

# Image Pyramids

Computational Photography (CSCI 3240U) & Computer Vision (CSCI 4220U)

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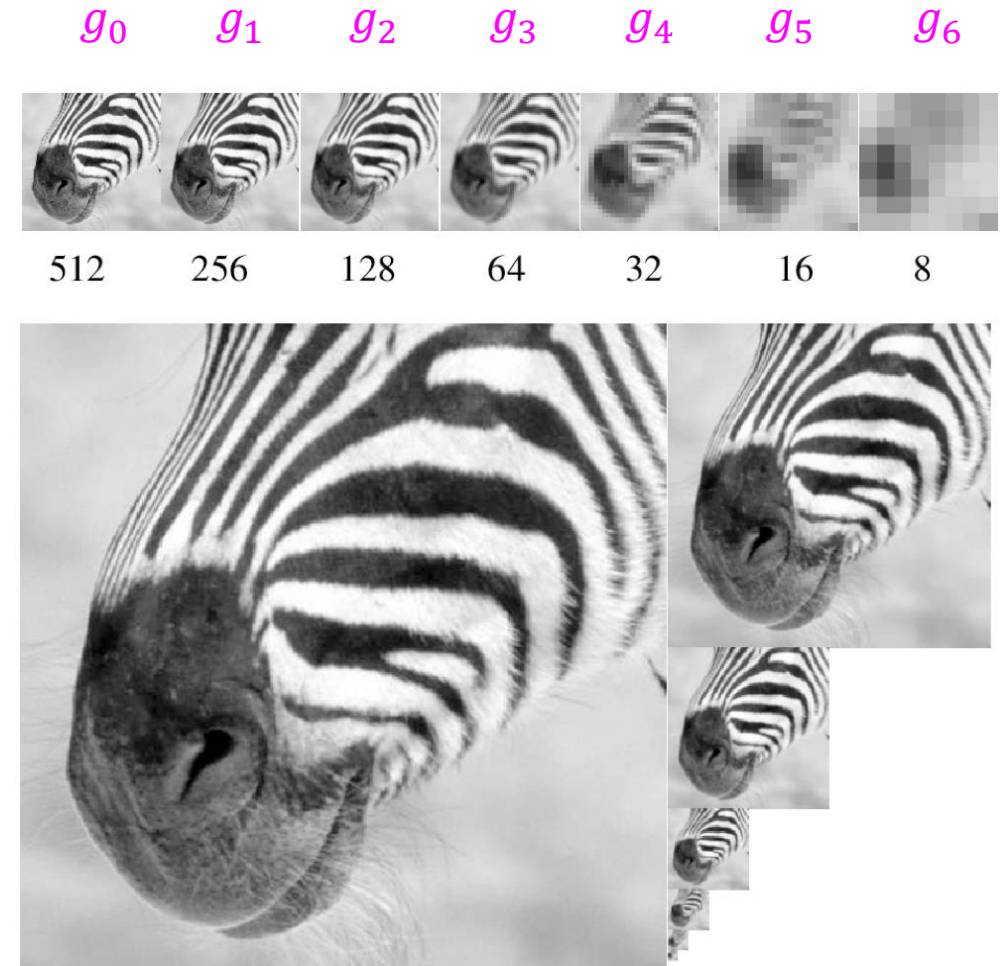


# Today's lecture

- Gaussian image pyramids
- Laplacian image pyramids
- Laplacian blending

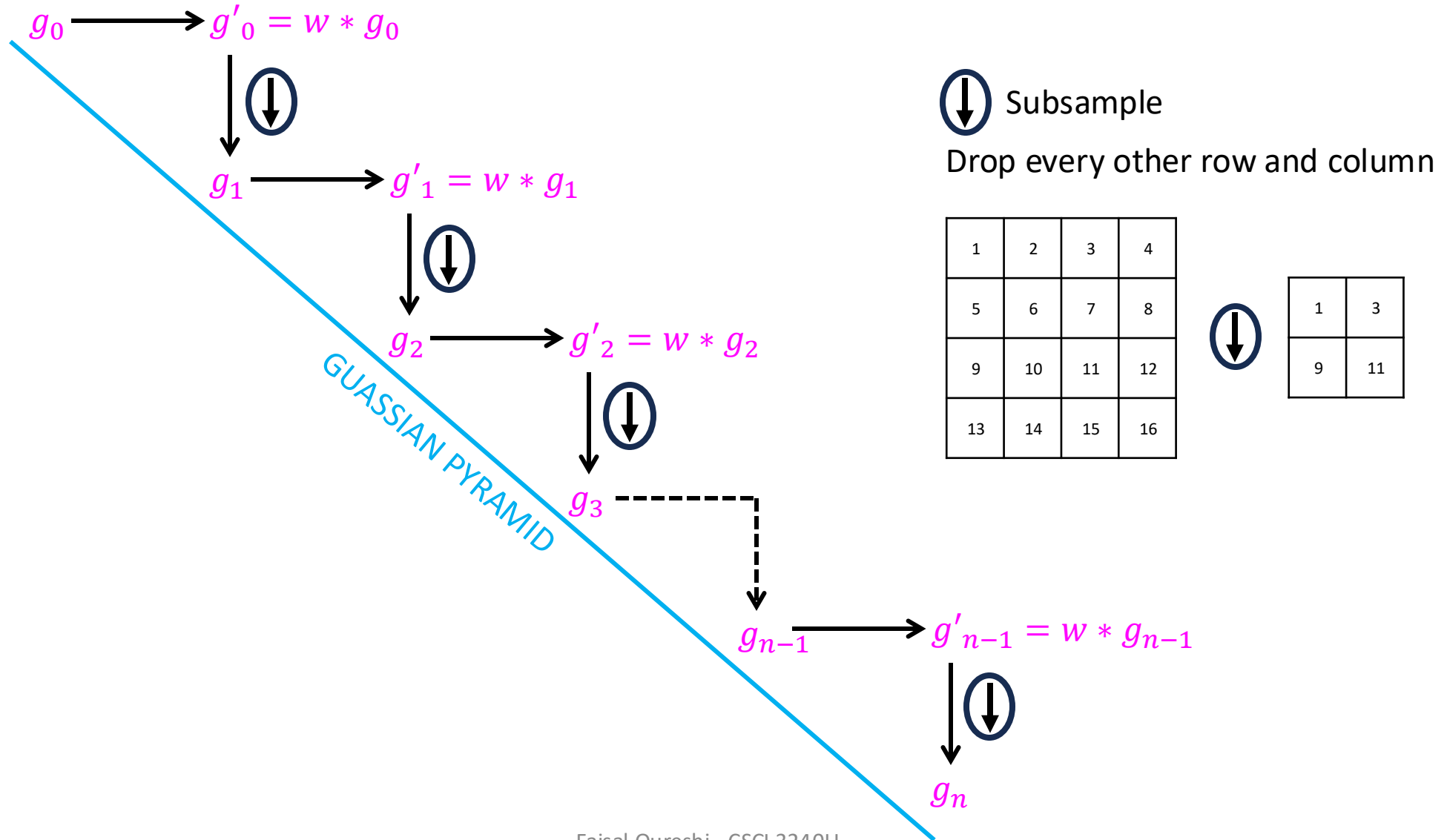
# Gaussian image pyramids

- Blur the image with a Gaussian kernel
- Reduce image dimensions by half
  - Discard every other row and column
- Repeat
  - Till the desired numbers of levels have been reached or till the image because 1x1



Courtesy: Forsyth

# Gaussian image pyramids



# Laplace operator

$$\nabla^2 f = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2}$$

Compute the Laplace operator output for the shaded pixel

$I =$

1	1	9	8	1
8	8	8	8	8
1	3	5	8	1
5	3	2	8	6

**Sobel**

$$H_x = \begin{bmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{bmatrix}$$

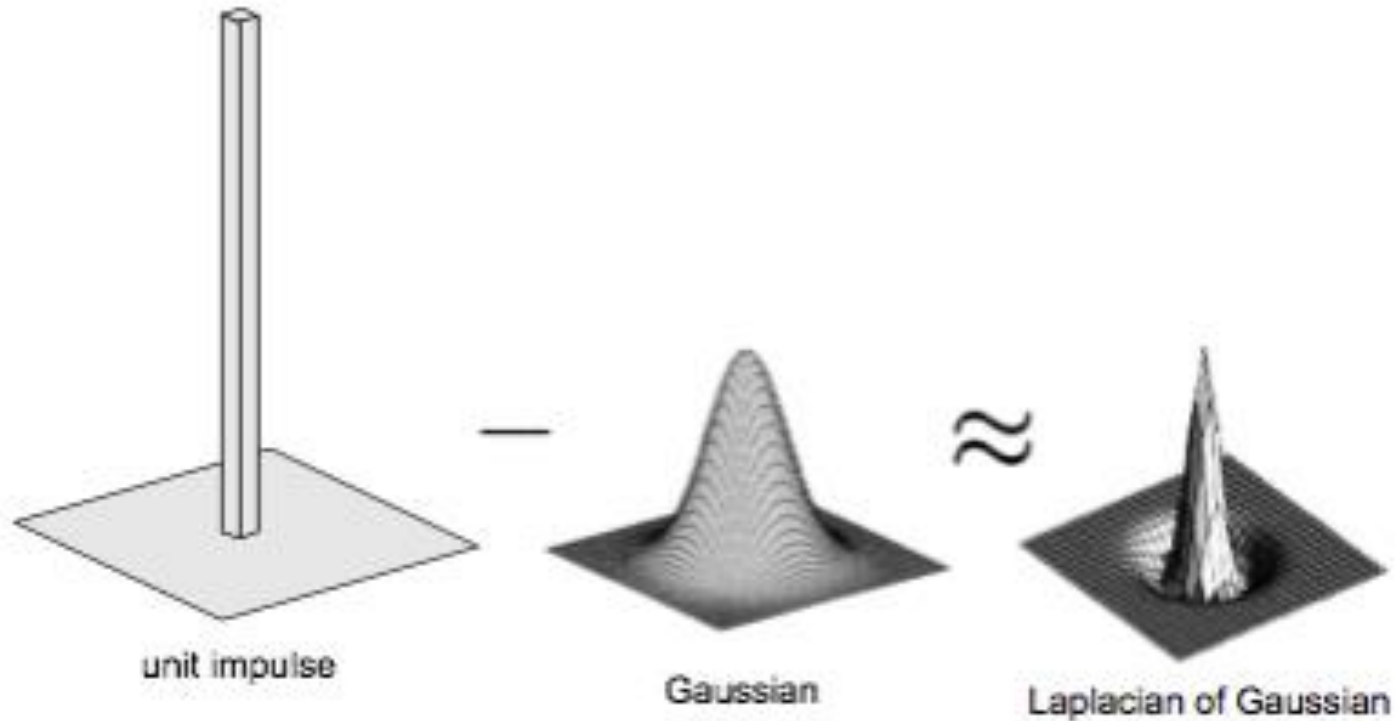
$$H_y = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}$$

**3x3 Gaussian kernel (approx.)**

$$G = 1/16 \begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix}$$

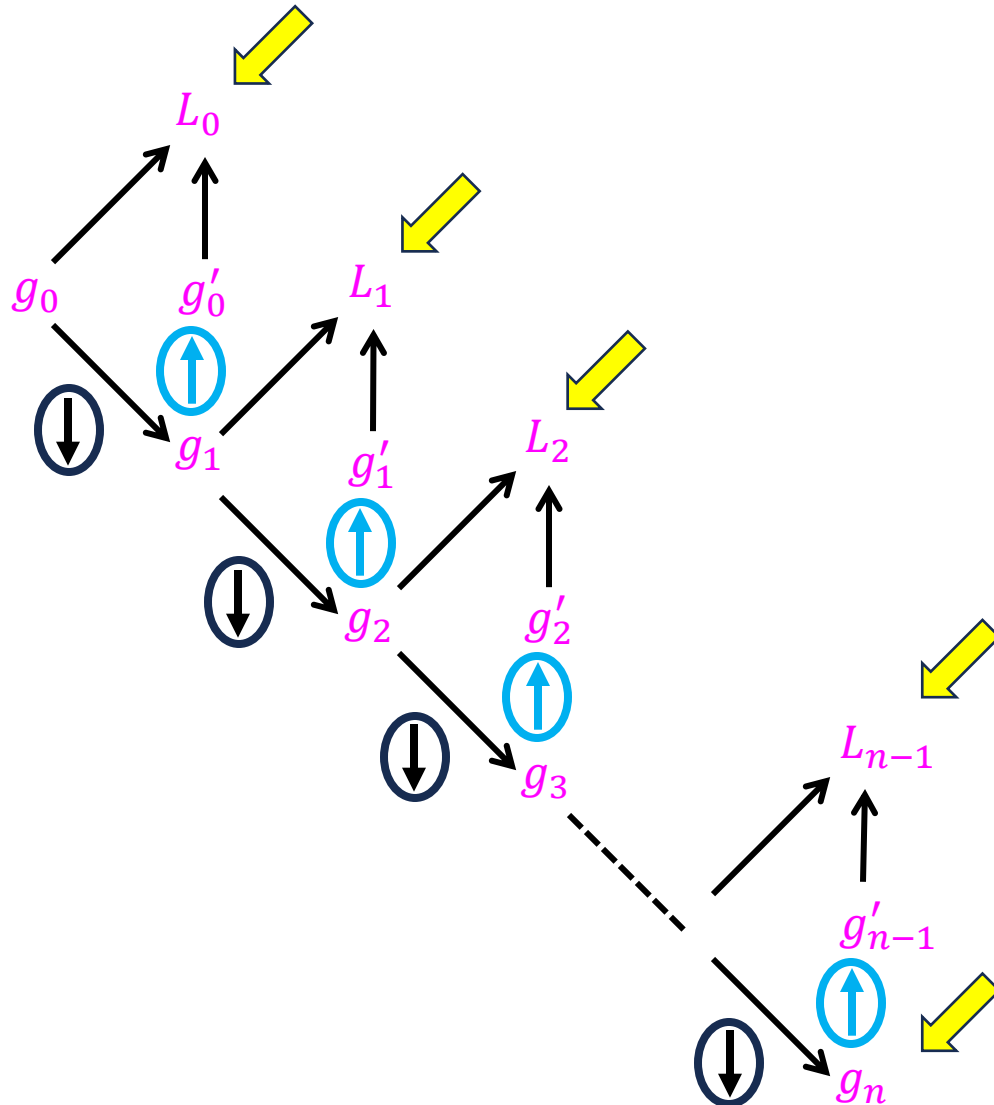
# Laplacian of a Gaussian

We can approximate the Laplacian of a Gaussian as follows



Source: Lazebnik

# Laplacian image pyramids



## Pyramid Down

1.  $\tilde{g}_i = w * g_i$
2. Downsample  $\tilde{g}_i$  by dropping every other row or column

## Pyramid Up

1. Upsample  $g_i$  by adding 0 between samples to create  $\tilde{g}_i$
2.  $g'_{i-1} = w * \tilde{g}_i$ . This will fill in the 0s added in the previous step

Pyramid Up

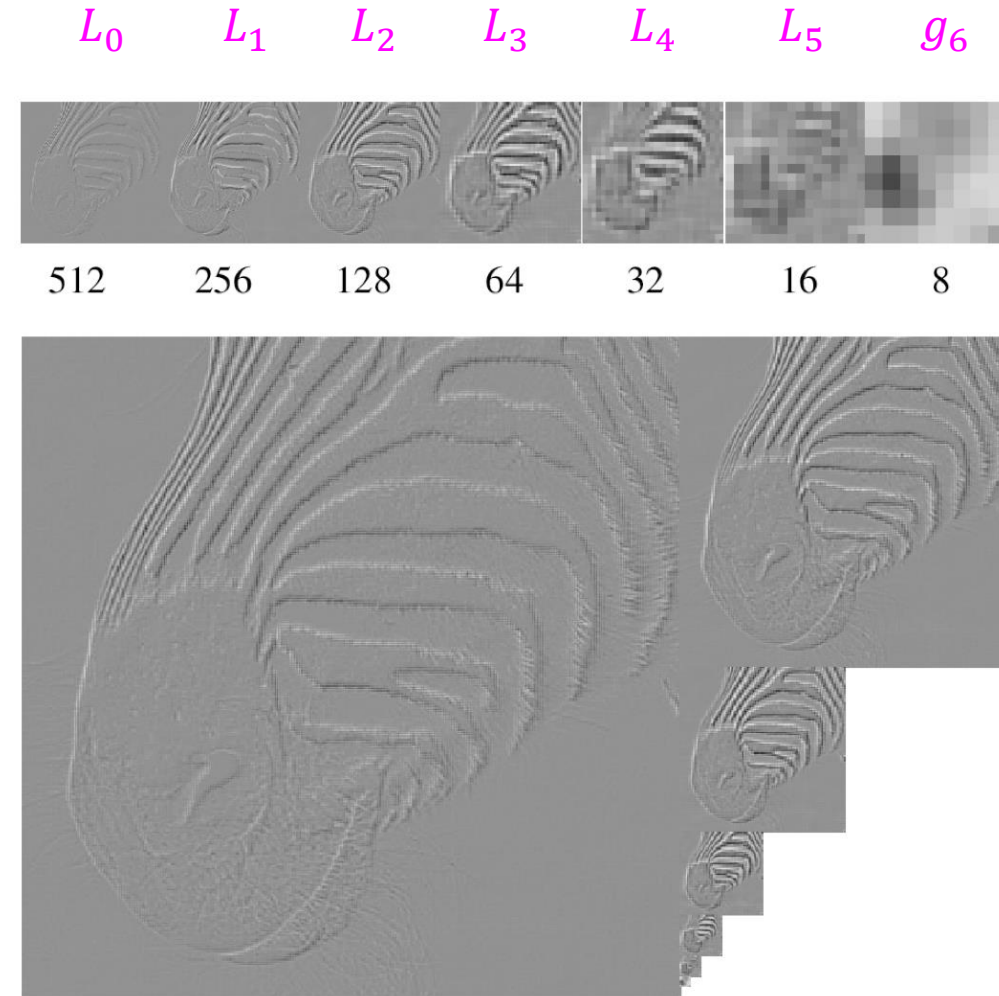
1	0	3	0
0	0	0	0
9	0	7	0
0	0	0	0

1	3
9	7

# Laplacian image pyramid

Given image  $I = g_0$

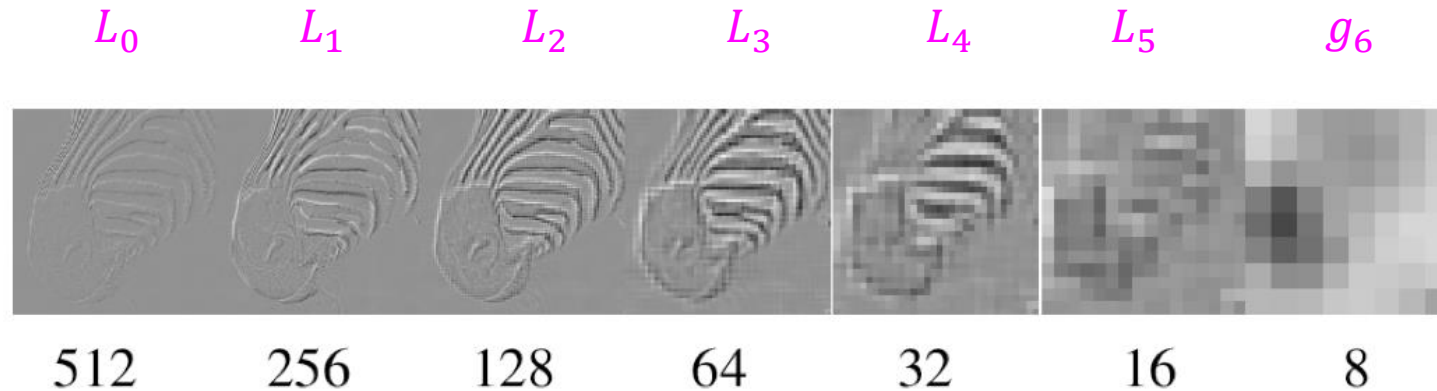
- Convolve  $g_i$  with low-pass filter  $w$  and down-sample by half to construct  $g_{i+1}$ 
  - Downsample by discarding every other row and column
- Upsample  $g_{i+1}$  by double by inserting 0s and interpolating the missing values by convolving it with  $w$  and create  $g'_i$
- Compute  $L_i = g_i - g'_i$
- Repeat



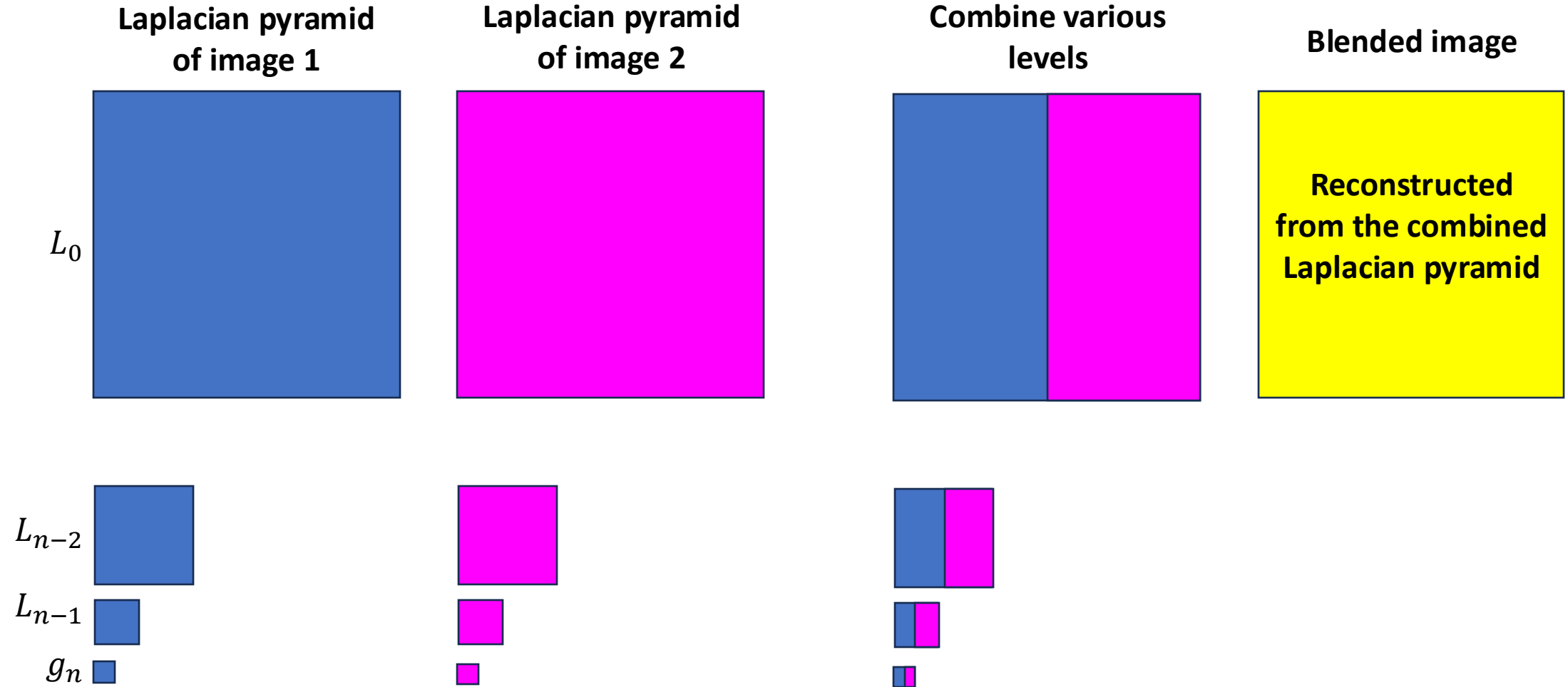


# Reconstructing the original image

- $g_n$  is upsampled by inserting 0s and interpolating the missing value by convolving with  $w$  to get  $g'_{n-1}$
- Compute  $g_{n-1} = g'_{n-1} + L_{n-1}$
- Repeat till  $g_0$



# Laplacian blending



# Uses

- Scale-invariant image analysis
- Template matching
- Image registration
- Image enhancement
- Interest point detection
- Object detection
- Image compression
- ...

# Summary

- Gaussian pyramid
  - Coarse-to-fine search
  - Multi-scale image analysis (hold this thought)
- Laplacian pyramid
  - More compact image representation
  - Can be used for image compositing (computation photography)
- Downsampling
  - Nyquist limit: The Nyquist limit gives us a theoretical limit to what rate we have to sample a signal that contains data at a certain maximum frequency. Once we sample below that limit, not only can we not accurately sample the signal, but the data we get out has corrupting artifacts. These artifacts are "aliases".
  - Need to sufficiently low-pass before downsampling

# Various image representations

- Pixels
  - Great for spatial processing, poor access to frequency
- Fourier transform
  - Great for frequency analysis, poor spatial info
- Pyramids
  - Trade-off between spatial and frequency information