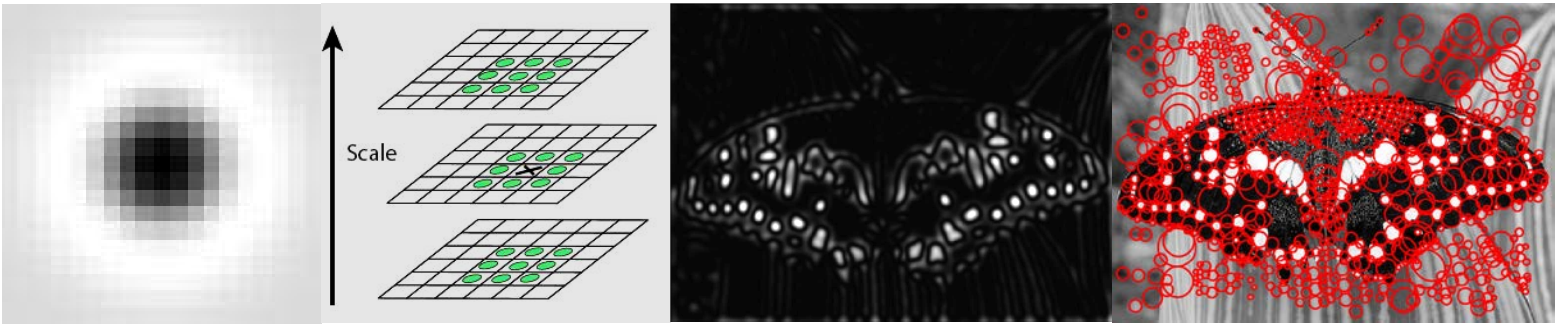
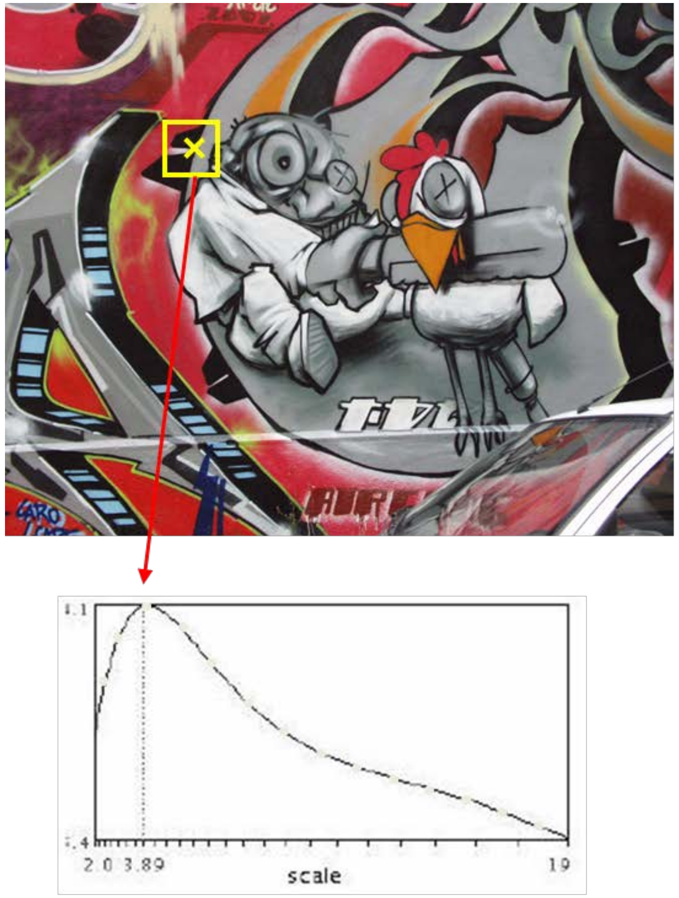


Lecture 3.2.2
Blob features

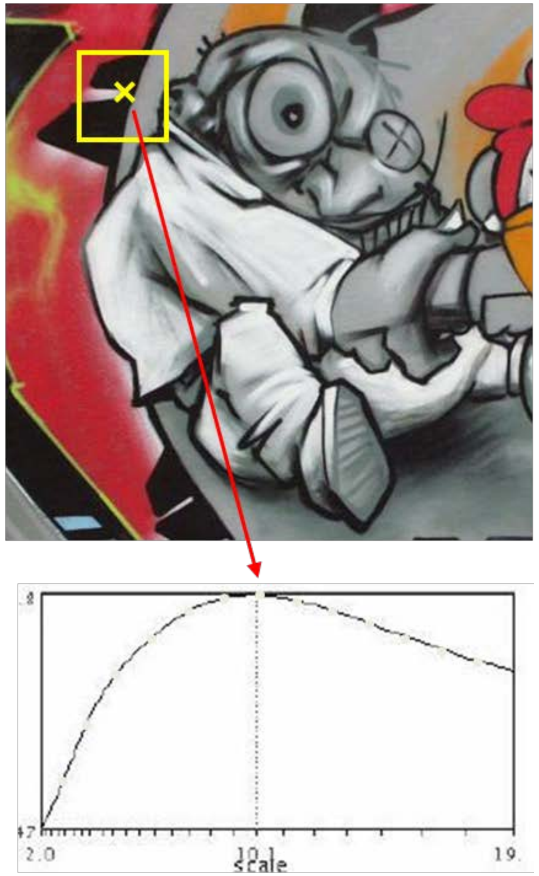
Trym Vegard Haavardsholm

Slides from Svetlana Lazebnik, Grauman&Leibe, S. Seitz, James Hays and Noah Snavely

Automatic scale selection



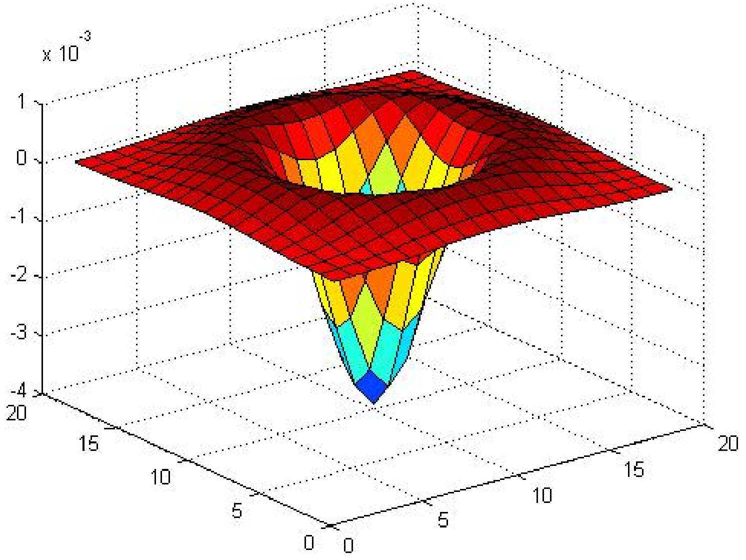
$f(I_{i_1 \ldots i_m}(x, \sigma))$

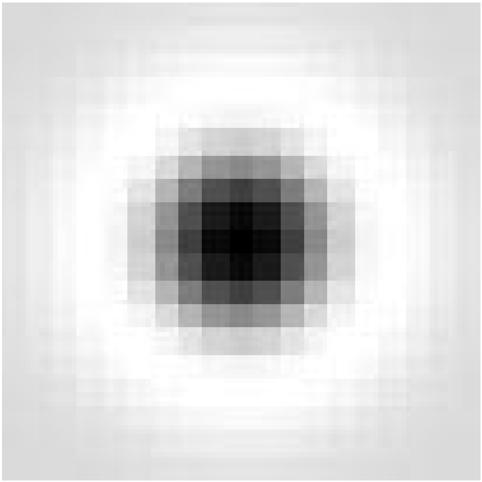


$f(I_{i_1 \ldots i_m}(x', \sigma'))$

Another common definition of *f*

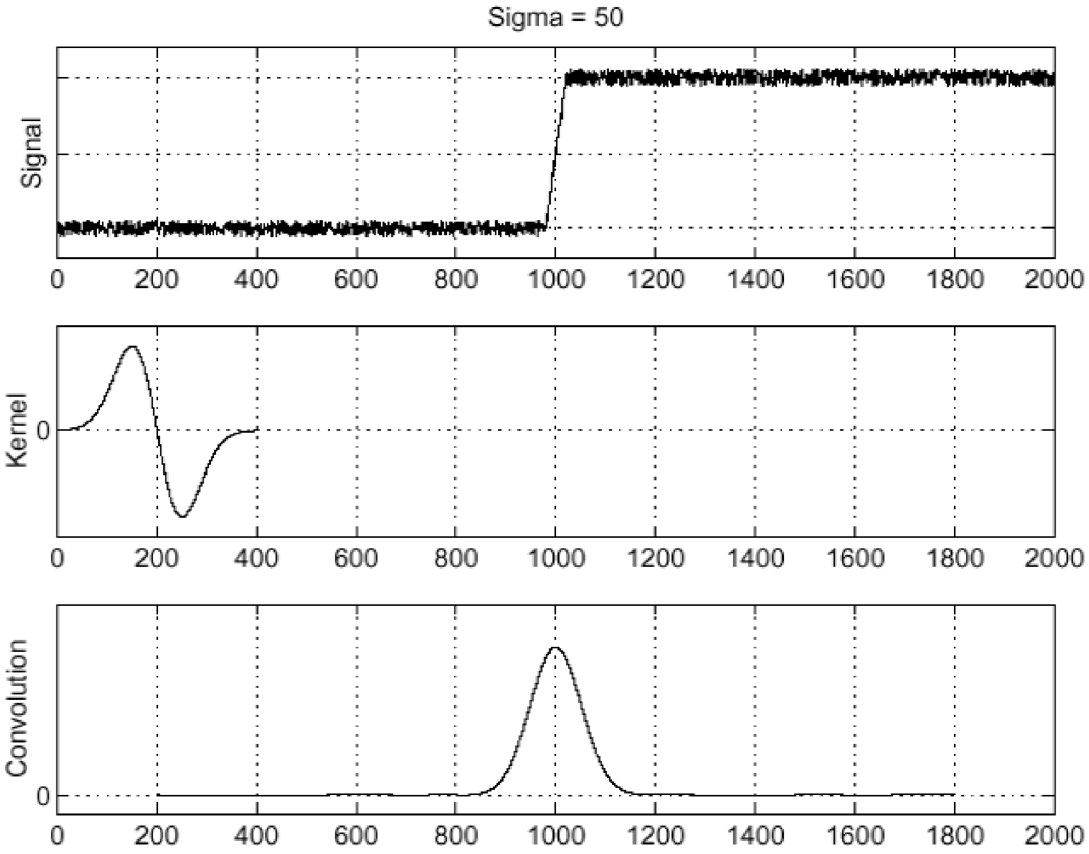
- The *Laplacian of Gaussian (LoG)*





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

Edges and blobs



$$f$$

Edge

$$\frac{d}{dx}g$$

Derivative
of Gaussian

$$f * \frac{d}{dx}g$$

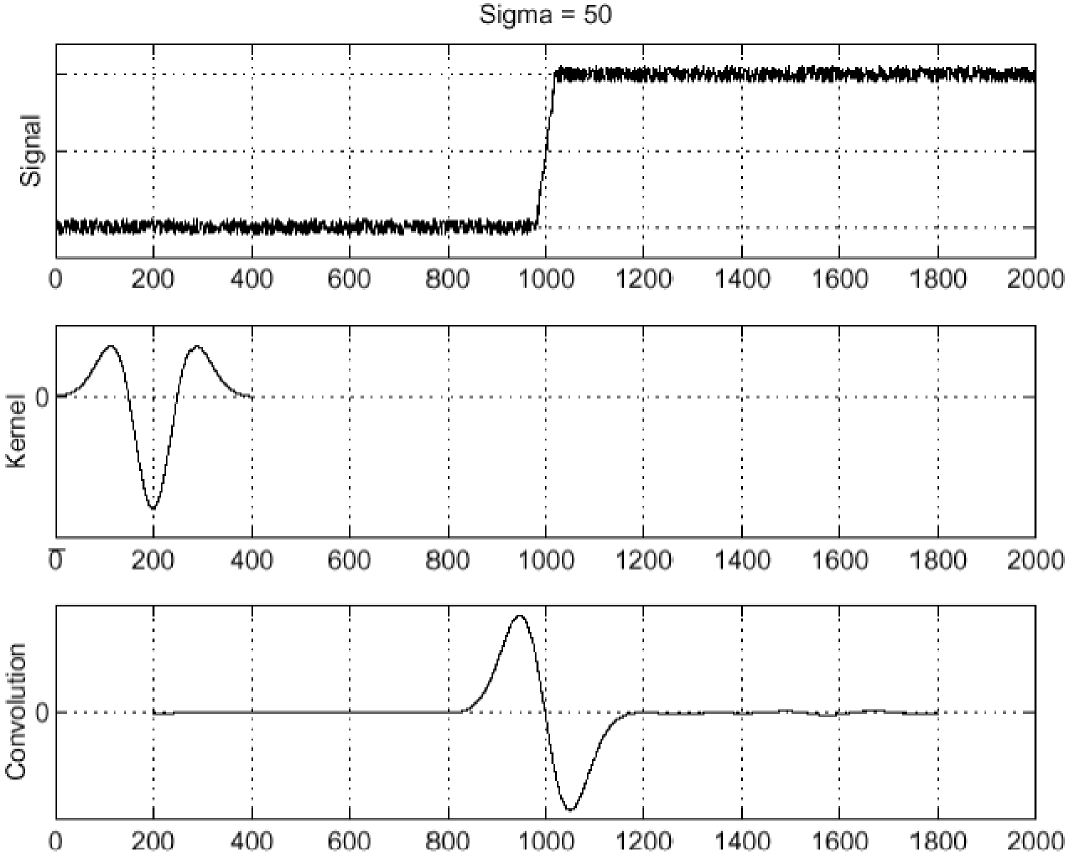
Edge = maximum
of derivative

Edges and blobs

f

$\frac{d^2}{dx^2} g$

$f * \frac{d^2}{dx^2} g$



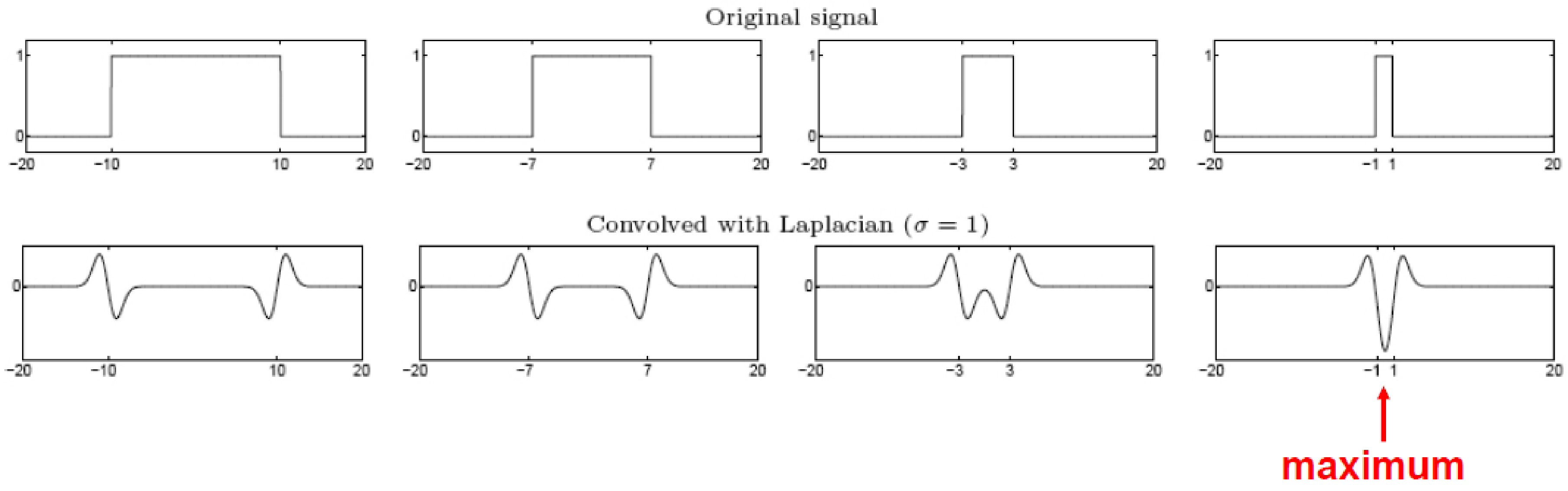
Edge

Second derivative of Gaussian (Laplacian)

Edge = zero crossing of second derivative

Edges and blobs

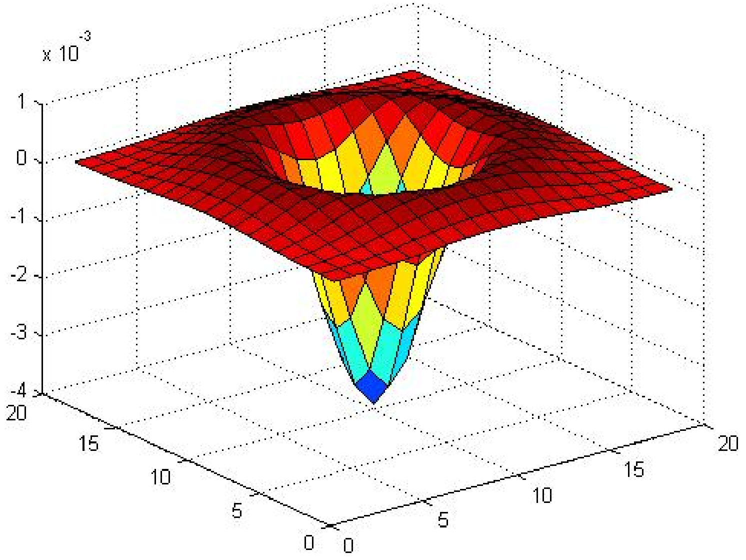
- Edge: Ripple
- Blob: Superposition of two ripples

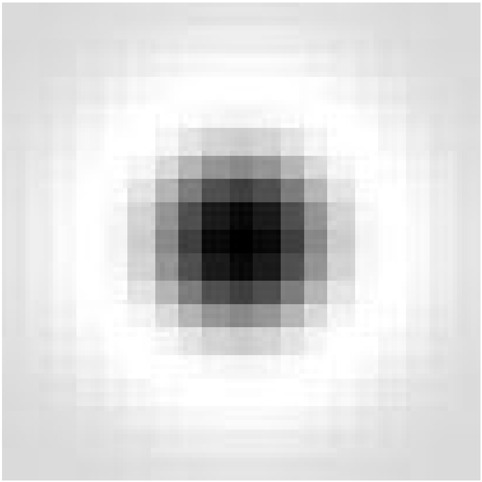


- The magnitude of the Laplacian response is maximum at the centre of the blob provided the scale of the Laplacian matches the scale of the blob

Laplacian of Gaussian

- Normalize to make the response independant of scale

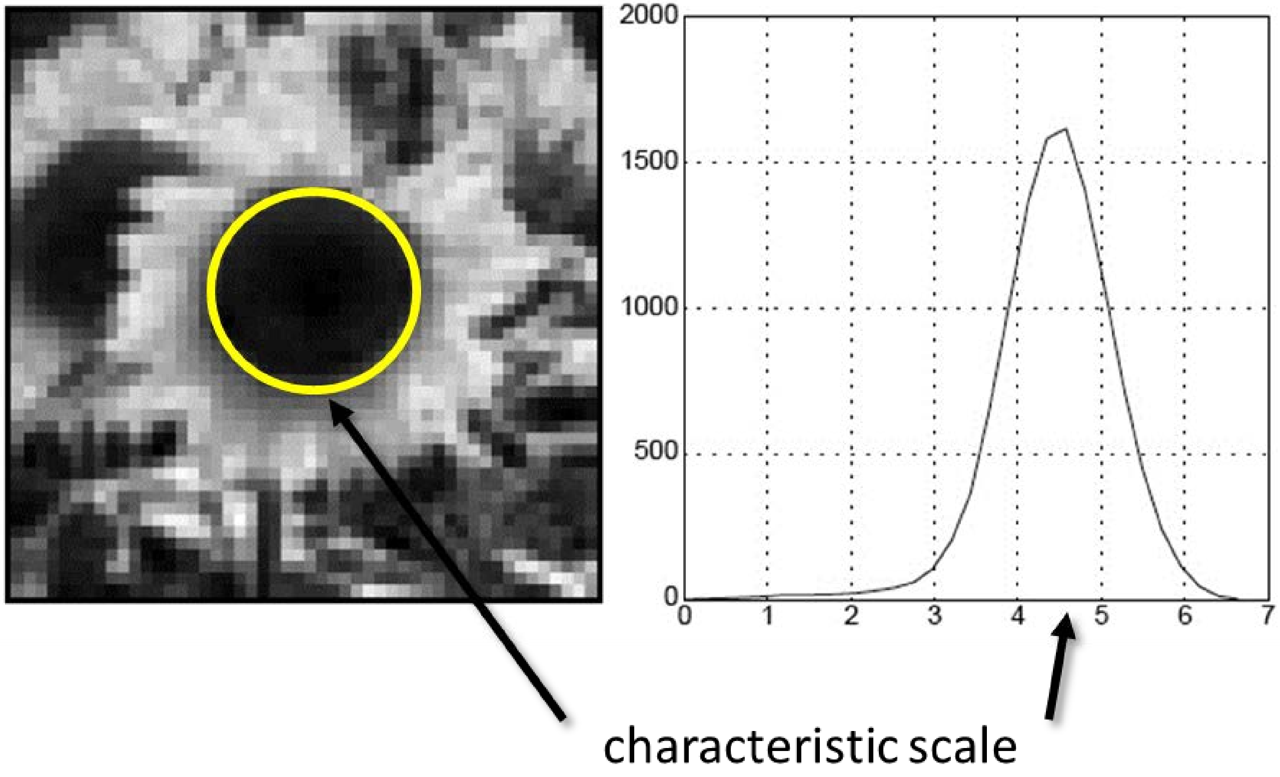




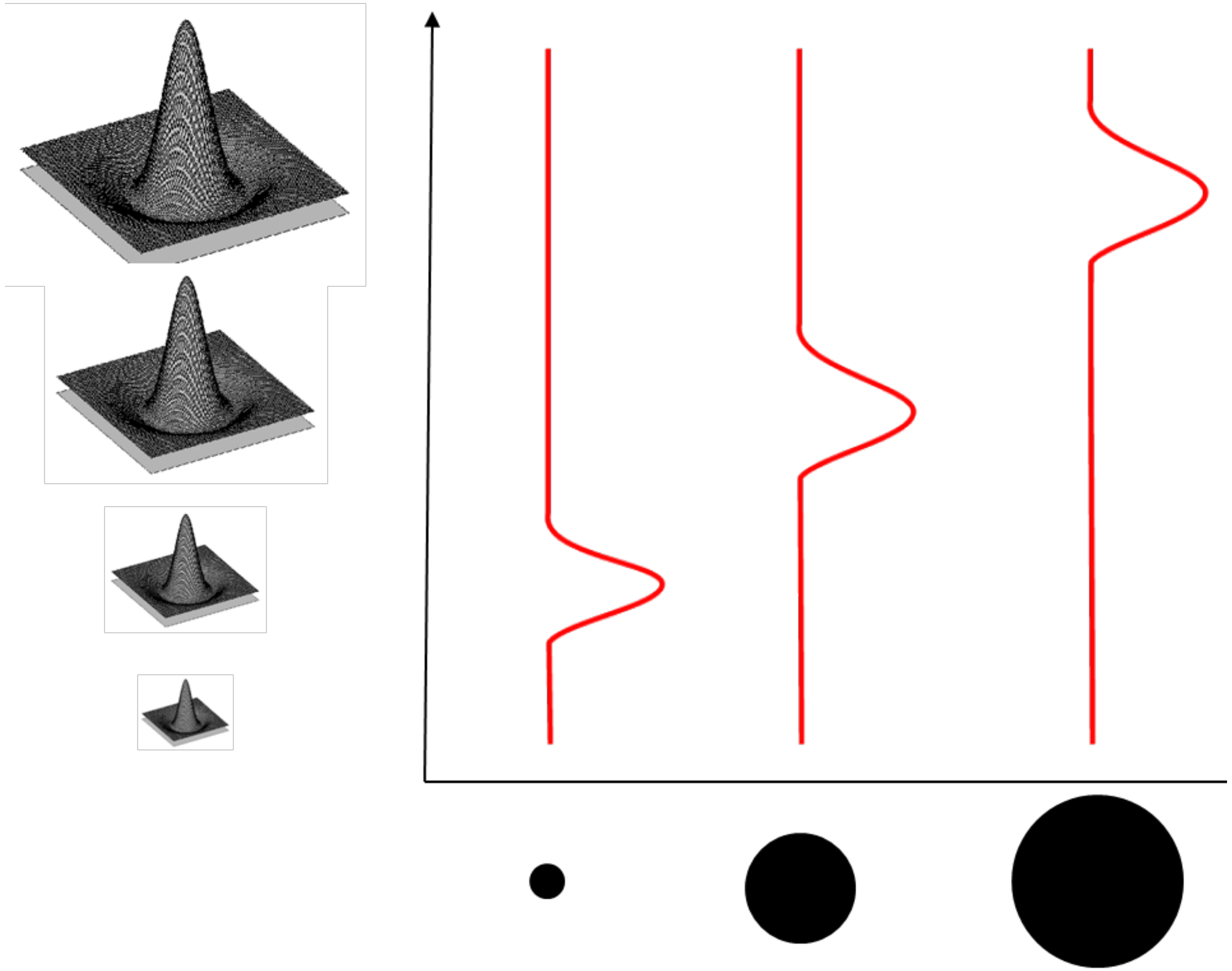
Scale-normalized: $$\nabla^2_{\text{norm}} g = \sigma^2 \left(\frac{\partial^2 g}{\partial x^2} + \frac{\partial^2 g}{\partial y^2} \right)$$

Characteristic scale

- We define the characteristic scale as the scale that produces peak of Laplacian response



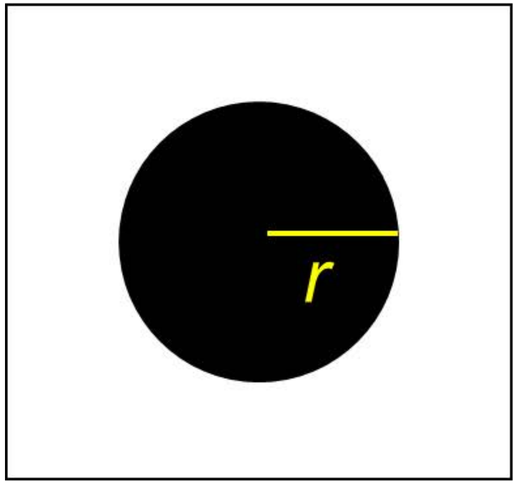
Characteristic scale



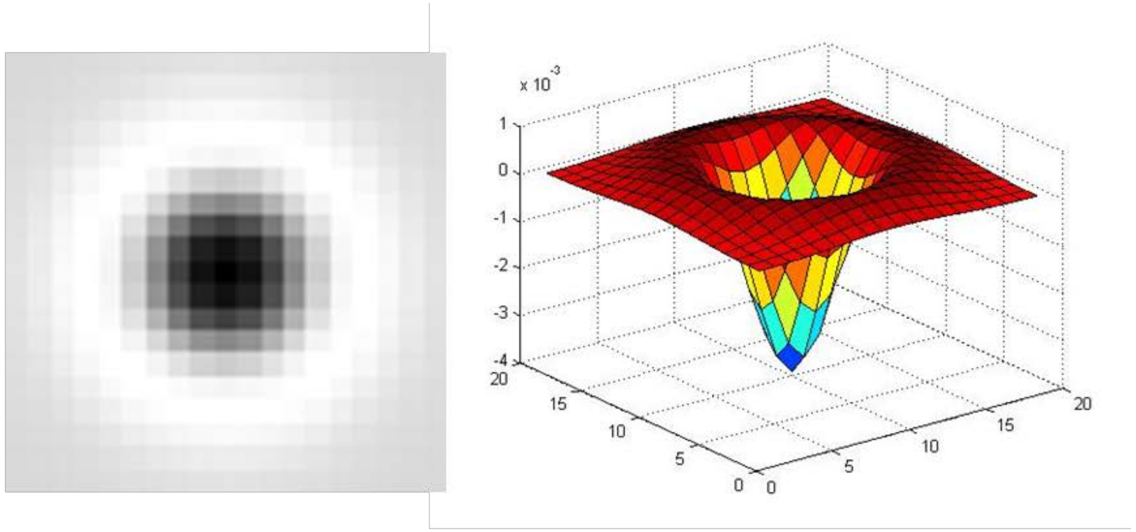
K. Grauman, B. Leibe

Scale selection

- At what scale does the Laplacian achieve a maximum response to a binary circle of radius r?



image



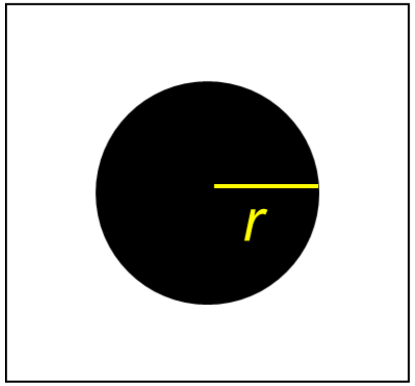
Laplacian

Scale selection

- To get maximum response, the zeros of the Laplacian have to be aligned with the circle
- The Laplacian is given by (up to scale):

$$(x^2 + y^2 - 2\sigma^2)\, e^{-(x^2+y^2)/2\sigma^2}$$

- Therefore, the maximum response occurs at $\sigma = r / \sqrt{2}.$



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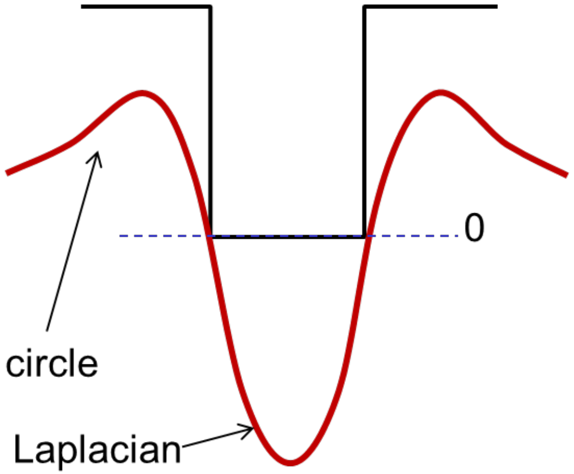
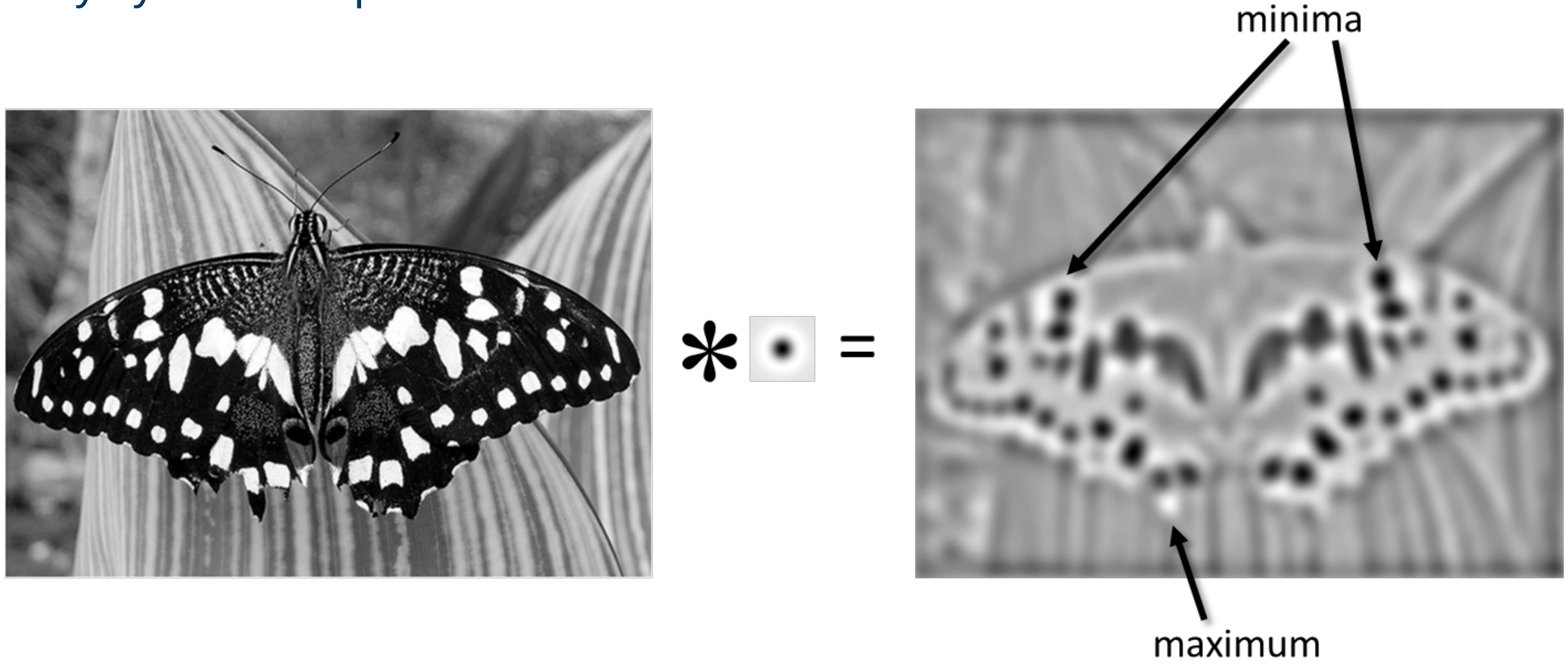


Laplacian of Gaussian

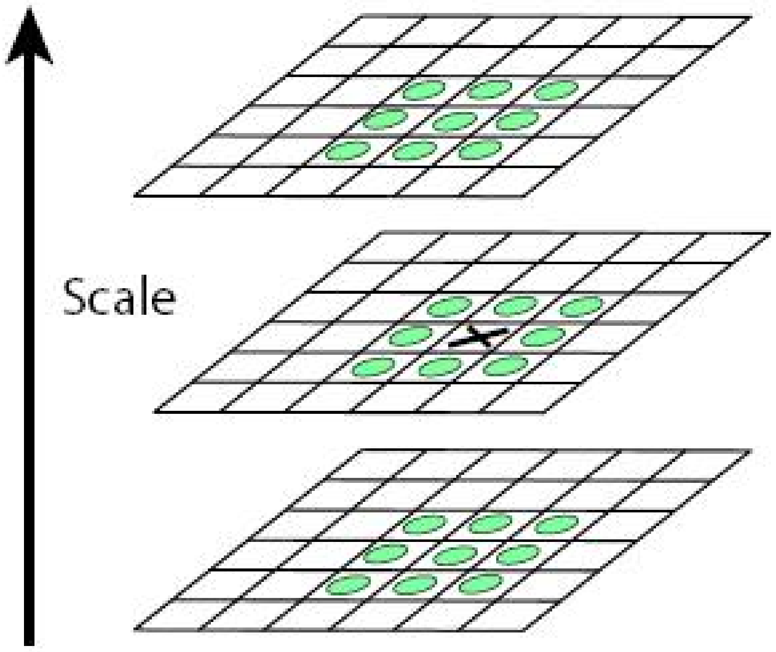
- Circularly symmetric operator for blob detection in 2D



- Find maxima and minima of LoG operator in space and scale

LoG blob detector

- Convolve the image with scale-normalized LoG at several scales
- Find maxima of squared LoG response in scale-space



LoG blob detector

- Example

LoG blob detector

- Example: Squared Log response

sigma = 2

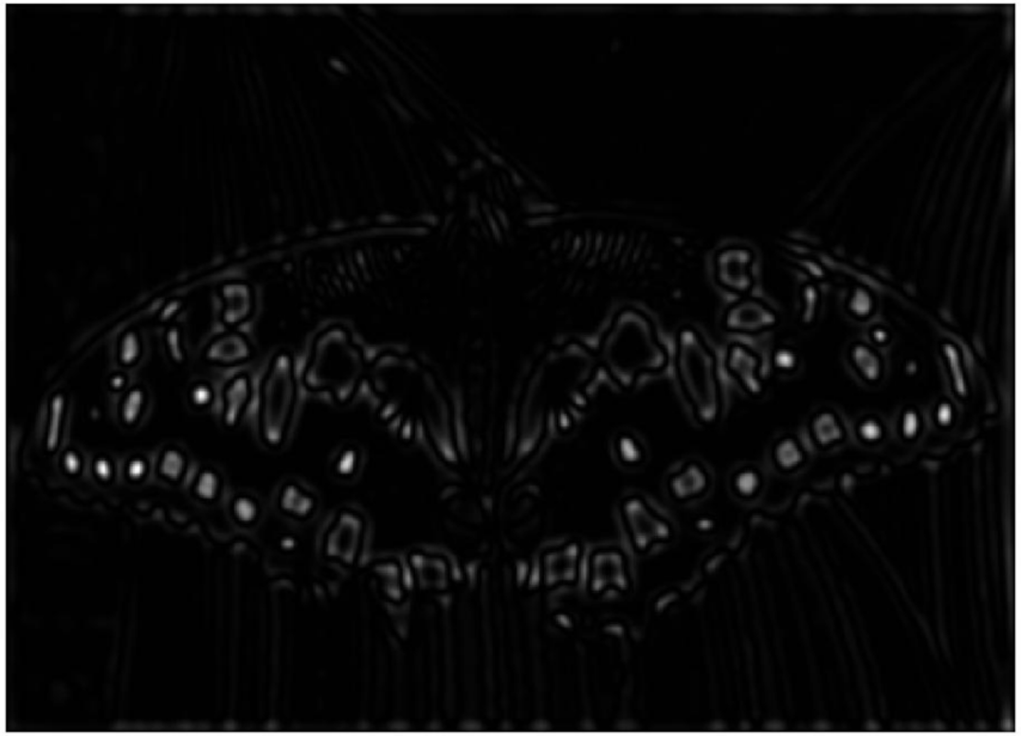
LoG blob detector

- Example: Squared Log response

sigma = 2.5018

LoG blob detector

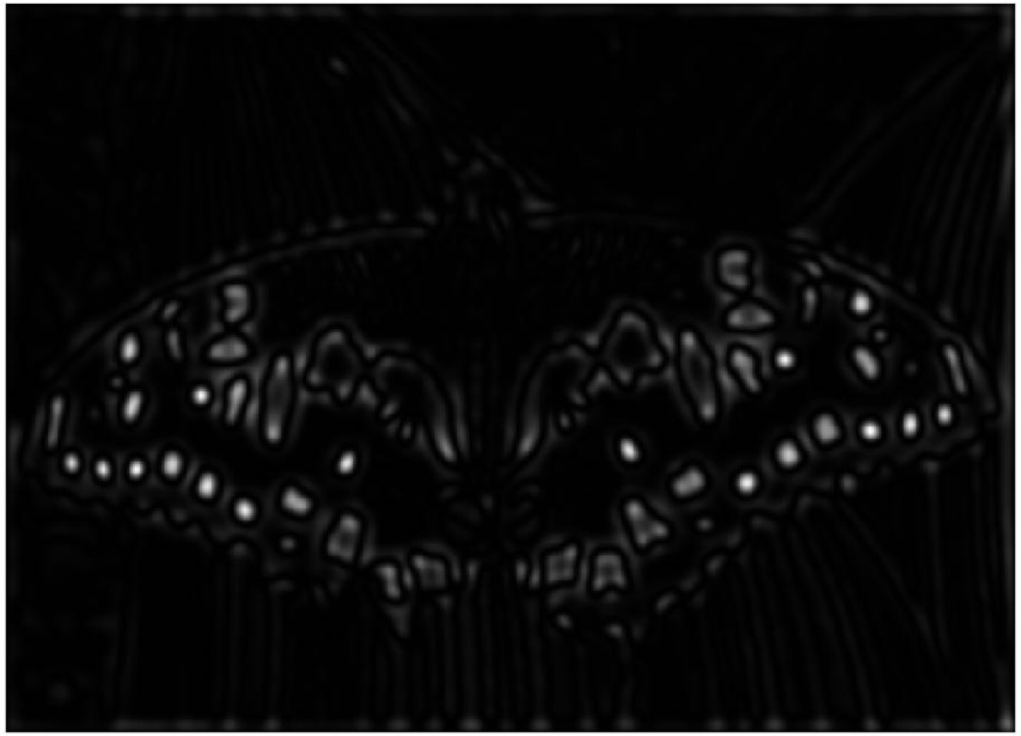
- Example: Squared Log response



sigma = 3.1296

LoG blob detector

- Example: Squared Log response



sigma = 3.9149

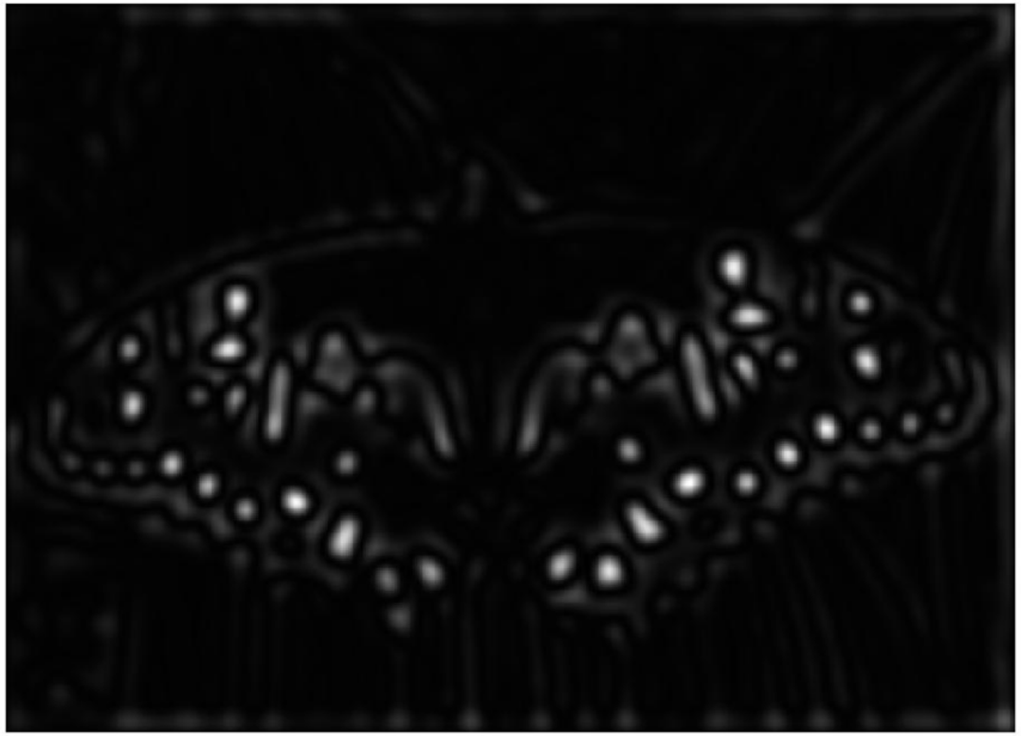
LoG blob detector

- Example: Squared Log response

sigma = 4.8972

LoG blob detector

- Example: Squared Log response



sigma = 6.126

LoG blob detector

- Example: Squared Log response

sigma = 7.6631

LoG blob detector

- Example: Squared Log response

sigma = 9.5859

LoG blob detector

- Example: Squared Log response

sigma = 11.9912

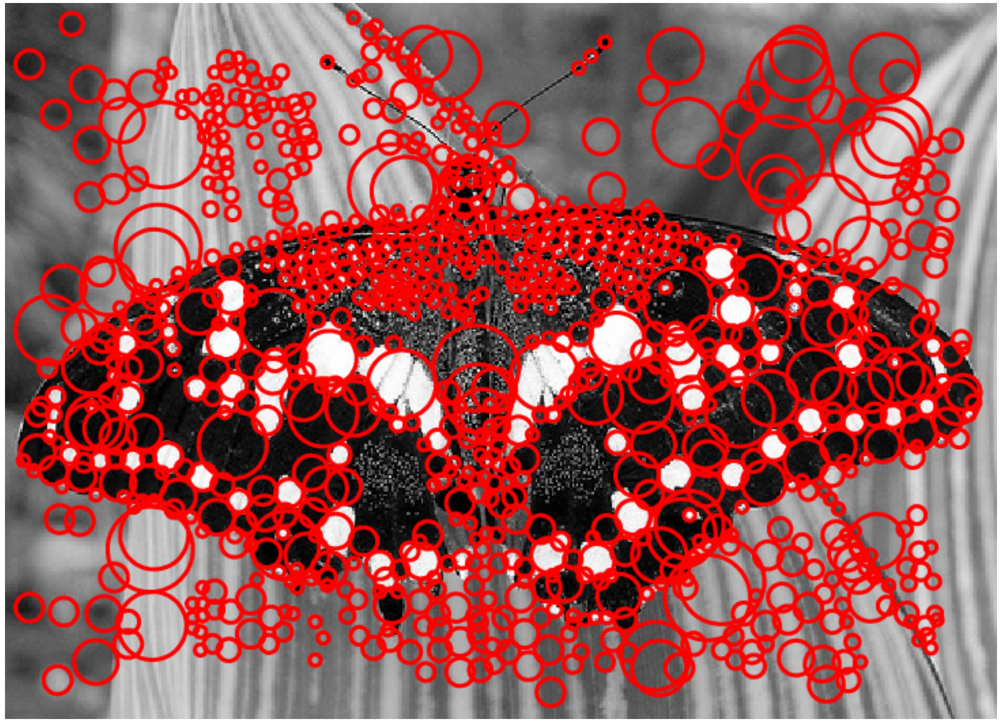
LoG blob detector

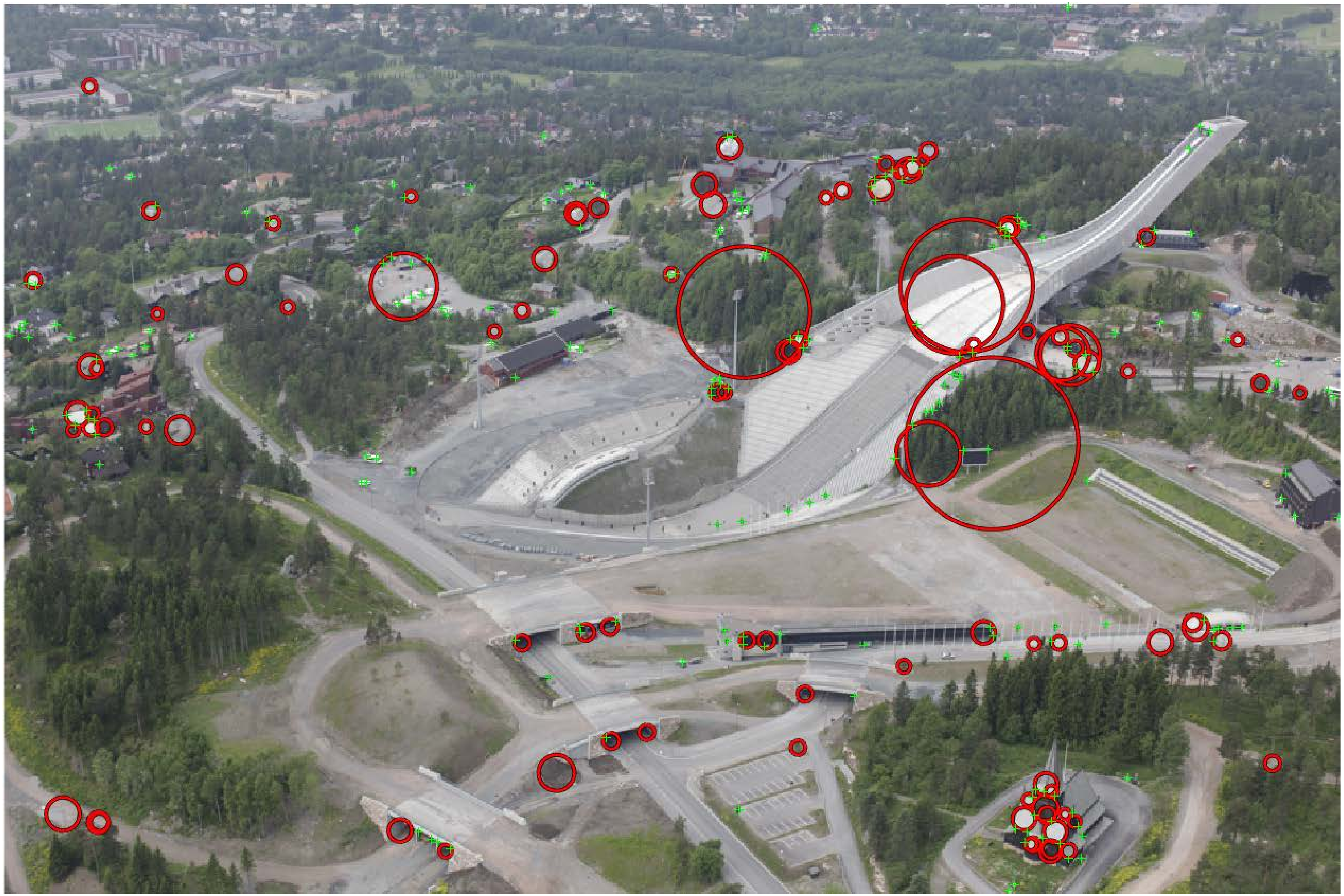
- Example: Squared Log response

sigma = 15

LoG blob detector

- Example: Detected blobs





Efficient implementation

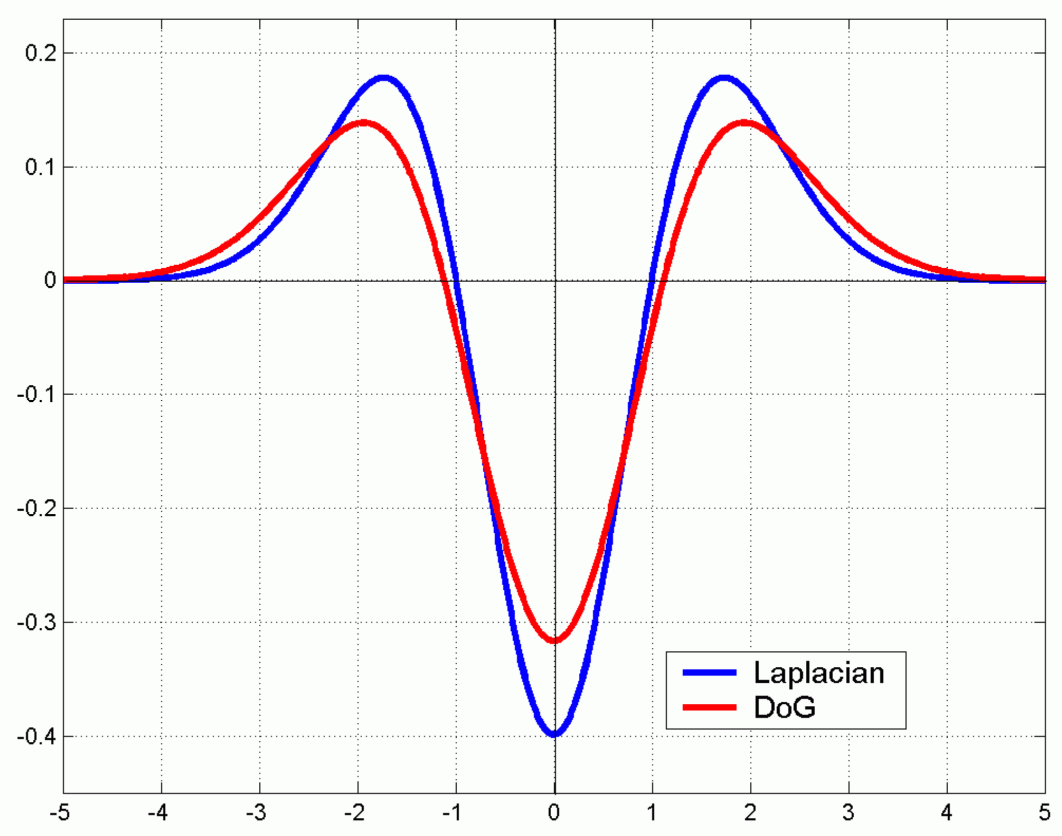
- Approximating the Laplacian with a difference of Gaussians (DoG)

$$L = \sigma^2 \left(G_{xx}(x, y, \sigma) + G_{yy}(x, y, \sigma) \right)$$

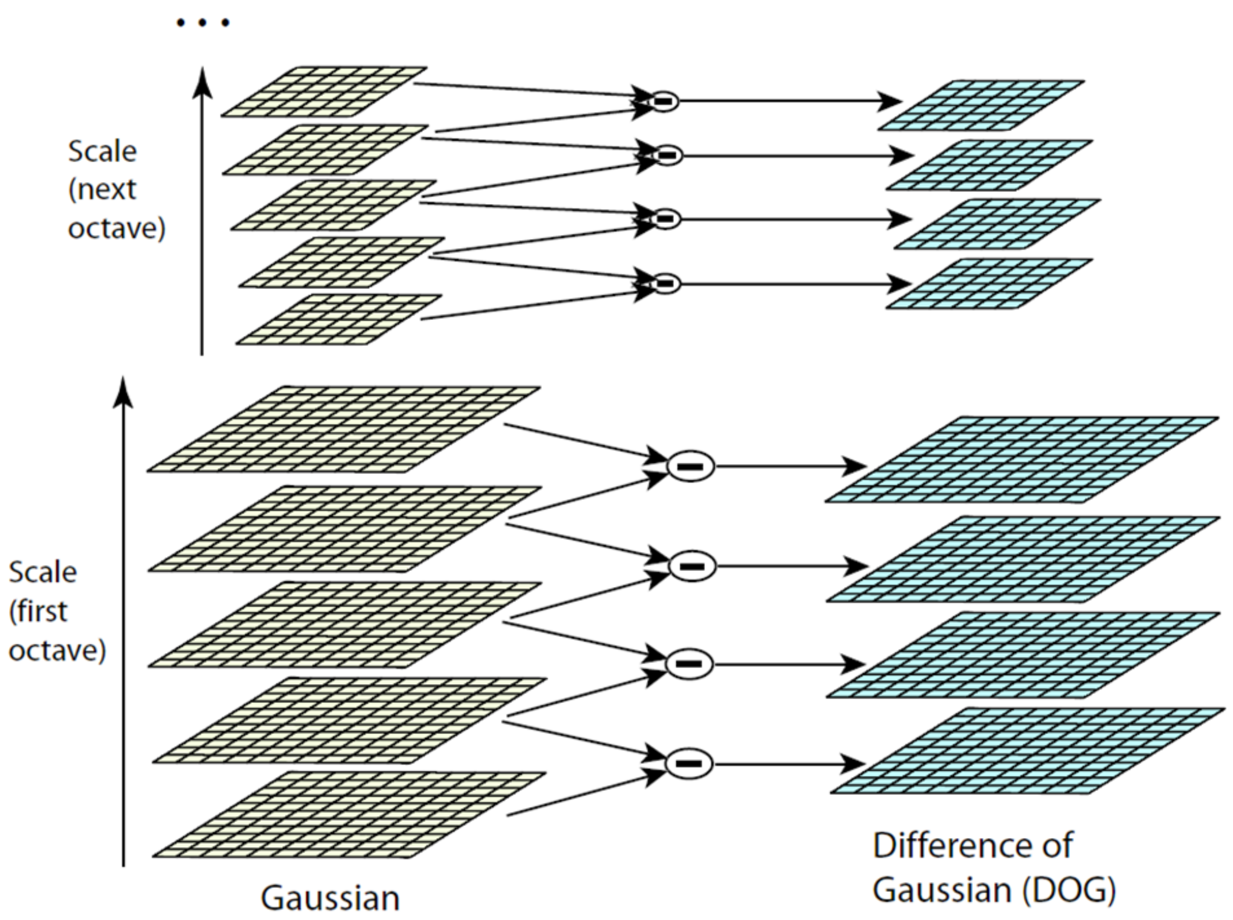
(Laplacian)

$$DoG = G(x, y, k\sigma) - G(x, y, \sigma)$$

(Difference of Gaussians)

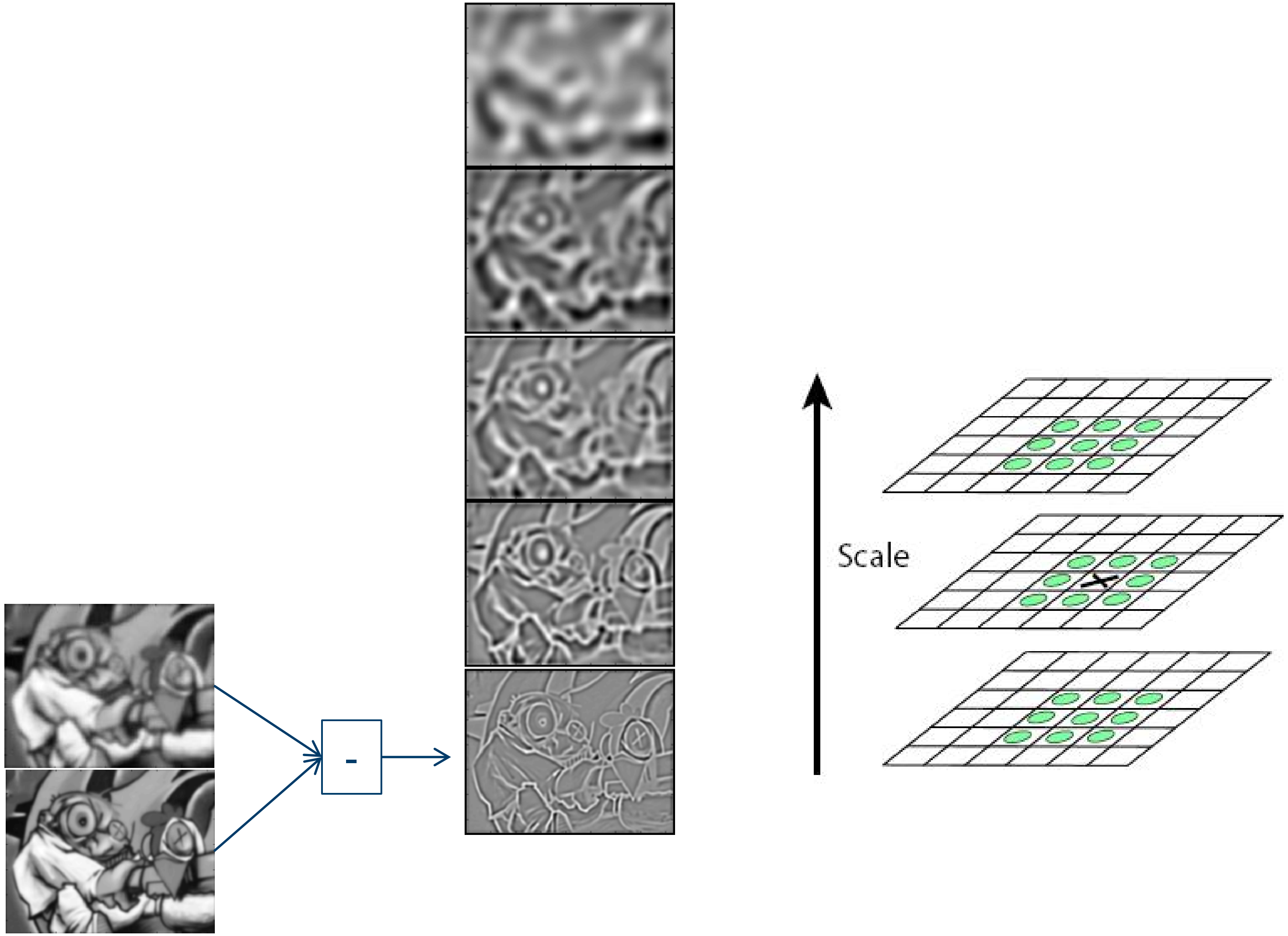


Efficient implementation



David G. Lowe. **["Distinctive image features from scale-invariant keypoints."]** *IJCV* 60 (2), pp. 91-110, 2004.

Difference of Gaussians (DoG)



Summary

- Corner detectors
  - Stable in space
  - Min eigenvalue, Harris

- Blob detectors
  - Stable in scale and space
  - LoG, DoG

- Combine methods!

- Further reading
  - David G. Lowe, [“Distinctive image features from scale-invariant keypoints”]
  - T. Lindeberg, [“Feature detection with automatic scale selection”]

- Lab next week:
  - Implement and test feature detectors!