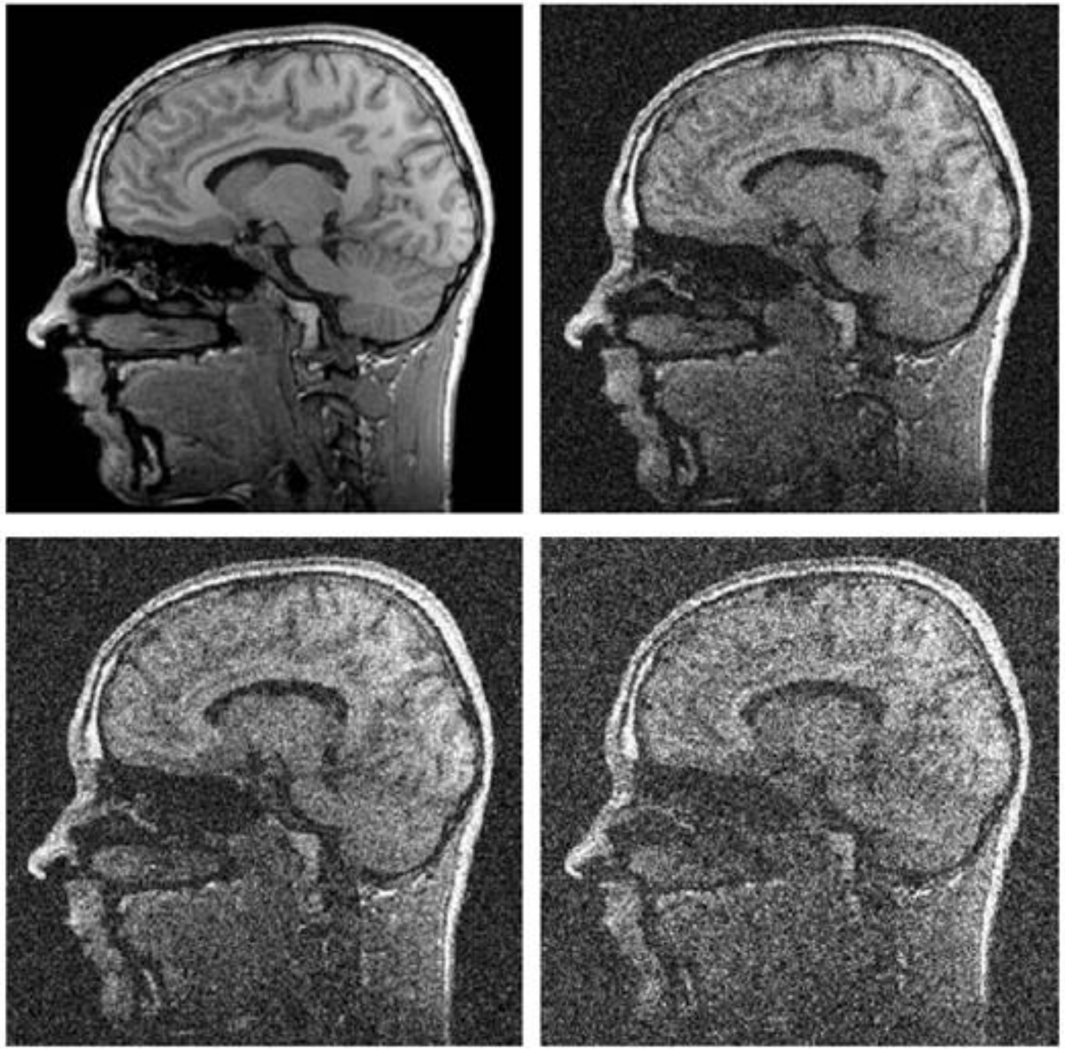
Why denoising?

- High noise levels reduce the visibility of small details and low-contrast changes.
- Generally improves the SNR.
- Performance of automated methods will improve.
- Visual Analysis becomes easier.



Denoising through averaging multiple images

When multiple images of the same object is available (experimental setup should be same), we can improve the image quality by averaging it.

Averaging n images reduces noise by a factor of $\sqrt{n}$

Ground Truth

Noisy Image

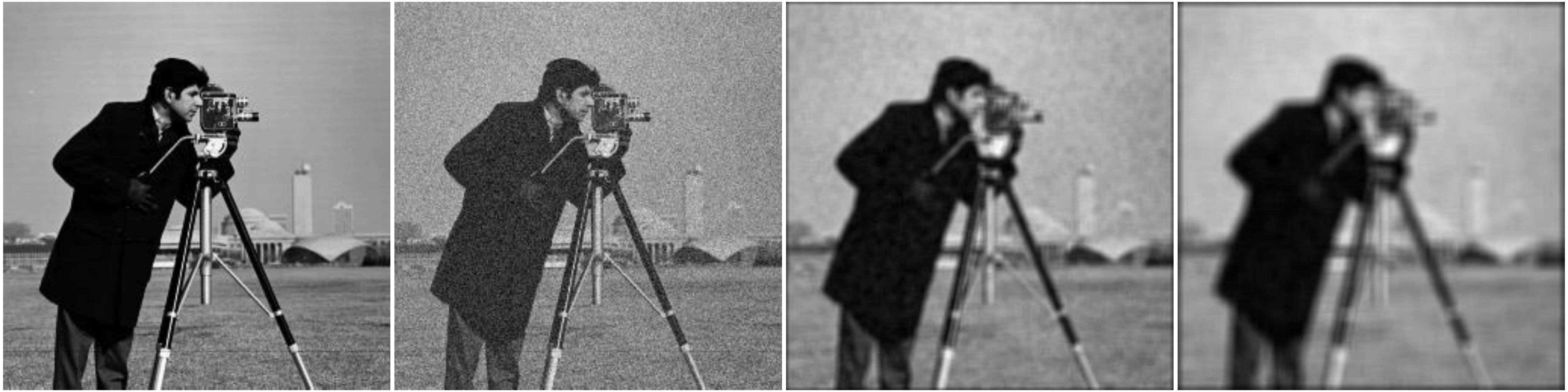
Average of 2 images

Average of 4 images

Denoising through local averaging

Noise can be reduced by replacing each and every pixel with the mean of the neighbouring pixels

The estimation with the better in smooth areas, but this process will blur images.



Ground Truth | Noisy Image | Local averaging with 5 x 5 box filter | Local averaging with 9 x 9 box filter

Image Quality Measure - PSNR

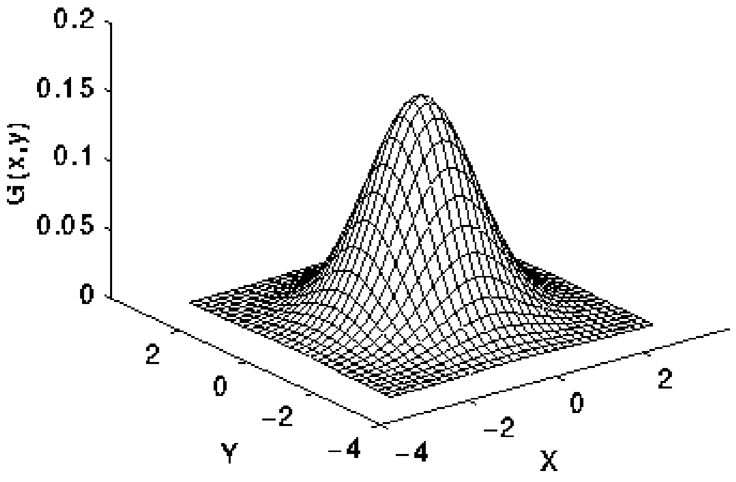
The term **peak signal-to-noise ratio (PSNR)** is an expression for the ratio between the maximum possible value (power) of a signal and the power of distorting noise that affects the quality of its representation.

$$PSNR = 20 \log_{10}\left(\frac{MAX_f}{\sqrt{MSE}}\right)$$

$$MSE = \frac{1}{mn}\sum_{0}^{m-1}\sum_{0}^{n-1}\|f(i,j) - g(i,j)\|^2$$

Denoising with Gaussian kernel

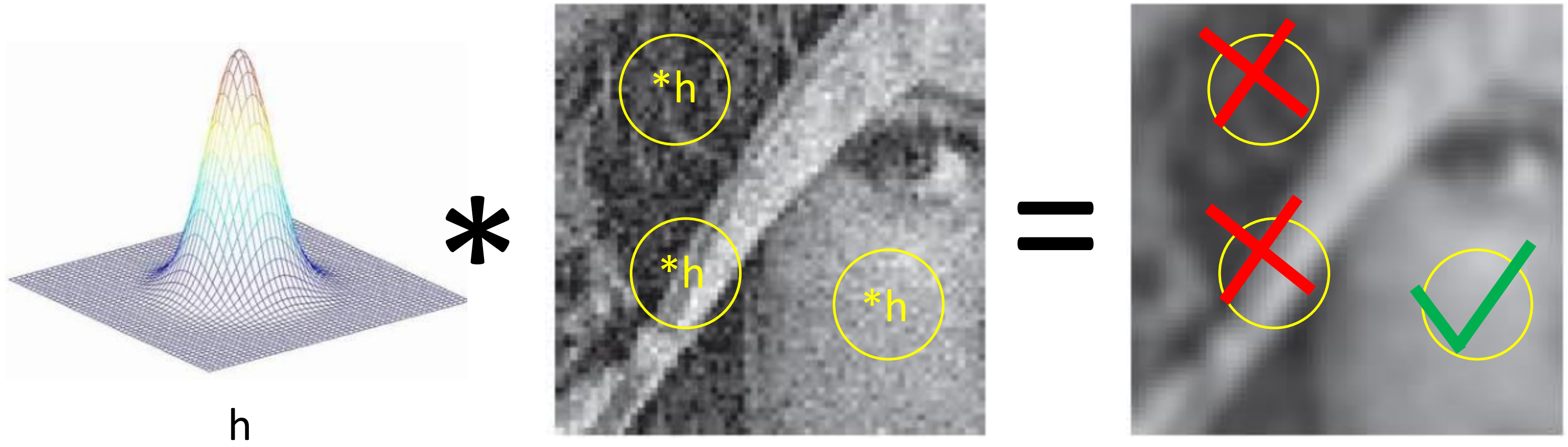
$$G_\sigma(x, y) = \frac{1}{2\pi\sigma^2} \exp\left(-\frac{x^2 + y^2}{2\sigma^2}\right)$$

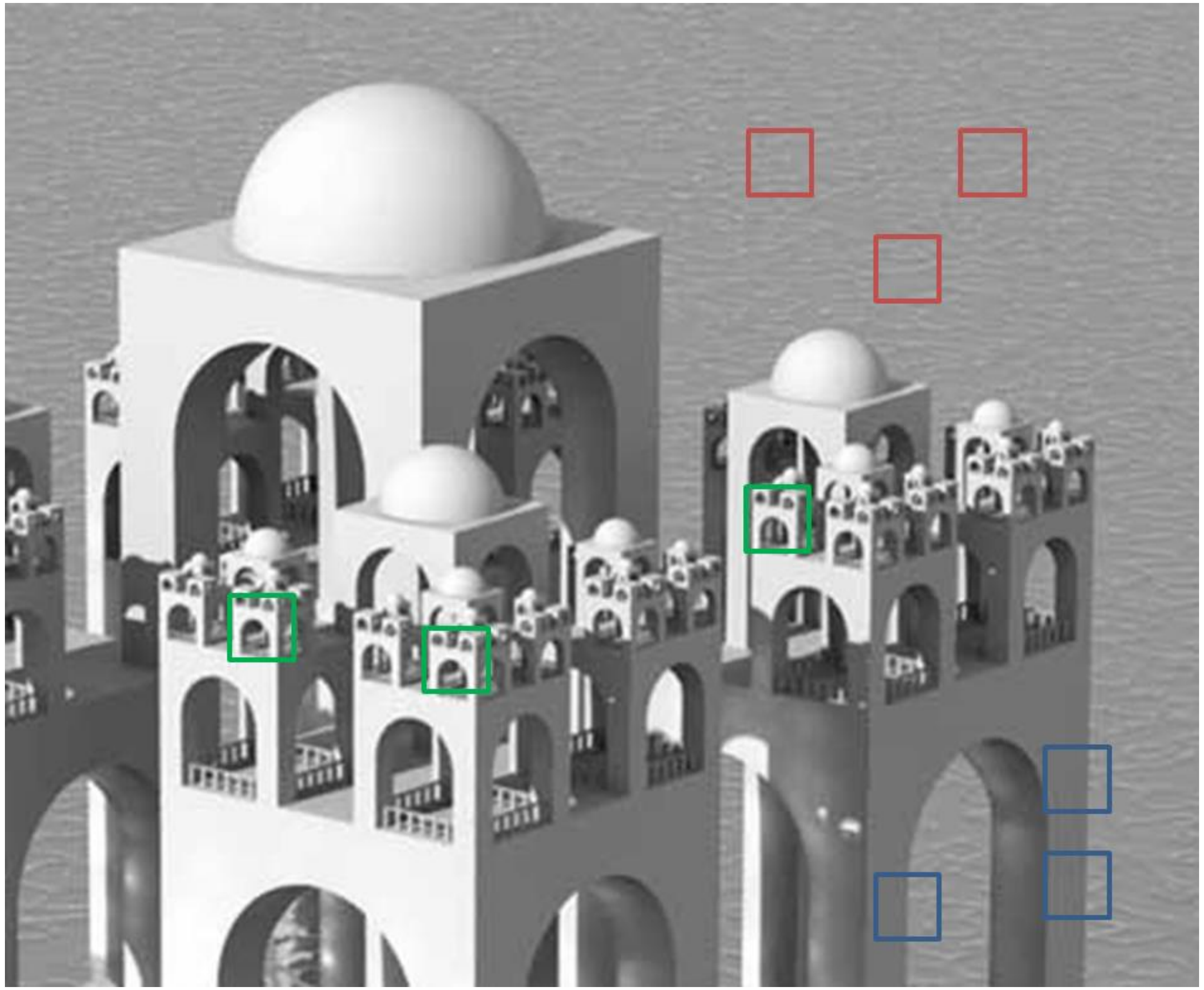


$\frac{1}{273}$

1	4	7	4	1
4	16	26	16	4
7	26	41	26	7
4	16	26	16	4
1	4	7	4	1

Non-Local means Method



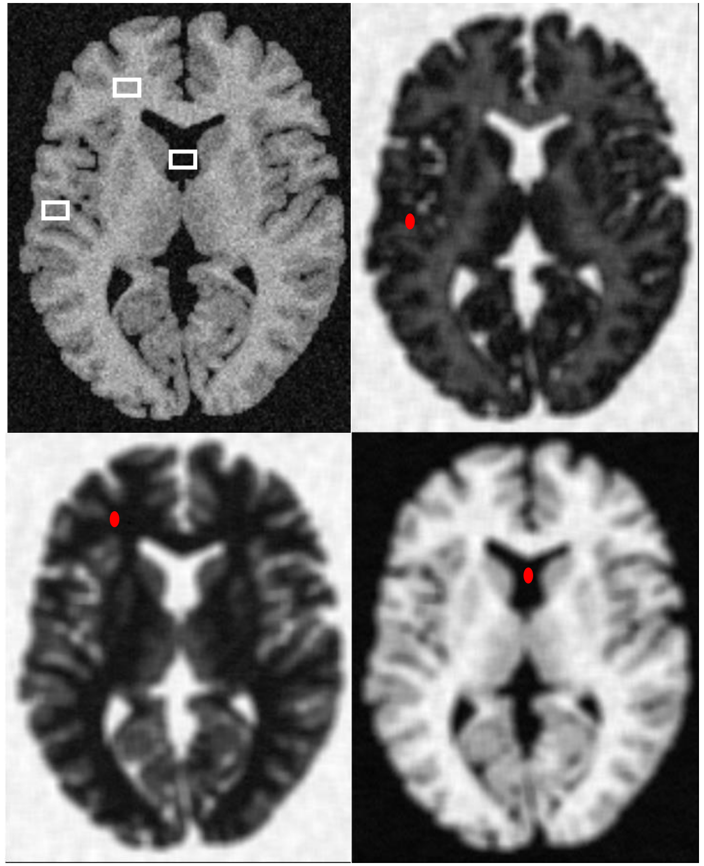


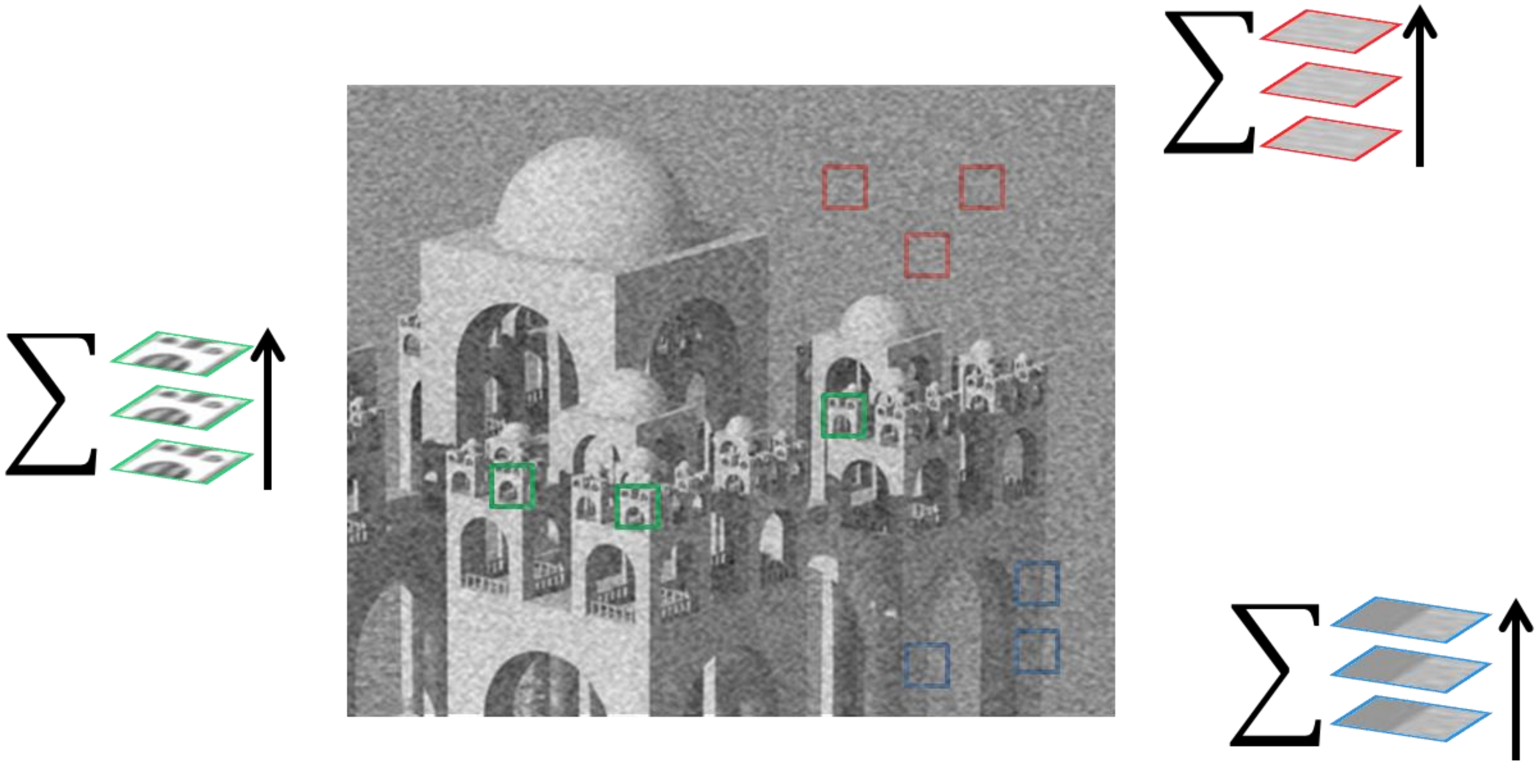
Patch Similarity – Euclidean Distance

Selecting samples m_1, m_2 ,m_3 … m_n

$$d_{i,j} = \|N_i - N_j\|$$

- NL pixels – selected based on the intensity similarity of pixel neighborhoods.





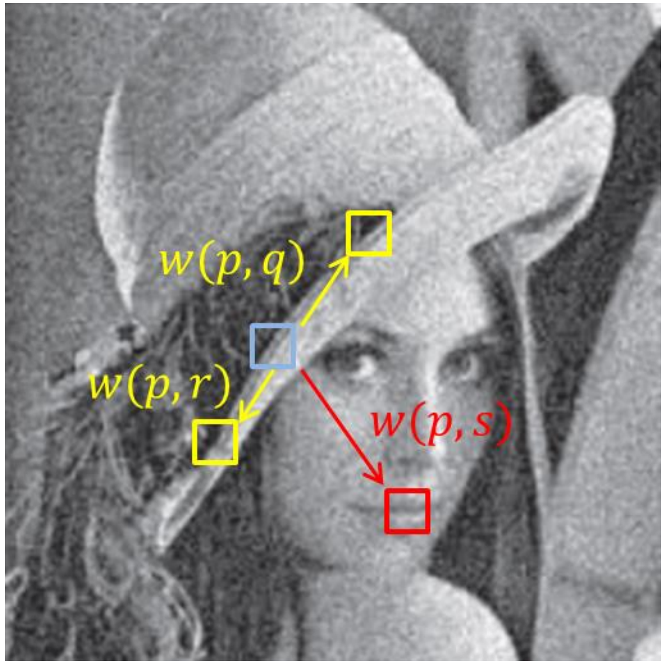
Unfortunately, patches are not exactly the same
$\Rightarrow$ simple averaging just won't work

- Non-local means compares entire patches (not individual pixel intensity values) to compute weights for denoising pixel intensities.
- Comparison of entire patches is more robust, i.e. if two patches are similar in a noisy image, they will be similar in the underlying clean image with very high probability.

$$NL(v)(i) = \sum_{j \in I} w(i,j) v(j),$$

$$w(i,j) = \frac{1}{Z(i)} e^{-\frac{\|v(\mathcal{N}_i)-v(\mathcal{N}_j)\|_{2,a}^2}{h^2}},$$

$$Z(i) = \sum_j e^{-\frac{\|v(\mathcal{N}_i)-v(\mathcal{N}_j)\|_{2,a}^2}{h^2}}$$

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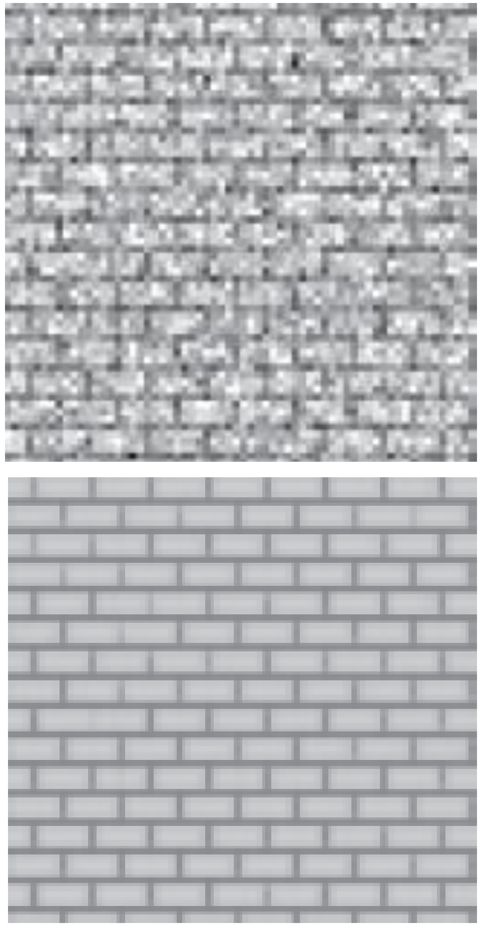

Order Statistic Filters

Suppose that X is a real-valued variable for a population and that $X = \{X_1, X_2, ..., X_n\}$ are the observed values of a sample of size *n* corresponding to this variable.

In statistics, the *k*th **order statistic** of a statistical sample is equal to its *k*th-smallest value (usually denoted as).

Thus

$$X_{(1)} \leq X_{(2)} \leq ...X_{(n-1)} \leq X_{(n)}$$

$$X_{(1)} = \min\{X_1, X_2, ..., X_n\}$$

$$X_{(n)} = \max\{X_1, X_2, ..., X_n\}$$

$$\text{median} = X_{(k)}; k = \frac{(n+1)}{2}$$