MRA: Multi Resolution Analysis

Denoising- Pyramids & Subbands

Dr. Tushar Sandhan

Introduction

- Image analysis at different resolutions

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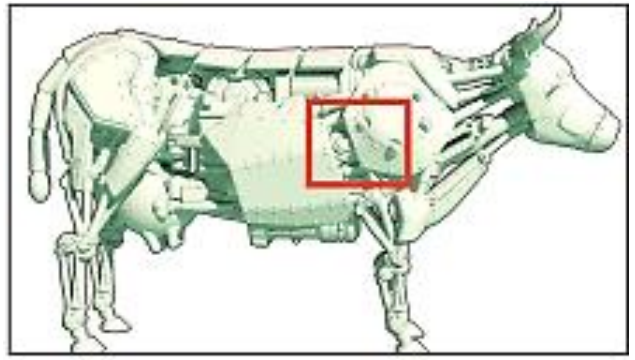


Image analysis

- Image statistics
  - change locally
  - info. is distributed at various scales
  - noise is present throughout the image

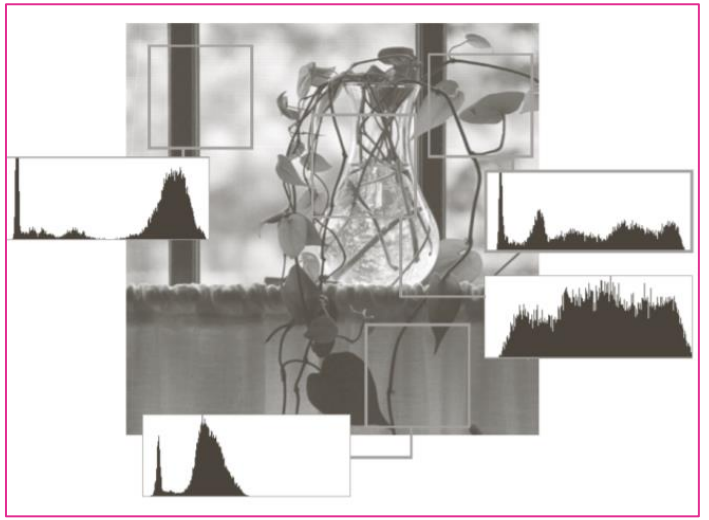

image: C. Nikou

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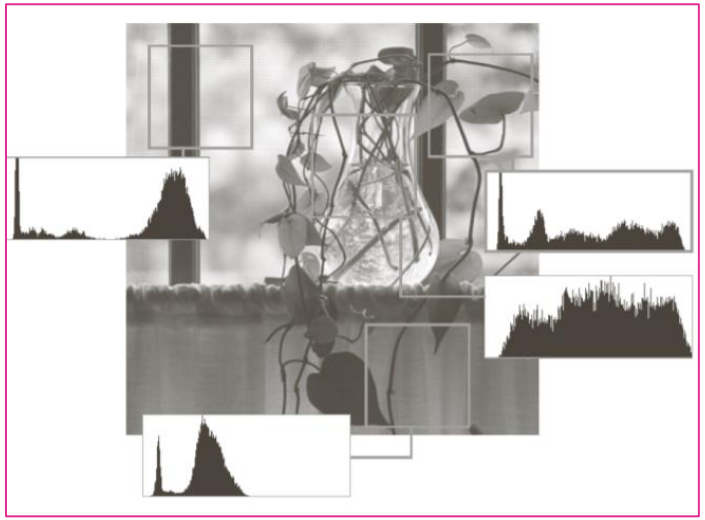
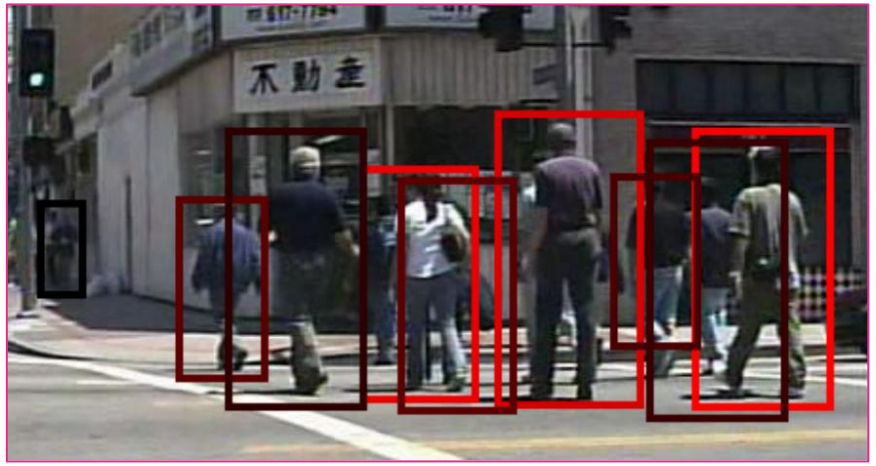


- Larger objects can be analyzed @ coarse/low resolution

- Smaller ones can be analyzed @ fine/high resolution



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MRA: Image Pyramid

- Image pyramid
  - a collection of images
  - gradually decreasing resolution
  - arranged in the shape of pyramid
  - researcher use Level numbers interchangeably

    e.g. Level-0 might be bottom or top!

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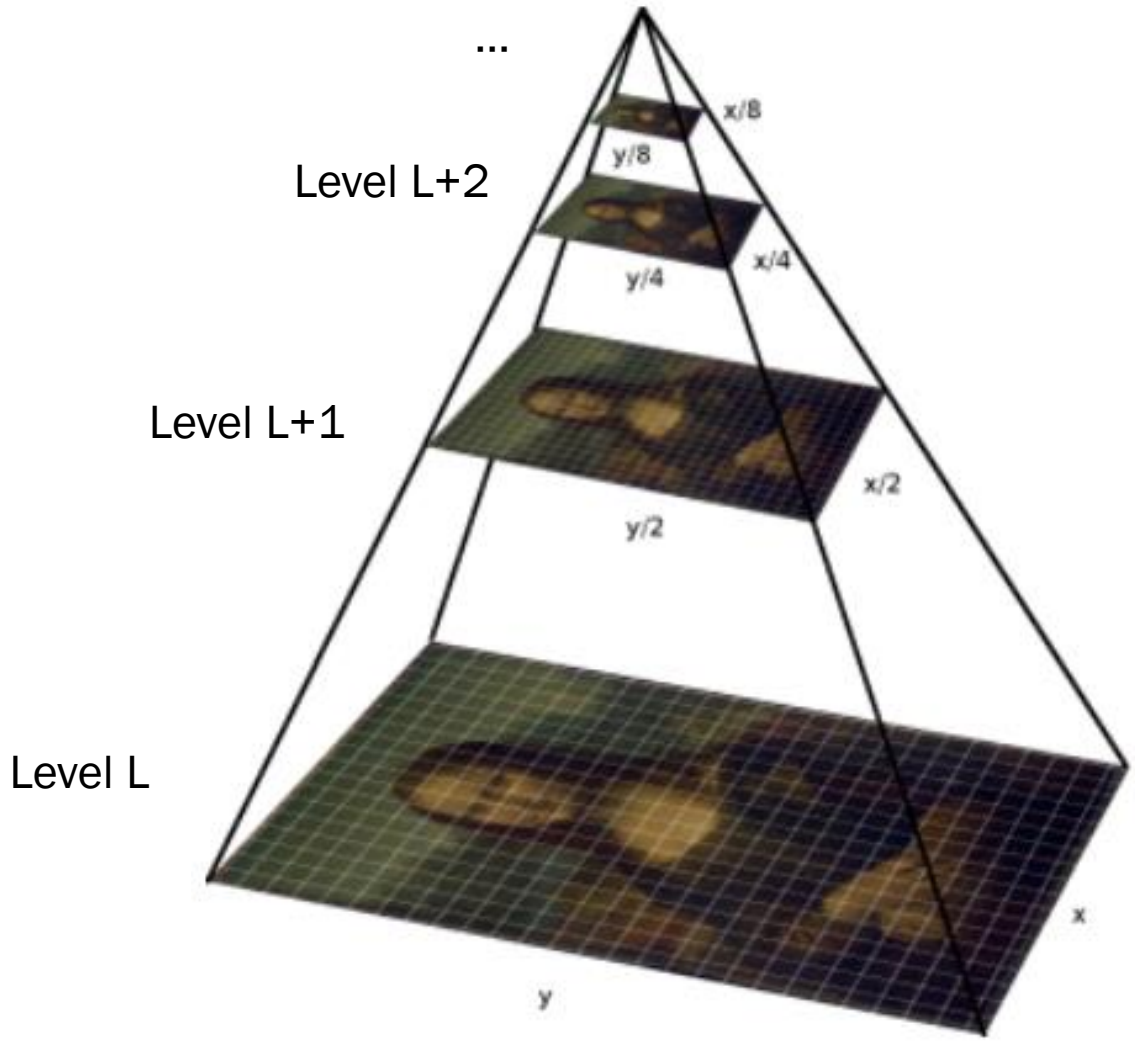

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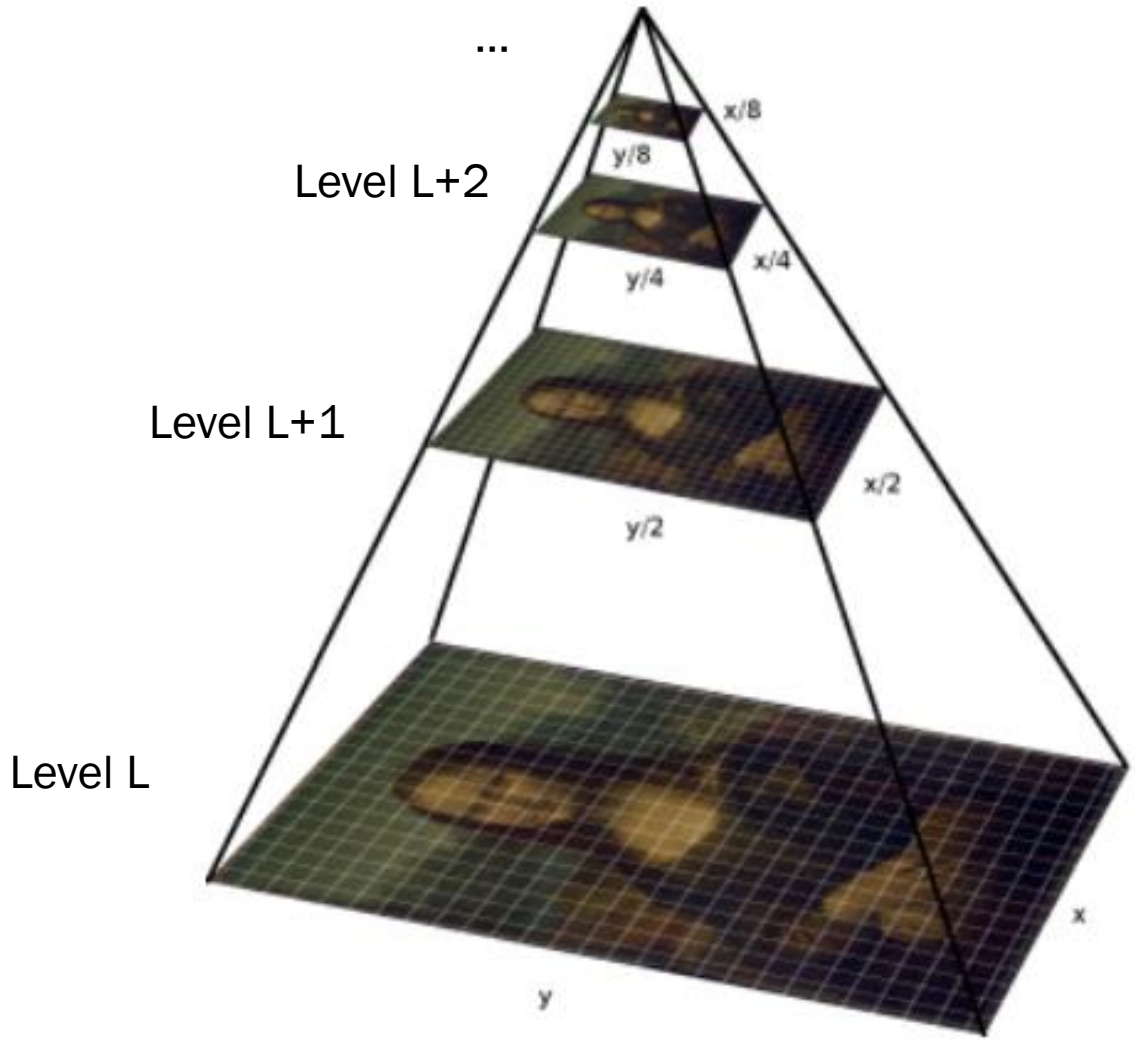
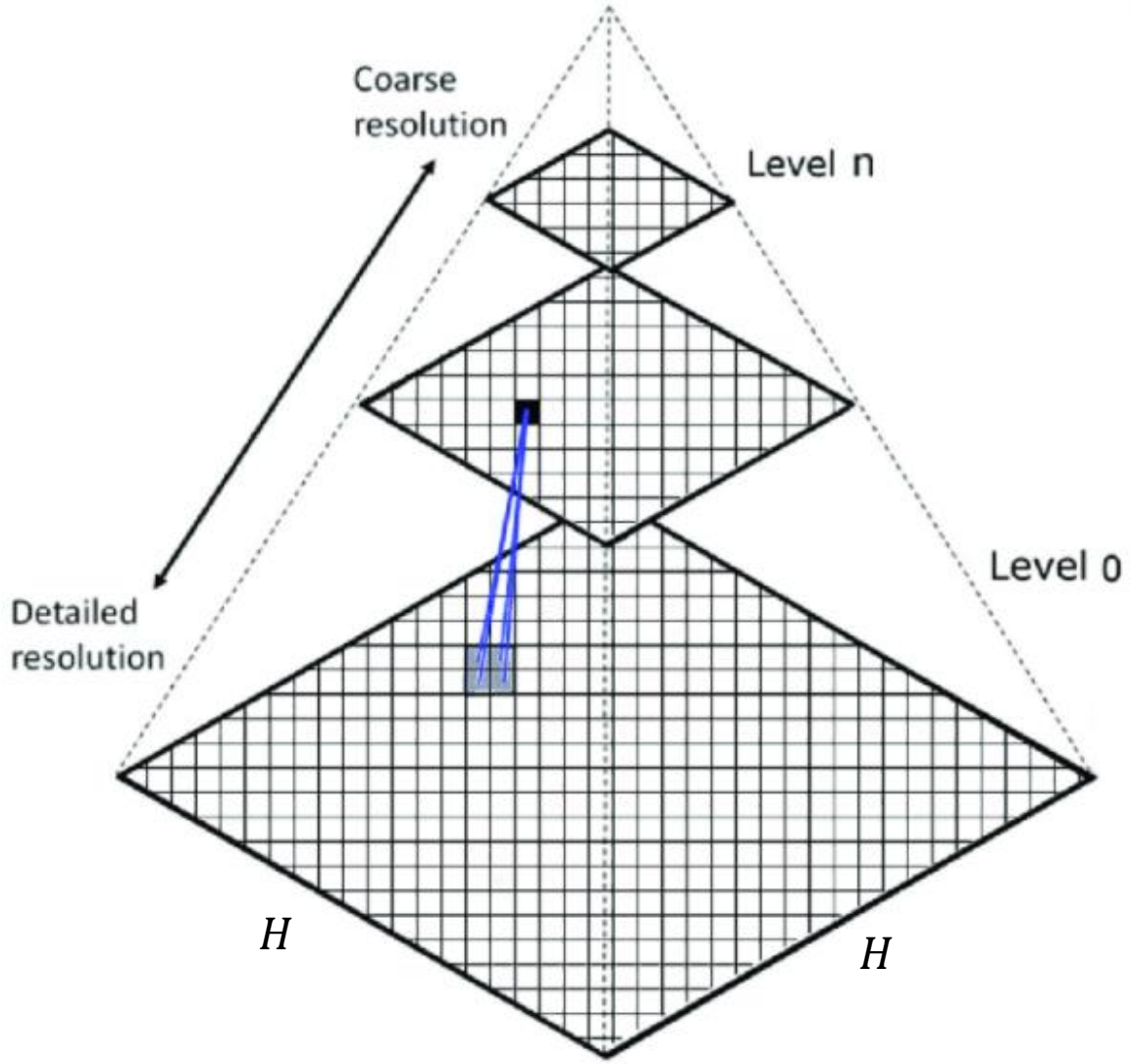
- Top level?
  - it is not necessary to go till summit of the pyramid
  - pyramid can be truncated at any level L+k
  - requirement of speed & accuracy determines k

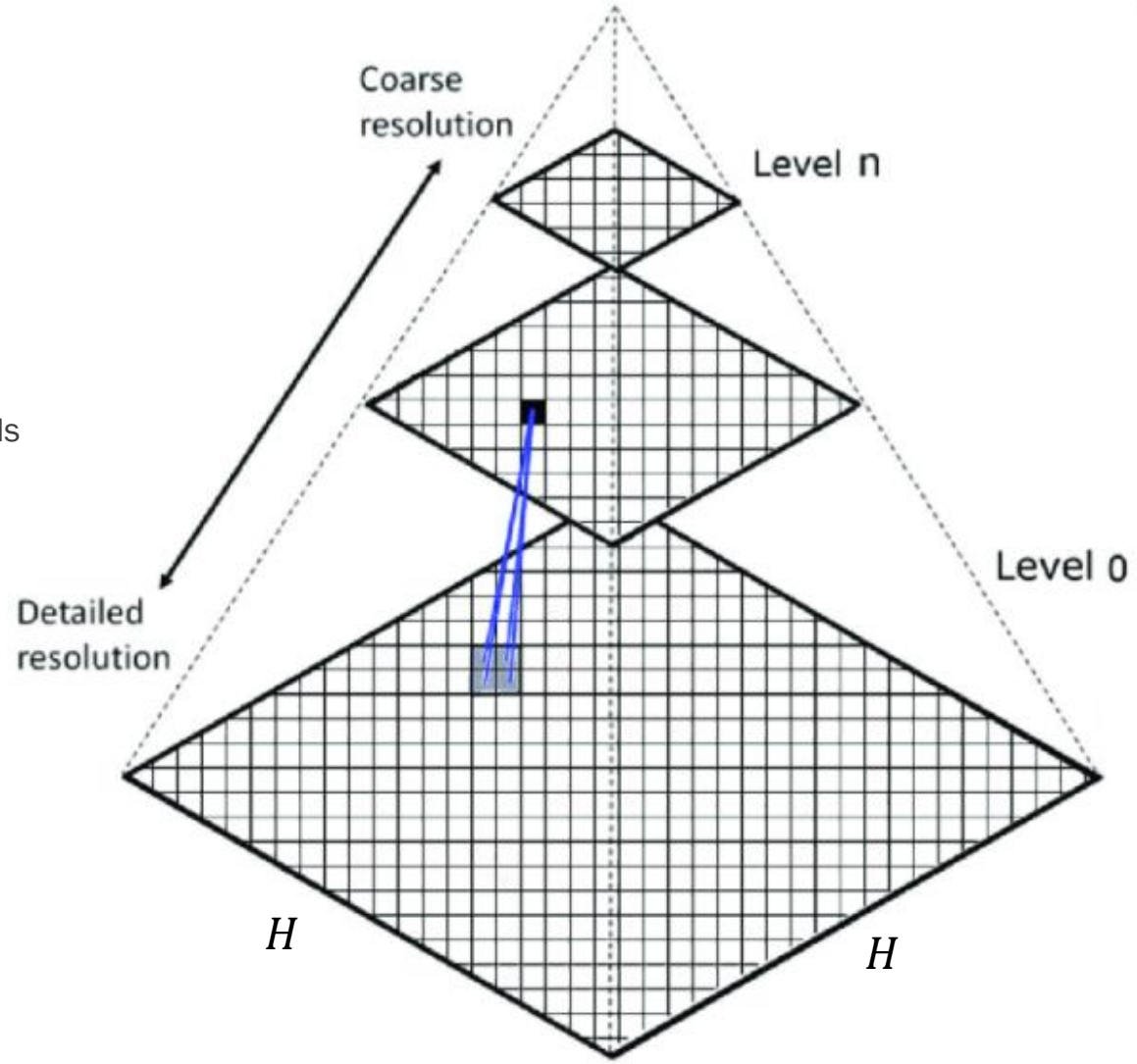


Pyramid



Pyramid

- Pixel correspondence among levels
  - any image patch at lower level directly corresponds to a smaller patch at upper level
  - levels can be of color image or grey scale
  - pyramid consistency
    - uniformly apply image operations (e.g. crop, rotation) on all levels



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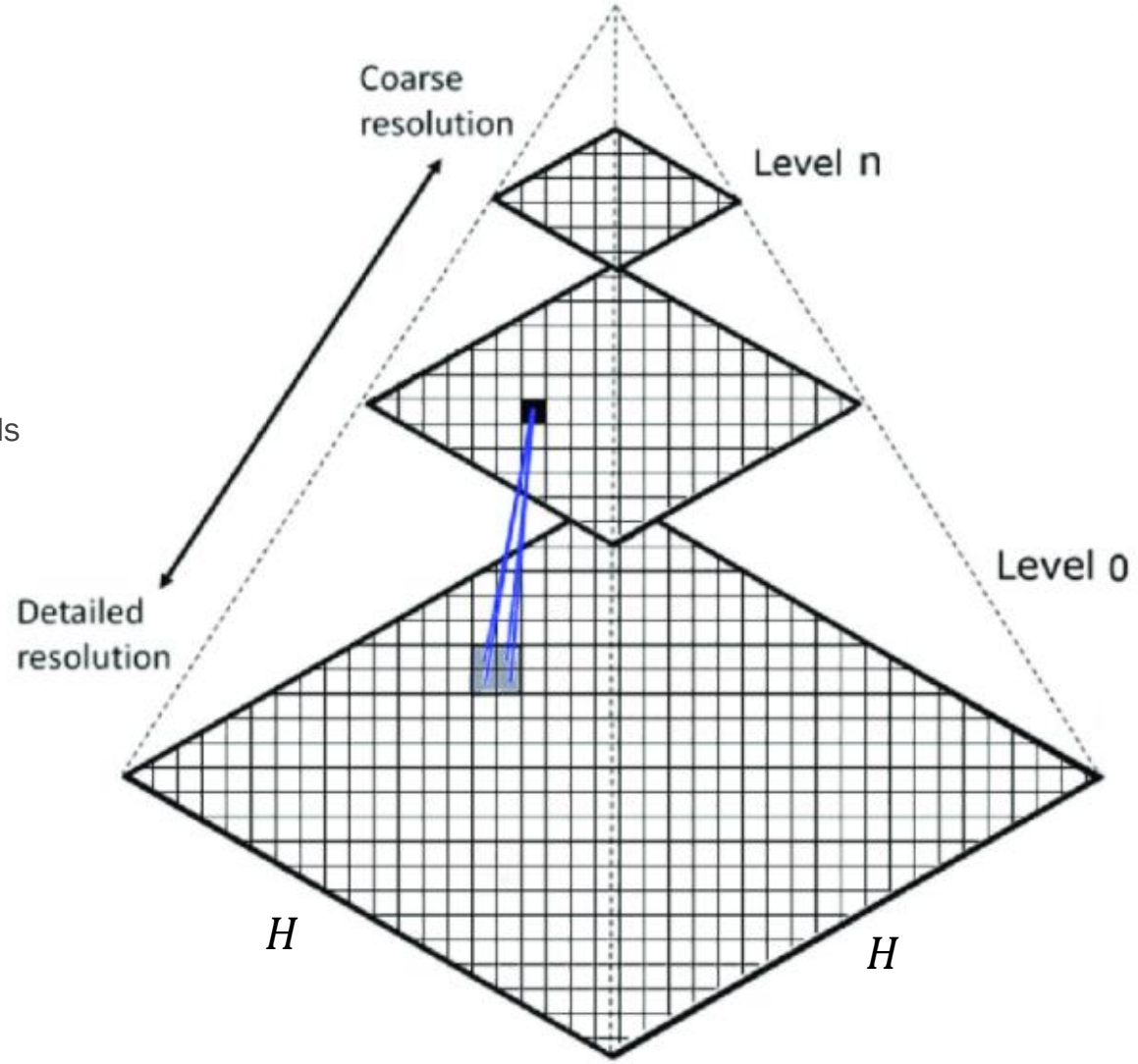
- What is the space complexity?



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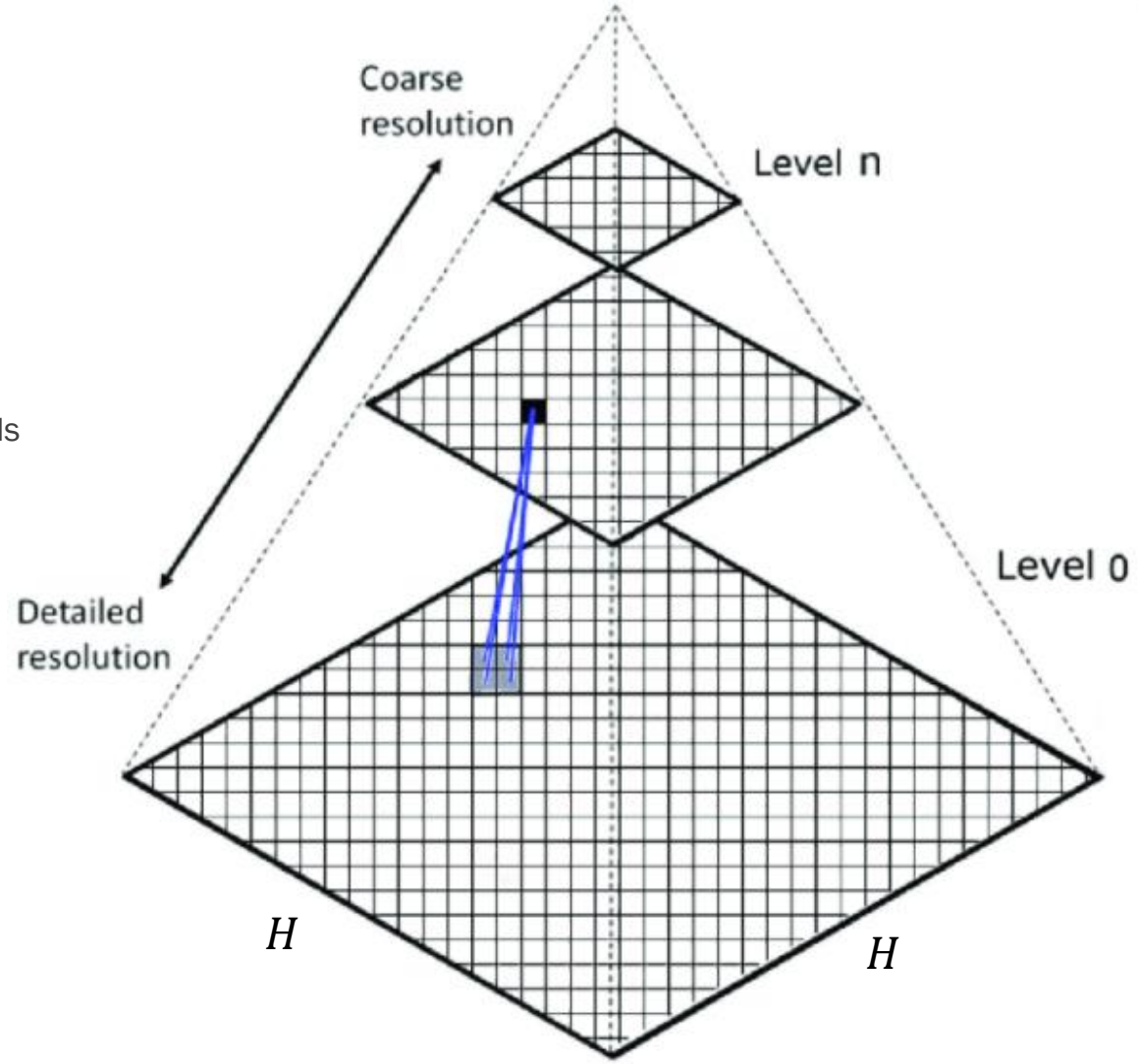
- What is the space complexity?

$$= N + \frac{N}{4} + \frac{N}{4^2} + \cdots + \frac{N}{4^k} \qquad N = H \text{ x } W$$

$$\leq \frac{4N}{3}$$



Pyramid

- Tiled Multi-Resolution (or Tiled Pyramidal) TIFF
  - it is simply a tiled multi-page TIFF image
  - each resolution is stored as a separate layer within the TIFF
  - it's standard TIFF extension supported by most image procc applications including photoshop
  - 'libtiff' library is capable of reading & writing such pyramids

    ref: http://www.libtiff.org

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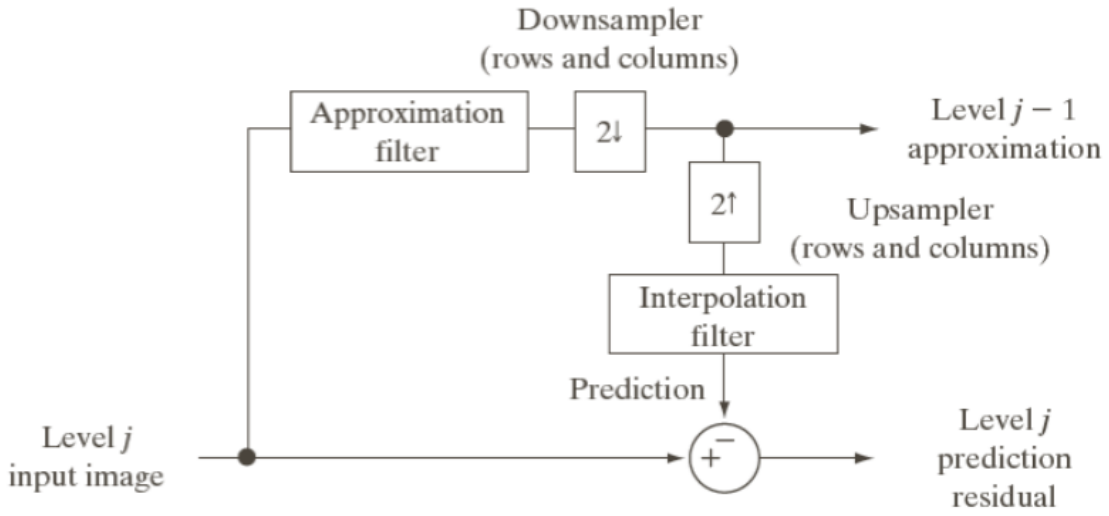
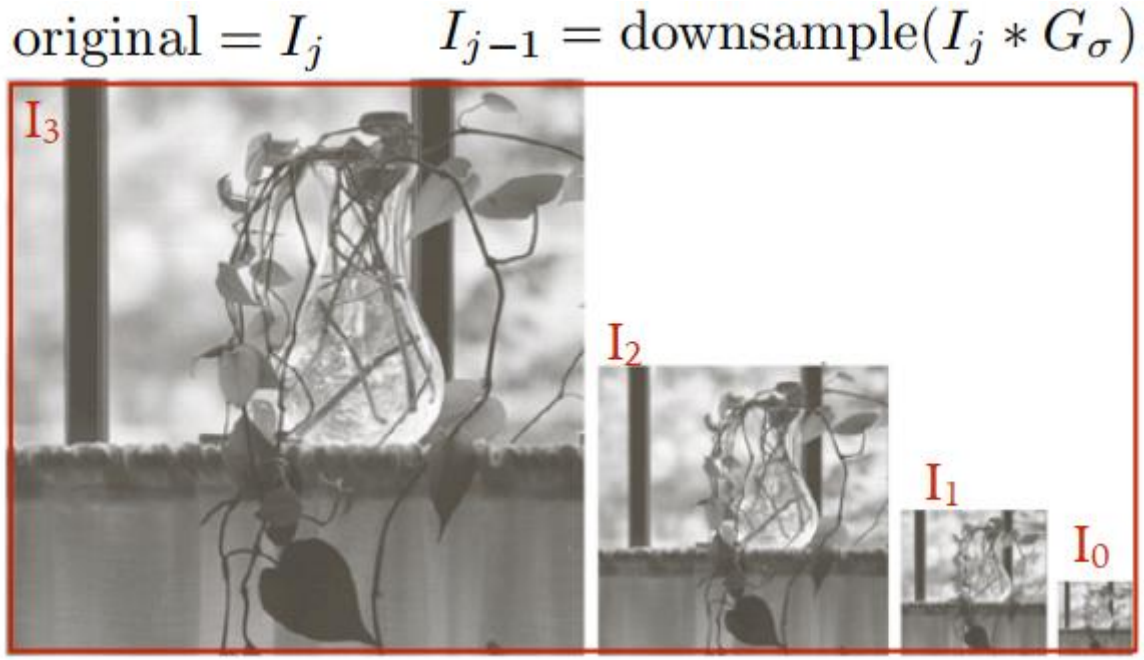
- Image pyramid processing
  - while using pyramid MRA, construct your own pyramids inside that image processing algorithm

Pyramid construction

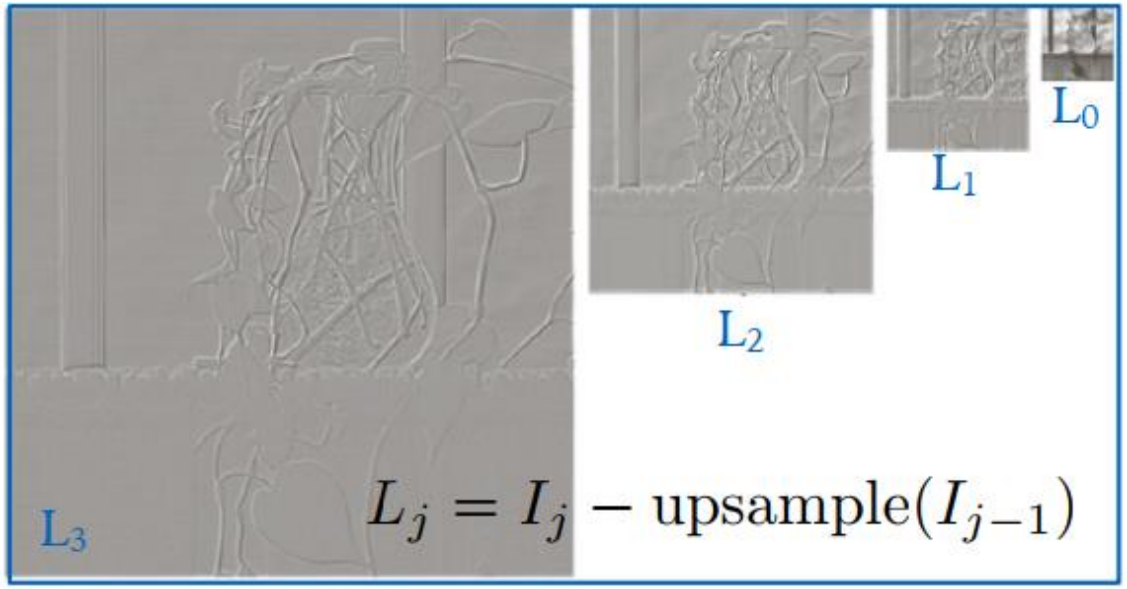
- Build the pyramid using below cornerstones
  1. Approximation filter
     - Gaussian filter
     - Averaging/mean filter
     - Low pass filter
  2. Detailed filter
     - Bilinear interpolation
     - Bicubic interpolation
     - Upsampler



Gaussian Pyramid



Approximation pyramid



Residual pyramid

Pyramid representation

- We mostly use residual format
  - note level-0 is same in approximation & residual
  - efficient representation

$$\mathrm{I}_0 = \mathrm{L}_0$$

$$L_j = I_j - \mathrm{upsample}(I_{j-1})$$

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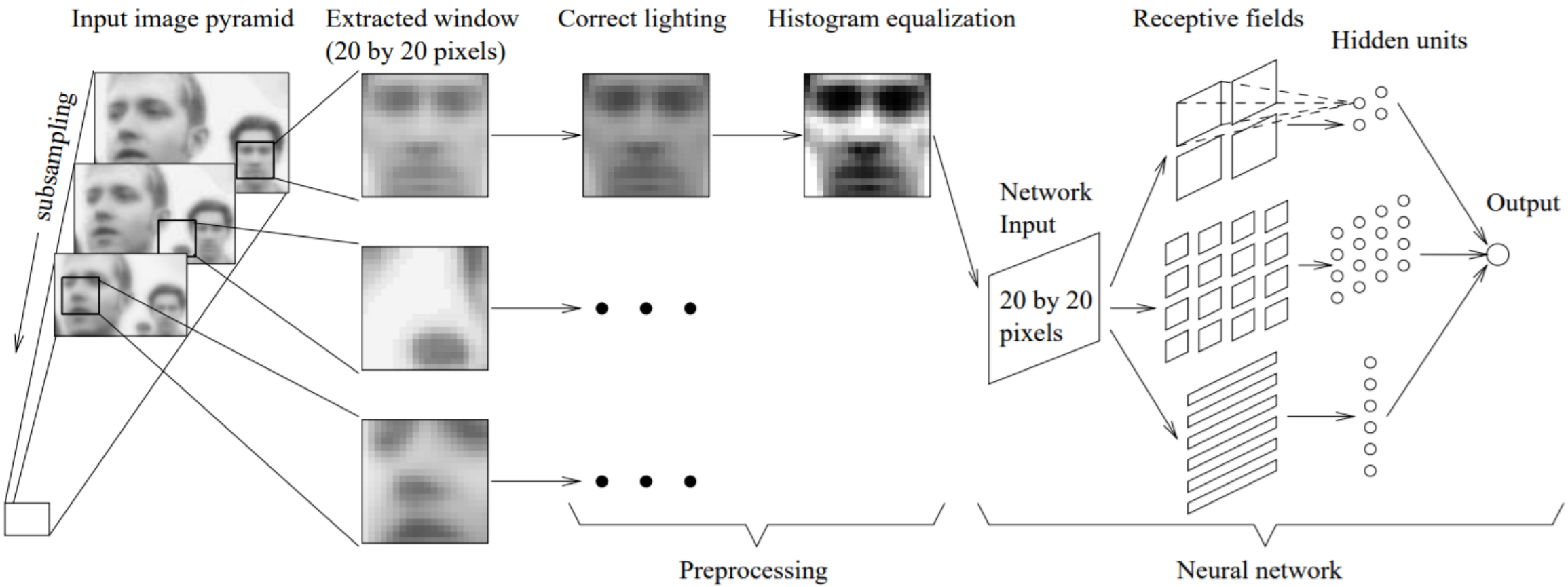
➢ Entire approximation pyramid can be obtained via residual pyramid

Pyramid processing



IEEE CVPR, HA.Rowley 1996

Sub-bands

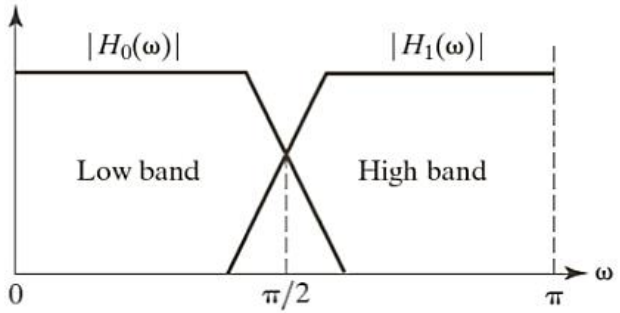
- Sub-bands are the bandpass filters
  - a series of bandpass filters also known as filter bank
  - Equi-rate: equal bandwidth sub-bands
  - Multi-rate: different bandwidth sub-bands
  - similar to image pyramid, we use below corner stones :

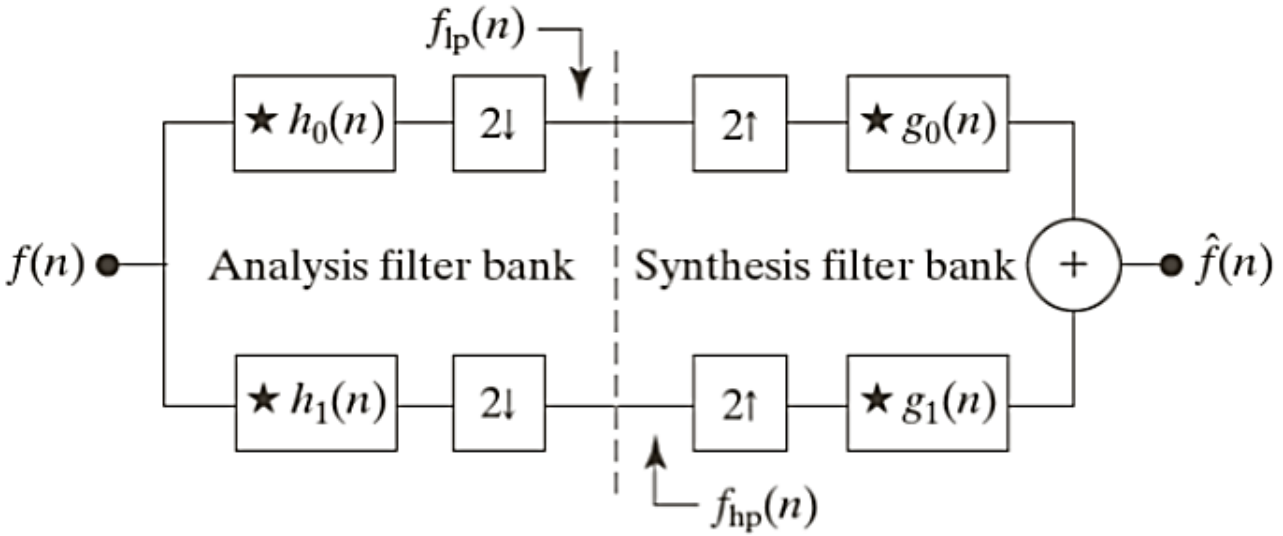
1. Analysis
   - decompose image into set of images of different freq bands

2. Synthesis
   - original image should be reconstructed from bands of analysis stage

Sub-bands

- Double bands
  - 2 band decomposition
  - filtering + 2↓

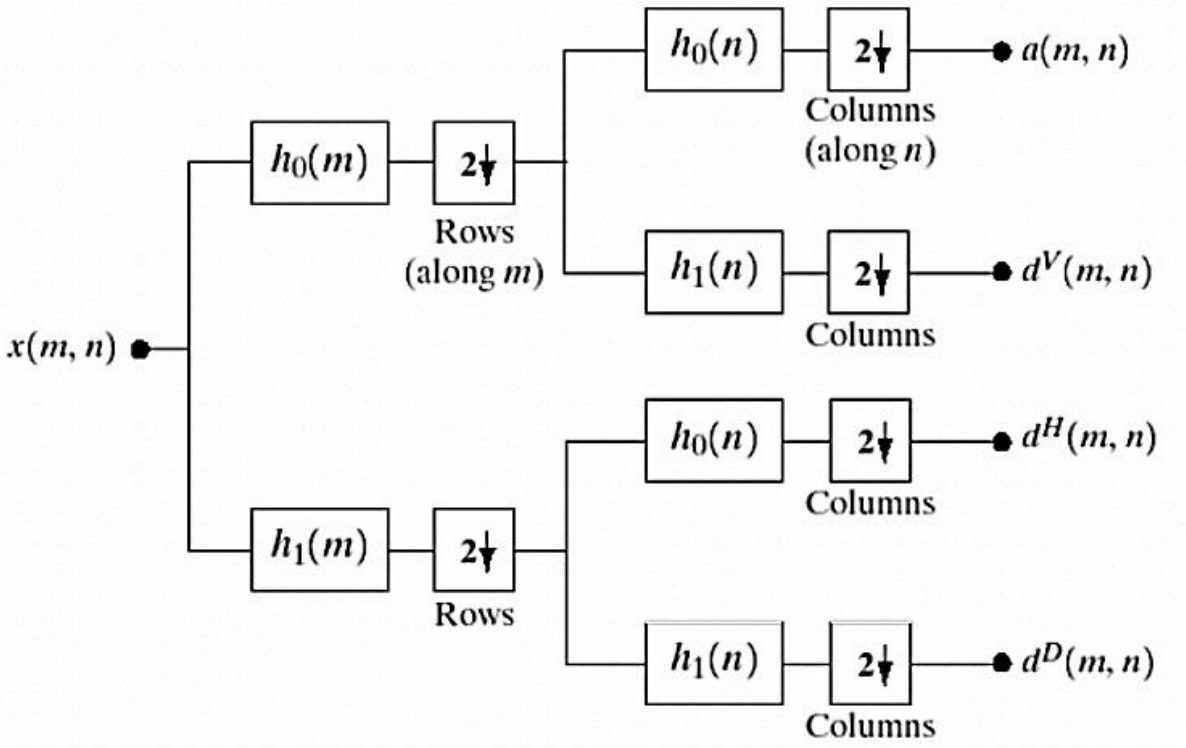




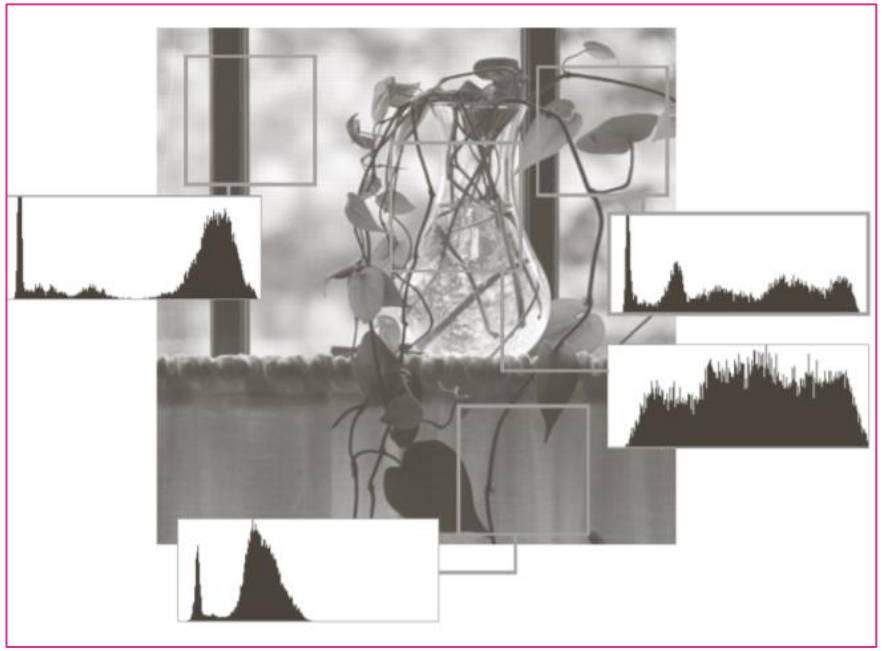
$$g_0(n) = (-1)^n h_1(n)$$
$$g_1(n) = (-1)^{n+1} h_0(n)$$

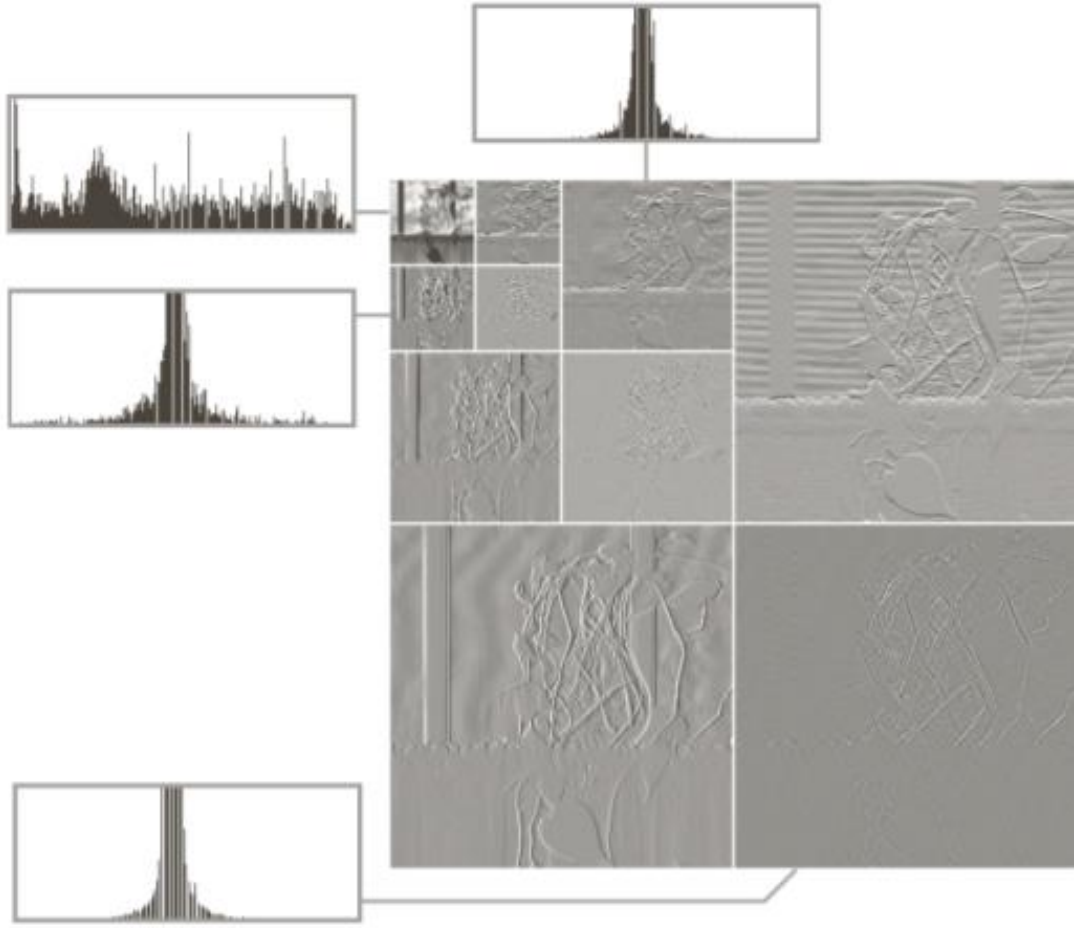
Sub-bands

- sub-band coding
  - 2 band decomposition expanded recursively



Sub-band decomposition





Sub-band denoise

- Different bit-rates or different coding technique can be used for each sub-band
  - useful in compression as well

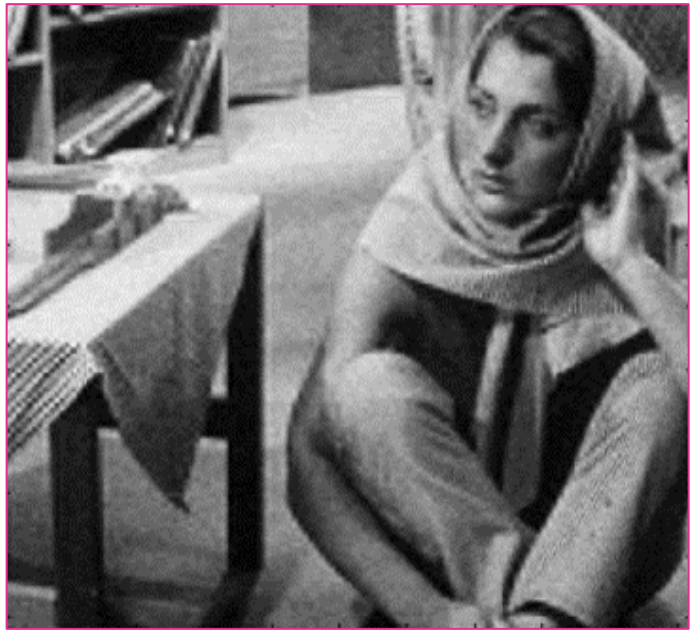
- Denoise
  - noise types
    - uniform
    - speckle
    - band-limited
  - sub-band denoise
    - different bands show different response to noise types
    - it allows errors to be distributed across sub-bands
    - filter each sub-band image separately with specific filtering parameters dedicated to those bands

Sub-band denoising

original

noisy

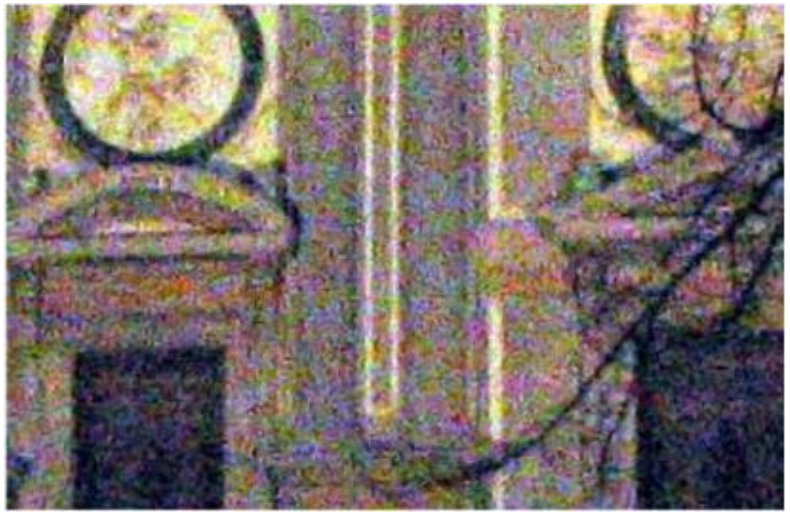
denoised



Multiresolution BF

- Results

input



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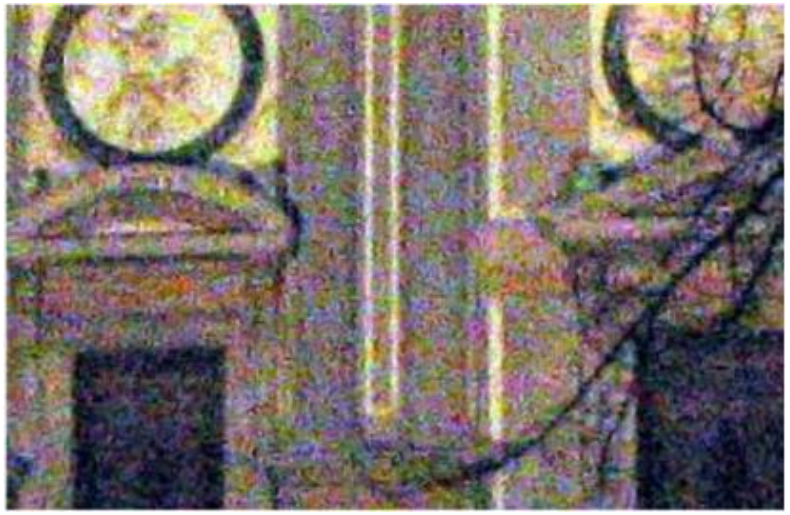

BF (psnr 29.6)

Multiresolution BF

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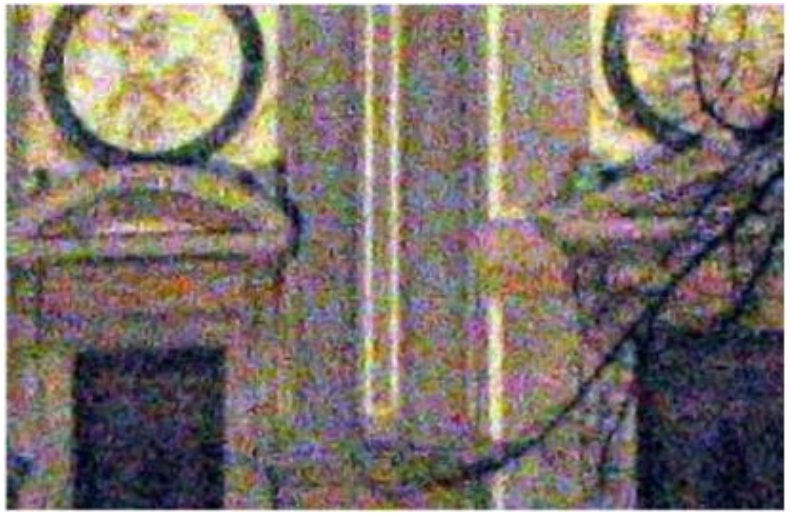

BF (psnr 29.6)

MRBF (psnr 31.4)

Conclusion

- Denoising
- Multiresolutions
  - Pyramids
  - Sub-bands

BF

MRBF

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❑ Multiresolutions
- Pyramids
- Sub-bands

❑ Denoising
- Even minute imperceptible improvement in the denoising is very important for scientific images

BF

MRBF

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MRBF