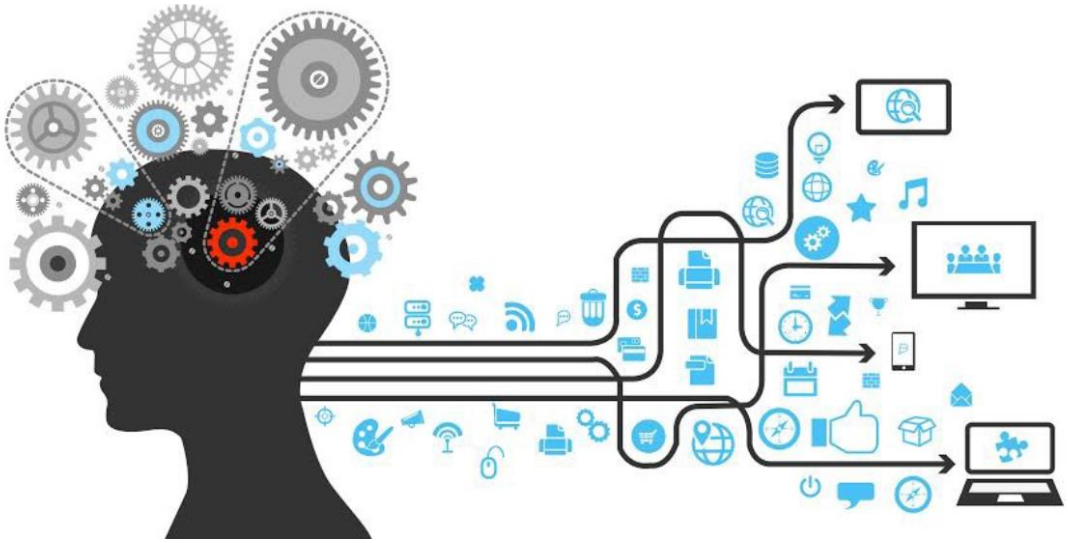
# Computer Vision

## *Early vision: Just one image*



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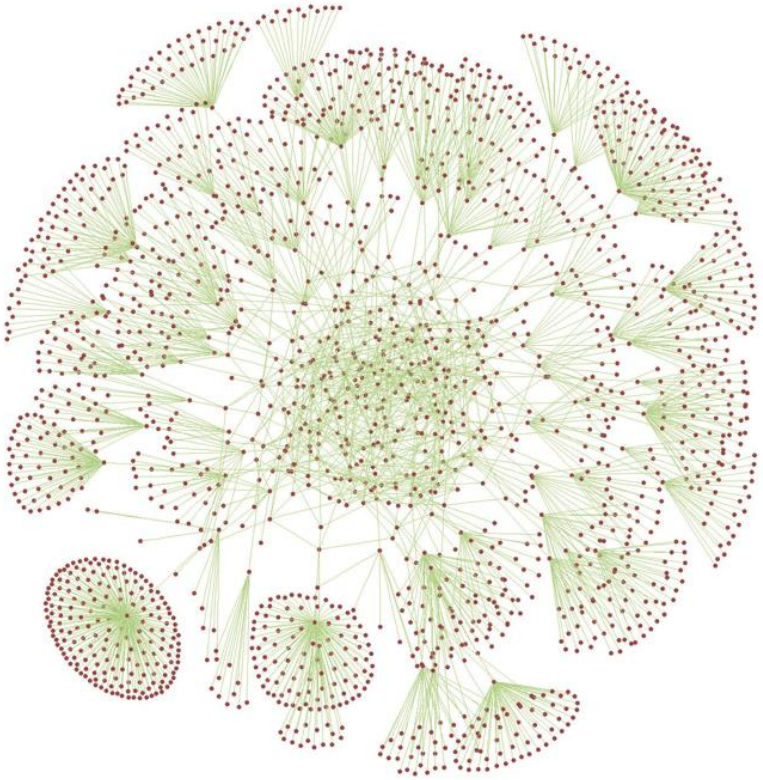
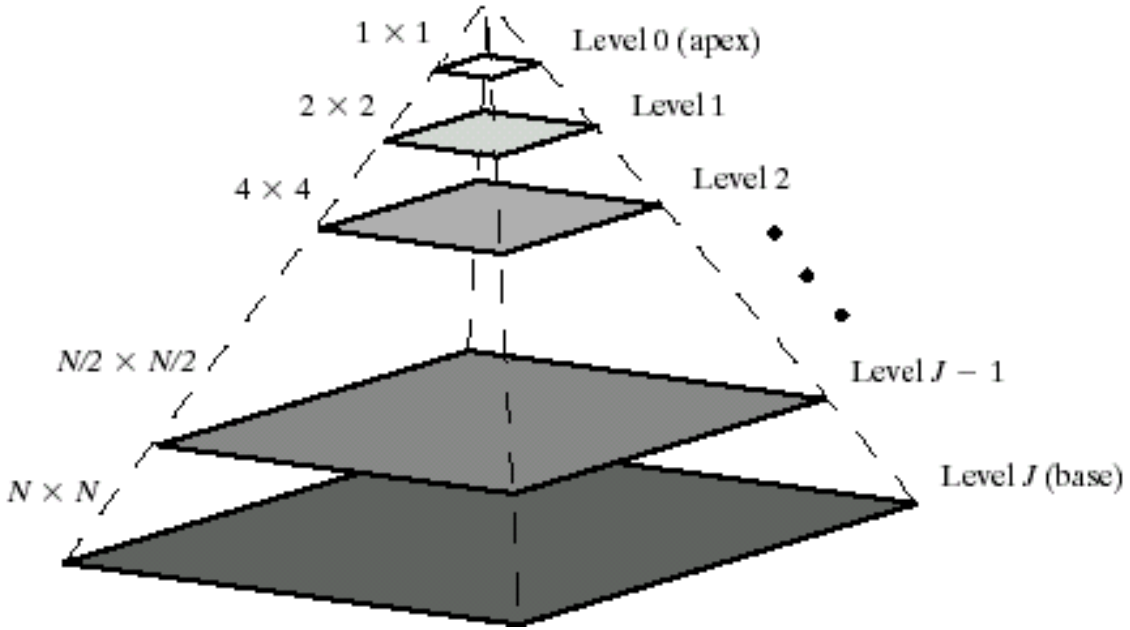
Medical Image Processing



# Image Pyramids

# Image pyramid

- Image pyramid
  - ***Collection of representations*** of an image
  - Smooth and then down-sample an image repeatedly: Get a pyramidal image

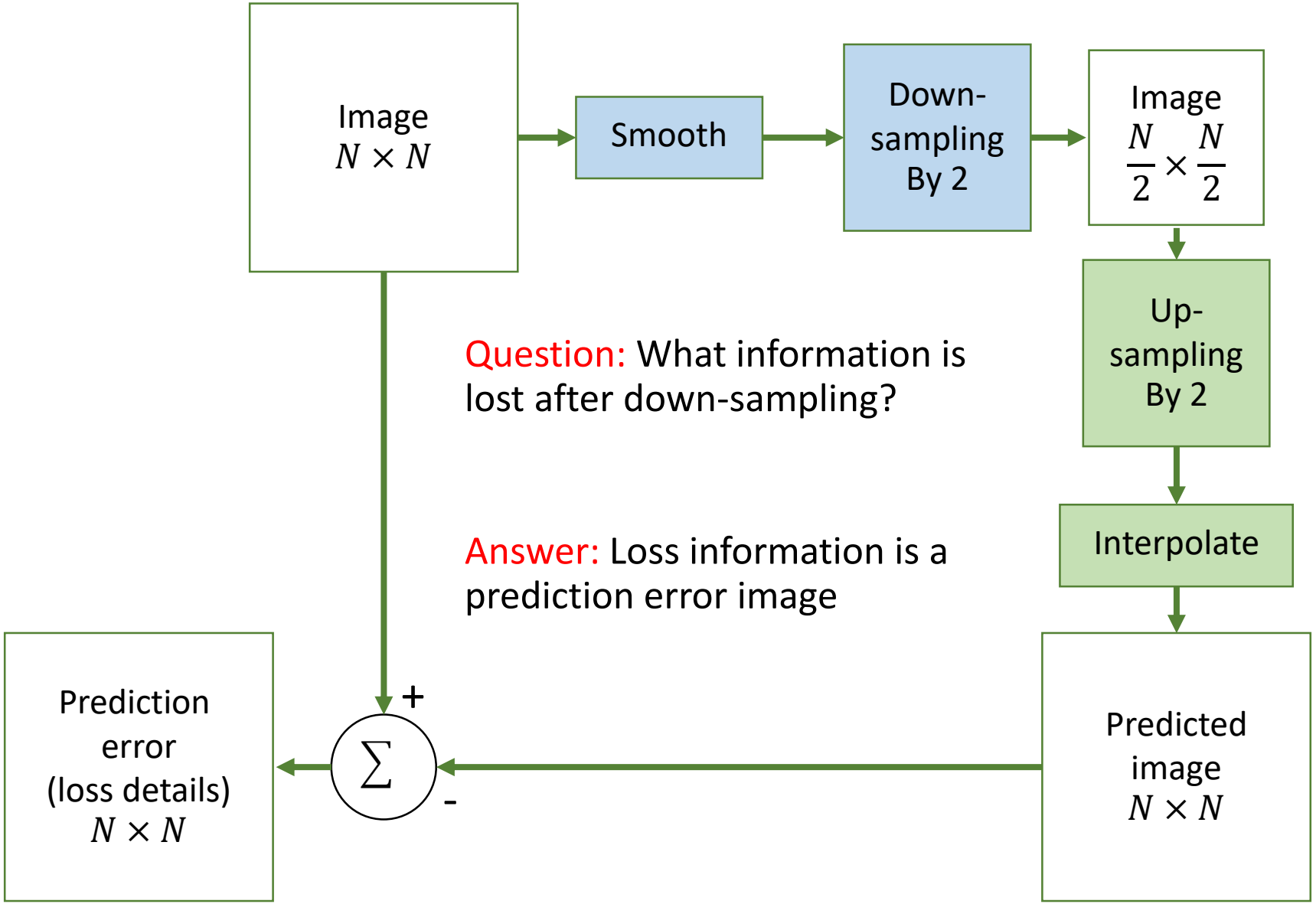



Pyramidal structured image

Coarser, decrease resolution

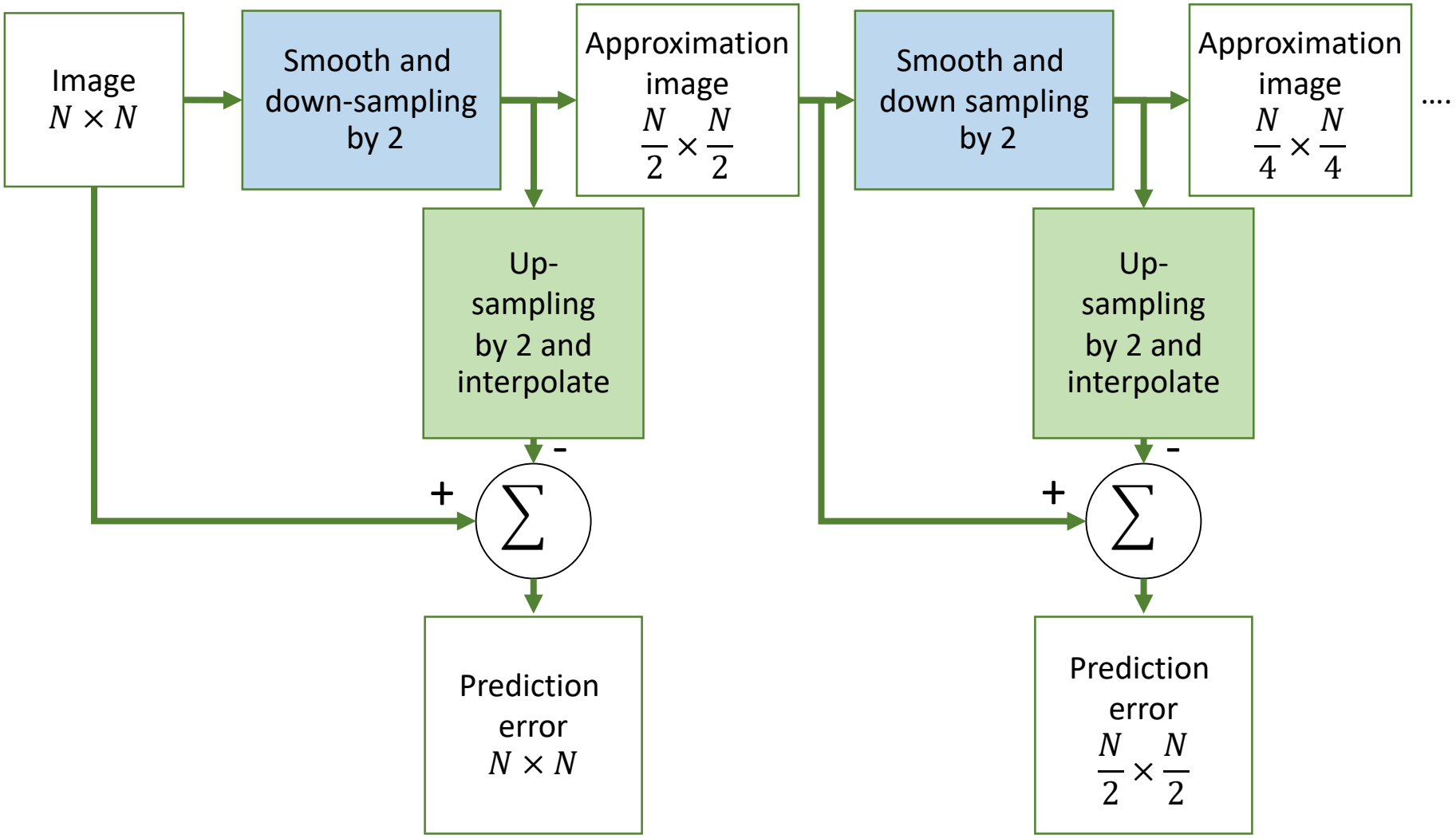
Finer, increase resolution

# Multiscale decomposition



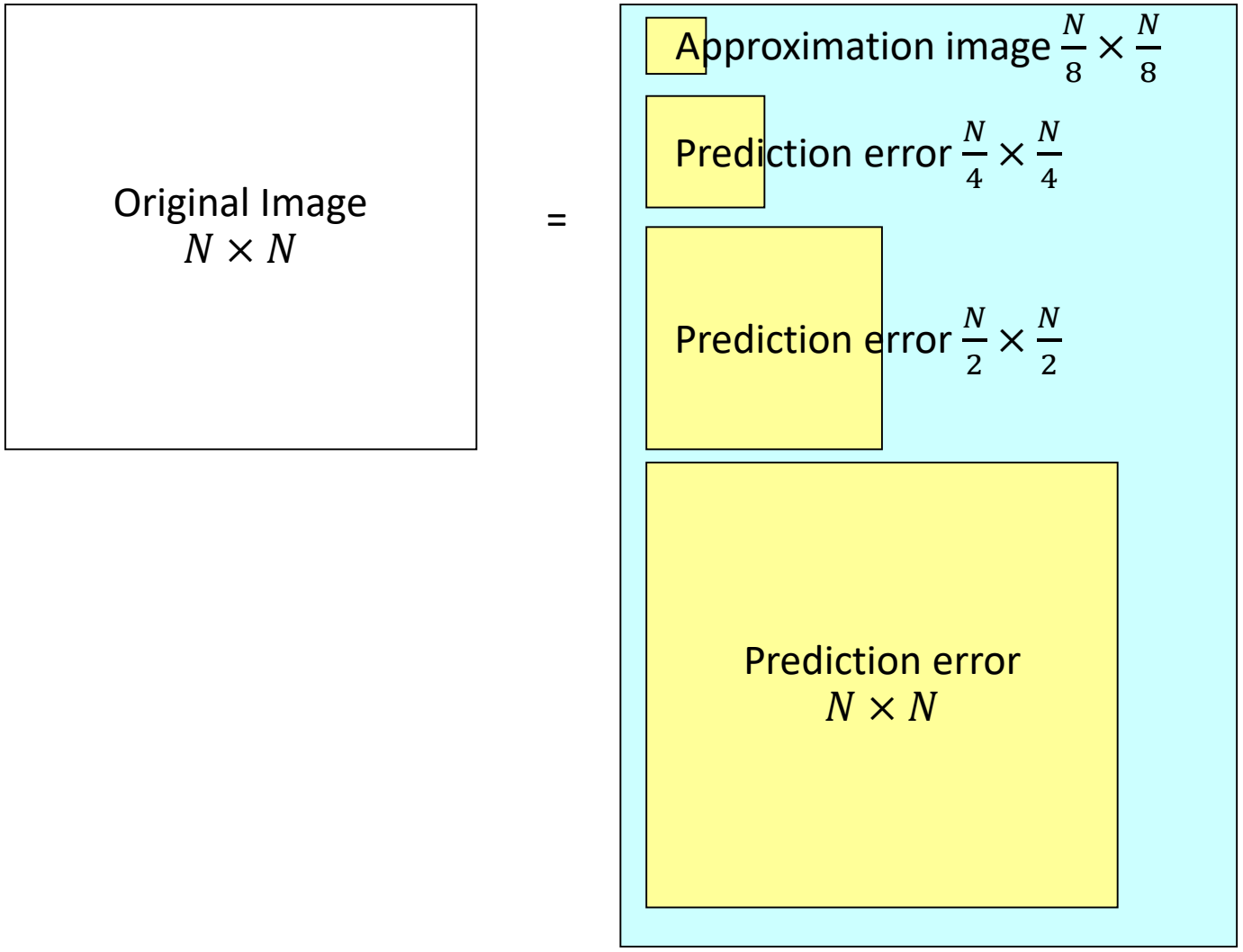
# Multiscale decomposition

- Decomposition process

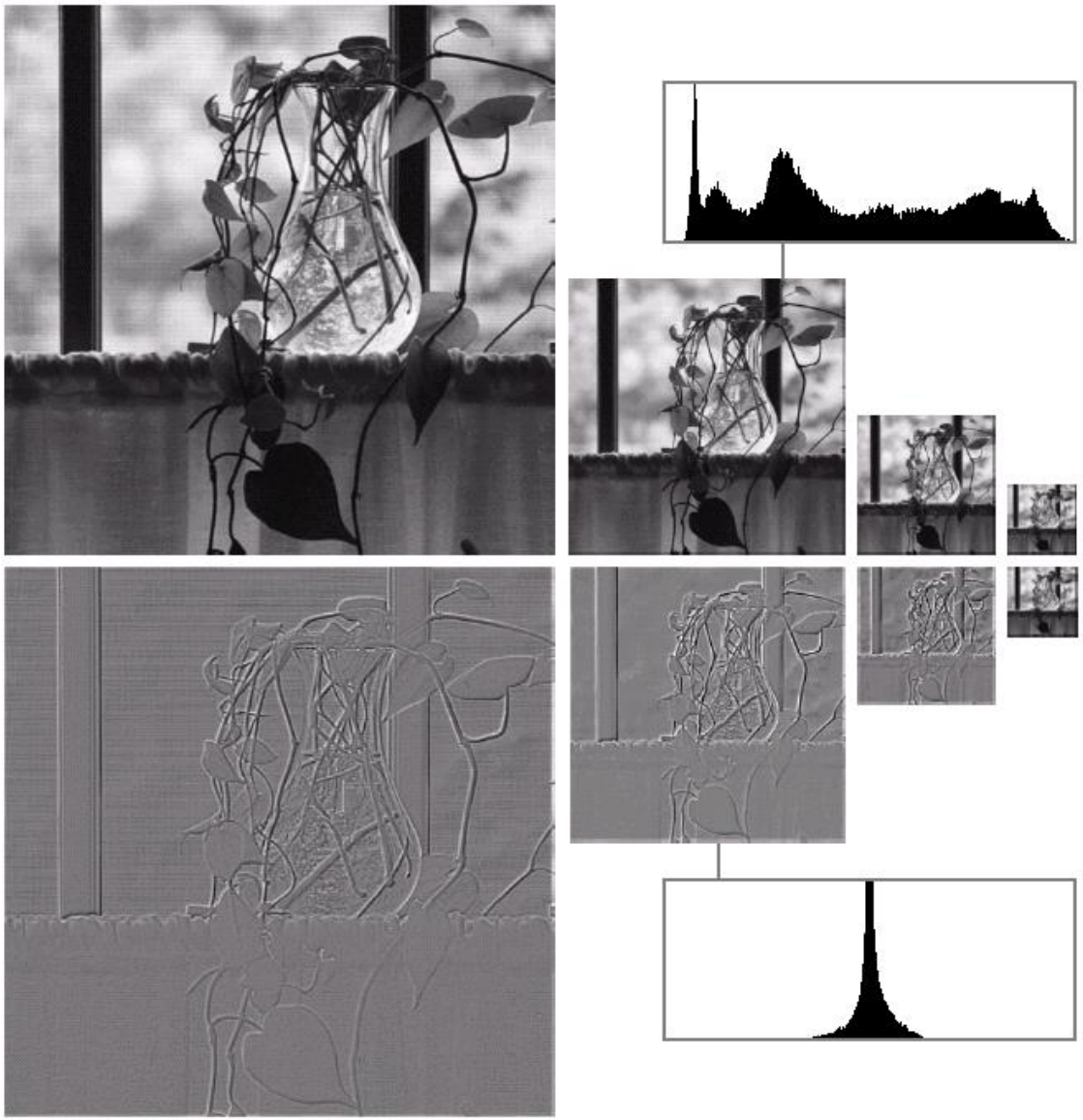


# Multiscale decomposition

- Multiresolution representation



# Example of image pyramid



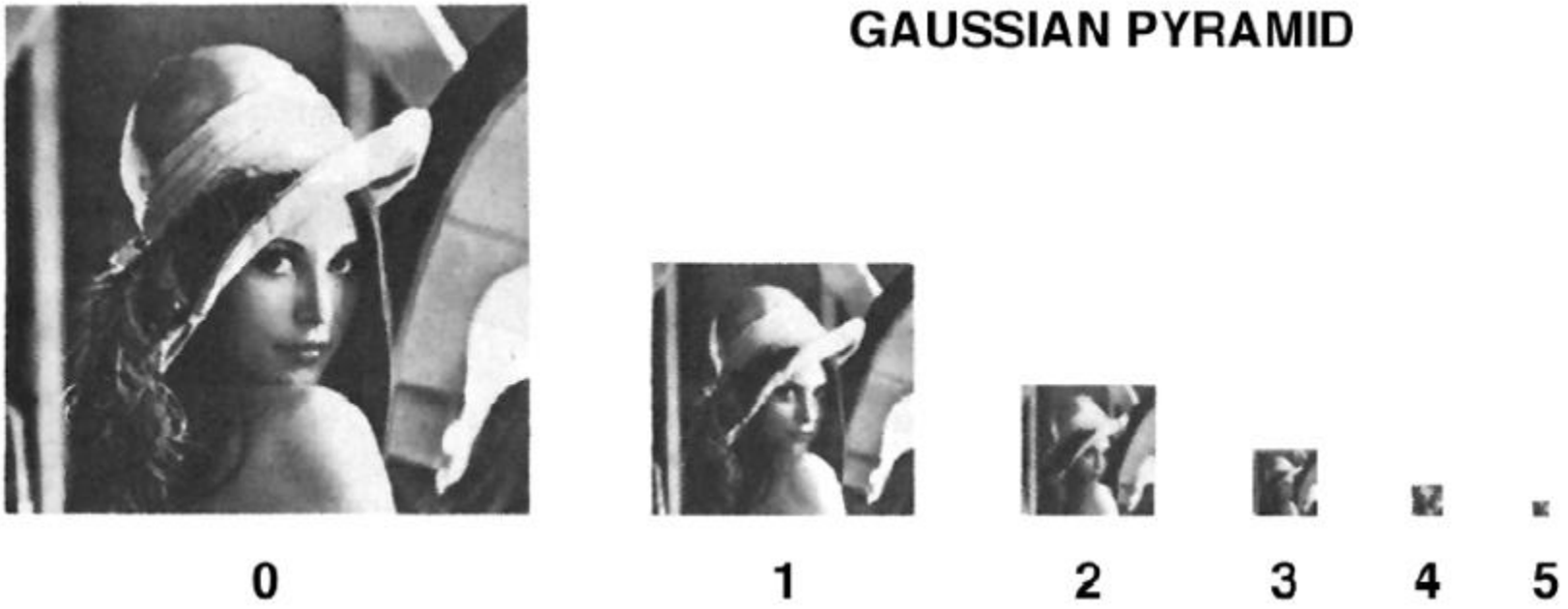
Approximation images
(using Gaussian smoothing)

Prediction errors (residues)

# Gaussian pyramid

- Smooth with Gaussians
  - Gaussian * Gaussian = another Gaussian

- Gaussians are low-pass filters, so representation is redundant



# Gaussian pyramid

512 256 128 64 32 16 8

# Gaussian pyramid

- Used for ***up- or down-sampling*** images

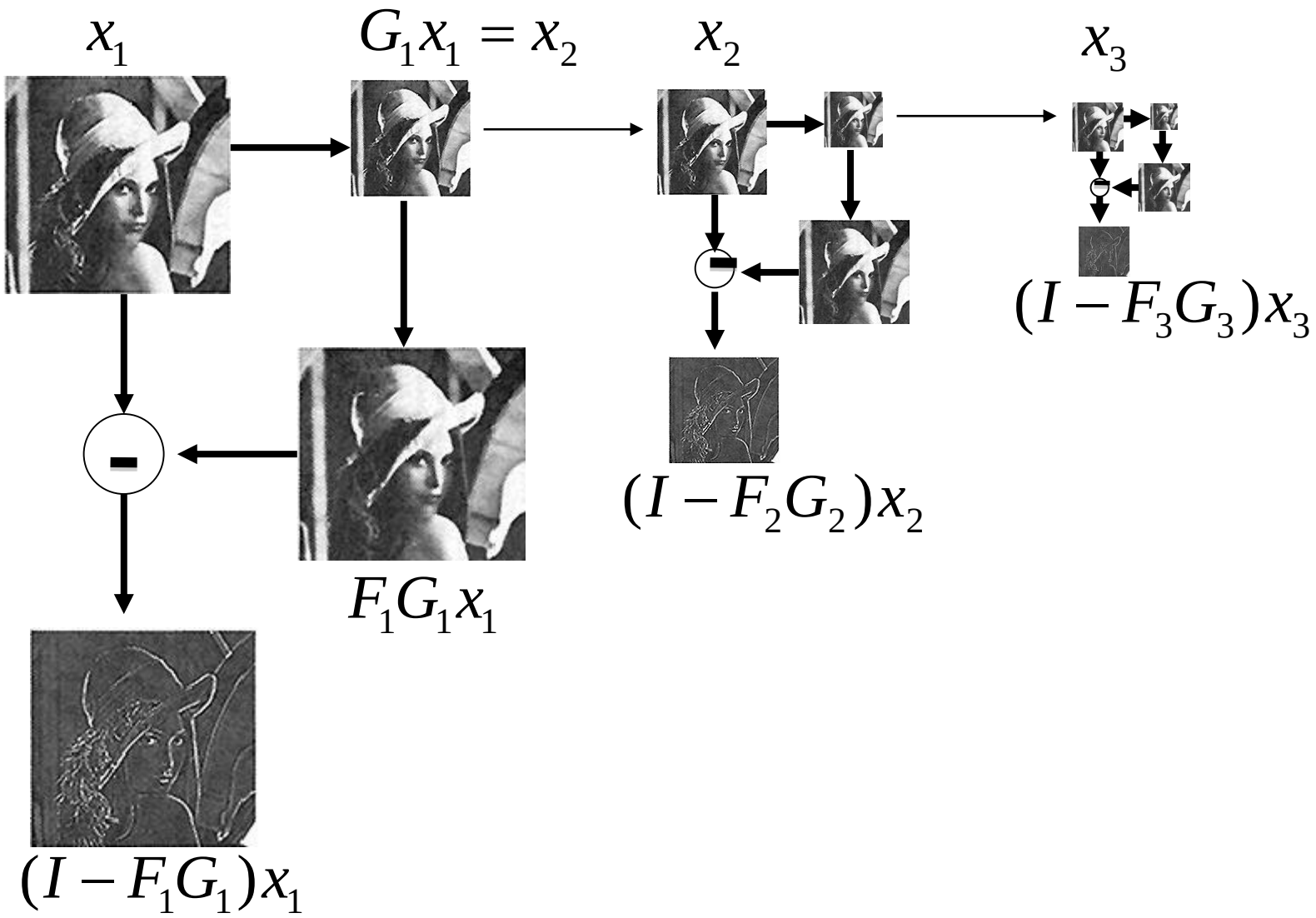
- Used for multi-resolution image analysis
  - Look for an object over various spatial scales
  - Coarse-to-fine image processing
  - From blur estimate or the motion analysis on very low-resolution image, up-sample and repeat
  - Often a successful strategy for avoiding local minima in complicated estimation tasks

# Laplacian pyramid

- Compute the difference between up-sampled Gaussian pyramid level and Gaussian pyramid level

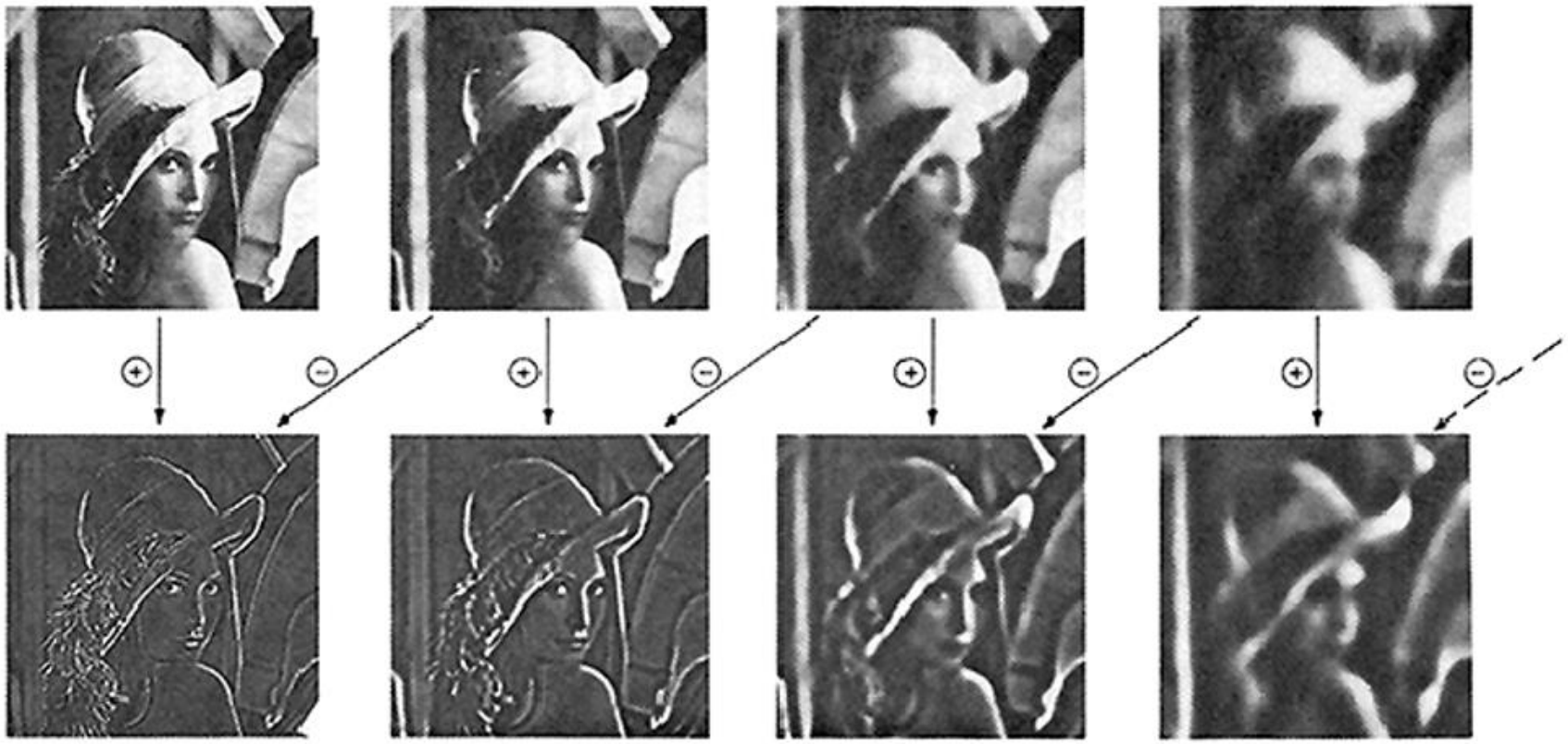
- Band-pass filter
  - Each level represents spatial frequencies unrepresented at other level

# Laplacian pyramid



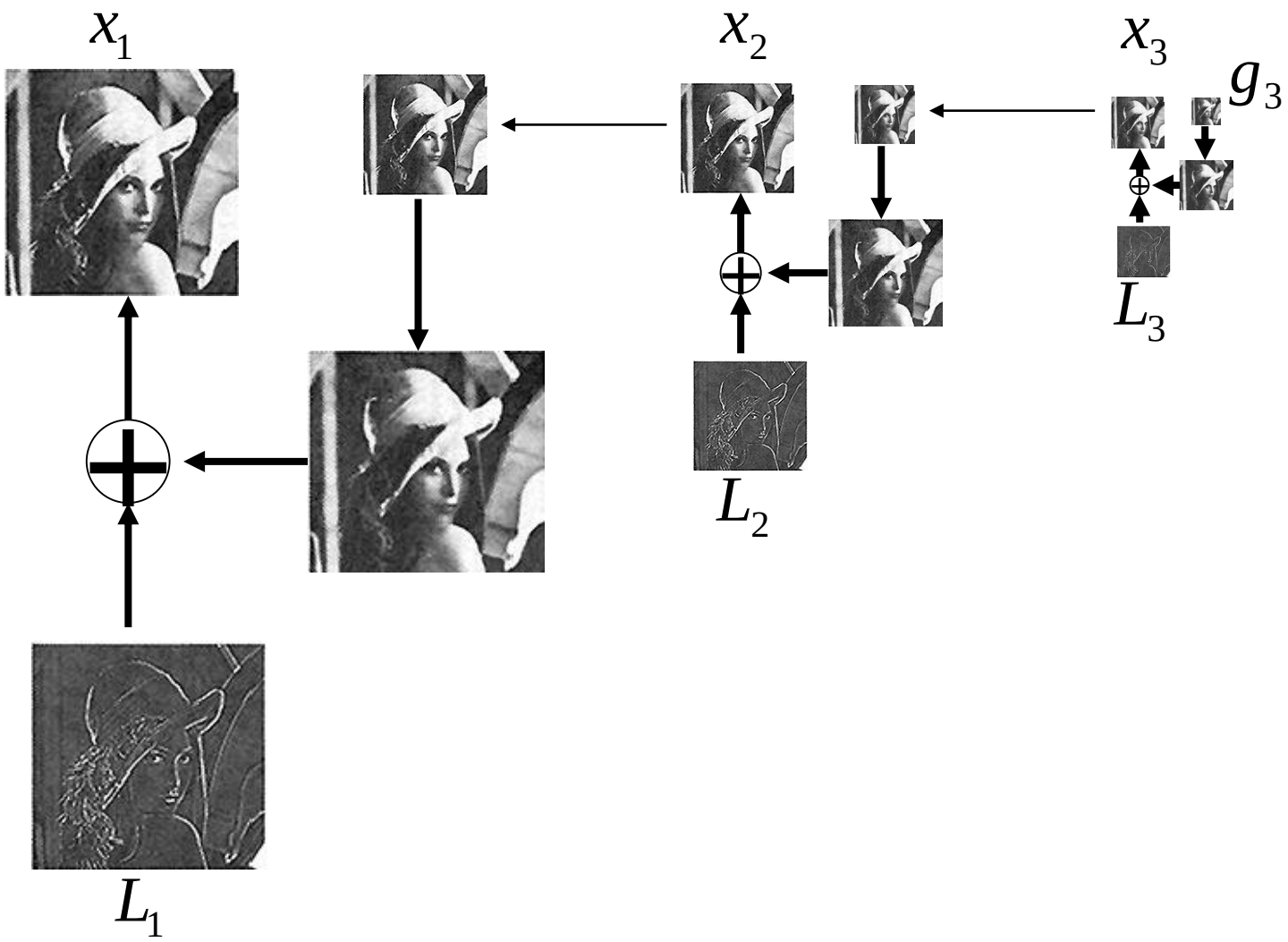
# Laplacian pyramid

- The information captured at each level of a Gaussian (top) and Laplacian (bottom) pyramid

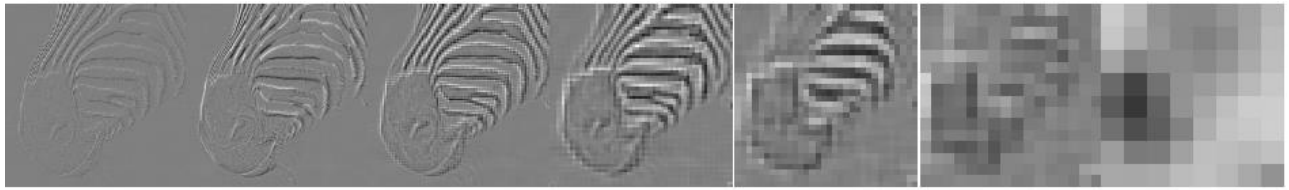


# Laplacian pyramid

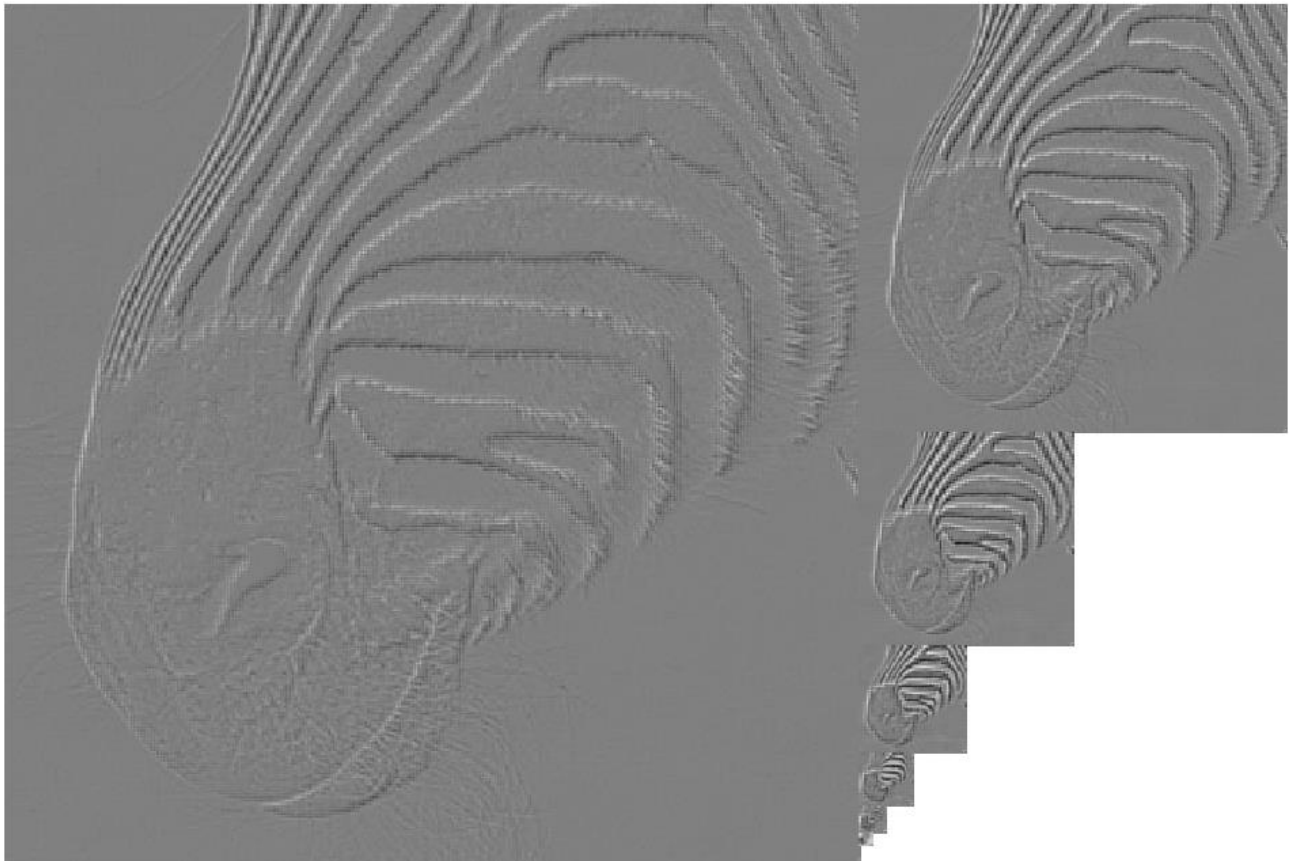
- Reconstruction: Recover $x_1$ from $L_1, L_2, L_3$ and $g_3$



# Laplacian pyramid

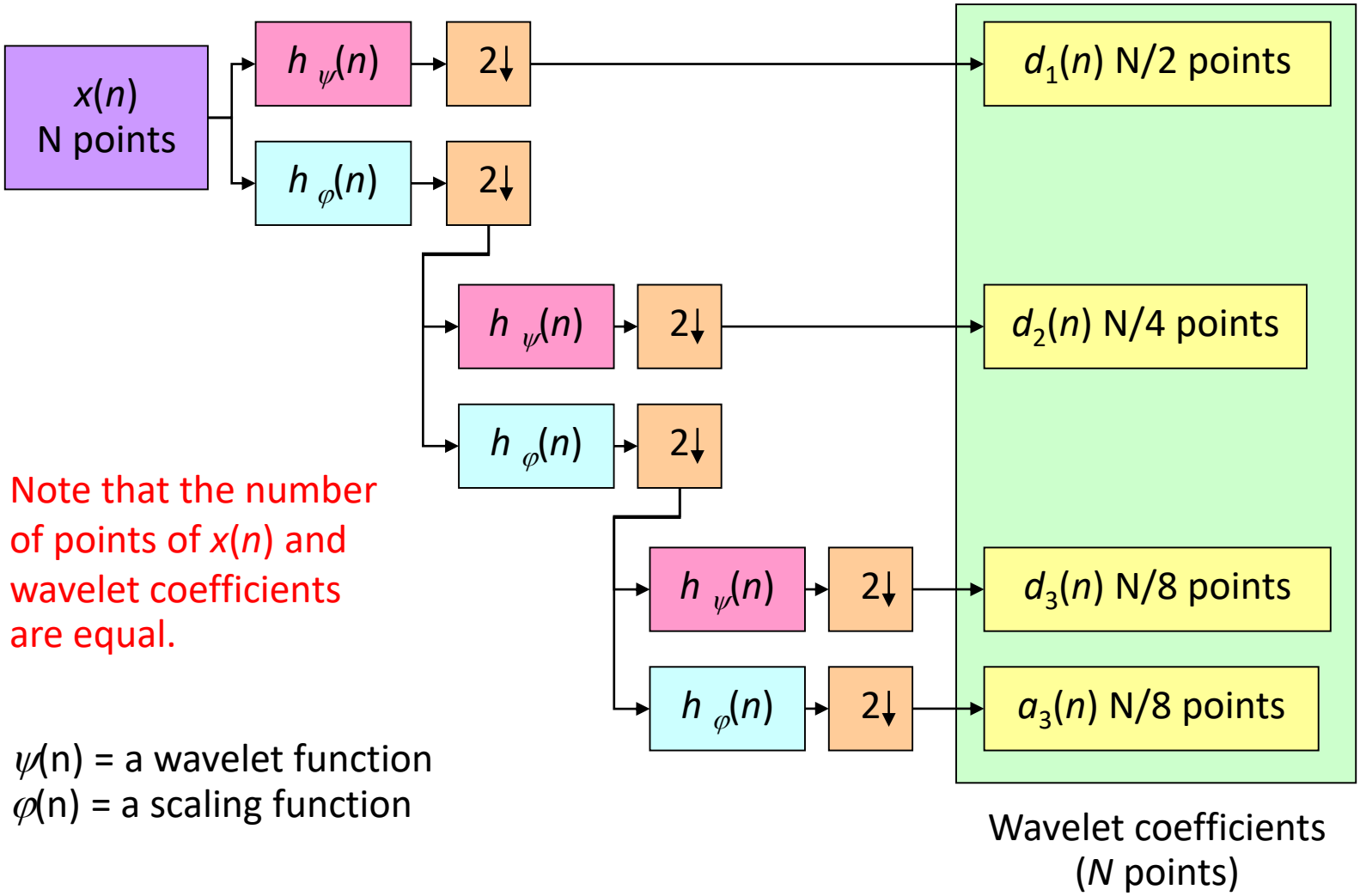


512 256 128 64 32 16 8



# Wavelet (Optional)

- 1D discrete wavelet transformation

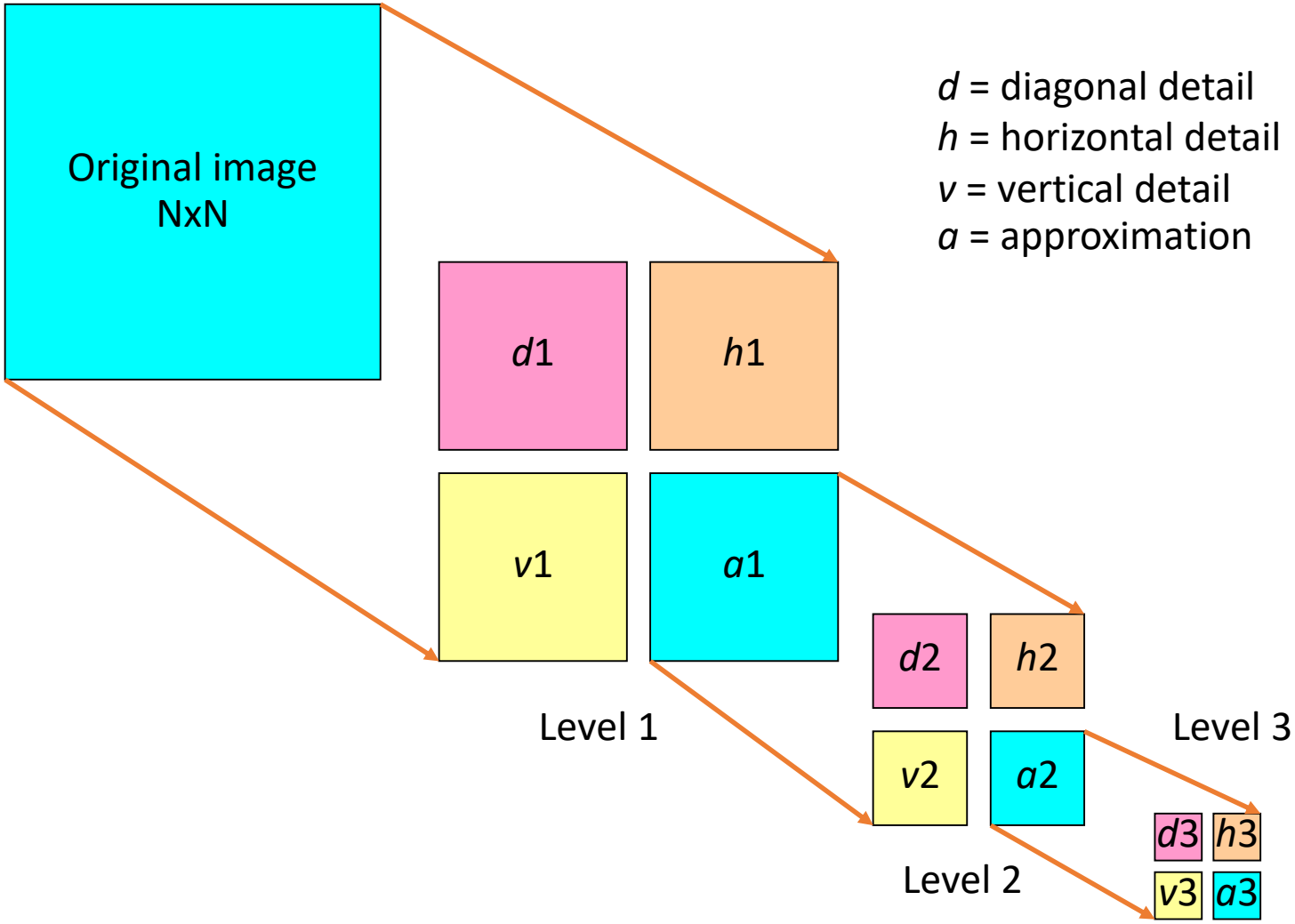



Note that the number of points of $x(n)$ and wavelet coefficients are equal.

$\psi$(n) = a wavelet function
$\varphi$(n) = a scaling function

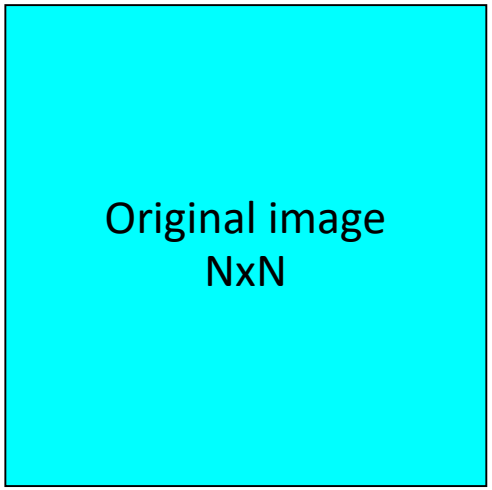
# Wavelet (Optional)

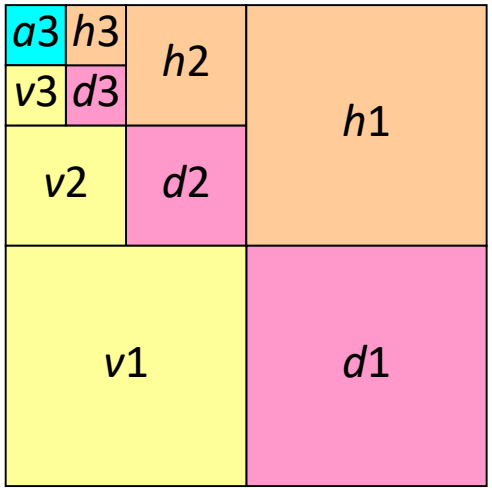
- 2D discrete wavelet transformation



# Wavelet (Optional)

- 2D discrete wavelet transformation
  - $d$ = Diagonal detail: filtering in both $x$ and $y$ directions using $h_{\psi}(n)$
  - $h$ = Horizontal detail: filtering in $x$ direction using $h_{\psi}(n)$ and in $y$ direction using $h_{\varphi}(n)$
  - $v$ = Vertical detail: filtering in $x$ direction using $h_{\varphi}(n)$ and in $y$ direction using $h_{\psi}(n)$
  - $a$ = Approximation: filtering in both $x$ and $y$ directions using $h_{\varphi}(n)$

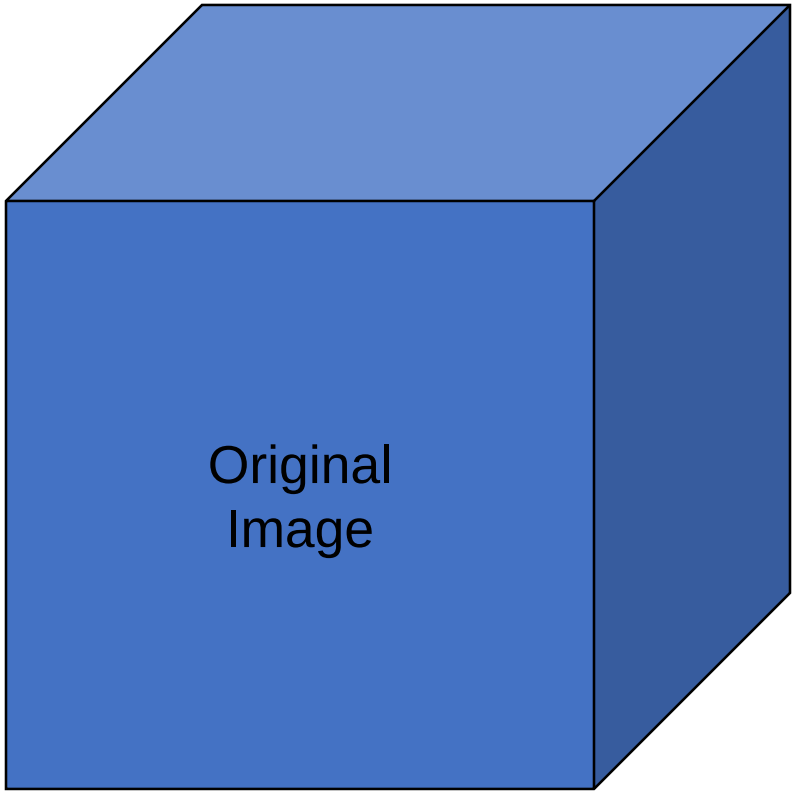



Wavelet coefficients
$N \times N$

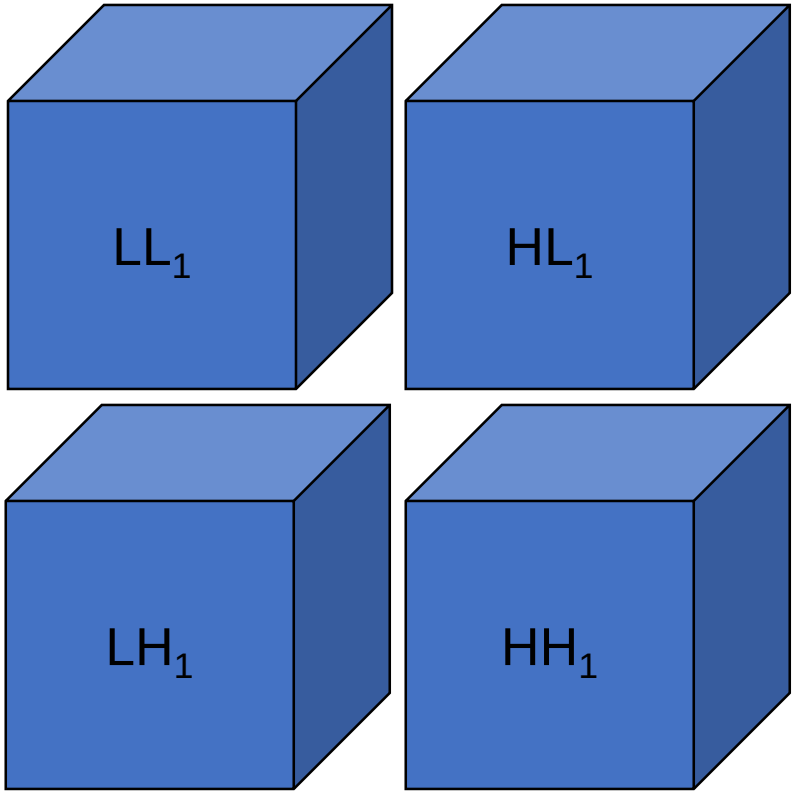
# Wavelet (Optional)

- Example



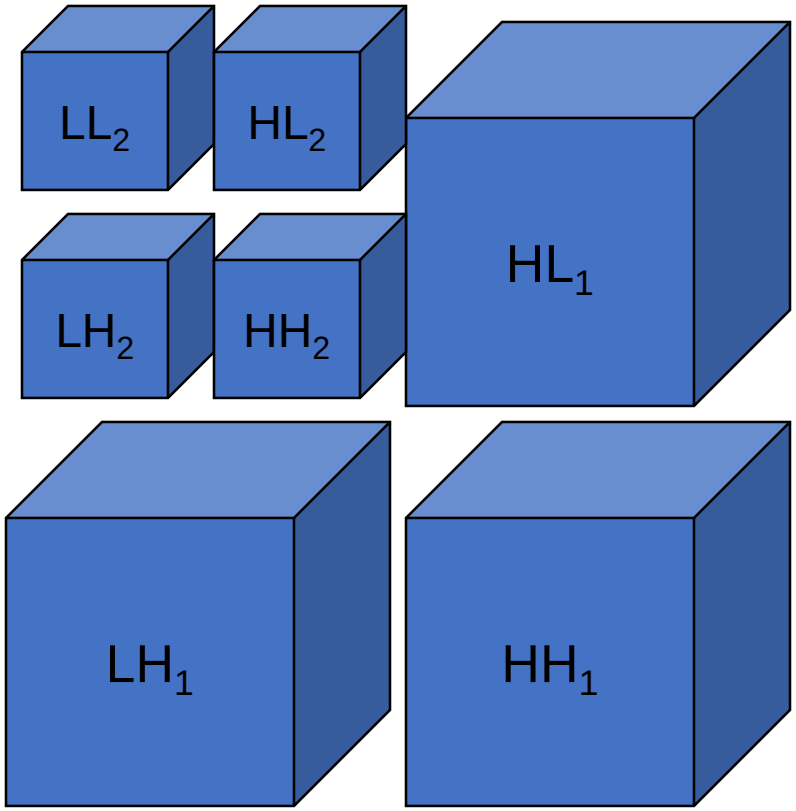

# Wavelet (Optional)

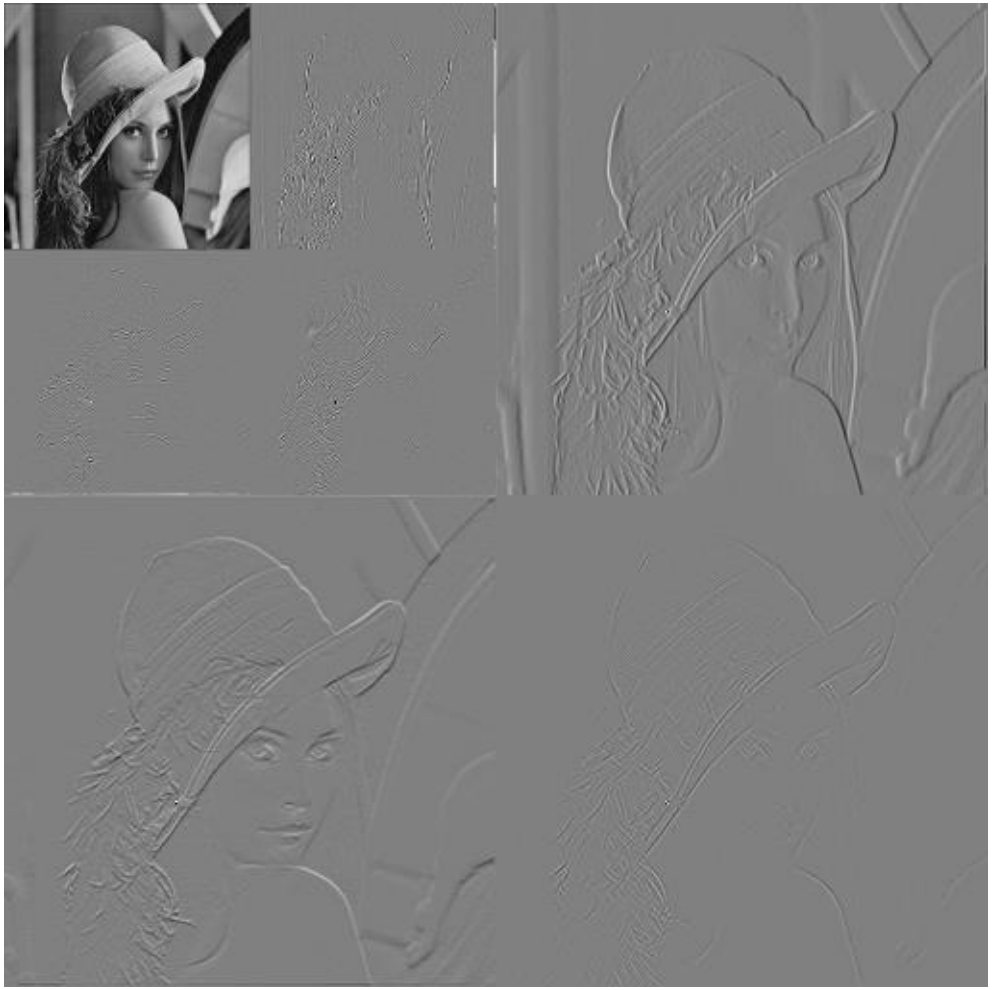
- Example




# Wavelet (Optional)

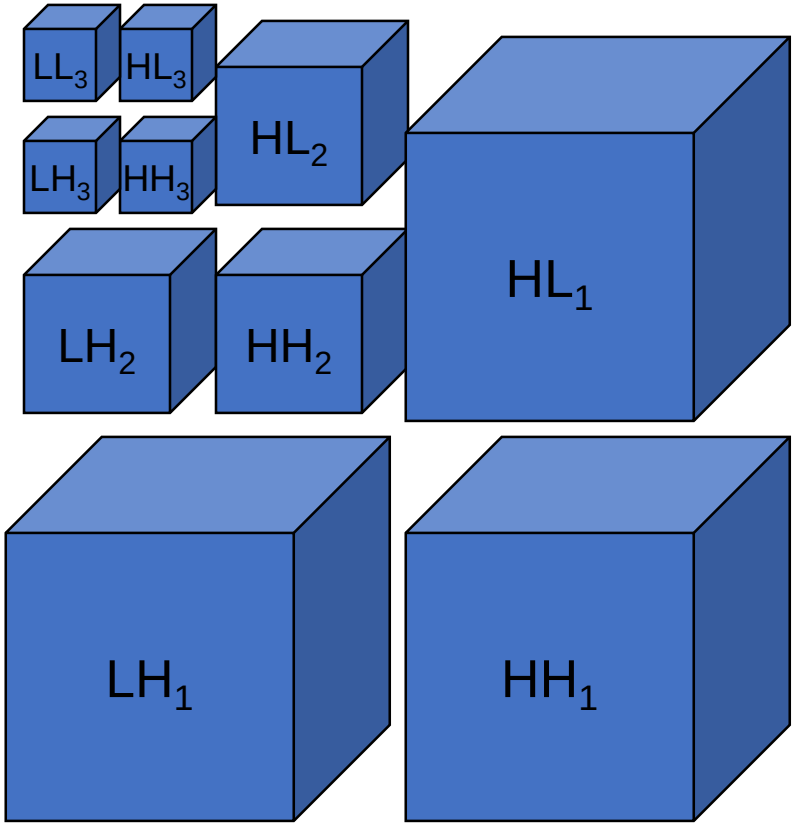
- Example

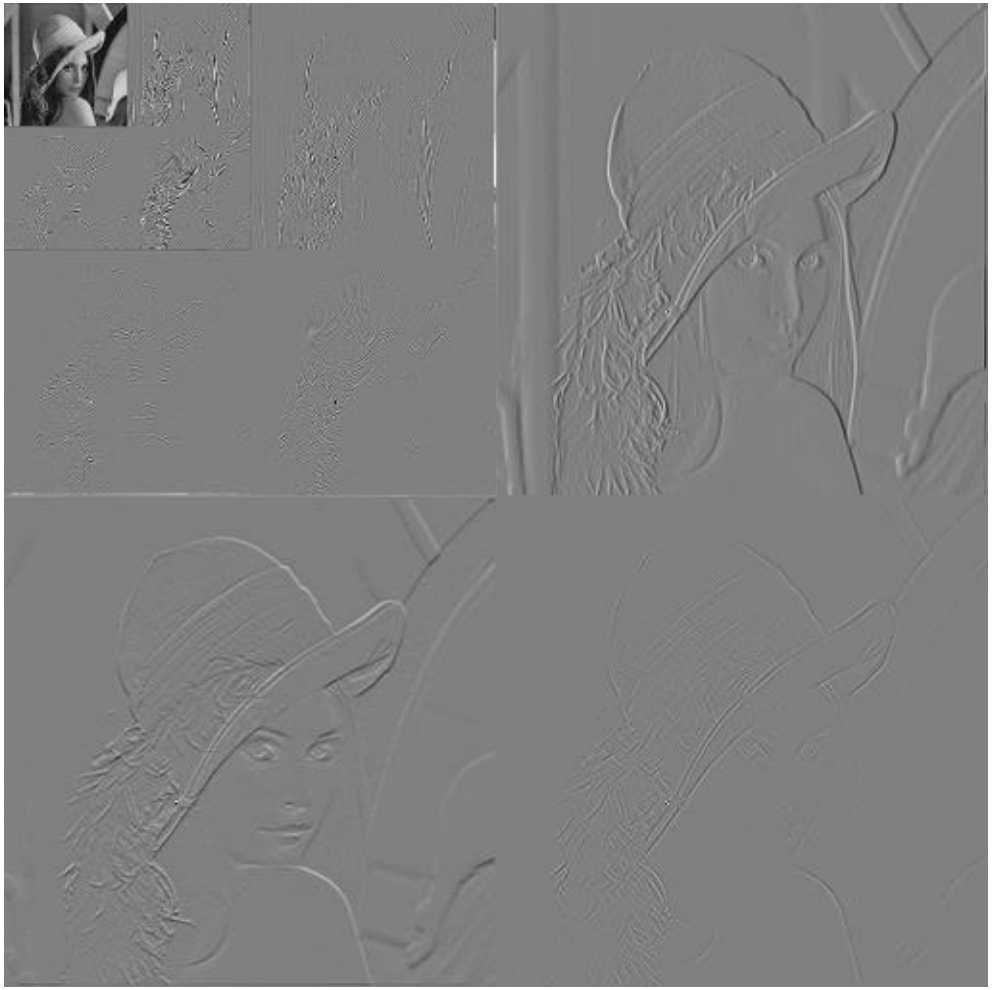


# Wavelet (Optional)

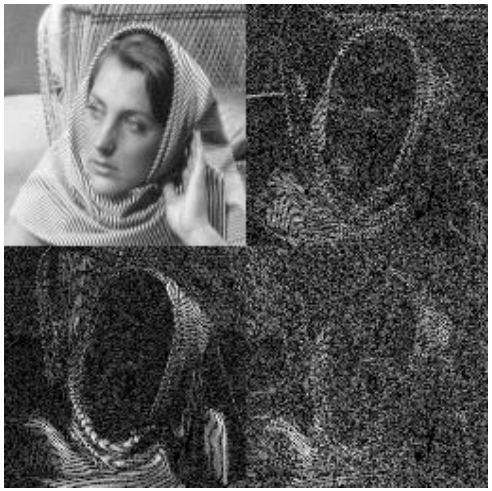
- Example



# Wavelet (Optional)

- Example



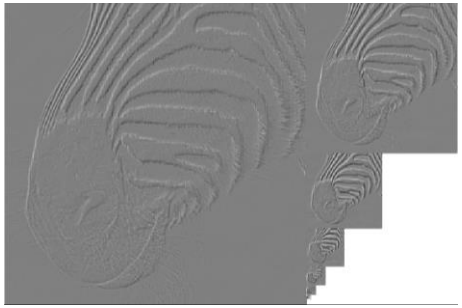
Level 1

Level 2

# Image pyramids

- Gaussian pyramid
  - Progressively blurred and subsampled versions of the image
  - Adds scale invariance to fixed-size algorithms

- Laplacian pyramid
  - Shows the information added in Gaussian pyramid at each spatial scale
  - Useful for noise reduction and coding



# Choice of scale

- Start with a small window at the point of interest
- Increase the window size until it does not cause a significant change in certain criterion
- May not result in unique scale
  - Depends on the initial window size