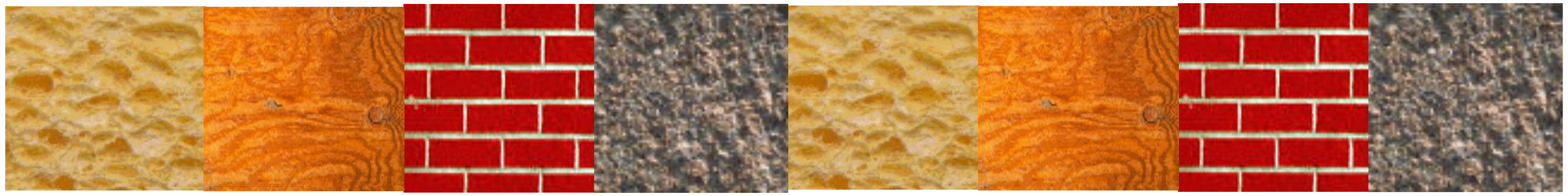
THE UNIVERSITY OF BRITISH COLUMBIA

CPSC 425: Computer Vision



Lecture 10: Texture

(unless otherwise stated slides are taken or adopted from **Bob Woodham, Jim Little** and **Fred Tung**)

Texture

What is **texture**?

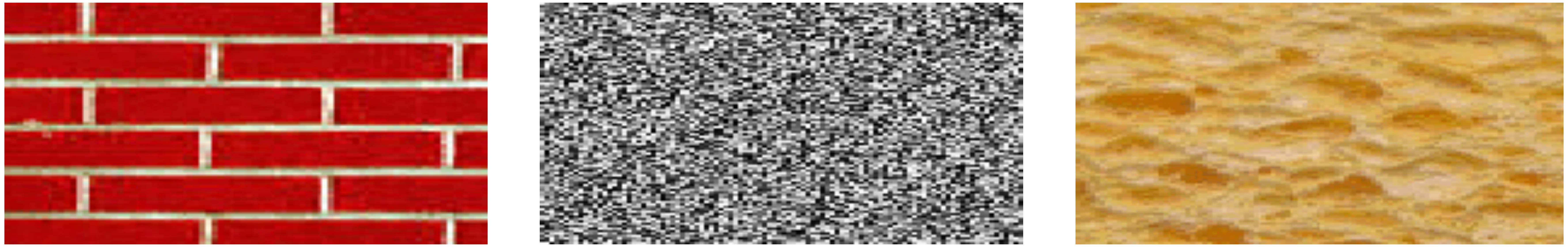


Figure Credit: Alexei Efros and Thomas Leung

Texture is widespread, easy to recognize, but hard to define

Views of large numbers of small objects are often considered textures
— e.g. grass, foliage, pebbles, hair

Patterned surface markings are considered textures
— e.g. patterns on wood

Definition of **Texture**

(Functional) **Definition**:

Texture is detail in an image that is at a scale too small to be resolved into its constituent elements and at a scale large enough to be apparent in the spatial distribution of image measurements

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Sometimes, textures are thought of as patterns composed of repeated instances of one (or more) identifiable elements, called **textons**.

— e.g. bricks in a wall, spots on a cheetah

Uses of **Texture**

Texture can be a strong cue to **object identity** if the object has distinctive material properties

Texture can be a strong cue to an **object's shape** based on the deformation of the texture from point to point.

— Estimating surface orientation or shape from texture is known as "**shape from texture**"

Texture

We will look at two main questions:

1. How do we represent texture?
→ Texture **analysis**

2. How do we generate new examples of a texture?
→ Texture **synthesis**

Texture **Segmentation**

Question: Is texture a property of a point or a property of a region?

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There is a "chicken–and–egg" problem. Texture segmentation can be done by detecting boundaries between regions of the same (or similar) texture. Texture boundaries can be detected using standard edge detection techniques applied to the texture measures determined at each point

Recall: Boundary Detection

Features:

— Raw Intensity

— Orientation Energy

— Brightness Gradient

— Color Gradient

— Texture gradient

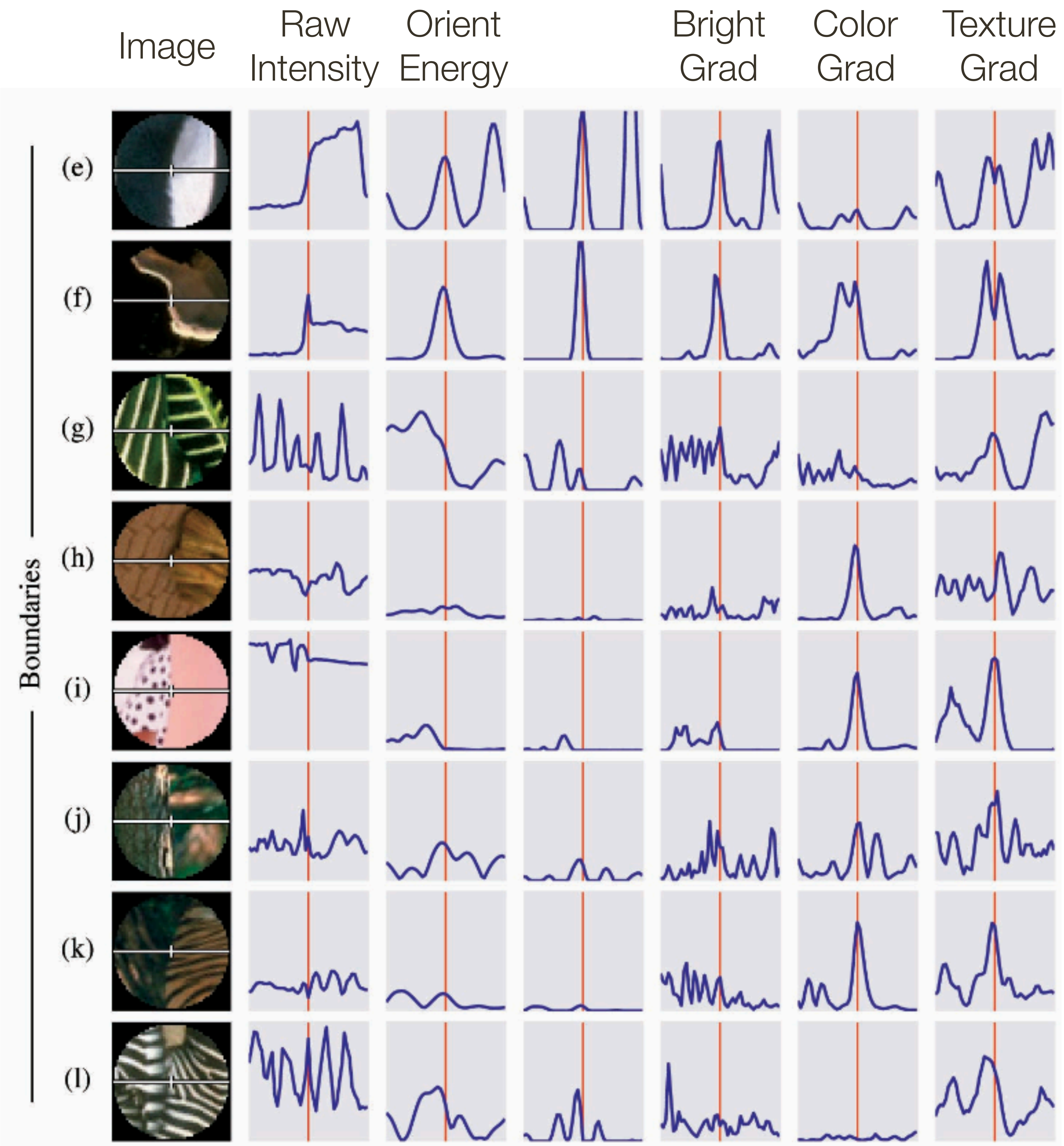

Figure Credit: Martin et al. 2004

Texture **Segmentation**

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Answer: We need a region to have a texture.

There is a “chicken–and–egg” problem. Texture segmentation can be done by detecting boundaries between regions of the same (or similar) texture. Texture boundaries can be detected using standard edge detection techniques applied to the texture measures determined at each point

We compromise! Typically one uses a local window to estimate texture properties and assigns those texture properties as point properties of the window’s center row and column

Texture **Representation**

Question: How many degrees of freedom are there to texture?

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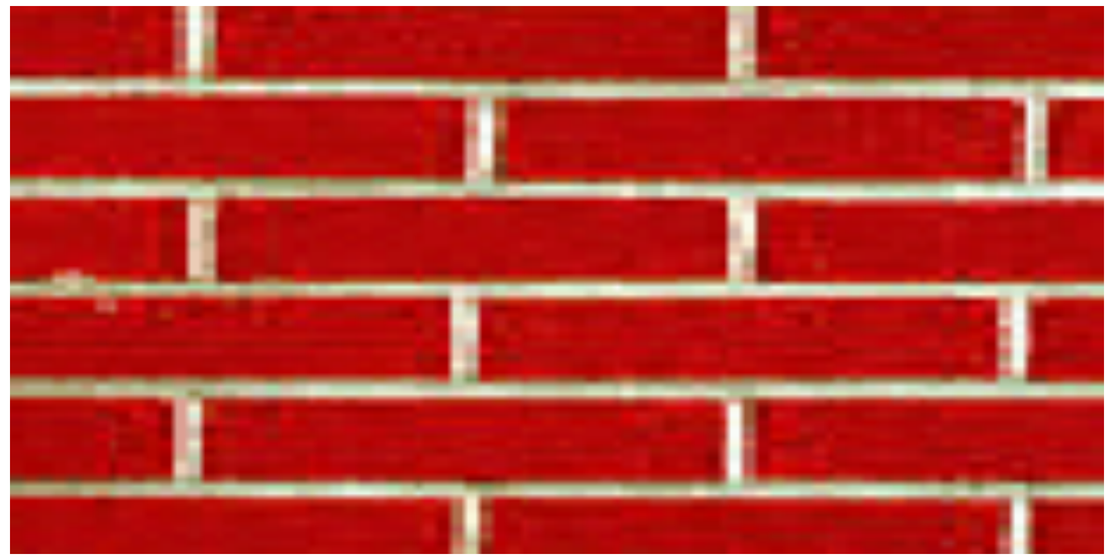
(**Mathematical**) Answer: Infinitely many

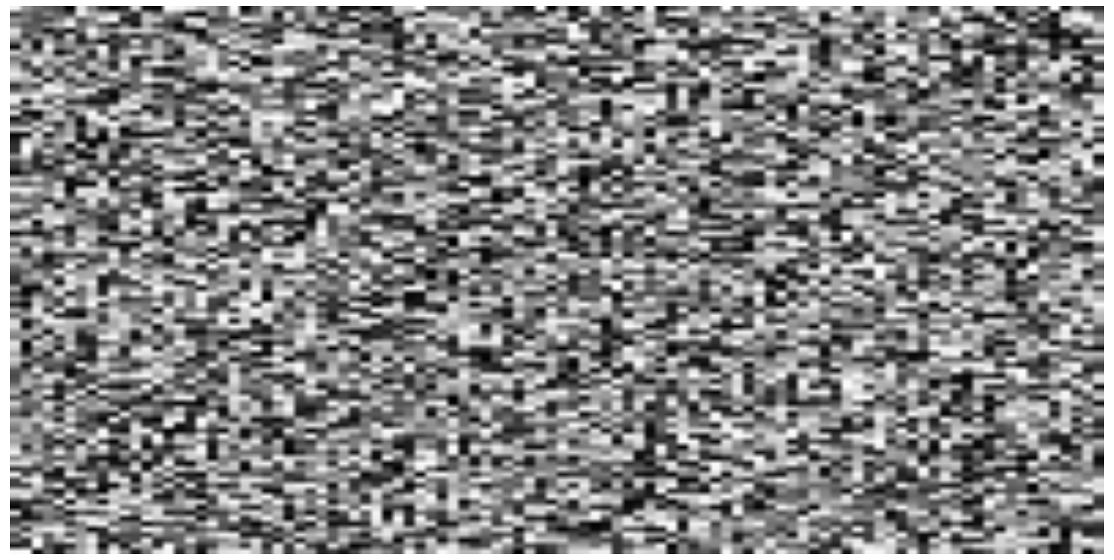
(**Perceptual Psychology**) Answer: There are perceptual constraints. But, there is no clear notion of a “texture channel” like, for example, there is for an RGB colour channel

Texture **Representation**

Observation: Textures are made up of generic sub-elements, repeated over a region with similar statistical properties

Idea: Find the sub-elements with filters, then represent each point in the image with a summary of the pattern of sub-elements in the local region





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Answer: Human vision suggests spots and oriented edge filters at a variety of different orientations and scales

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Question: How do we “summarize”?

Answer: Compute the mean or maximum of each filter response over the region
— Other statistics can also be useful

Texture **Representation**

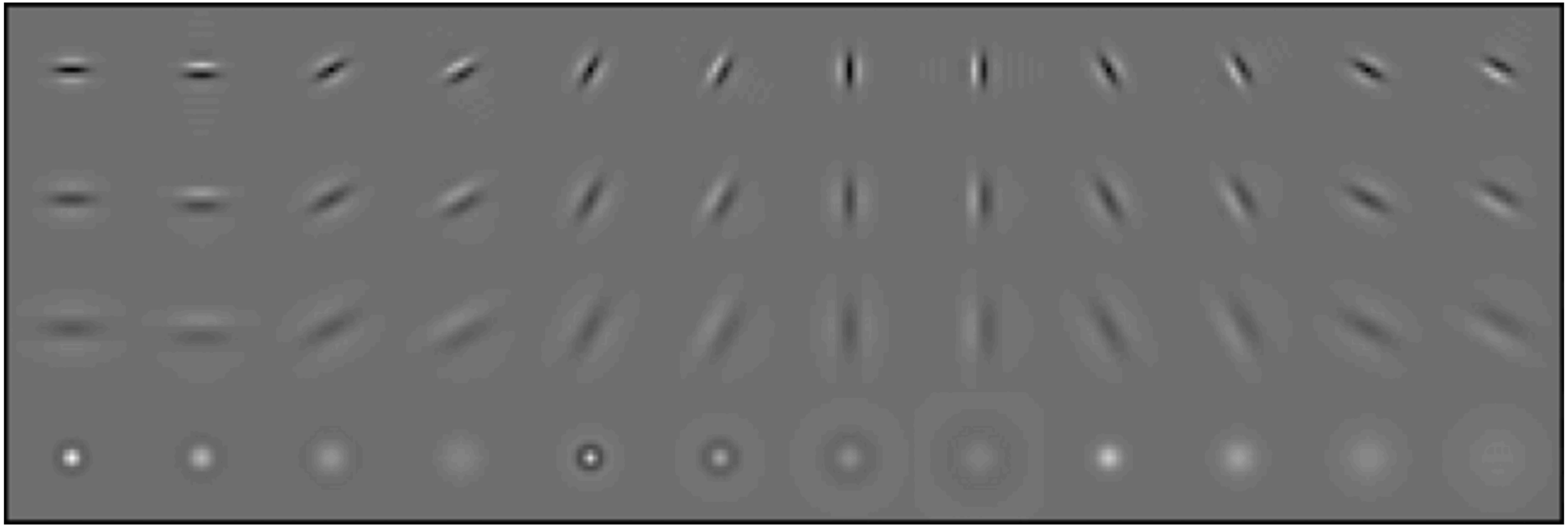
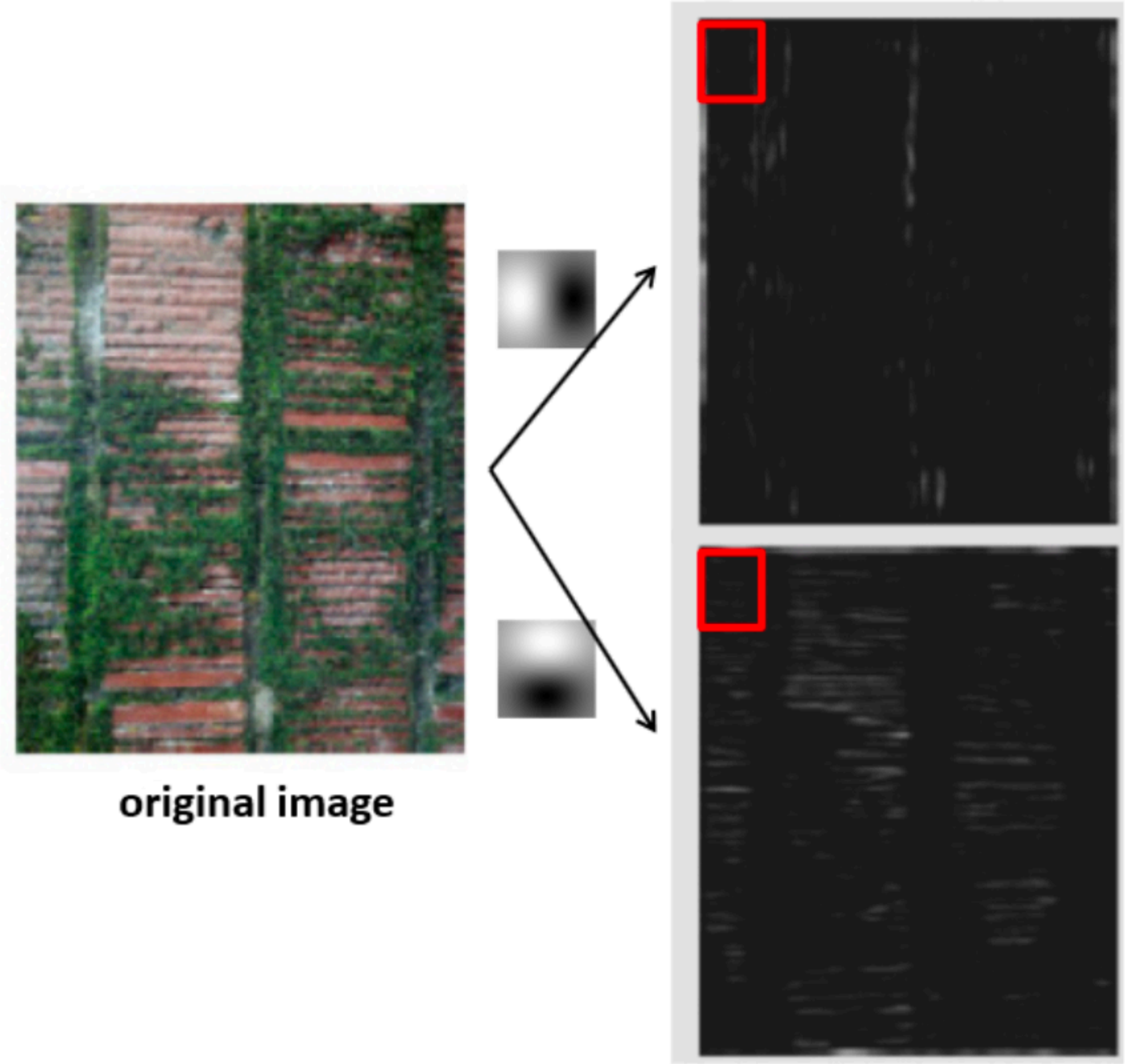


Figure Credit: Leung and Malik, 2001

Texture **Representation**



original image

derivative filter responses, squared

	mean d/dx value	mean d/dy value
Win. #1	4	10

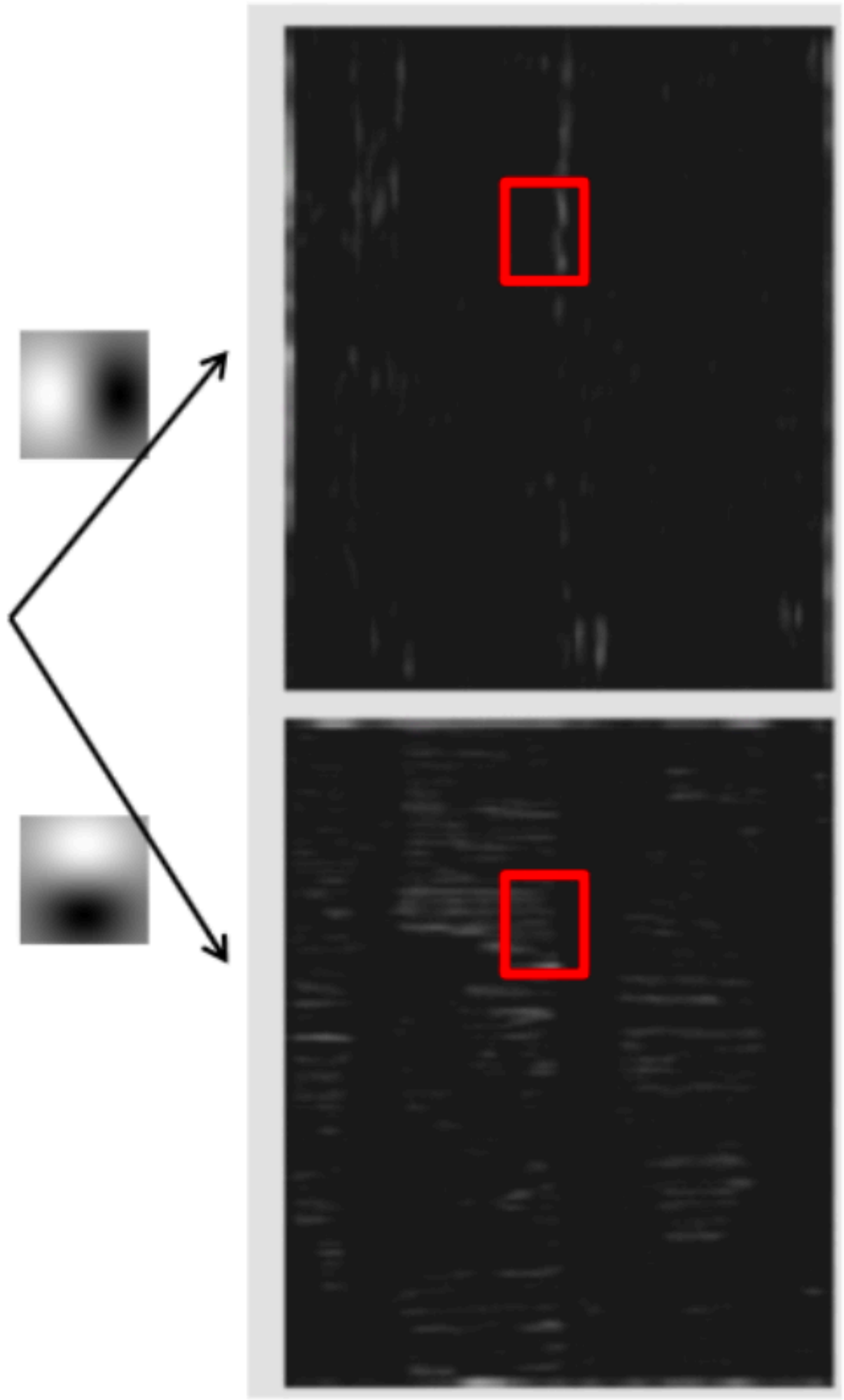
⋮

statistics to summarize patterns in small windows

Slide Credit: Trevor Darrell

Texture **Representation**

original image



derivative filter responses, squared

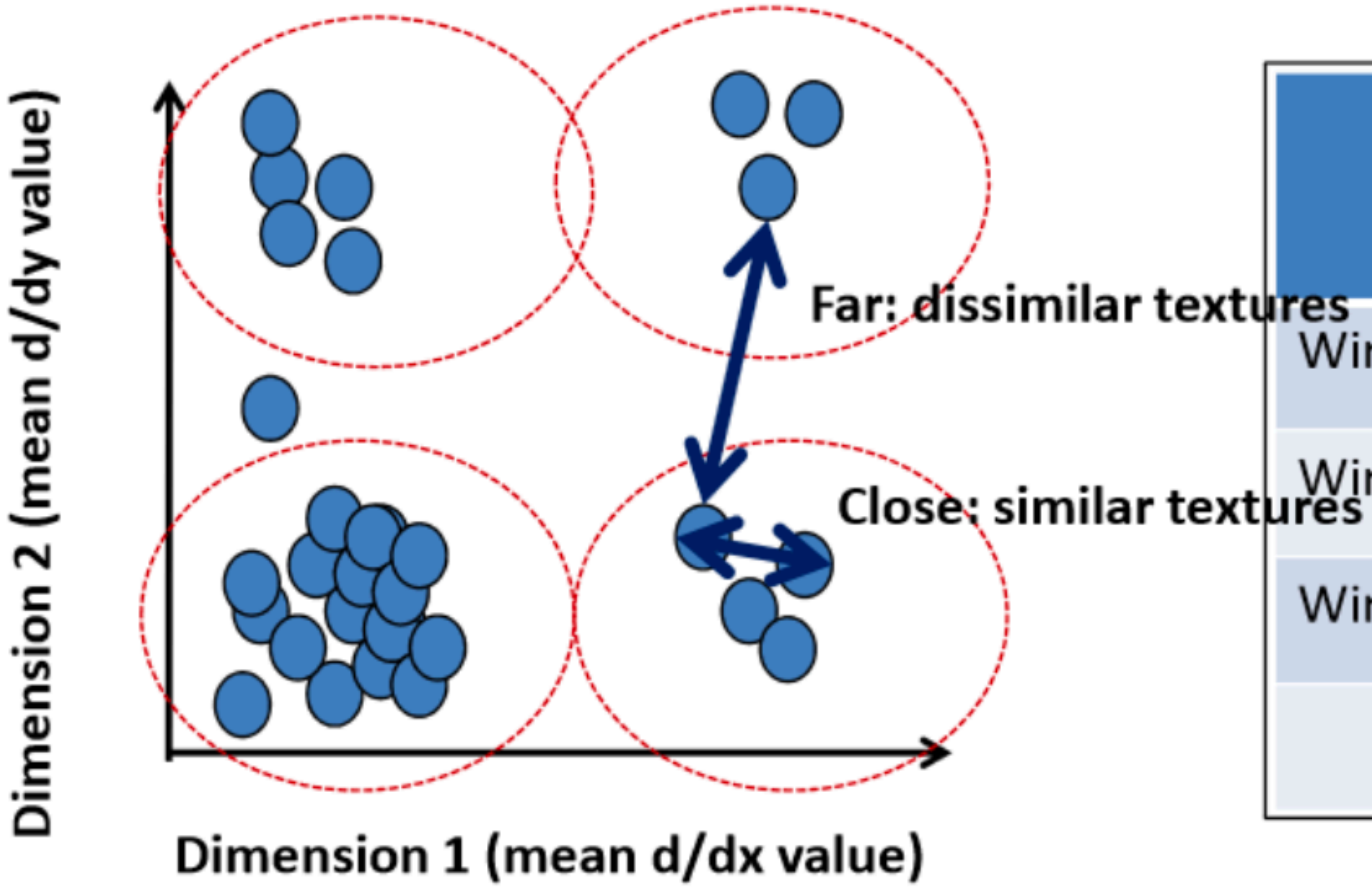
	mean d/dx value	mean d/dy value
Win. #1	4	10
Win.#2 ⋮	18	7
Win.#9	20	20

⋮

statistics to summarize patterns in small windows

Slide Credit: Trevor Darrell

Texture **Representation**



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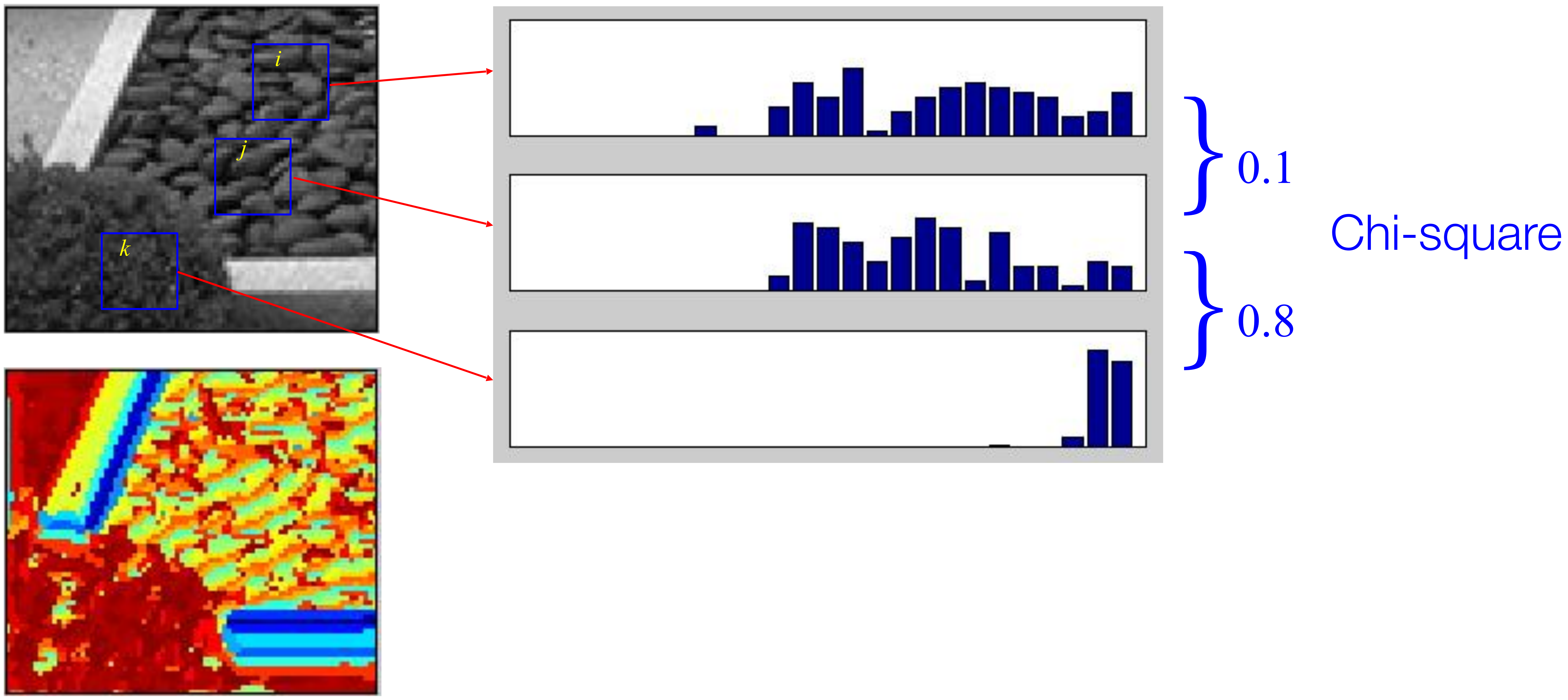
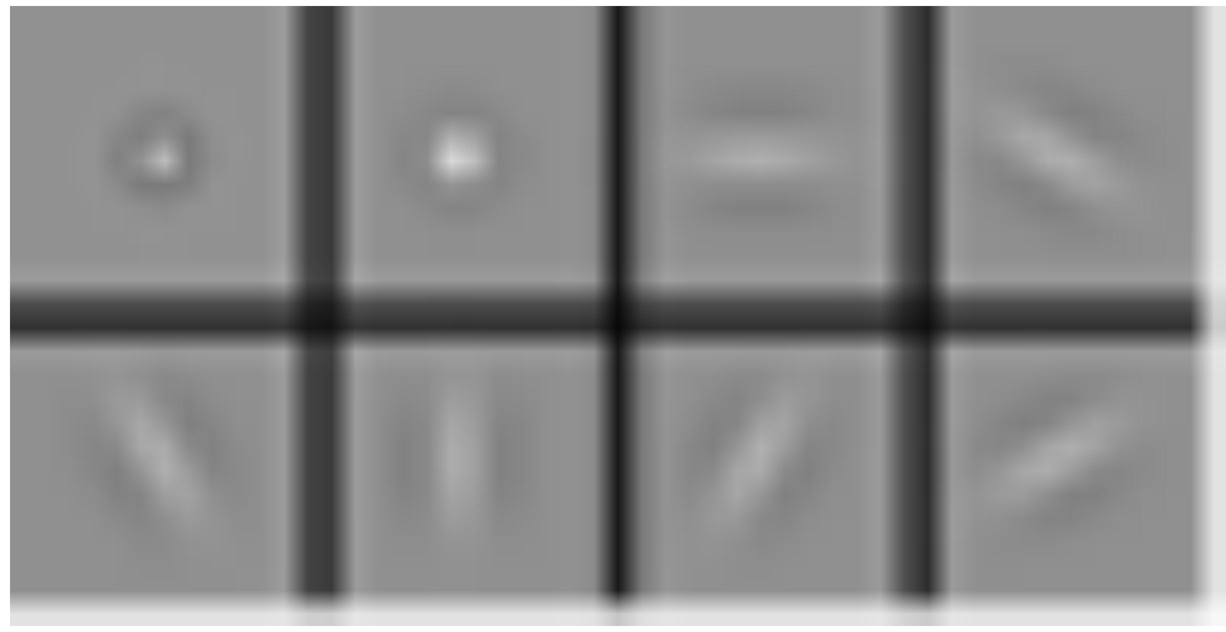
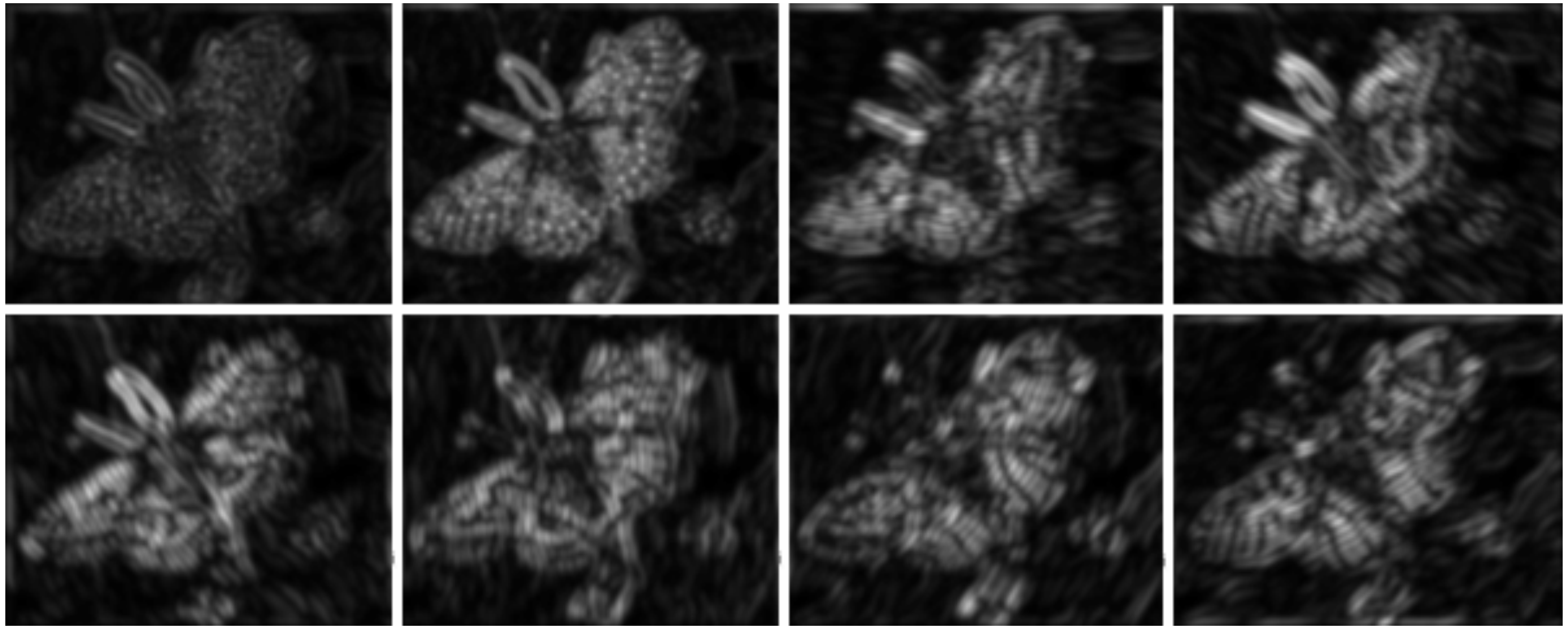


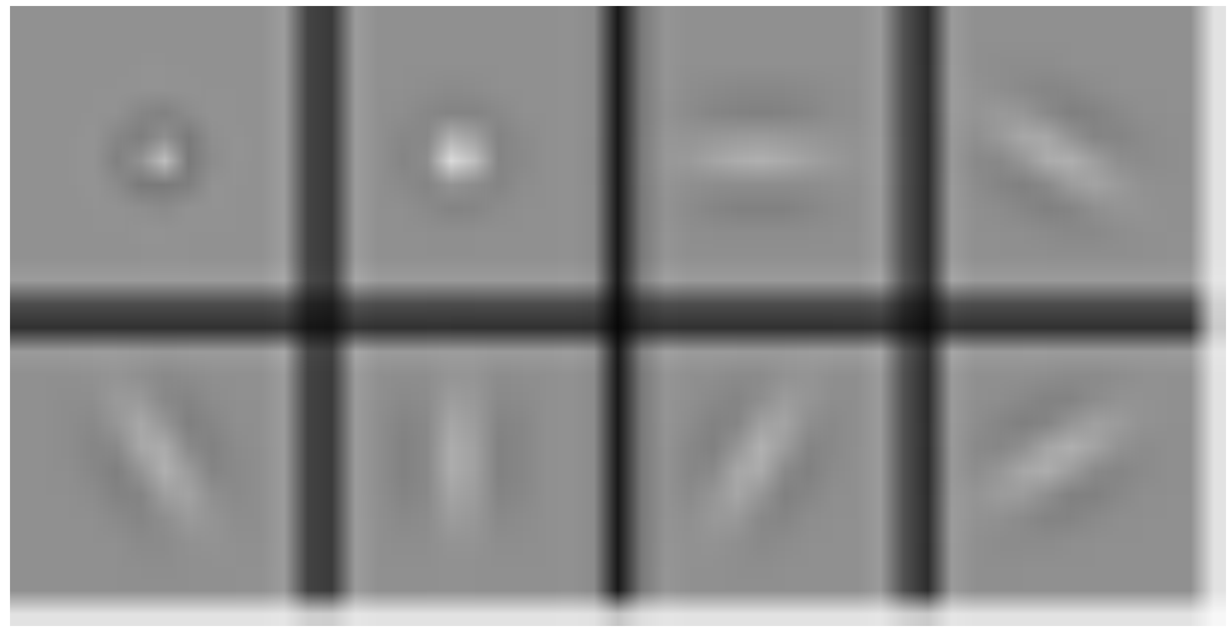
Spots and Bars (Fine Scale)

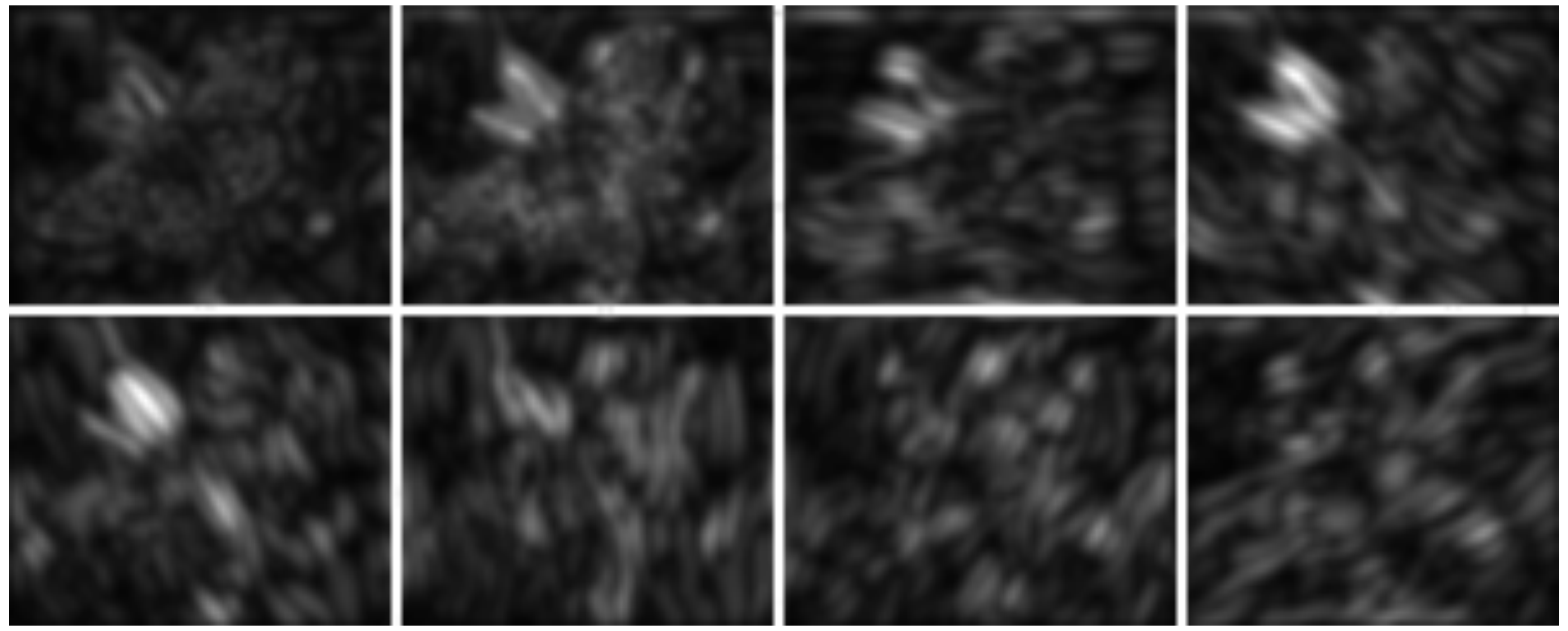




Forsyth & Ponce (1st ed.) Figures 9.3–9.4

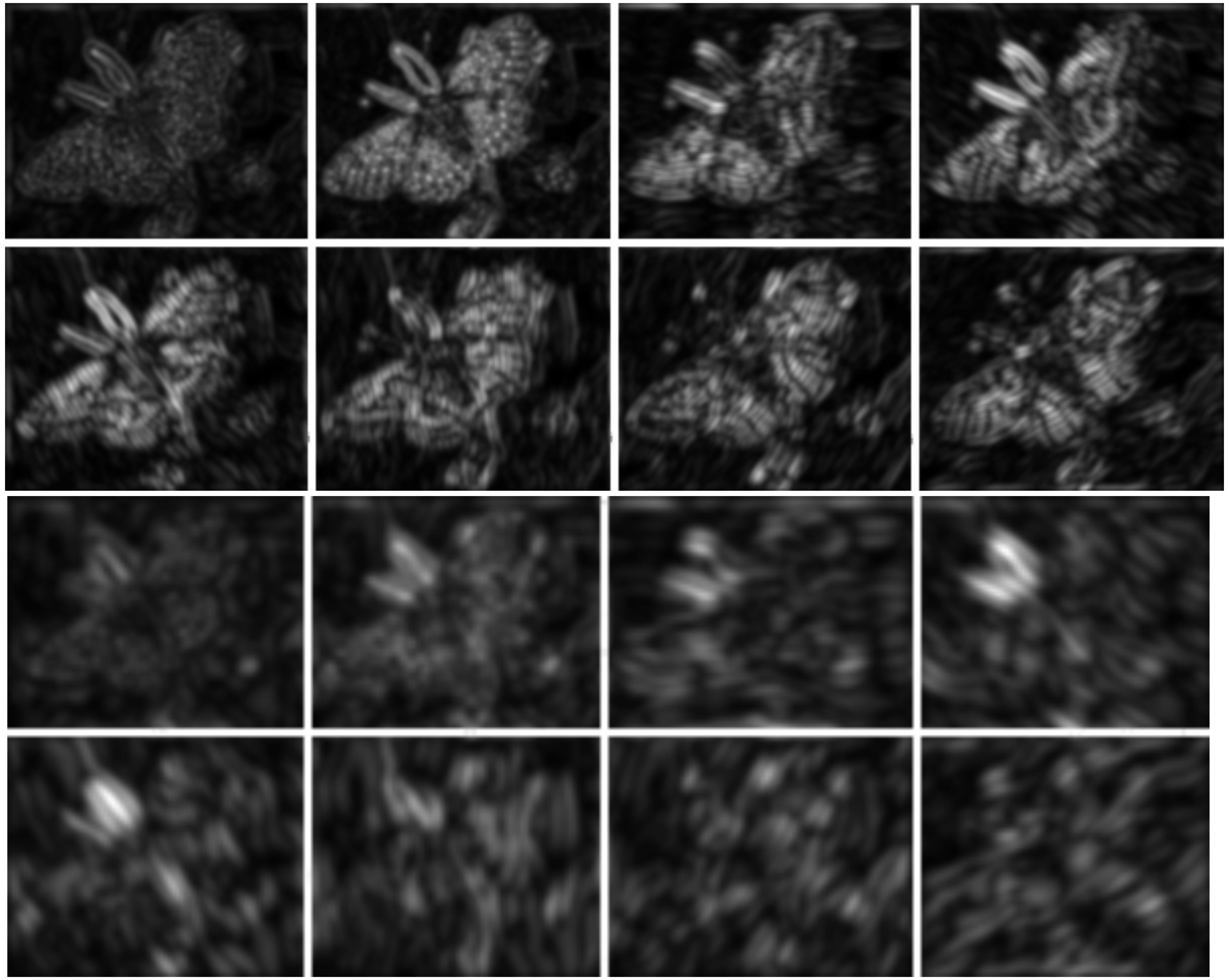
Spots and Bars (Coarse Scale)





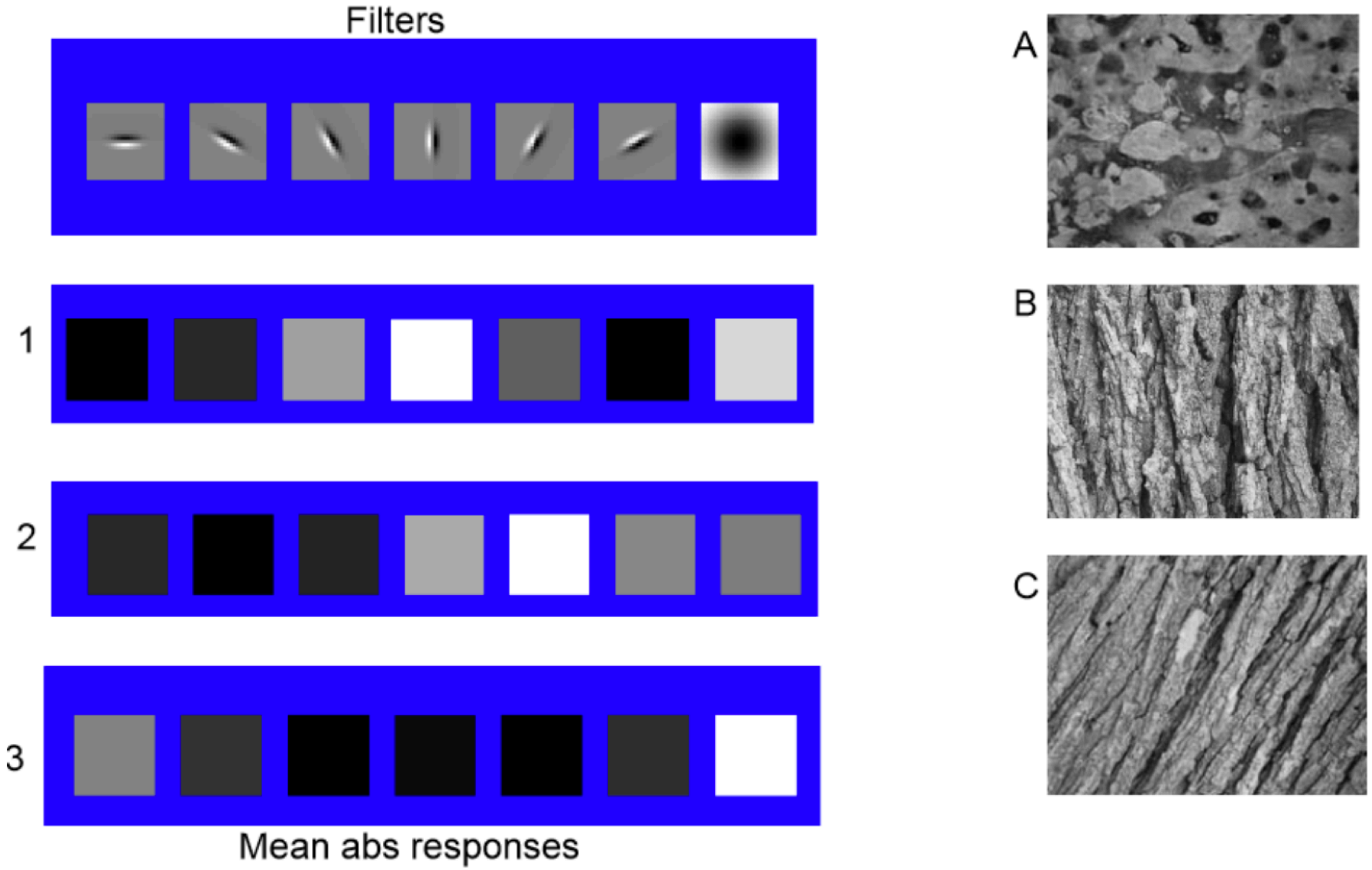
Forsyth & Ponce (1st ed.) Figures 9.3 and 9.5

Comparison of Results



Forsyth & Ponce (1st ed.) Figures 9.4–9.5

A Short **Exercise**: Match the texture to the response



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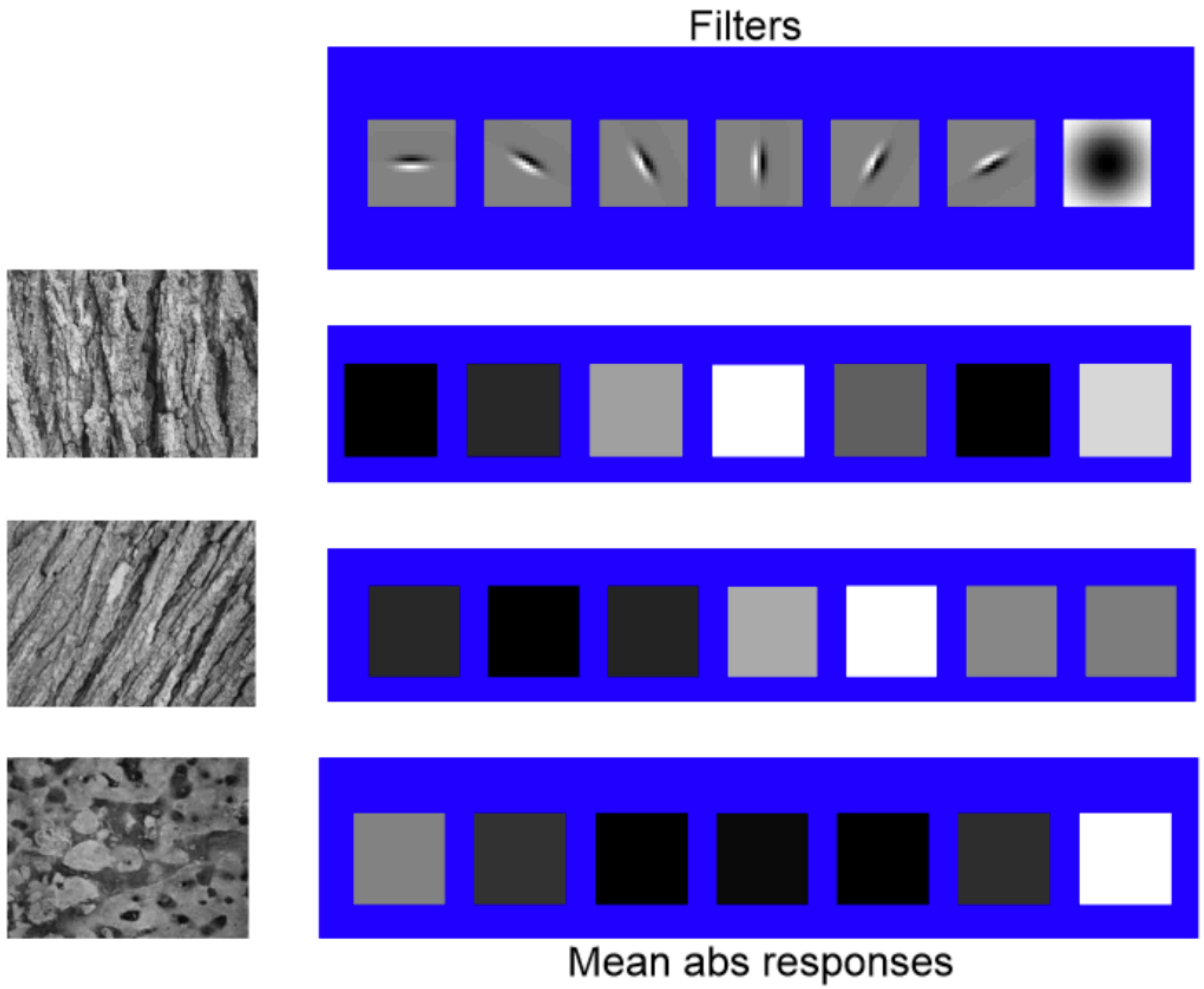

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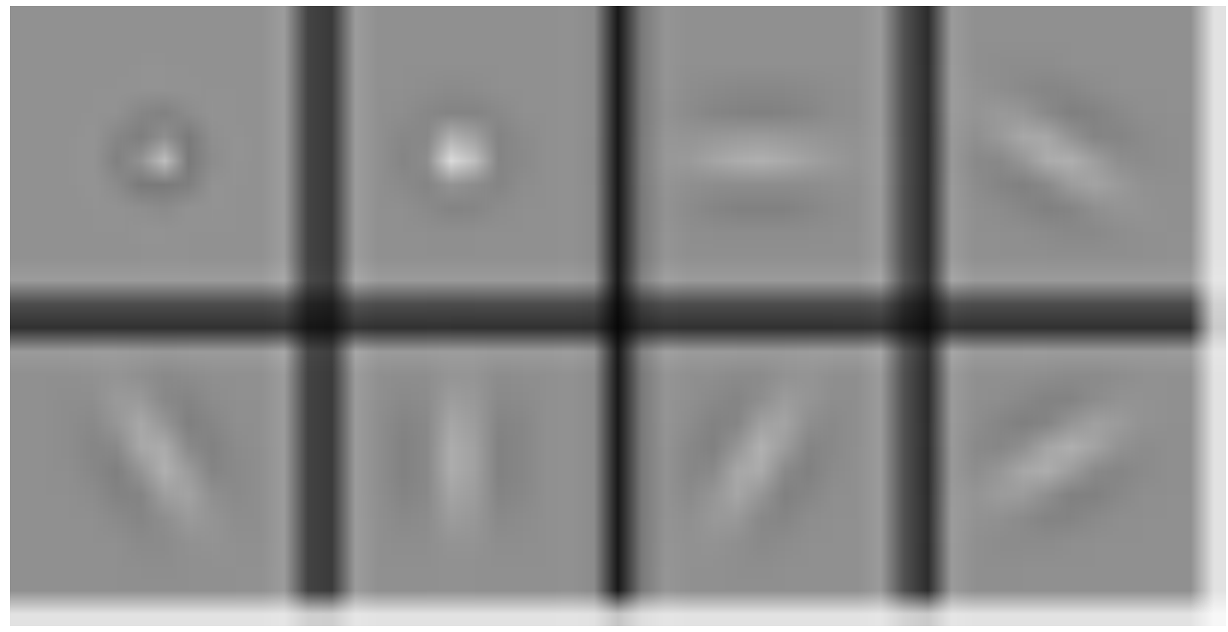
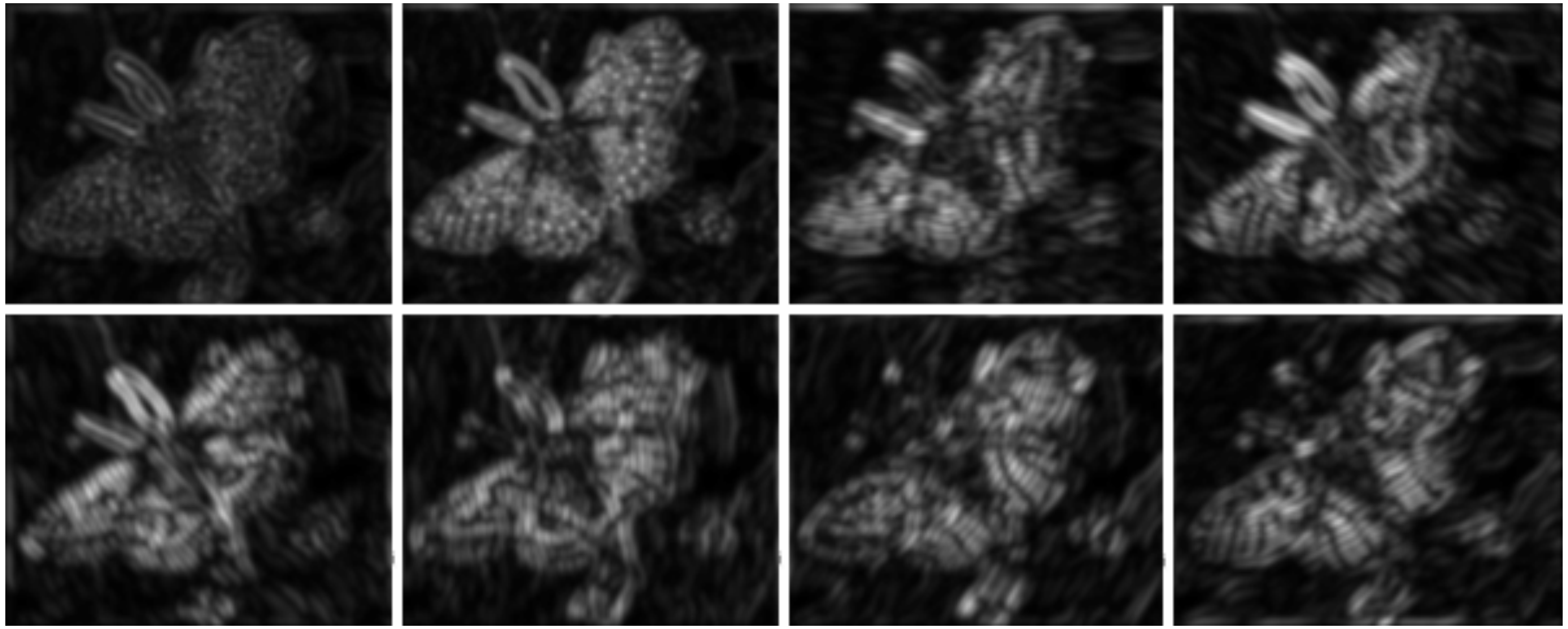
Spots and Bars (Fine Scale)





Forsyth & Ponce (1st ed.) Figures 9.3–9.4

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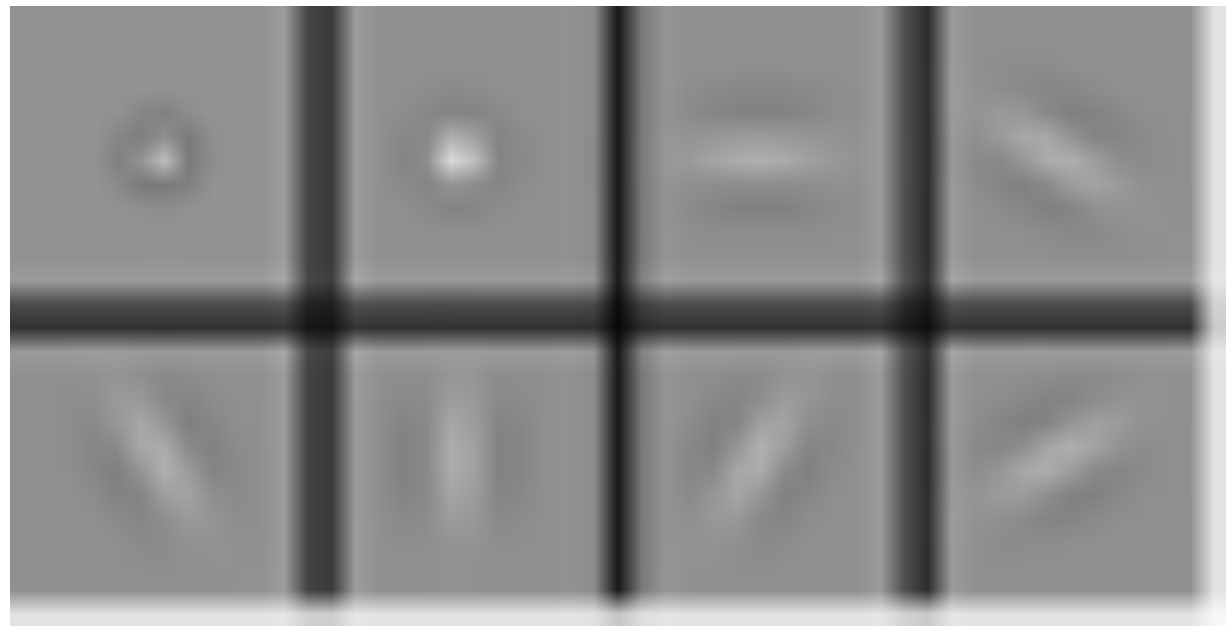
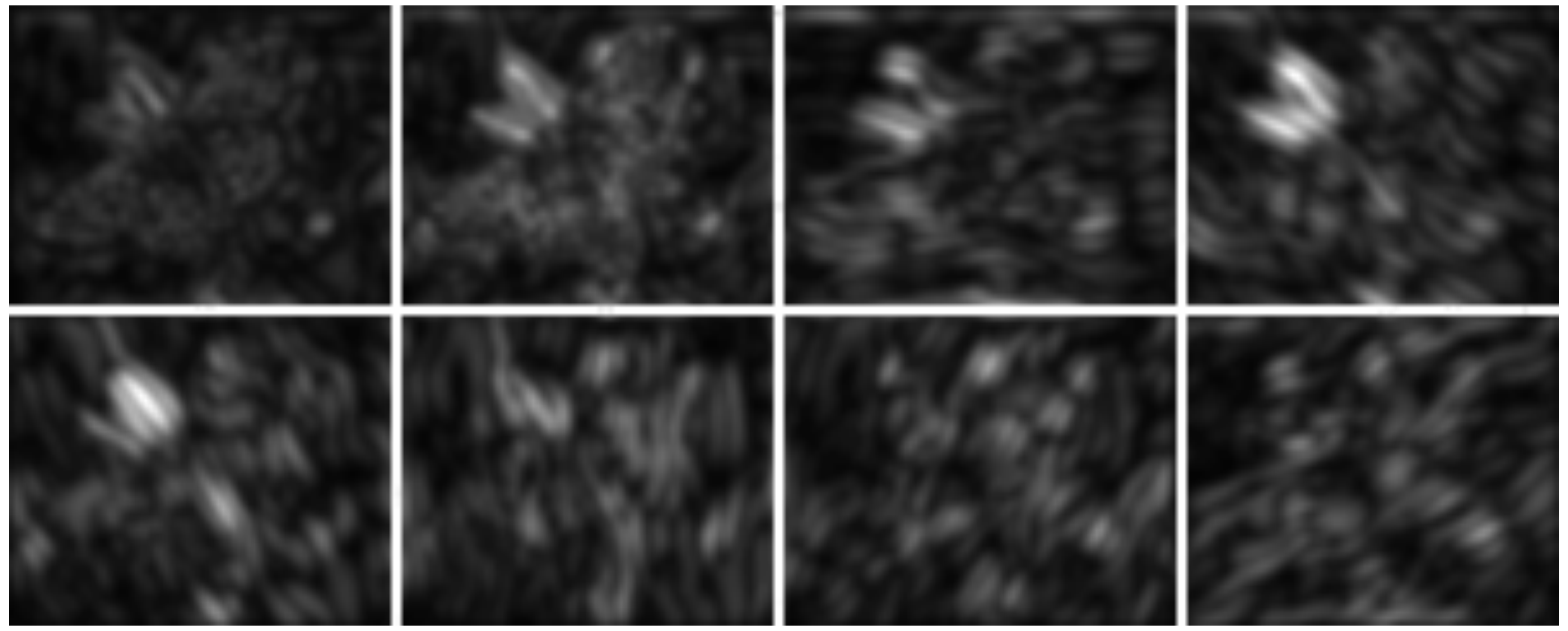
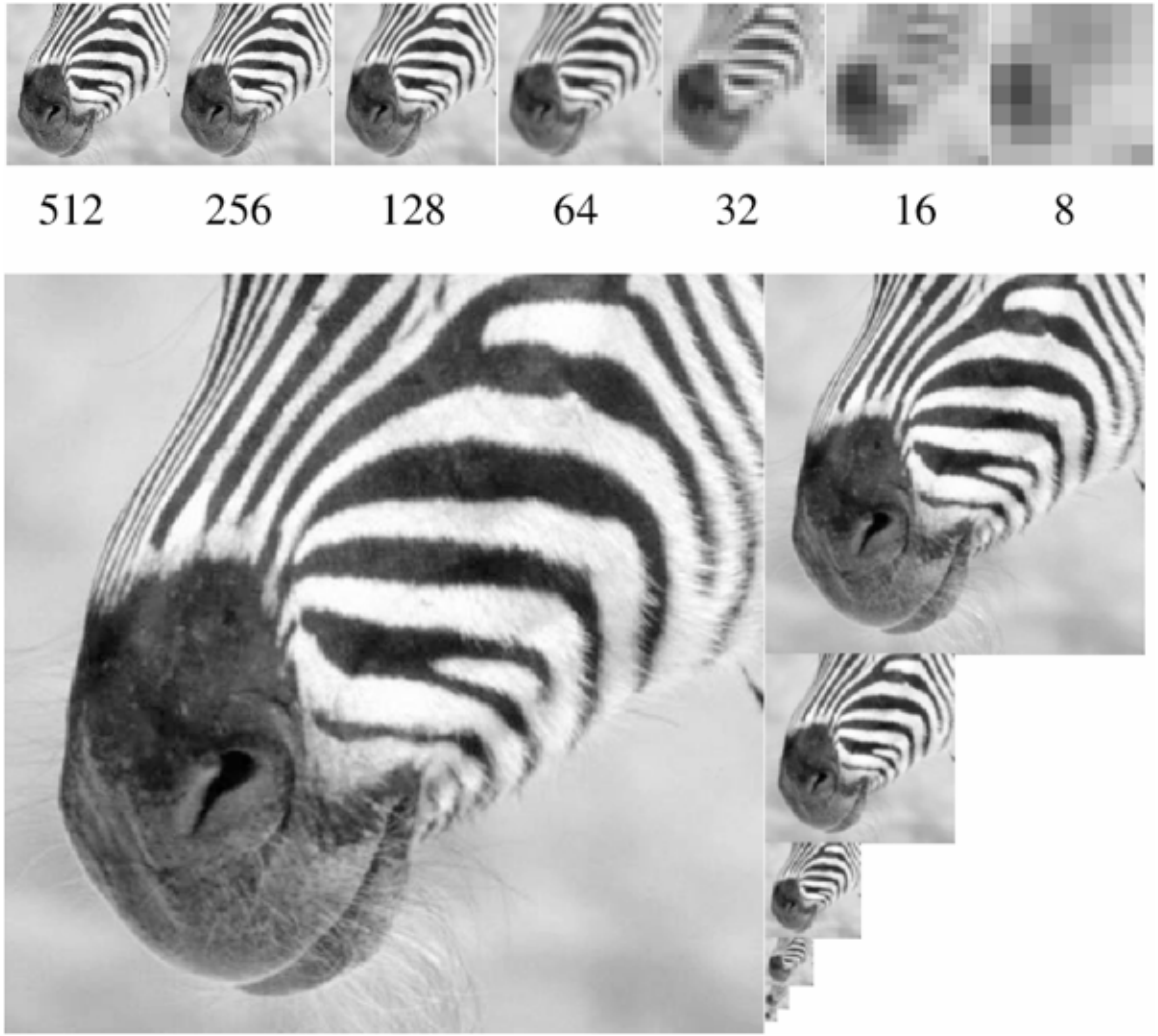




Forsyth & Ponce (1st ed.) Figures 9.3 and 9.5

Gaussian Pyramid



Forsyth & Ponce (2nd ed.) Figure 4.17

What happens to the details?

— They get smoothed out as we move to higher levels

What is preserved at the higher levels?

— Mostly large uniform regions in the original image

How would you reconstruct the original image from the image at the upper level?

— That's not possible

Slide Credit: Ioannis (Yannis) Gkioulekas (CMU)

Laplacian Pyramid

Building a **Laplacian** pyramid:

— Create a Gaussian pyramid

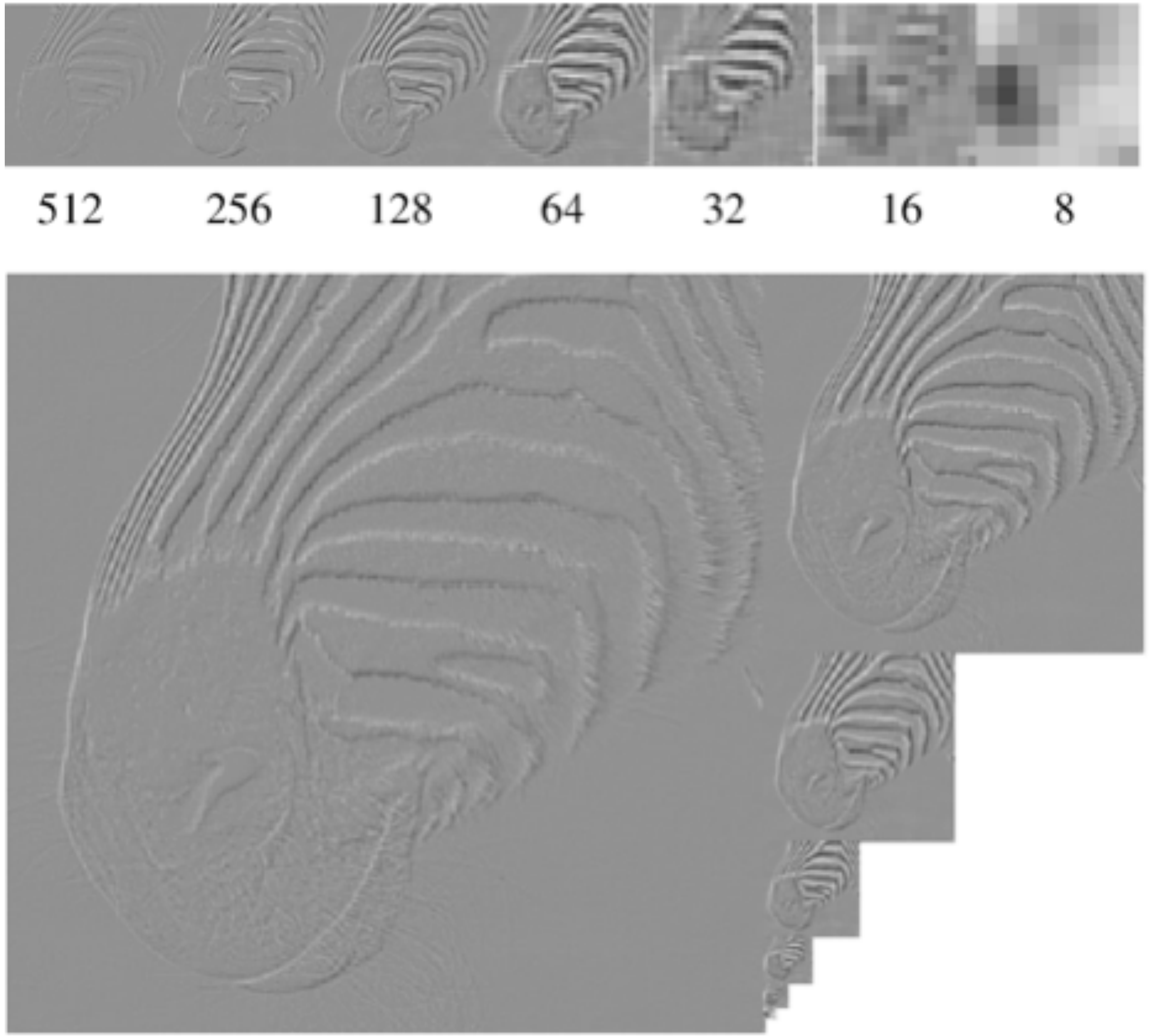
— Take the difference between one Gaussian pyramid level and the next (before subsampling)

Properties

— Also known as the difference-of-Gaussian (DOG) function, a close approximation to the Laplacian

— It is a band pass filter – each level represents a different band of spatial frequencies

Laplacian Pyramid

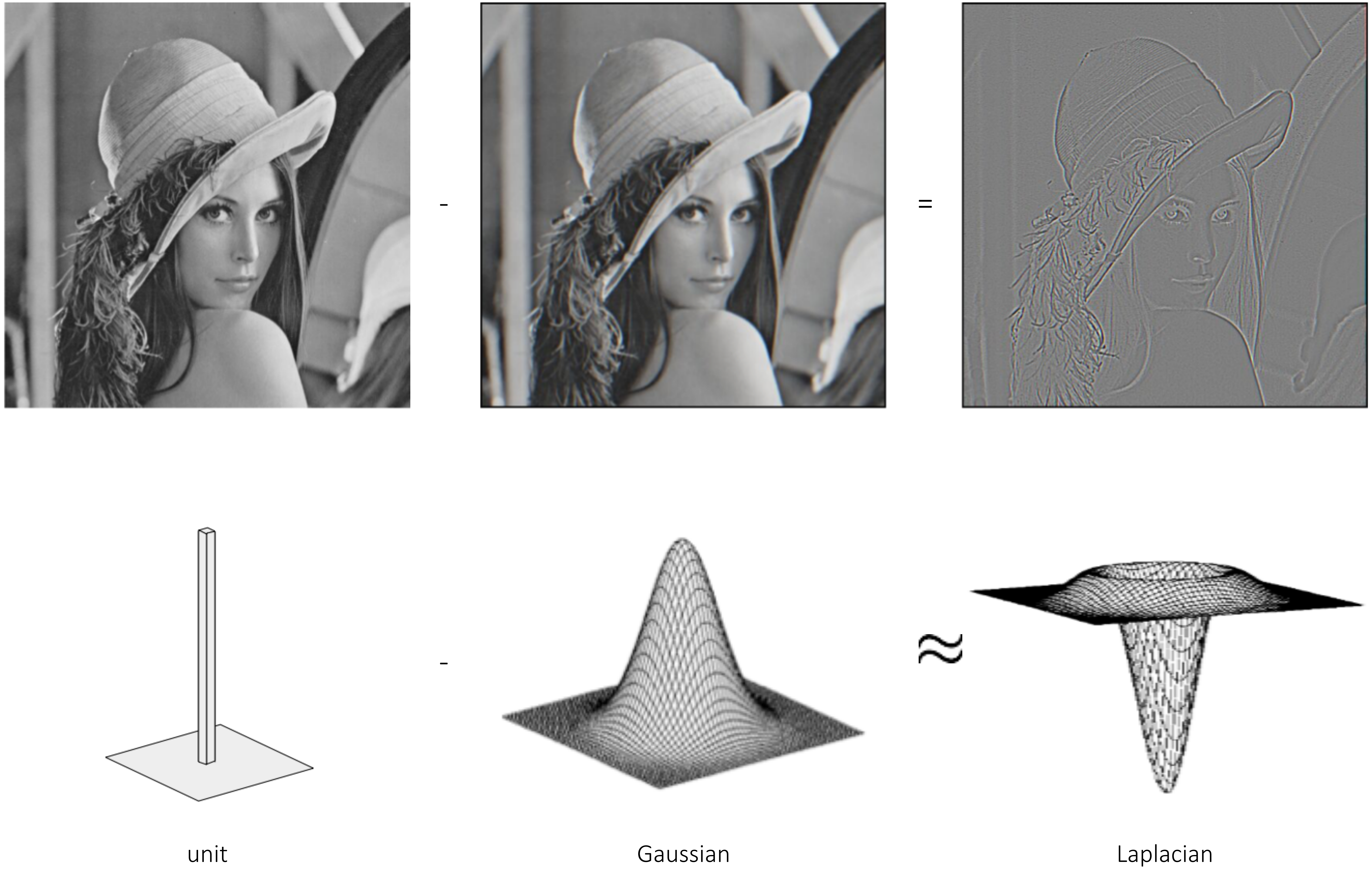


At each level, retain the residuals instead of the blurred images themselves.

Why is it called Laplacian Pyramid?

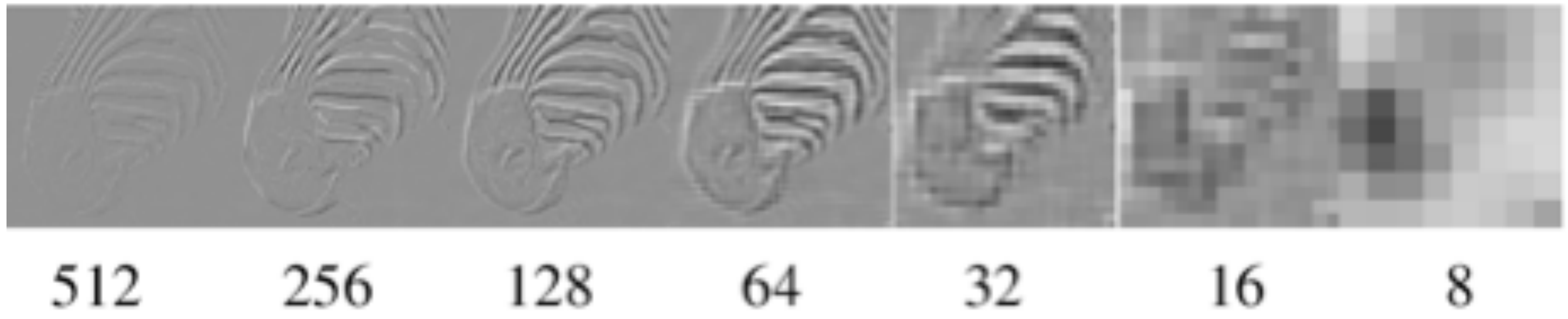
Slide Credit: Ioannis (Yannis) Gkioulekas (CMU)

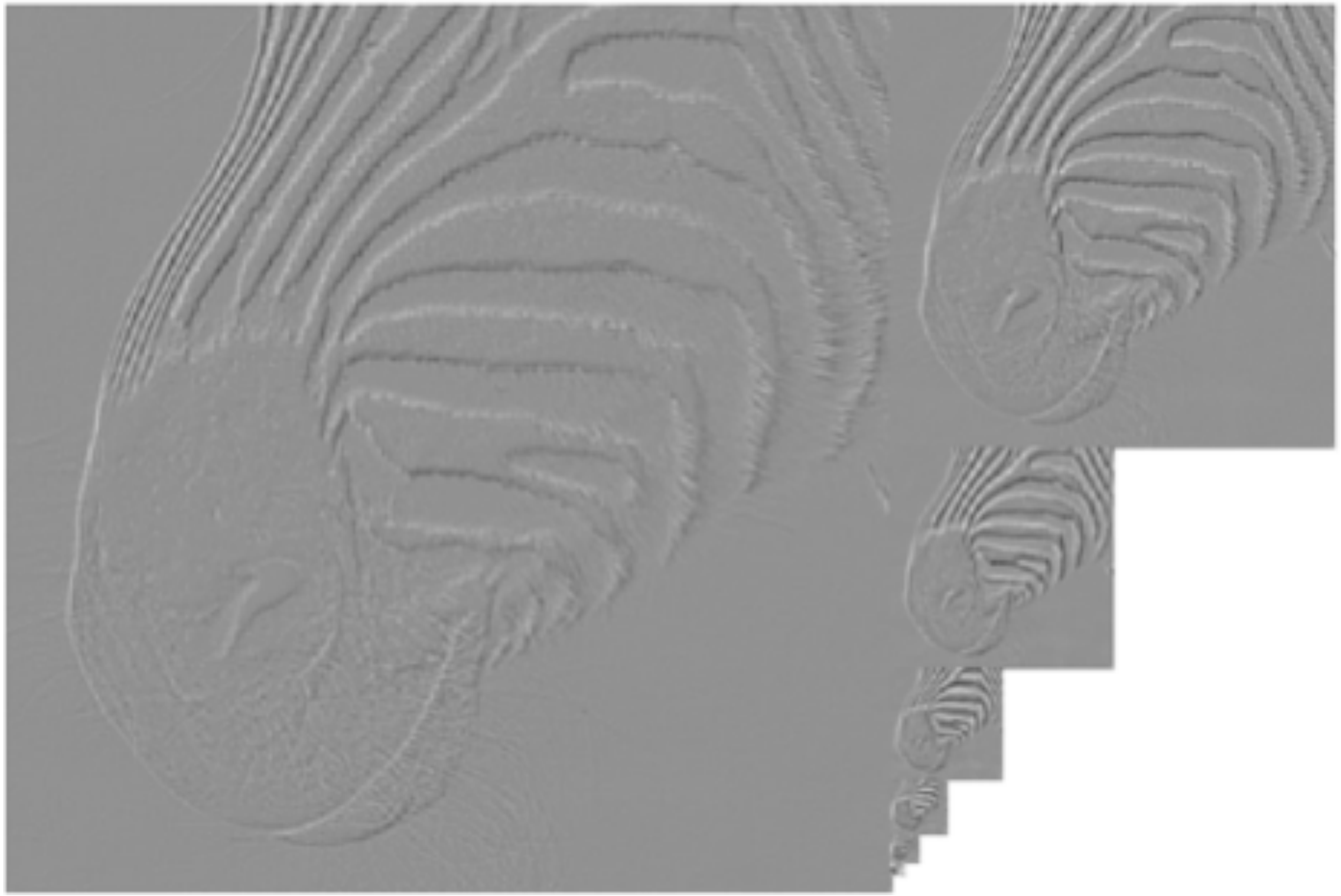
Why **Laplacian** Pyramid?



Slide Credit: Ioannis (Yannis) Gkioulekas (CMU)

Laplacian Pyramid





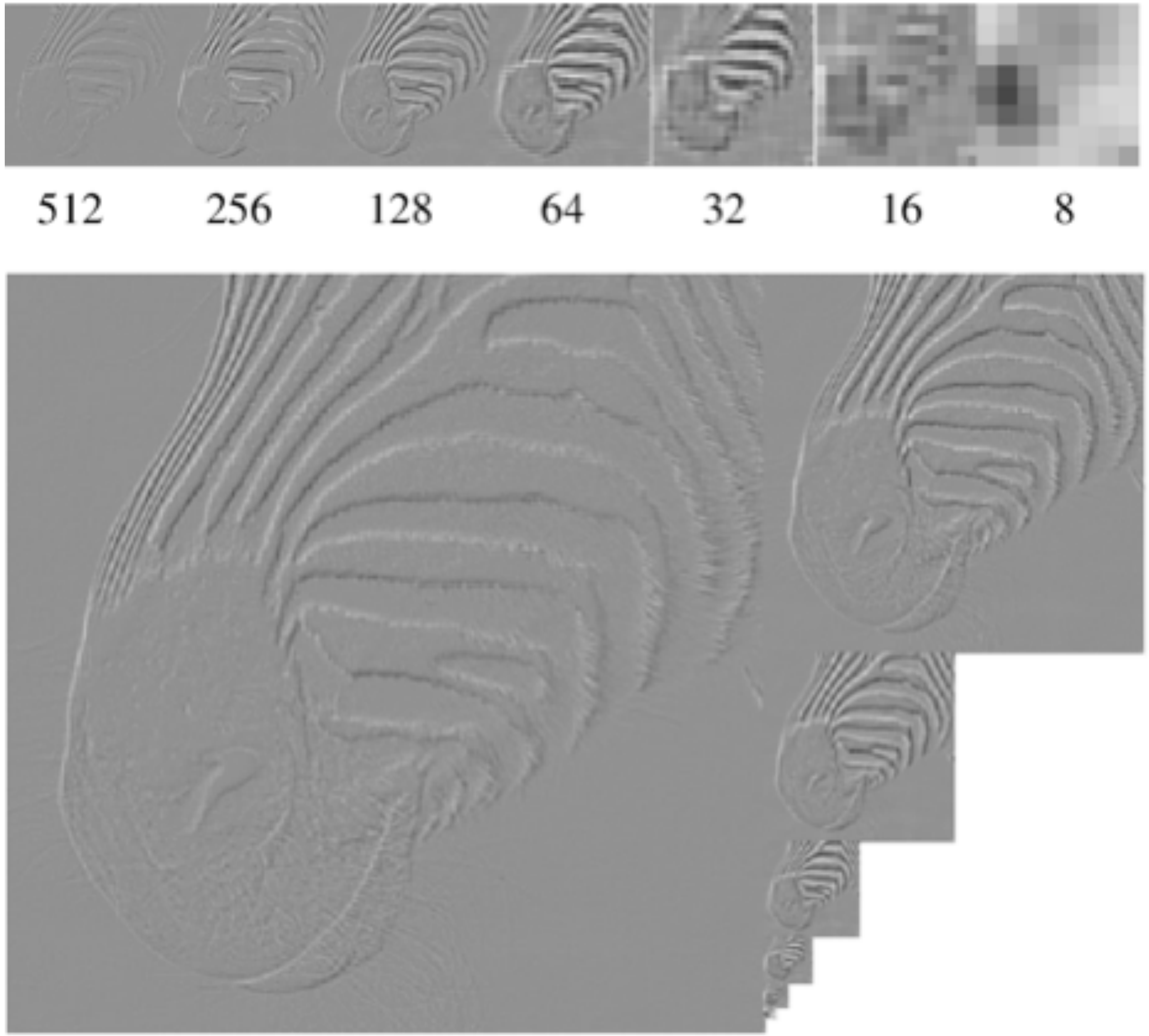
At each level, retain the residuals instead of the blurred images themselves.

Why is it called Laplacian Pyramid?

Can we reconstruct the original image using the pyramid?
— Yes we can!

Slide Credit: Ioannis (Yannis) Gkioulekas (CMU)

Laplacian Pyramid



At each level, retain the residuals instead of the blurred images themselves.

Why is it called Laplacian Pyramid?

Can we reconstruct the original image using the pyramid?
— Yes we can!

What do we need to store to be able to reconstruct the original image?

Slide Credit: Ioannis (Yannis) Gkioulekas (CMU)

Let's start by just looking at **one level**

level 0

=

level 1 (upsampled)

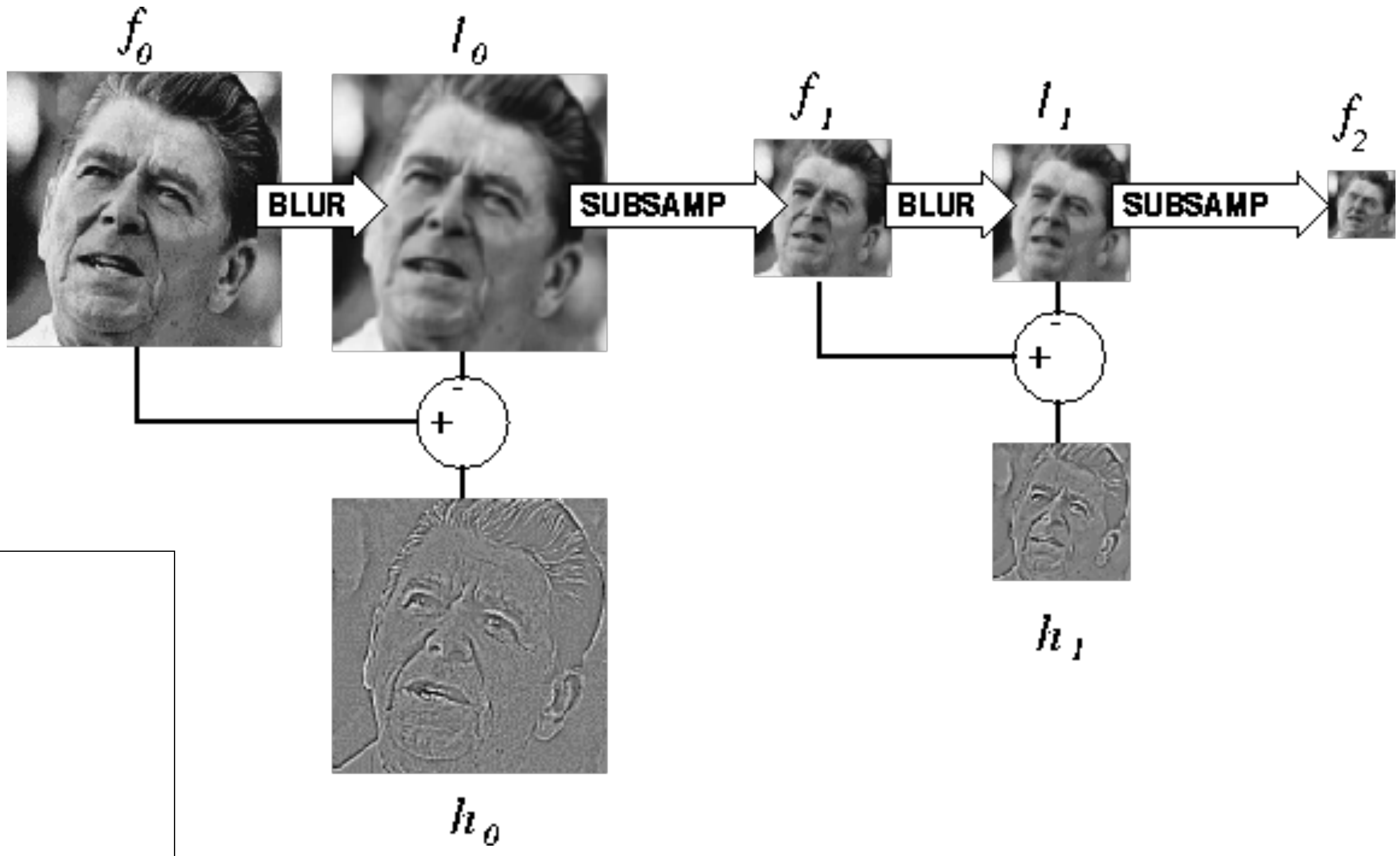
+

residual

Does this mean we need to store both residuals and the blurred copies of the original?

Slide Credit: Ioannis (Yannis) Gkioulekas (CMU)

Constructing a **Laplacian** Pyramid



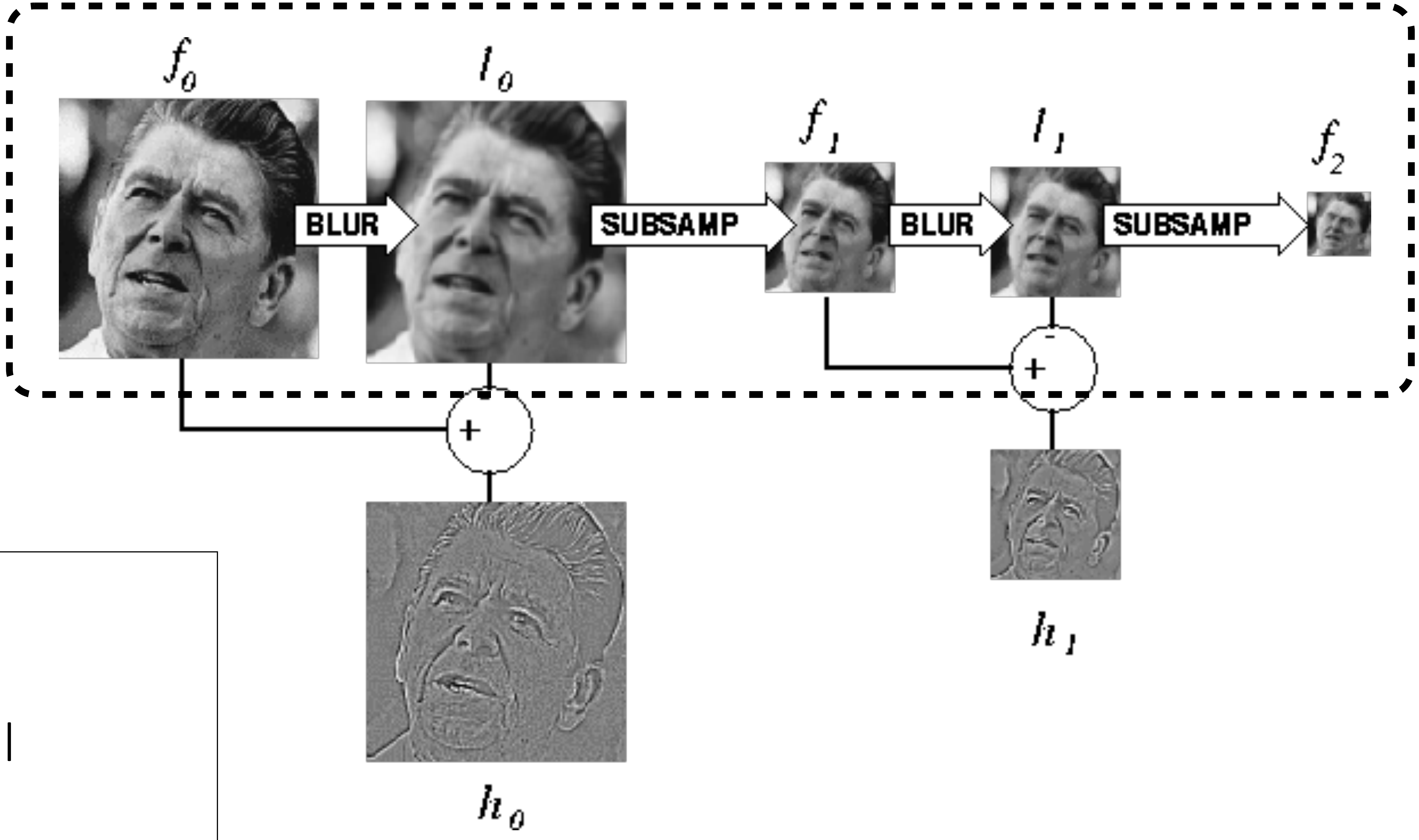
Algorithm

```
repeat:
    filter
    compute residual
    subsample
until min resolution reached
```


Slide Credit: Ioannis (Yannis) Gkioulekas (CMU)

Constructing a **Laplacian** Pyramid

What is this part?



Algorithm

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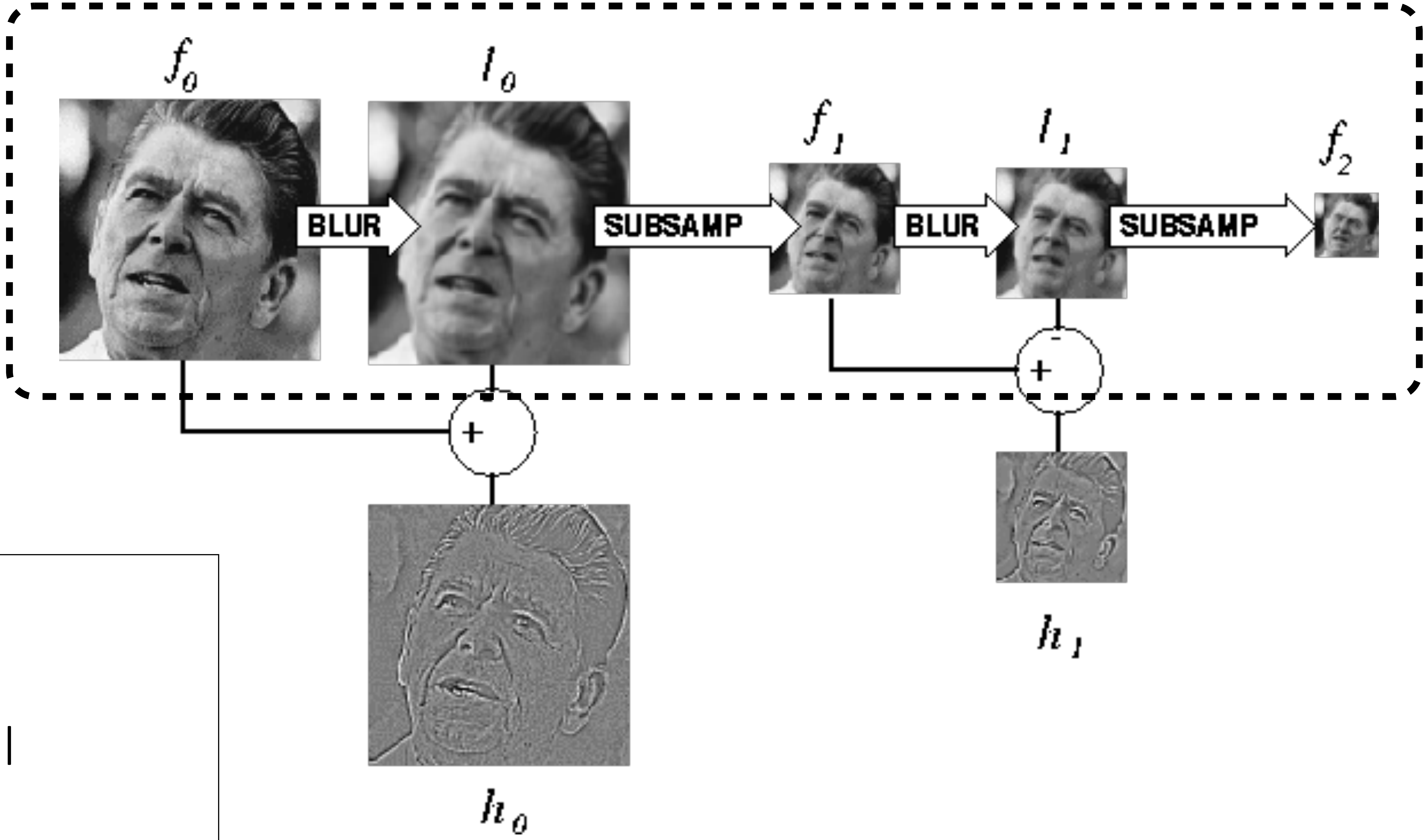
Slide Credit: Ioannis (Yannis) Gkioulekas (CMU)

Constructing a **Laplacian** Pyramid

It's a Gaussian Pyramid



Algorithm

repeat:
filter
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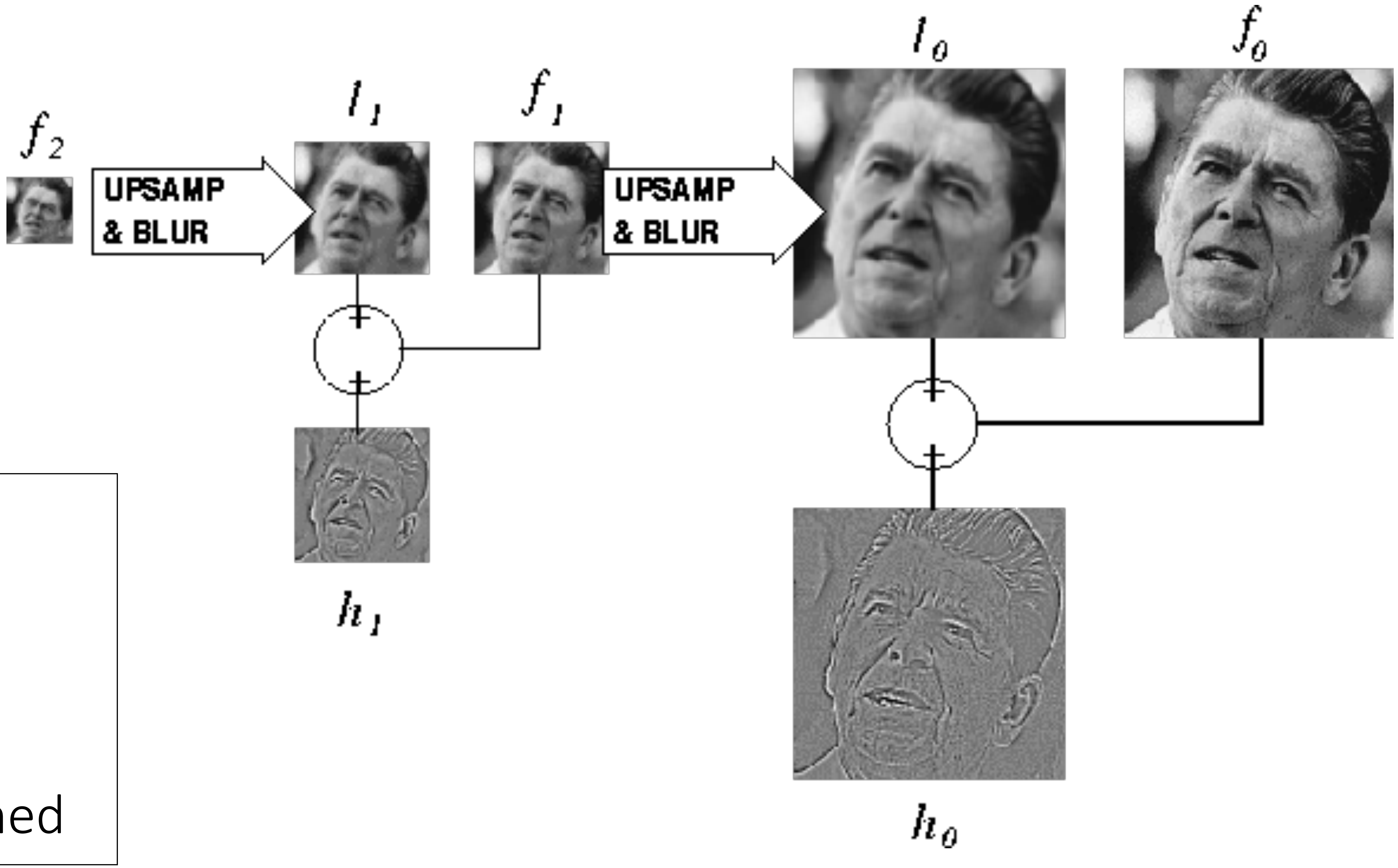
subsample
until min resolution reached

Slide Credit: Ioannis (Yannis) Gkioulekas (CMU)

Reconstructing the Original Image



Algorithm

repeat:

upsample

sum with residual

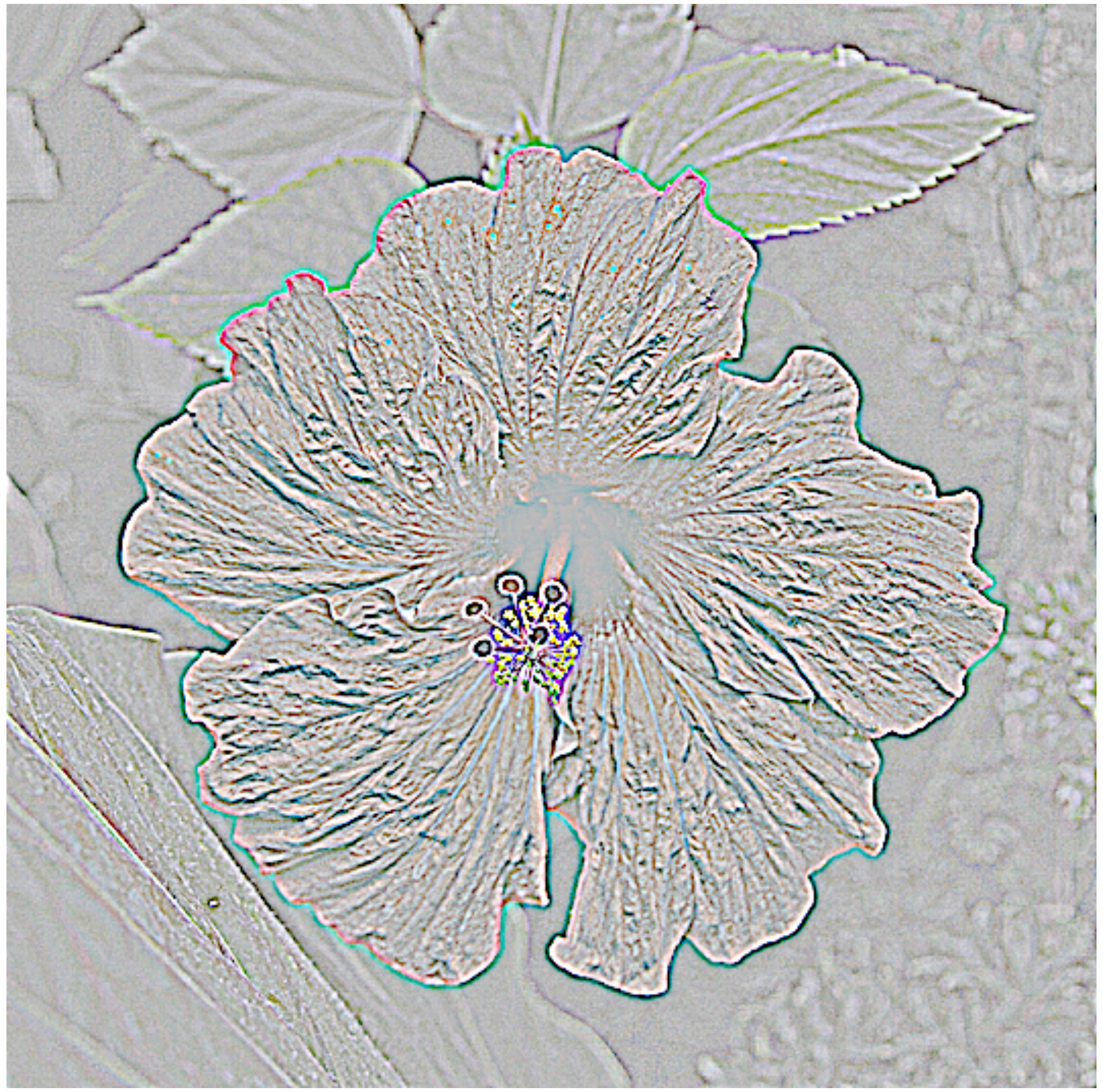
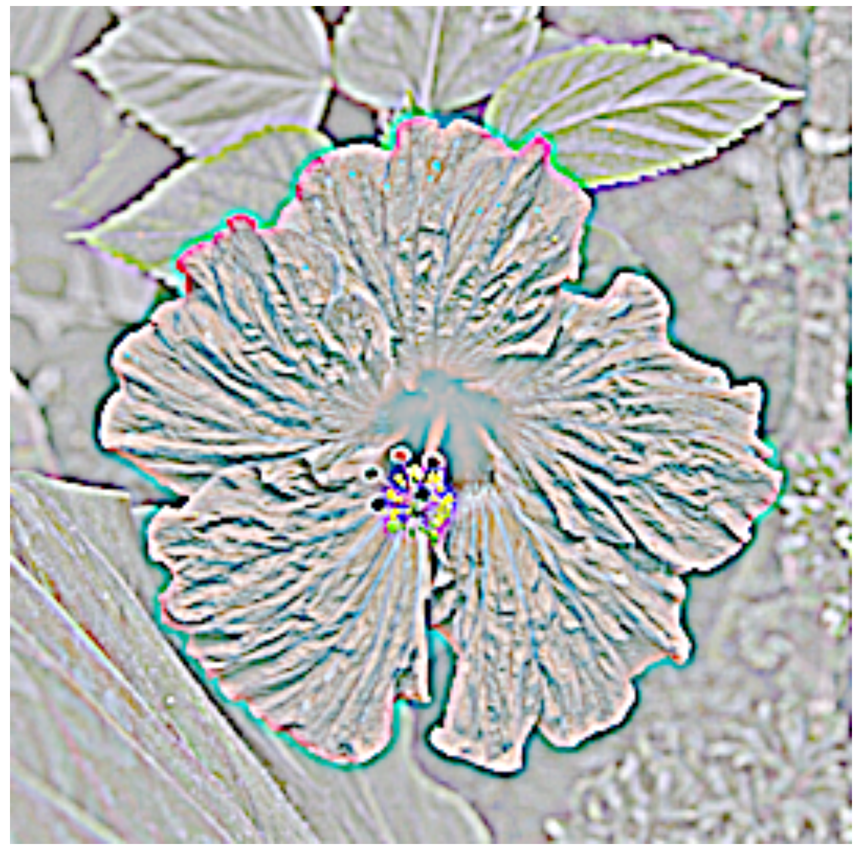
until orig resolution reached

Slide Credit: Ioannis (Yannis) Gkioulekas (CMU)

Gaussian vs **Laplacian** Pyramid



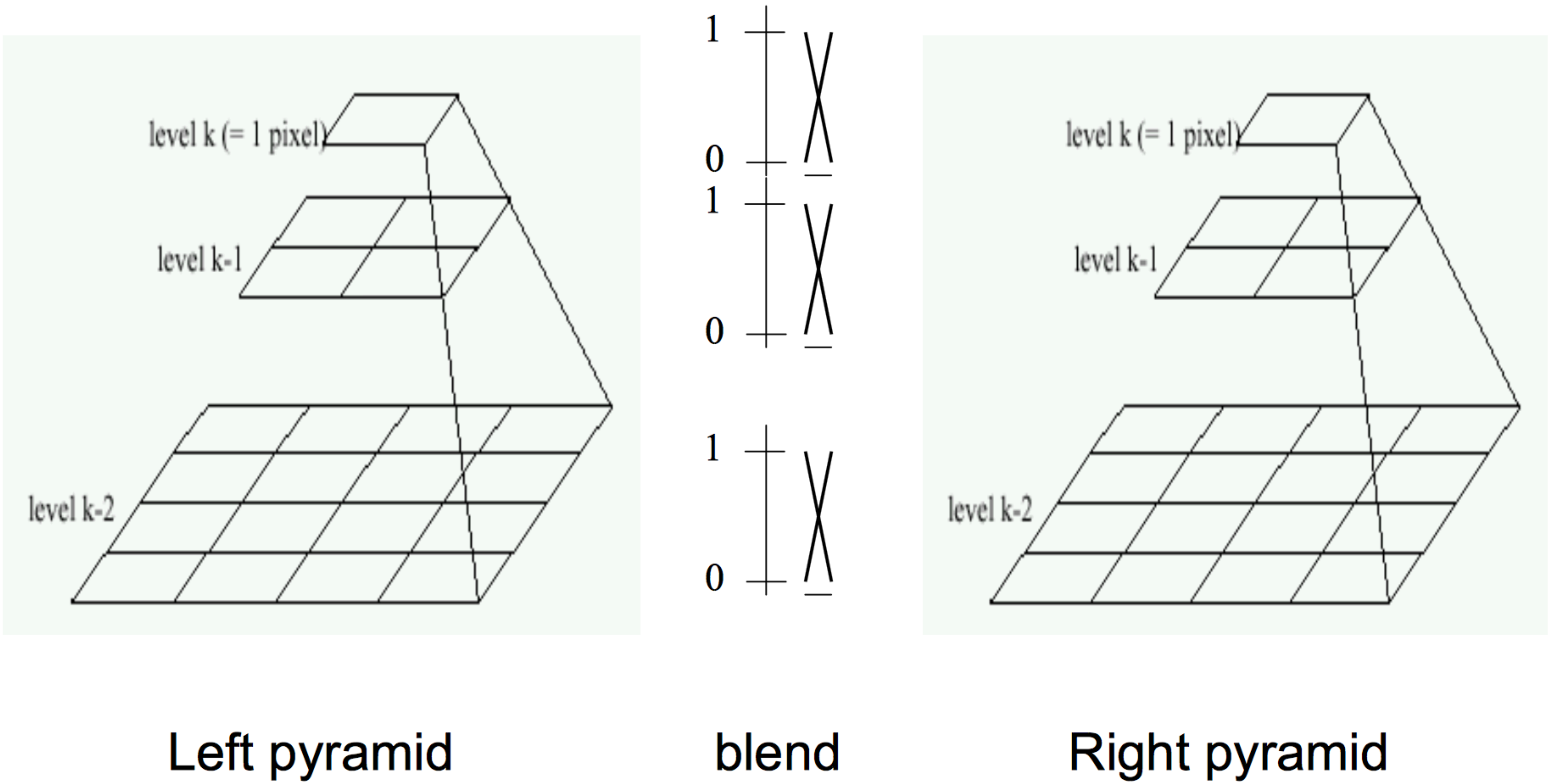

Shown in opposite order for space

Which one takes more space to store?

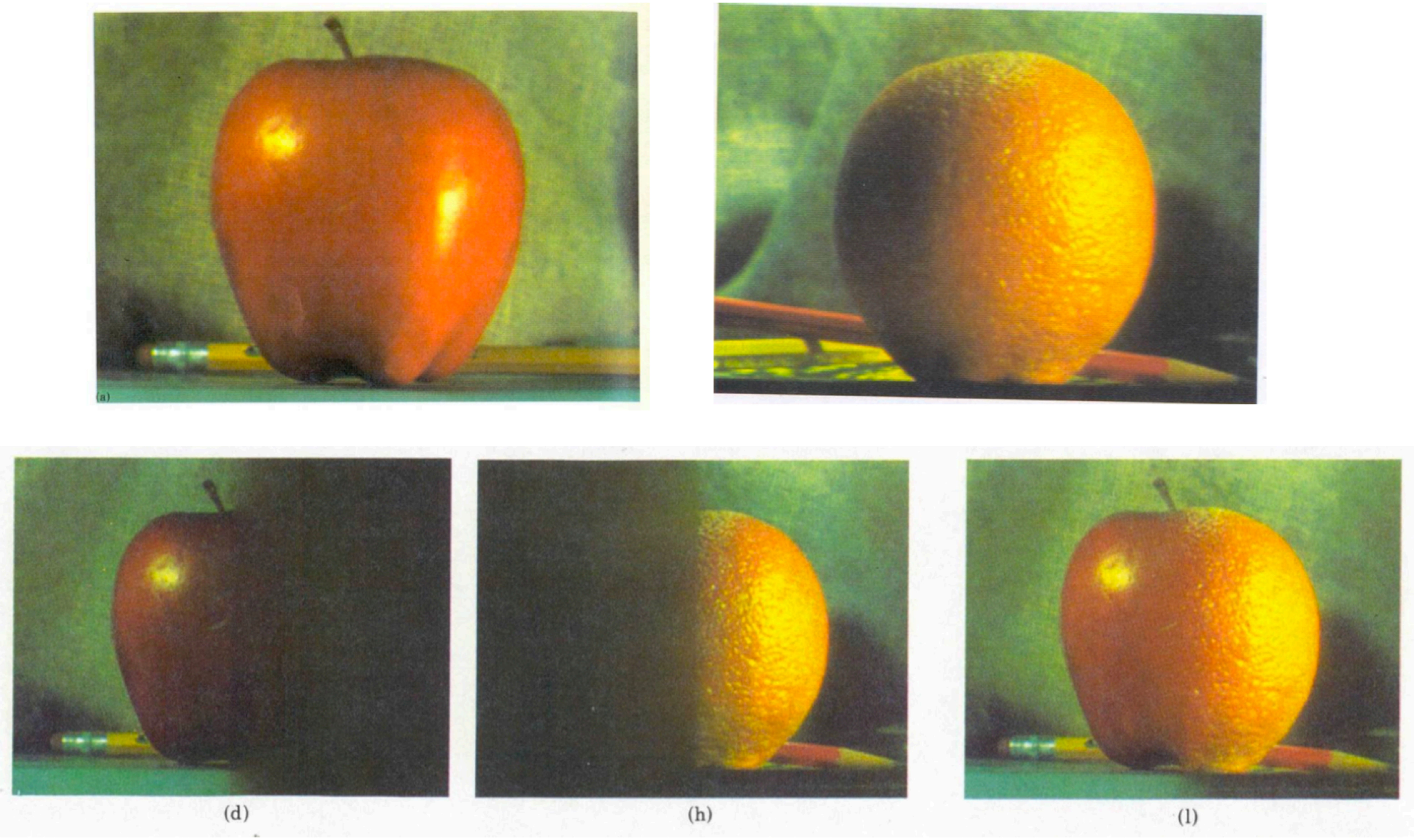
Slide Credit: Ioannis (Yannis) Gkioulekas (CMU)

Aside: Image Blending



Burt and Adelson, "A multiresolution spline with application to image mosaics,"ACM Transactions on Graphics, 1983, Vol.2, pp.217-236.

Aside: Image Blending



Burt and Adelson, “A multiresolution spline with application to image mosaics,”ACM Transactions on Graphics, 1983, Vol.2, pp.217-236.

Aside: Image Blending

Algorithm:

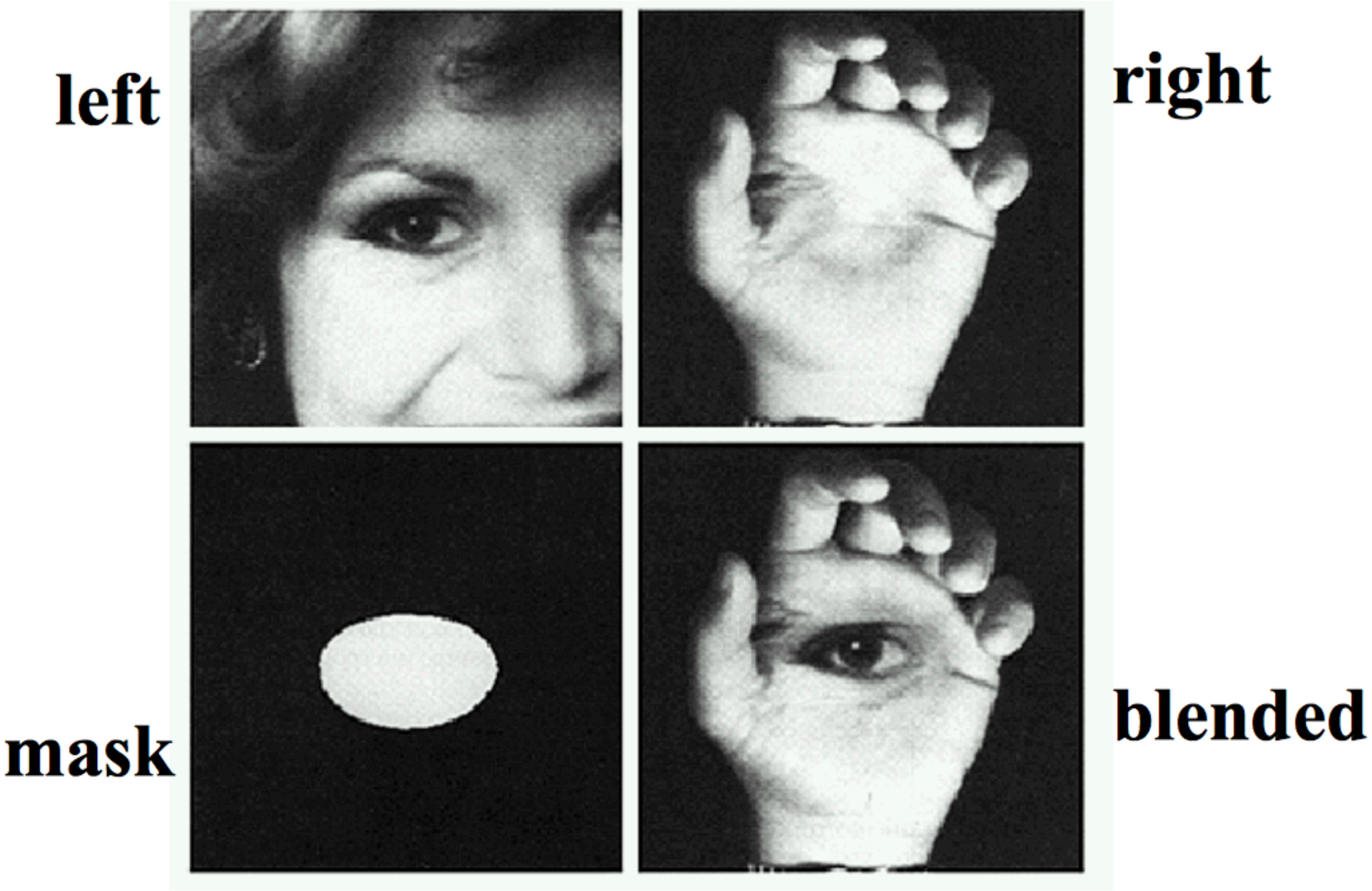
1. Build Laplacian pyramid LA and LB from images A and B

2. Build a Gaussian pyramid GR from mask image R (the mask defines which image pixels should be coming from A or B)

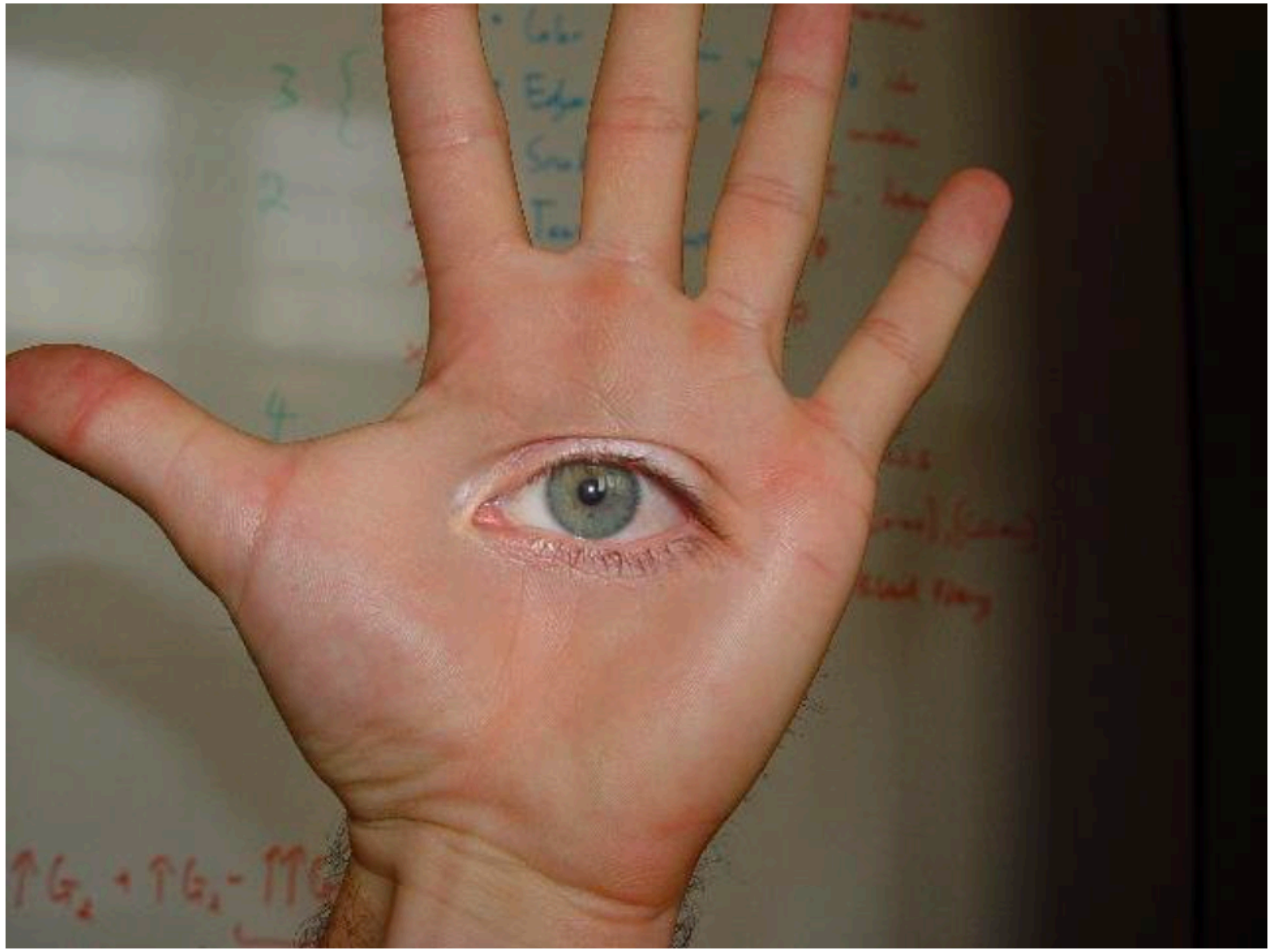
3. From a combined (blended) Laplacian pyramid LS, using nodes of GR as weights: LS(i,j) = GR(i,j) * LA(i,j) + (1-GR(i,j)) * LB(i,j)

4. Reconstruct the final blended image from LS

Aside: Image Blending



Aside: Image Blending



© david dmartin (Boston College)

Aside: Image Blending

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Oriented Pyramids

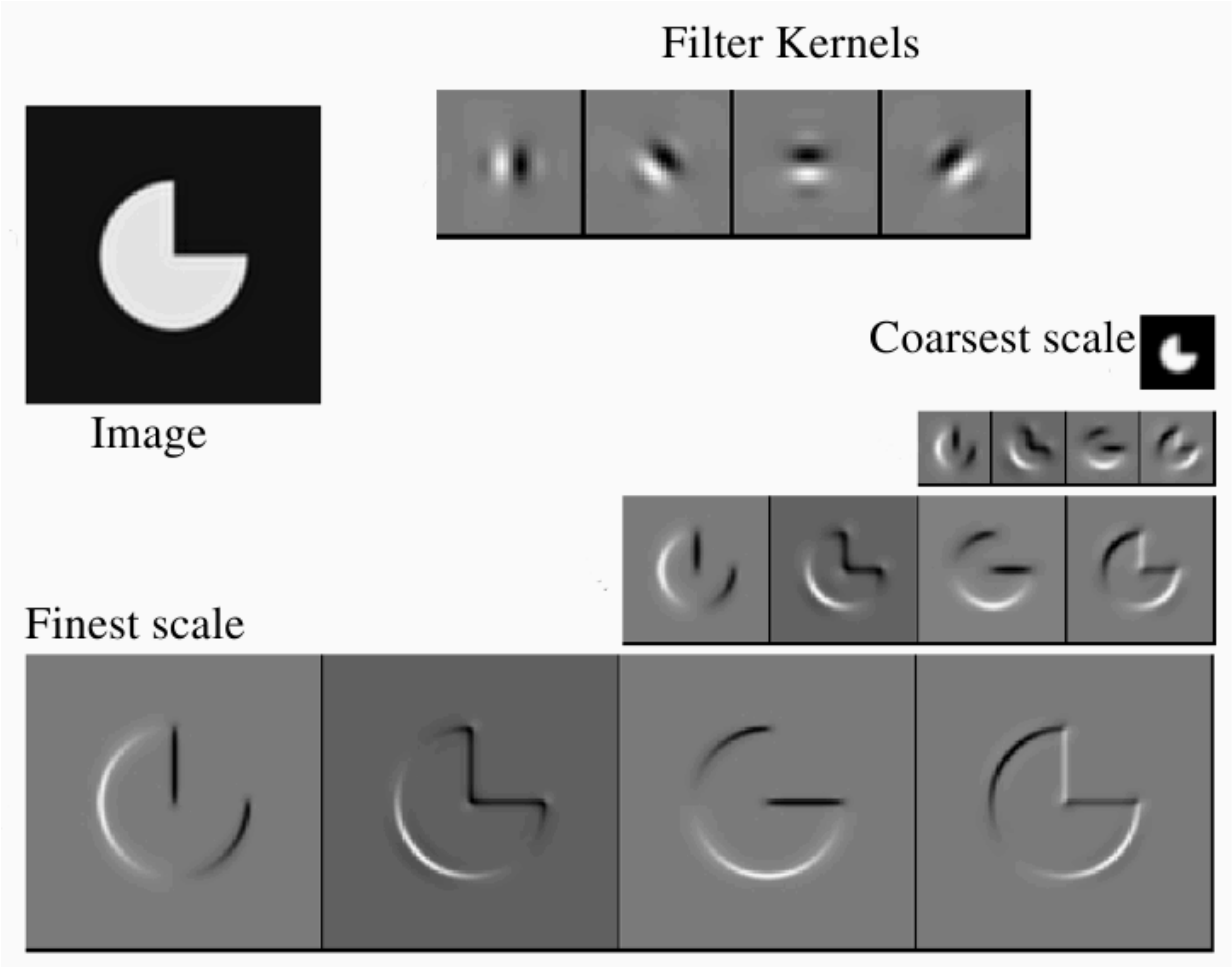
Laplacian pyramid is orientation independent

Idea: Apply an oriented filter at each layer

— represent image at a particular scale and orientation

— Aside: We do not study details in this course

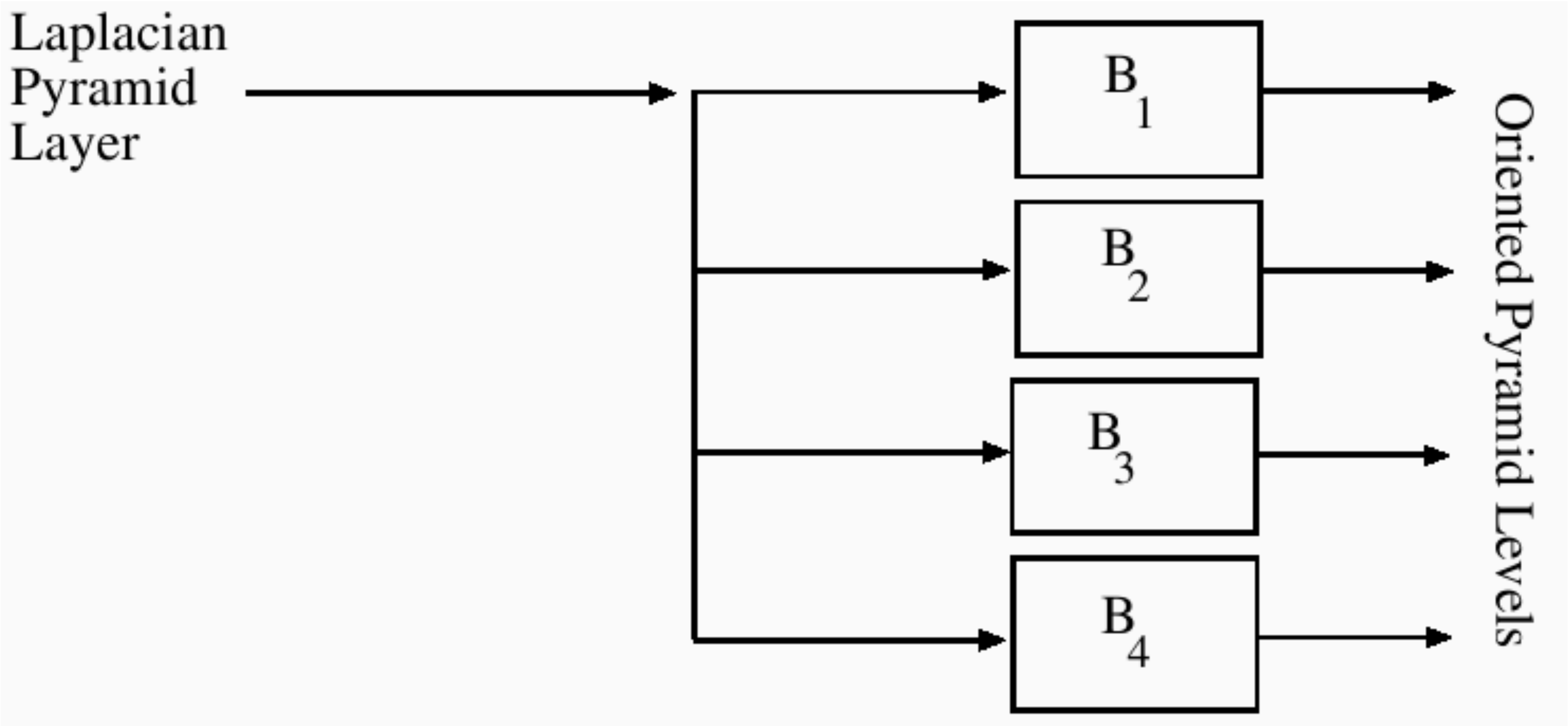
Oriented Pyramids



Forsyth & Ponce (1st ed.) Figure 9.13

Oriented Pyramids

Oriental Filters



Forsyth & Ponce (1st ed.) Figure 9.14