Digital Image

(B4M33DZO, Summer 2024)

Lecture 1:

Monadic Operations

https://cw.fel.cvut.cz/wiki/courses/b4m33dzo/start

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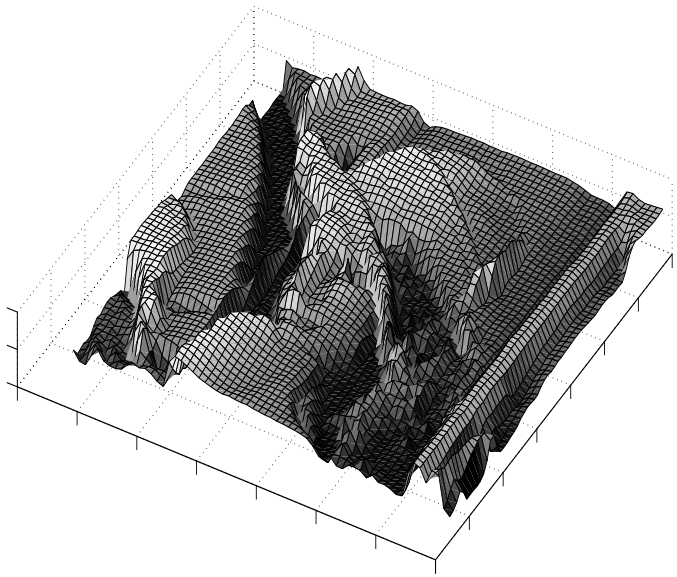
What is the image?

In theory – continuous function of two variables:

$$I(x, y) : \mathbb{R}^2 \to \mathbb{R}^n$$

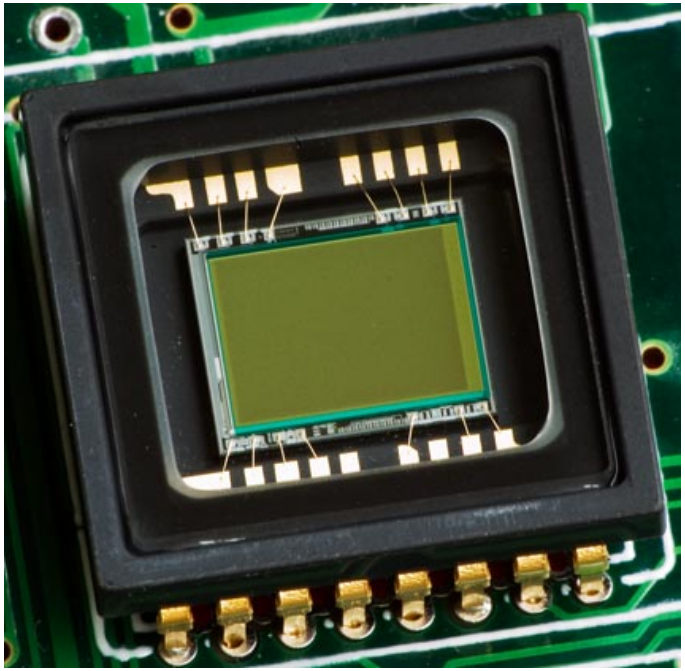
where $n = 1$: luminance, $n = 3$: color, etc.

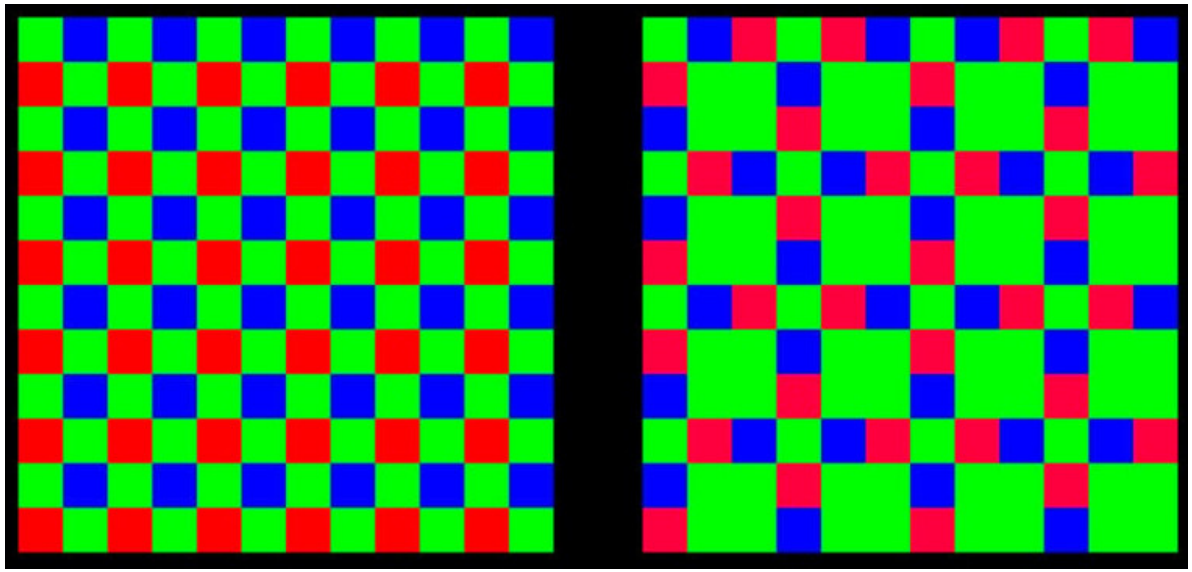


In practice – matrix of pixels (equidistant samples):

$$I[x, y] : \mathbb{N}^2 \to \mathbb{R}^n$$

How to capture an image?



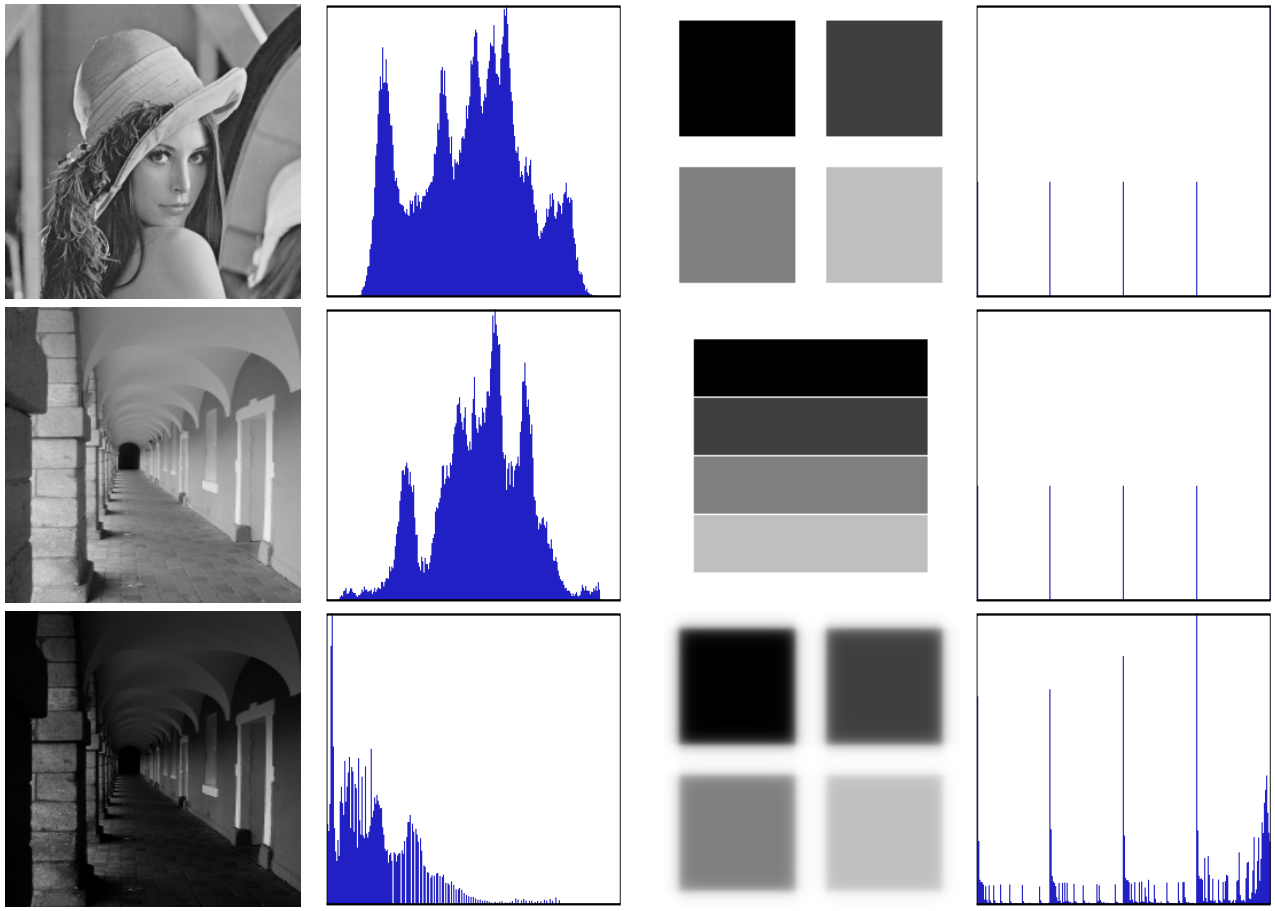


What is image processing?

Specific modification of image function:

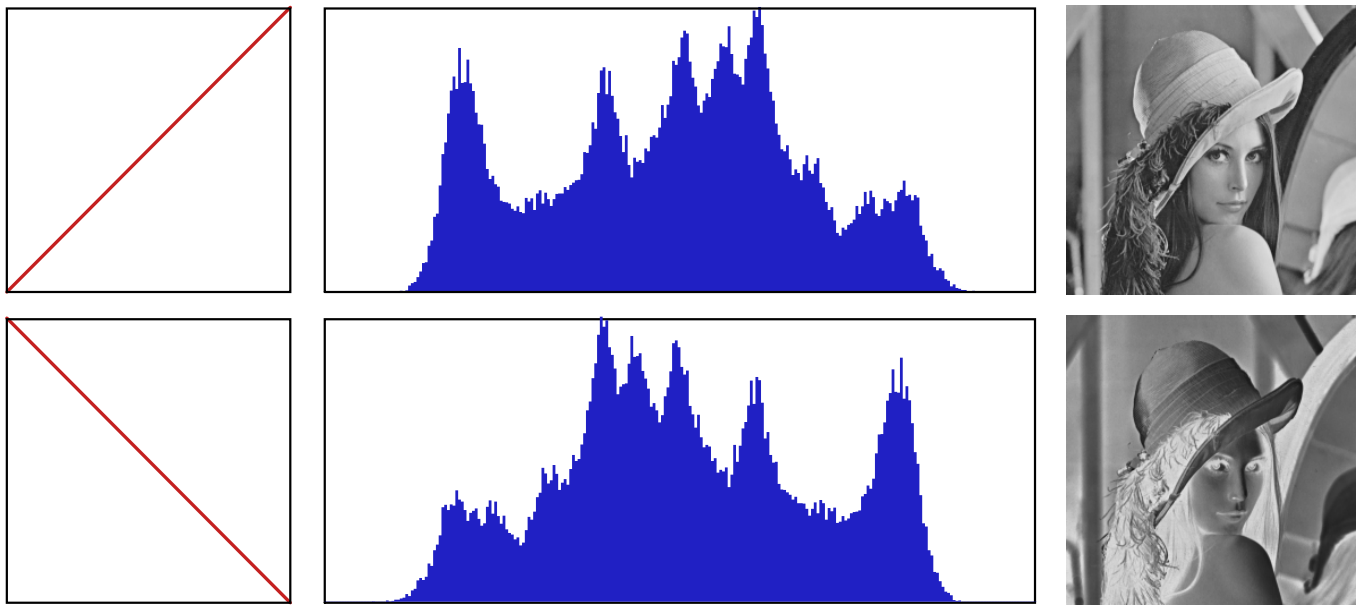
Histogram

Probability density function (pdf) of pixel luminance:



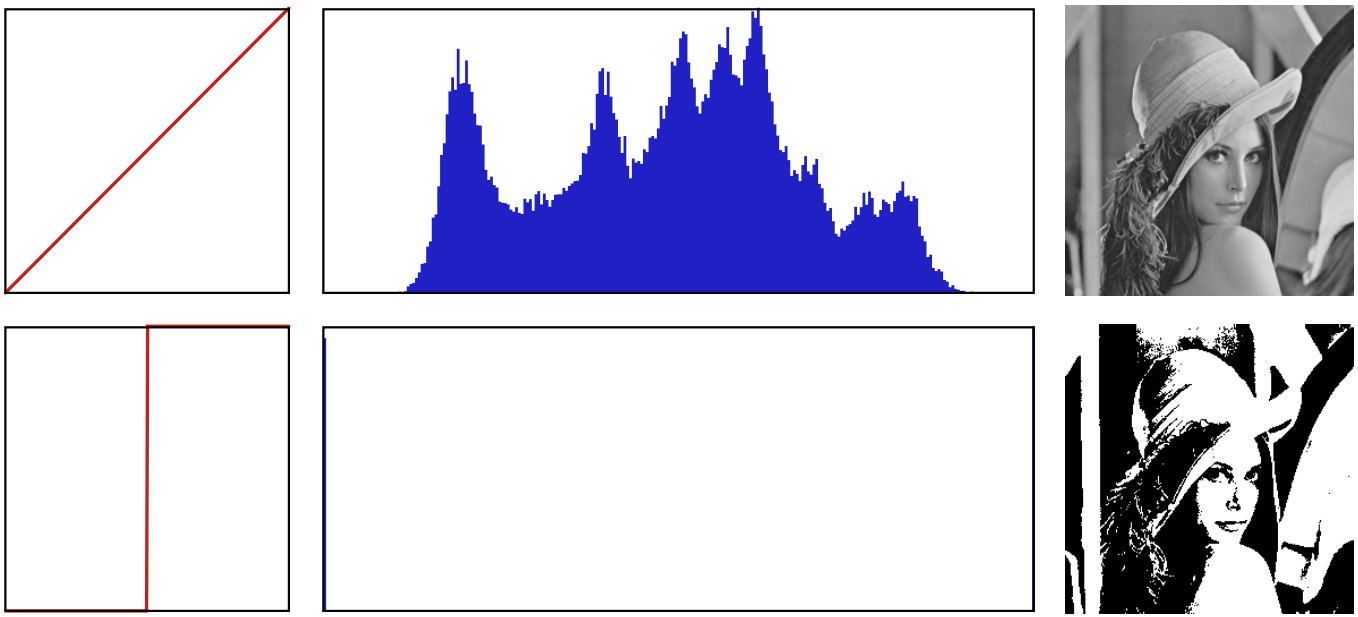
Monadic Operations

Negative: $T(I) = 1 - I$



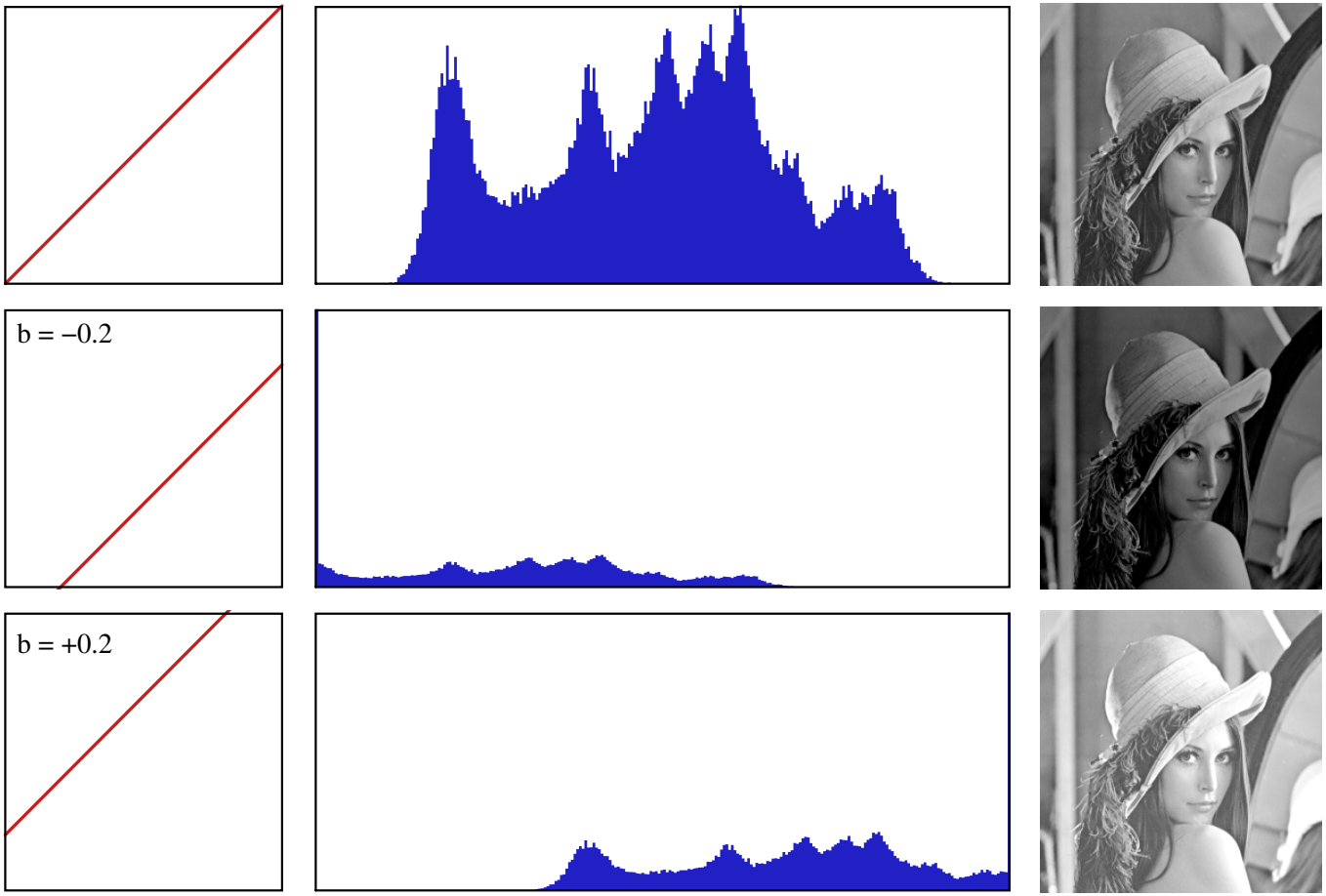
Monadic Operations

Threshold: $T(I) = \begin{cases} 0 & I < \theta \\ 1 & I \geq \theta \end{cases}$



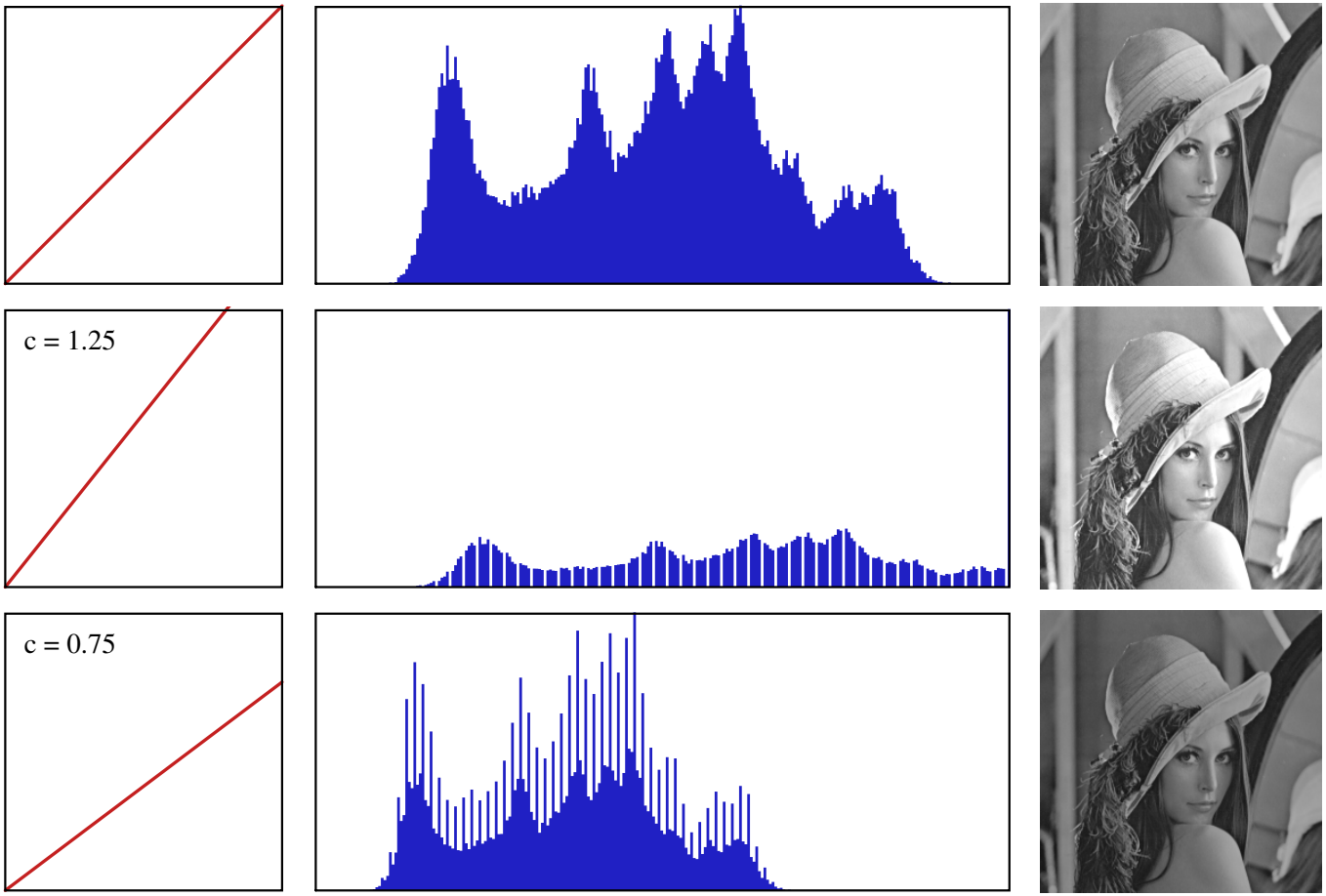
Monadic Operations

Brightness shift: $T(I) = I + b \quad b \in \langle -1, 1 \rangle$



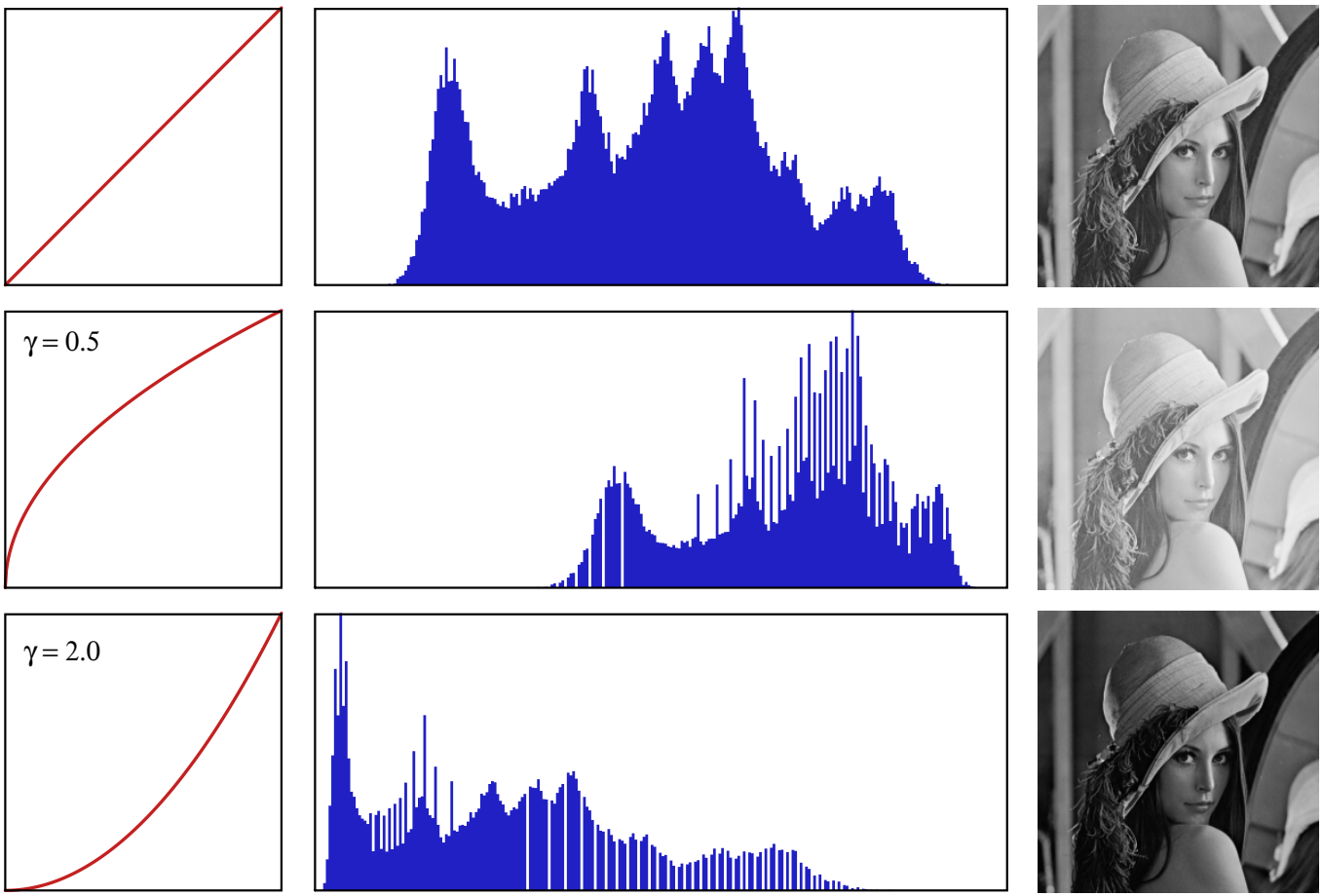
Monadic Operations

Contrast: $T(I) = I \cdot c \quad c \in \langle 0, \infty)$



Monadic Operations

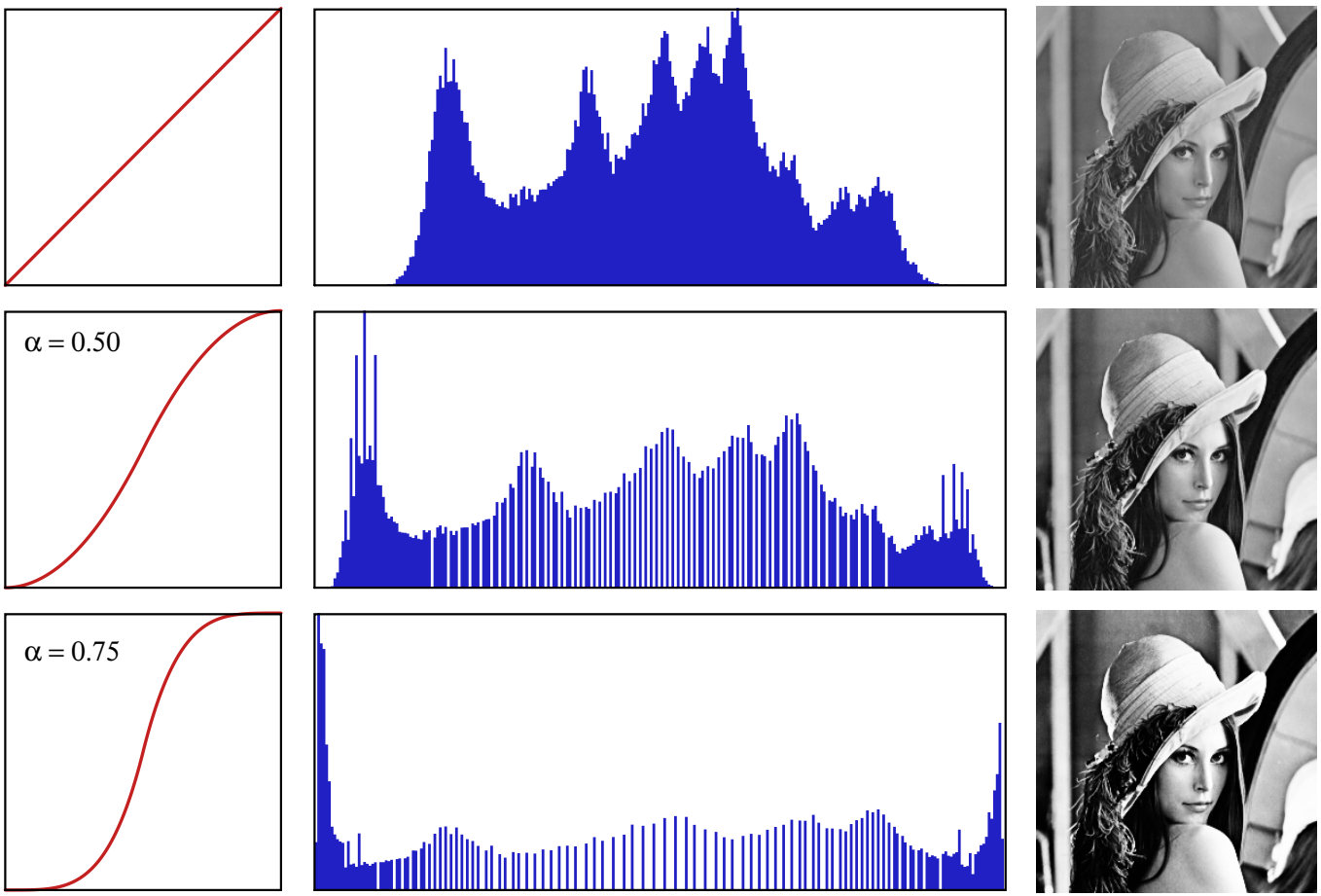
Gamma correction: $T(I) = I^{\gamma} \quad \gamma \in (0, \infty)$



Monadic Operations

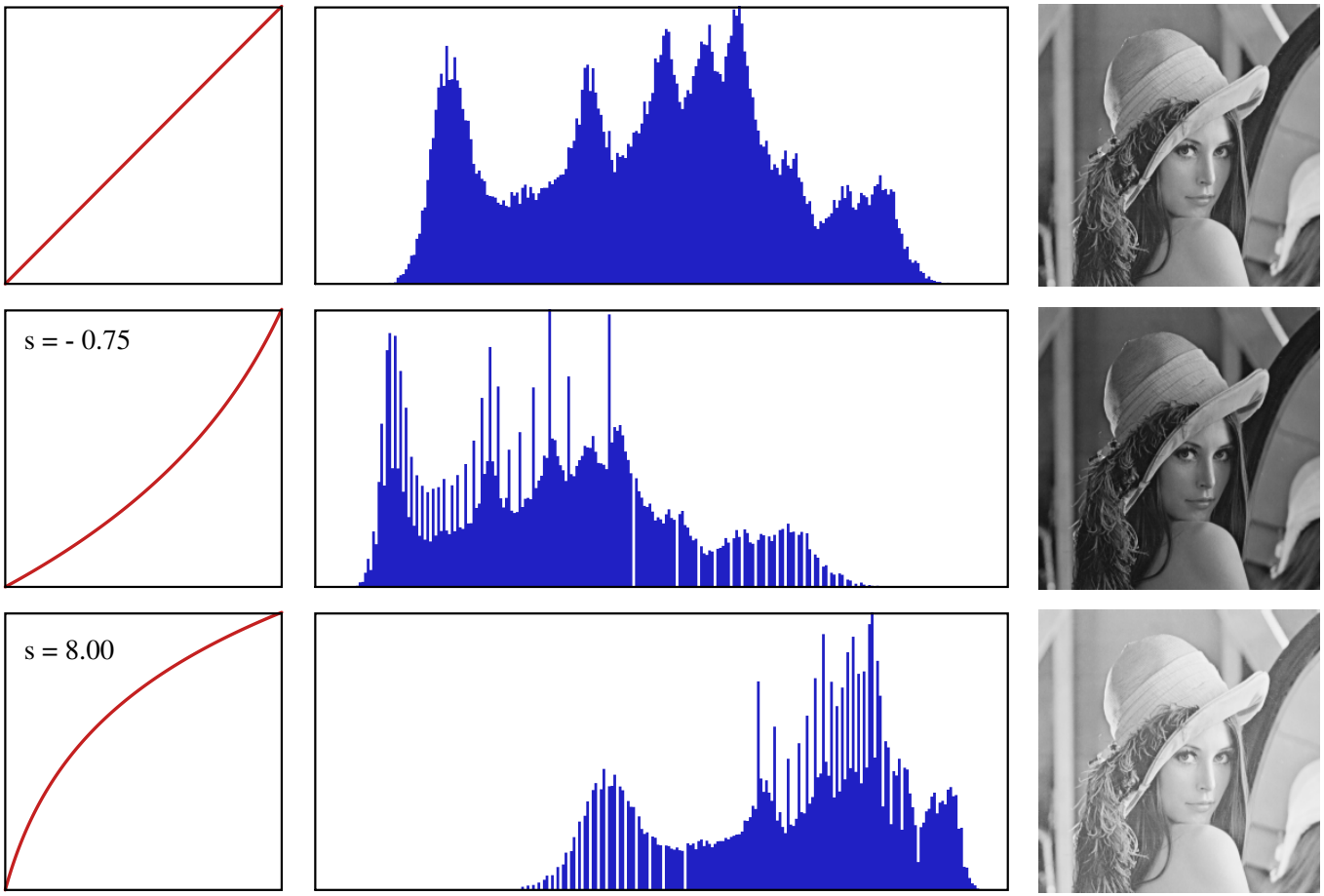
Non-linear contrast:

$$T(I) = \begin{cases} \frac{1}{2}(2I)^{\gamma} & I \in \langle 0, \frac{1}{2}) \quad \gamma = \frac{1}{1-\alpha} \\ 1 - \frac{1}{2}(2-2I)^{\gamma} & I \in \langle \frac{1}{2}, 1\rangle \quad \alpha \in (0,1) \end{cases}$$



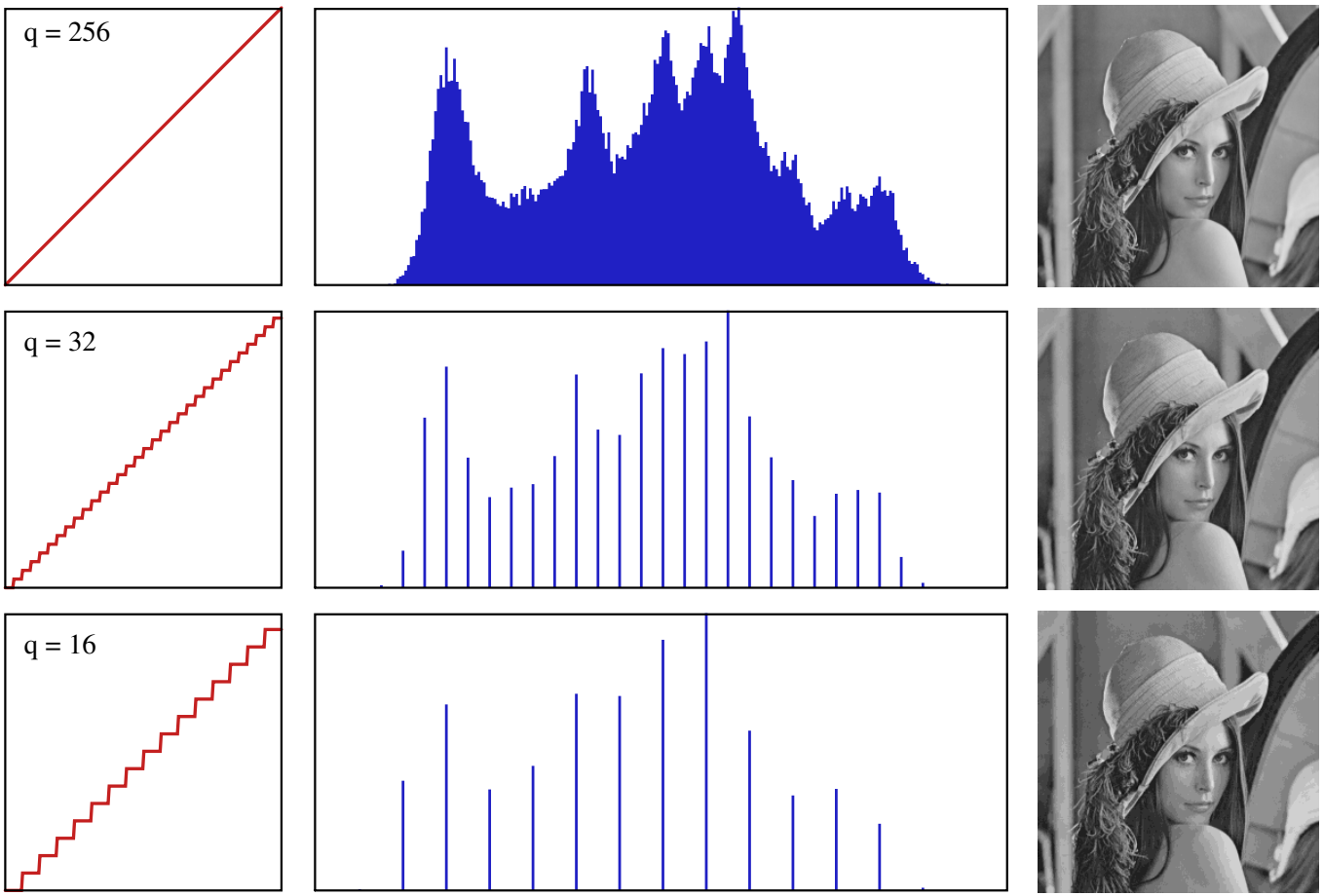
Monadic Operations

Logarithmic scale: $T(I) = \frac{\log(1+I \cdot s)}{\log(1+s)} \quad s \in (-1, \infty)$



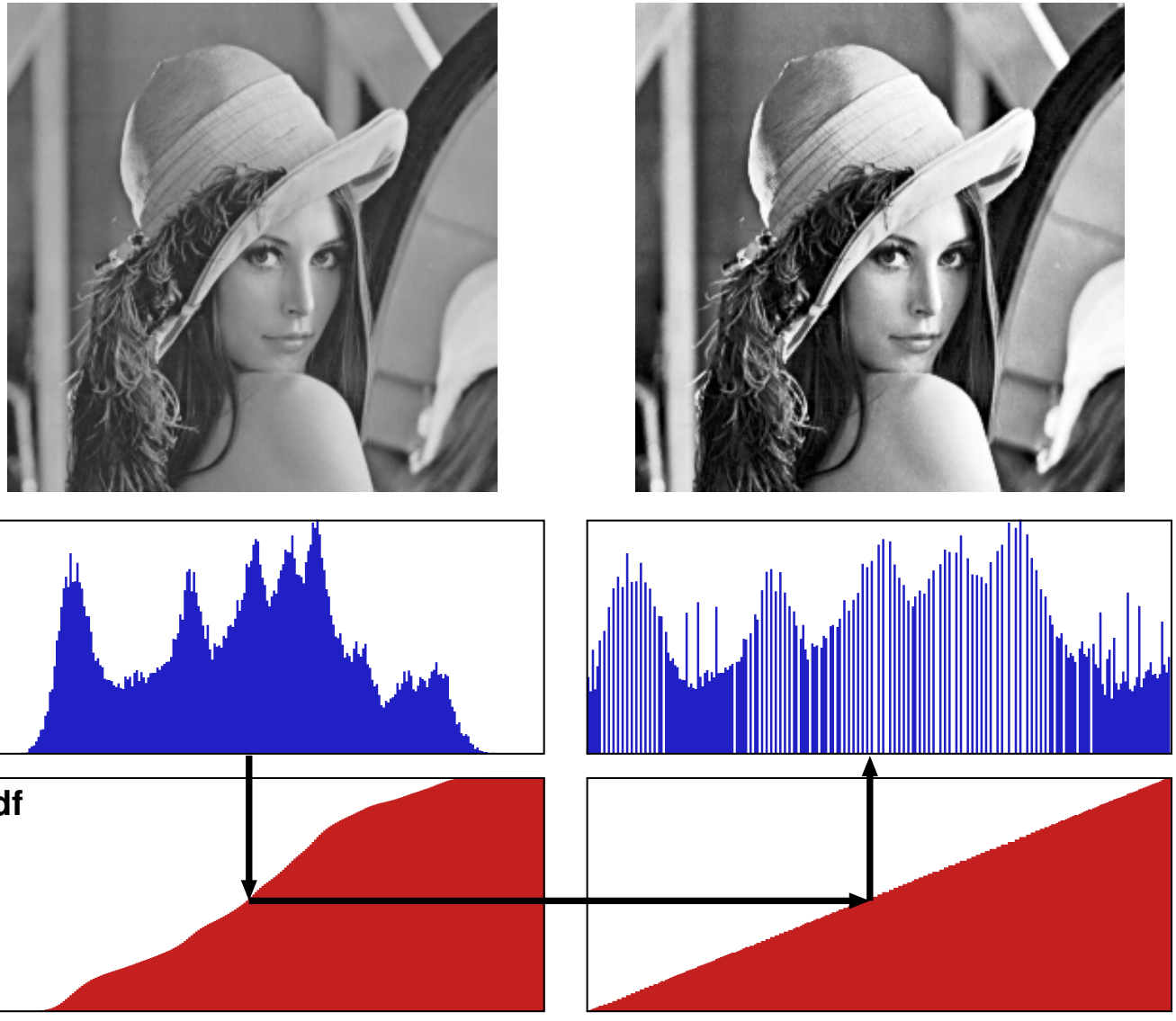
Monadic Operations

Quantization: $T(I) = \lfloor I \cdot q \rfloor \quad q \in (1, \infty)$



Monadic Operations

Equalization: $T(I) = \mathrm{cdf}(I) = \sum_{i=0}^{I} \mathrm{pdf}(i)$



Equalization

I

$I < T_{0.1}$
$I_{eq} < 0.1$

$I < T_{0.3}$
$I_{eq} < 0.3$

$I < T_{0.5}$
$I_{eq} < 0.5$

$I < T_{0.7}$
$I_{eq} < 0.7$

$I < T_{0.9}$
$I_{eq} < 0.9$

Equalization

I

$I < 0.21$

$I_{eq} < 0.1$

$I < 0.39$

$I_{eq} < 0.3$

$I < 0.51$

$I_{eq} < 0.5$

$I < 0.60$

$I_{eq} < 0.7$

$I < 0.75$

$I_{eq} < 0.9$

Equalization - Transformation function

$$T(Q) = \int_0^Q p(x)\mathrm{d}x \tag{1}$$

$p(x)$: pdf of image intensities
$T(Q)$: the resulting transformation function

Mapping

$$T(I) = \text{cdf}_B^{-1}(\text{cdf}_A(I))$$