CSCE 448/748 – Computational Photography
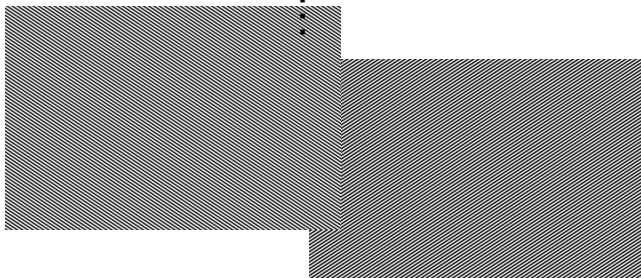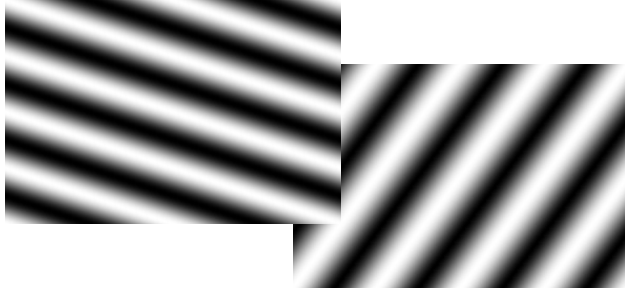
Pyramids

Nima Kalantari

Fourier domain
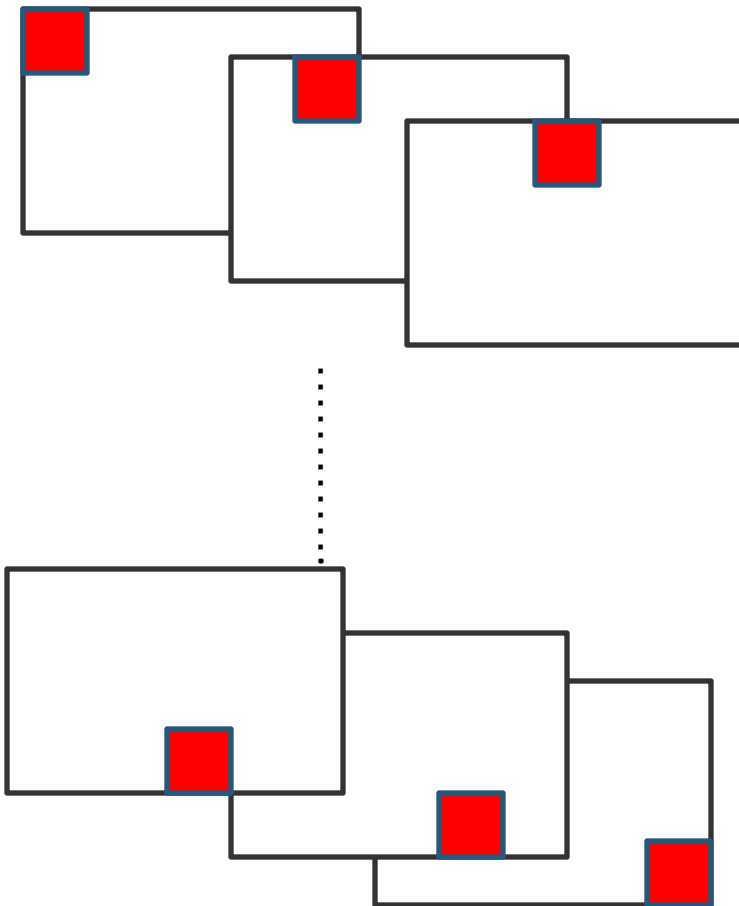
- **Basis functions:**

Tells you *what* is in the image….

… but not *where* it is

Spatial Domain

- Basis functions:

Tells you *where* things are….

… but no concept of *what* it is

Image Analysis

- **Want representation that combines *what* and *where***
  - **Image Pyramids**

GAUSSIAN PYRAMID

Practical uses

- **Searching**

- **Image blending**

- **Compression**
  - **Capture important structures with fewer bytes**

- **Denoising**
  - **Model statistics of pyramid sub-bands**

Outline

- **Gaussian**

- **Laplacian**

- **Image blending**

Gaussian Pyramid

Image half-sizing
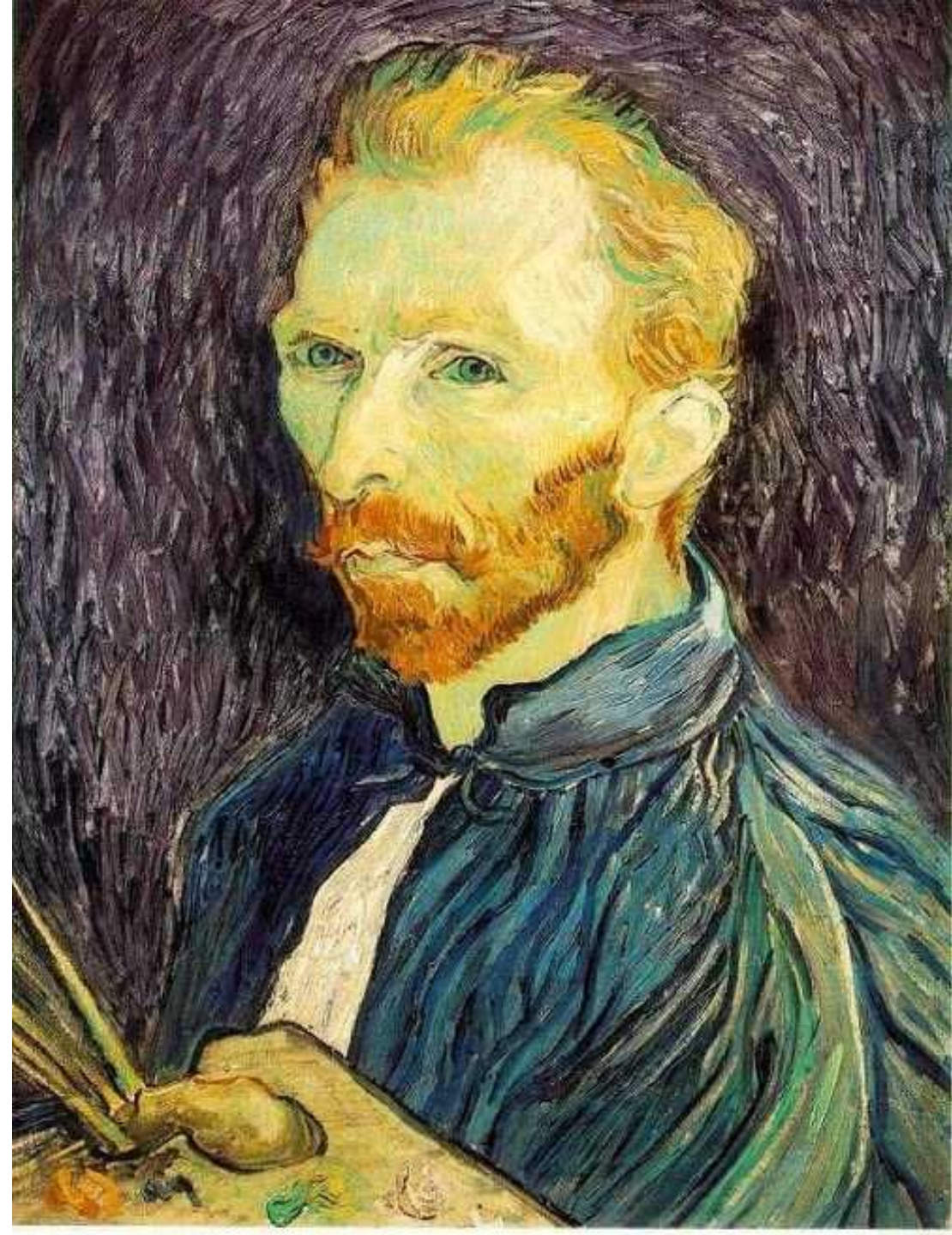
- How to generate a half-sized version?

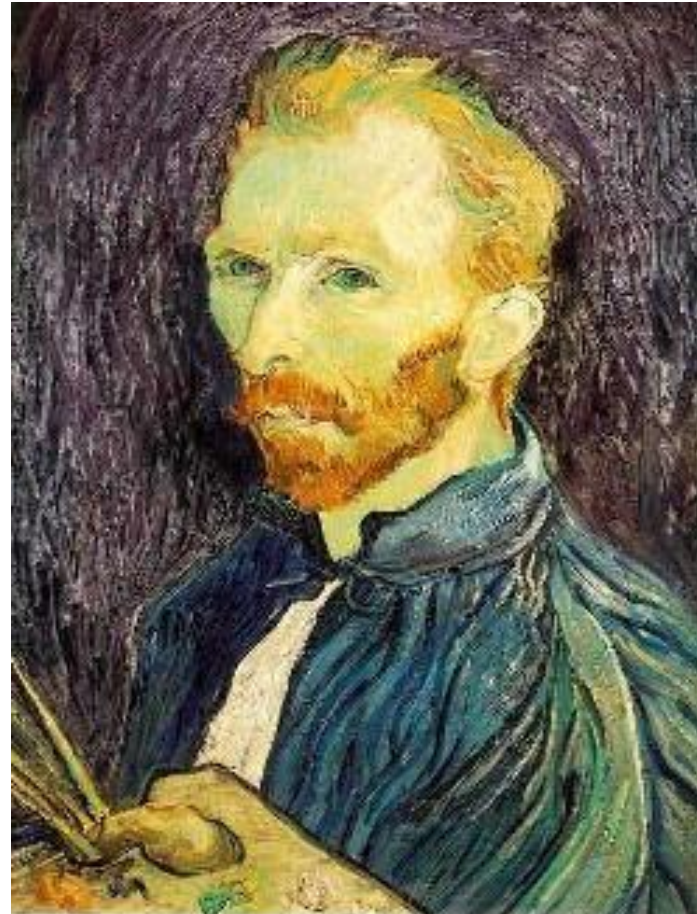# Image sub-sampling

- Throw away every other row and column to create a 1/2 size image
  - Image sub-sampling

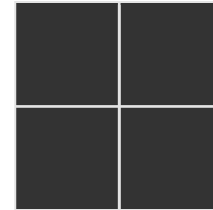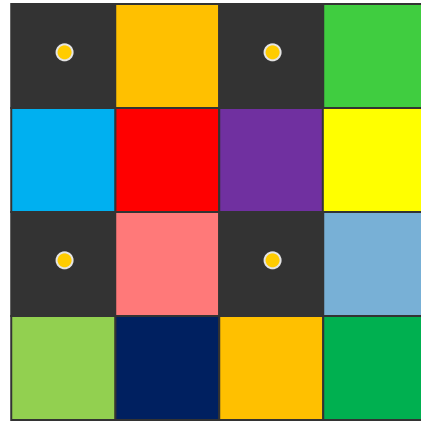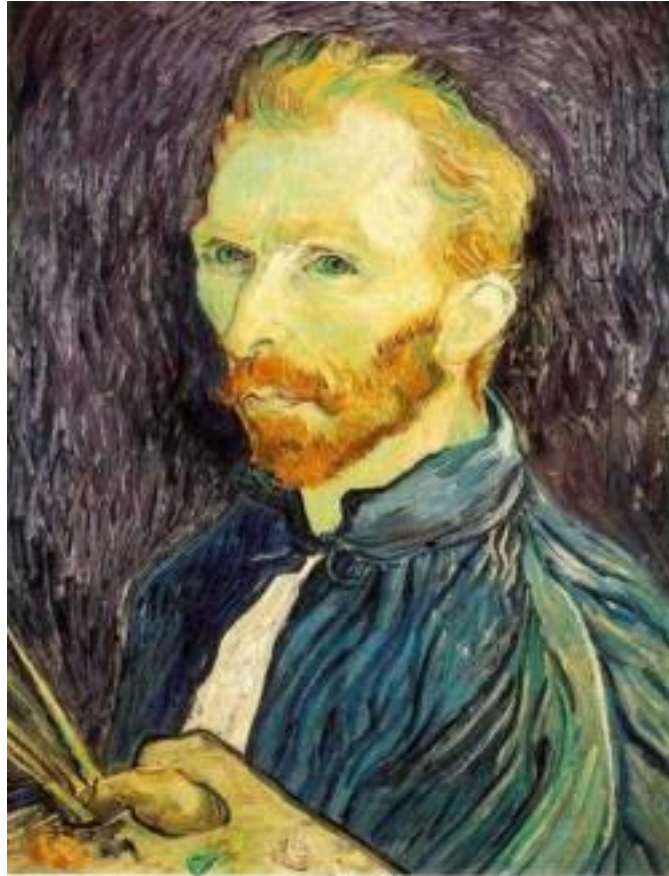- Problem
  - Aliasing

1/2

1/4

1/8

Extreme example

Aliasing

- High frequency signal sampled slowly

    — Sample more often

        - Cannot be done; goal is to downsize

    — Get rid of high frequencies

        - Filter the image and then subsample

Gaussian (lowpass) pre-filtering
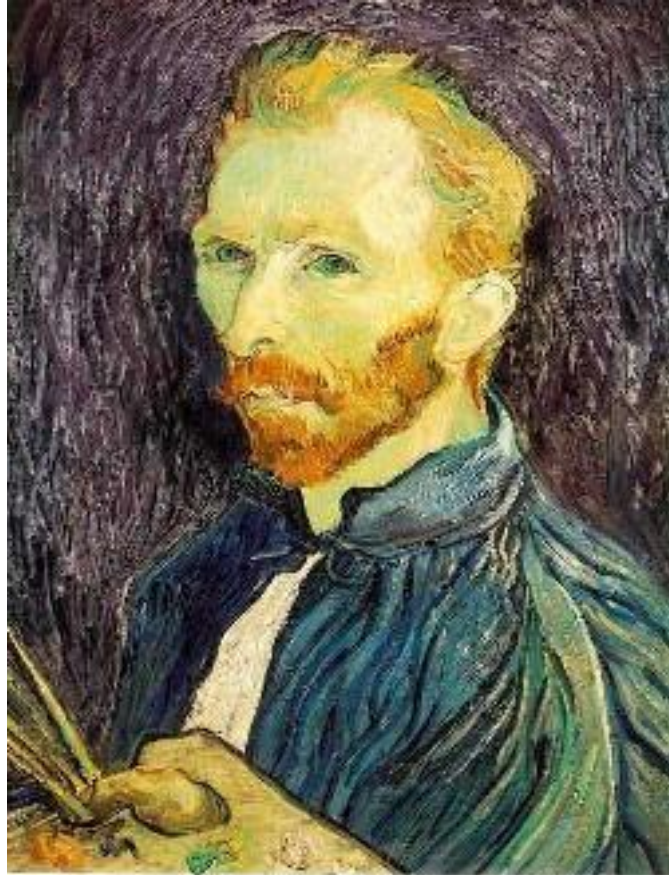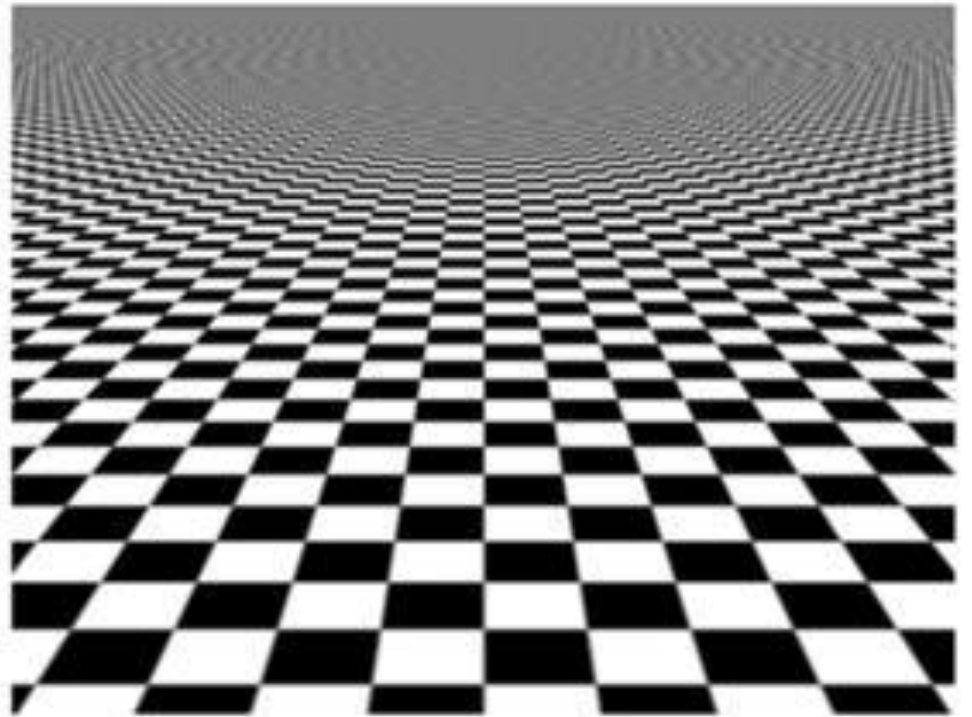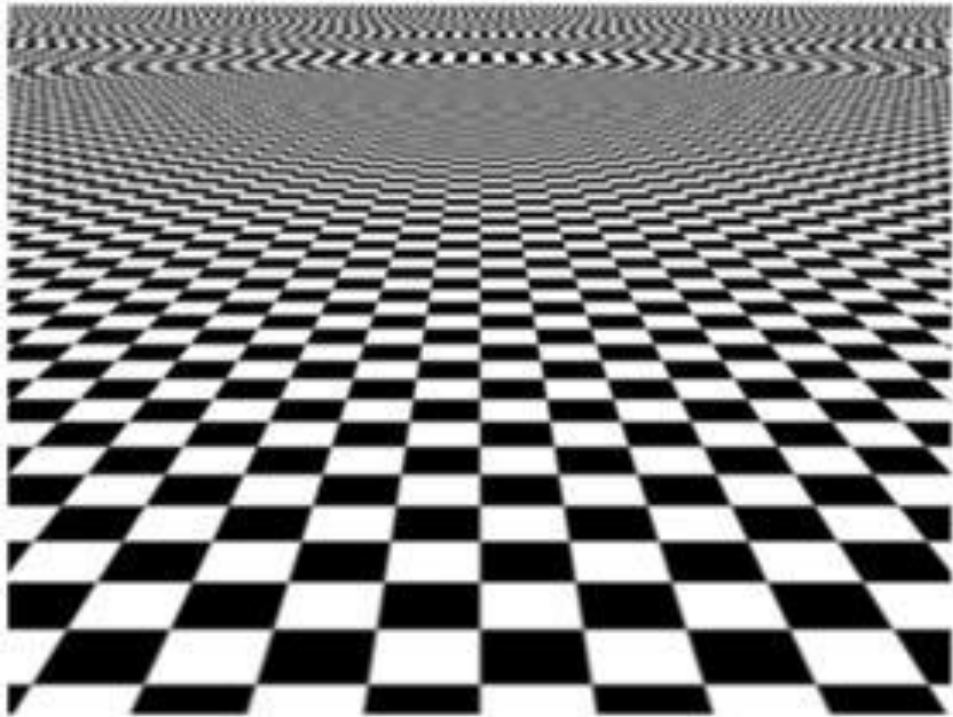

1/2

1/4

1/8

Direct subsampling

1/2

1/4

1/8

Extreme case

Gaussian pyramid
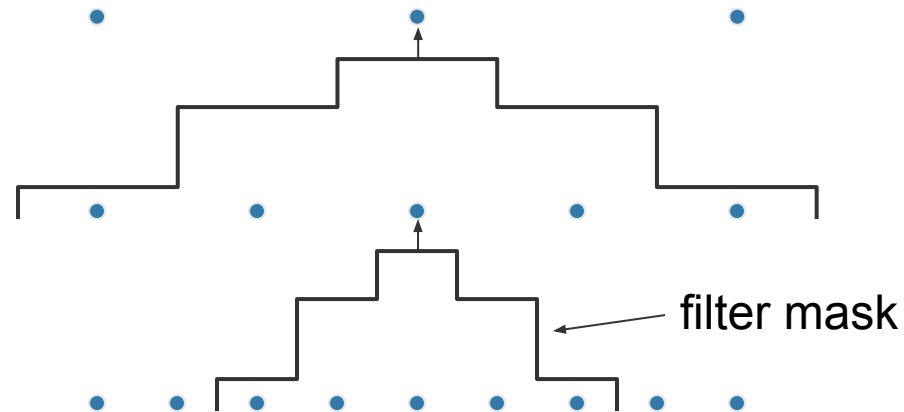
Gaussian pyramid construction

 Repeat

— Filter

— Subsample

 Until minimum resolution reached

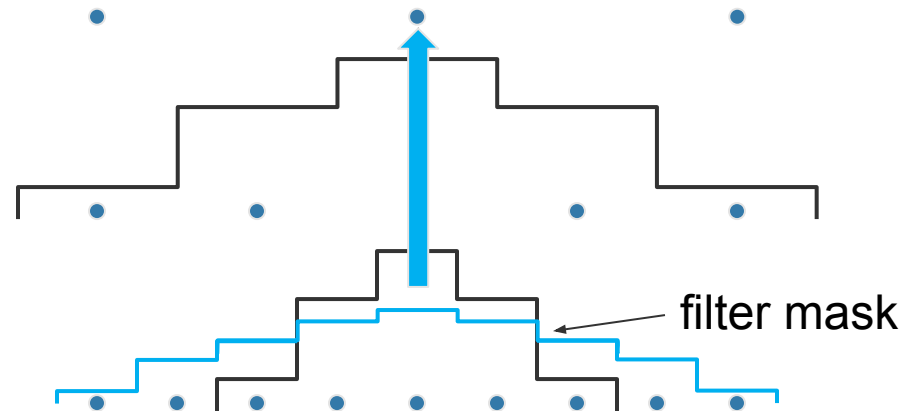— can specify desired number of levels (e.g., 3-level pyramid)

filter mask

Gaussian pyramid construction

- Repeat
  - Filter
  - Subsample
- Until minimum resolution reached
  - can specify desired number of levels (e.g., 3-level pyramid)

filter mask

Gaussian pyramid

- A bar in the pyramid

  — Big images, a hair on nose

  — Smaller images, a stripe

  — Smallest image, zebra's nose

- The whole pyramid is only 4/3 of the original image
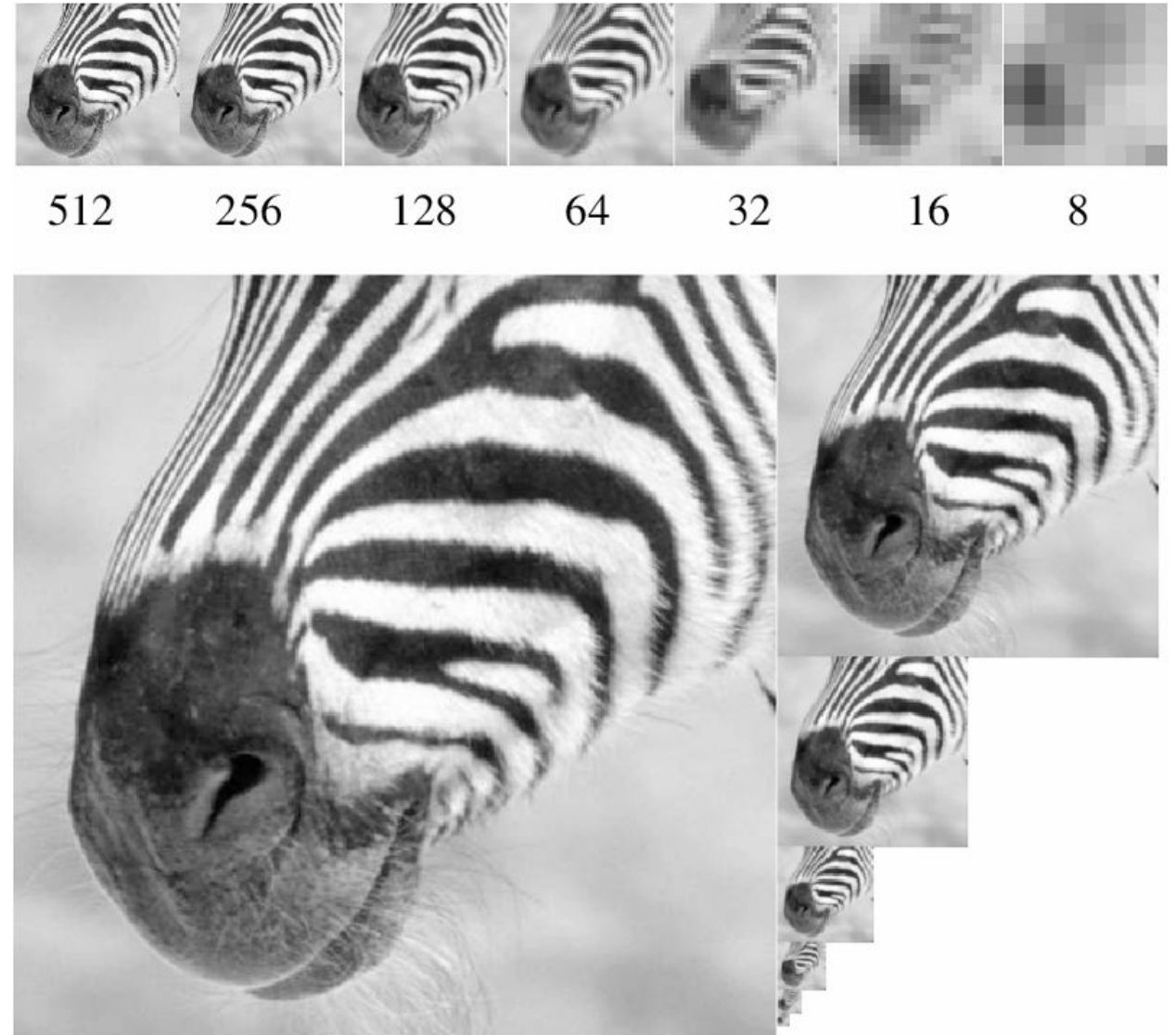
What are they good for?

- Improve Search
  - Search over translations
    - Classic coarse-to-fine strategy
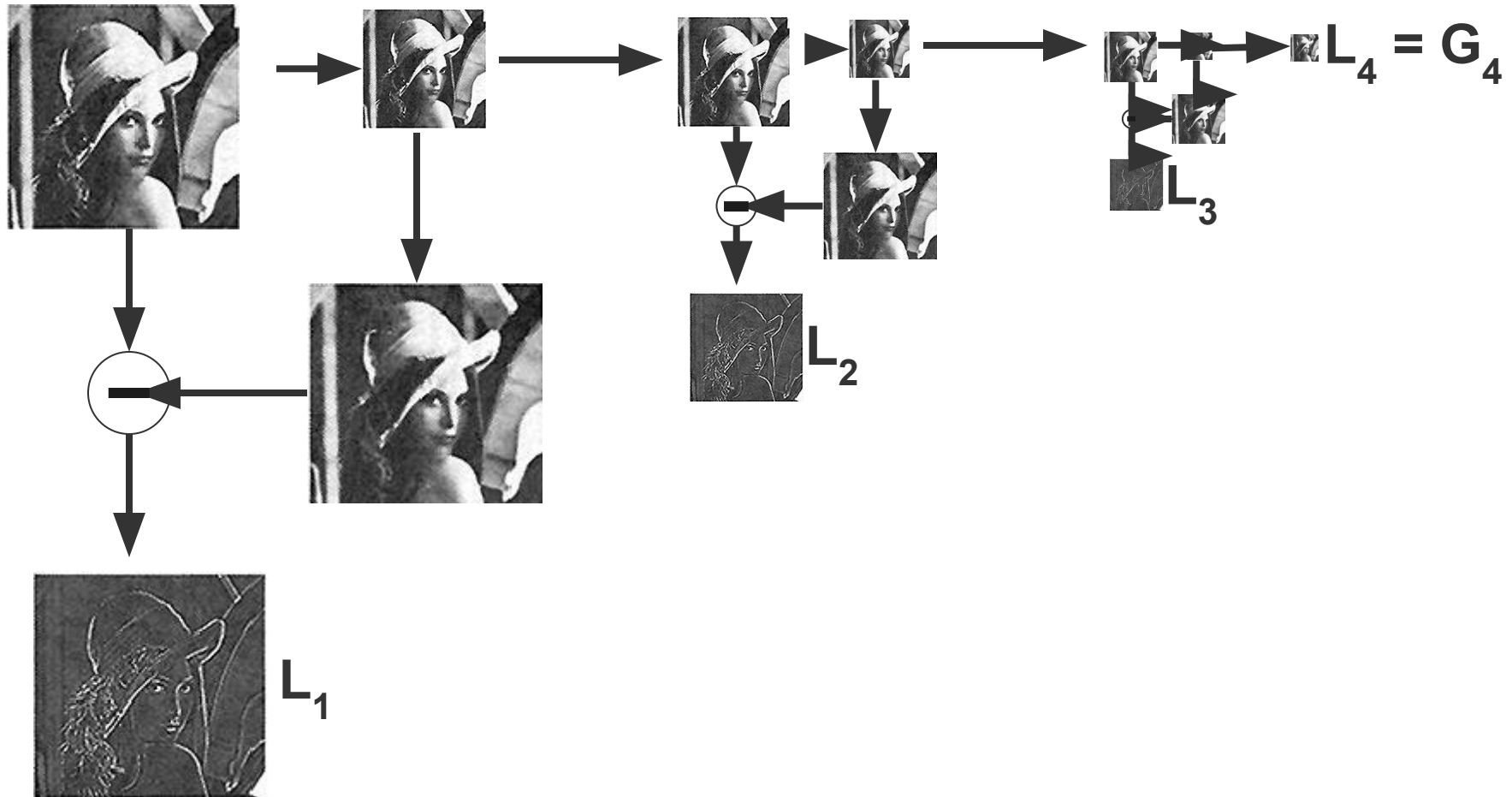   - Project 2!
  - Search over scale
    - Template matching
    - E.g., find a face at different scales

Outline

- **Gaussian**

- **Laplacian**

- **Image blending**

Laplacian pyramid algorithm
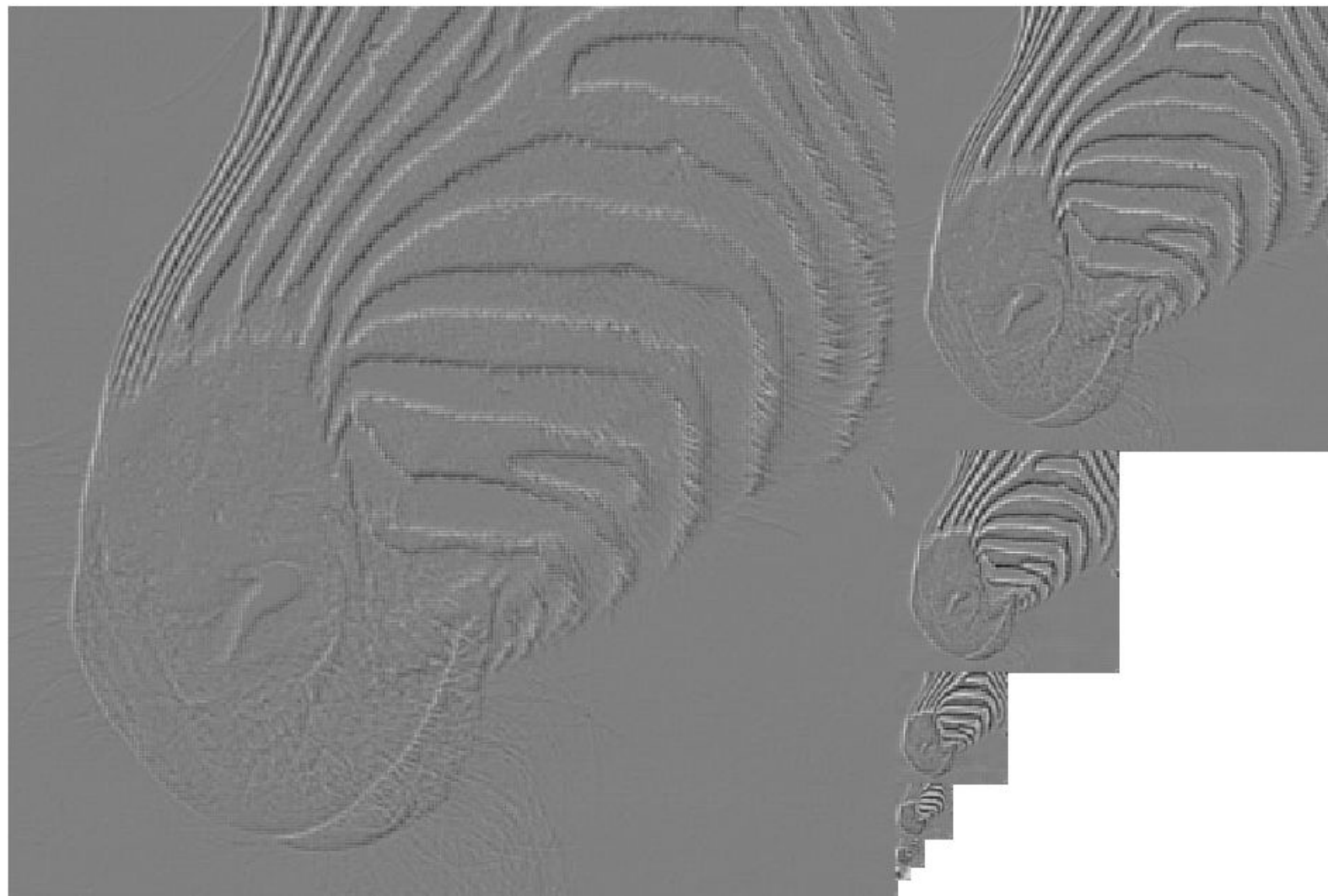
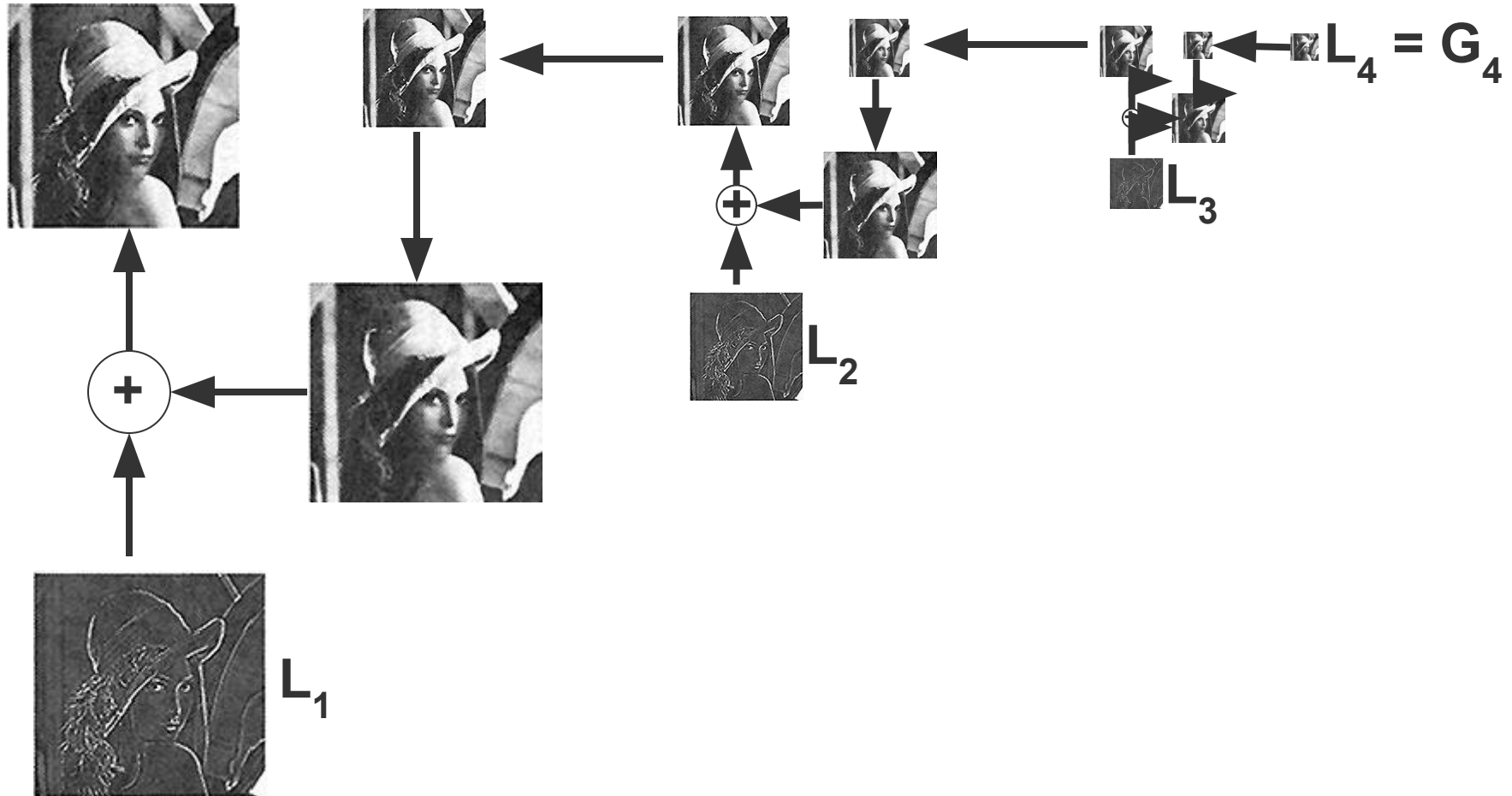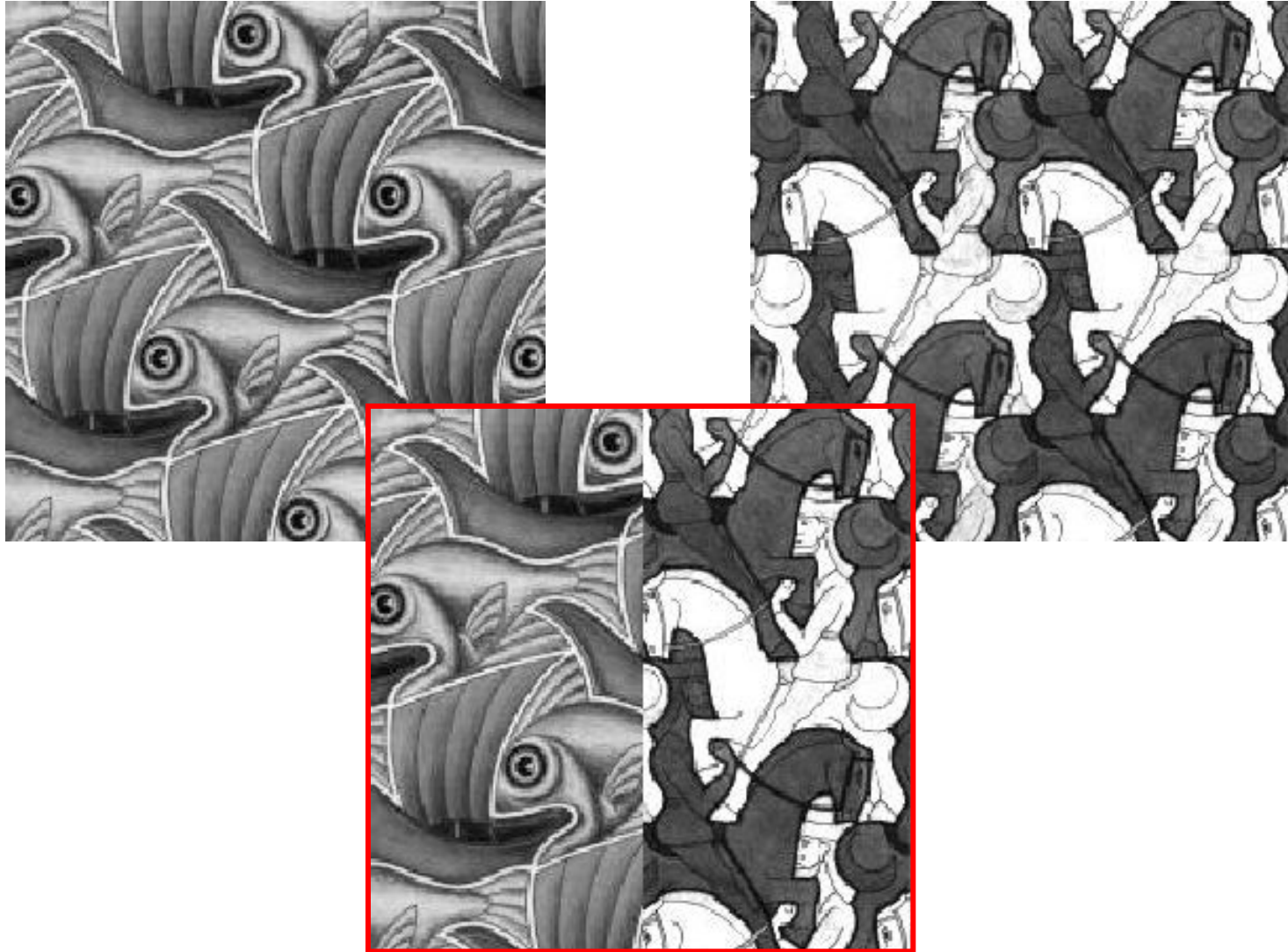512   256   128   64   32   16   8
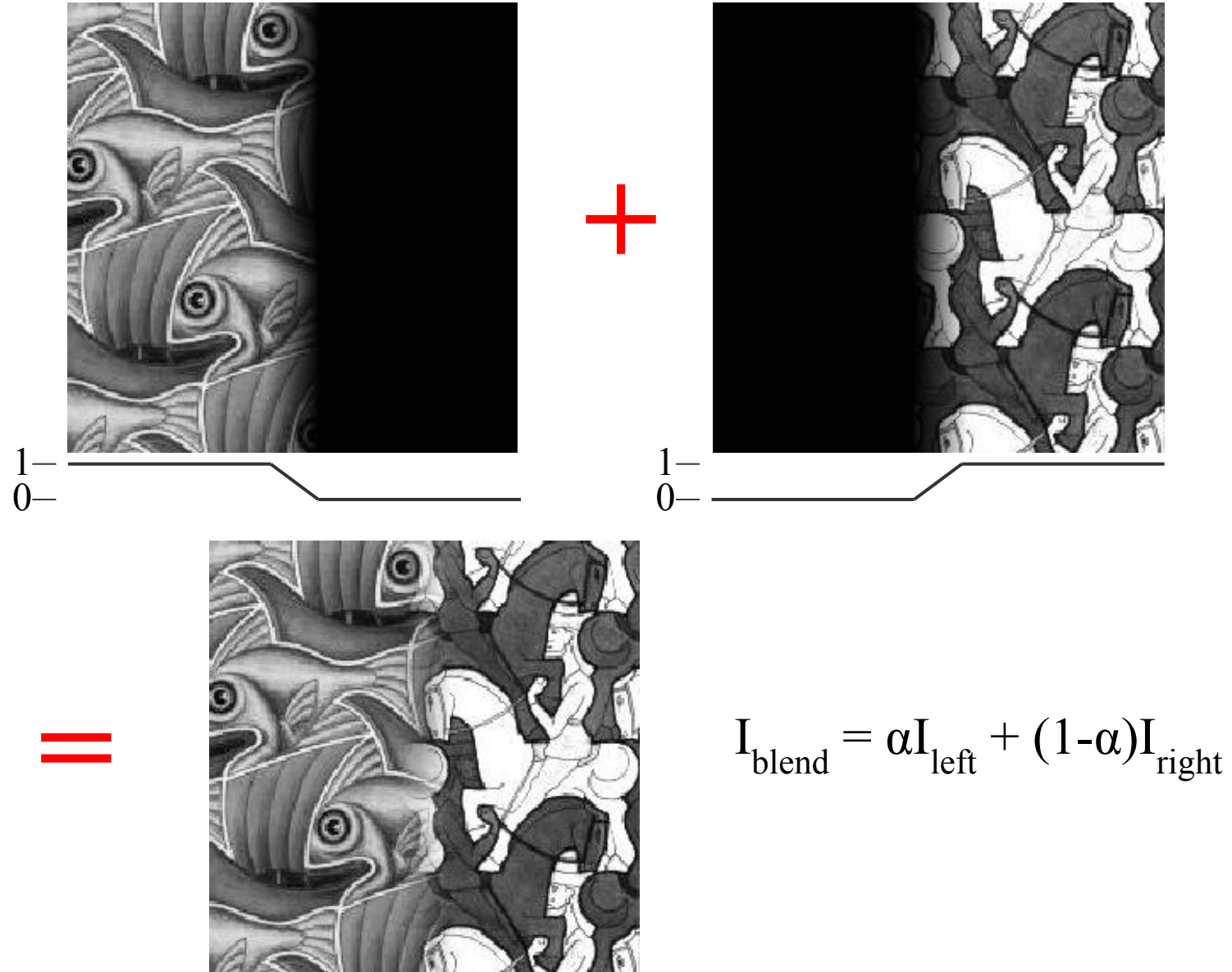
512 256 128 64 32 16 8

Collapsing the pyramid

$L_4 = G_4$

L_3

L_2

L_1

Outline

- **Gaussian**

- **Laplacian**

- **Image blending**

Image Blending
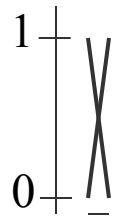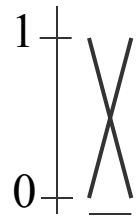
Feathering

$$I_{blend} = \alpha I_{left} + (1-\alpha) I_{right}$$
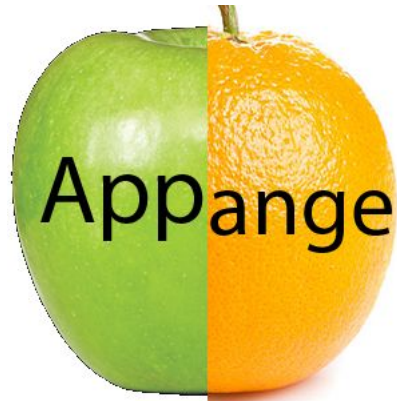
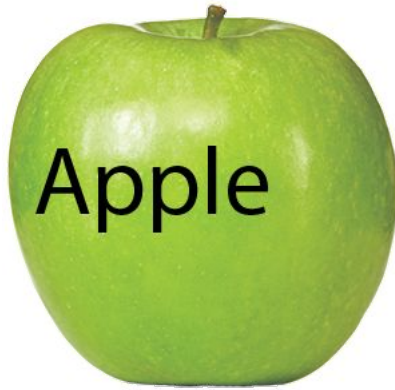# Affect of Window Size
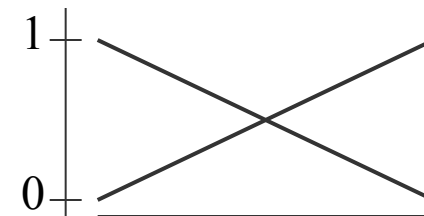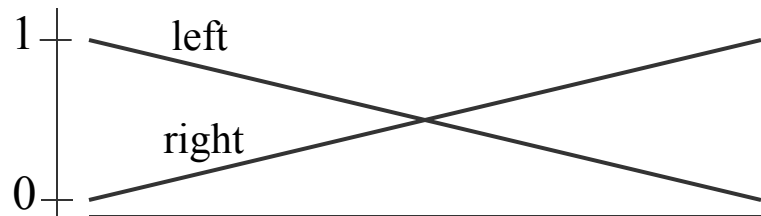
Affect of Window Size

Good Window Size

"Optimal" Window: smooth but not ghosted

However…

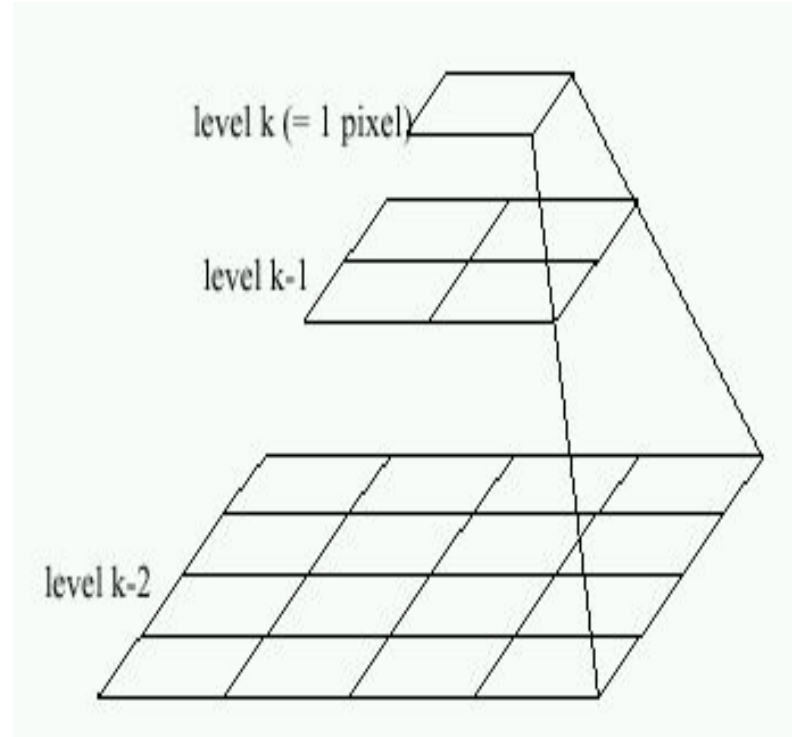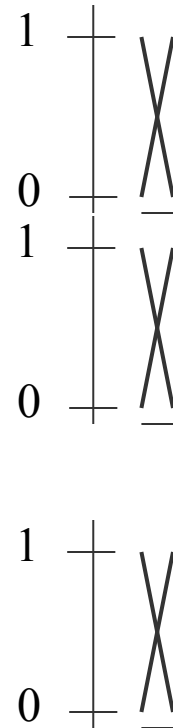 One window may not work for every region
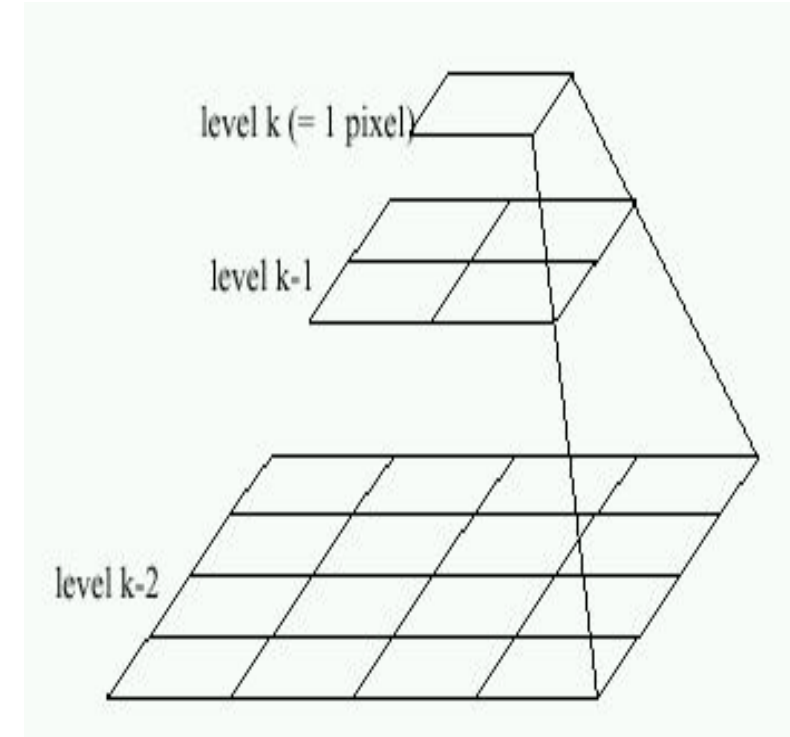
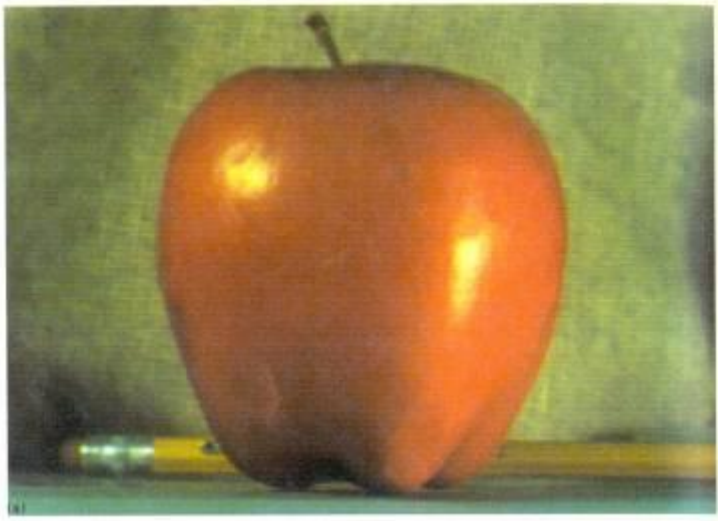Small window   Large window

Pyramid Blending

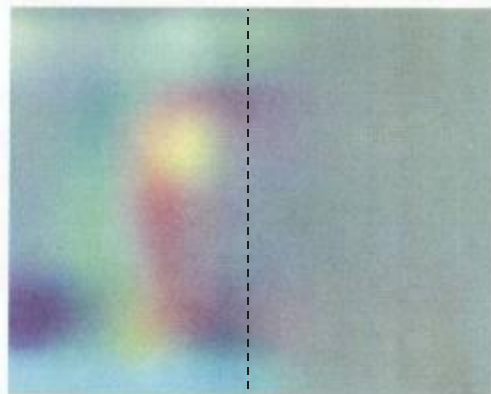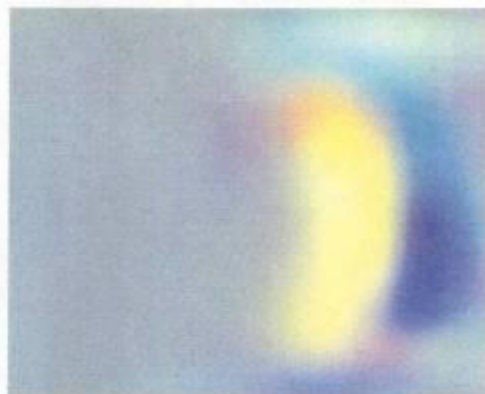Left pyramid   blend   Right pyramid
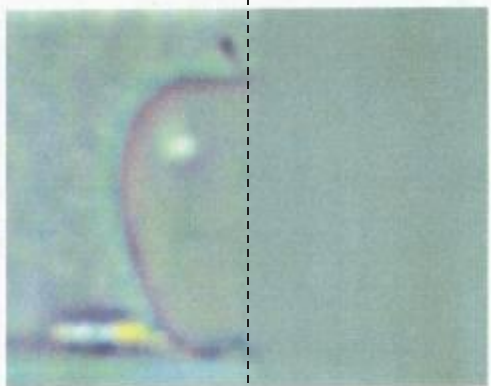
Pyramid Blending

laplacian level 4
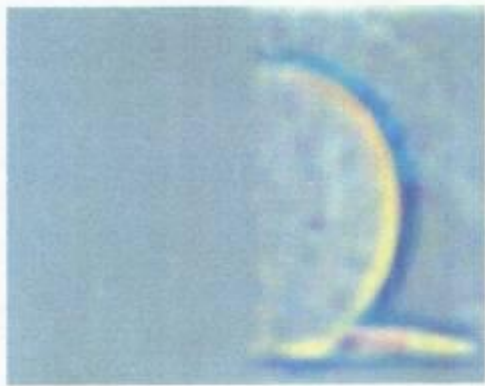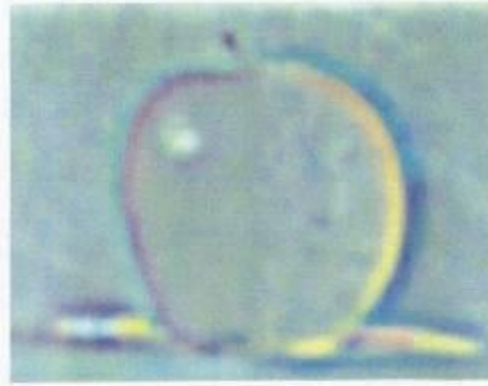
laplacian level 2

laplacian level 0
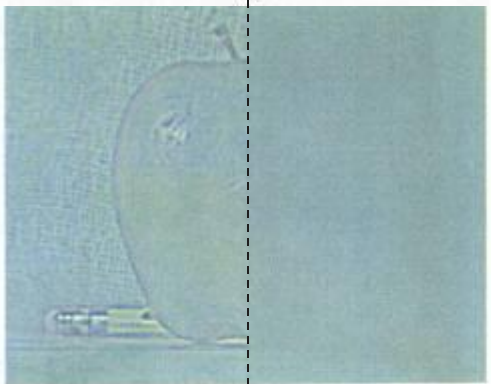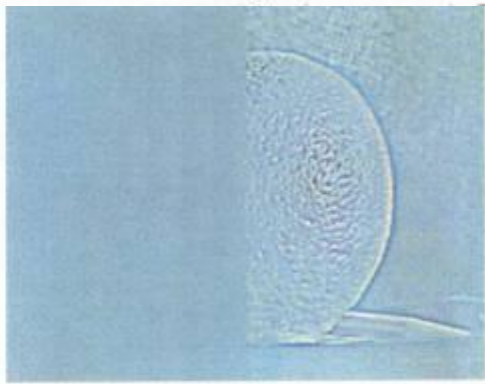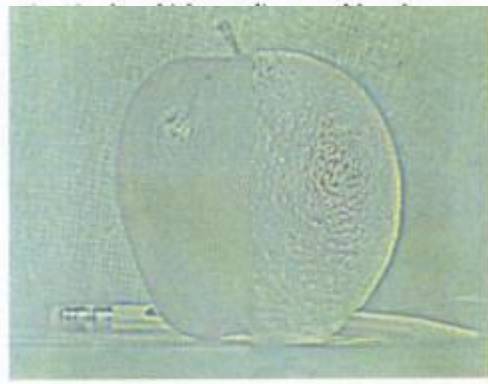
left pyramid   right pyramid   blended pyramid
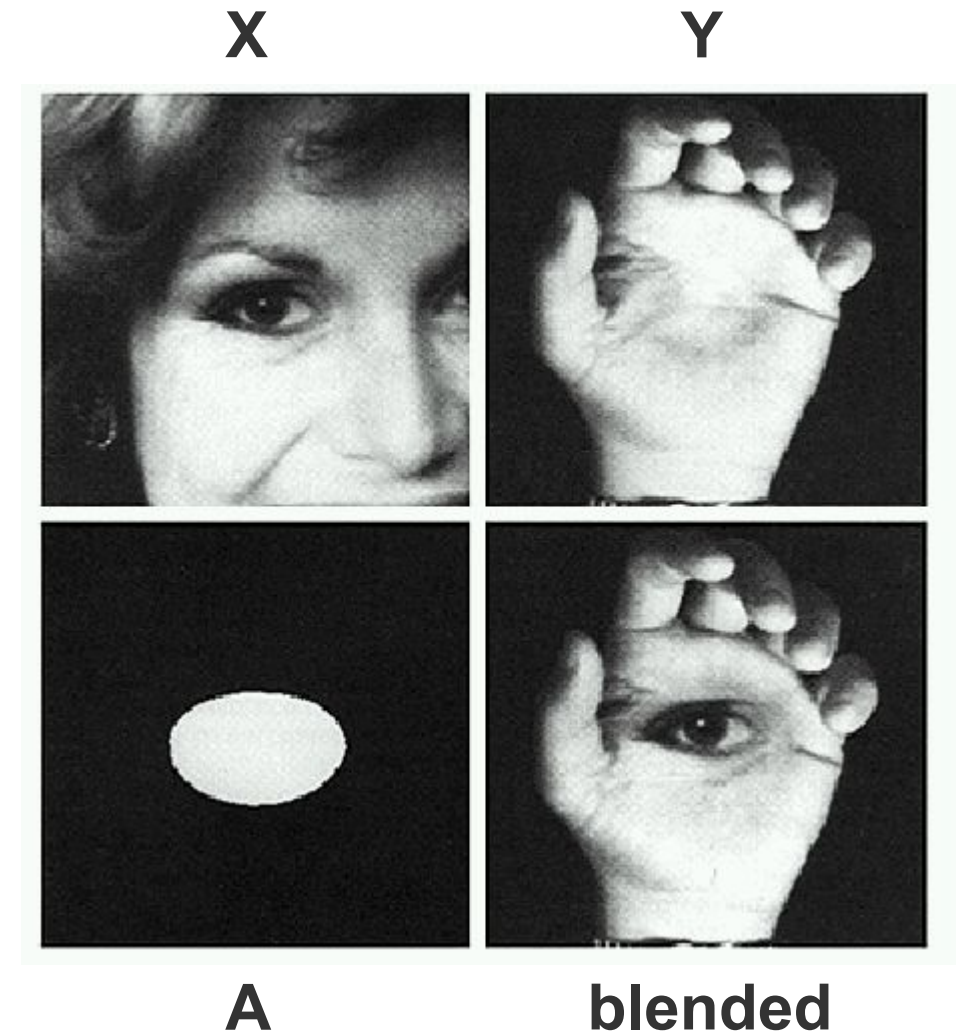
Pyramid Blending

Blending Regions

- **Input: Images X and Y as well as a mask A**

- **Output: blended image**

X   Y

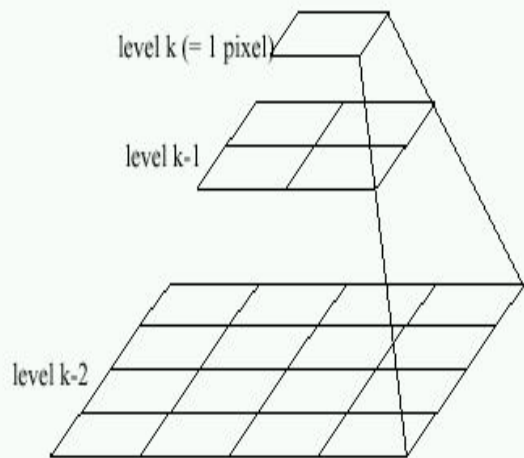A   blended

Laplacian Pyramid/Stack Blending

- General Approach:
  1. Build Laplacian pyramid LX and LY from images X and Y
  2. Build a Gaussian pyramid GA from the binary alpha mask A
  3. Form a combined pyramid LBlend from LX and LY using the corresponding levels of GA as weights:
     - LBlend(i, j) = GA(i, j) * LX(i, j) + (1 - GA(i, j)) * LY(i,j)
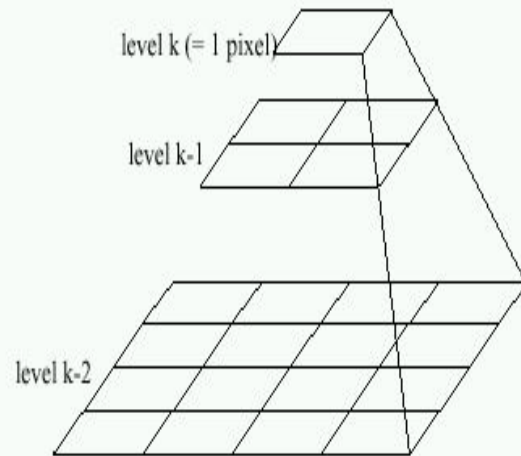 4. Collapse the LBlend pyramid to get the final blended image
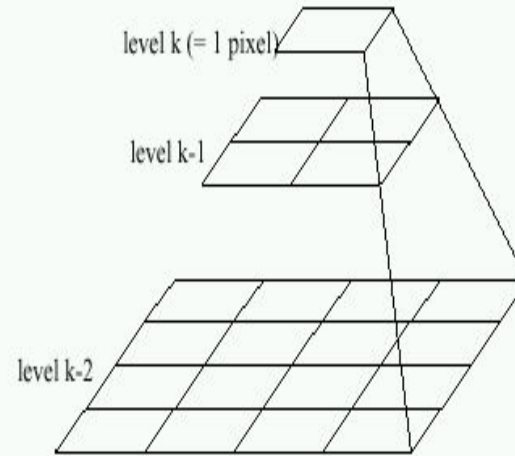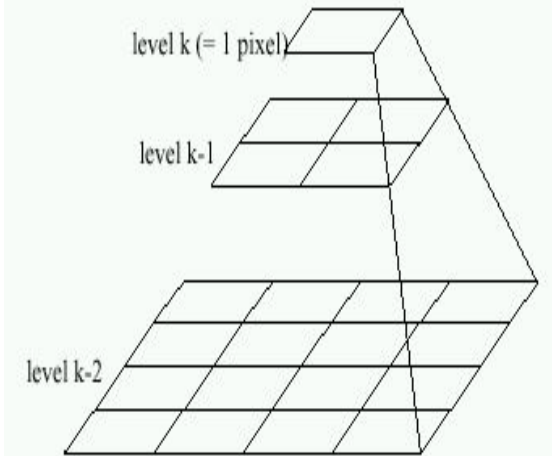
Laplacian Pyramid/Stack Blending

Collapse

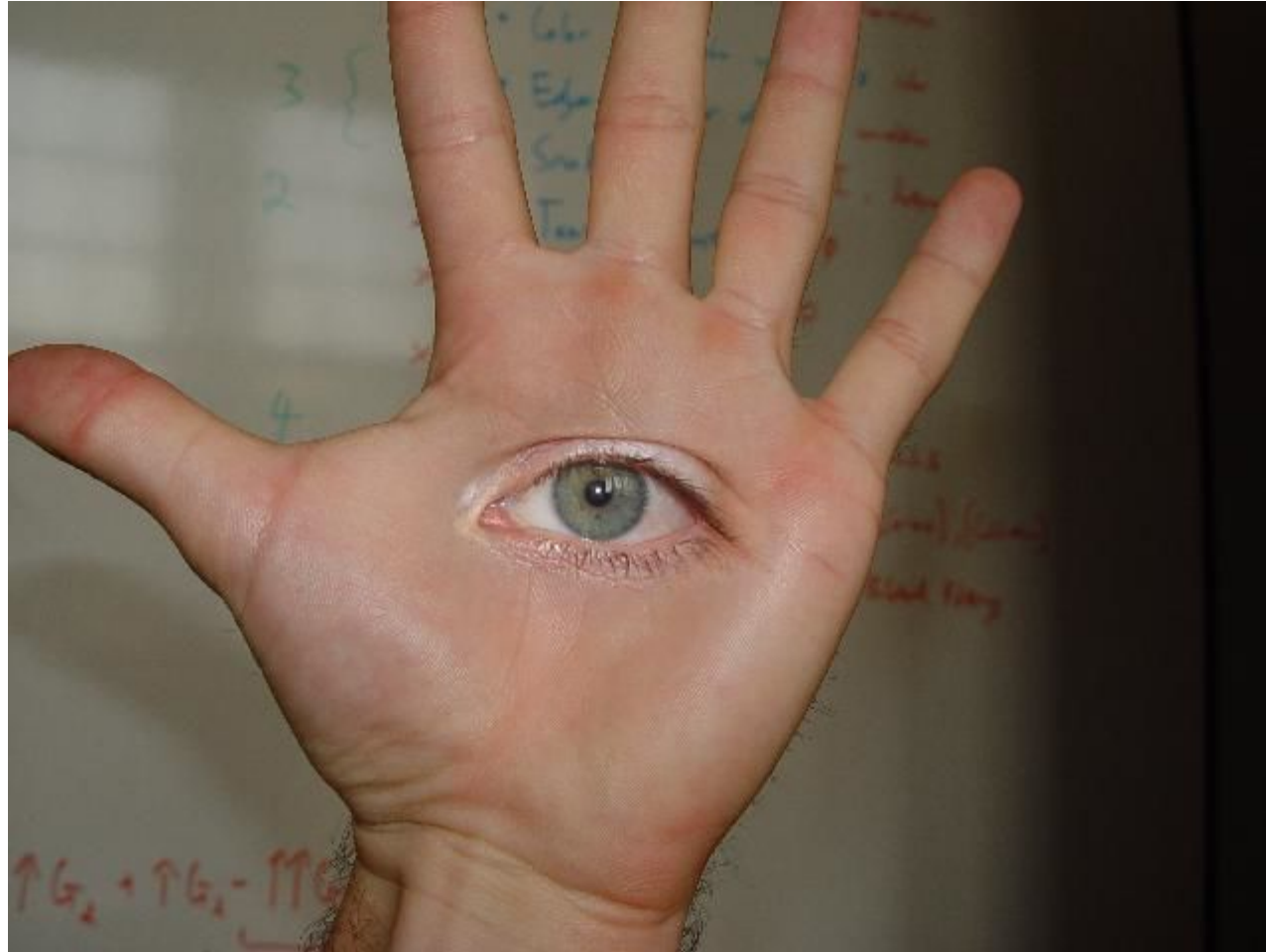Laplacian LX

Gaussian GA

Laplacian LY

Blended

Horror Photo

© david dmartin (Boston College)

Simplification: Two-band Blending

- **Brown & Lowe, 2003**
  - **Only use two bands: high freq. and low freq.**
  - **Blends low freq. smoothly**
  - **Blend high freq. with no smoothing: use binary alpha**

2-band "Laplacian Stack" Blending

Low frequency ($\lambda > 2$ pixels)

High frequency ($\lambda < 2$ pixels)

Linear Blending

2-band Blending