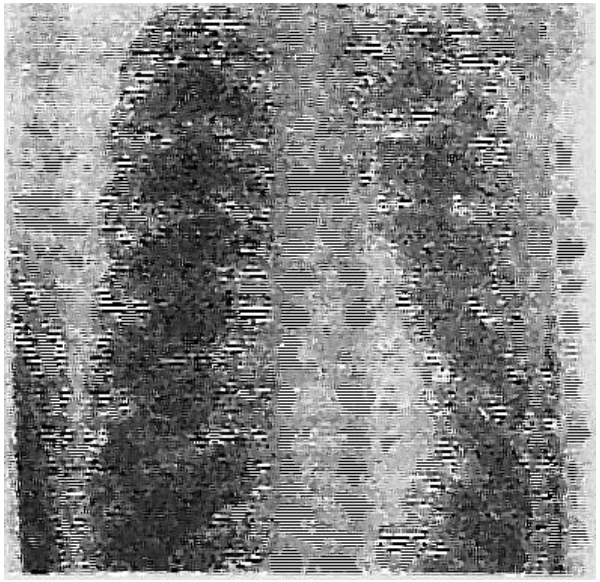
- Histogram equalization hanya dilakukan pada bagian tertentu dari citra

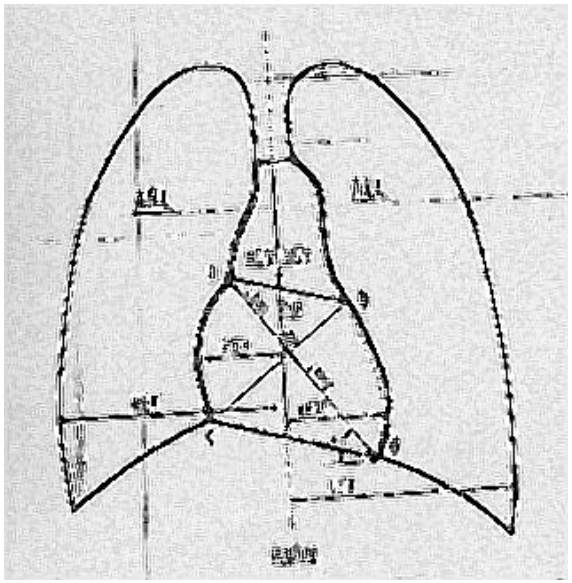
Citra masukan over exposed Citra keluaran lebih tajam

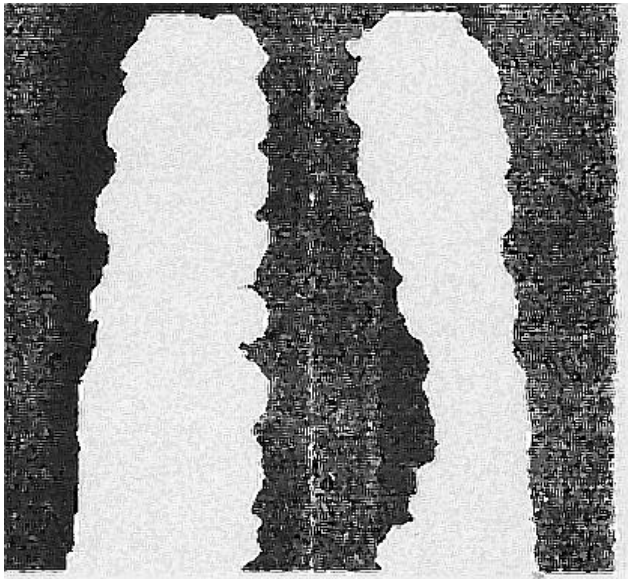
Image Substraction

- Dilakukan jika kita ingin mengambil bagian tertentu saja dari citra

Aplikasi Kedokteran (Biomedik)
(Sumber: Thesis S2 Kartono)



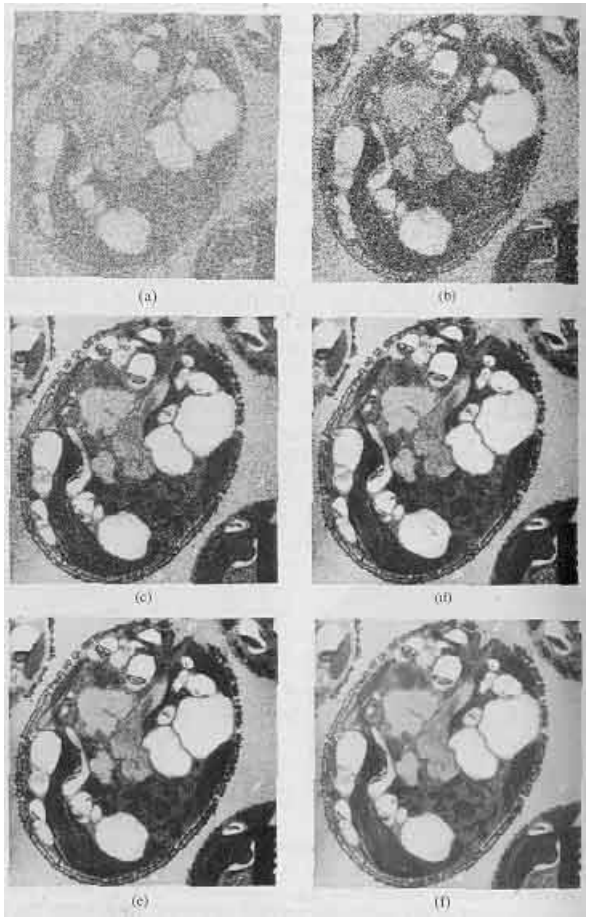




(a) Thorax X-Ray (b) Standard Landmarks (c) Thorax Tissue

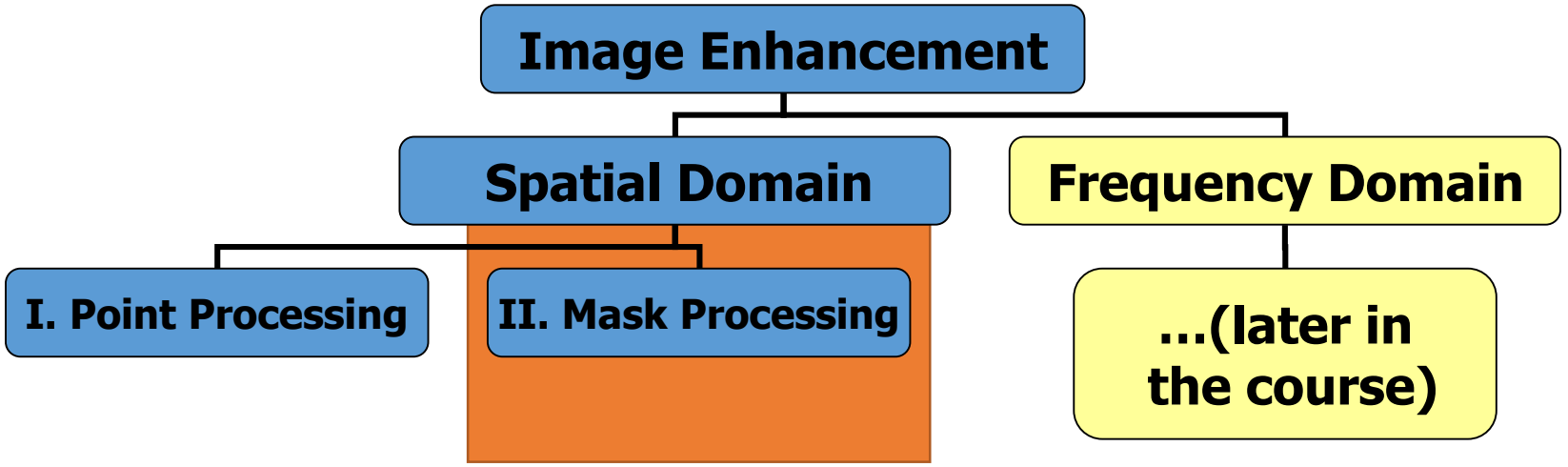
Kita bisa mengambil bagian jaringan parunya saja, dengan operasi AND citra (a) dan citra (c). Citra (c) dapat diperoleh melalui proses clustering dan thresholding

Image Averaging



- Dilakukan jika kita memiliki beberapa citra yang bergambar sama, namun semua citra memiliki noise (gangguan)
- Noise satu citra berbeda dengan noise citra lainnya (tidak berkorelasi)
- Cara memperbaikinya adalah dengan melakukan operasi rata-rata terhadap semua citra tersebut (yang masing-masing mengandung white noise)

Lingkup Pembahasan



Mask Processing

- Jika pada *point processing* kita hanya melakukan operasi terhadap masing-masing piksel, pada *mask processing* kita melakukan operasi terhadap suatu **jendela ketetanggaan** pada citra.
- Kemudian kita menerapkan (mengkonvolusikan) suatu *mask* terhadap jendela tersebut.
- *Mask* sering juga disebut *filter* atau *kernel.*

Mask Processing

1	2	3
8	x	4
7	6	5

- Contoh:
- Jendela ketetanggan 3x3,
- 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

W_1	W_2	W_3
W_4	W_5	W_6
W_7	W_8	W_9

Contoh sebuah mask berukuran 3x3. Filter ini akan diterapkan / dikonvolusikan pada setiap jendela ketetanggaan 3x3 pada citra

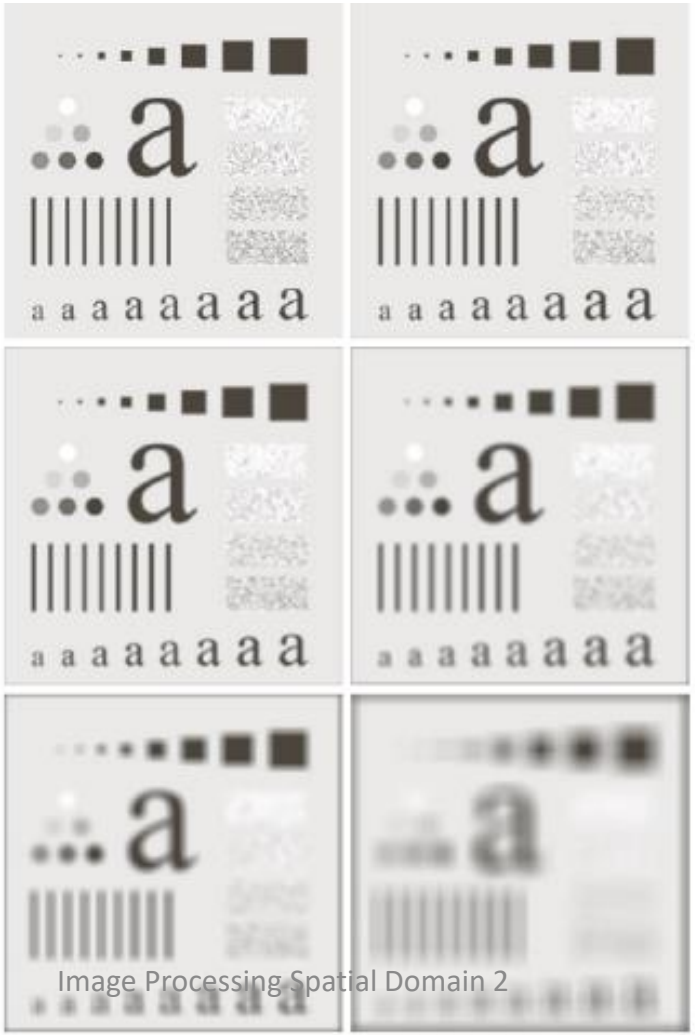
G_{11}	G_{12}	G_{13}	G_{14}	G_{15}
G21	G_{22}	G_{23}	G_{24}	G_{25}
G_{31}	G_{32}	G_{33}	G_{34}	G_{35}
G_{41}	G_{42}	G_{43}	G_{44}	G_{45}
G_{51}	G_{52}	G_{53}	G_{54}	G_{55}

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

Jenis-jenis filter spasial

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

Smoothing



1/9 x

1	1	1
1	1	1
1	1	1

Average lowpass filter

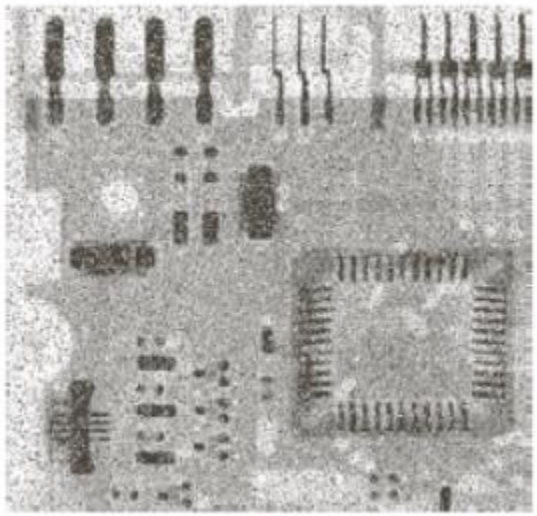
$$\frac{1}{n} \times [A]$$

Where A is a matrix with n elements of 1s

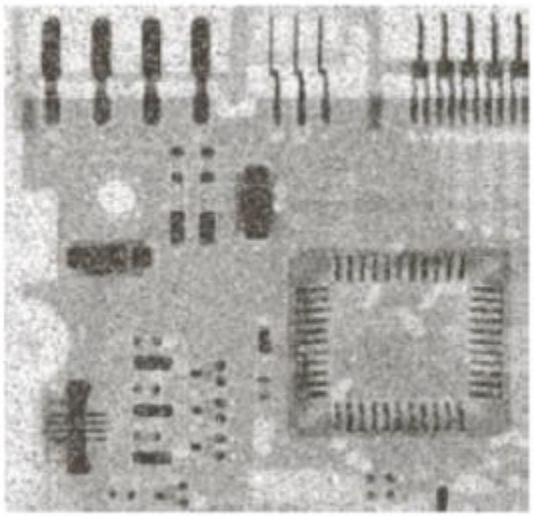
(a) Gambar Asli
(b)-(f) hasil dari spatial lowpass filtering dengan ukuran mask 3,5,9,15,35

Mean Filter

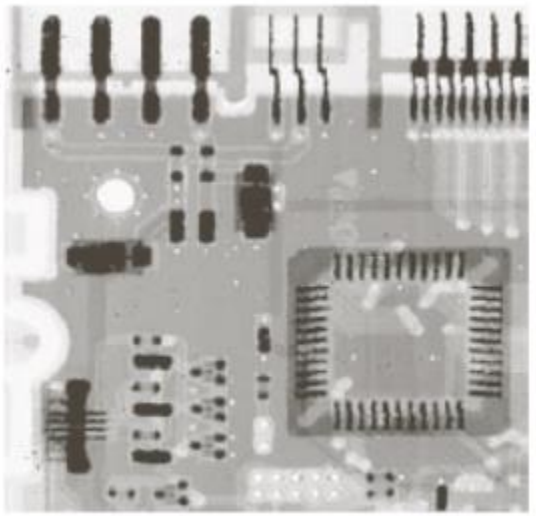
- Particularly useful for noise removal



Original



Added salt and pepper noise



Filtered

Penerapan mean filter dan filter median

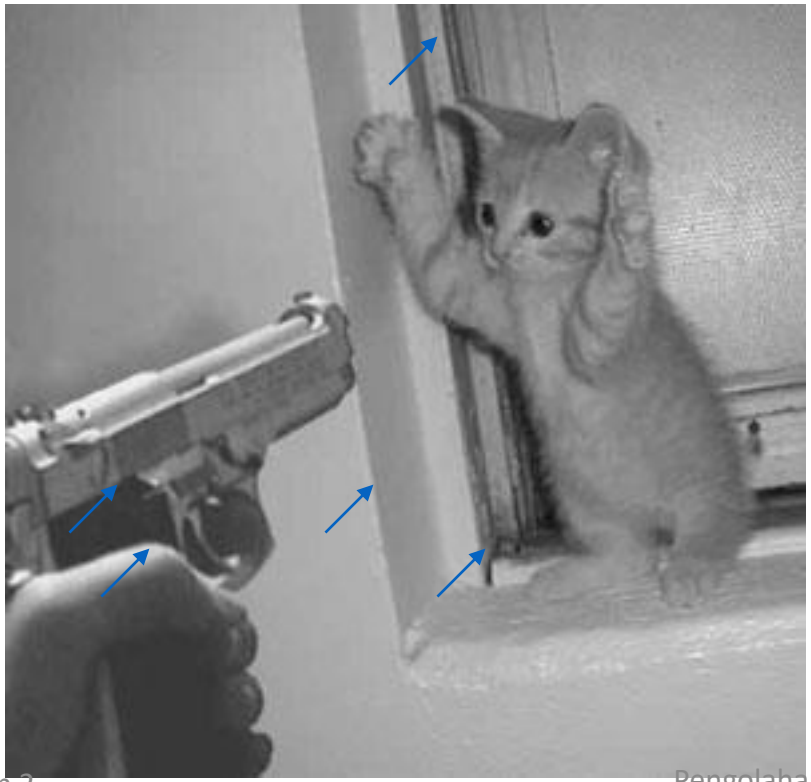
(a) Gambar asli
(b) Gambar yang diberi noise
(c) Hasil dari 5x5 average filtering
(d) Hasil dari 5x5 median filtering

Sharpening

- Why?

Edge detection

- Pada suatu citra monokrom, suatu edge (sisi) dapat ditandai dengan adanya *suatu perbedaan intensitas* yang besar

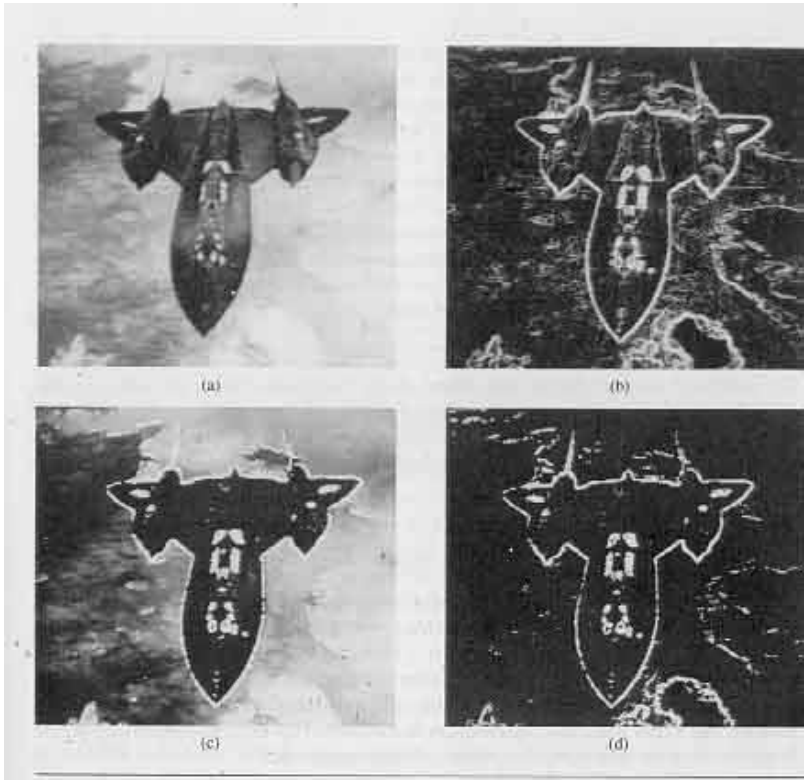


Edge detection

- Bagaimana ‘mendeteksi’ perbedaan intensitas tersebut?
  - Dengan mempertegas perbedaan

  (kalikan satu intensitas dengan nilai negatif, kemudian kalikan nilai positif pada intensitas lainnya)
    - Kasus A: 2 bersisian dgn 100 (edge) → 2*(-1) + 100*(1)= 99
    - Kasus B: 2 bersisian dgn 4 (not edge) → 2*(-1) + 4*(1)= 2
  - Lakukan tresholding untuk memperjelas mana bagian sisi dan mana yang bukan
    - Ambil treshold = 90, maka Kasus A akan dianggap sebagai sisi, Kasus B tidak dianggap sisi

Sobel dan Prewitt Mask



-1	-2	-1
0	0	0
1	2	1

-1	0	1
-2	0	2
-1	0	1

Sobel

-1	-1	-1
0	0	0
1	1	1

-1	0	1
-1	0	1
-1	0	1

Prewitt

(a) Gambar awal, (b) hasil dari Prewitt mask, (c) thresholding dari (b) pada nilai > 25 (white) (d) thresholding dari (b) pada nilai >25 (white) dan < 25 (black)

Image Gradients

- What is a gradient?
- In the context of an image?
- What does it have to do with edges?

Gradient

- *Brightness gradient of image f(x,y):*

$$\Delta f = \left(\frac{\partial f(x,y)}{\partial x}, \frac{\partial f(x,y)}{\partial y}\right)$$

- *Digital derivative:*

$$\Delta x = f(x+n, y) - f(x, y)$$
$$\Delta y = f(x, y+n) - f(x, y)$$

umumnya n=1.

Magnitude of gradient vector

- *Rumus 1:*

$$|| \nabla f || = \sqrt{\Delta x^2 + \Delta y^2}$$

- *Rumus 2:*

$$|| \nabla f || = \max(abs(\Delta x), abs(\Delta y))$$

- *Rumus 3:*

$$|| \nabla f || = abs(\Delta x) + abs(\Delta y)$$

- *The quickest speed with which the intensity changes at f(x,y)*

Direction of gradient vector

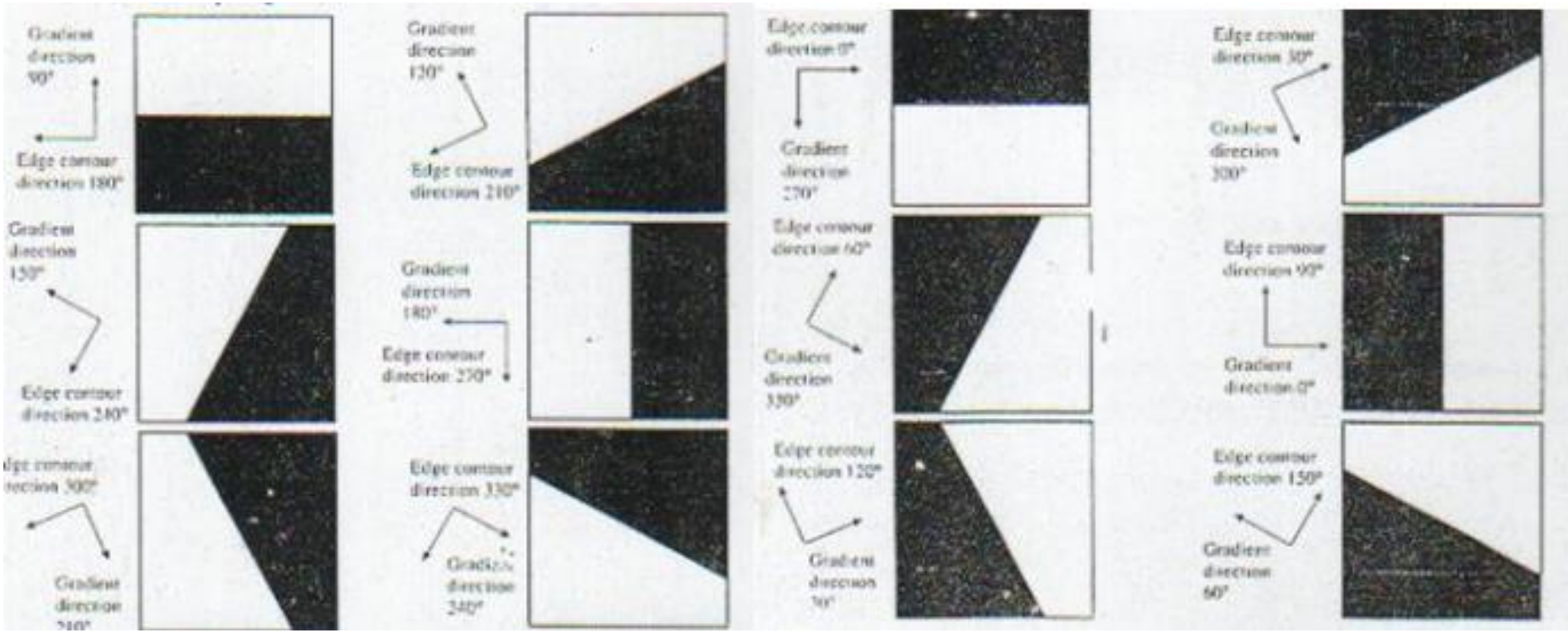
- *The direction in which the intensity changes the quickest at f(x,y)*
- *Direction*

$$\phi = \tan^{-1} atau \arctan \frac{\Delta y f(i, j)}{\Delta x f(i, j)}$$

Direction of gradient vector

- Edge contour direction: along the contour, right side is white (high value)
- Edge gradient direction: orthogonal to the contour, towards white (high value)

Direction of gradient vector



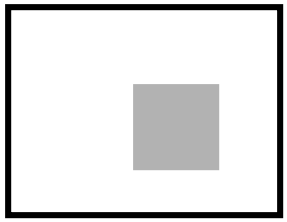
Sumber: MSU

Gradients and Derivatives

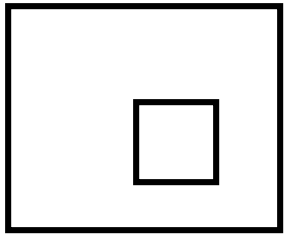
- What is the correlation?

1st derivative and 2nd derivative

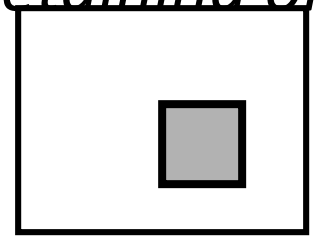
- *Contoh image:*



- *Hasil 1st derivative (outlining):*



- *Hasil 2nd derivative (retaining original image):*

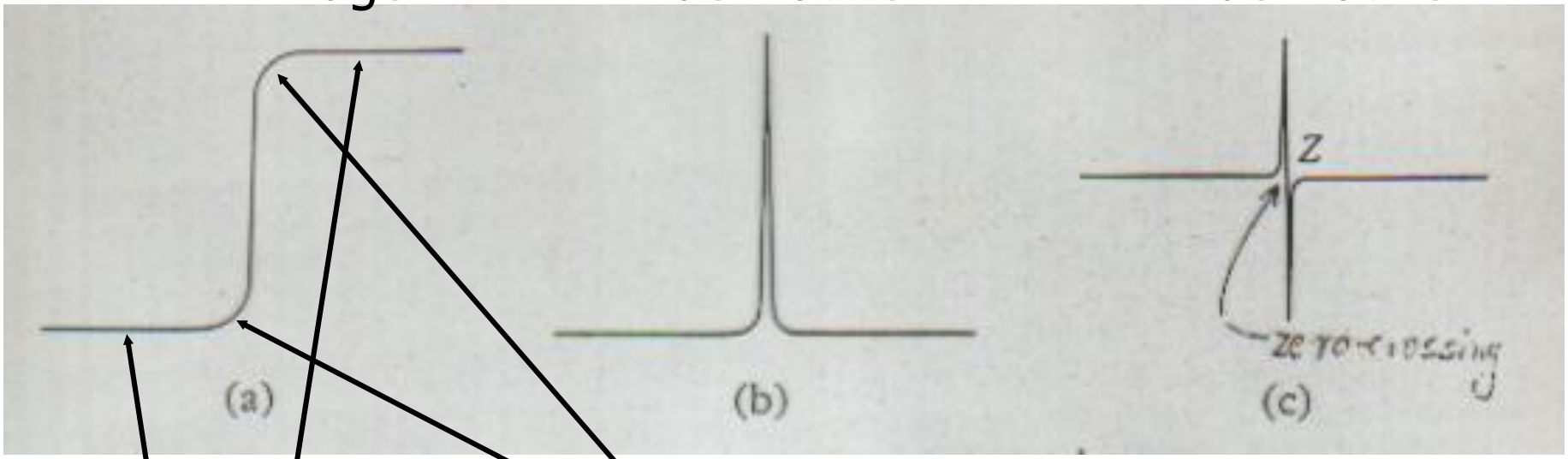


Gradients and Derivatives

- Take home brainstorming:
  - 1^{st} and 2^{nd} order derivatives

Konsep Zero-Crossing

1-D image 1st derivative 2nd derivative



Frekwensi rendah dan frekwensi tinggi.

(a) Perubahan intensitas; (b) Mempunyai *peak*; (c) *Steep zero-crossing.*

Sumber: MSU

Laplacian of Gaussian Filtering

- Laplacian operator (HPF):

$$\nabla^2 f = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2}$$

- Laplacian bertujuan untuk meningkatkan kwalitas detil (detail enhancement)
- Laplacian of Gaussian filtering bertujuan untuk menghilangkan noise dan meningkatkan kwalitas detil.

Laplacian of Gaussian Filtering

- *Laplacian of Gaussian:* $\nabla^2 G_\sigma(x, y, \sigma) = \nabla^2 G_\sigma * F(x, y)$

$$\nabla^2 G_\sigma(x, y, \sigma) = \left(\frac{r^2 - 2\sigma^2}{\sigma^4}\right) \exp\left(\frac{-r^2}{2\sigma^2}\right)$$

dengan $r = \sqrt{x^2 + y^2}$

- *Selanjutnya dicari lokasi zero-crossing untuk menentukan garis batas antara hitam dan putih.*

Laplacian of Gaussian Filtering

(a) (b) (c)

(a) Original image (320 x 320 pixels)

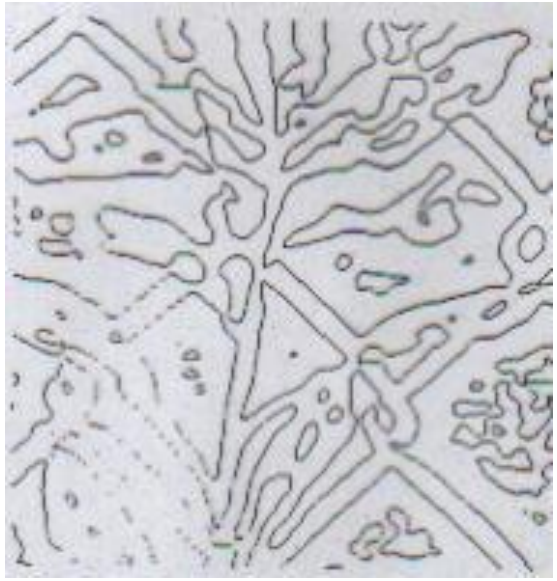
(b) Gaussian filtering dengan σ = 8 piksel (Sumber: MSU)

(c) Gaussian filtering dengan σ = 4 piksel

Laplacian of Gaussian Filtering

(a)

(b)



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(a) Laplacian of Gaussian

(b) Positive = putih dan negative = hitam

(c) zero-crossings

(Sumber: MSU)

Thoughts to take home:

- Derivatives, Gradients, and Edges
- 1st and 2nd derivatives
- Edge detection methods
- Smoothing and Sharpening filters

- Other topics:
  - Median filter values?
  - Mask operation that convolves pixels with changed values?