Unit-#7 Public version

Until the last time, we learned through exercises about the difference between soft and hard tissue image of CT. The differences are caused by "filters". This time, you can learn about "filters" through the exercises. (If you can use Photoshop, please try it in Photoshop.)

*** The contents covered here are the basic items of "Convolution Neural Network" used in Deep Learning.

[Practice]

Please download the following compressed file and save it in an appropriate folder.

"circle-bar.tif"

https://www5.dent.niigata-u.ac.jp/~nisiyama/grad/circle-bar.tif

"circle-bar.zip"

https://www5.dent.niigata-u.ac.jp/~nisiyama/grad/circle-bar.zip

Please download one of the above. "TIF" file may be displayed without being downloaded. If you downloaded the "zip" file, unzip it into a suitable folder and restore it to a "TIF" file before using it.

Now, open the saved "circle-bar.tif" file with ImageJ three times and display three identical images. (Or duplicate 2 copies with "Duplicate")

Repeat "Process" ➔ "Sharpen" multiple times (two or three times) for one image. Also, repeat "Process" ➔ "Smooth" several times (two or three times) on another image. Compare these changes with the untouched original image (the third remaining image).
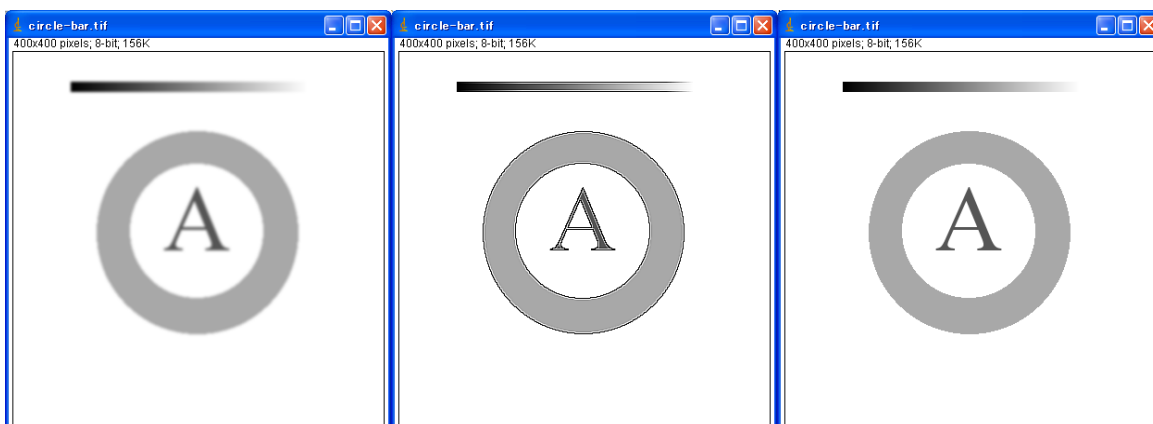

Fig. 1. Left: Smooth processing, Mid: Sharpen processing, Right: Original image

[Assignments]

Please reopen the above "circle-bar.tif" image and execute "Process" ➜ "Filters" ➜ "Convolve ...", then you can open the window to set parameters of convolution filter (Fig. 2 and 3).
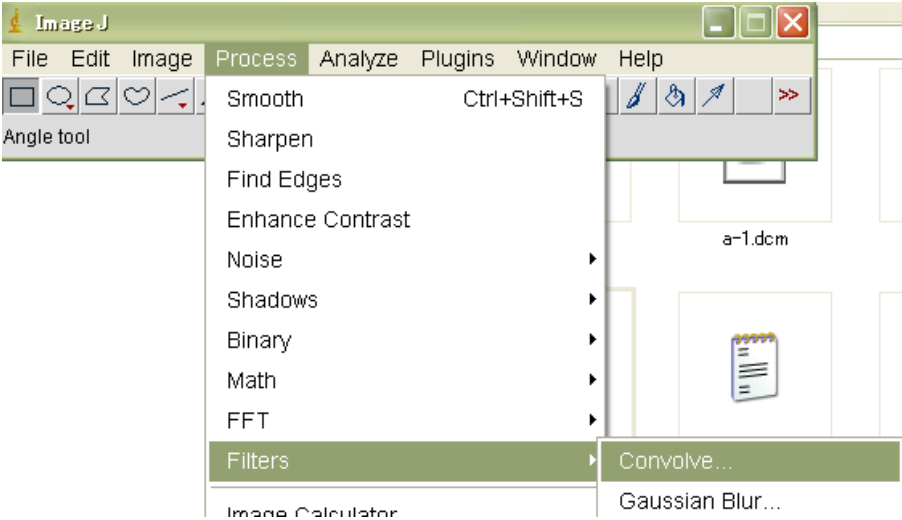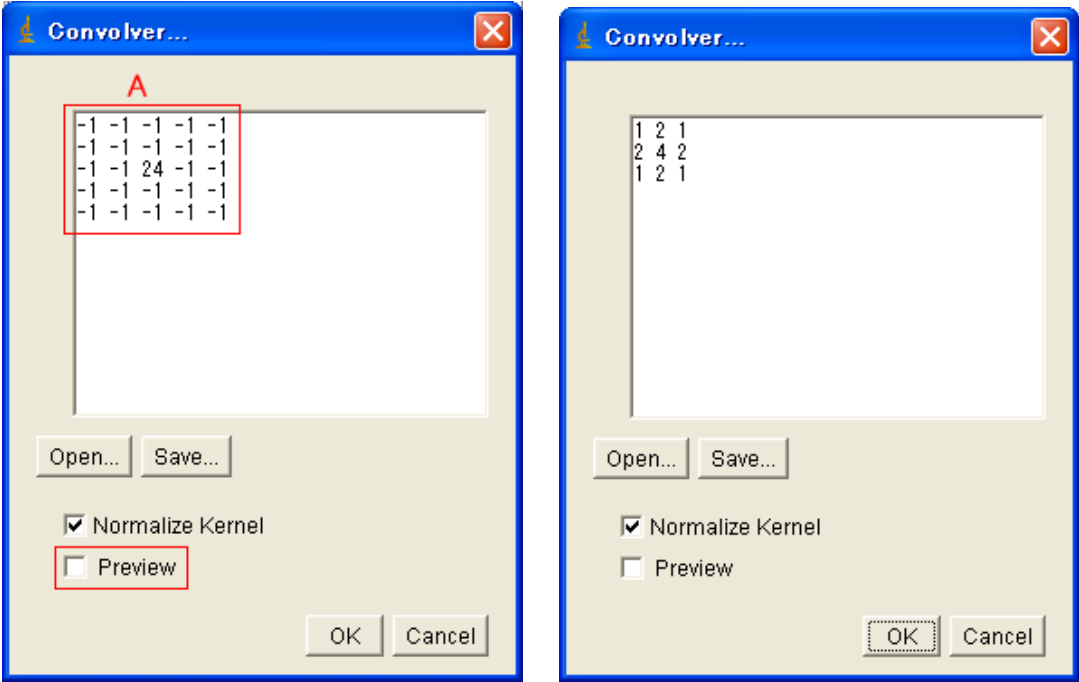

Fig. 2

Fig. 3. Window to set parameters of convolution filter

Please clear the 5x5 numeric value part (part "A" in Fig. 3) and fill that area with 3x3 matrix values separated by [space] and [Enter] with values of (A) to (e) in Fig. 4. Then please repeat click the "Preview" box to check or uncheck and you can see the change of "circle-bar.tif" image.

Note that if another window is open, such as reading this sentence during operation, the "circle-bar.tif" image may be hidden and not visible, so minimize or back out irrelevant windows.

1	2	1
2	4	2
1	2	1

(a)

−1	0	1
−2	0	2
−1	0	1

(b)

1	2	1
0	0	0
−1	−2	−1

(c)

1	1	1
1	−8	1
1	1	1

(d)

−1	−1	−1
−1	9	−1
−1	−1	−1

(e)

Fig. 4. Various filters

Which filters from (a) to (e) in Fig. 4 correspond to "Process" ➜ "Sharpen"?

Also, what is that filter generally called?

[Appendix]
About convolution filters

I think Wikipedia's "visual explanations of convolution" is a very good description of one-dimensional convolution.

https://en.wikipedia.org/wiki/Convolution

The "convolution" for the image is of course done in two dimensions. It is an operation that performs some processing on the values around and of a specific point, and adds each value obtained, as to fold ("convolute") the surrounding points to a specific point.

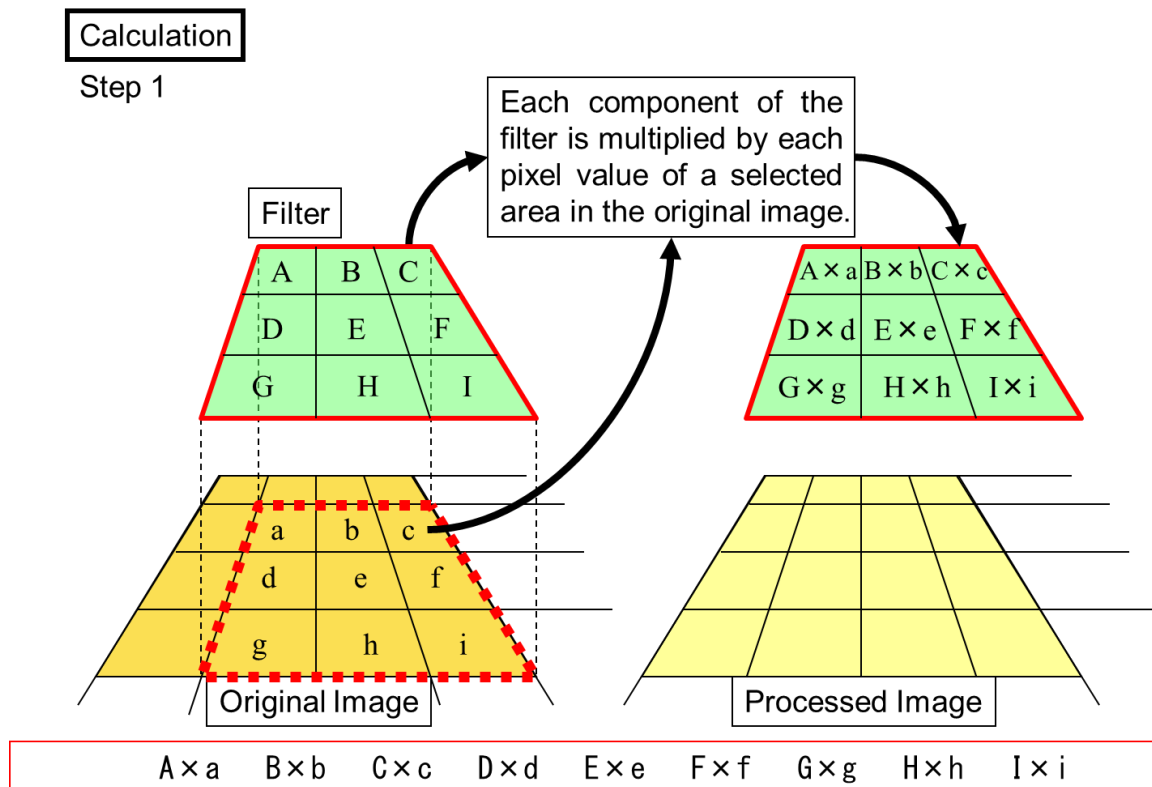*The general procedure for 2D images is explained using the 3 × 3 filter.*

* Step 1

Let the 3 × 3 filter be [(A, B, C), (D, E, F), (G, H, I)].

Let [(a, b, c), (d, e, f), (g, h, i)] be pixel data of an area in the original image to which the 3x3 filter is applied.

The first step is to multiply these corresponding values.

So the 3 × 3 matrix [(A × a, B × b, C × c), (D × d, E × e, F × f), (G × g, H × h, I × i)] will be obtained.

*Step 2

Next, add all nine multiplication values (3 × 3) to obtain the sum.

Next, s = 1 / (A + B + C + D + E + F + G + H + I) is multiplied by the above sum to obtain the value X.

Usually, the value X obtained up to this point is written to the corresponding pixel of the processed image.

Note: The original and the processed image are different, and the original image is not changed.

Generally, the value: X is calculated as shown below.
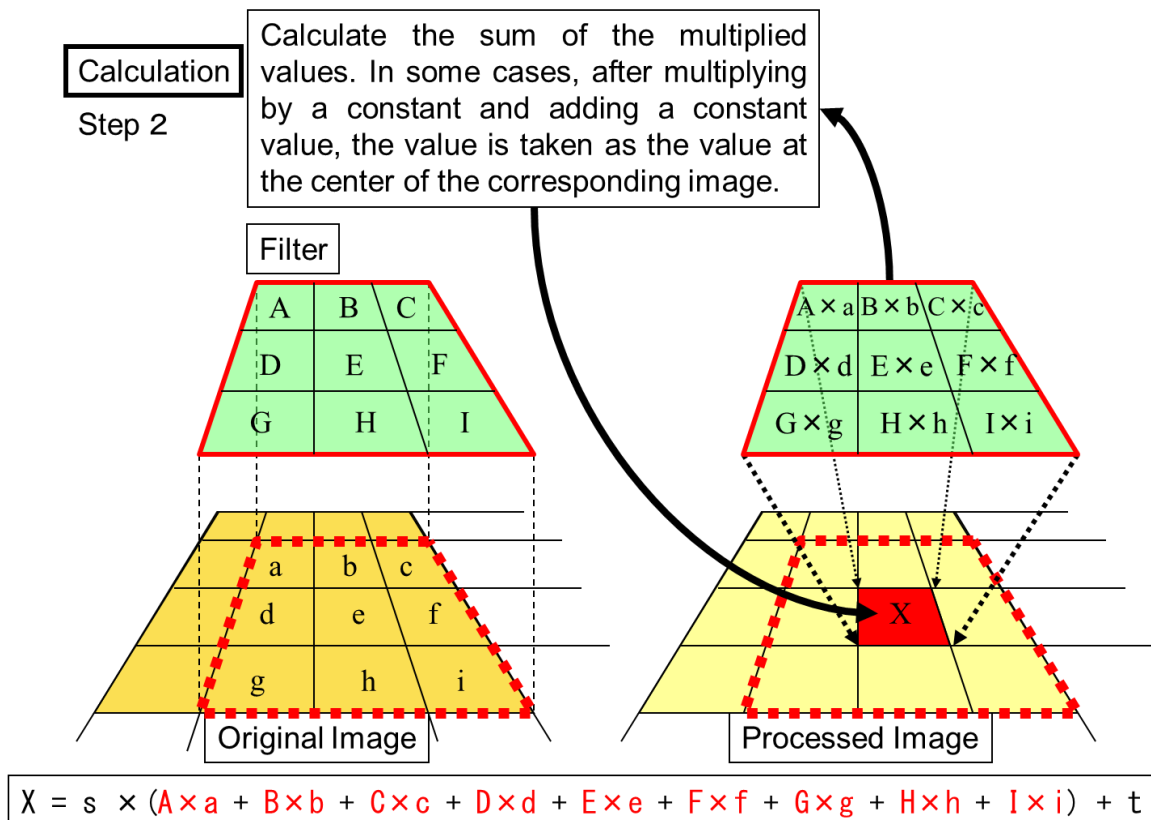
$$X = s \times (A \times a + B \times b + C \times c + D \times d + E \times e + F \times f + G \times g + H \times h + I \times i) + t$$

By the above operation, the state of the peripheral area corresponding to the filter is folded (convoluted) to the center.
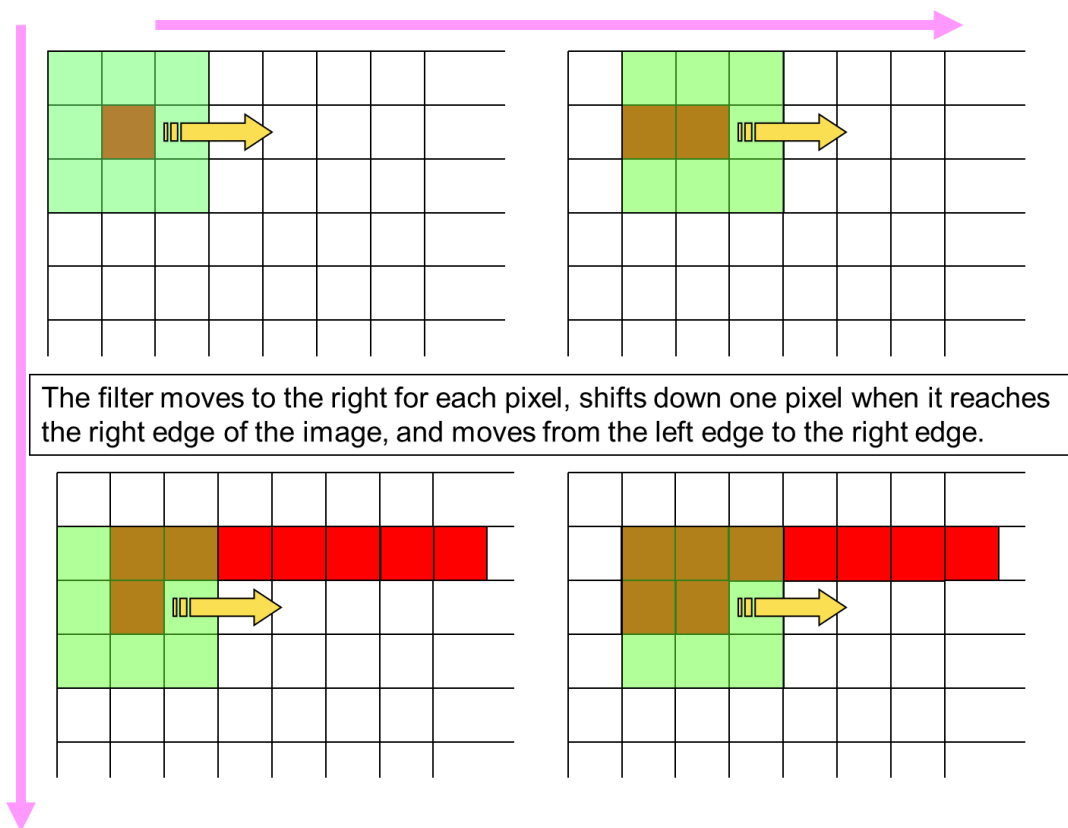
*Step 3

Perform the above operation while shifting the image one pixel at a time.

When the filter reaches the right edge of the image, move down one pixel, return to the left edge of the image and repeat.

Perform this operation to the bottom line of the image.

Note: The following conceptual diagram only shows the positional relationship between the original image, the processed image, and the filter.

Note: The figure below shows only the positional relationship between the original and the processed image and the filter.

The filter moves to the right for each pixel, shifts down one pixel when it reaches the right edge of the image, and moves from the left edge to the right edge.

As you can see in the above figure, when processing with a 3x3 filter, only the width of 1 pixel on the outer edge of the image will not be processed.

There is also a method to increase by 1 pixel around the image in advance.

The above three steps can be summarized as a generalized expression as follows.

$$X = s \times \sum_{i,j=1}^{n} \left(P_{i,j} \times Q_{i,j} \right) + t$$

$P_{i,j}$: value at the "i" raw and "j" column of n × n matrix.
$Q_{i,j}$: Values of i rows and j columns of selected n × n parts of the image.

Usually

$$s \times \sum_{i,j=1}^{n} P_{i,j} = 1 、 t = 0$$

Calculation

The process is repeated by moving the filter one pixel at a time vertically to the original image.

Filter

The process is repeated by moving the filter one pixel horizontally relative to the original image.

A	B	C
D	E	F
G	H	I

a	b	c
d	e	f
g	h	i

Calculation

Original Image

Processed Image

X

$$X = s \times (A \times a + B \times b + C \times c + D \times d + E \times e + F \times f + G \times g + H \times h + I \times i) + t$$

Simply put, the surrounding values will change the center value. For example, filter (a) would add some degree of the surrounding value to the center value, which would blur the edge. About filter (e), if the surrounding value is higher than the center value, it may be a negative value. Conversely, if the surrounding values are negative, the center value will be larger.