Advanced Information Engineering

#12 January 4 (Mon.), 2020

Kenjiro T. Miura

Assignment # 3
1. Answer

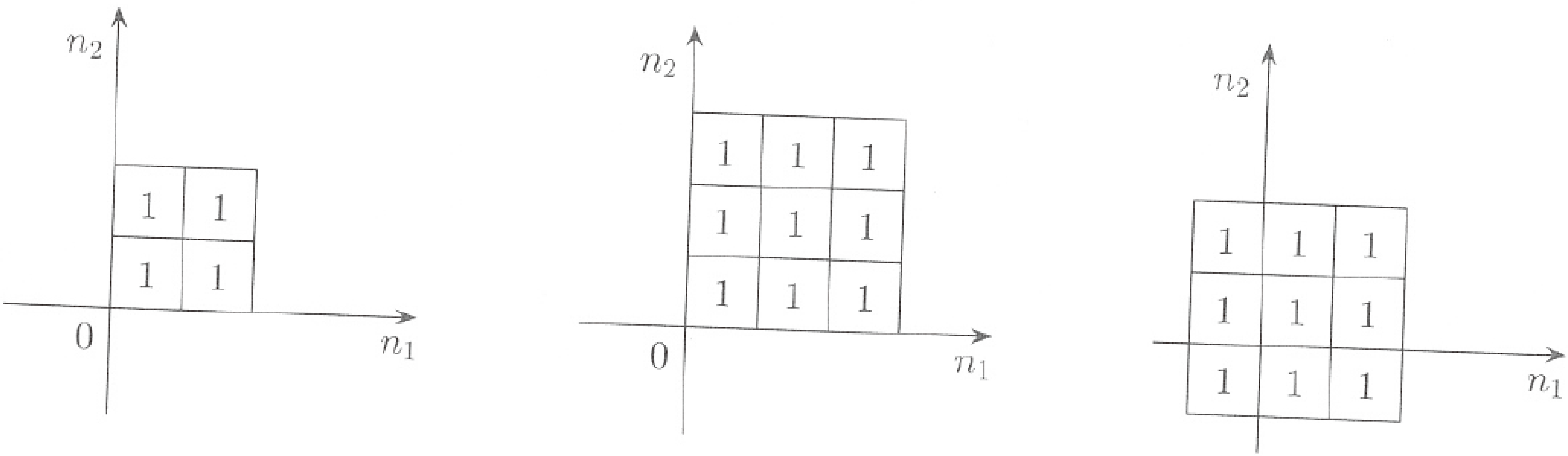
1. Illustrate the following signals:

   (a) $x(n_1, n_2) = 2\delta(n_1 + 1, n_2) + 3\delta(n_1, n_2) - \delta(n_1, n_2 - 1)$

   (b) $x(n_1, n_2) = u(n_1 - 1, n_2 - 1)$

- At blackboard.

Assignment #3
2.(a) Answer



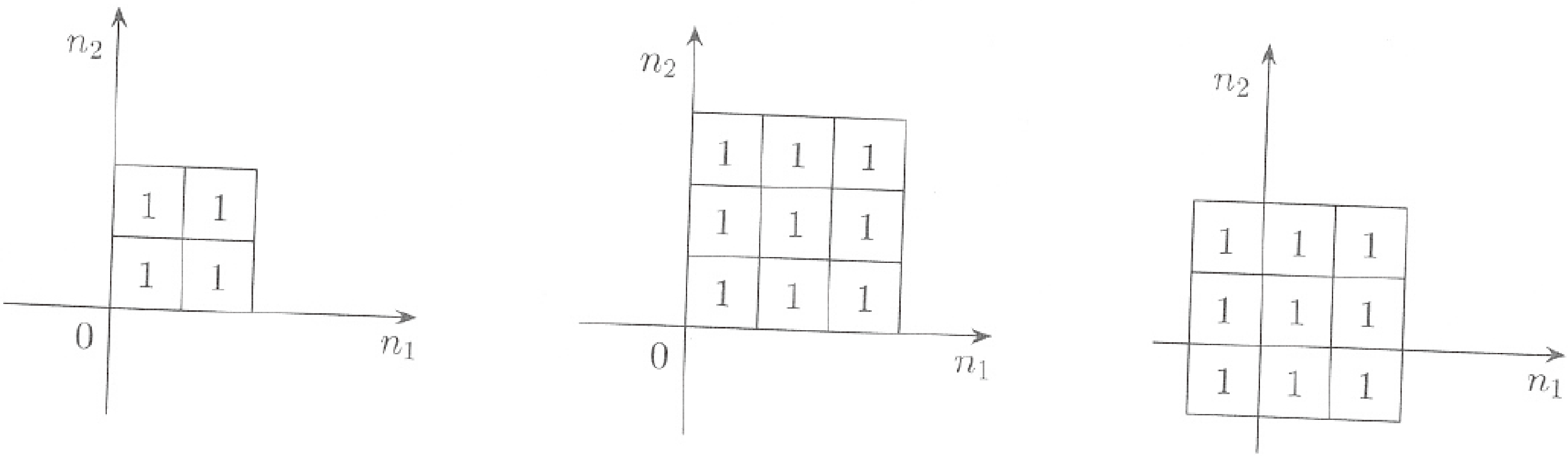
(a) $x(n_1, n_2)$ (b) $h(n_1, n_2)$ (c) $h(n_1, n_2)$

2. Let's think sbout the input signal $x(n_1, n_2)$ and its impulse response $h(n_1, n_2)$ in Fig. 3.24.

   (a) Represent $x(n_1, n_2)$ by a set of impulse $\delta(n_1, n_2)$.

- At blackboard.

Assignement #3
2.(b) Answer

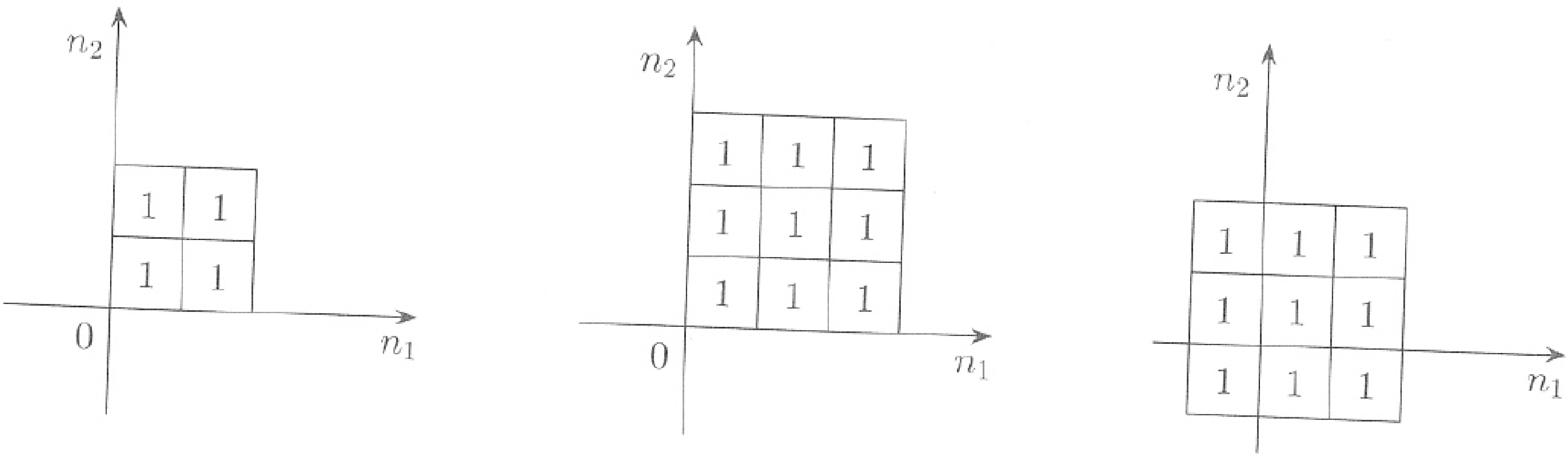


(a) $x(n_1, n_2)$ (b) $h(n_1, n_2)$ (c) $h(n_1, n_2)$

(b) Assume that the system is linear shift-invariant. Perform the comvolution $y(n_1, n_2) = h(n_1, n_2) * x(n_1, n_2)$ and find the output $y(n_1, n_2)$. Please use $h(n_1, n_2)$ in Fig.3.24(b).

- At black board.

Assignment #3
2.(c) Answer



(a) $x(n_1, n_2)$ (b) $h(n_1, n_2)$ (c) $h(n_1, n_2)$

(c) Again assume that the system is linear shift-invariant. Perform the convolution $y(n_1, n_2) = h(n_1, n_2) * x(n_1, n_2)$ and find the output $y(n_1, n_2)$. Please use $h(n_1, n_2)$ in Fig.3.24(c).

- At black board.

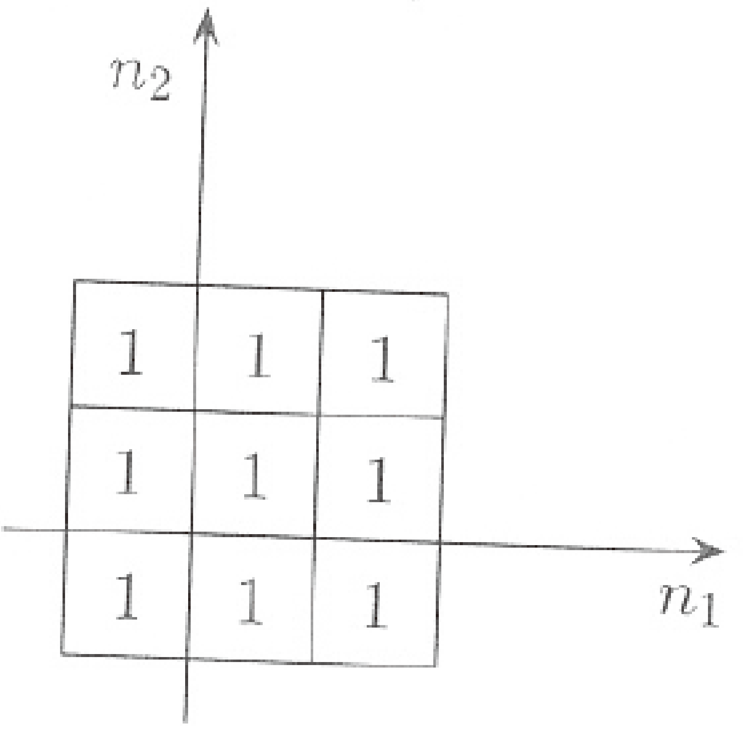
Assignment # 3
3. Answer

Let's think about the impulse response h(n1; n2) in Fig.3.24(c).

(a) Perform z transform and find the transfer function z.

(b) Is the signal separable or non-separable?

(c) Find the frequency characteristic.



(c) $h(n_1, n_2)$

- At blackboard.

Color Image Signal

- The display uses additive color mixing of RGB colors to represent colors.
- If two colors are mixed and become white, these colors are called complementary colors.
- Complementary color of red ?
- Complementary color of white ?

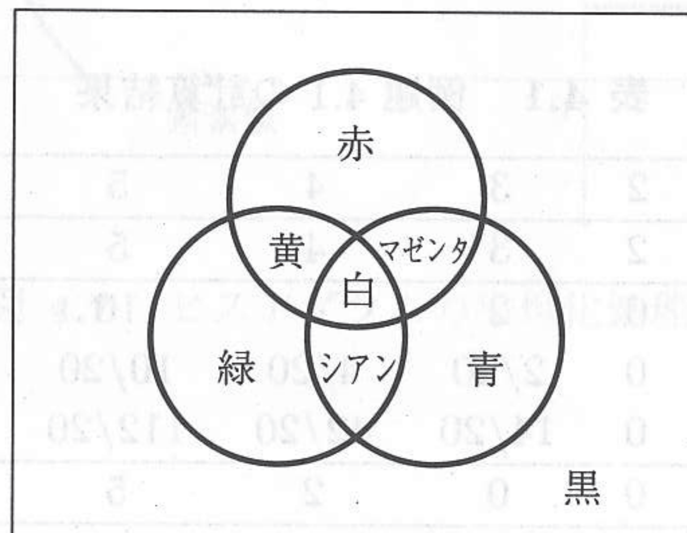


図 4.9　加法混色

The 3 Primary Colors of the Object

- Object Color(CMY) :
  Color of surface and reflection light when the object is lit by white light.
- Some spectrum of white light is absorbed by the object（subtractive color mixing）.
- Color printer uses CMY inks. Is black necessary ?

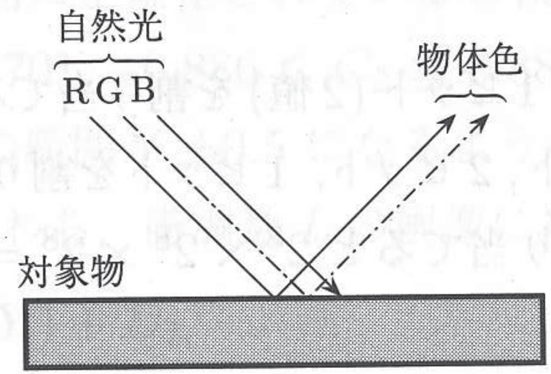


図 4.10　物体色の概念

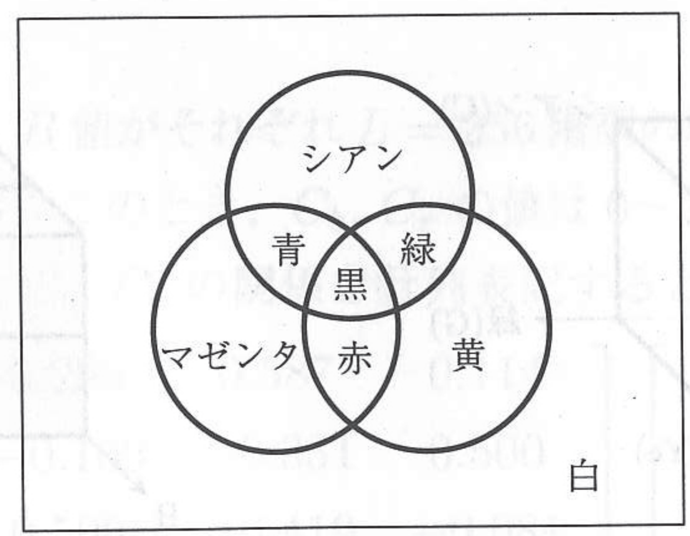


図 4.11　減法混色

RGB Color Space

- Color image signal usually consists of three signal values.
- RGB color space is a 3D space using the orthogonal coordinate system of RGB based on additive color mixing.
- How many colors can be represented when 1 bit is assigned to each of RGB ?
- How many colors can be represented when 8 bits are assigned to each of RGB ?

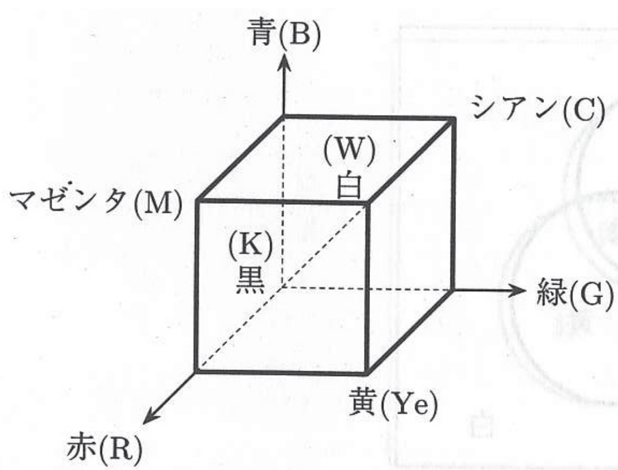


図 4.12 RGB 色空間

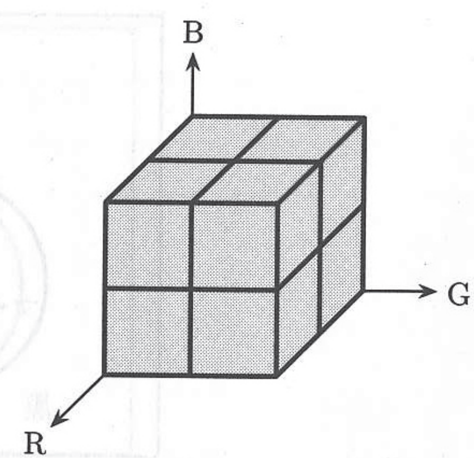


図 4.13 RGB 色空間の分割 (8 色)

Luminance and Color Difference Space

- The human visual characteristics are different for luminance and color, color signal is subdivided into luminance and color information.
- YC_bC_r is used.
- Luminance $Y=0.299R+0.587G+0.114B$

  (This is used for monochromatic signal converted from color image signal.)
- C_b : color difference from B, C_r: color difference from R
- For a image with tone L, offset D_L is to be L/2,

  $C_b=(0.5/0.886)(B-Y)+D_L$

  $C_r=(0.5/0.701)(R-Y)+D_L$

Luminance and Color Difference Space

$$\begin{bmatrix} Y \\ C_b \\ C_r \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ -0.169 & -0.331 & 0.500 \\ 0.500 & -0.419 & -0.081 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} + \begin{bmatrix} 0 \\ D_L \\ D_L \end{bmatrix}$$

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1 & 0 & 1.402 \\ 1 & -0.344 & -0.714 \\ 1 & 1.722 & 0 \end{bmatrix} \begin{bmatrix} Y \\ C_b \\ C_r \end{bmatrix} + \begin{bmatrix} 0 \\ D_L \\ D_L \end{bmatrix}$$

Color Space

- RGB color space is suitable for display and imaging devices.
- YC_bC_r color space is suitable for image transfer and compression.
- The human vision's sensitivity in the high frequency domain is worse for color difference than luminance and there are compression color format reducing color difference signal.
- There are other various color spaces adjusted to human vision and devices.

Example Exercise

- Find the formula to convert RGB values to CMY values of a pixel. We assume that RGB values are normalized as 0～1.

Answer

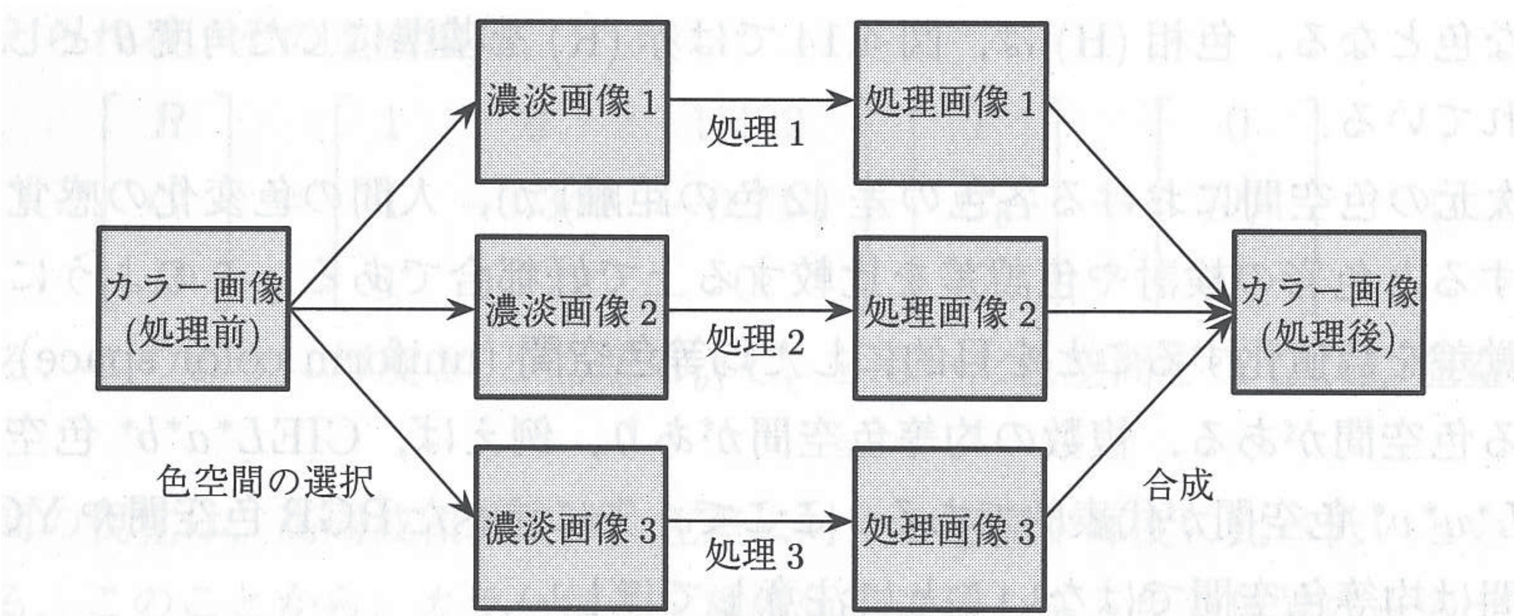
Ye, C, M は，R, G, B の補色である．ゆえに，それらの相互変換は，

$$\begin{bmatrix} C \\ M \\ Ye \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

ここで，値 1 は白色を意味する．

Color Image Processing

- Select a color space and separate colors and obtain 3 gray-scale images.
- Process each gray-scale image, not necessarily the same.
- Synthesize the results and obtain the final image.
- For noise reduction and edge enhancement, to avoid color distortion, it is common to use luminance and color difference space and process only luminance.



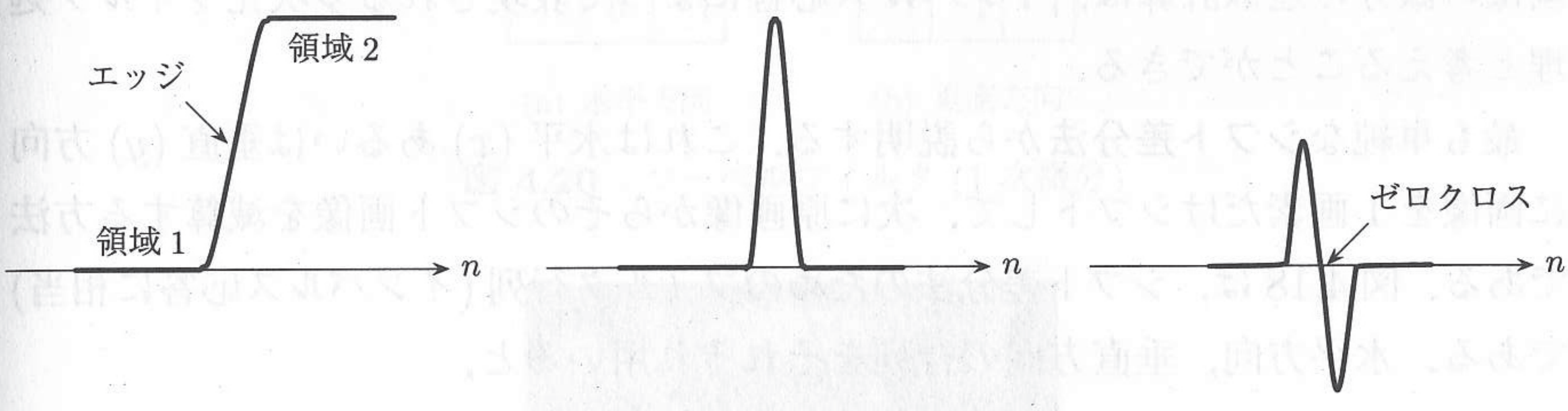
Edge Detection

- Edge is a place where the intensity changes rapidly in an image.
- Edge detection is used to recognize specific objects or detect phenomena in the image.

Edge Detection by Differentiation

$$\Delta_n g(n) = g(n) - g(n-1)$$

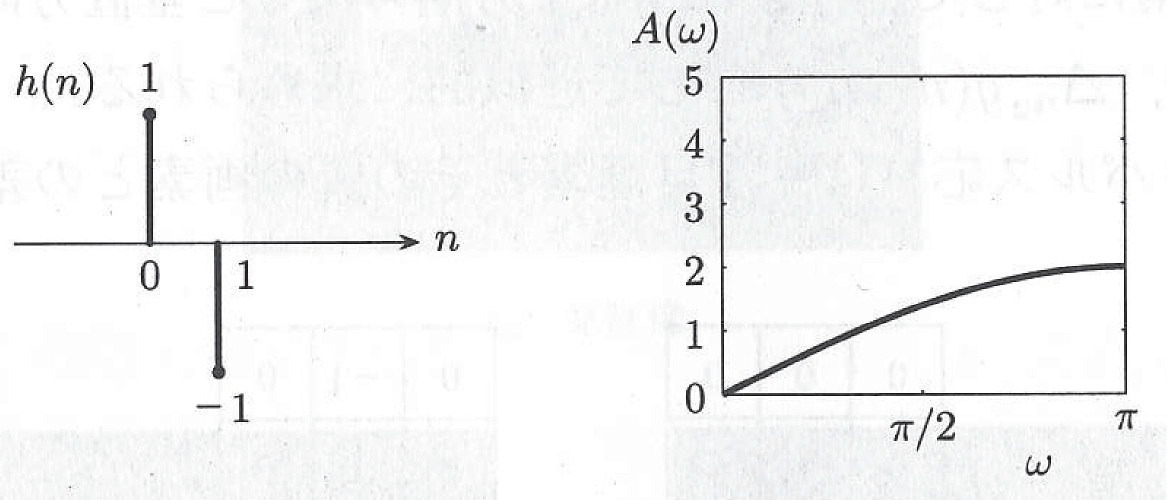
$$\Delta_n^2 g(n) = \Delta_n g(n+1) - \Delta_n g(n)$$
$$= g(n+1) - 2g(n) + g(n-1)$$



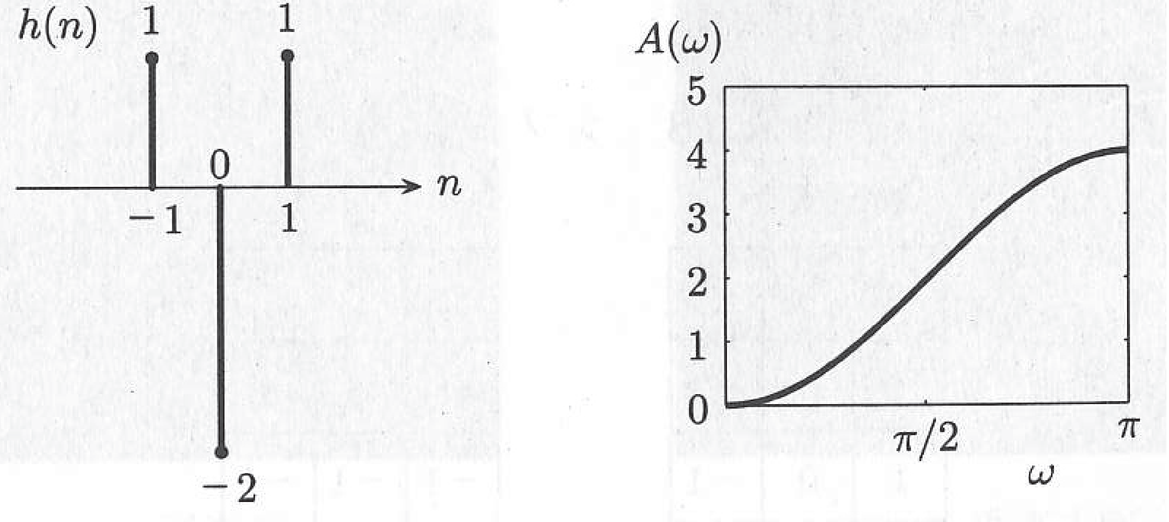
(a) 原信号 $g(n)$　(b) 1 次微分 $\Delta_n g(n)$　(c) 2 次微分 $\Delta_n^2 g(n)$

Edge Detection by Differentiation

- Since it’s a linear shift-invariant filer, it can be realized by ?
- DC gain of amplitude = 0 →What filter ?



(a) 1 次微分



(b) 2 次微分

Edge Detection by a Linear Differential Filter

- The simplest one is shift difference, but half pixel is deviated.

0	0	0
0	1	−1
0	0	0

(a) 水平方向

0	−1	0
0	1	0
0	0	0

(b) 垂直方向

Prewitt Filter

- Avoid half pixel deviation and strong against noise.
- A filter which performs sum of differences of the interested pixel with two adjacent pixels.

1	0	−1
1	0	−1
1	0	−1

(a) 水平方向

1	1	1
0	0	0
−1	−1	−1

(b) 垂直方向

Sobel Filter

- Avoid half pixel deviation and strong against noise.
- A filter which performs sum of differences of the interested pixel with two adjacent pixels.

1	0	−1
2	0	−2
1	0	−1

(a) 水平方向

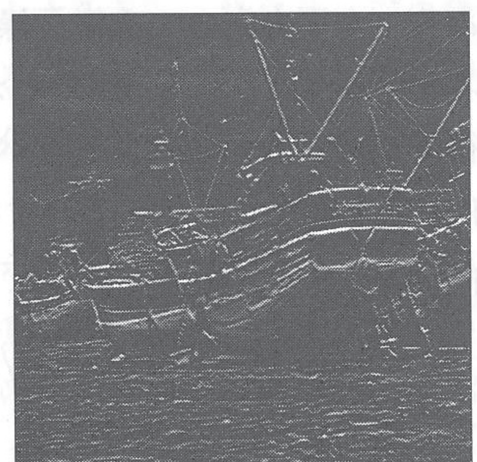
1	2	1
0	0	0
−1	−2	−1

(b) 垂直方向

Processing Example by Prewitt Filter

(a) 原画像

(b) 水平方向



(c) 垂直方向

Laplacian Filter

- 2nd order differentiation which doesn't depend on edge direction. 3 representative types.
- Since weak against noise and responds strongly for lines and points, smoothing or other processing is necessary to reduce noise before application.

0	1	0
1	−4	1
0	1	0

(a)

1	0	1
0	−4	0
1	0	1

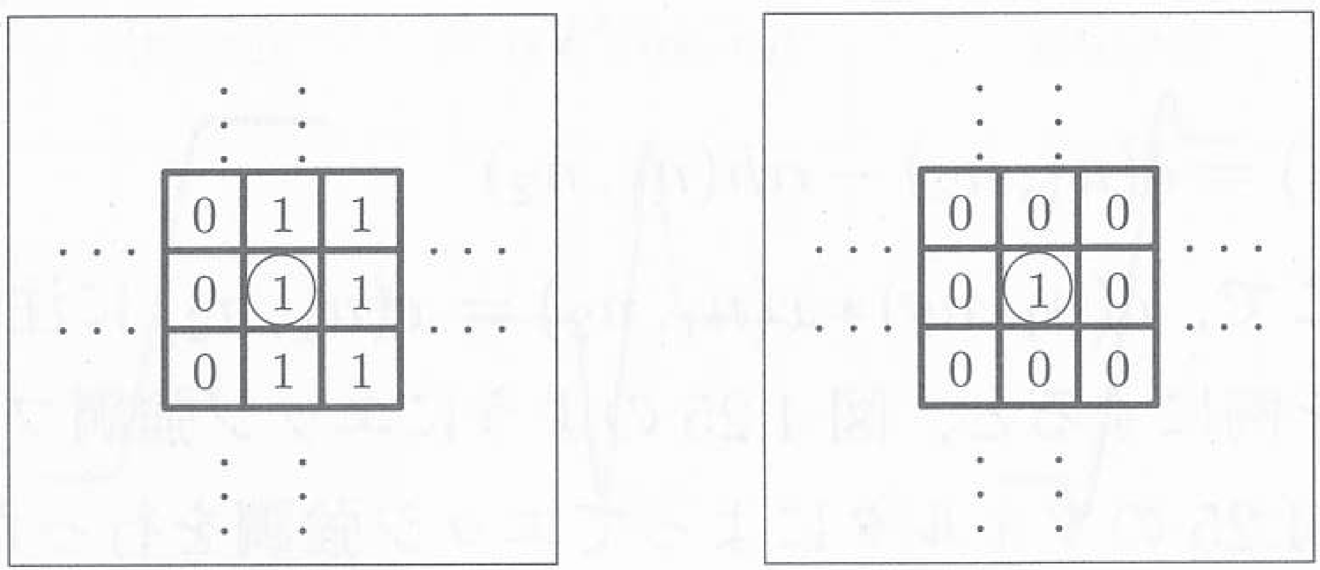
(b)

1	1	1
1	−8	1
1	1	1

(c)

Example Exercise

- Show the results of Sobel (horizontal and vertical) and Laplacian filters applied to the circled pixels in Fig. (a) and (b).



(a) (b)

Answers

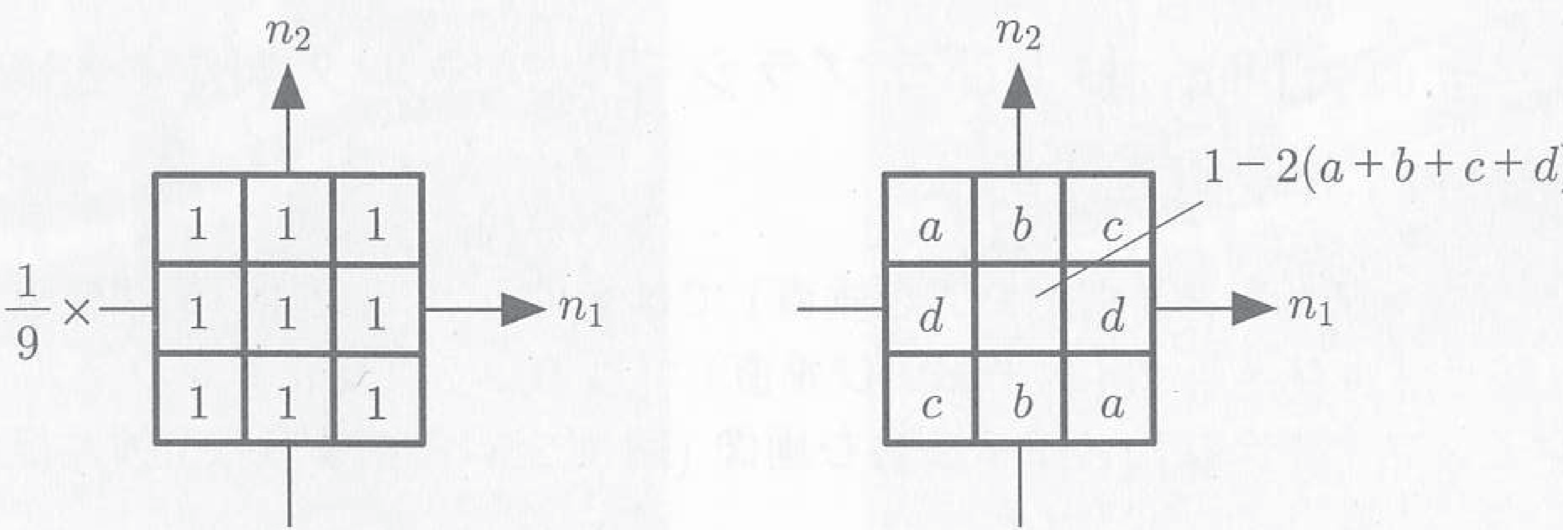
- (a) Sobel filter（horizontal, vertical）4 and 0. Laplacian filer -3.
- (b)Sobel filter（horizontal, vertical）0 and 0. Laplacian filter -8.
- Laplacian filter responds strongly against noise.

Smoothing of Image

- Process to limit the bandwidth of the signal and remove noise.
- There are linear and non-linear filters.

Smoothing by Linear Filter

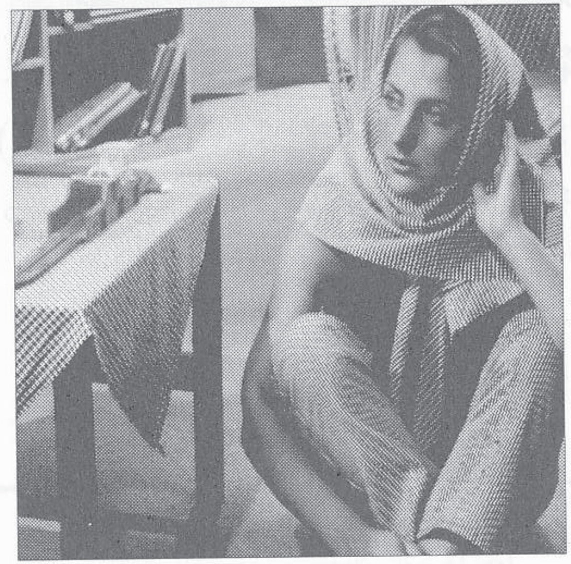
- Filter based on linear shift-invariant system and corresponds moving average filter (impulse response).
- There are more generaliazed versions



(a) 3×3 移動平均　　(b) 3×3 の荷重移動平均

Examples of moving average filter

- The moving average filter is a low-pass filer and the DC gain of the amplitude is 1.



(a) 原画像

(b) 3×3

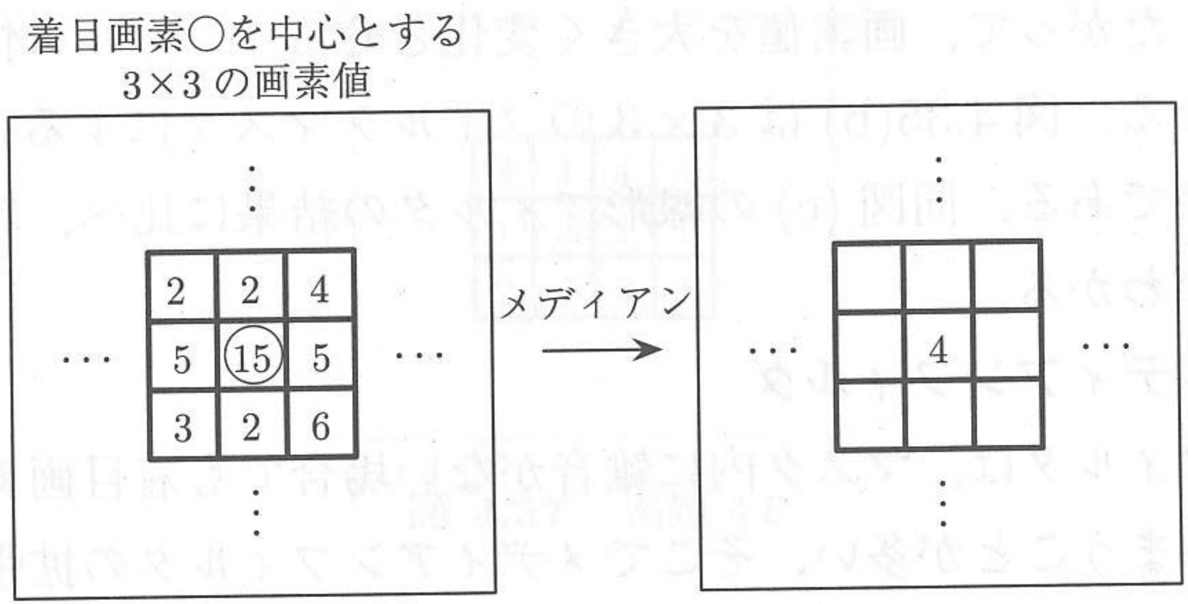
(c) 9×9

Smoothing by Non-linear Filter

- By smoothing by linear filter, lose the sharpness of edges and blur the image.
- To avoid it, non-linear filter is adopted.

Median Filter

- Sort values of the pixels inside the mask (processing region)values, take its median (center value).
- Effective against impulsive noise, which changes pixel values largely.



Application examples of median filter

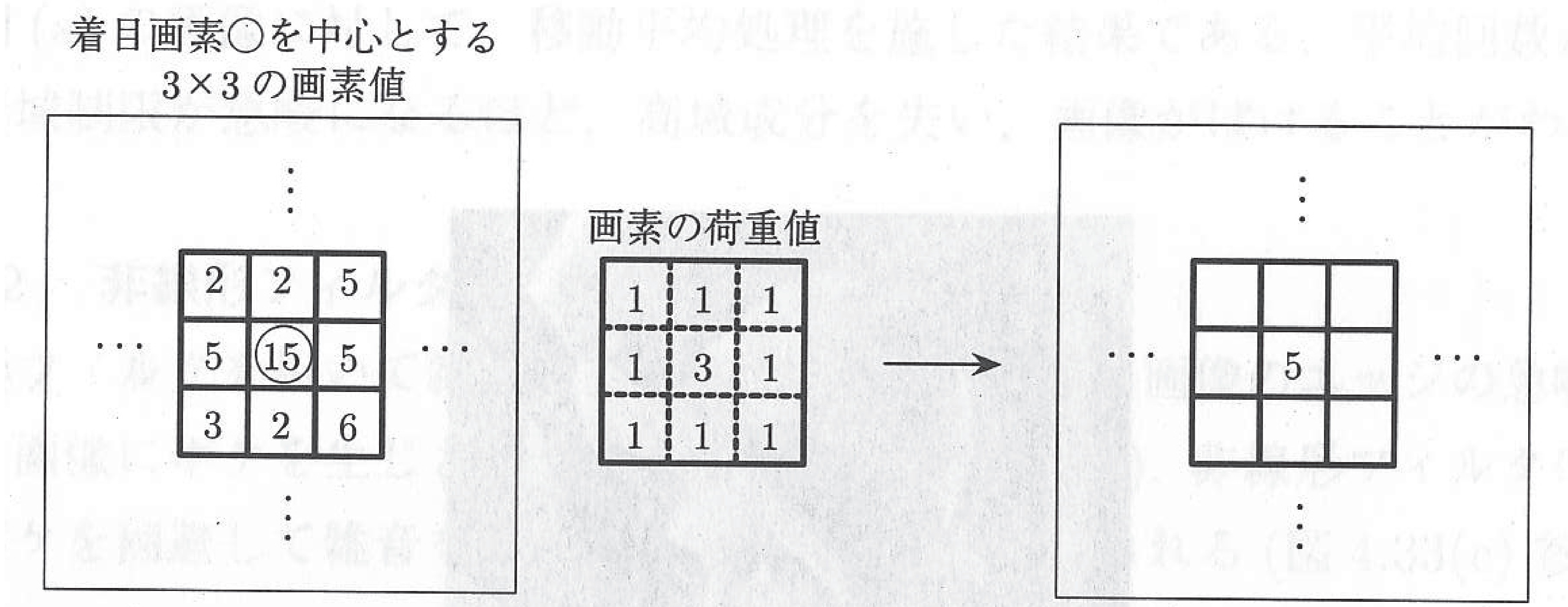
(a) 雑音による劣化画像
PSNR=18.5[dB], SNR=12.8[dB]

(b) メディアンフィルタ
PSNR=34.5[dB], SNR=28.7[dB]

(c) 移動平均(3×3)
PSNR=26.4[dB] SNR=20.6[dB]

Weighted Median Filter

- Median filter changes pixel values even without noise in the mask and may lose necessary signal information.
- To avoid it, we have weighted median filter.
- Count multiply some specific pixel.



Exercise Examples

(a) 3 × 3 の移動平均フィルタを施せ.
(b) サイズ 3 × 3 の正方形のメディアンフィルタを施せ.
(c) 図 4.36 の荷重メディアンフィルタを施せ.

3	2	4	4
1	9	1	1
2	2	3	1

画素の荷重値

1	1	1
1	3	1
1	1	1

Answers

- (a) 3 for each
- (b) 2 for each
- (c) 3 and 2