

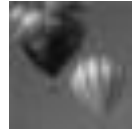
Image Pyramids

Image Pyramids?



What is an Image Pyramid?

Low resolution

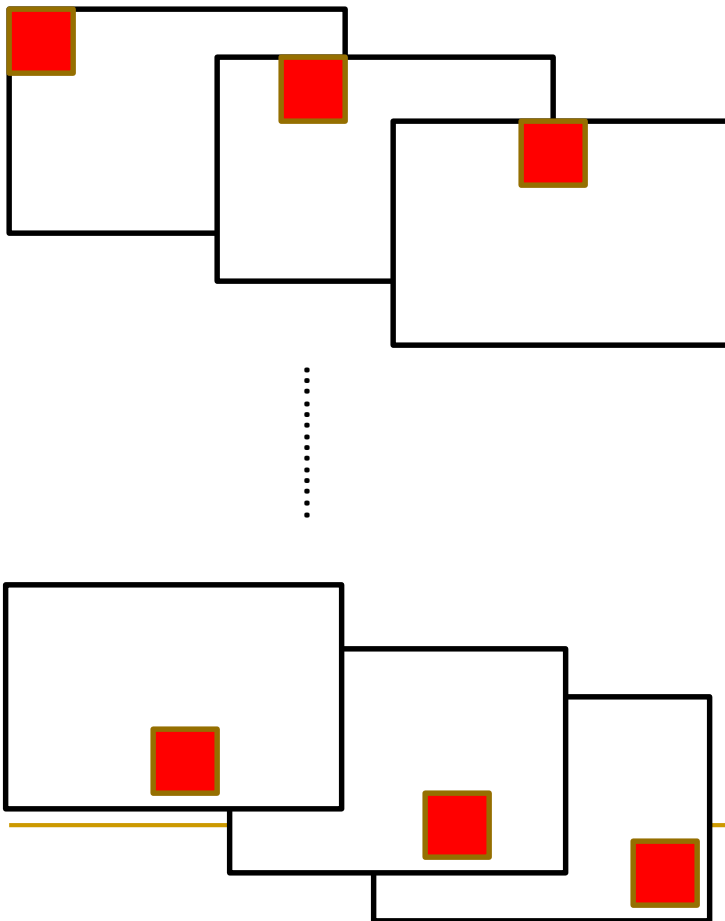


High resolution

Image Pyramid

Spatial Domain

Basis functions:

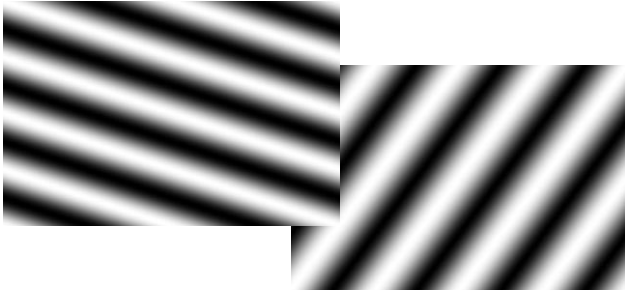


Tells you *where* things are....

... but no concept of *what* it is

Fourier domain

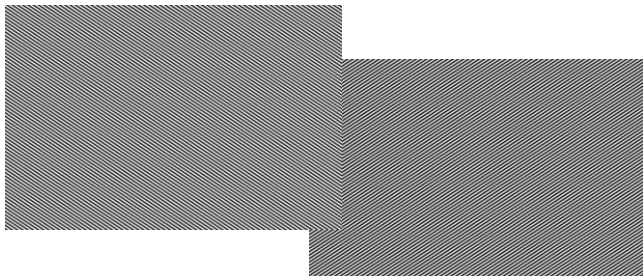
Basis functions:



...



...



Tells you *what* is in the image....

... but not *where* it is

Image Analysis

- Want representation that combines *what* and *where*.

→ Image Pyramids

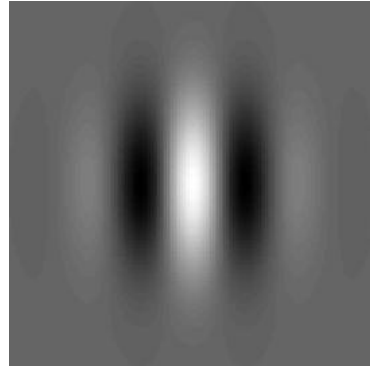


GAUSSIAN PYRAMID



Image Pyramid

Why Pyramid?

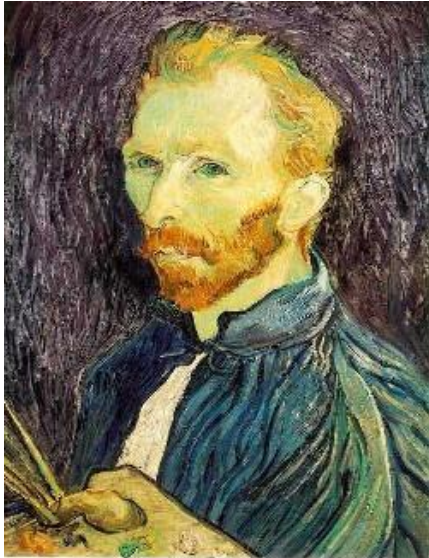


....equivalent
to....



Dropping Pixels v.s. Smoothing and then dropping Pixels

Why does this look so bad?



$1/2$

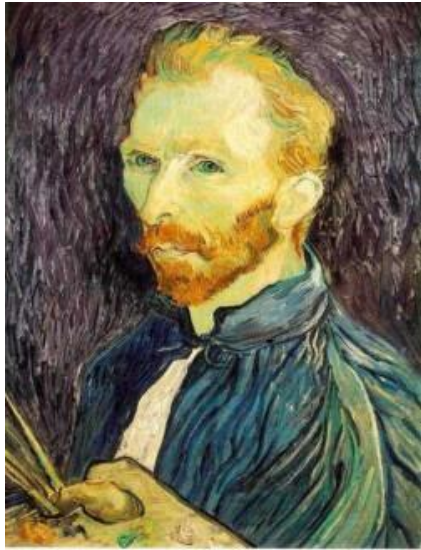


$1/4$ (2x zoom)



$1/8$ (4x zoom)

Subsampling with Gaussian pre-filtering



Gaussian $1/2$

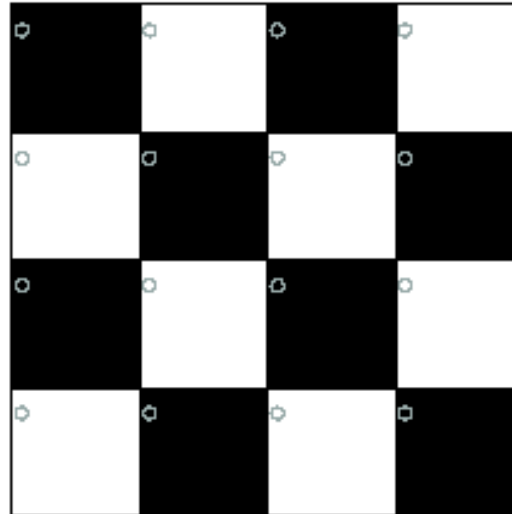
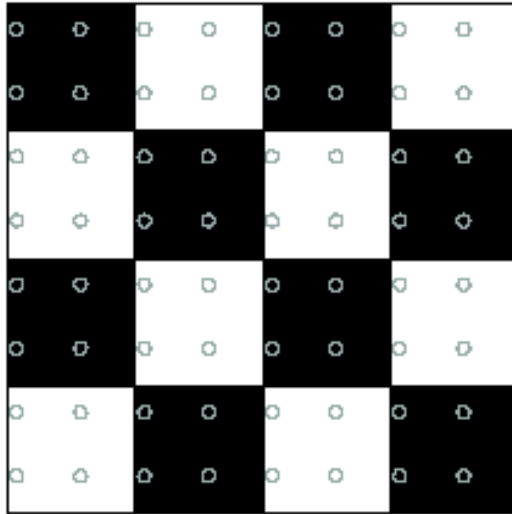


G $1/4$



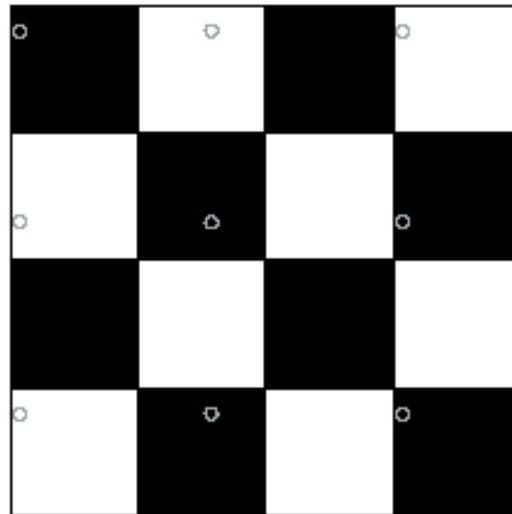
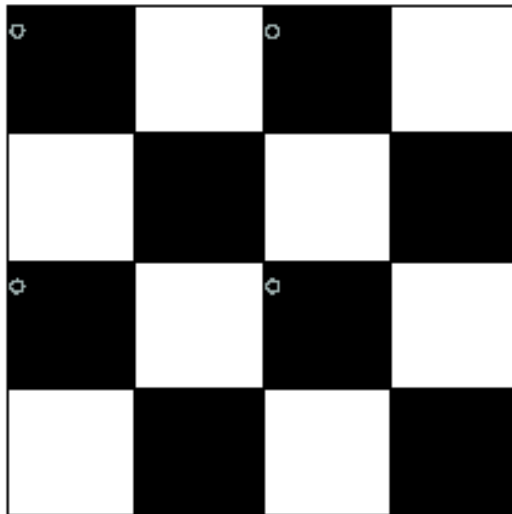
G $1/8$

Sampling



Good sampling:

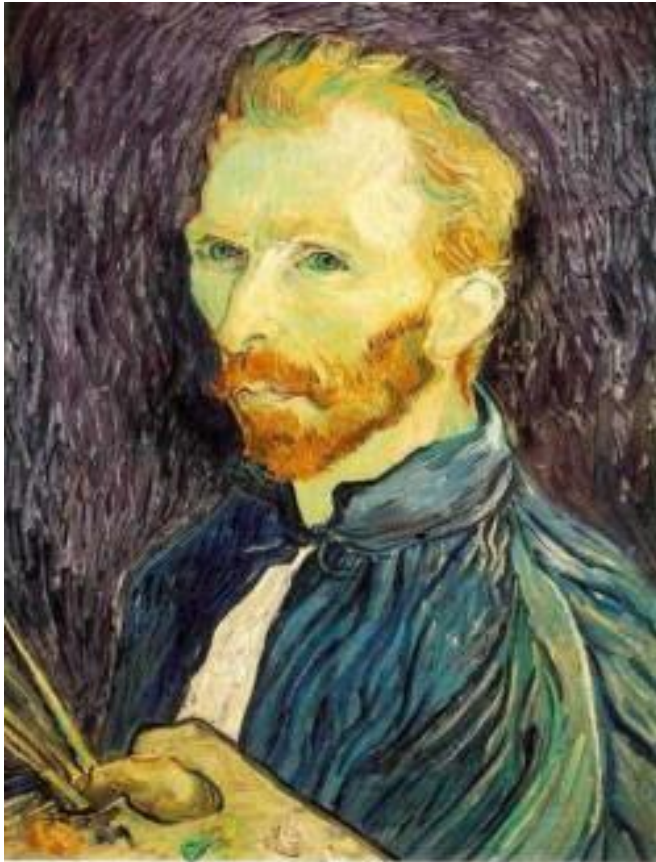
- Sample often or,
- Sample wisely



Bad sampling:

- see aliasing in action!

Gaussian pre-filtering



Gaussian 1/2



G 1/4



G 1/8

- Solution: filter the image, *then* subsample

Keep filters same size

- Change image size
- Scale factor of 2



GAUSSIAN PYRAMID



Practical uses

- **Compression**

- Capture important structures with fewer bytes

- **Denoising**

- Model statistics of pyramid sub-bands

- **Image blending**

Image pyramids

- **Gaussian**
- **Laplacian**



0

GAUSSIAN PYRAMID



1



2



3



4



5

Fig. 4. First six levels of the Gaussian pyramid for the "Lady" image. The original image, level 0, measures 257 by 257 pixels and each higher level array is roughly half the dimensions of its predecessor. Thus, level 5 measures just 9 by 9 pixels.

The Gaussian Pyramid

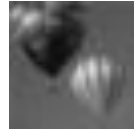
Low resolution



G_4



G_3



G_2



G_1



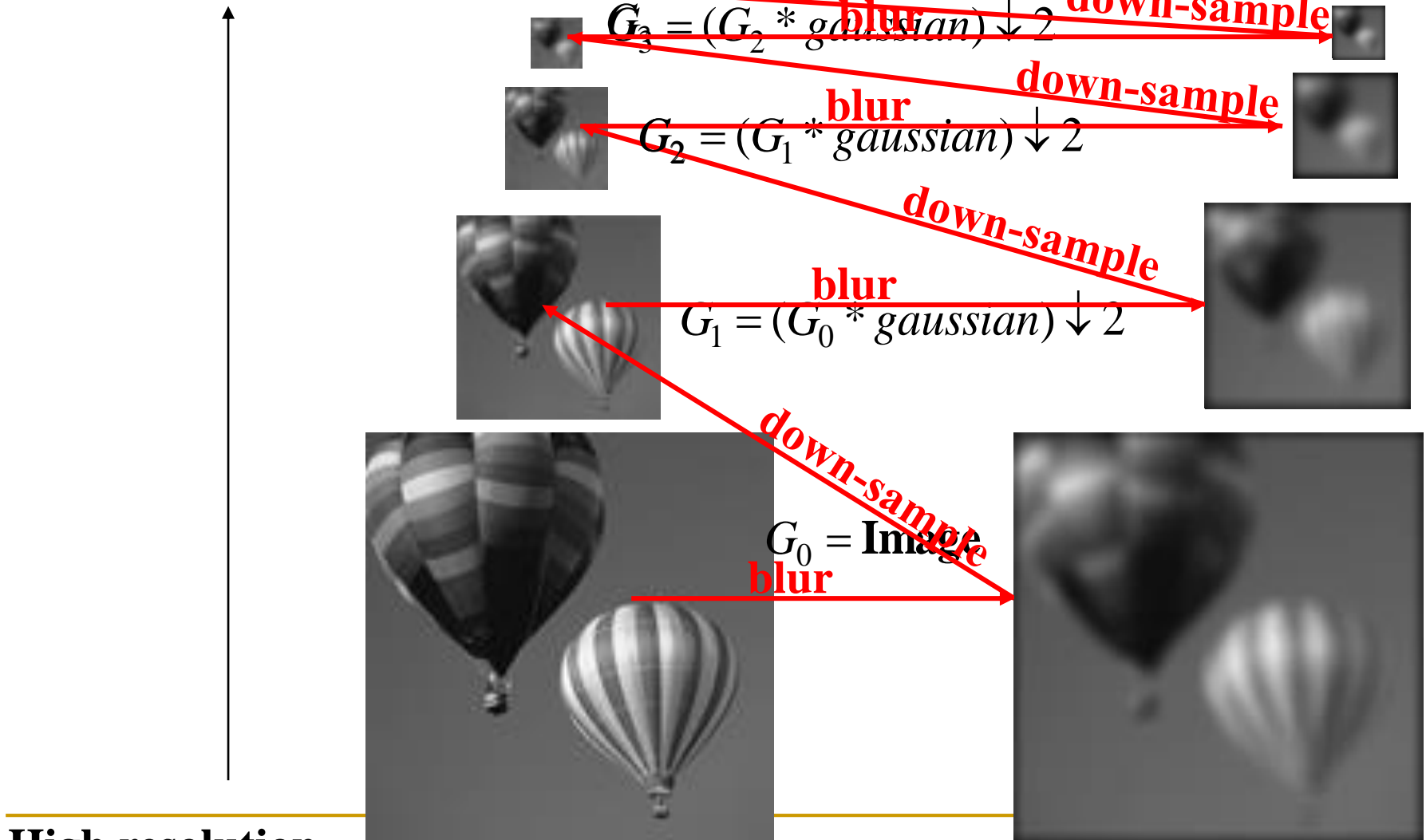
$G_0 = \text{Image}$

High resolution

Image Pyramid

The Gaussian Pyramid

Low resolution



High resolution

Image Pyramid



512

256

128

64

32

16

8



The Laplacian Pyramid

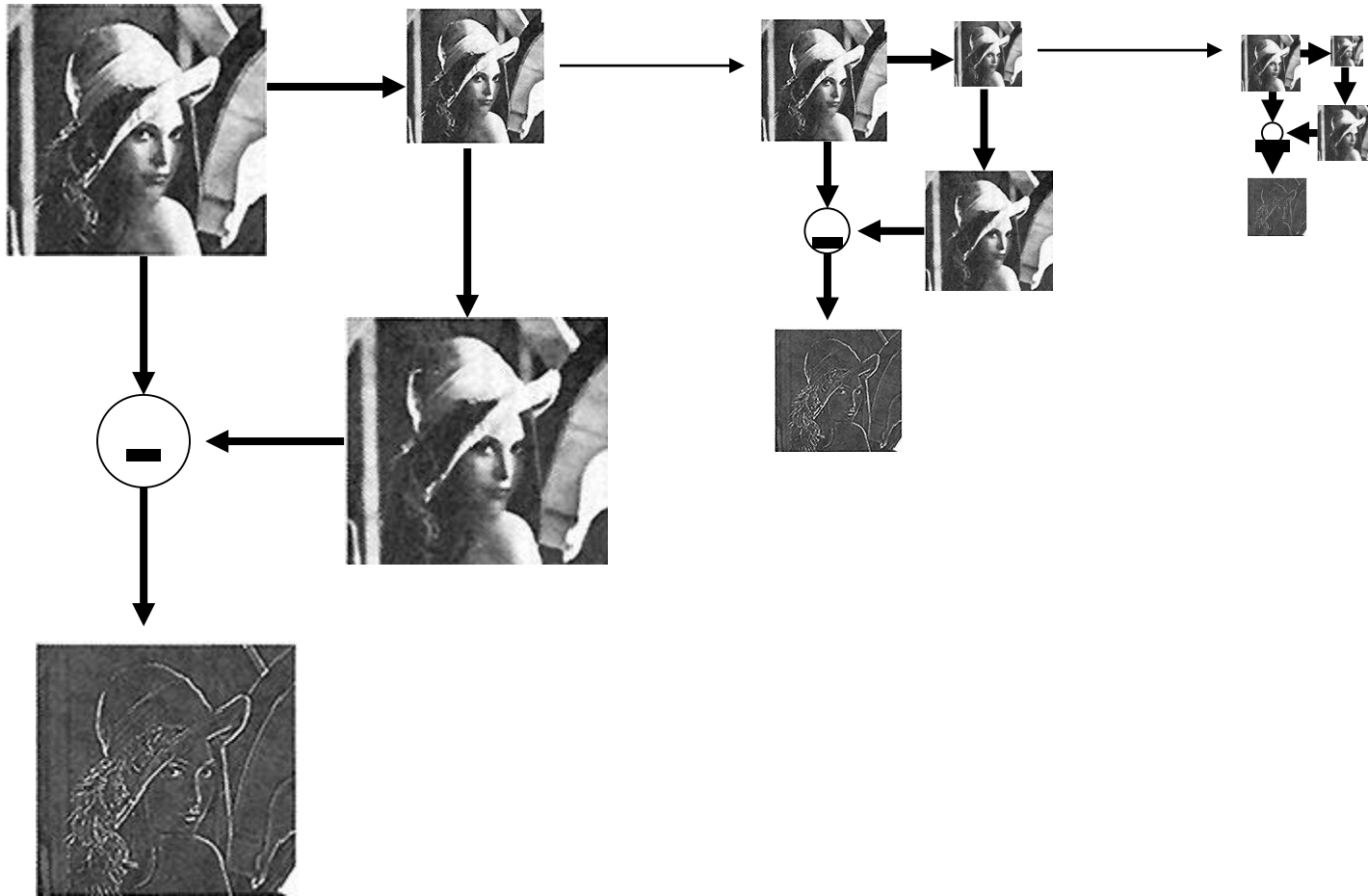
■ Synthesis

- ❑ preserve difference between upsampled Gaussian pyramid level and Gaussian pyramid level
- ❑ band pass filter - each level represents spatial frequencies (largely) unrepresented at other levels

■ Analysis

- ❑ reconstruct Gaussian pyramid, take top layer

Laplacian pyramid algorithm



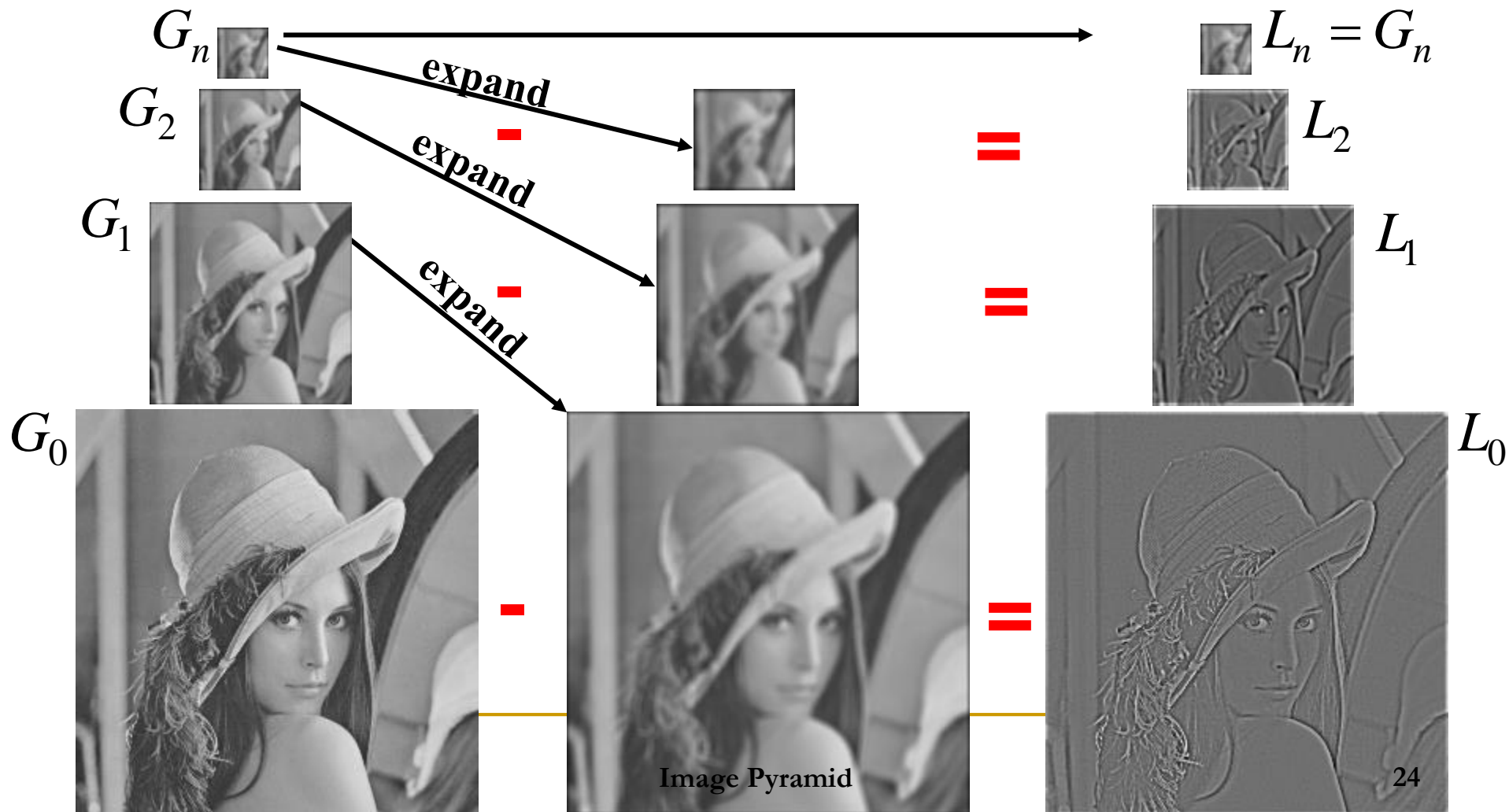
The Laplacian Pyramid

$$L_i = G_i - \text{expand}(G_{i+1})$$

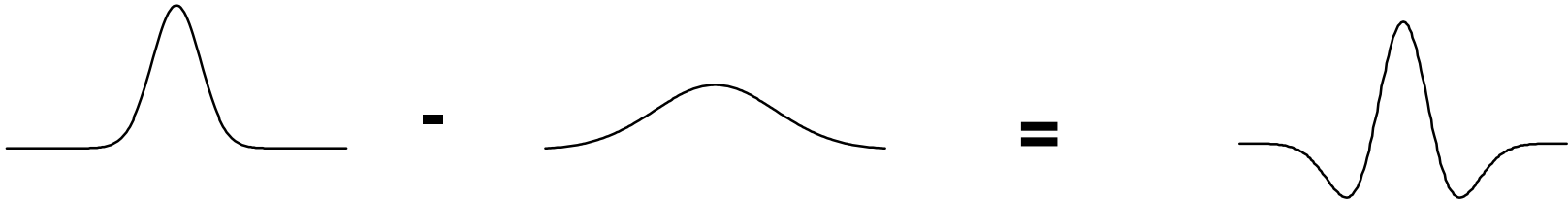
Gaussian Pyramid

$$G_i = L_i + \text{expand}(G_{i+1})$$

Laplacian Pyramid



Laplacian ~ Difference of Gaussians



DOG = Difference Of Gaussians



512

256

128

64

32

16

8





512

256

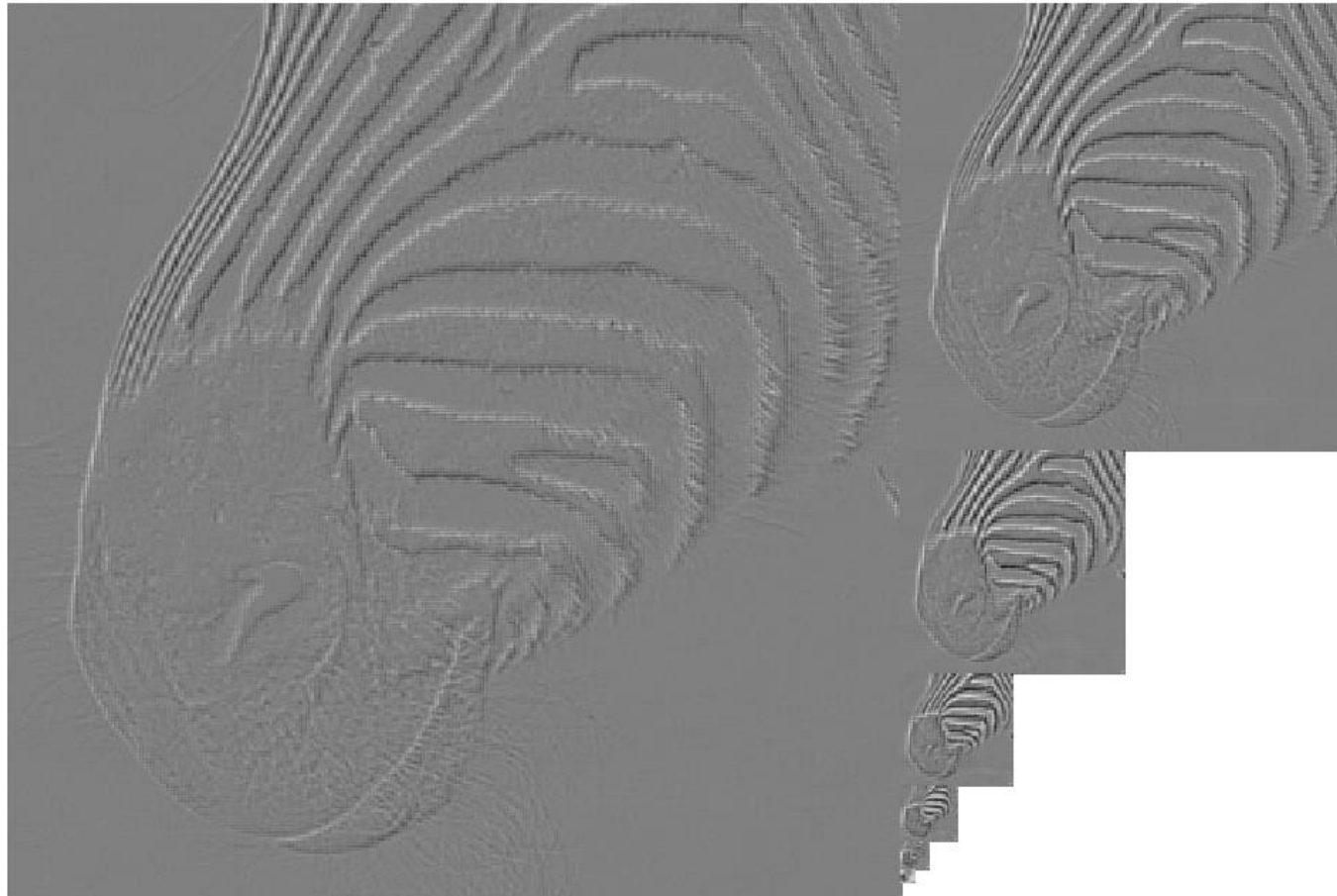
128

64

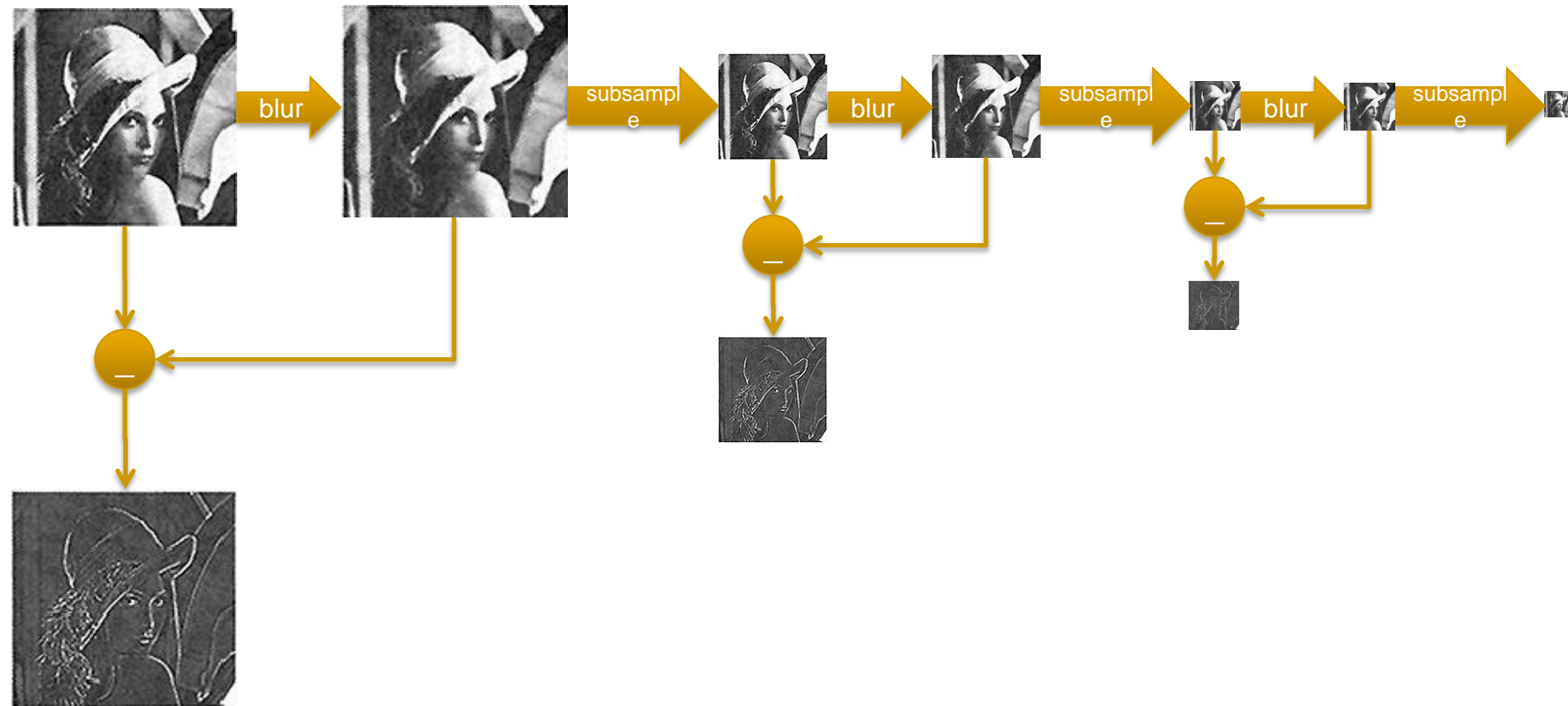
32

16

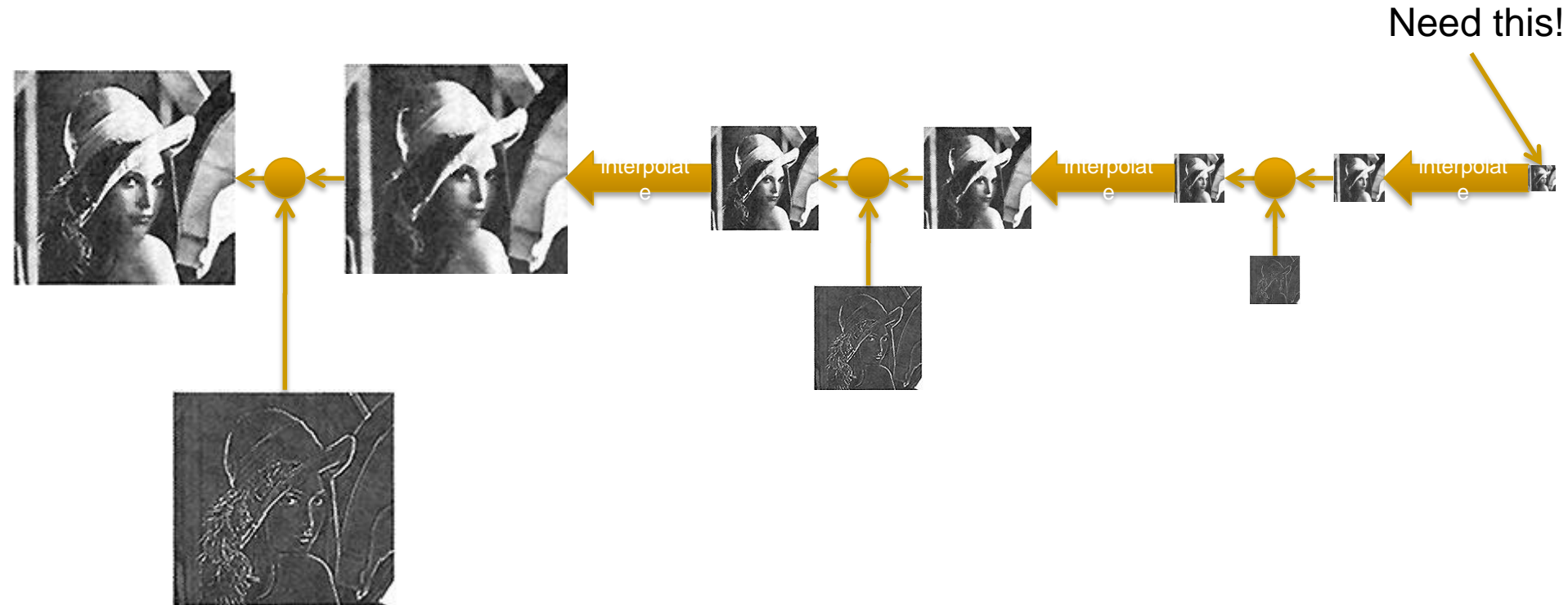
8



Laplacian pyramid algorithm

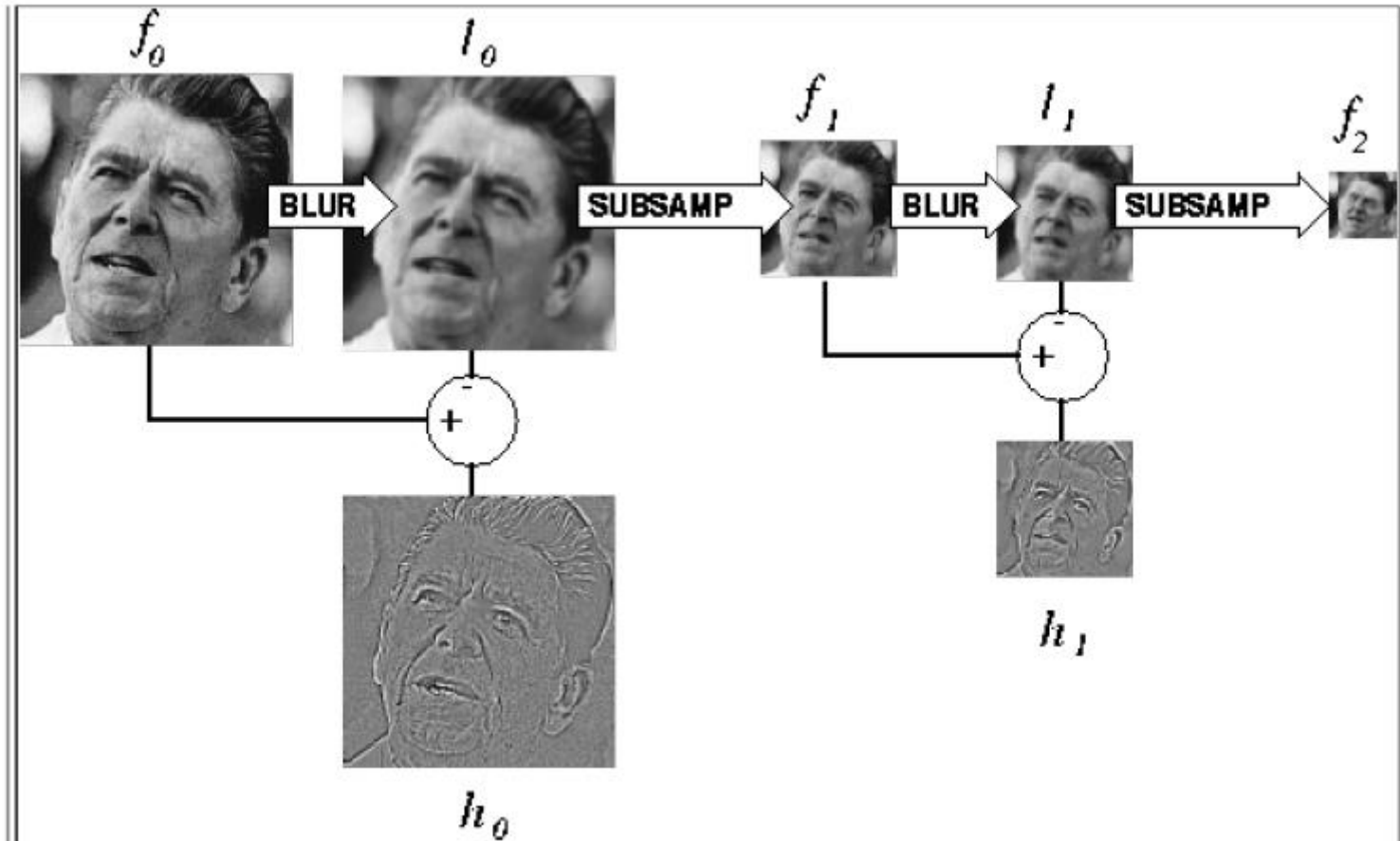


Can we reconstruct the original?



Laplacian Pyramid

Gaussian Pyramid



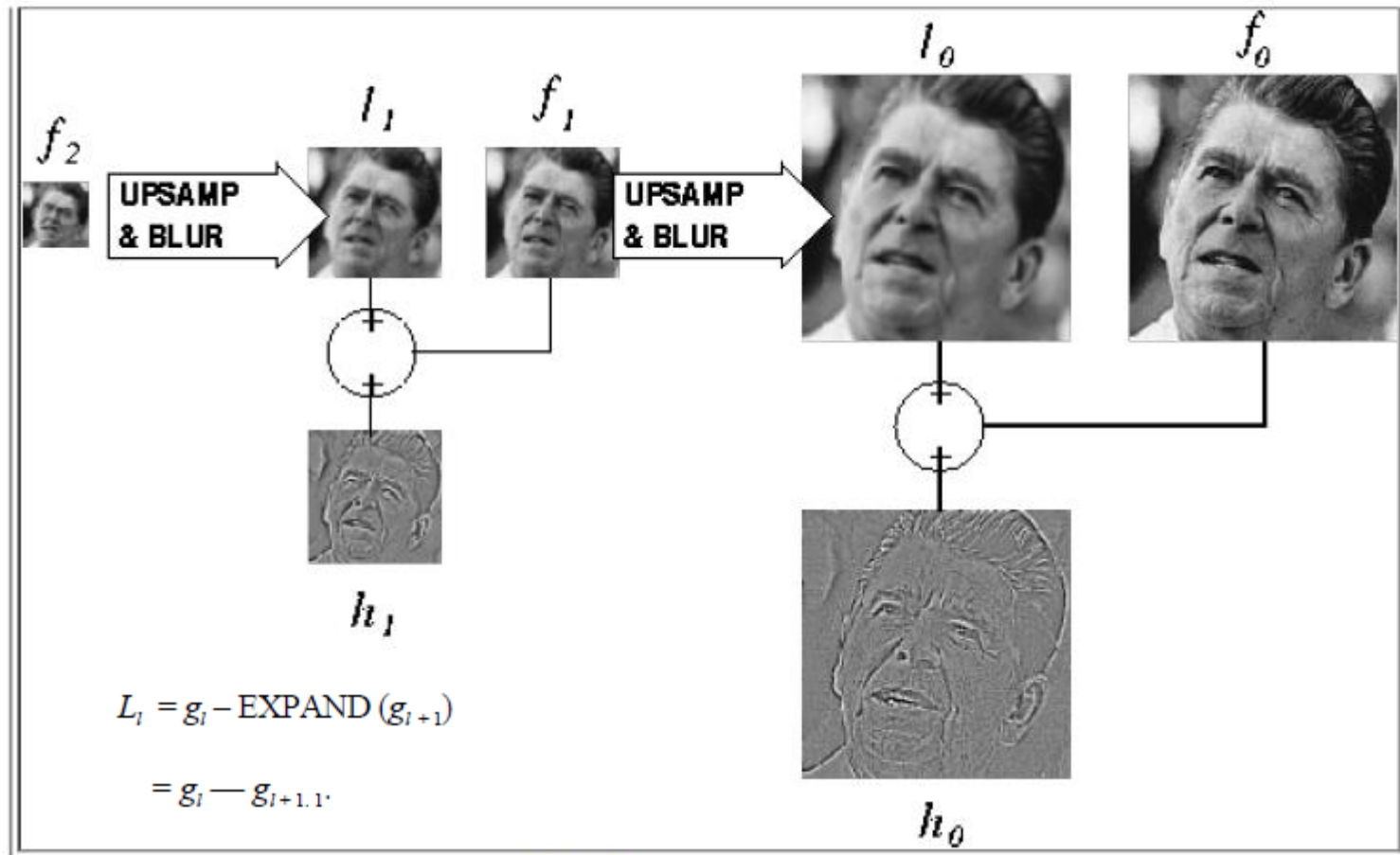
■ Laplacian Pyramid decomposition

- Created from Gaussian pyramid by subtraction

Image Pyramid

Laplacian Pyramid

Gaussian Pyramid



■ Laplacian Pyramid decomposition

- Created from Gaussian pyramid by subtraction
- Image Pyramid

Hybrid Image in Laplacian Pyramid

High frequency \rightarrow Low frequency

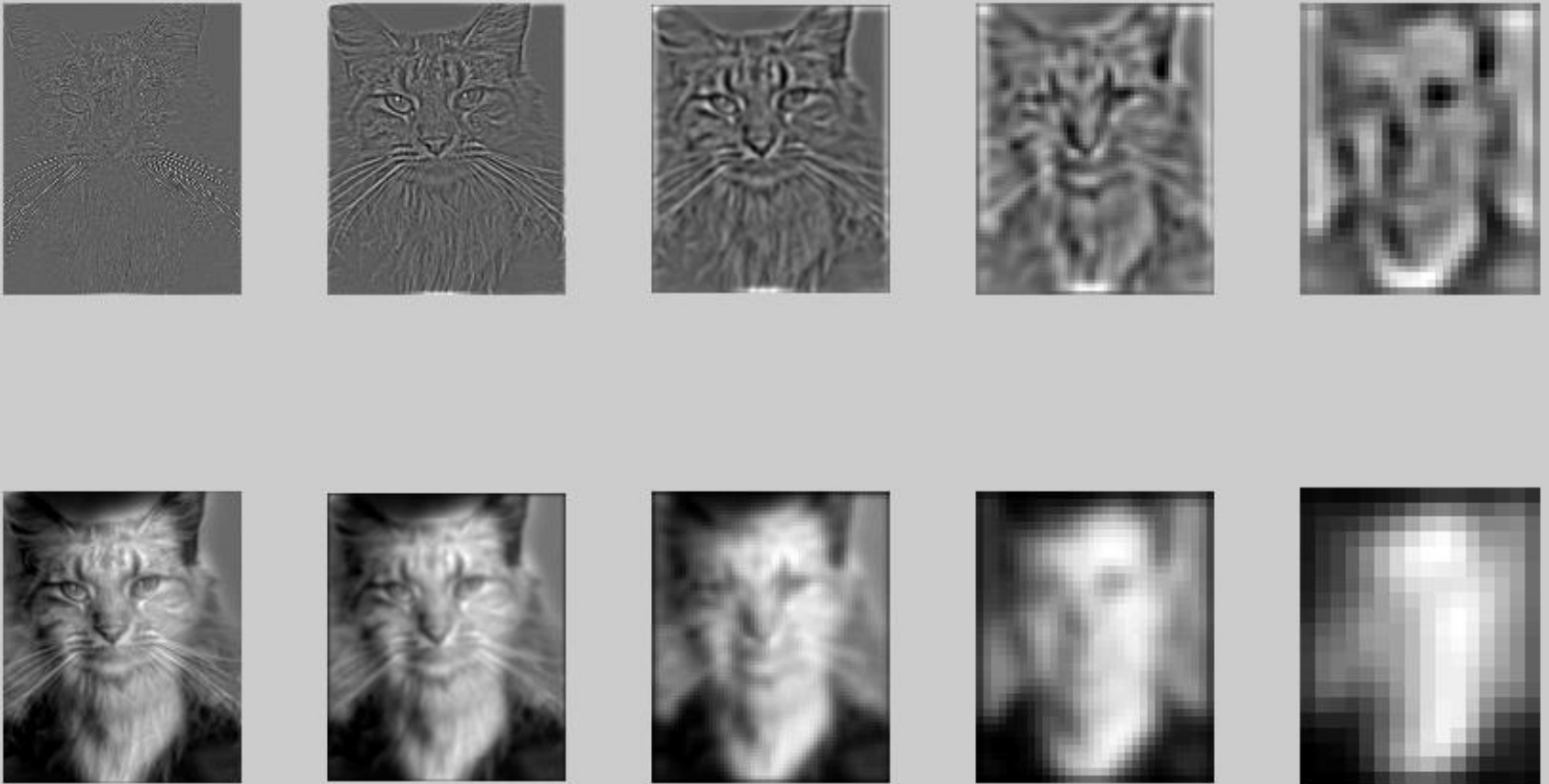


Image Pyramid

Why use these representations?

- **Handle real-world size variations with a constant-size vision algorithm.**
- **Remove noise**
- **Analyze texture**
- **Recognize objects**
- **Label image features**

E. H. Adelson | C. H. Anderson | J. R. Bergen | P. J. Burt | J. M. Ogden

Pyramid methods in image processing

The image pyramid offers a flexible, convenient multiresolution format that mirrors the multiple scales of processing in the human visual system.

Image Blending

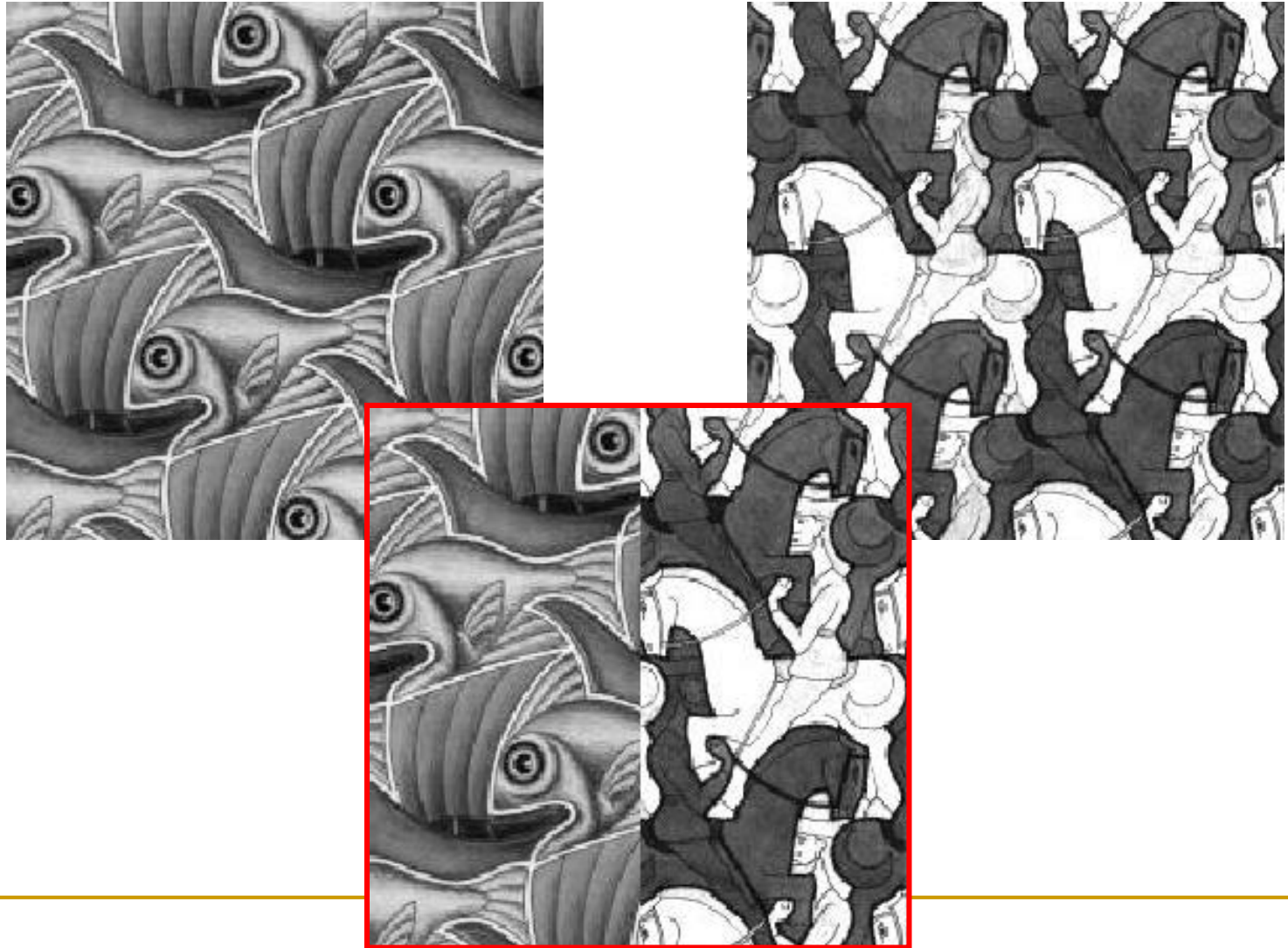
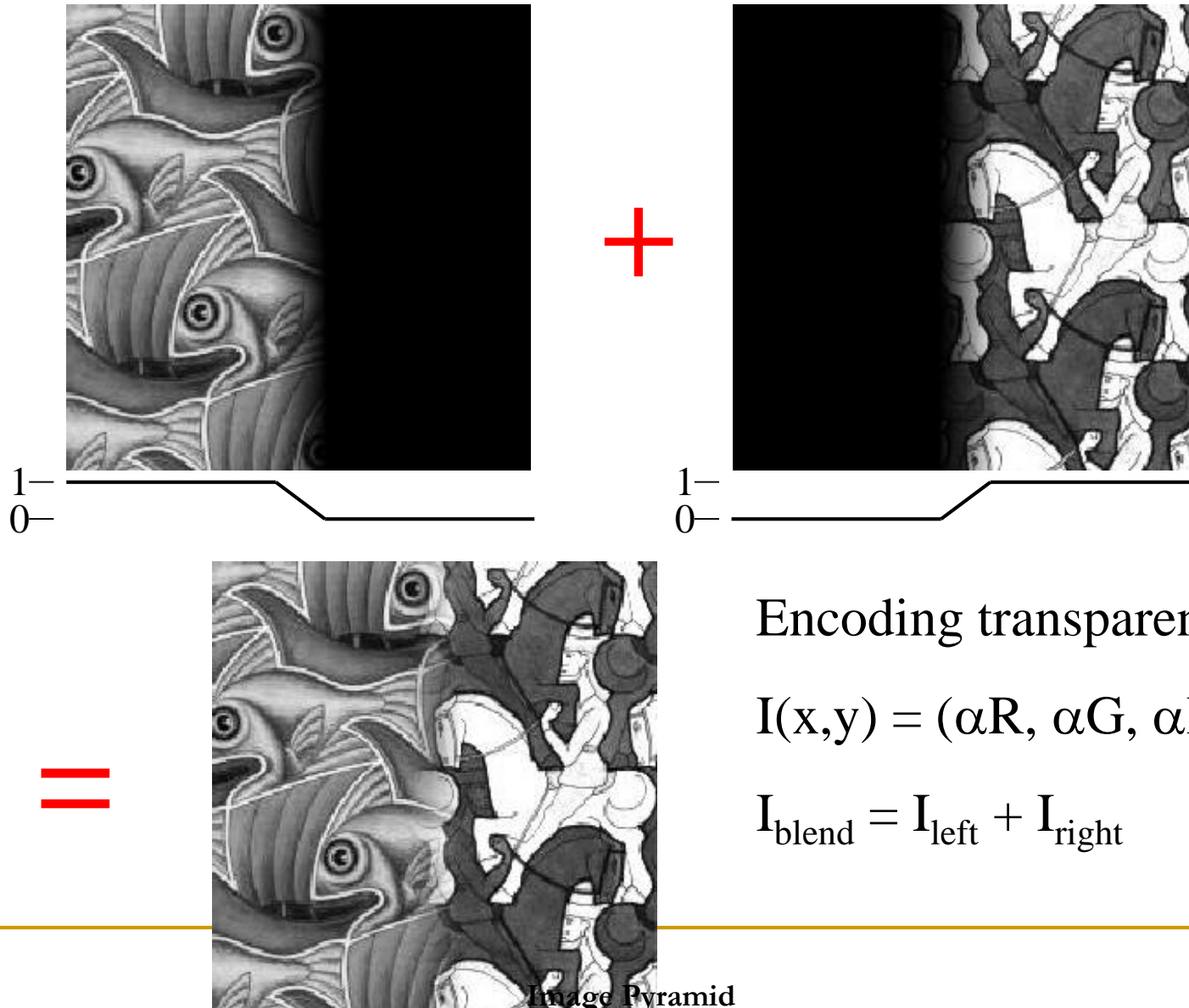


Image Pyramid

Feathering

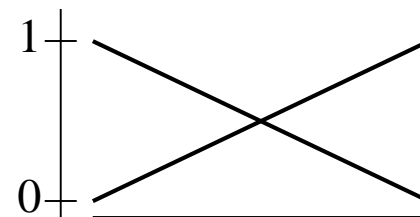
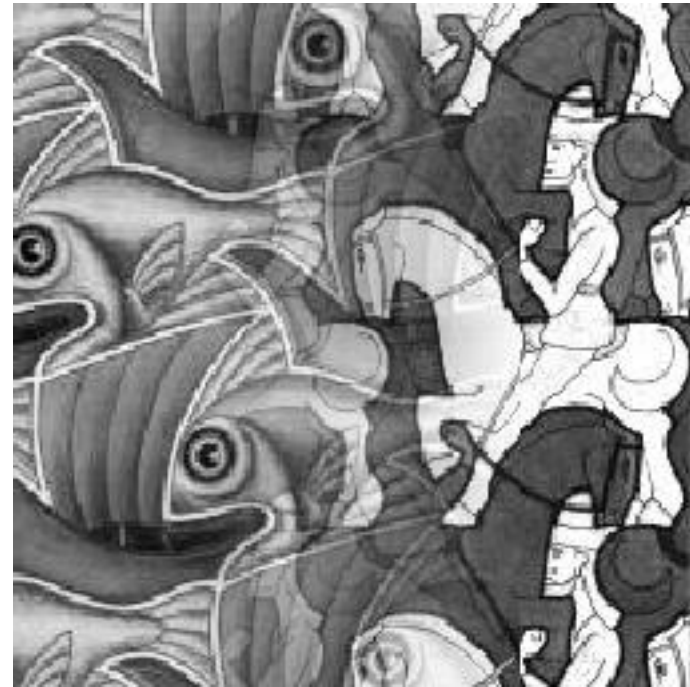
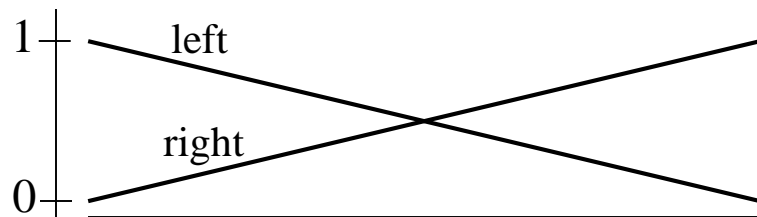


Encoding transparency

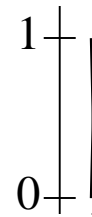
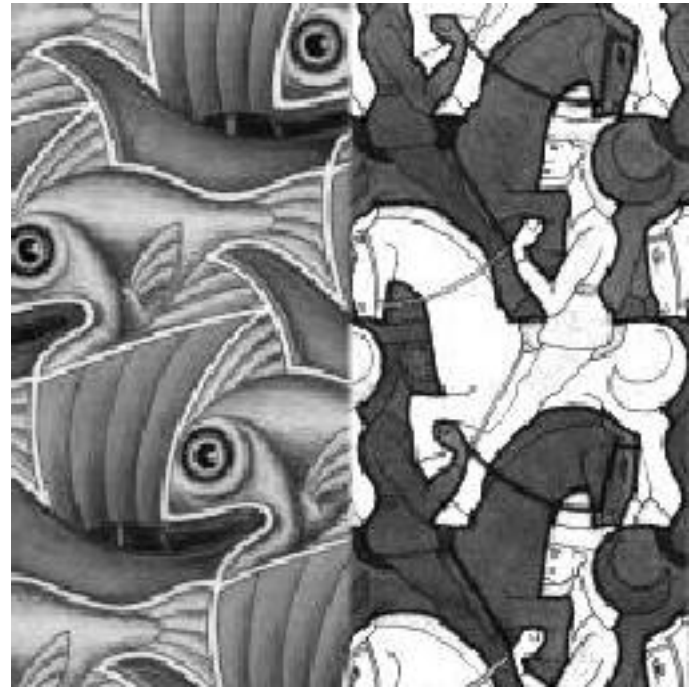
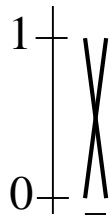
$$I(x,y) = (\alpha R, \alpha G, \alpha B, \alpha)$$

$$I_{\text{blend}} = I_{\text{left}} + I_{\text{right}}$$

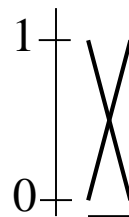
Affect of Window Size



Affect of Window Size

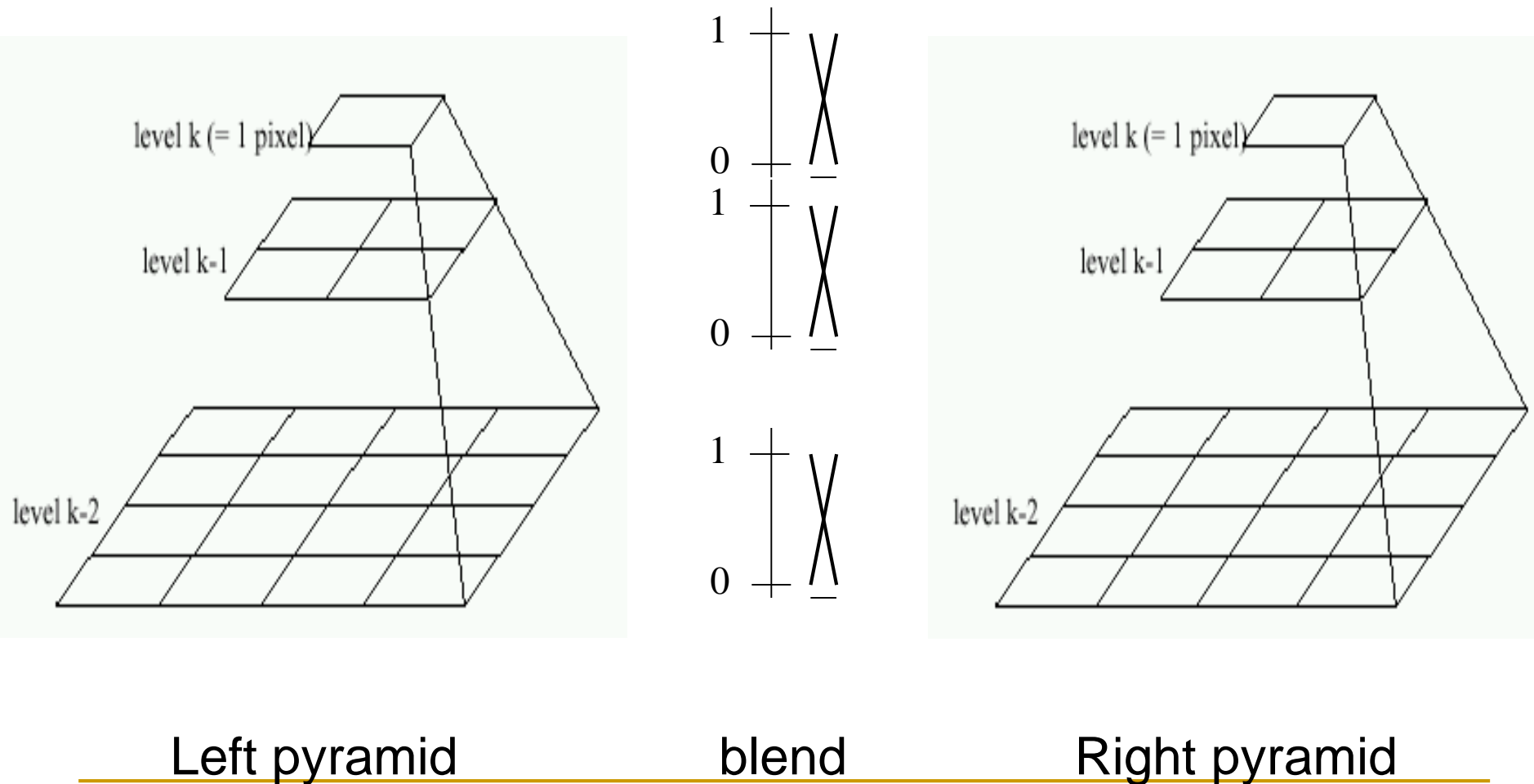


Good Window Size

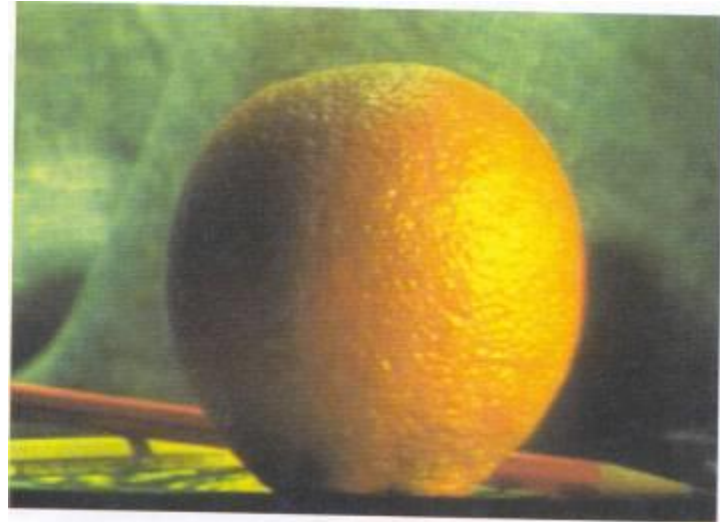


“Optimal” Window: smooth but not ghosted

Pyramid Blending



Pyramid Blending



(d)



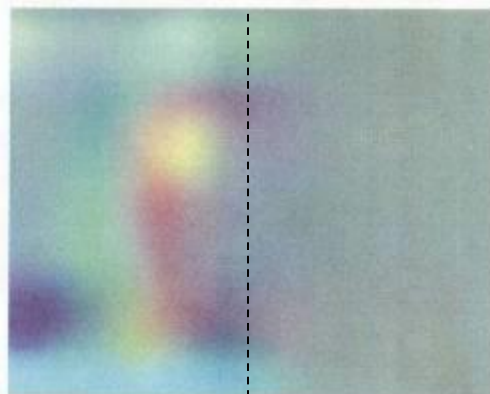
(h)



(l)

Image Pyramid

laplacian
level
4



(c)

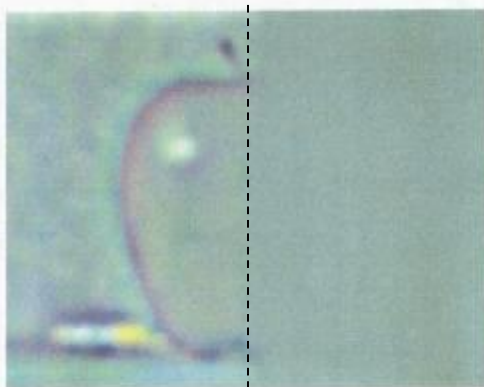


(g)

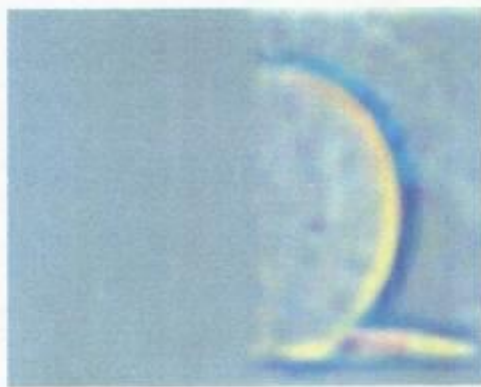


(k)

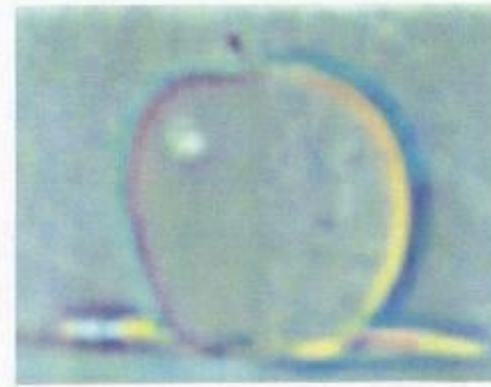
laplacian
level
2



(b)

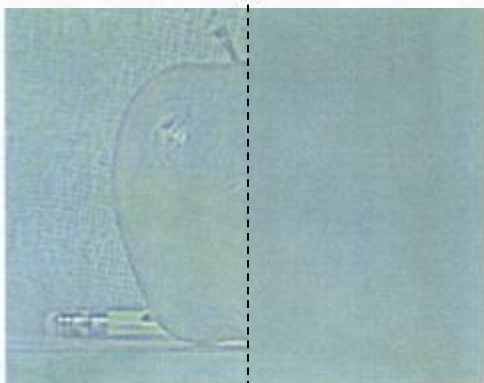


(f)

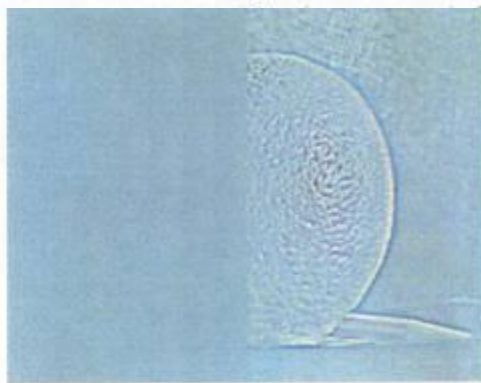


(j)

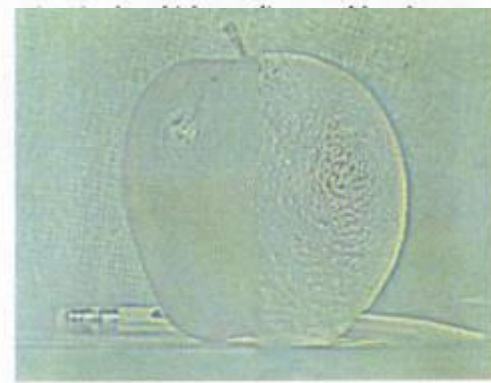
laplacian
level
0



(a)



(e)



(i)

left pyramid

right pyramid

blended pyramid

Laplacian Pyramid: Region Blending

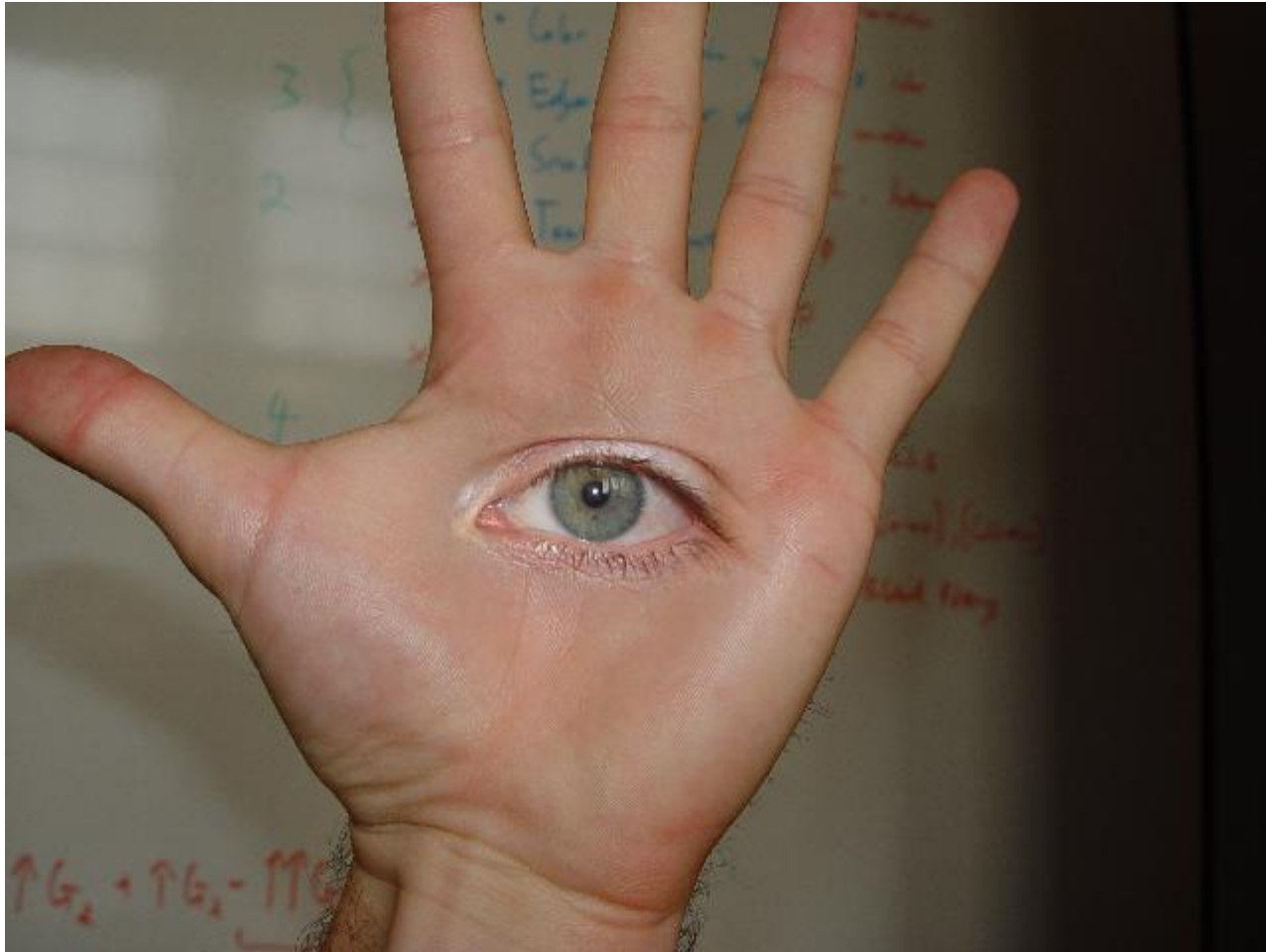
General Approach:

1. Build Laplacian pyramids LA and LB from images A and B
2. Build a Gaussian pyramid GR from selected region R
3. Form a combined pyramid LS from LA and LB using nodes of GR as weights:
 - $LS(i,j) = GR(i,j) * LA(i,j) + (1 - GR(i,j)) * LB(i,j)$
4. Collapse the LS pyramid to get the final blended image

Blending Regions



Horror Photo



© david dmartin (Boston College)

Image Morphing



[Female Image]



[Male Image]

Image Morphing



[No Blending]



[With Blending]

Season Blending (St. Petersburg)



Image Pyramid

9:13:13 29-OCT-1998

10:24:59 15-NOV-1998