JPAC 2008

Fundamentals of Image Technology

June 2, 2008

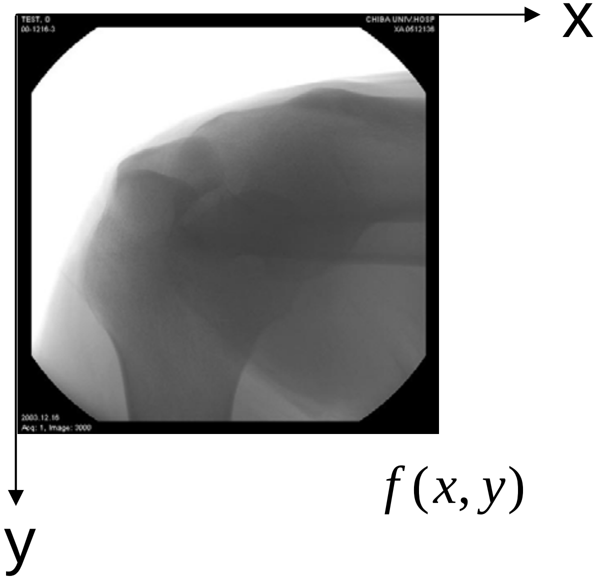
Hideaki Haneishi

Contents

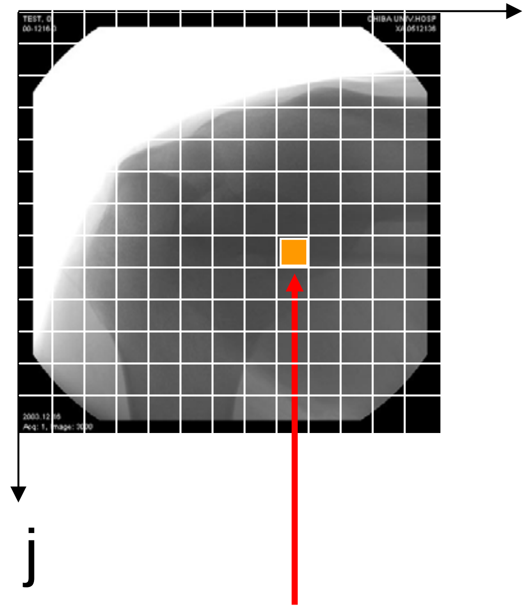
- Sampling and quantization
- Tone mapping
- Pixel-wise operation between multiple images
- Filtering
- Exercise of filtering

Digitization of image

Continuous image



Discrete (digital) image



pixel or pel
(picture element)

Pixel value at position (i,j) : $f(i,j)\ or\ f_{ij}$

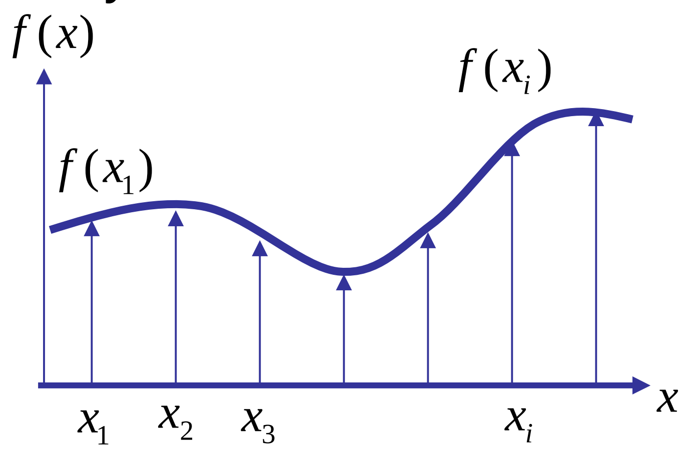
Digitization is performed by sampling and quantization.

Sampling and quantization

One-dimensional explanation

Signal intensity

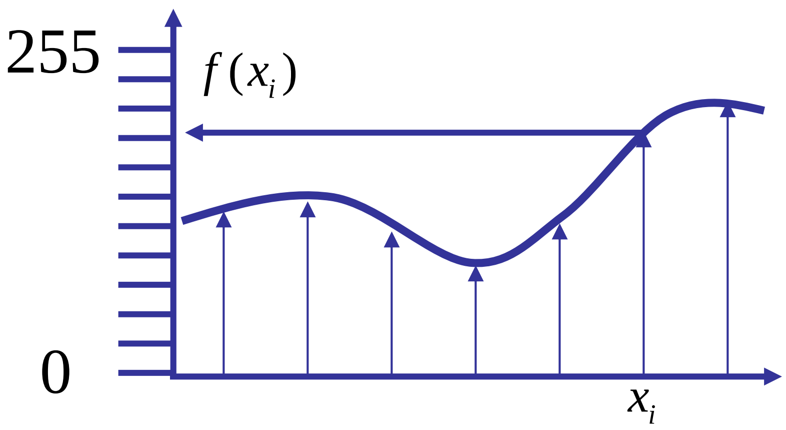
Sampling



Sampling is to take the data discretely from a continuous signal in a certain interval.

Signal intensity

Quantization



At each sampling point, continuous value f(x) is approximated by a proper integer.

Quantization level：

Quantization is usually done into 2^n levels

(n corresponds to the # of bits)

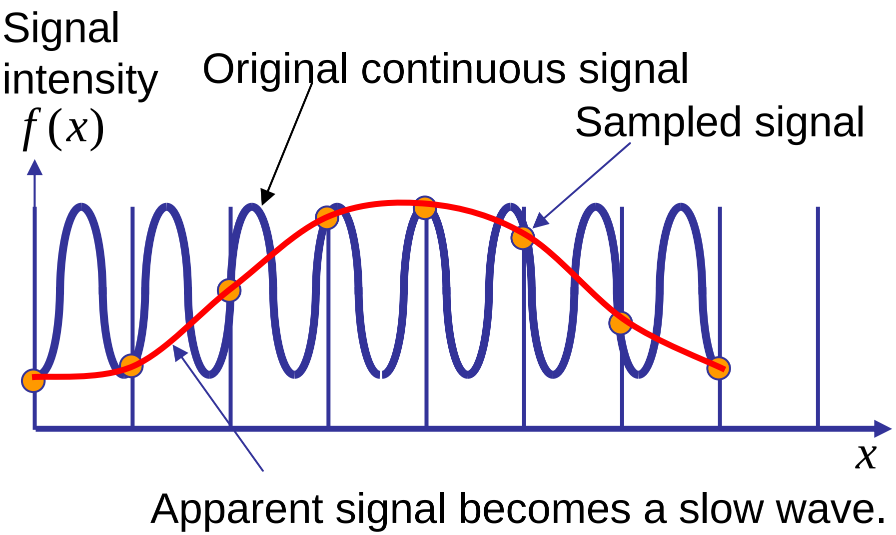
8bits⇒256 levels

10bits⇒1024 levels

…

Sampling theorem

If the rapidly oscillating wave is sampled in coarse interval, how is sampled data?



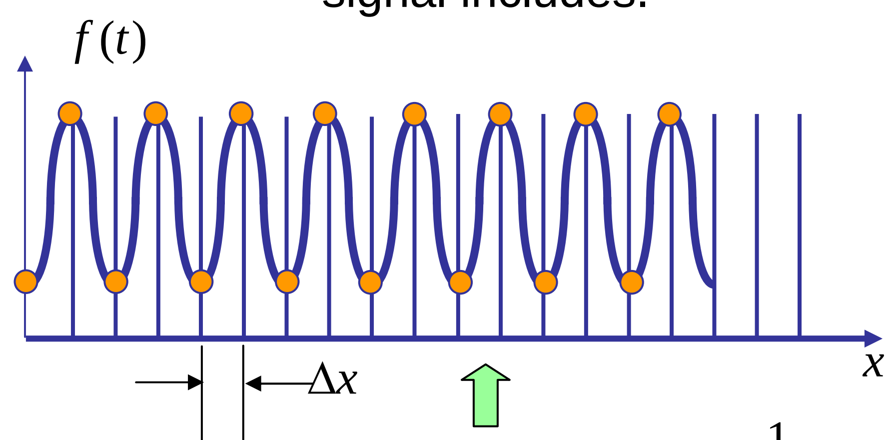
Sampling theorem

If the sampling satisfies the following condition, original continuous signal can fully be recovered from the sampled data.

$$\Delta x \leq \frac{1}{2u_{max}}$$

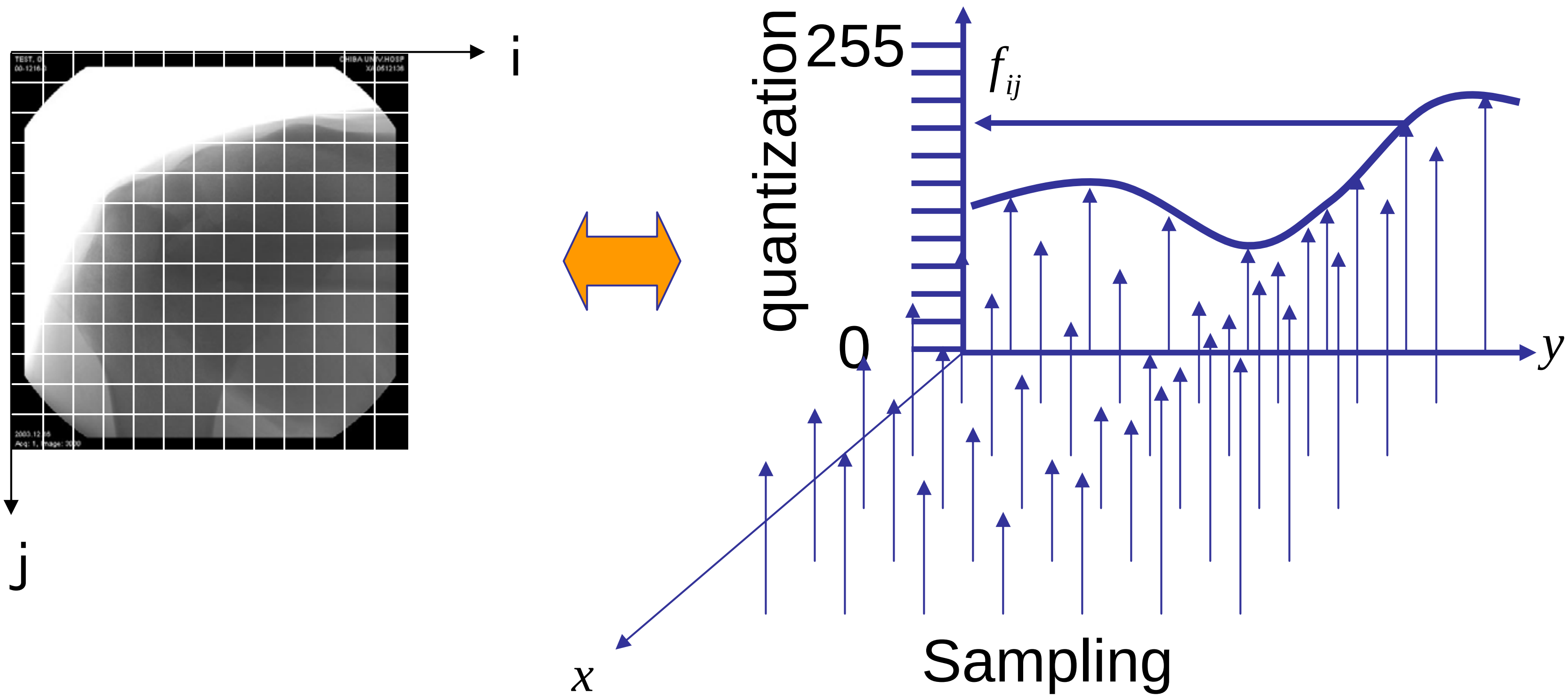
Δx: sampling pitch

u_{max}: Maximum frequency that the original continuous signal includes.

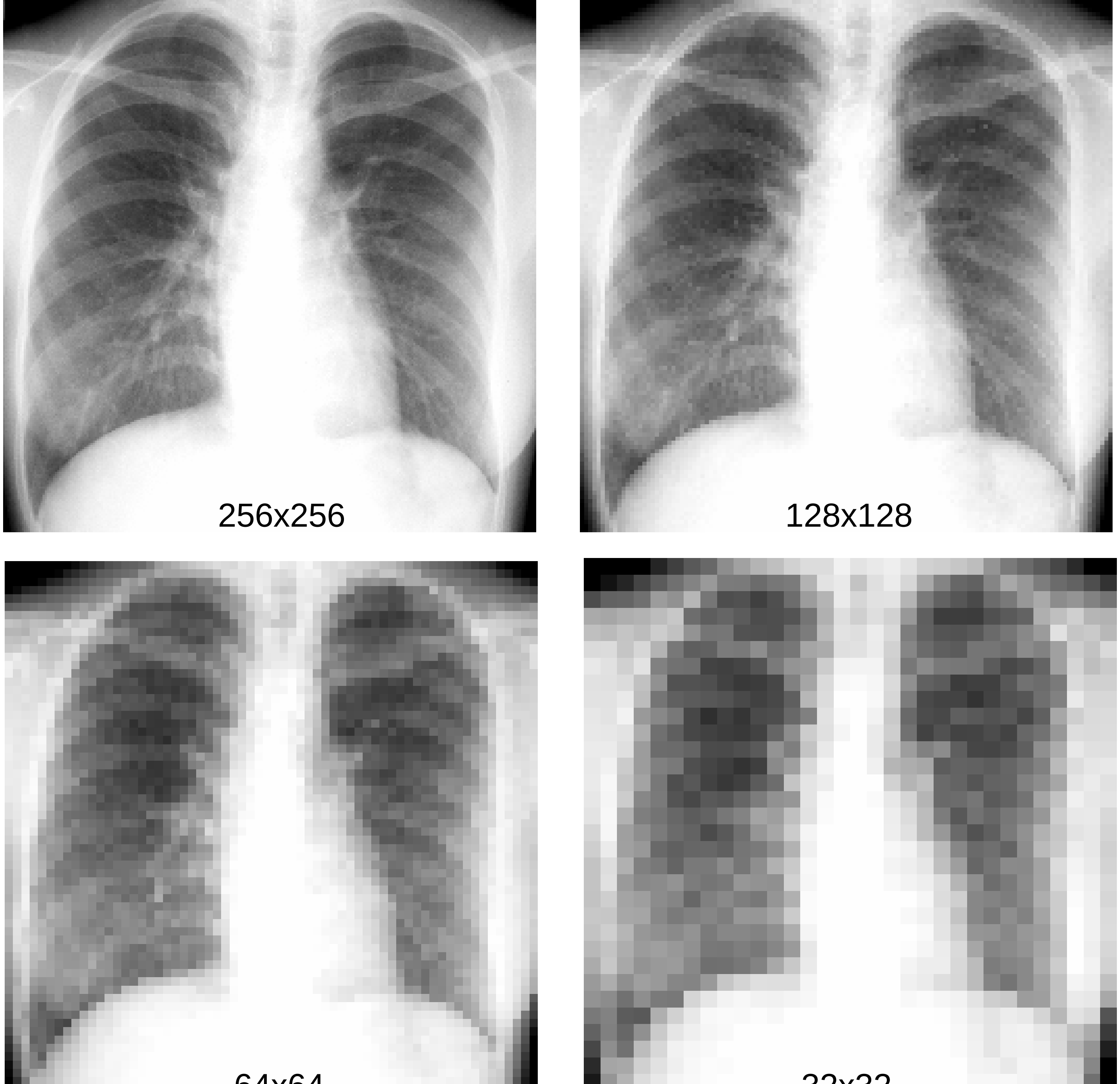


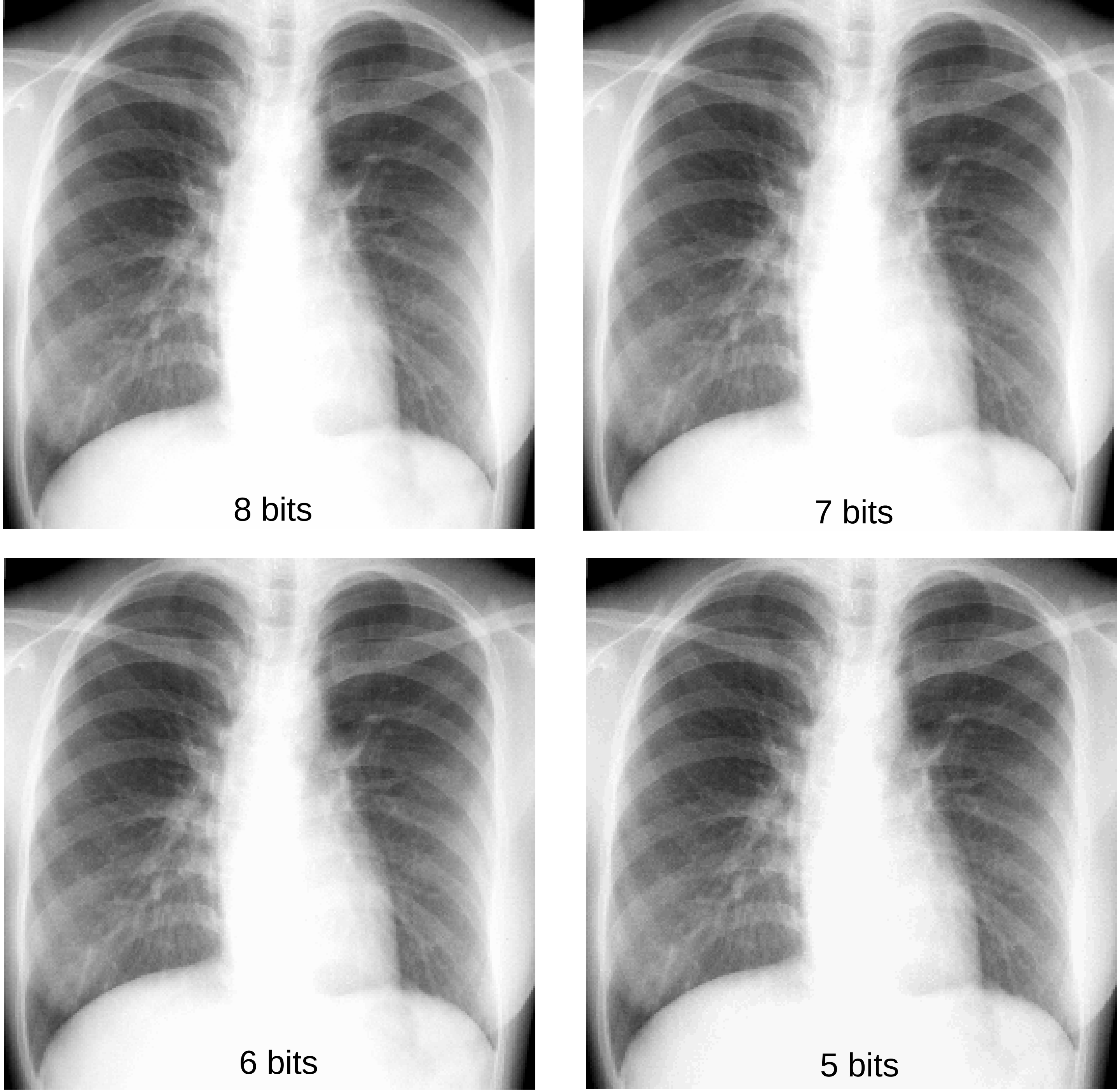
Just the case that $\Delta x = \dfrac{1}{2u_{max}}$

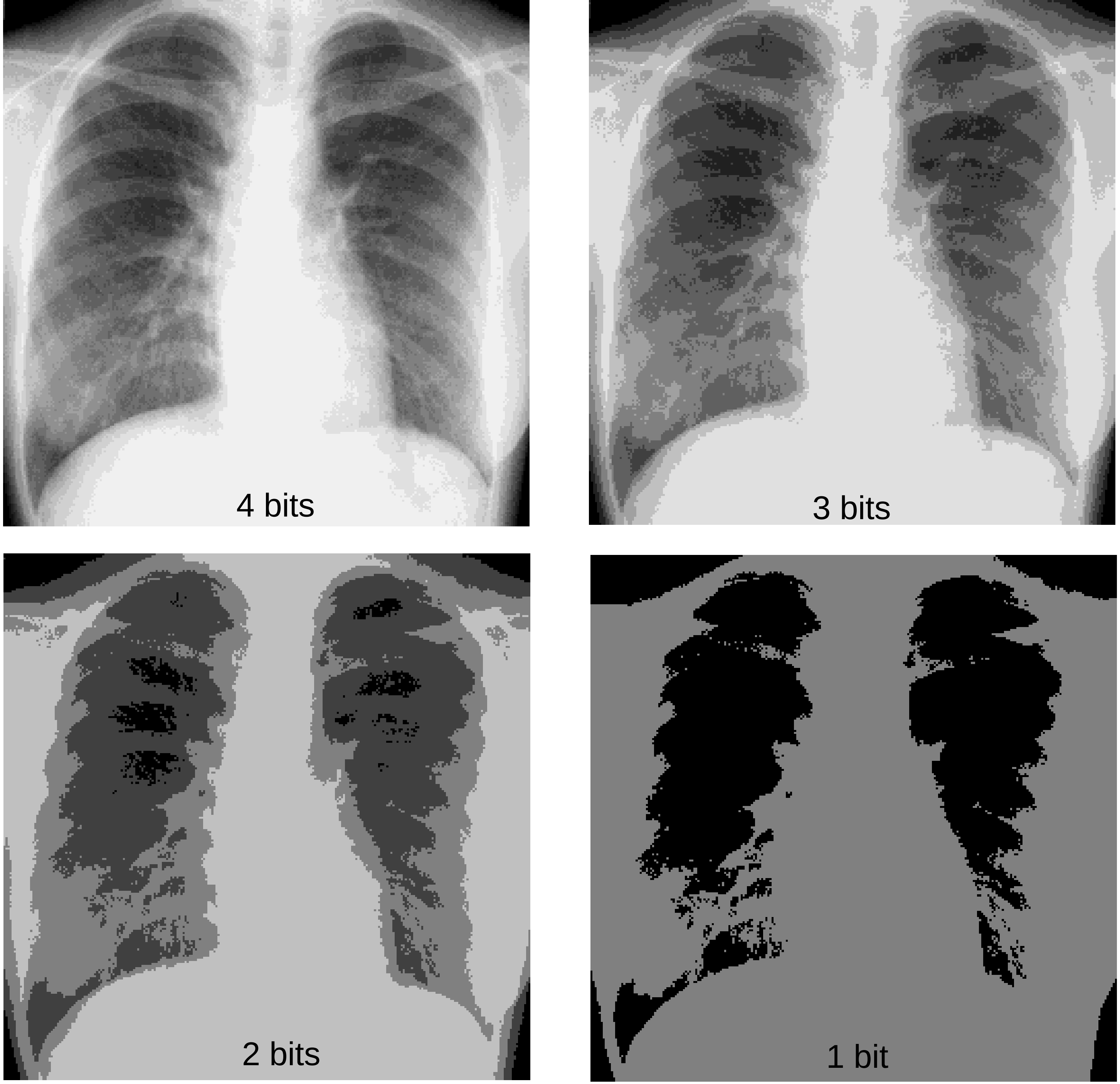
Two-dimensional sampling and quantization



Simulation of sampling and quantization


256x256
128x128
64x64
32x32


8 bits
7 bits
6 bits
5 bits


4 bits
3 bits
2 bits
1 bit

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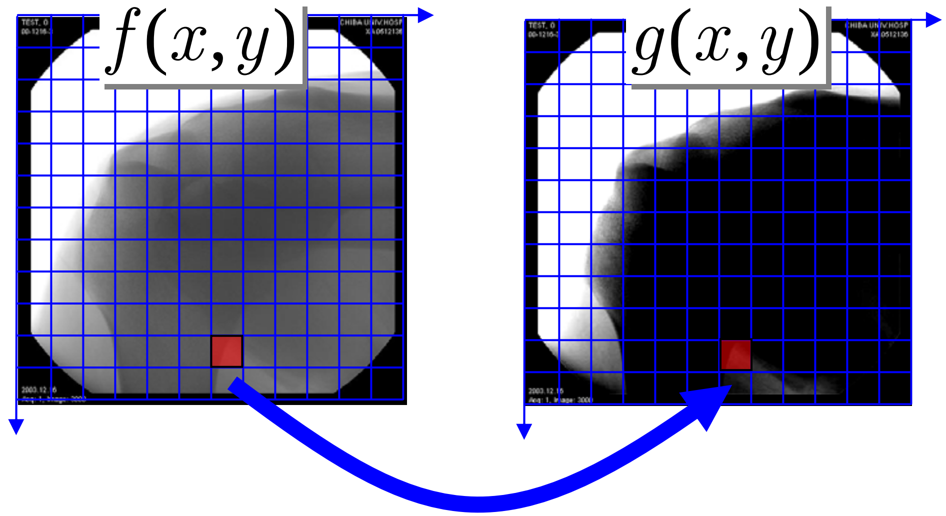
Contents

Tone mapping (point processing)

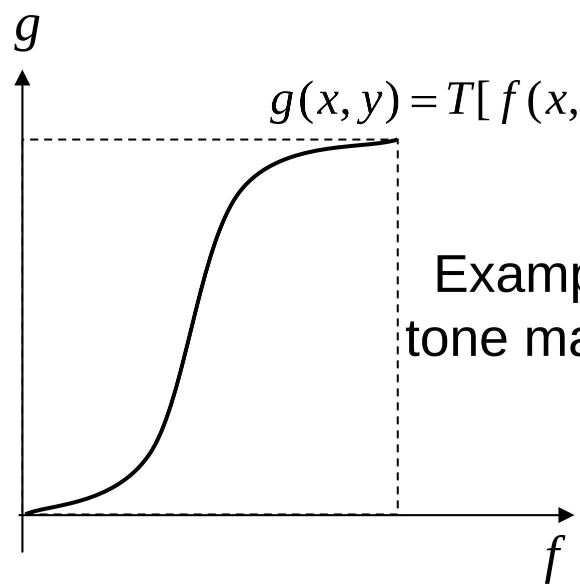
General expression of tone mapping

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

$f(x,y)$: input image
$g(x,y)$: processed image
$T[\,]$: tone mapping operator



Tone mapping is performed pixel by pixel.



Example of tone mapping

Examples of tone mapping introduced

- Linear transformation
- Nonlinear transformation using gamma
- Histogram equalization

Increase/decrease of brightness

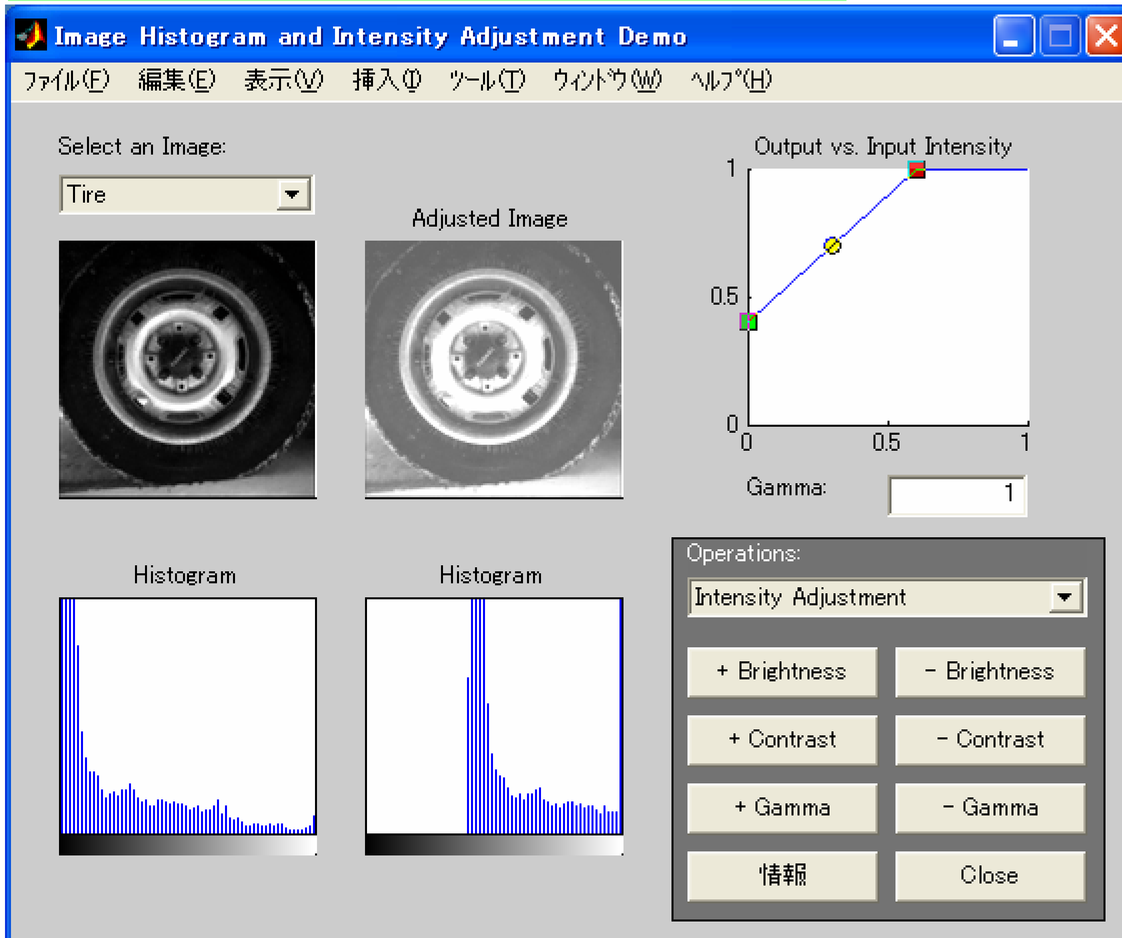
general expression $g(x,y) = T[f(x,y)]$

A linear transformation

$g(x,y) = \underline{a}f(x,y) + \underline{b}$

contrast **brightness**

Example (from demo of MATLAB)



Increase/decrease of contrast

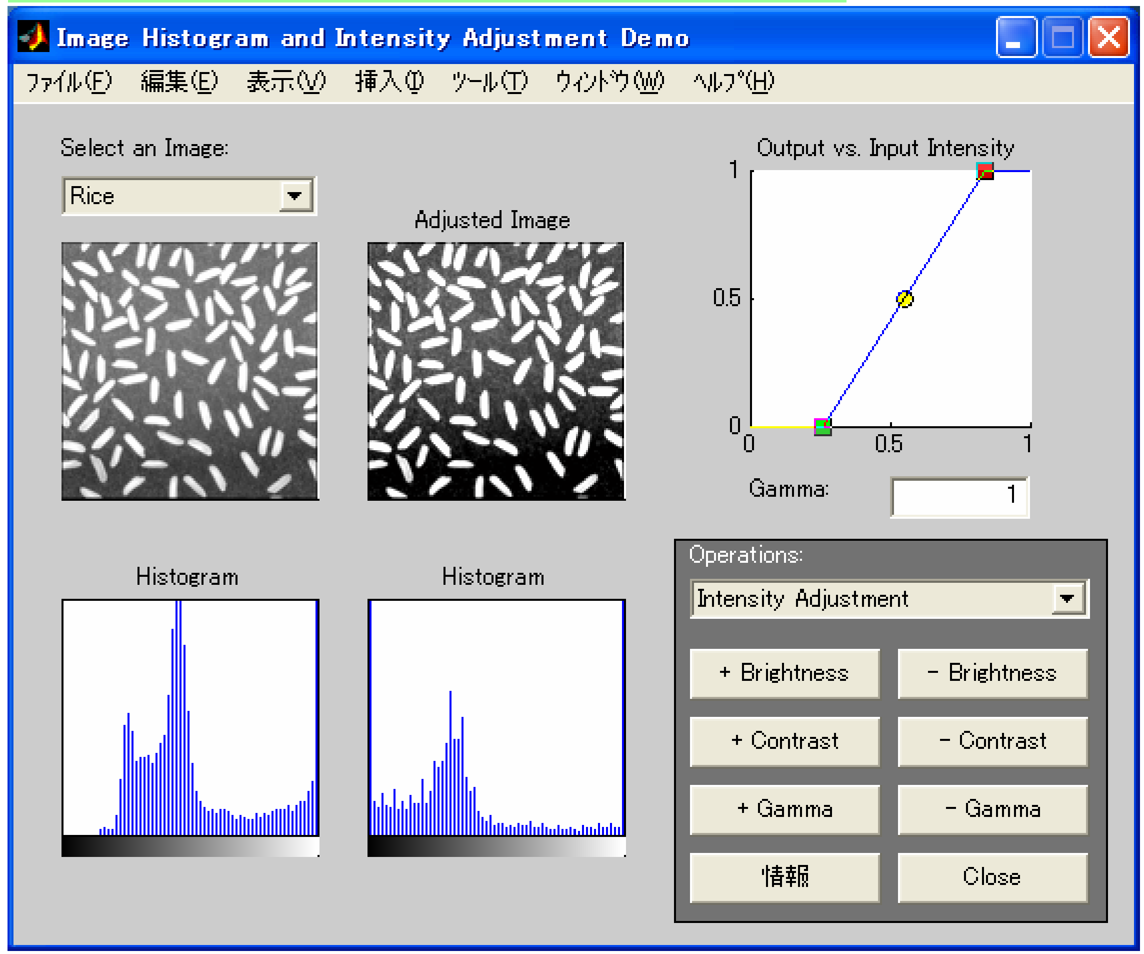
general expression $g(x,y) = T[f(x,y)]$

A linear transformation

$g(x,y) = \underline{a}f(x,y) + \underline{b}$

contrast brightness

Example (from demo of MATLAB)



Increase/decrease of contrast

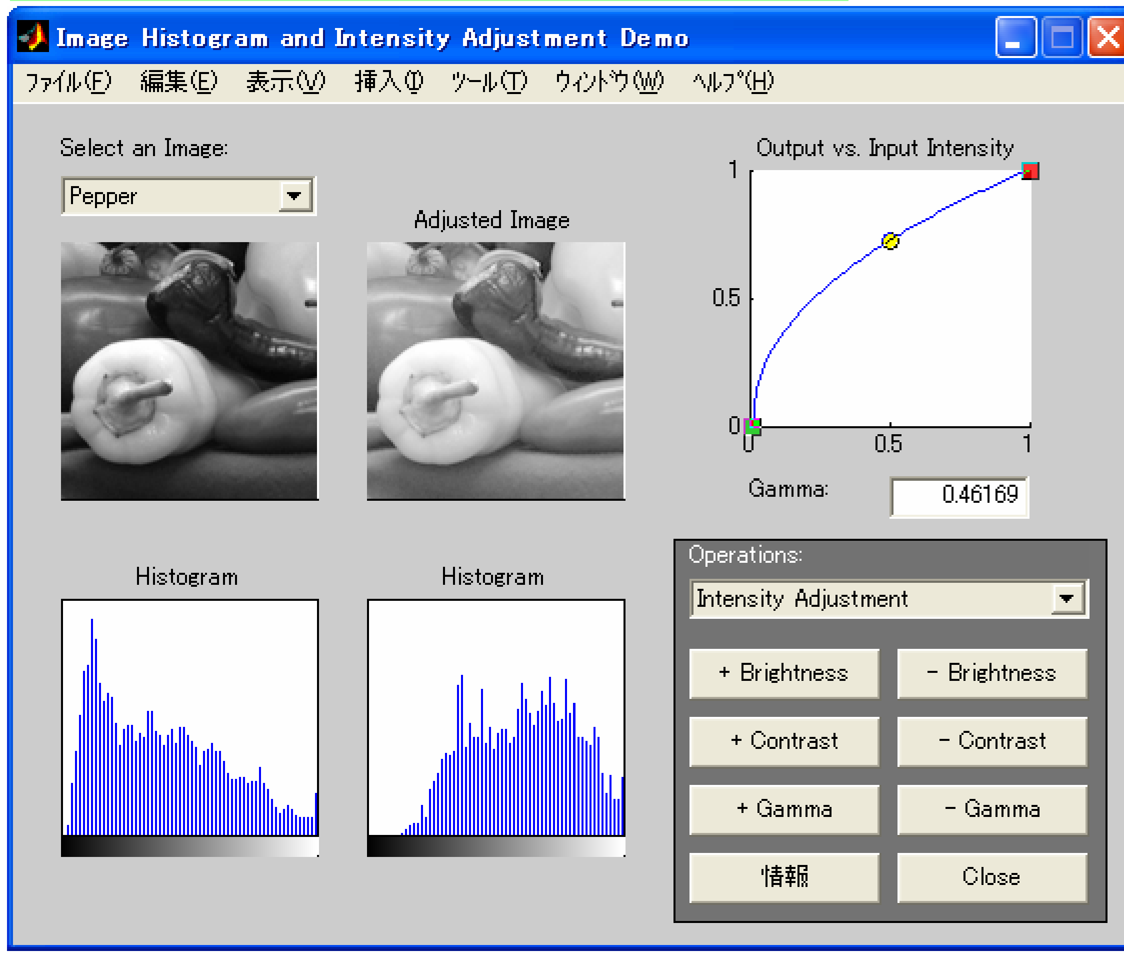
general expression $g(x,y) = T[f(x,y)]$

A non-linear transformation

$$g(x,y) = [f(x,y)]^{\gamma}$$

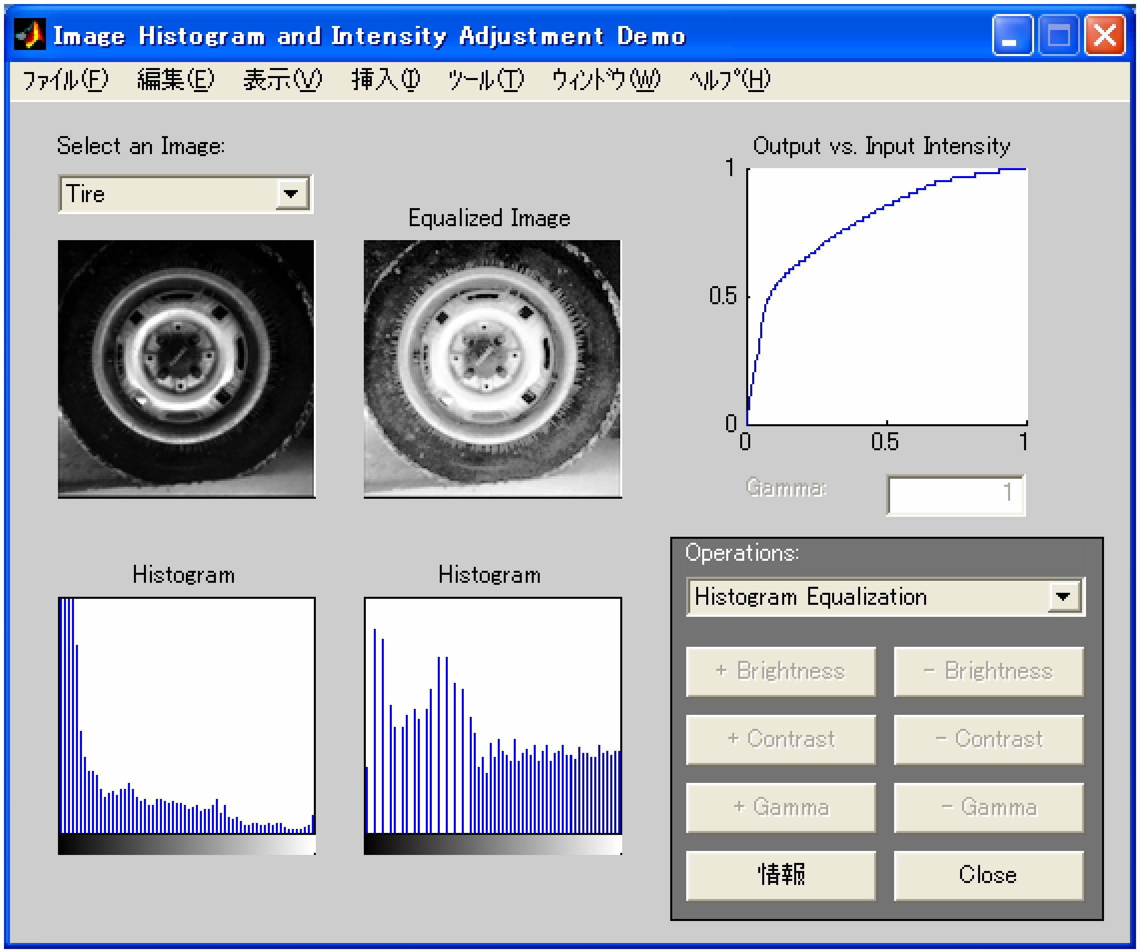
gamma

Example (from demo of MATLAB)



Histogram equalization

Example (from demo of MATLAB)



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Contents

Image addition

Noise reduction:
When multiple images with a fixed foreground and random noise are available, averaging those image produces a noise-reduced image.

Obtained image

$$g_1(x,y) = f(x,y) + n_1(x,y)$$
$$g_2(x,y) = f(x,y) + n_2(x,y)$$
$$\vdots$$
$$g_m(x,y) = f(x,y) + n_m(x,y)$$

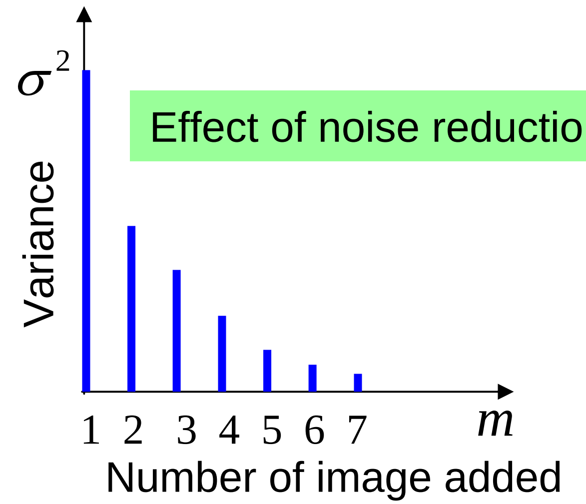
Processing

$$\bar{g}(x,y) = \frac{1}{m}\sum_{i=1}^{m} g_i(x,y)$$

Effect

$$\bar{g}(x,y) = \frac{1}{m}\sum_{i=1}^{m} f(x,y) + \frac{1}{m}\sum_{i=1}^{m} n_i(x,y)$$
$$= f(x,y) + \underline{\frac{1}{m}\sum_{i=1}^{m} n_i(x,y)}$$

Noise components are averaged.



Variance of noise decreases as $\frac{\sigma^2}{m}$

$\Leftrightarrow$ SD of noise decreases as $\frac{\sigma}{\sqrt{m}}$

Image addition - example -

No addition

Average of
10 images

Image subtraction

In a model that subjects of interest (foreground) is added to the background, if an image of background only is available, the subjects are enhanced by subtracting the background image from foreground + background Image.

Obtained image

$$g(x,y) = f(x,y) + b(x,y)$$

and

$$b(x,y)$$

Processing

$$h(x,y) = g(x,y) - b(x,y)$$

Effect

$$\begin{aligned} h(x,y) &= [f(x,y) + b(x,y)] - b(x,y) \\ &= f(x,y) \end{aligned}$$

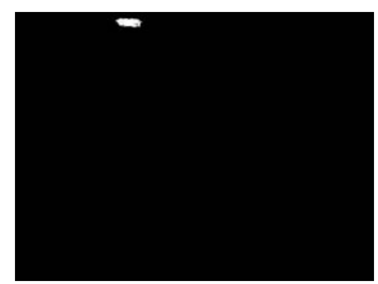
Example

$g(x,y)$

$-$

$b(x,y)$

$=$



$h(x,y)$

Image multiplication/division

In a model that subjects of interest (foreground) is illuminated non-uniformly, if the illumination distribution is obtained as an image, non-uniformity is corrected by dividing the image of the subject by the illumination distribution.

Obtained image

$$g(x,y) = i(x,y)\, f(x,y)$$

and

$$i(x,y)$$

Processing

$$h(x,y) = \frac{g(x,y)}{i(x,y)}$$

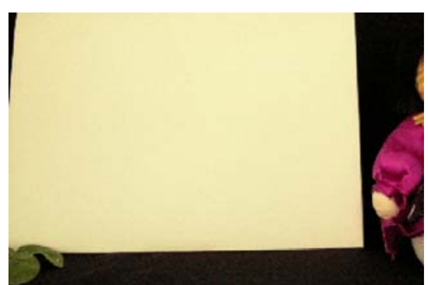
Effect

$$h(x,y) = \frac{i(x,y)\, f(x,y)}{i(x,y)} = f(x,y)$$

Example

$g(x,y)$

/



$i(x,y)$

=

$f(x,y)$

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Contents