EE 604
Digital Image Processing

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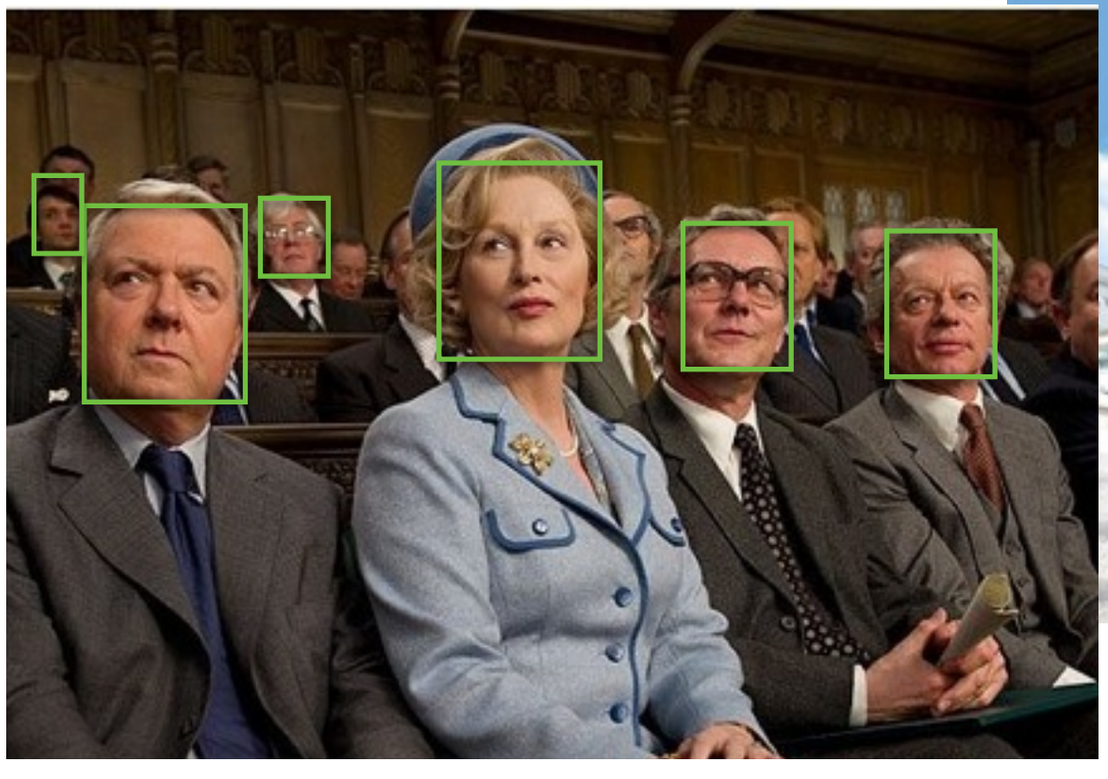
Multiscale Image Analysis

The multiscale concept

- Images contain useful information at different scales

- Analyzing information at any one scale will not be effective



The multiscale concept

- How to analyze image in multiple scales?
    - Vary the window size
    - Alternatively, vary the image size, keeping window size the same

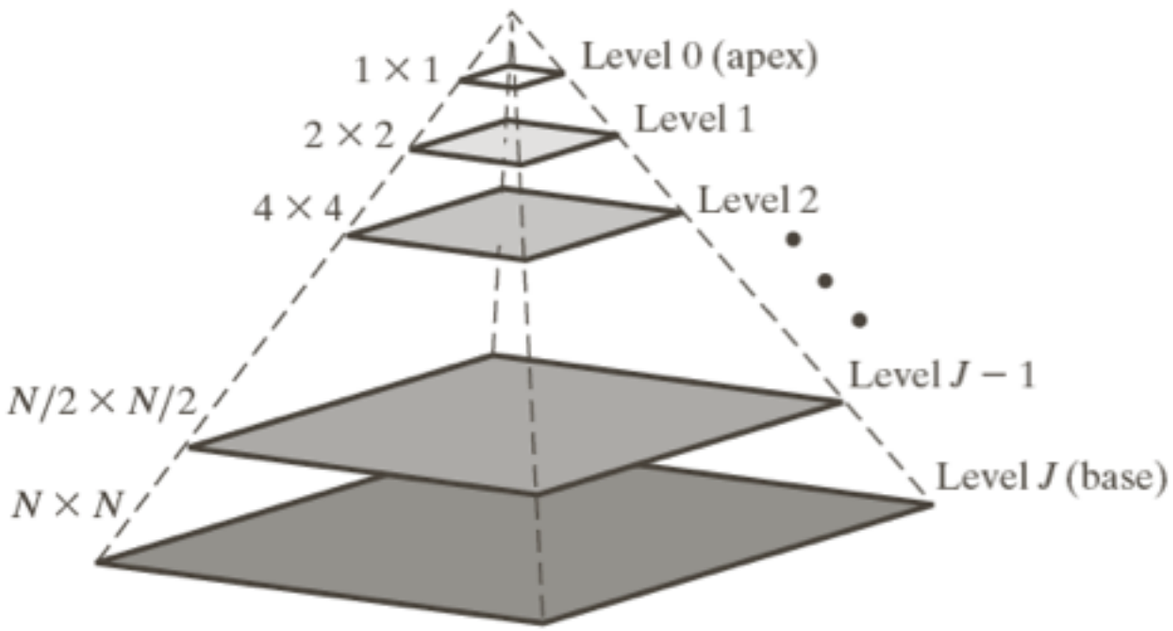
The multiscale concept

- How to analyze image in multiple scales?
    - Vary the window size
    - Alternatively, vary the image size, keeping window size the same.
- Larger objects can be examined at low resolution
- Smaller objects need to be examined at higher resolution

Multiscale analysis

- Various ways of multiscale analysis
    - **Image pyramid**
    - Subband coding
    - Wavelet decomposition

Image pyramid



(high scale)

low resolution
j=J=0

high resolution
j=J =$\log_2$N

(low scale)

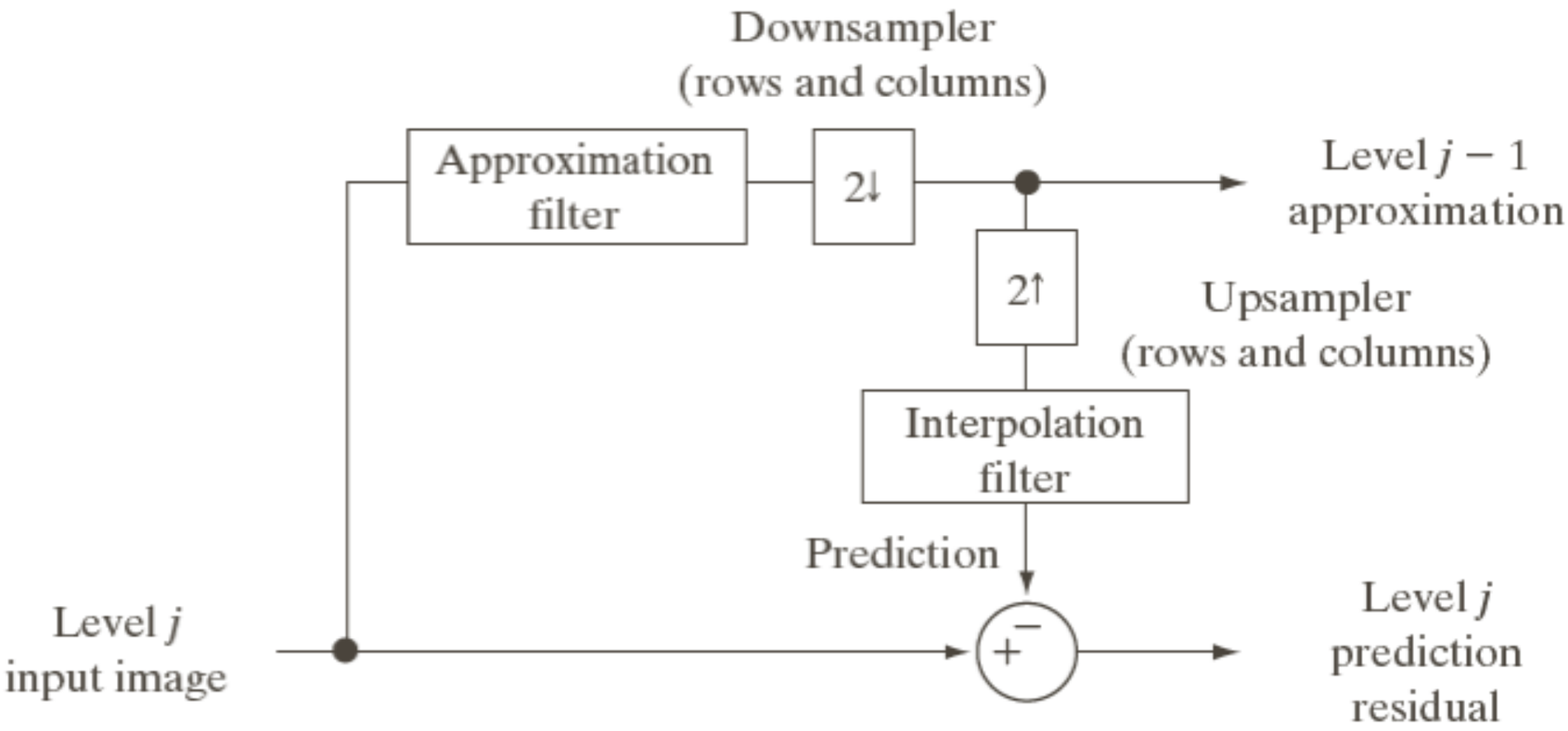
Example:

For a 256x256 image, N=256, J = 8, and there will be J+1=9 levels of decomposition

Often truncated at some intermediate level

A collection of images of decreasing resolution arranged in the shape of a pyramid.

Image pyramid

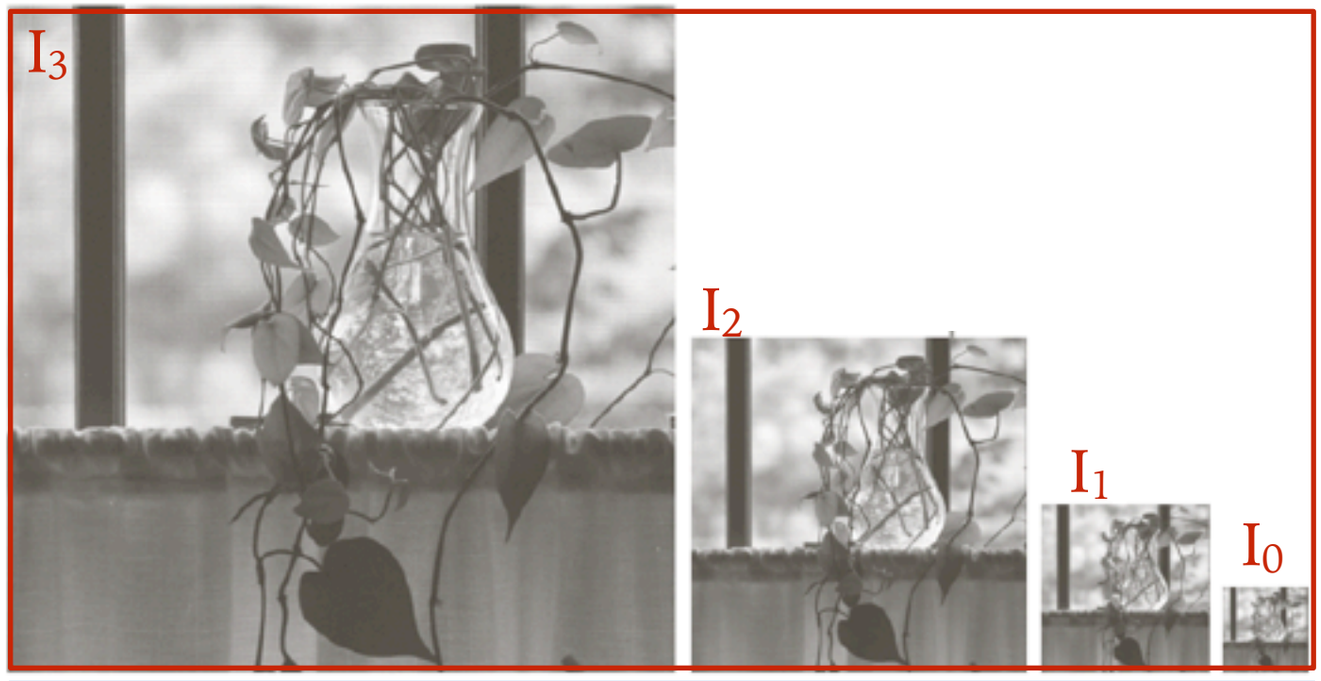


Approximation filter: mean filter, **Gaussian filter**

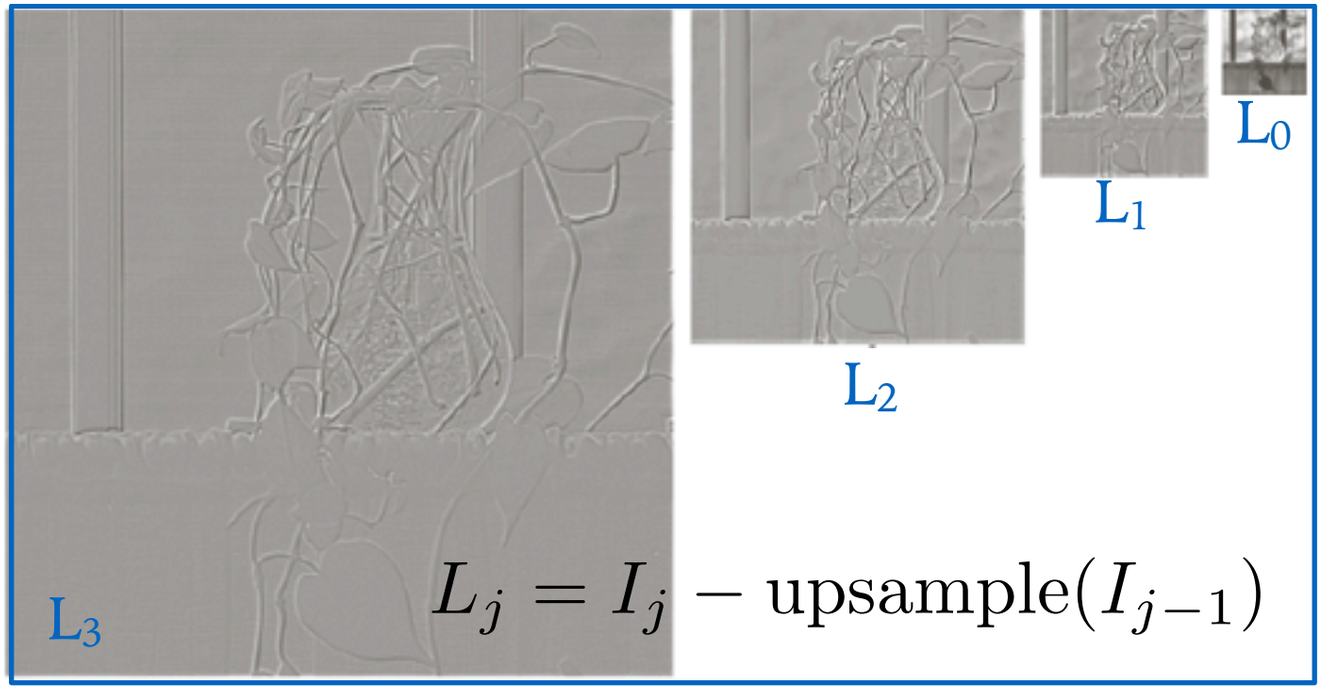
Interpolation filter: Bilinear, bicubic

Image pyramid

$\text{original} = I_j$ $I_{j-1} = \text{downsample}(I_j * G_\sigma)$



Approximation pyramid based on Gaussian filter



Prediction residual pyramid

Image pyramid

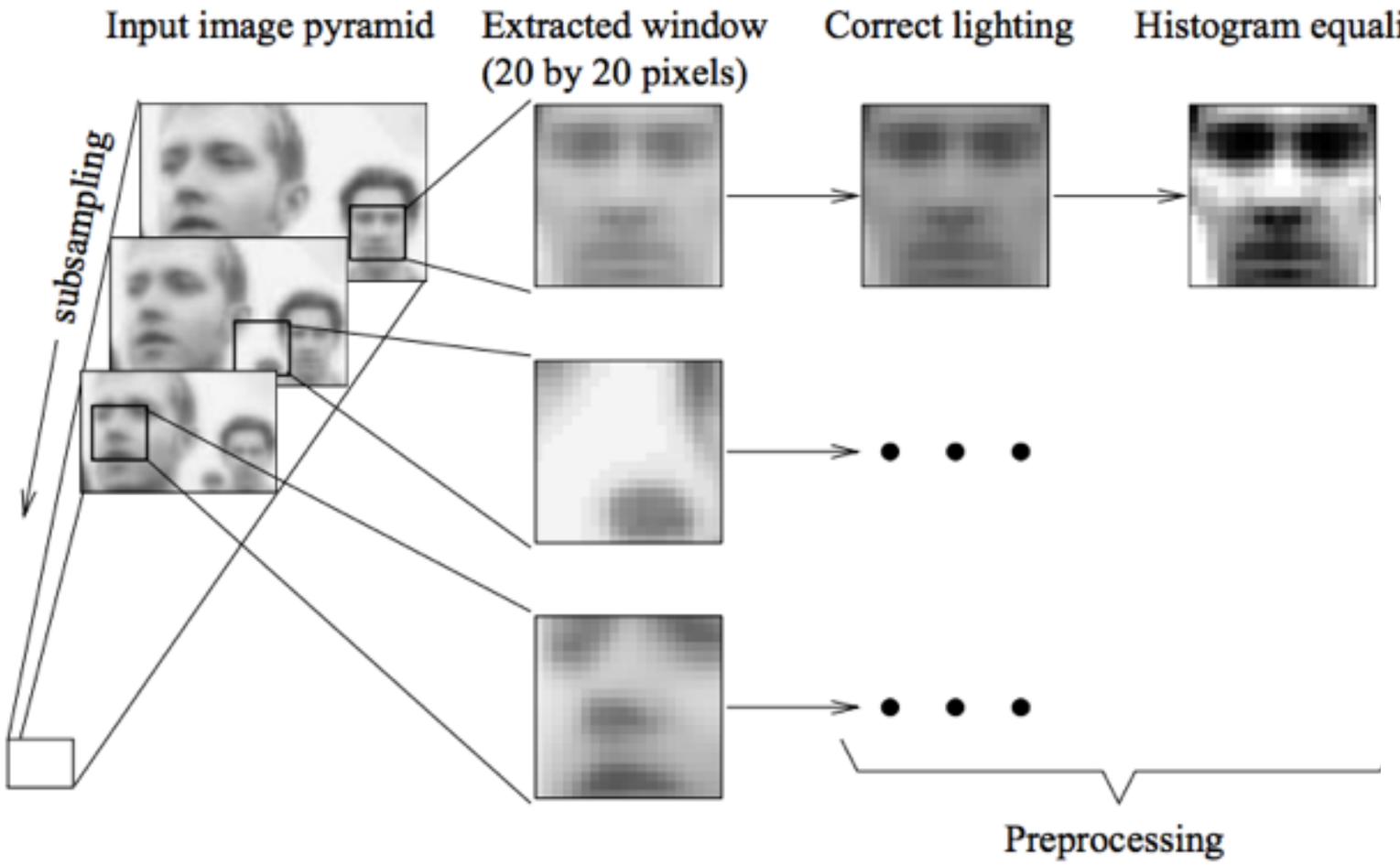
- Note that the last level is the same in Approximation and Prediction residual pyramid
- In the absence of quantization/interpolation error, the entire Approximation pyramid can be obtained from the Prediction residual pyramid

$$L_j = I_j - \text{upsample}(I_{j-1}) \qquad \mathrm{I}_0 = \mathrm{L}_0$$

$$I_j = L_j + \text{upsample}(I_{j-1}) \qquad \mathrm{I}_1 = \mathrm{L}_1 + \text{upsample}(\mathrm{L}_0) \ \ldots.$$

We only store the Prediction residual pyramid! - more efficient representation

Multiscale face detection



To classifier

Rowley et al 1995

Multiscale analysis

- Various ways of multiscale analysis
    - Image pyramid
    - **Subband coding**
    - Wavelet decomposition

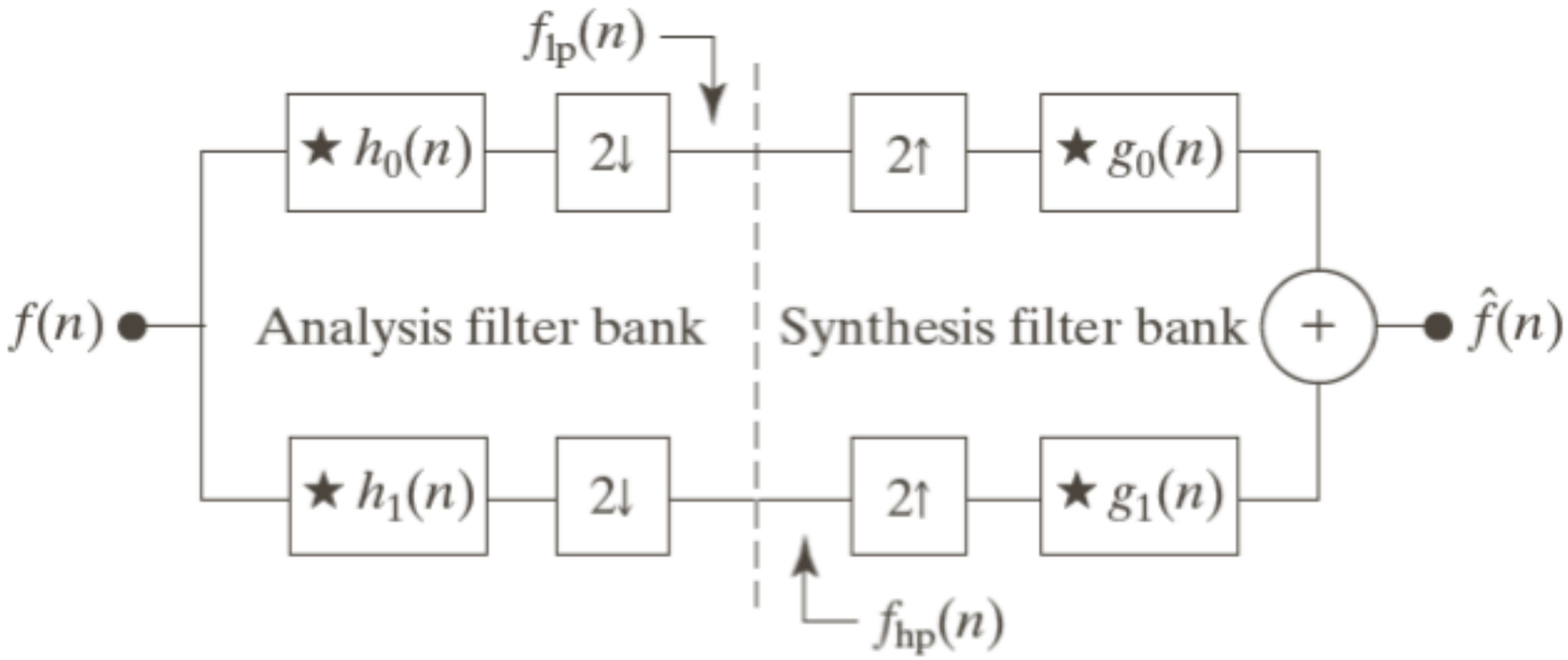
Subband coding

- **Analysis:** Decompose an image (signal) into a set of images corresponding to different frequency bands.

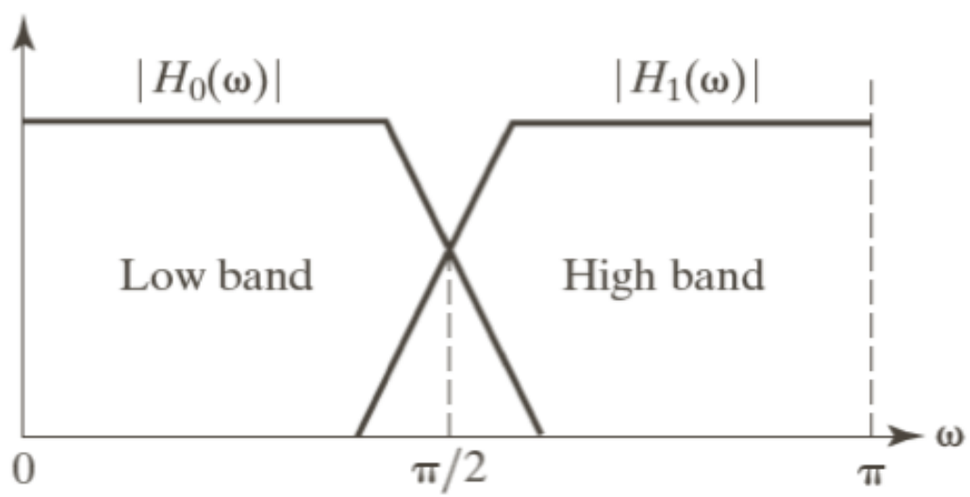
- **Synthesis:** Decomposition is such that the original image can be reconstructed from the decomposed images.

- We need a series of bandpass filters (filter bank) preferably with nice properties.

Subband coding (1D)

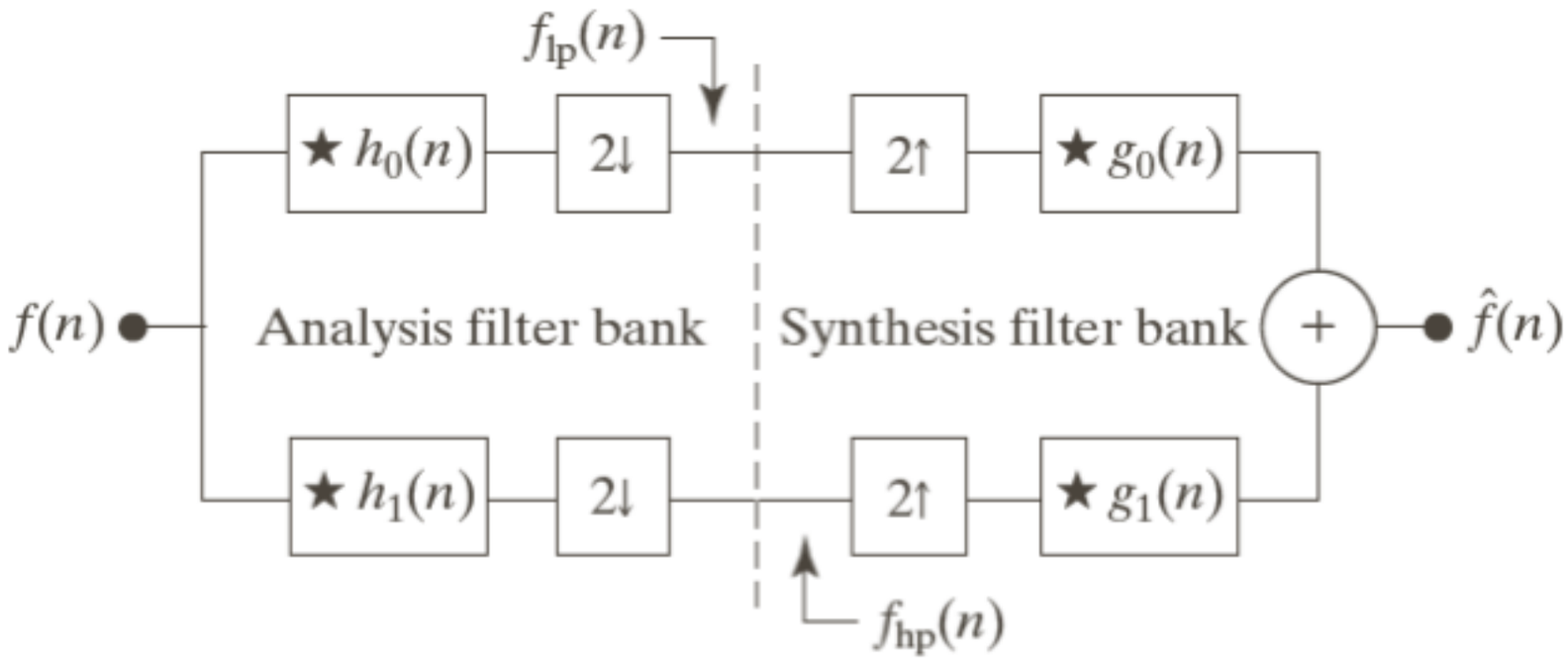


2-band decomposition



The key is to design good filters:
h_0, h_1, g_0, g_1

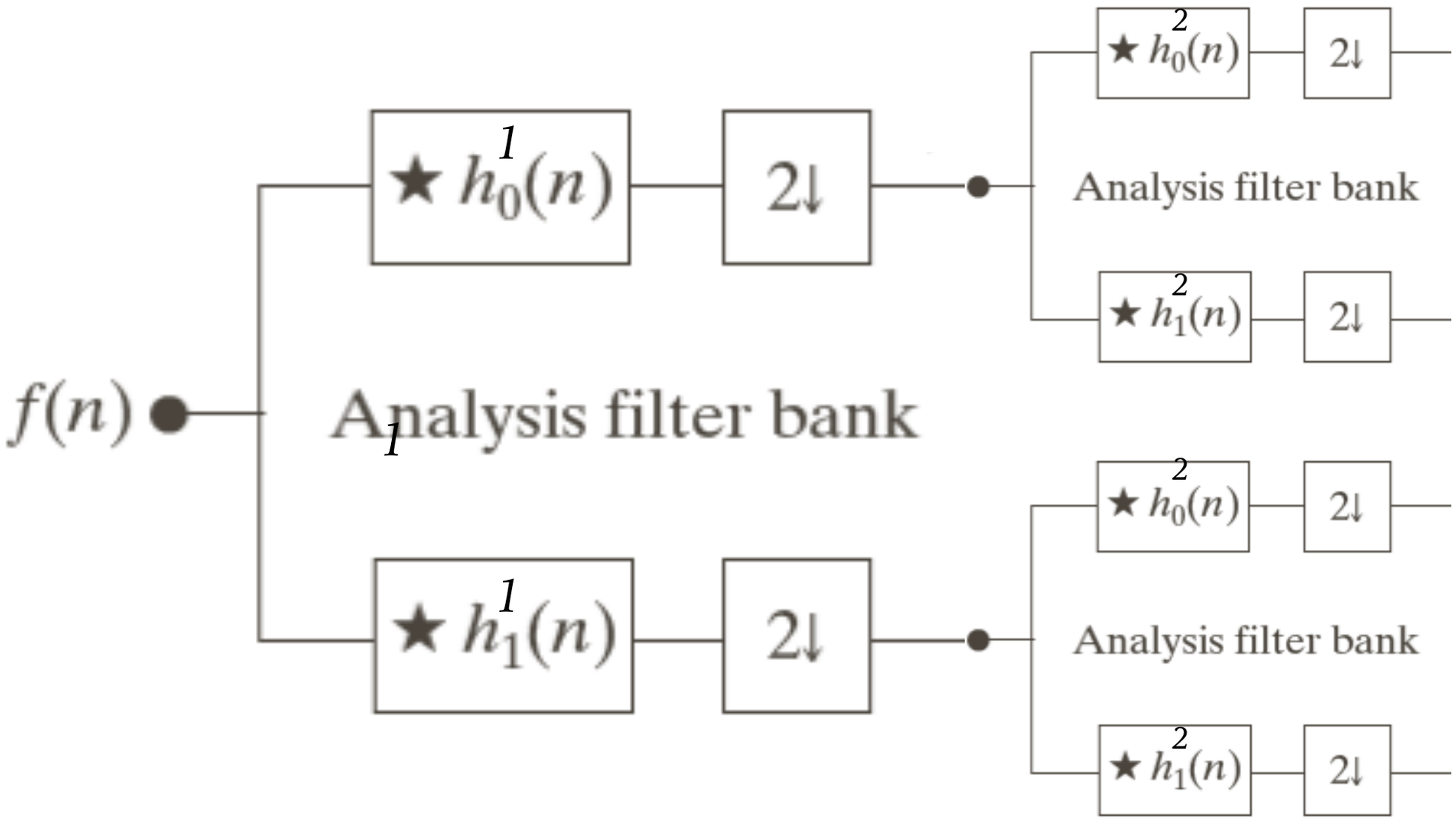
Subband coding (1D)



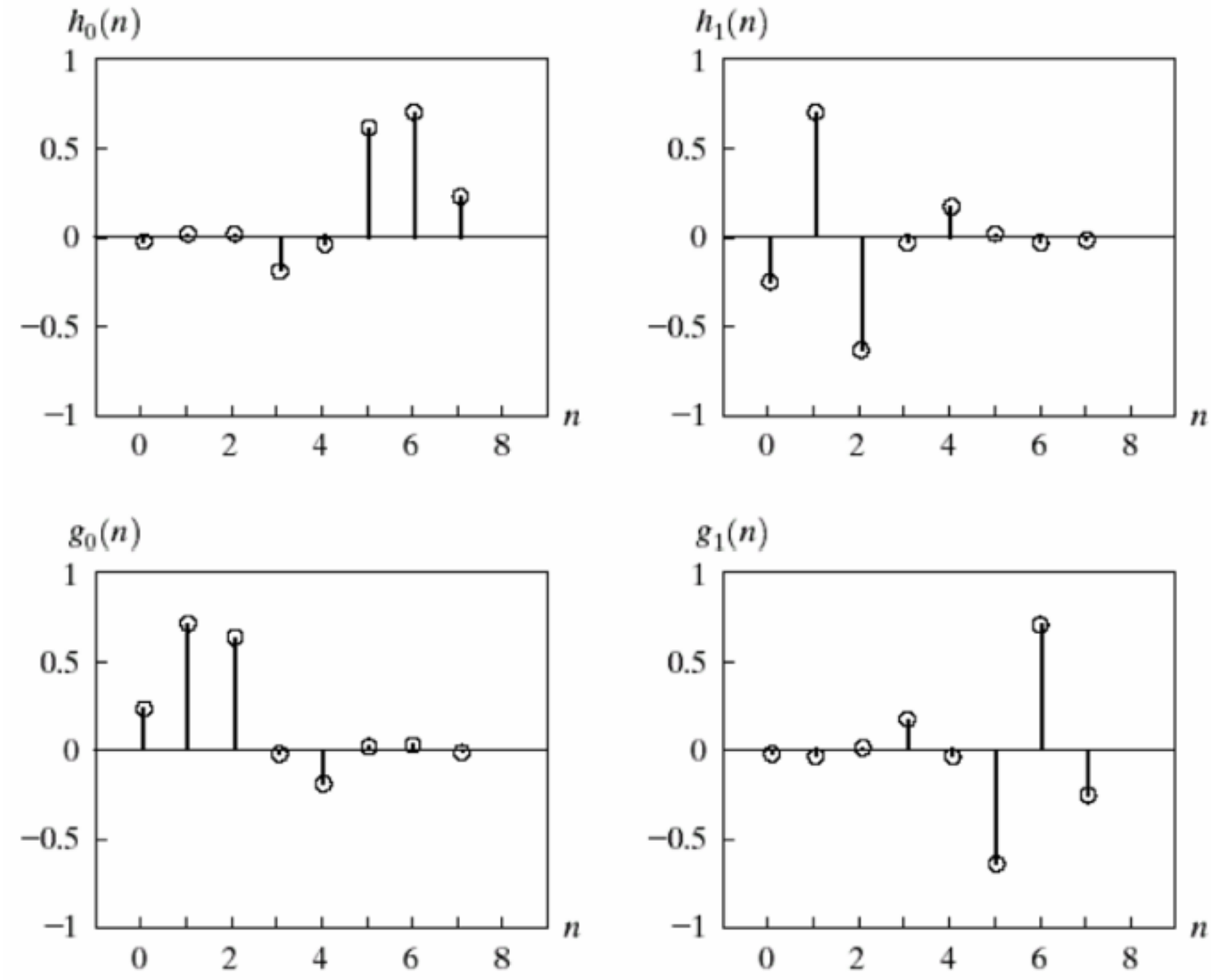
$$g_0(n) = (-1)^n h_1(n)$$

$$g_1(n) = (-1)^{n+1} h_0(n)$$

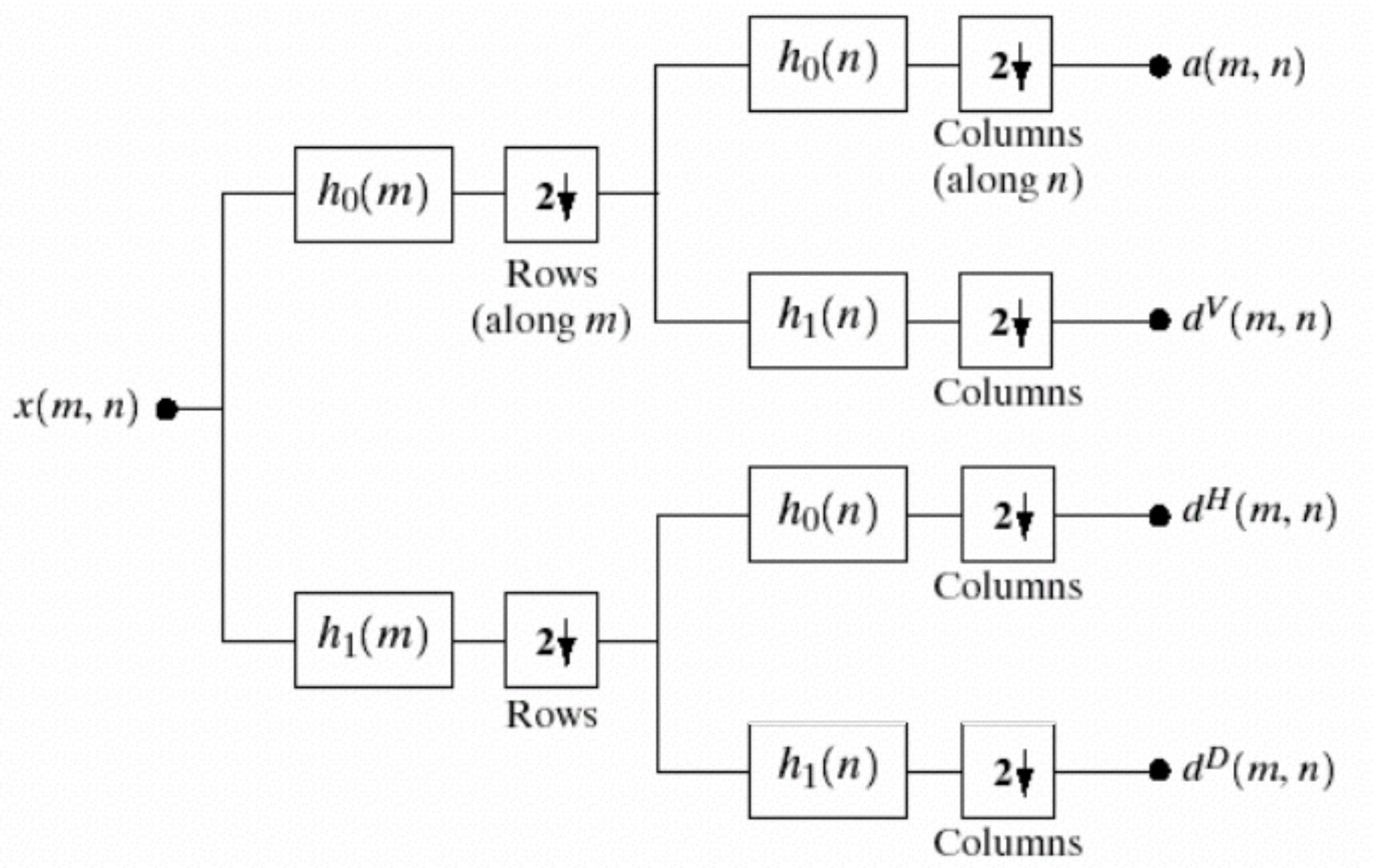
Iterated filter bank



Daubechis 8-tap



Subband coding (2D)



Subband coding (2D)