Image Denoising
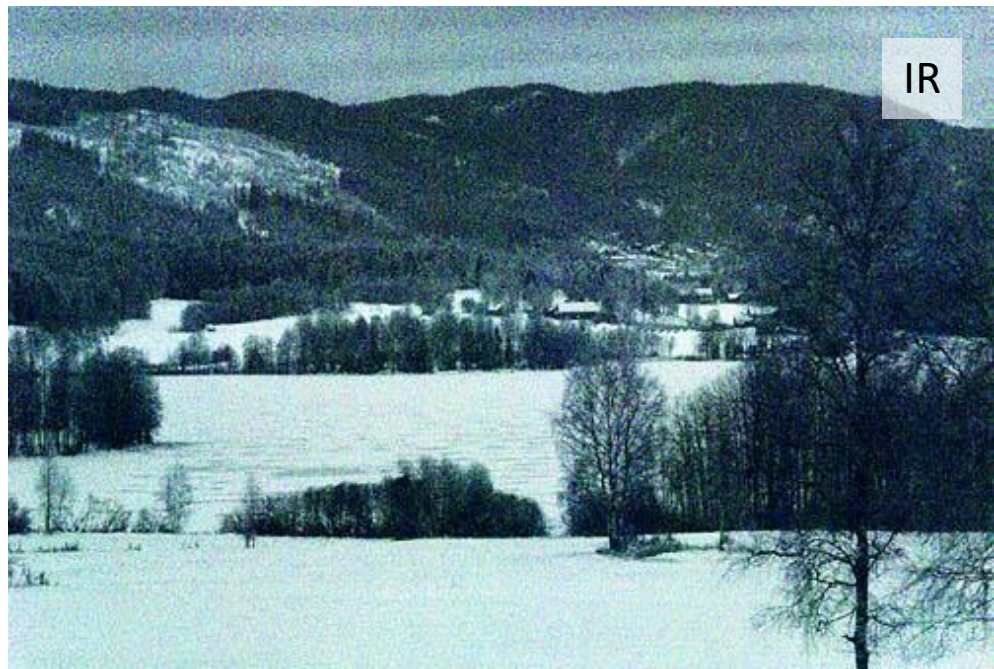
Indoor – low light
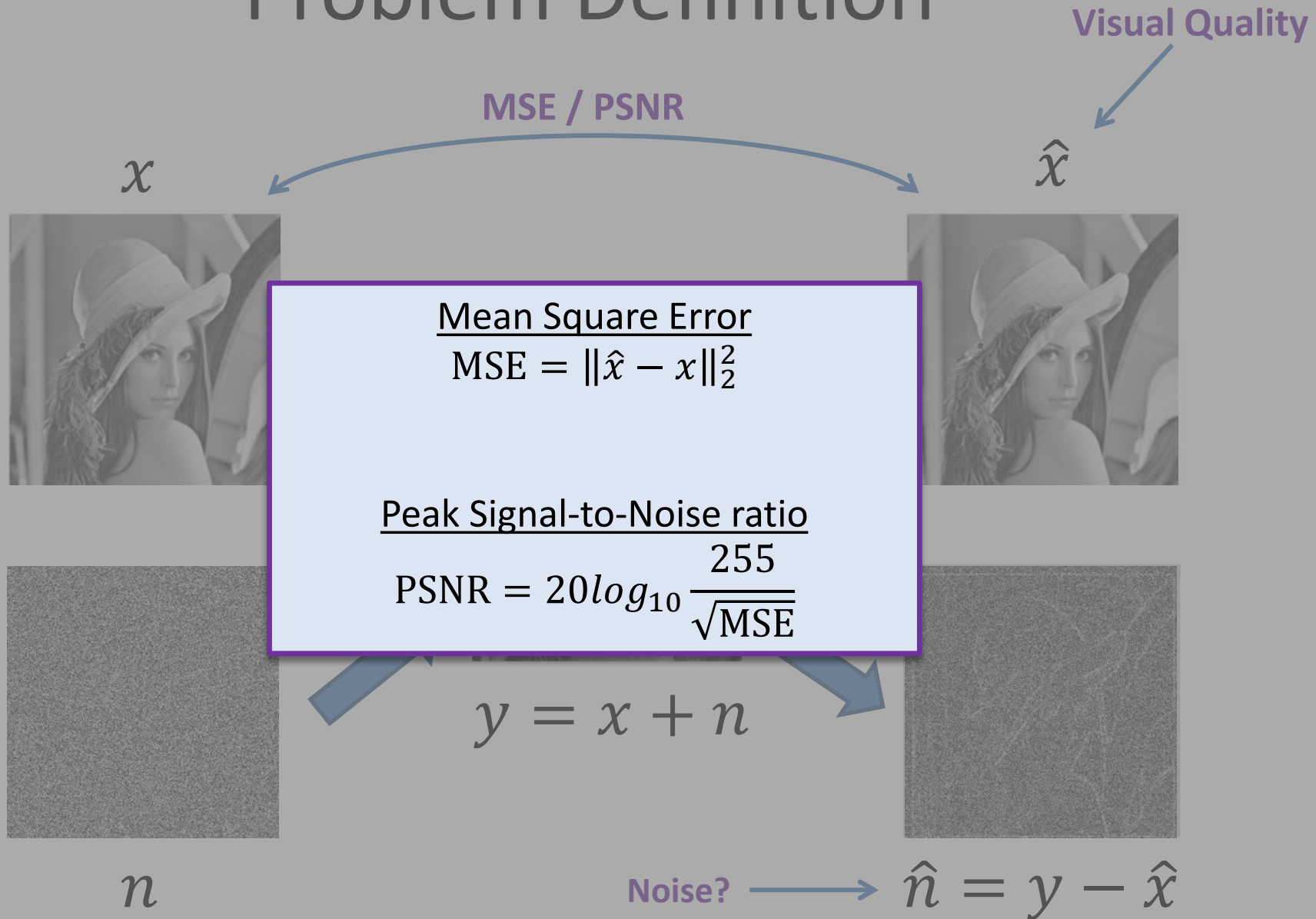

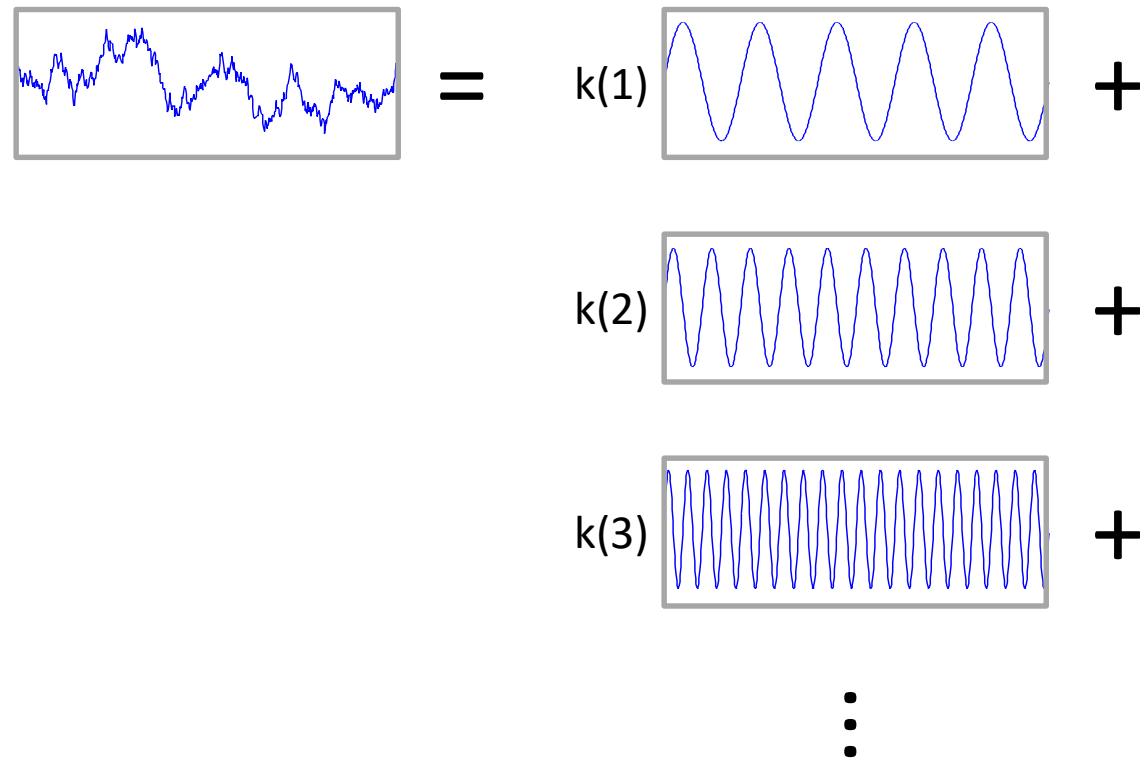IR

US

Can we (humans) denoise?
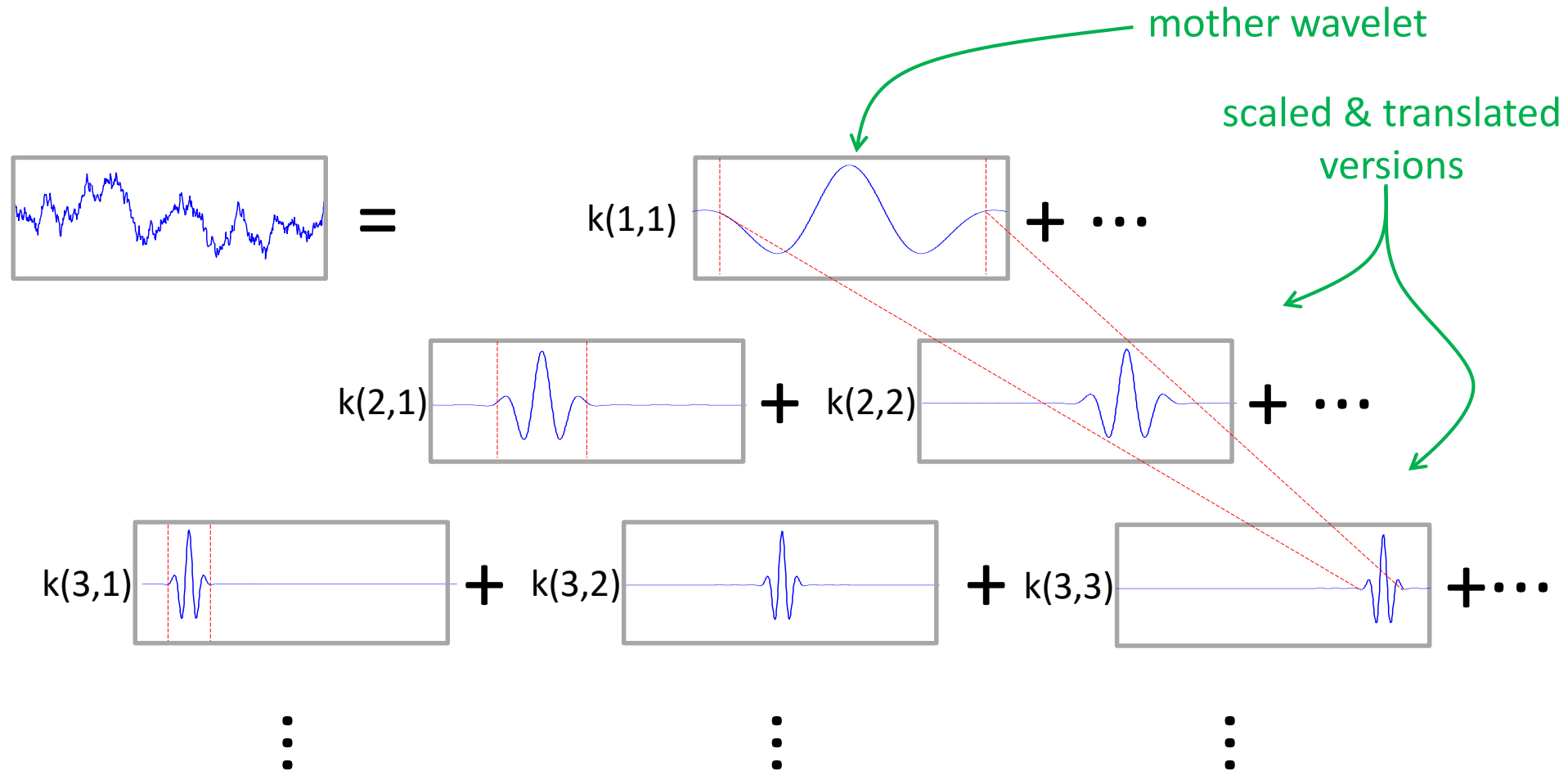
Problem Definition

MSE / PSNR

x

$\hat{x}$

Mean Square Error
$$\text{MSE} = \|\hat{x} - x\|_2^2$$

Peak Signal-to-Noise ratio
$$\text{PSNR} = 20 log_{10} \frac{255}{\sqrt{\text{MSE}}}$$

$y = x + n$

n

Noise? $\longrightarrow$ $\hat{n} = y - \hat{x}$
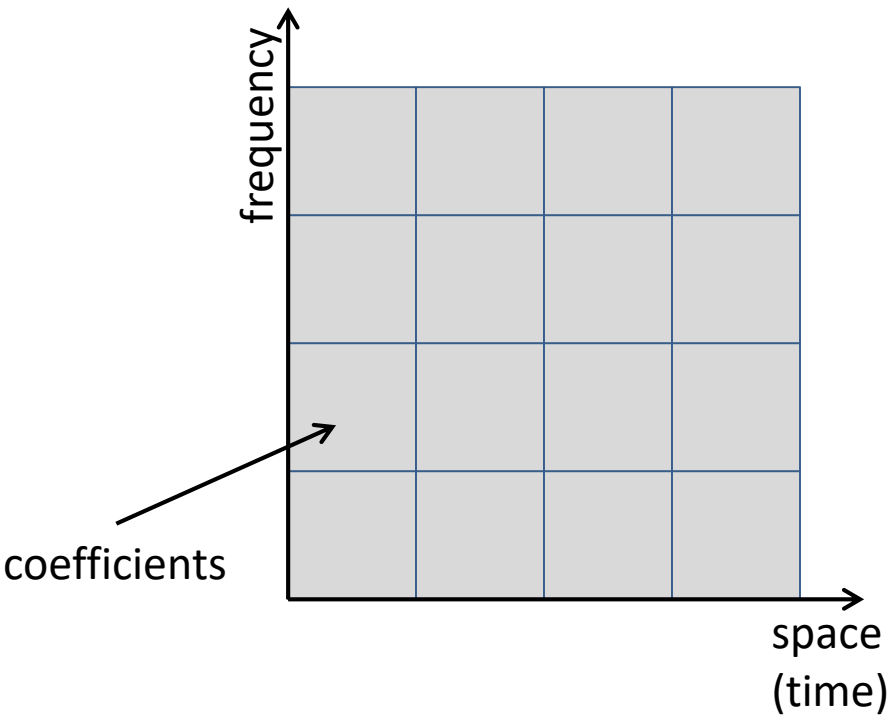
Fourier Decomposition

Wavelet Decomposition
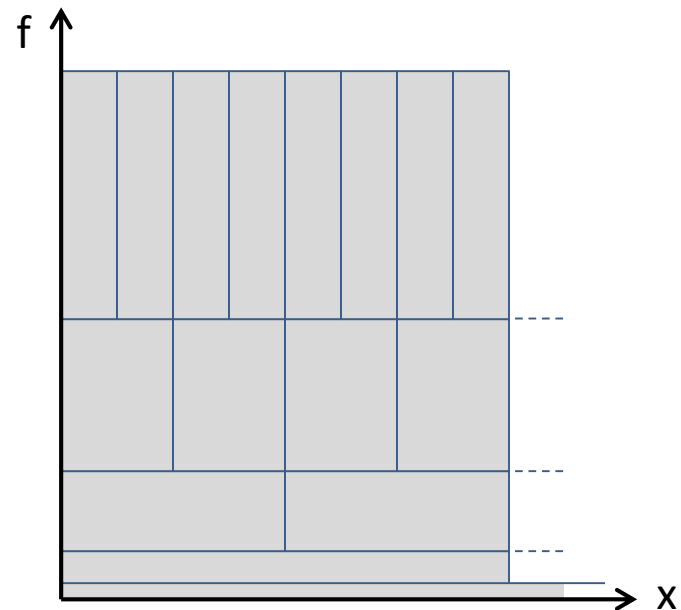
Space-Frequency Localization
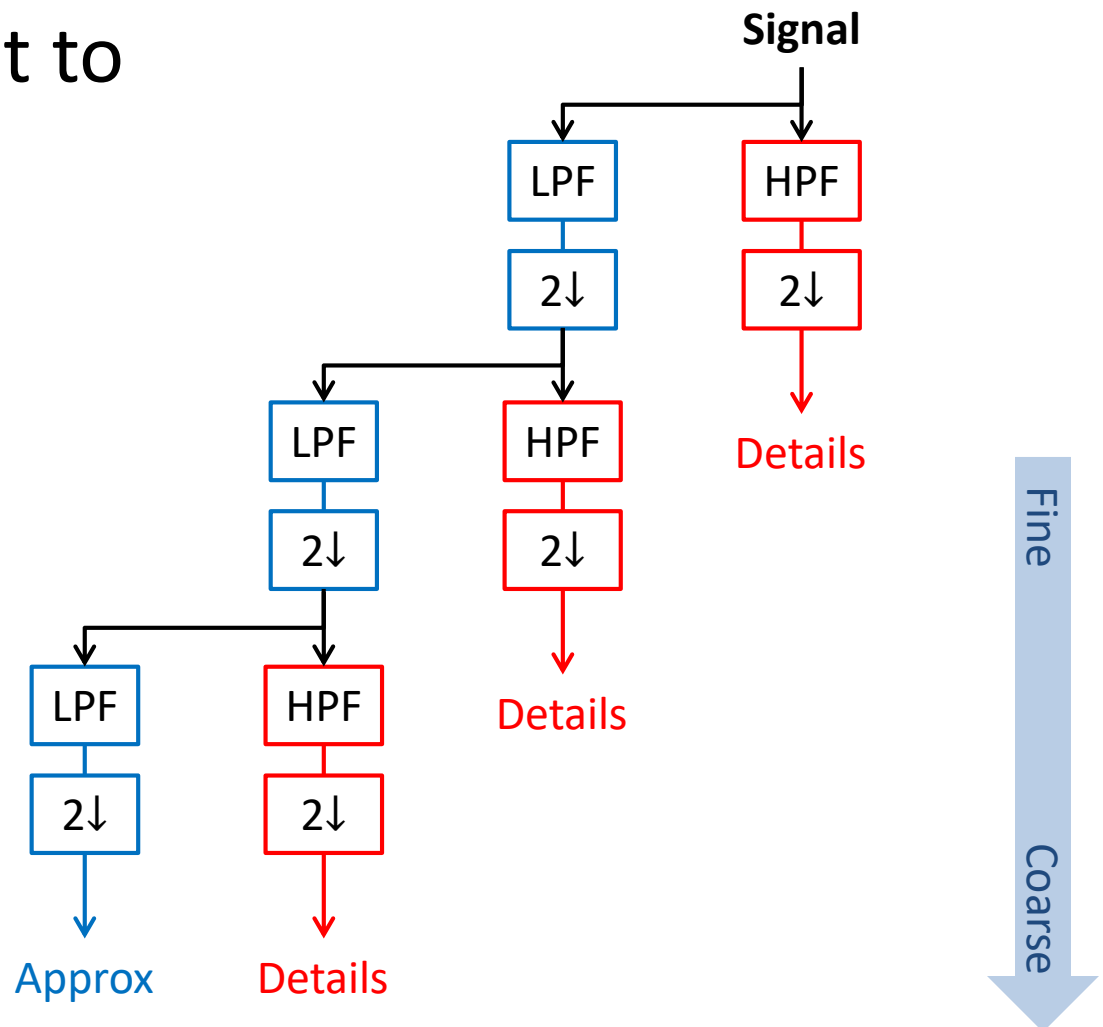
Windowed Fourier
Uniform tiling

Wavelets
Non-uniform tiling

Discrete Wavelet Transform (DWT)

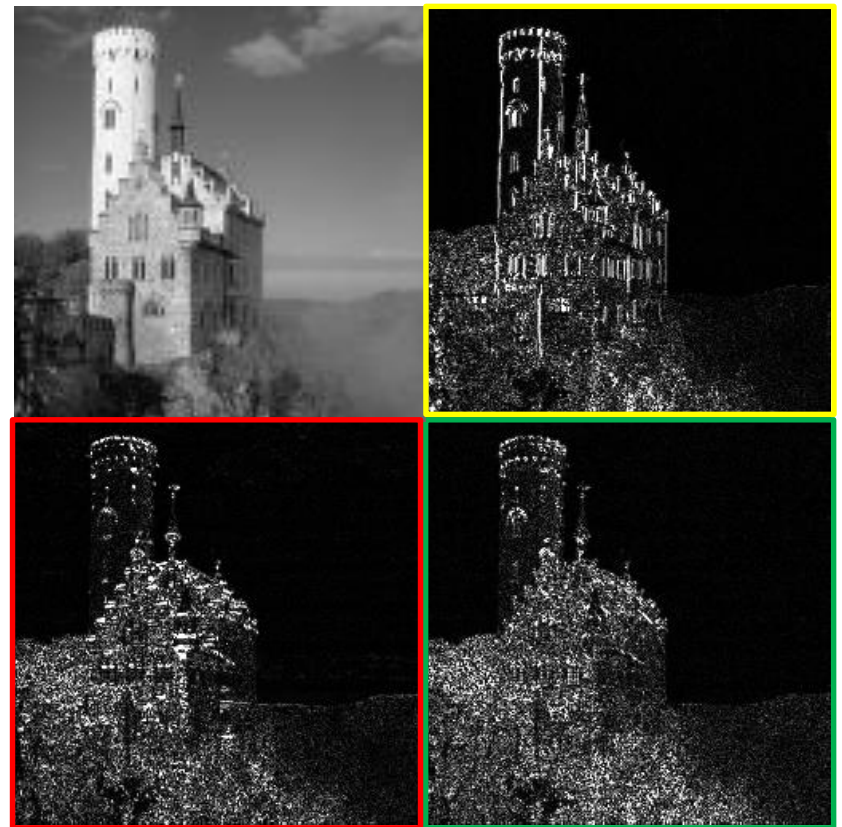- Recursively, split to
  - Approximation
  - Details

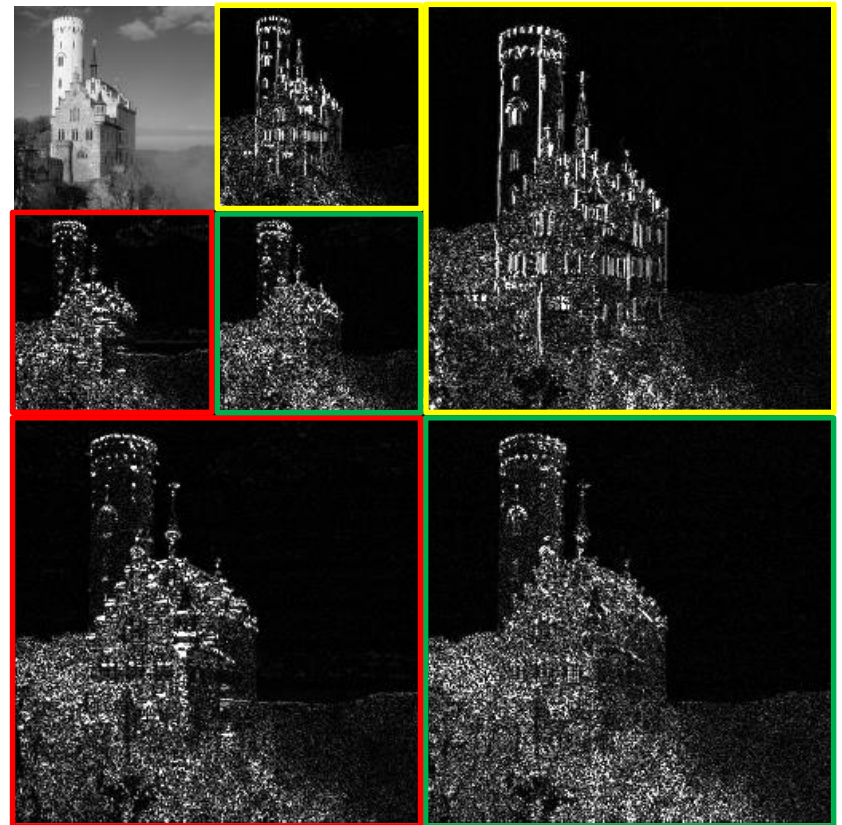# Wavelet Transform - Example

Original image

1 level DWT

Wavelet Transform - Example
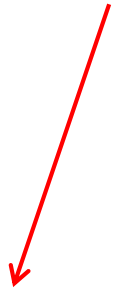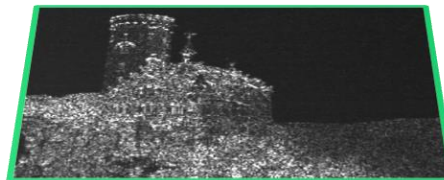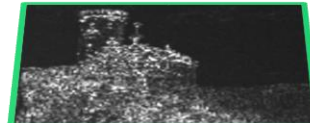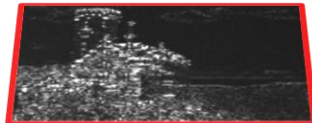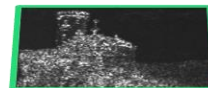
Original image

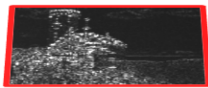2 level DWT

Wavelet Pyramid

Low-pass residual
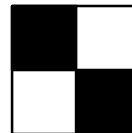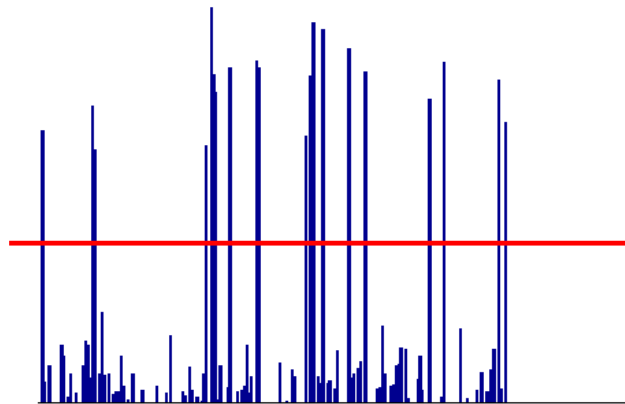(approximation)

Sub-band
(detail)

scale

orientation

Wavelet Thresholding (WT)

- Wavelet $\Rightarrow$ Sparser Representation
- Improved separation between signal and noise at different scales and orientations

Thresholding (hard/soft) is more meaningful