# Computational Photography

* Study the basics of computation and its impact on the entire workflow of photography, from capturing, manipulating and collaborating on, and sharing photographs.

Georgia Tech College of Computing

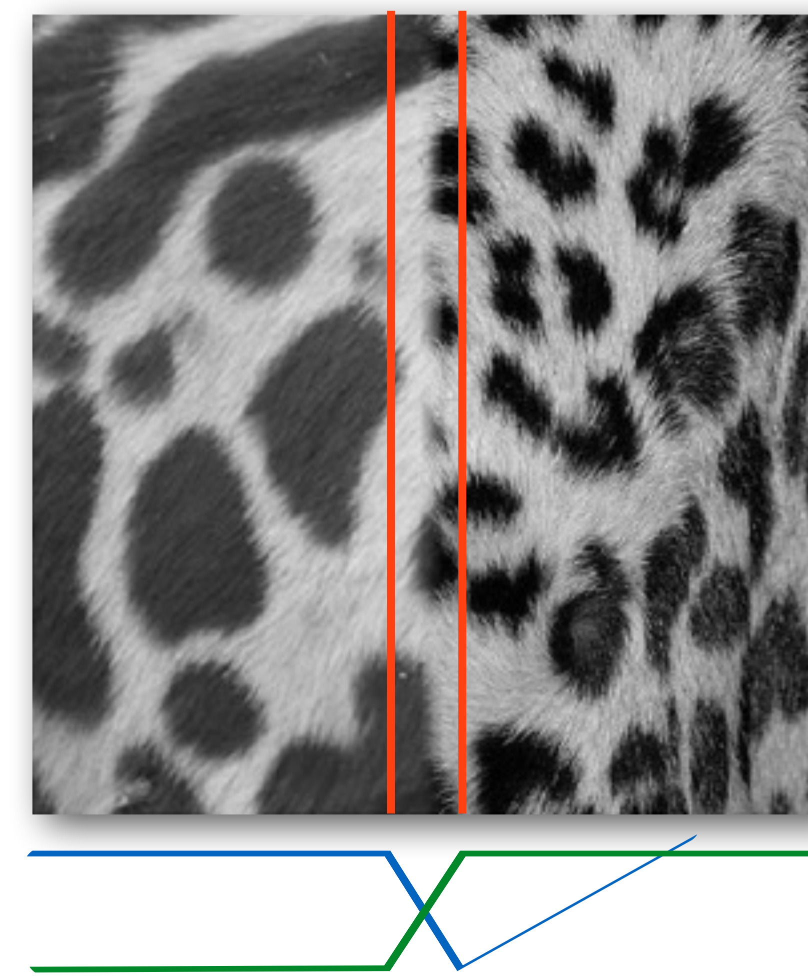
# Digital Images: Merging and Blending Images using Image Pyramids

* Combing multiple Images to Generate a Novel Image: Image Pyramids

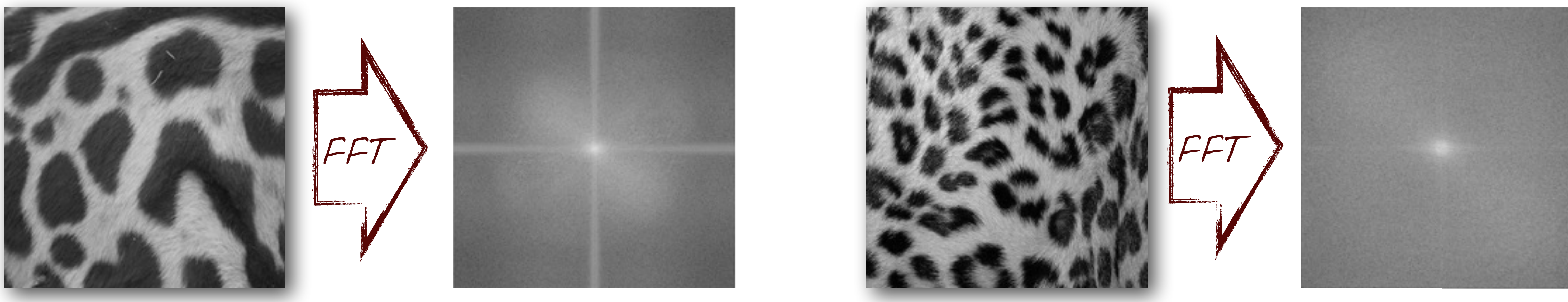

1. Gaussian and the Laplacian Pyramids
2. Use of Pyramids to encode the Frequency domain
3. Compute a Laplacian Pyramid form a Gaussian Pyramid
4. Blend two images using Pyramids

# Recall: Optimal Window Size

* Avoid seams: Window = size of largest prominent "feature"
* Avoid ghosting: Window $\leq 2 \times$ size of smallest prominent "feature"
* Use Fourier domain
  * Largest frequency $\leq 2 \times$ size of smallest frequency
  * Image frequency content should occupy one "octave" (power of two)



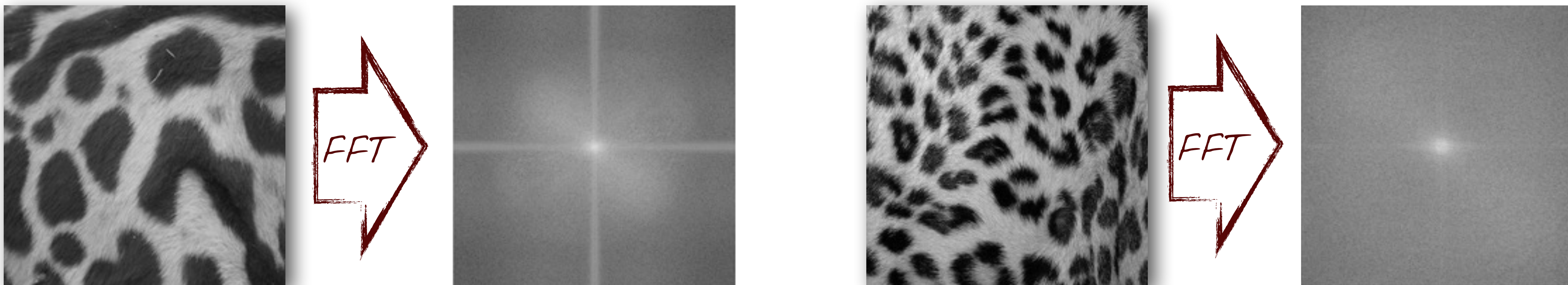
# Recall: Frequency Spread needs to be Modeled




- Compute: $FFT(I_l) \Rightarrow F_l, \quad FFT(I_r) \Rightarrow F_r$
- Decompose Fourier image into octaves (bands)

$$F_l = F_l^1 + F_l^2 + F_l^3 + \ldots, \quad F_r = F_r^1 + F_r^2 + F_r^3 + \ldots$$

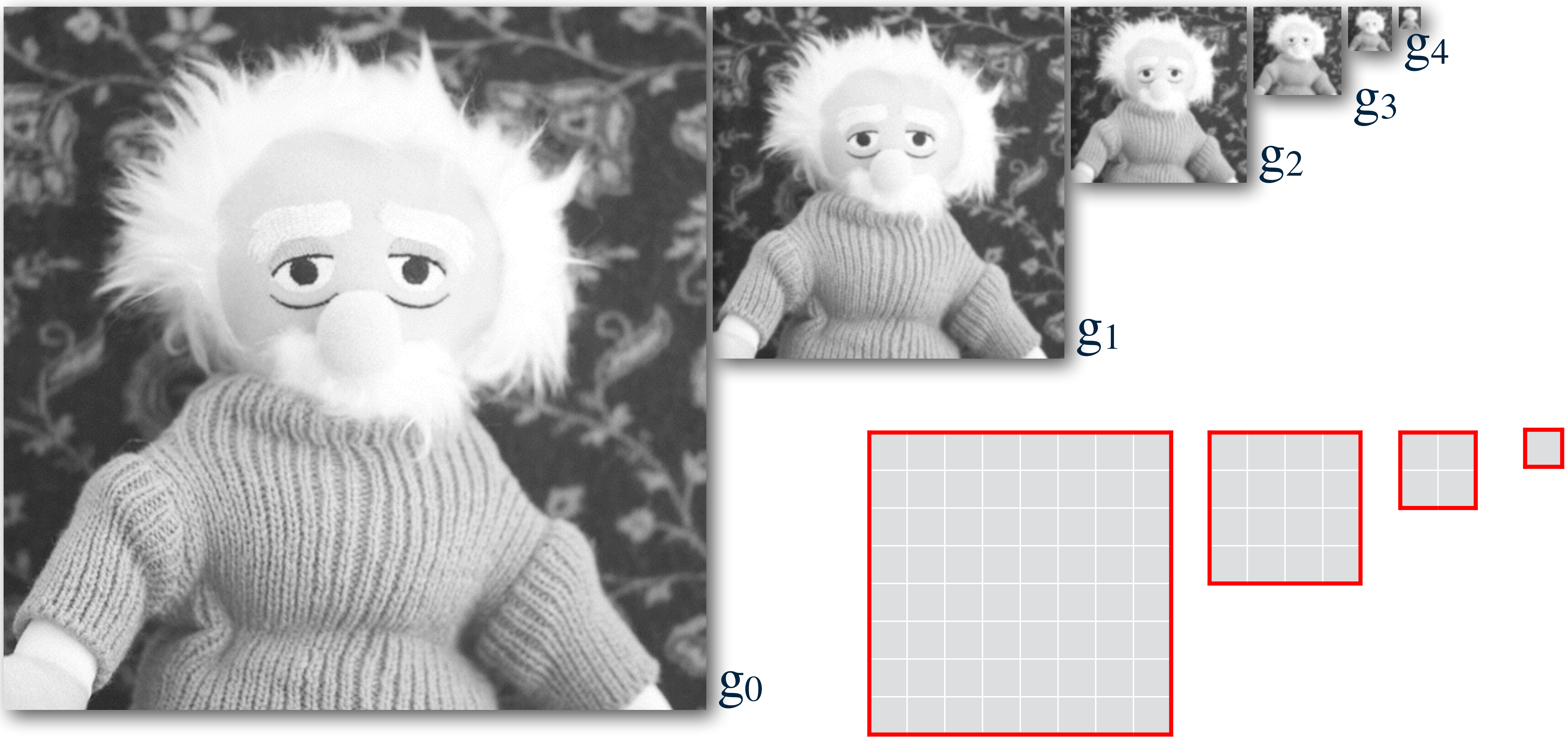
# Recall: Frequency Spread needs to be Modeled



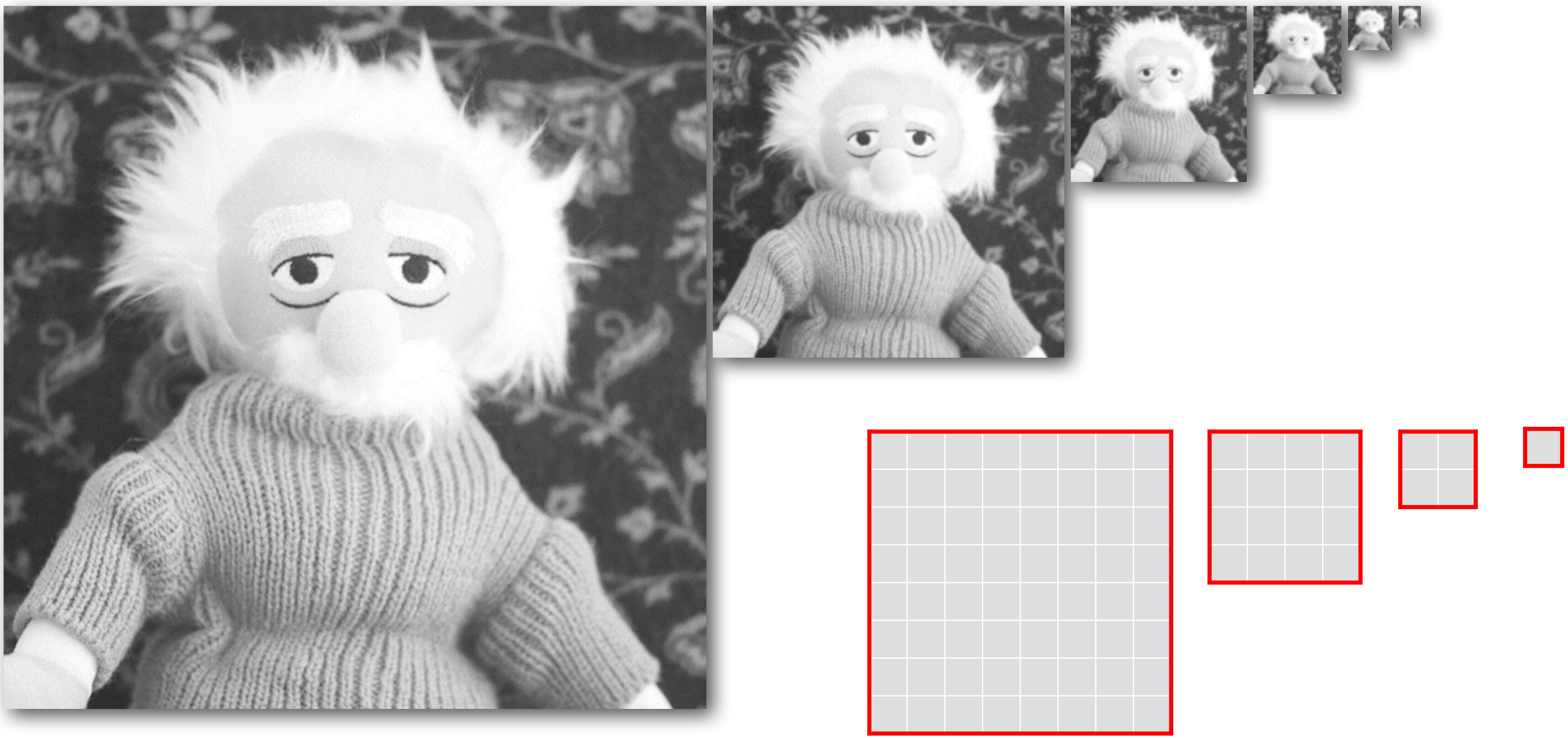

- "Feather" corresponding octaves of: $F_l$ $F_r$
- Compute inverse FFT and feather in spatial domain
- Sum feathered octave images in frequency domain

Burt and Adelson (1983)

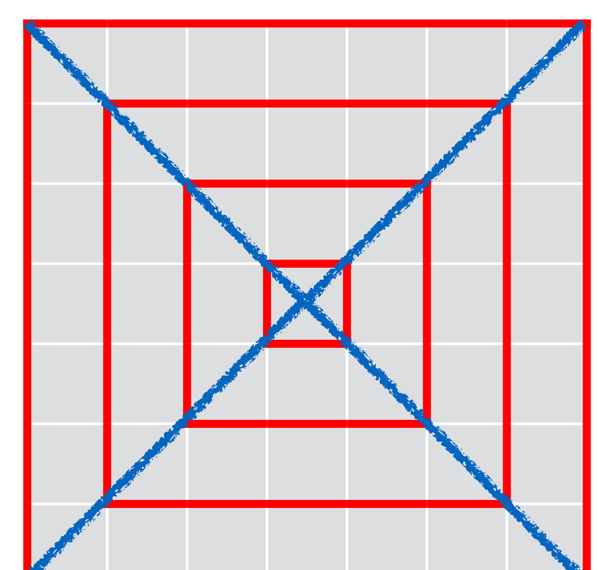
# Pyramid Representation: A Gaussian Pyramid

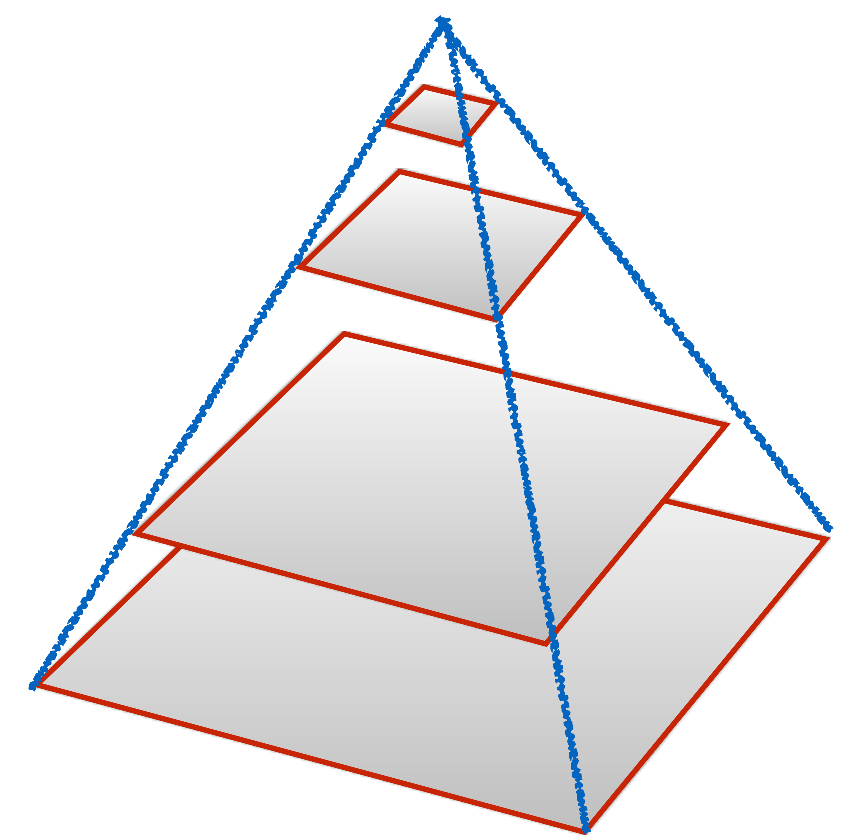


# Pyramid Representation: A Gaussian Pyramid

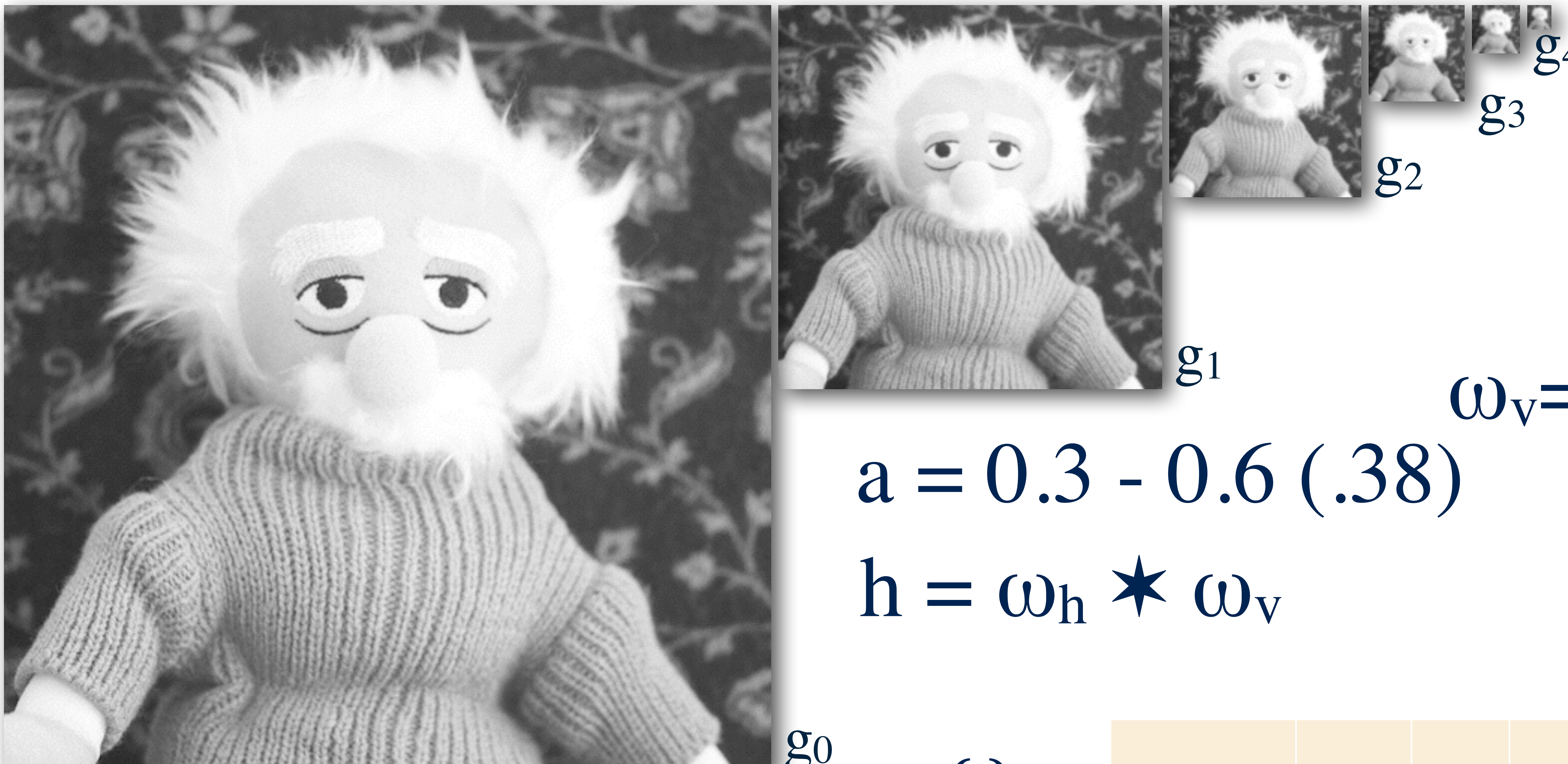


# Pyramid Representation: A Gaussian Pyramid





# Pyramid Representation of Images (A Gaussian Pyramid)




$$a = 0.3 - 0.6\ (.38)$$

$$h = \omega_h \star \omega_v$$

$\omega_v =$

| |
|---|
| 1/4 - a/2 |
| 1/4 |
| a |
| 1/4 |
| 1/4 - a/2 |

$\omega_h =$

| | | | | |
|---|---|---|---|---|
| 1/4 - a/2 | 1/4 | a | 1/4 | 1/4 - a/2 |

Burt and Adelson (1983)

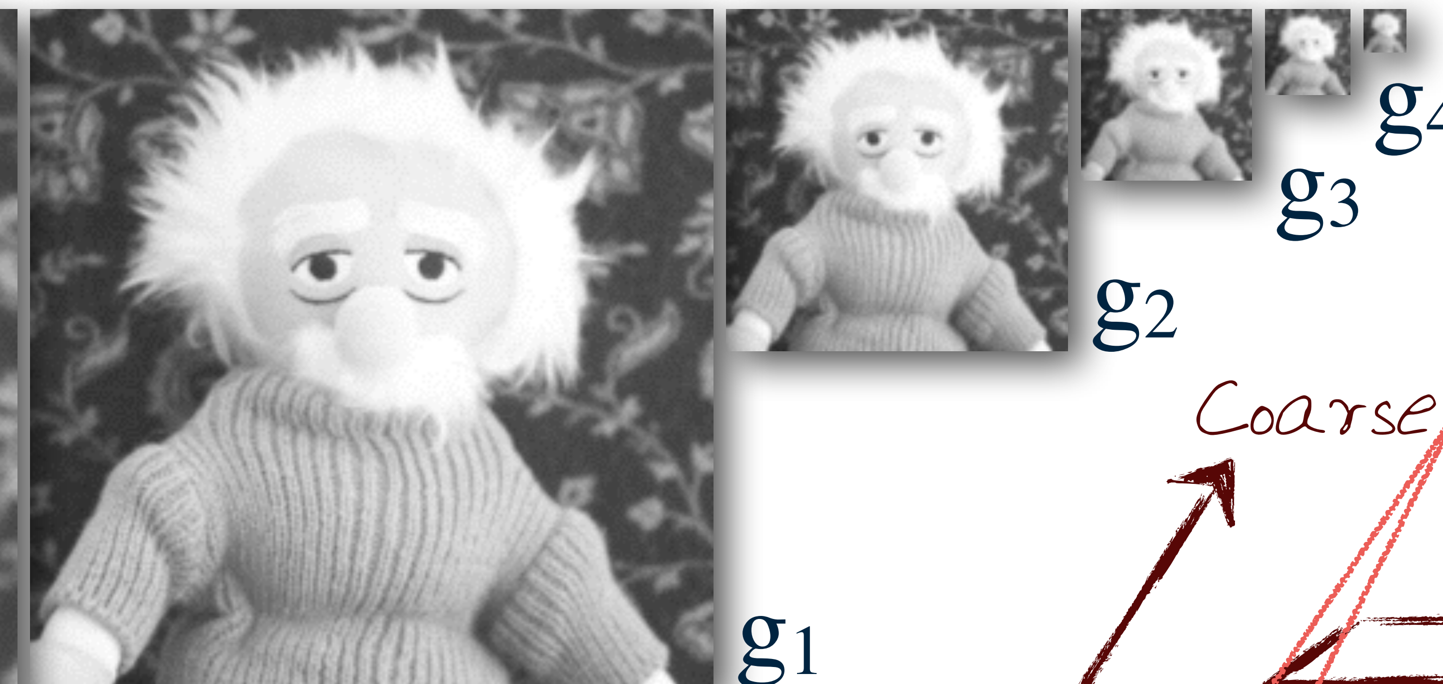
# Pyramid Representation of Images (A Gaussian Pyramid)

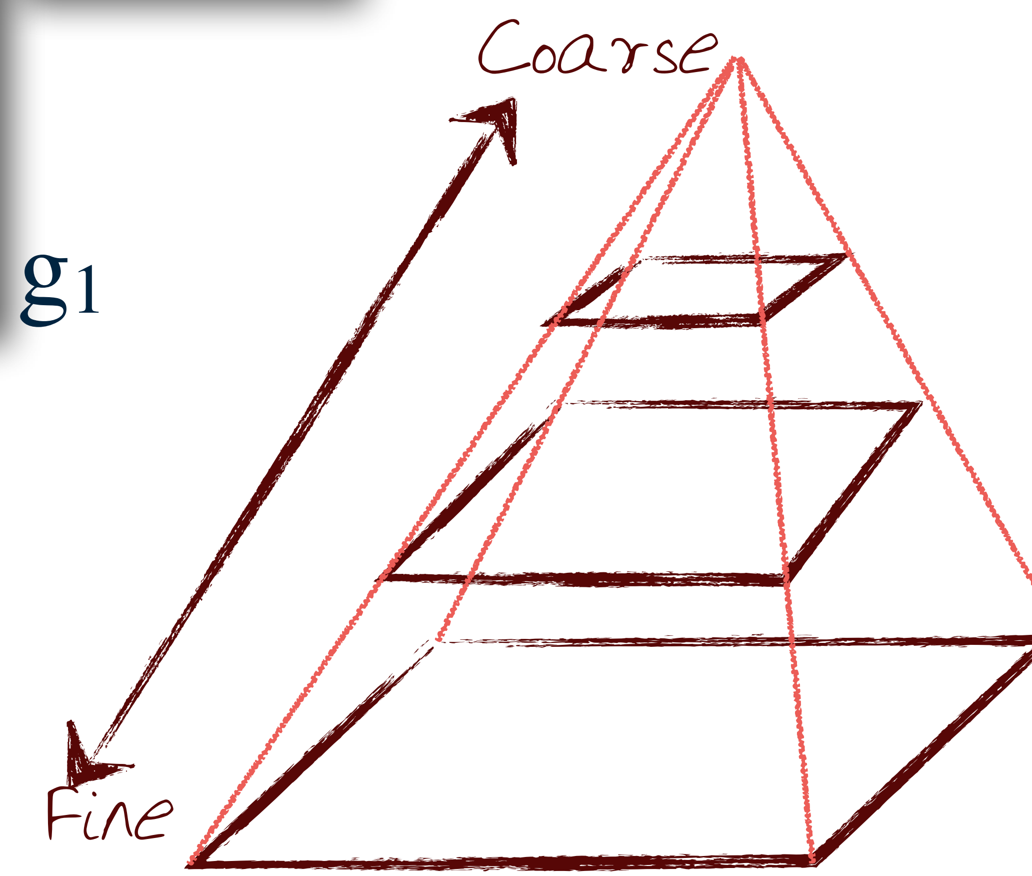
$g_1$ $g_2$ $g_3$ $g_4$ $g_5$

$$g_k = h \star g_{(k-1)}$$

$$g_k = \mathrm{REDUCE}(g_{(k-1)})$$

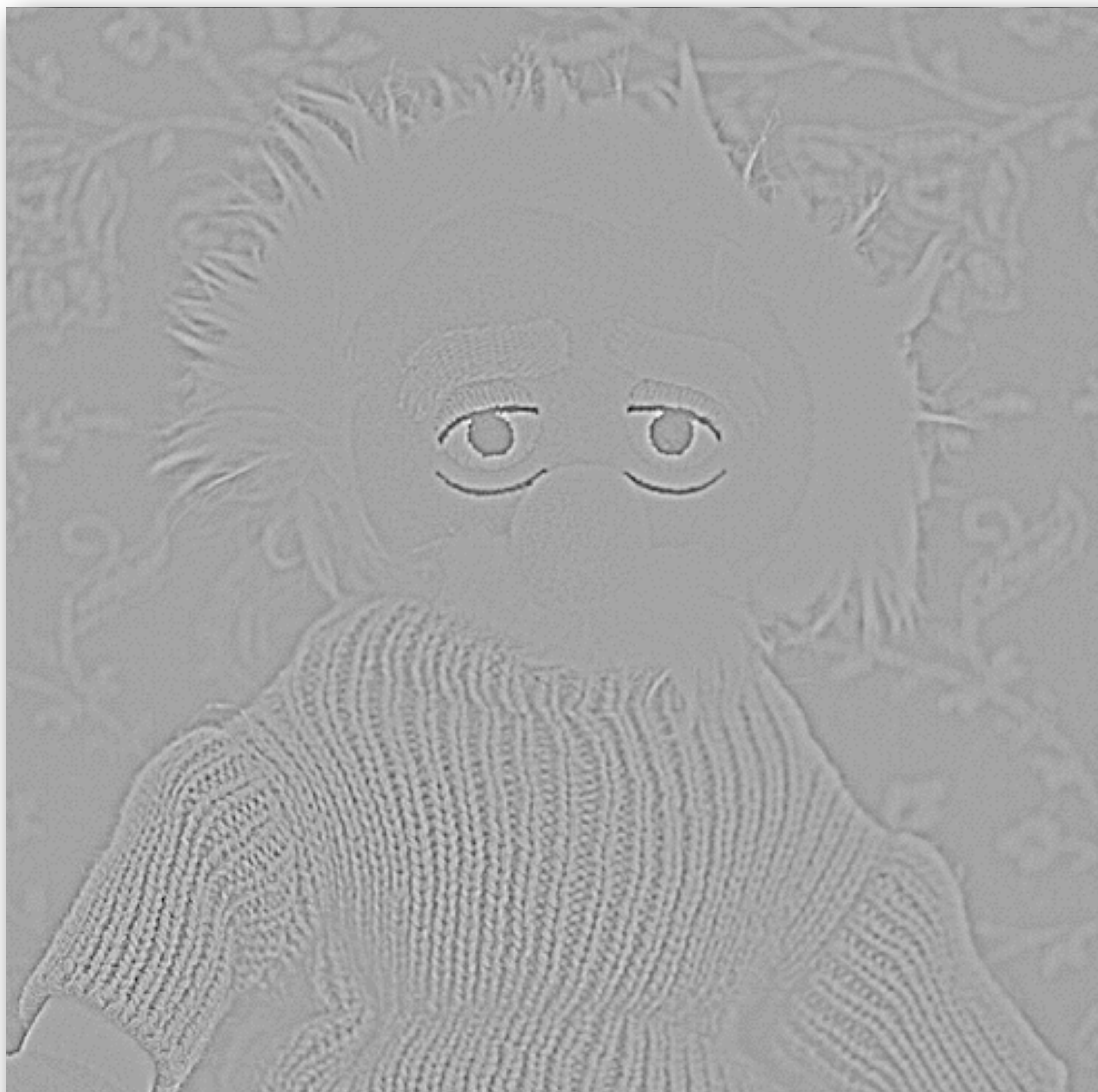
# Pyramid Representation of Images (A Gaussian Pyramid)


$$g_k = \mathrm{REDUCE}(g_{(k-1)})$$

# Pyramid Representation of Images (A Gaussian Pyramid)



$g_1$

$$g_k = \mathrm{REDUCE}(g_{k-1})$$

$$g_{j,n} = \mathrm{EXPAND}(g_{j,n-1})$$

EXPAND is inverse of REDUCE, as it seeks to add new values in between knowns ones.

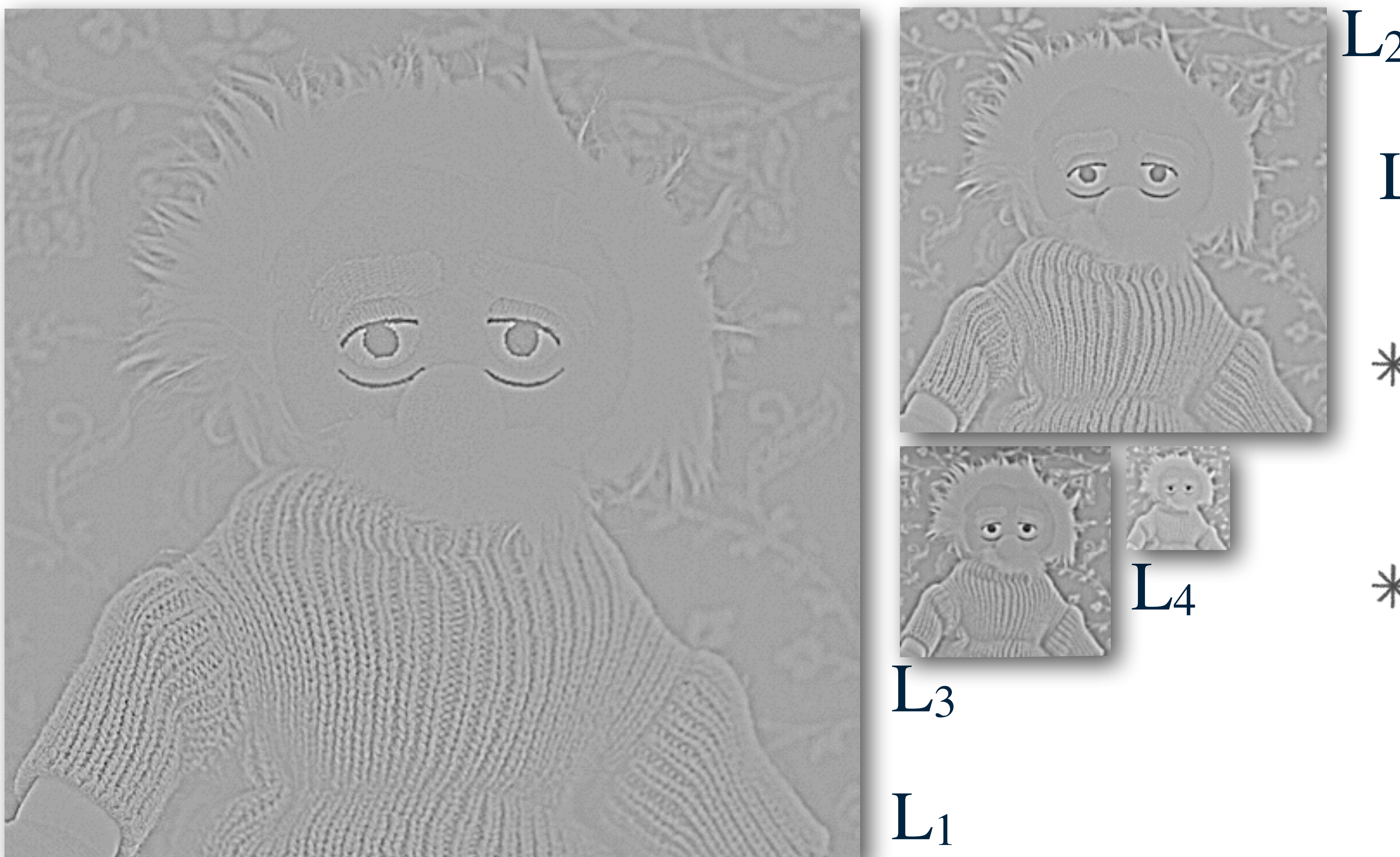
$g_0$

$g_{0,1}$

$g_0 - g_{0,1}$

$\mathbf{g_{j,n}}$ is $\mathbf{g_j}$ expanded $\mathbf{n}$ times

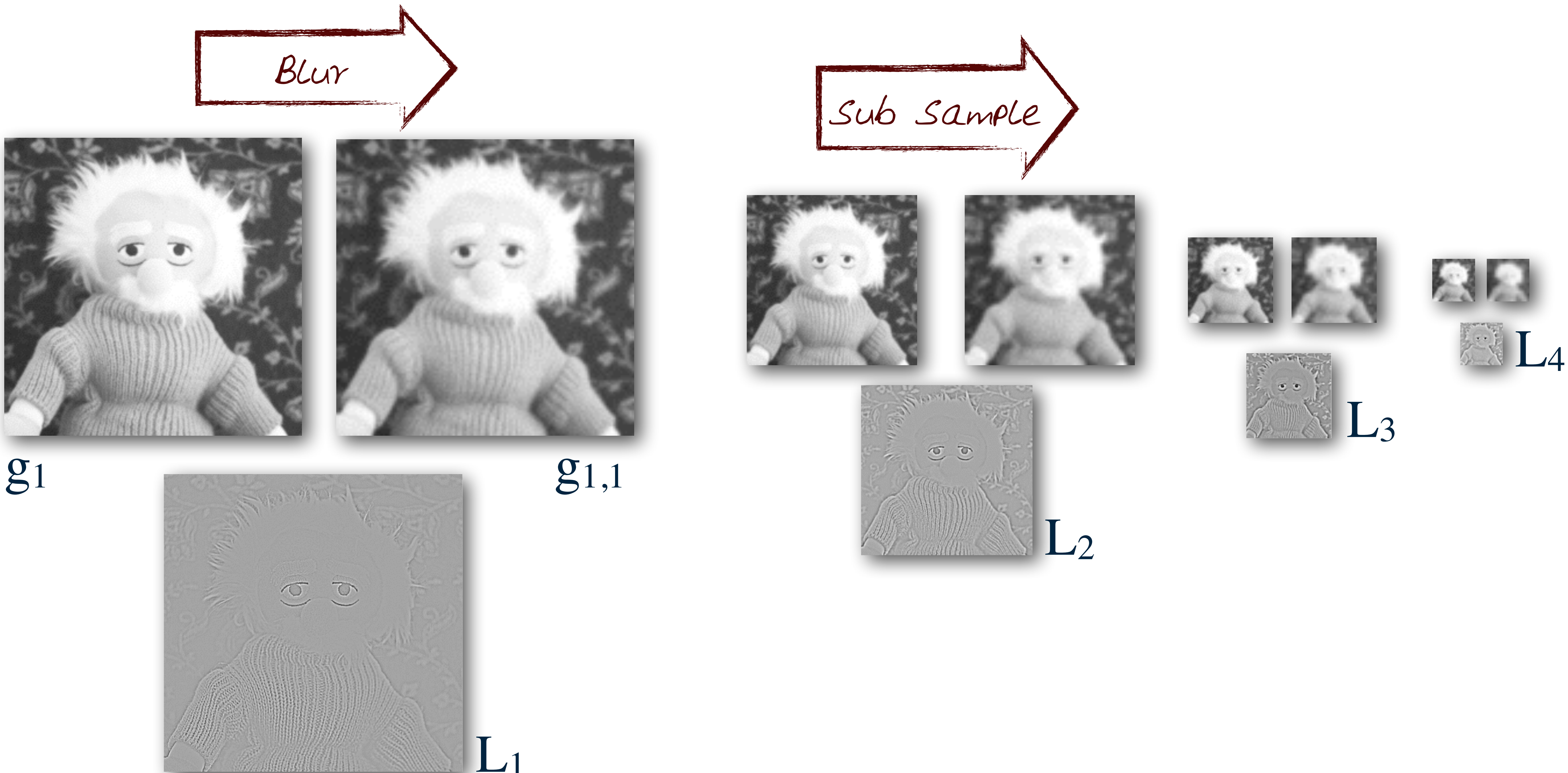
# Pyramid Representation of Images (A Laplacian Pyramid)



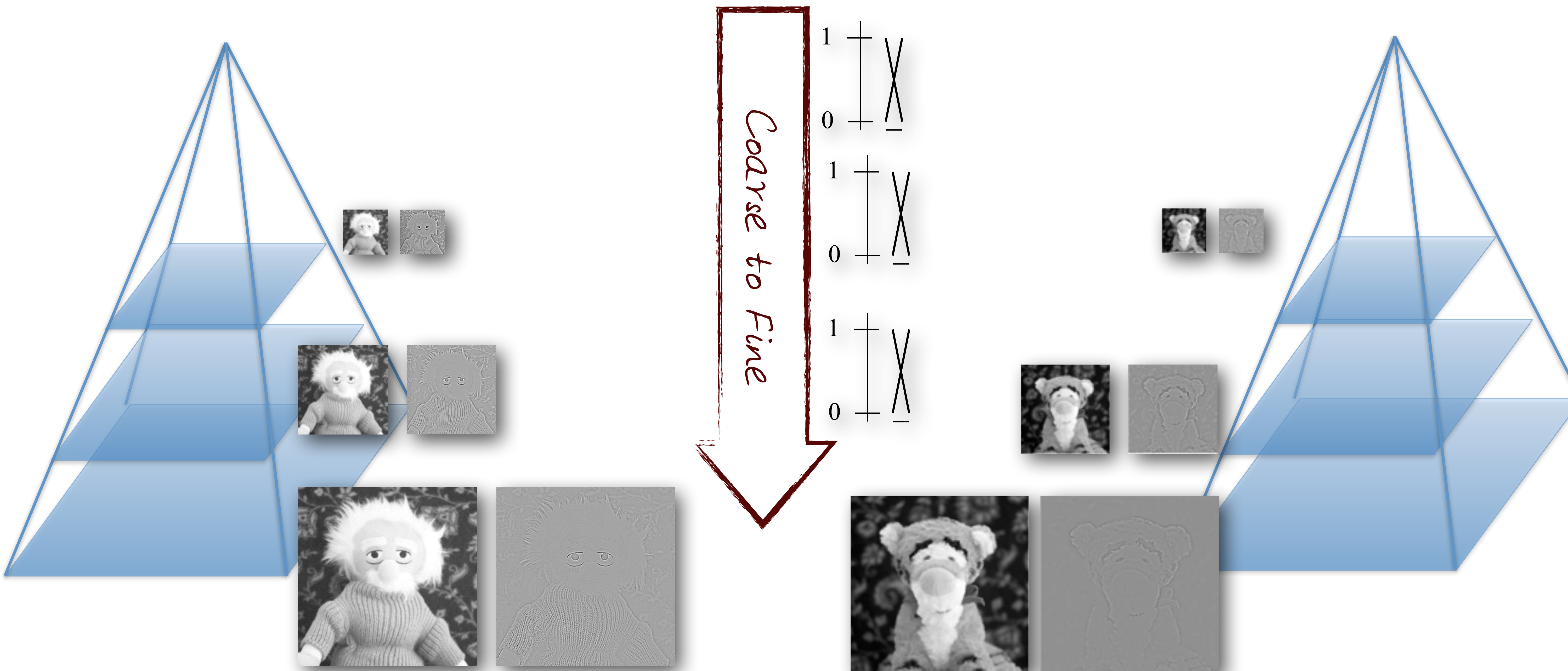

$$L_l = g_l - \text{EXPAND}(g_{l+1})$$

* A series of "error" images,
* A difference between two levels of a Gaussian Pyramid

# Computing Gaussian and Laplacian Pyramids



# Pyramid Blending



# Blend 1

# Pyramid Blending Process

A

B

R

- Build Laplacian pyramids
- Build a Gaussian pyramid from selected region R
- Form a combined pyramid using $\mathbf{G_R}$ as weights:
  - $L_O(i,j) = G_R(i,j,)^* \, L_A(i,j) + (1\text{-}G_R(i,j))^* \, L_B(i,j)$
- Collapse the $L_O$ pyramid to get the final blended image

# Blend 2

# Summary

- merge two images leveraging the Frequency Domain
- Gaussian and the Laplacian Pyramids
  - mathematical formulation to compute a Laplacian
- Blend two images using Pyramids

# Next Class

* Merging and Blending of Images: Cutting Images

# Further Reading


* Richard Szeliski (2010) Computer Vision: Algorithms and Applications, Springer.
* Burt and Adelson (1983) "The Laplacian Pyramid as a Compact Image Code", In IEEE Transactions on Communications, 31 (4). p 532-540. 1983 (DOI)
* Burt and Adelson (1983) "A multiresolution spline with application to image mosaics". In ACM Transactions on Graphics, 2 (4). 1983 (DOI)
* Look for "pyramids" on OpenCV and matlab sites

# Credits

* For more information, see
  * Richard Szeliski (2010) Computer Vision: Algorithms and Applications, Springer.
* Some concepts in slides motivated by similar slides by A. Efros and J. Hays.
* Some images retrieved from
  * List will be available on website.
  * by Irfan Essa

# Computational Photography

* Study the basics of computation and its impact on the entire workflow of photography, from capturing, manipulating and collaborating on, and sharing photographs.

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