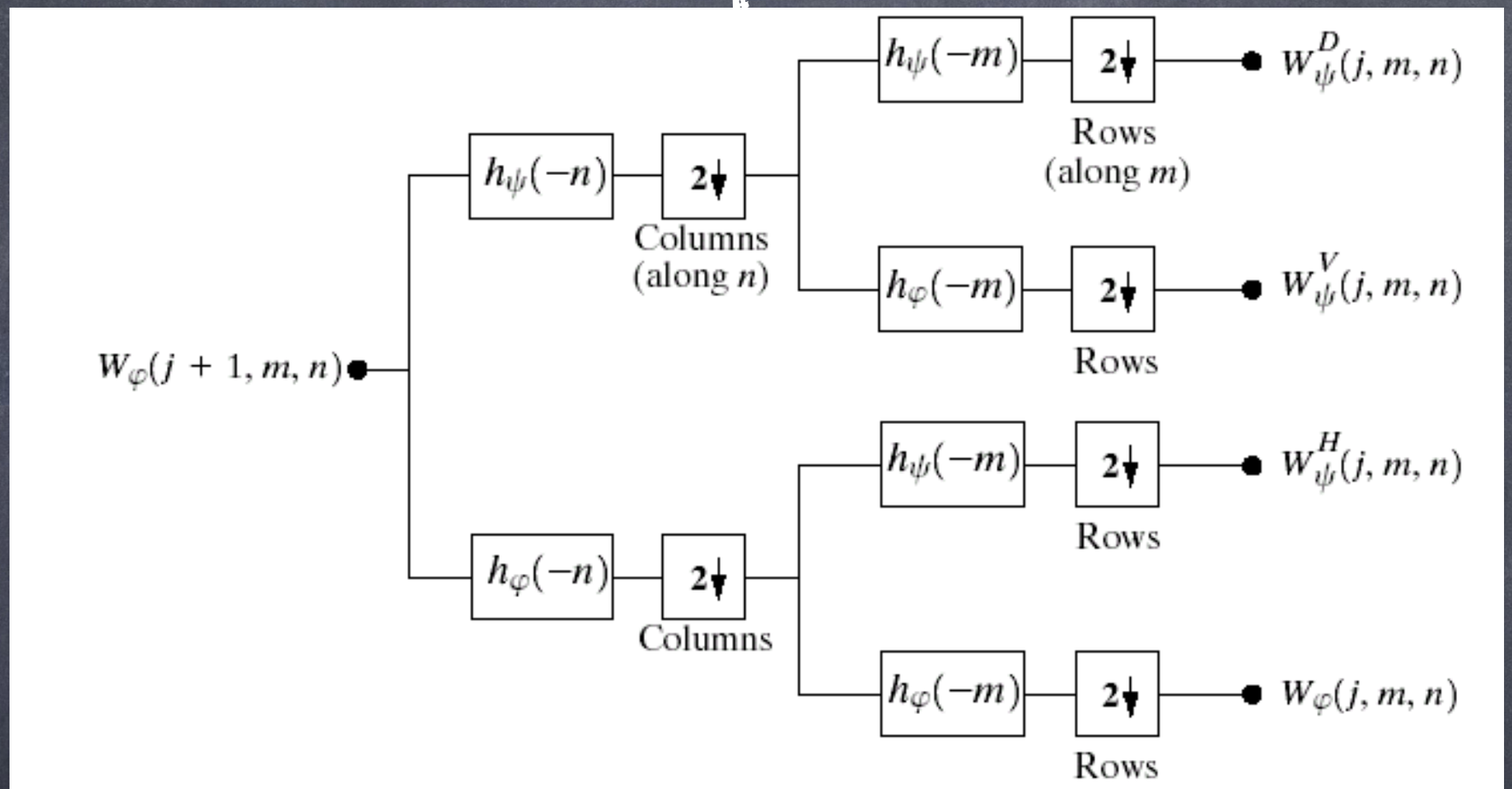
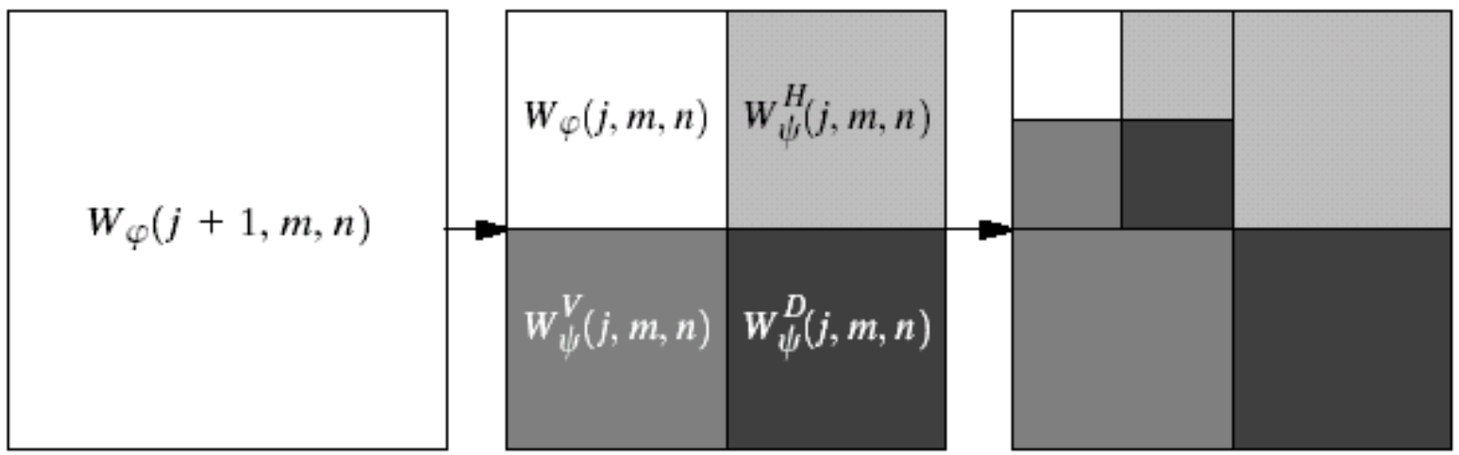
# Computer Vision

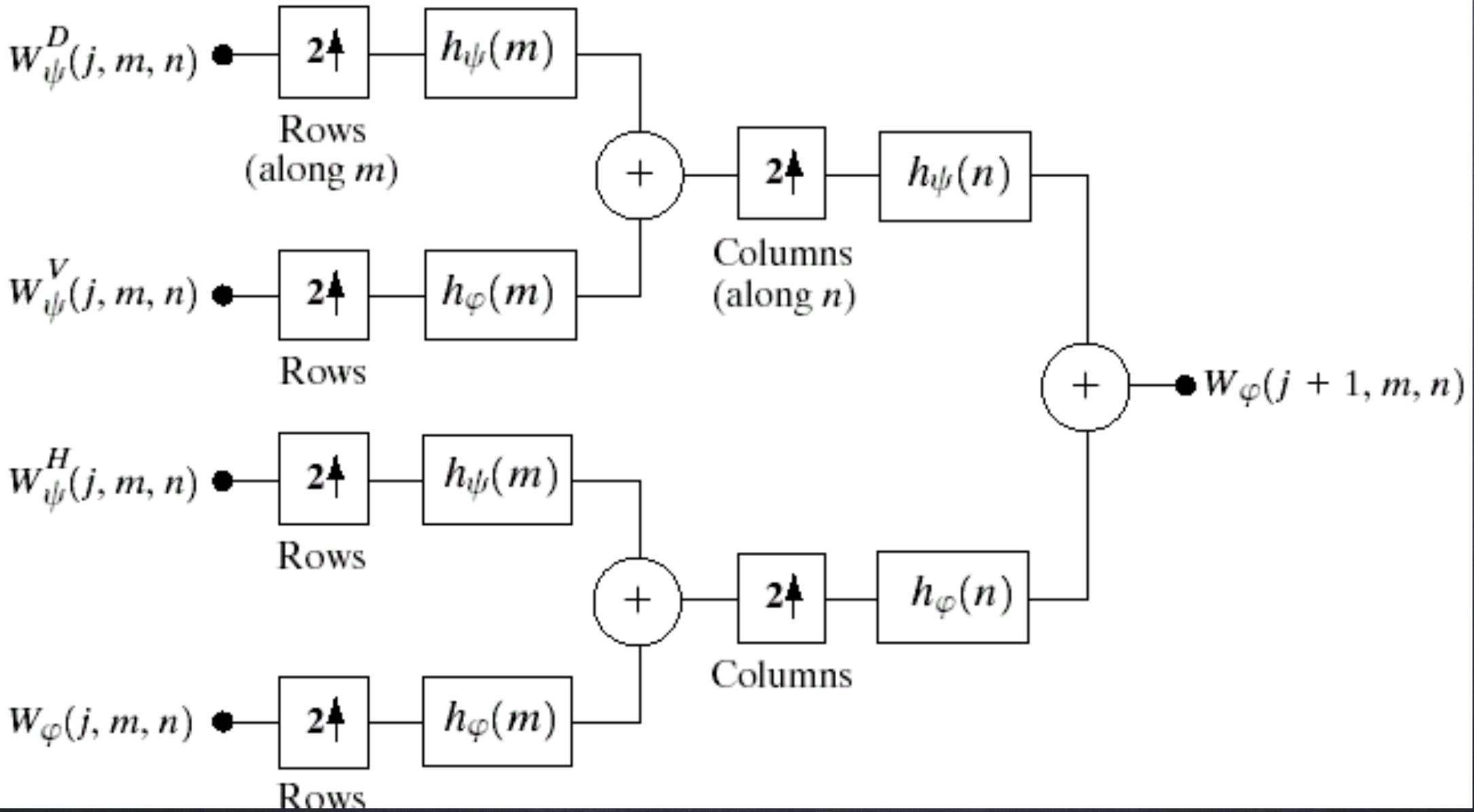
CSE/ECE 344/544

# 2-D Wavelet Transform: Decomposition



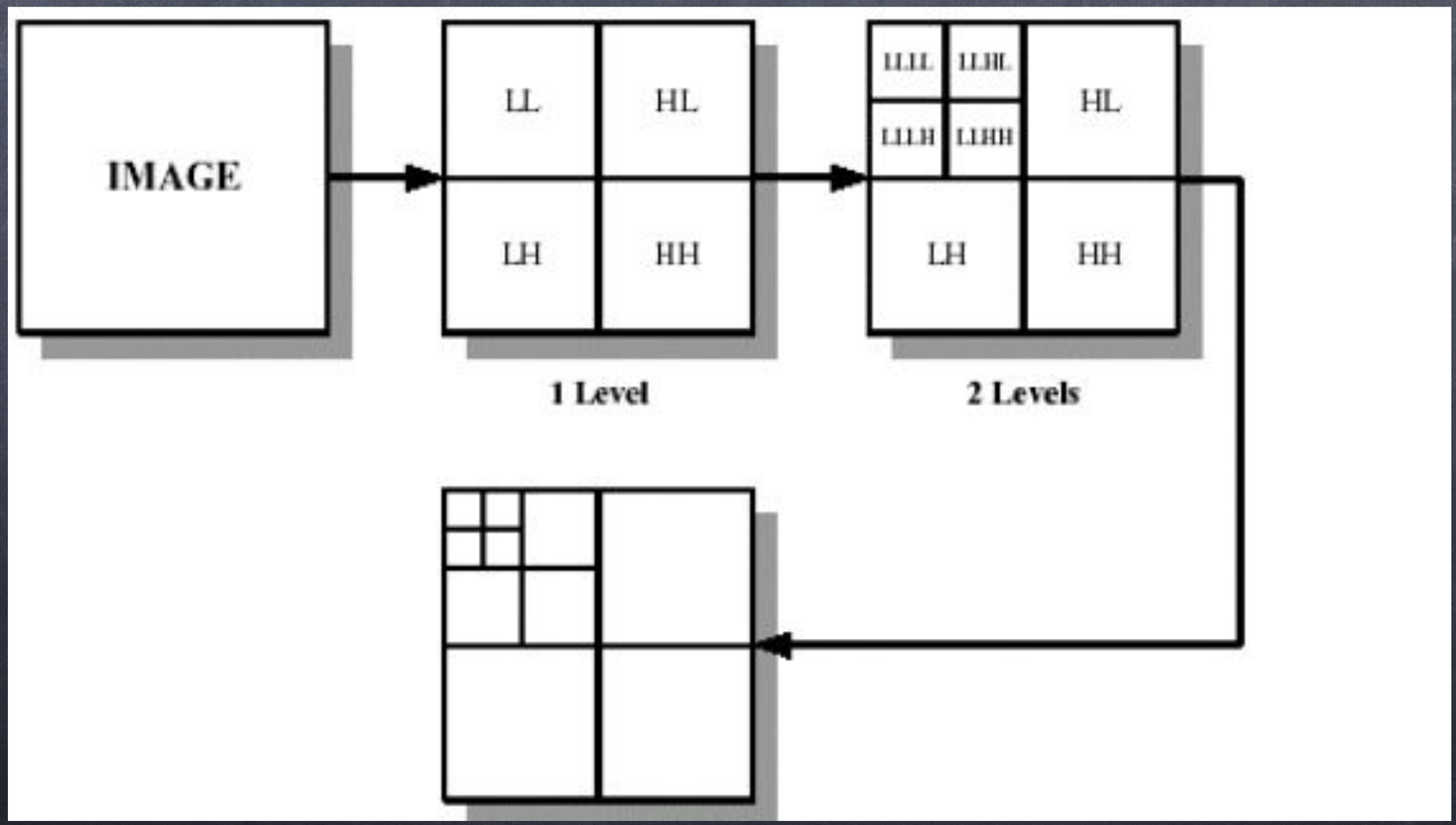



# 2-D Wavelet Transform: Reconstruction (IDWT)



# Discrete Wavelet Transform

- 2-D DWT for Image

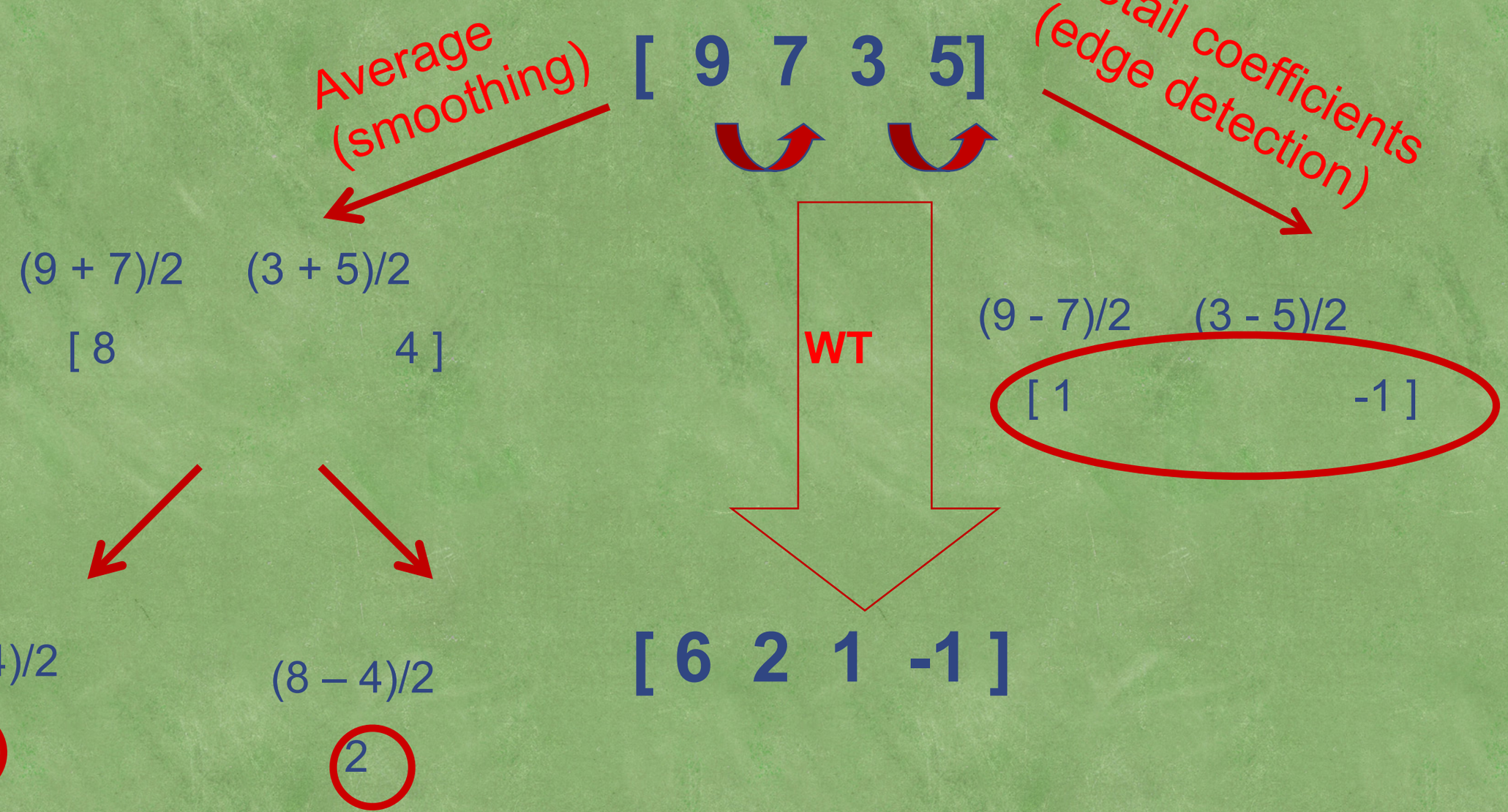


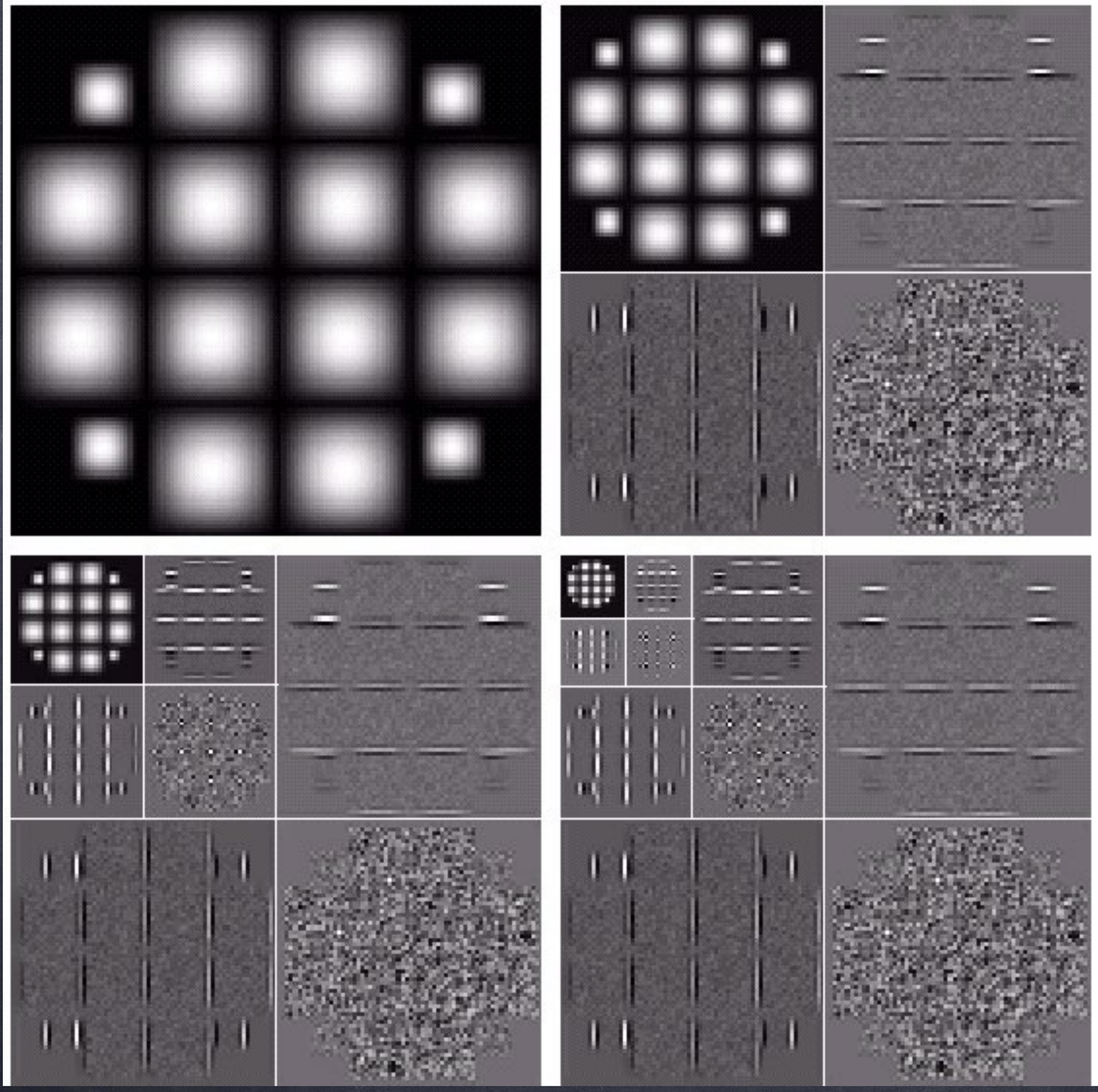
# Common Wavelet Filters

- Haar: simplest, orthogonal, not very good
- Daubechies 8/8: orthogonal
- Daubechies 9/7: bi-orthogonal
  most commonly used if numerical
  reconstruction errors are acceptable
- LeGall 5/3: bi-orthogonal, integer operation,
  can be implemented with integer operations
  only, used for lossless image coding

# Example of DWT (Haar Basis)

Let's consider a 1D 4-pixel Image [ 9 7 3 5]

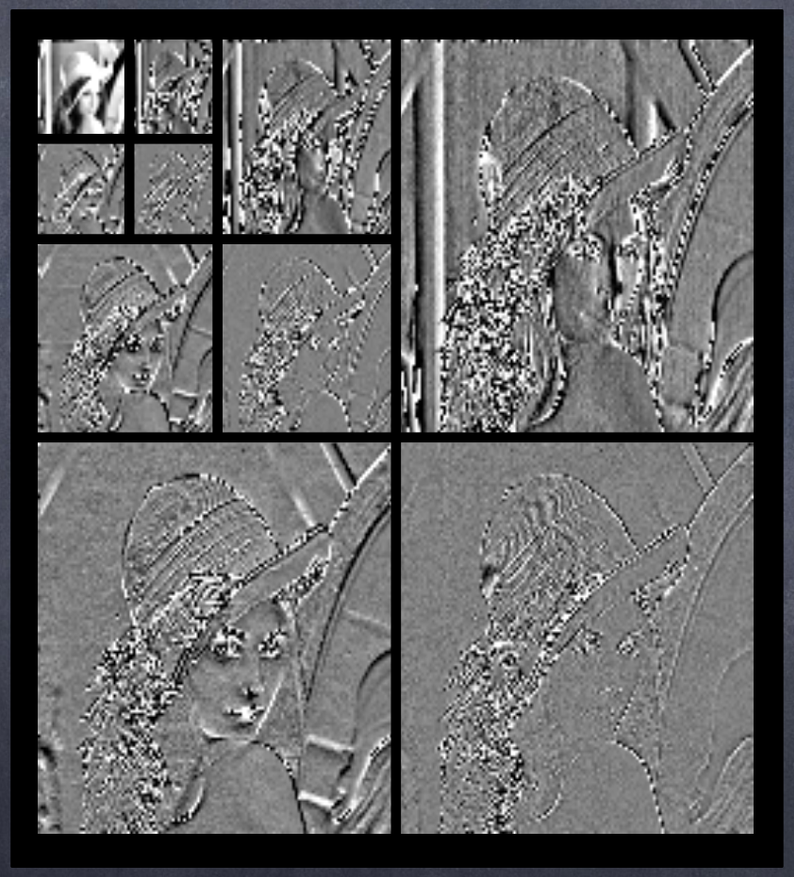


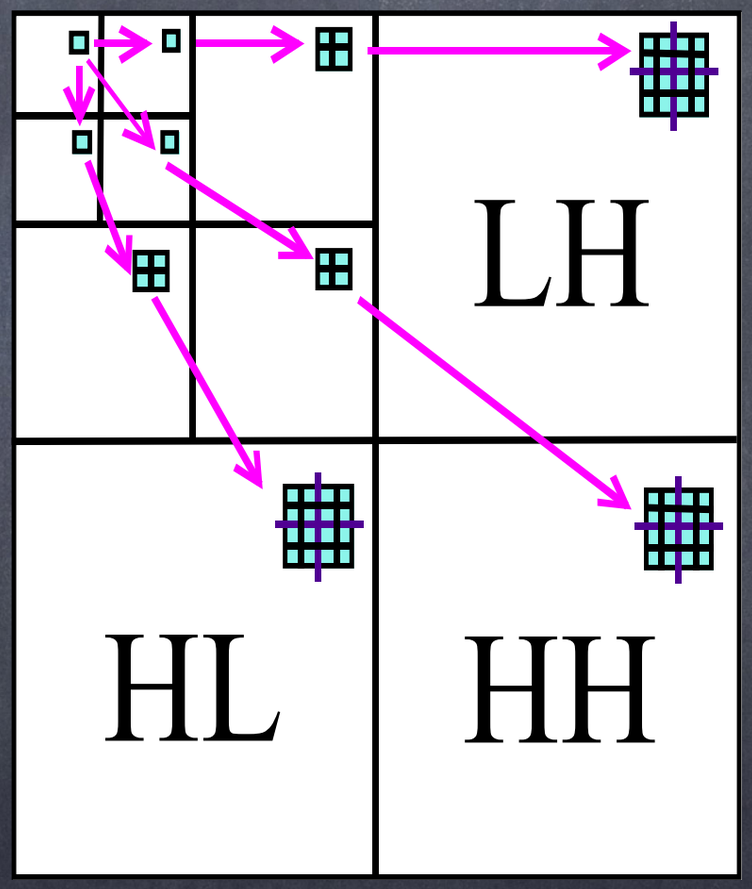


a b
c d

**FIGURE 7.23** A three-scale FWT.

# Spatial and Frequency Properties





# Image Denoising Using Wavelets

- Calculate DWT of the image.
- Threshold the wavelet coefficients. The threshold may be universal or subband adaptive.
- Compute the IDWT to get the denoised estimate.
- Soft thresholding is used in the different thresholding methods. Visually more pleasing images.

# One example of Threshold

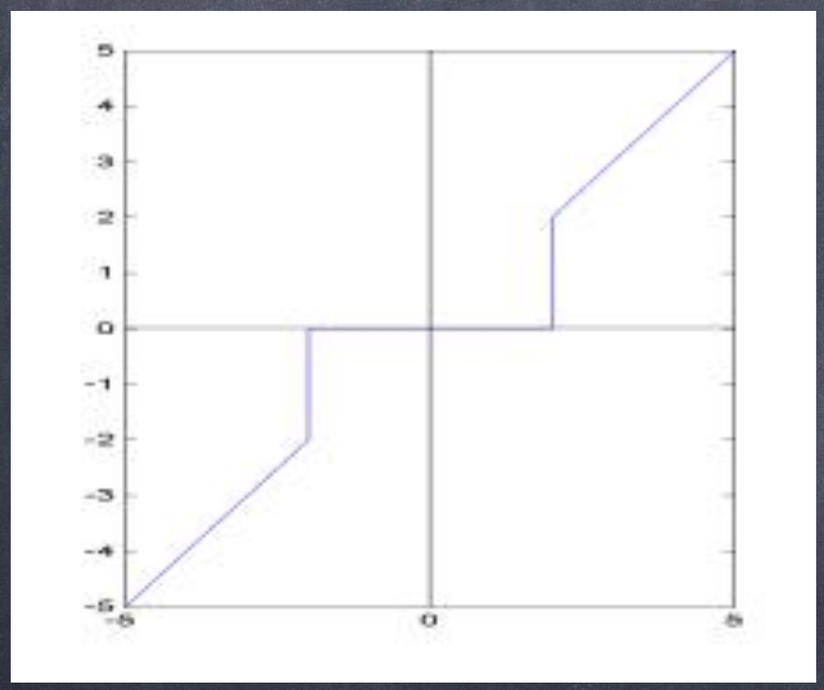
- Apply Donoho's universal threshold,

$$\sigma\sqrt{2\log M}$$

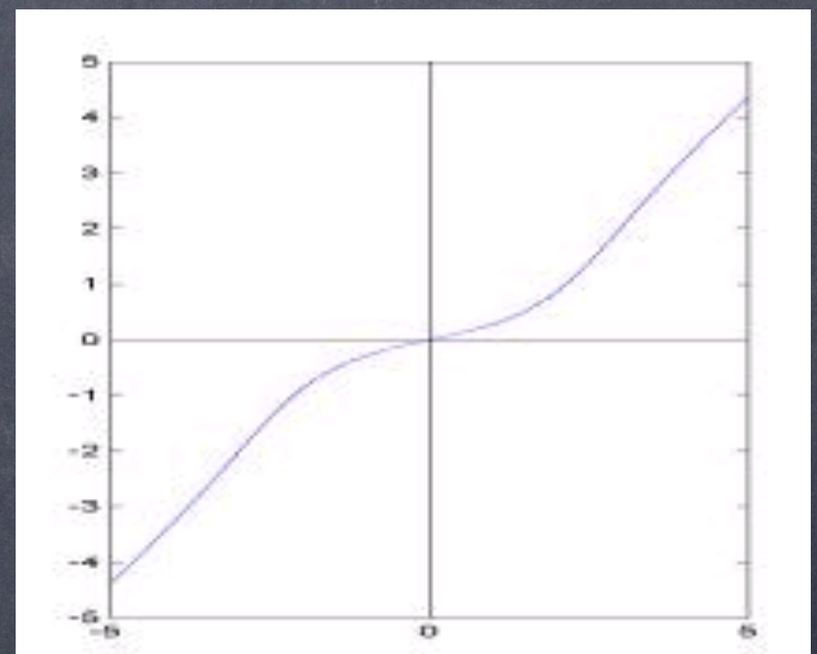
- M is the number of pixels.
- The threshold is usually high, overly smoothing.

# Threshold techniques

## Hard threshold




## Soft threshold



# Image Enhancement

- Image contrast enhancement with wavelets, especially important in medical imaging

- Make the small coefficients very small and the large coefficients very large.

- Apply a nonlinear mapping function to the coefficients.

# Enhancement

(a) Original Image

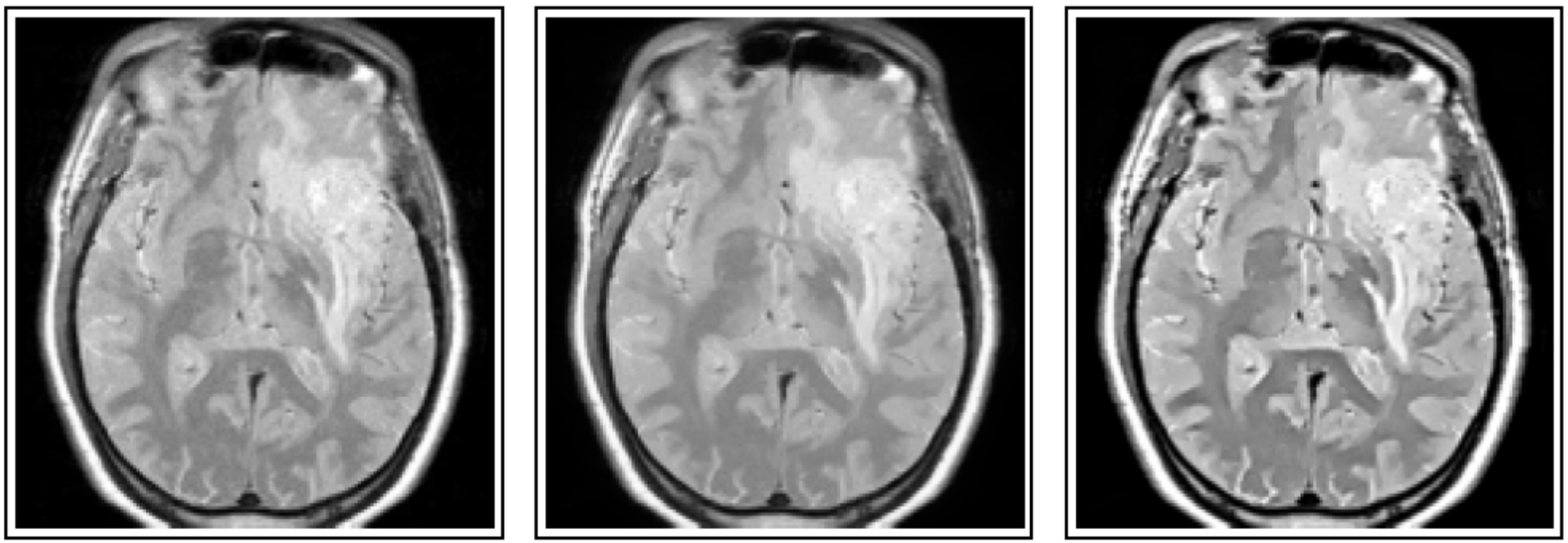
(c) Proposed Method

# Denoising and Enhancement

- Apply DWT
- Shrink transform coefficients in finer scales to reduce the effect of noise
- Emphasize features within a certain range using a nonlinear mapping function
- Perform IDWT to reconstruct the image.

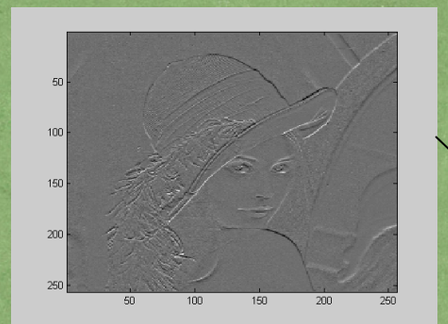
# Examples

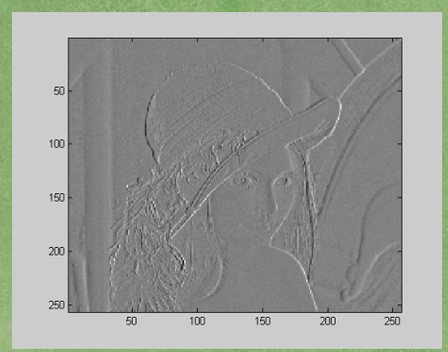
Original Denoised Denoising with Enhancement

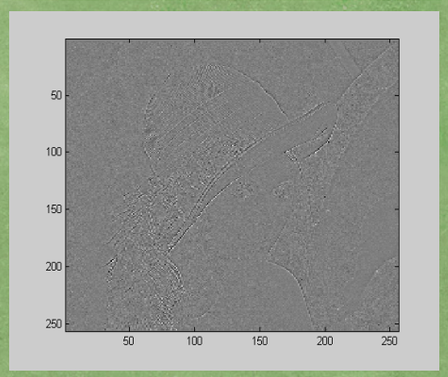


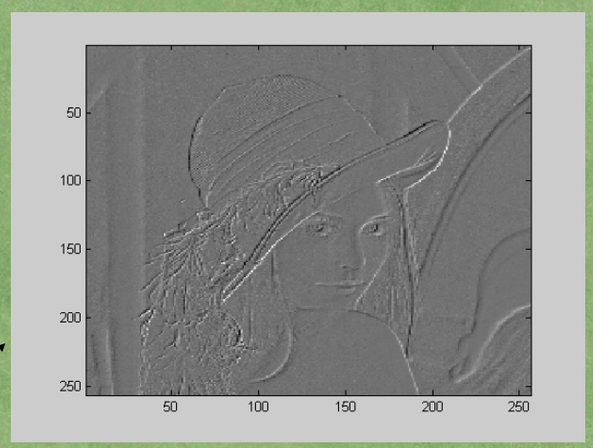
(a) (b) (c)

# Edge Detection using Wavelets



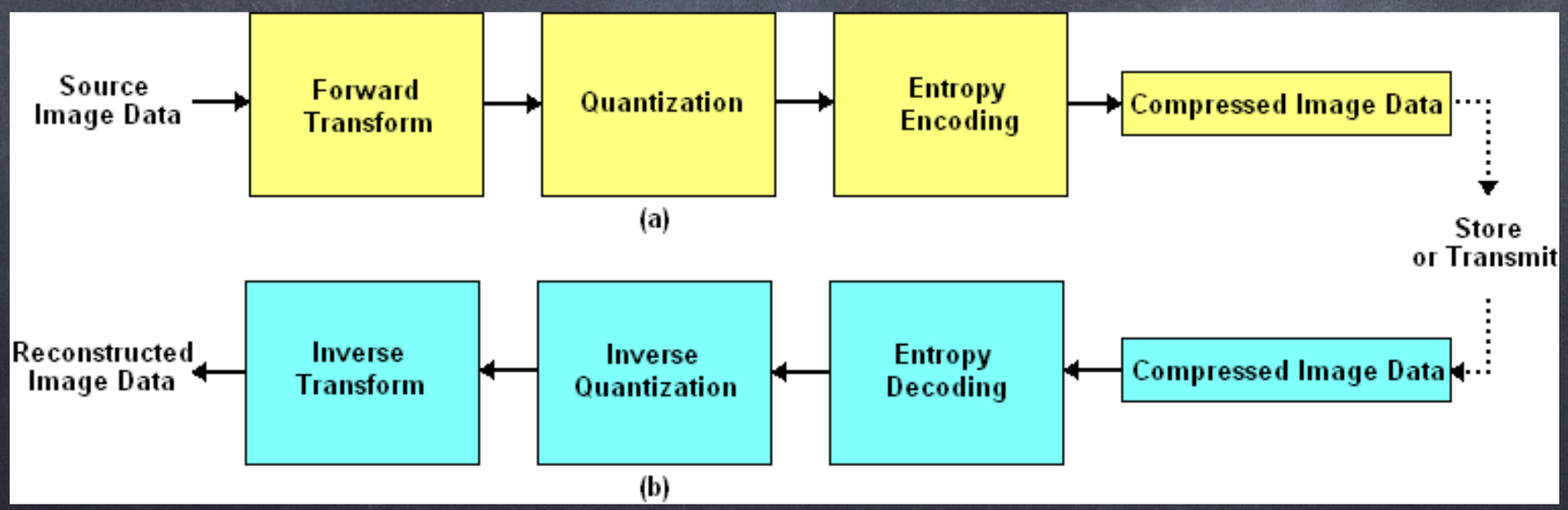




Can you think of the algorithm to do it?

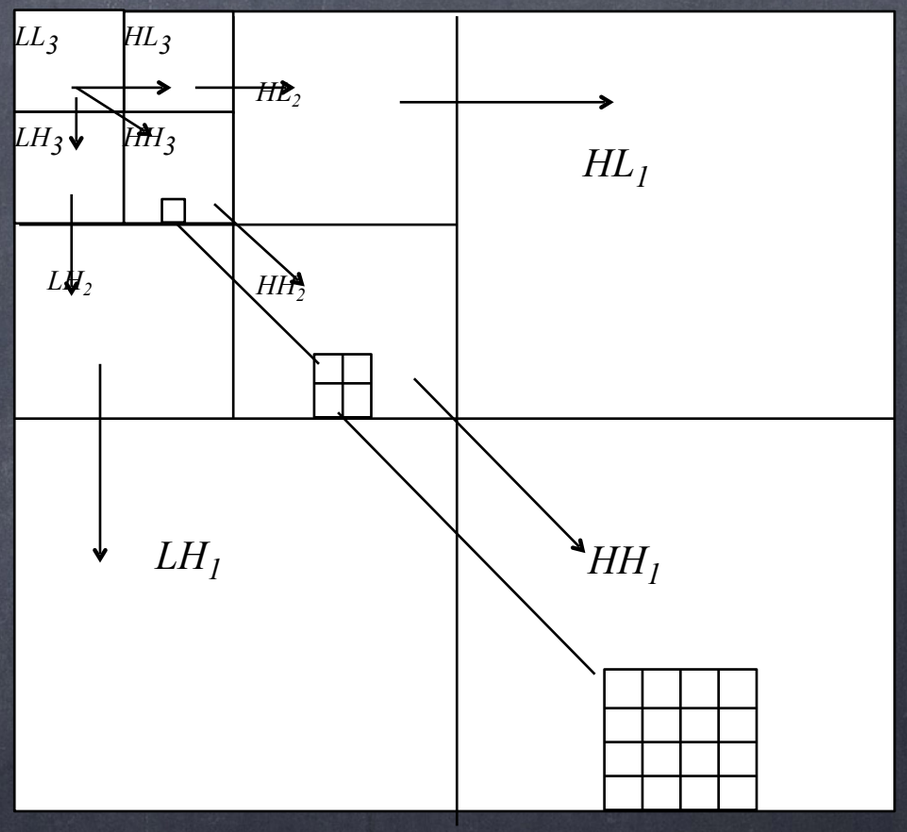
# JPEG 2000 Compression

- Not in the course but for completeness we will discuss the idea



# DWT for Image Compression

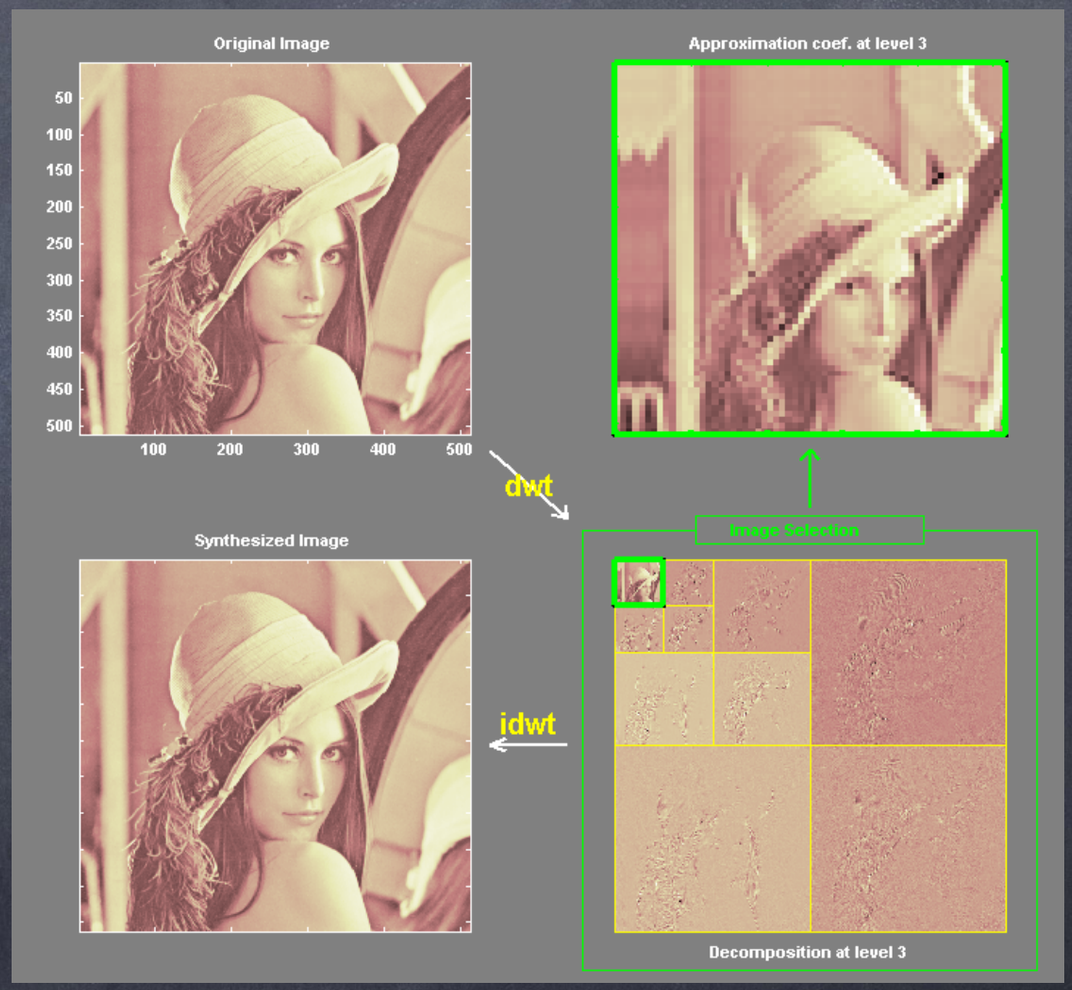
- **Image Decomposition**
  - Parent
  - Children
  - Descendants: corresponding coeff. at finer scales
  - Ancestors: corresponding coeff. at coarser scales



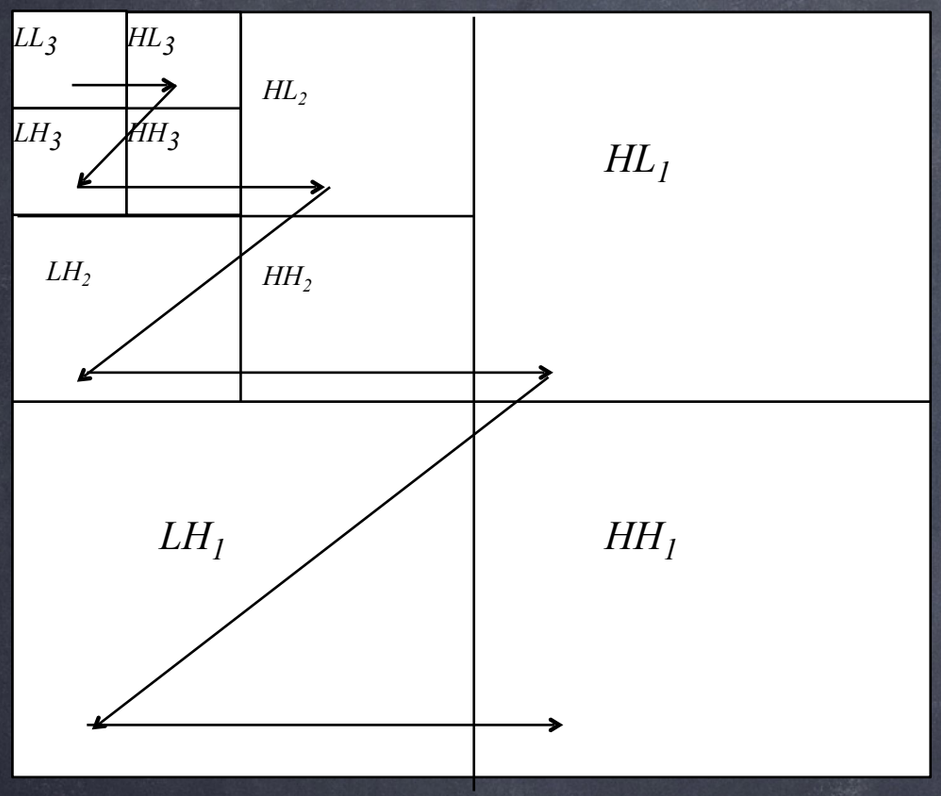

-Parent-children dependencies of subbands: arrow points from the subband of parents to the subband of children.

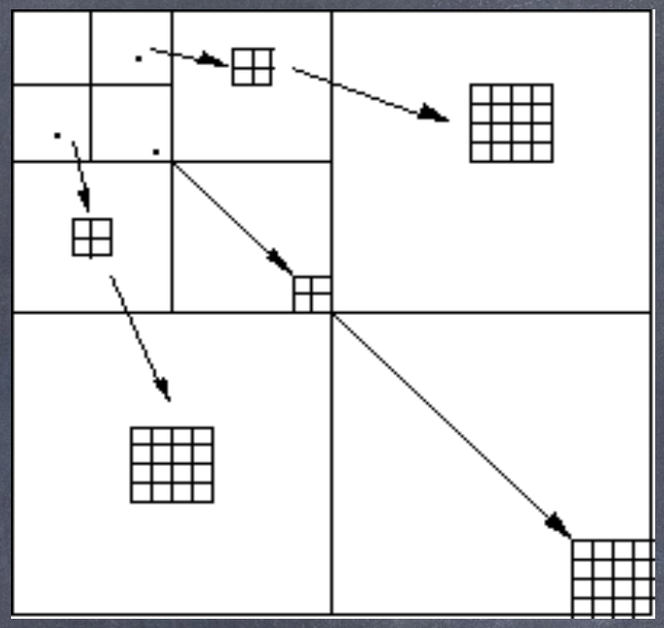
# DWT for Image Compression

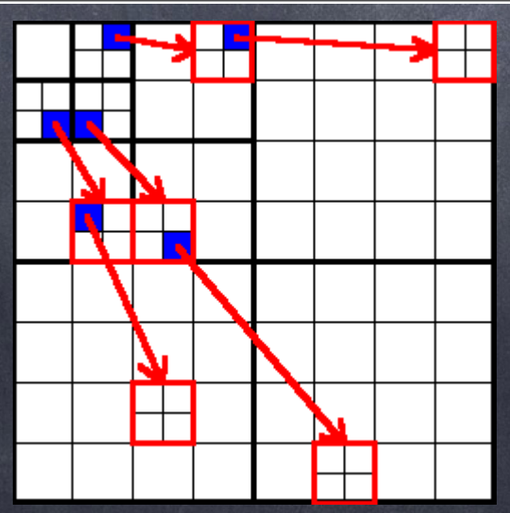
- **Image Decomposition**
  - Feature 1:
    - Energy distribution concentrated in low frequencies
  - Feature 2:
    - Spatial self-similarity across subbands

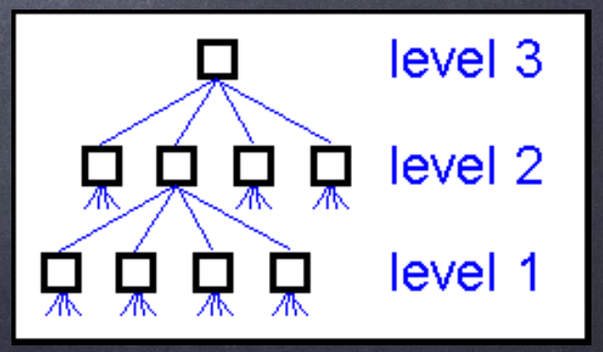


# Different Coding Schemes



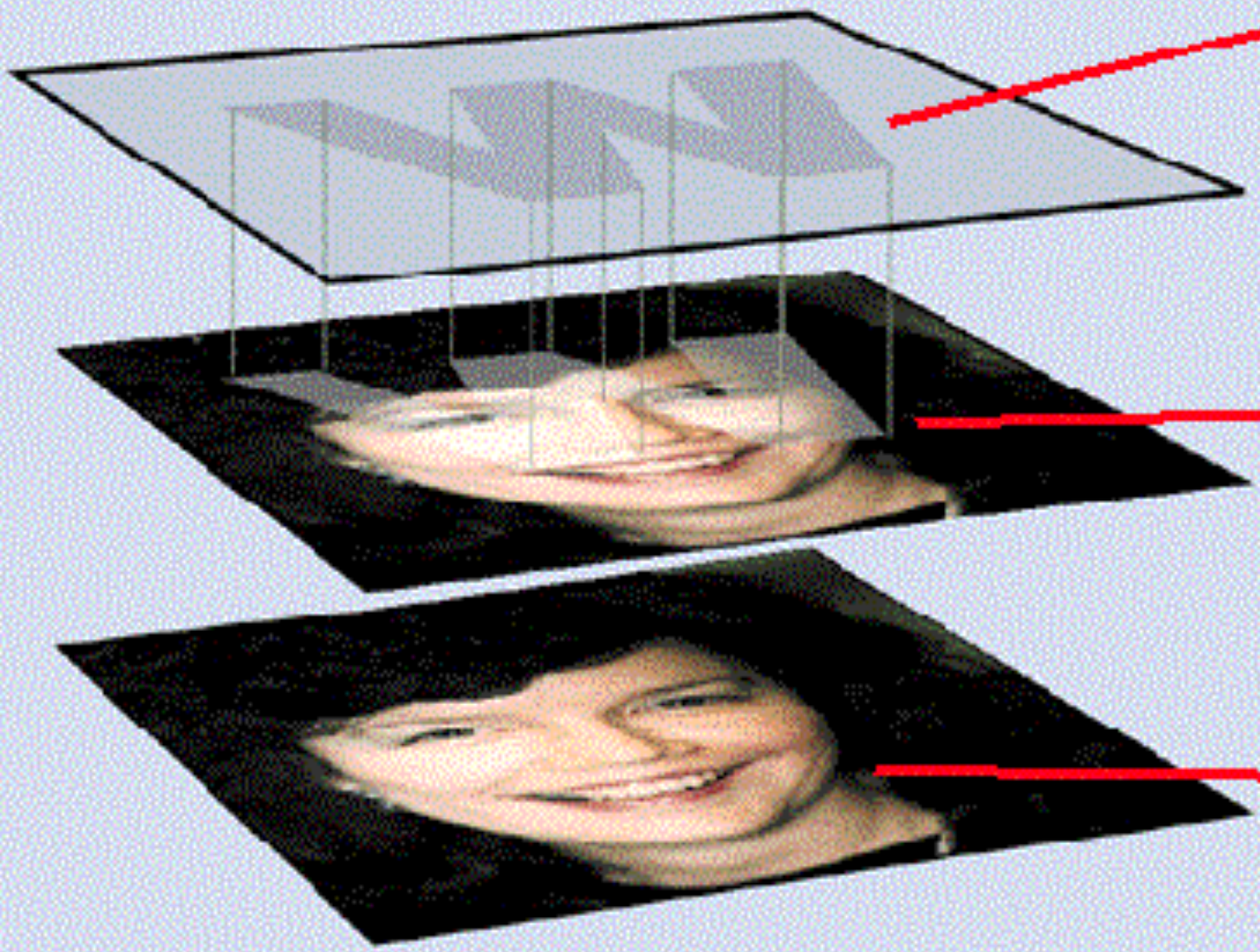







# Watermarking

## Watermarks: Secret Code for Protection



1 Depending on the chosen technique, noise is added to every data element or just to a pseudo-random subset.

2 Hidden information (watermark) is embedded in the noise signal of the original.

3 Watermark is invisible and can be retrieved only by extraction software.

# Watermarking

## How Watermarking in Wavelet Works?

# Fusion: How do we combine two images?