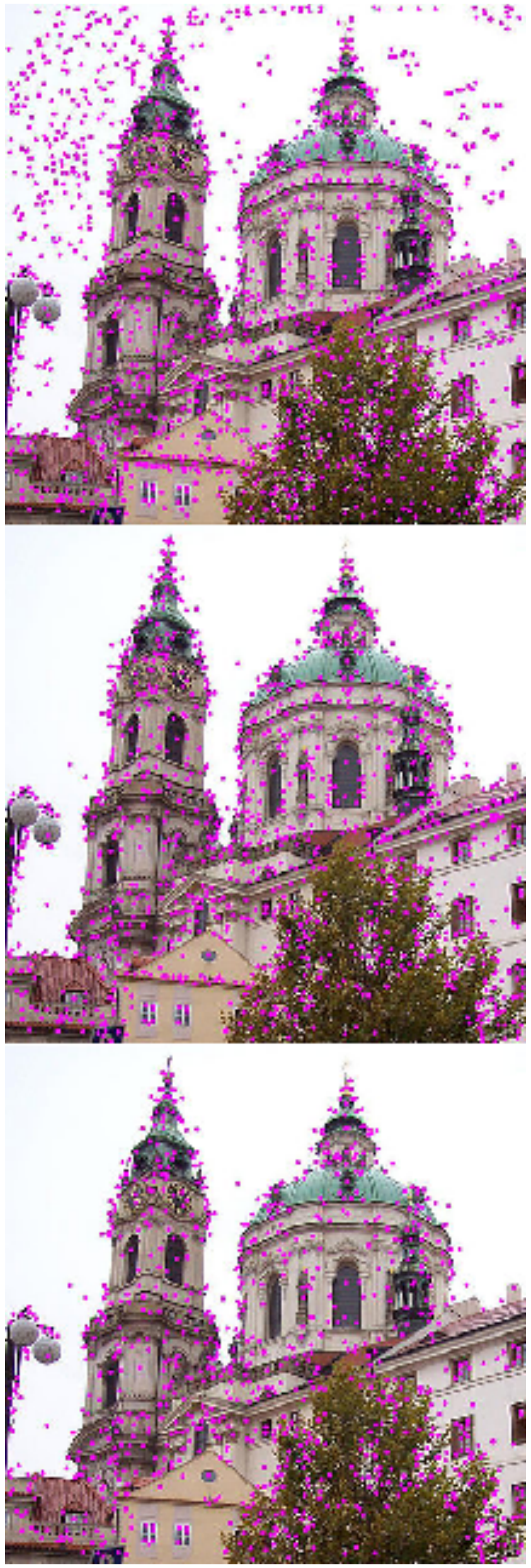
SIFT

Computer Vision

Carnegie Mellon University (Kris Kitani)



SIFT

(Scale Invariant Feature Transform)

SIFT describes both a **detector** and **descriptor**

1. Multi-scale extrema detection
2. Keypoint localization
3. Orientation assignment
4. Keypoint descriptor

Distinctive Image Features from Scale-Invariant Keypoints

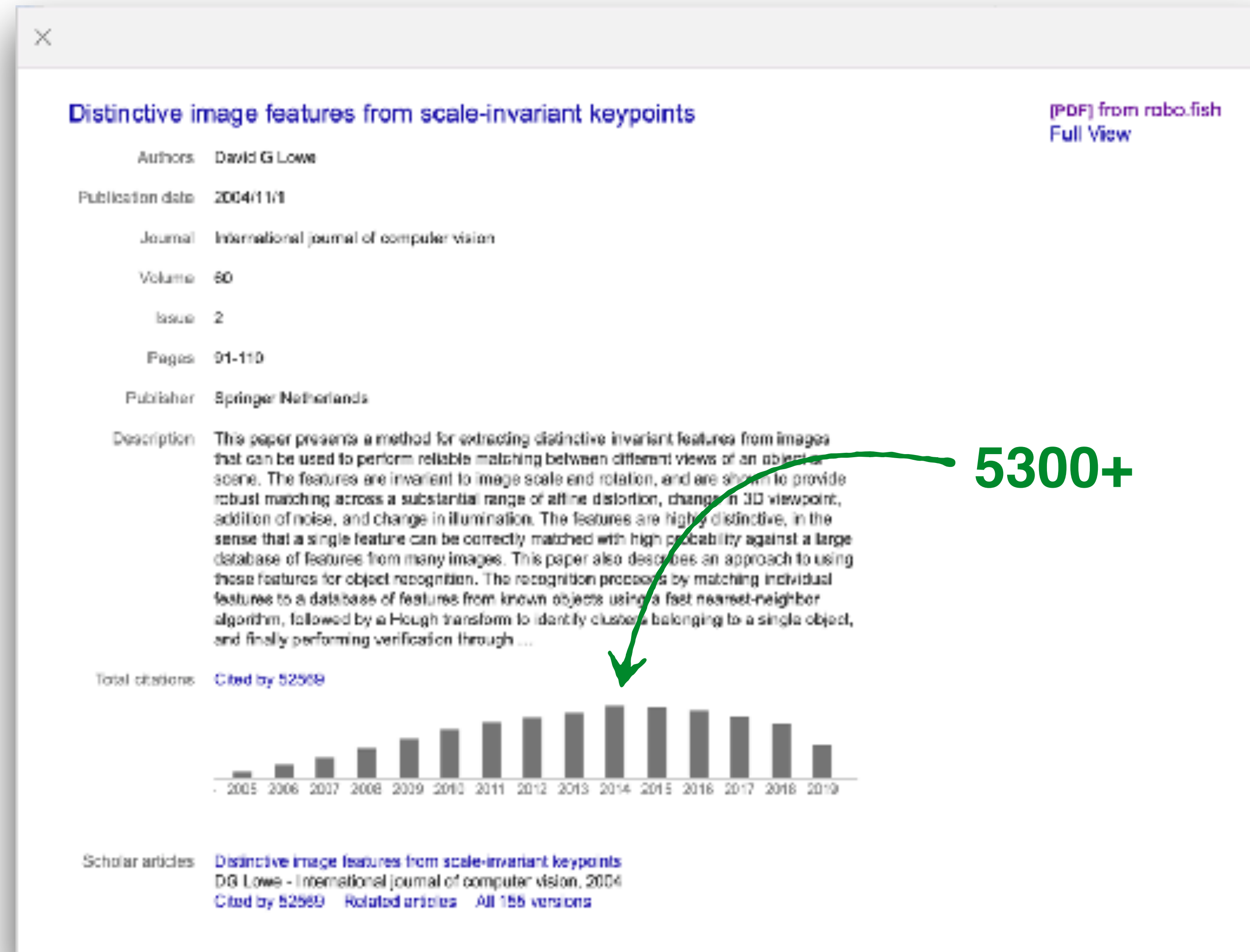
David G. Lowe
Computer Science Department
University of British Columbia
Vancouver, B.C., Canada
lowe@cs.ubc.ca

January 5, 2004

Abstract

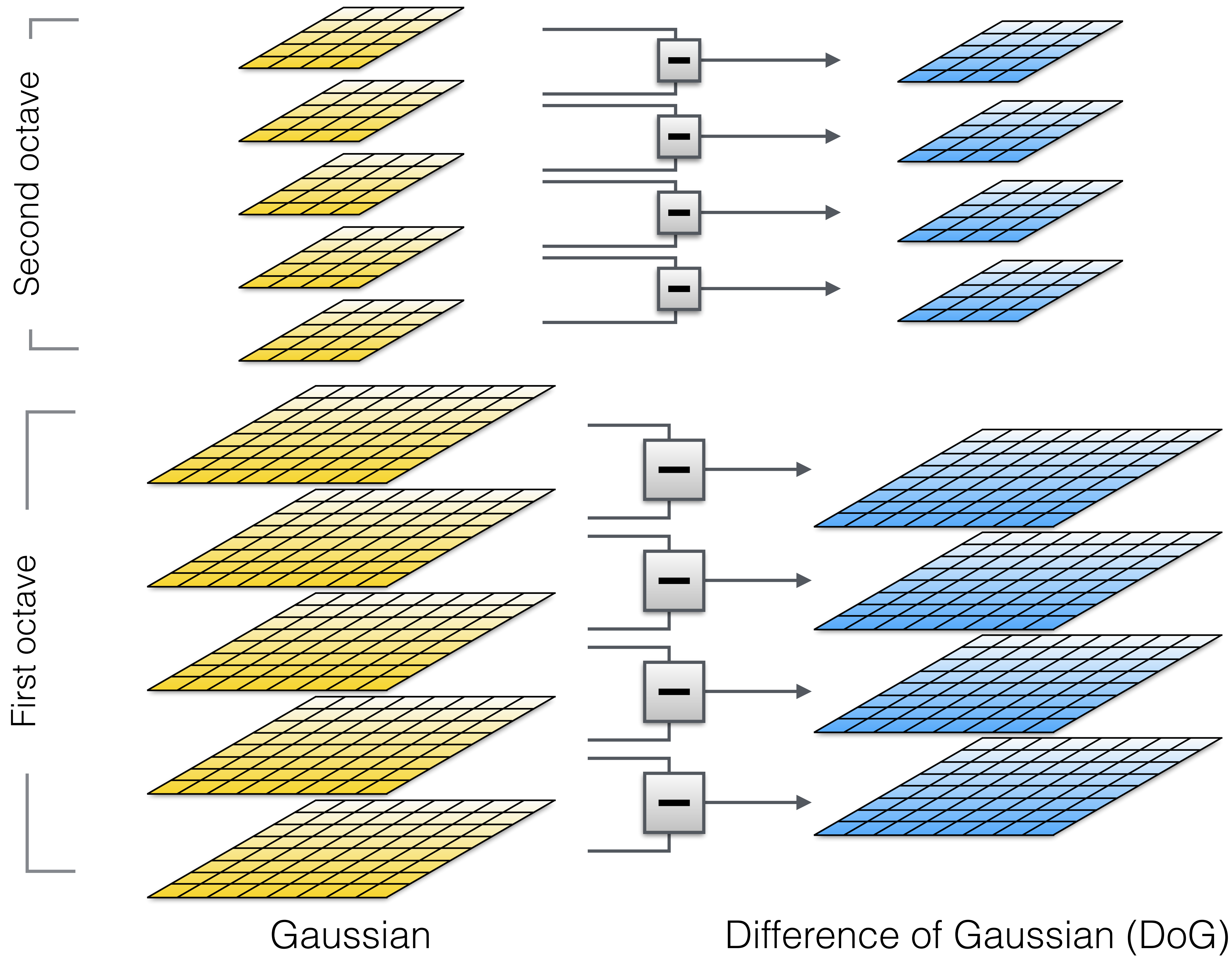
This paper presents a method for extracting distinctive invariant features from images that can be used to perform reliable matching between different views of an object or scene. The features are invariant to image scale and rotation, and are shown to provide robust matching across a a substantial range of affine distortion, change in 3D viewpoint, addition of noise, and change in illumination. The features are highly distinctive, in the sense that a single feature can be correctly matched with high probability against a large database of features from many images. This paper also describes an approach to using these features for object recognition. The recognition proceeds by matching individual features to a database of features from known objects using a fast nearest-neighbor algorithm, followed by a Hough transform to identify clusters belonging to a single object, and finally performing verification through least-squares solution for consistent pose parameters. This approach to recognition can robustly identify objects among clutter and occlusion while achieving near real-time performance.

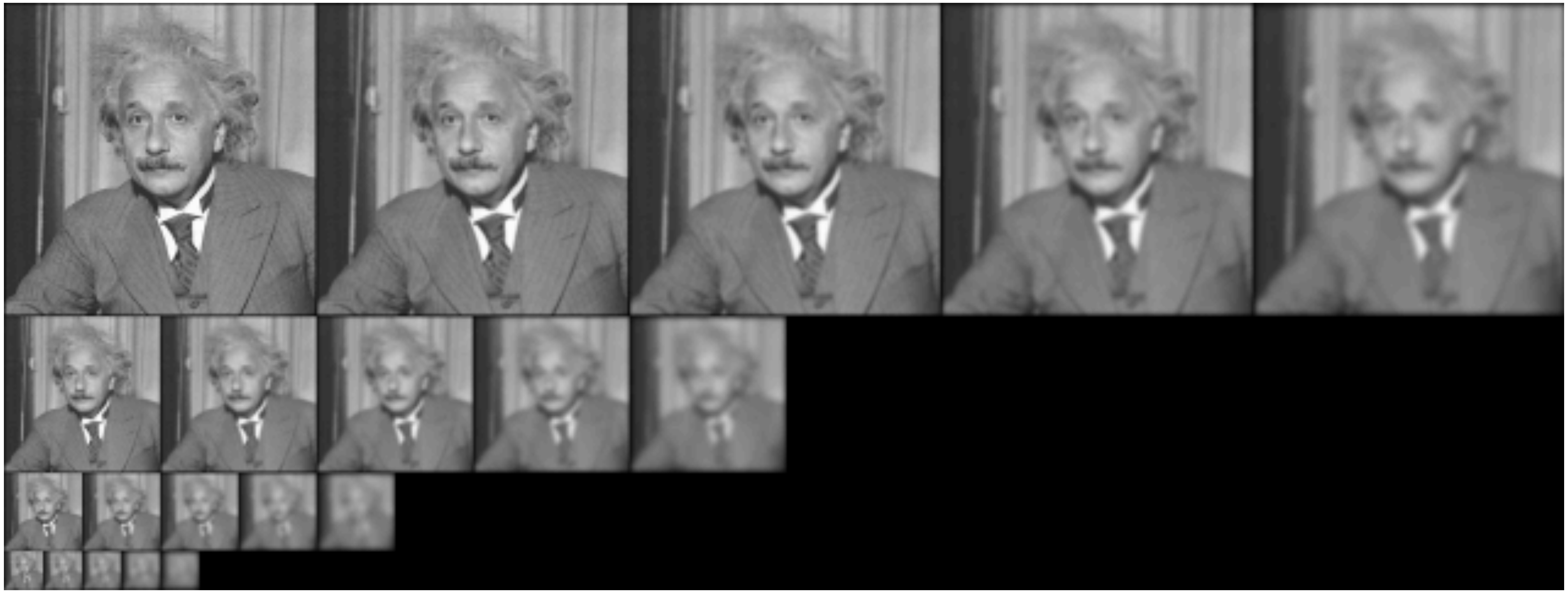
Accepted for publication in the *International Journal of Computer Vision*, 2004.



Huge impact on the computer vision community

1. Multi-scale extrema detection

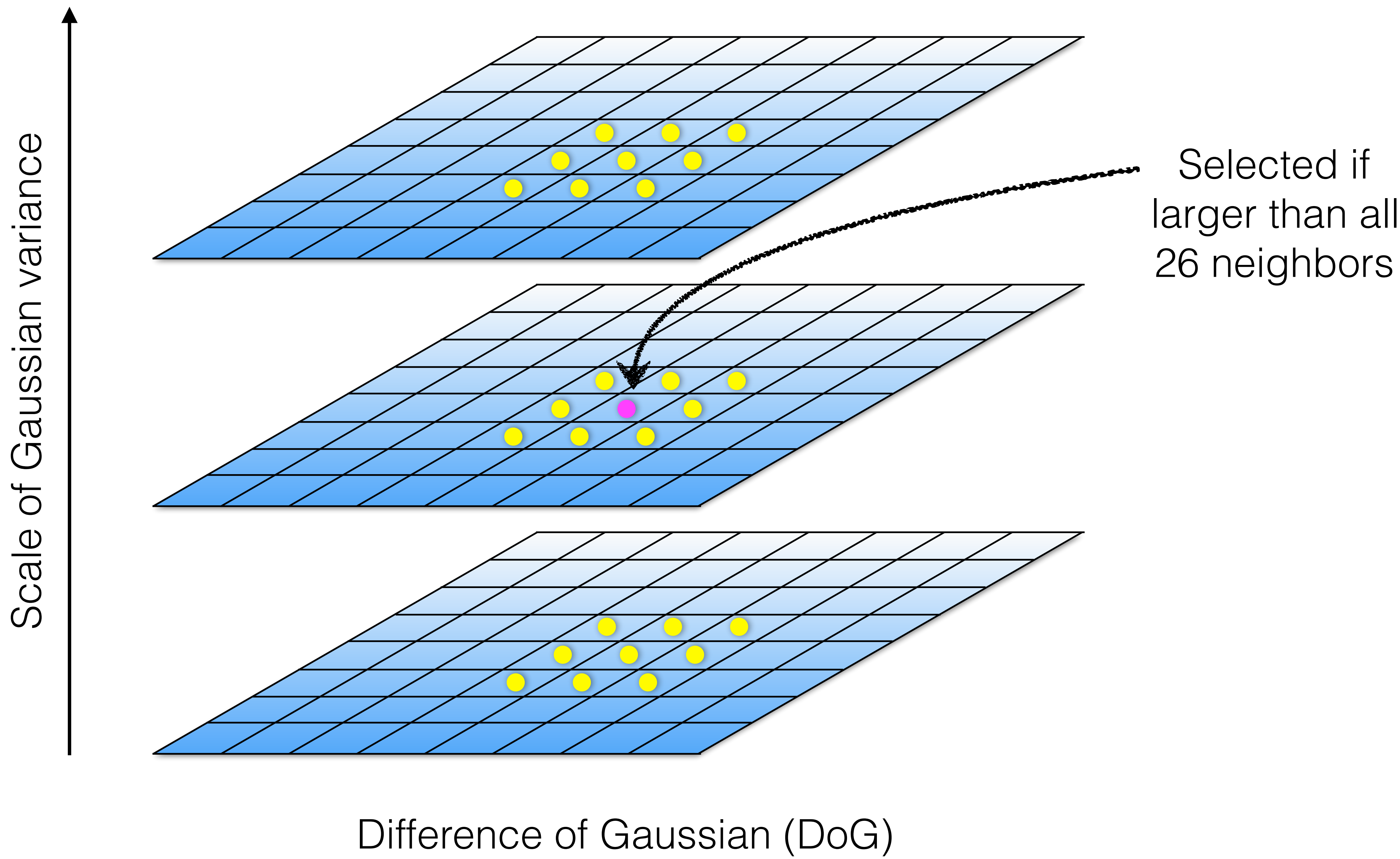




Gaussian

Laplacian

Scale-space extrema



2. Keypoint localization

2nd order Taylor series approximation of DoG scale-space

$$\mathbf{x} = \{x, y, \sigma\} \longleftarrow \textbf{3D space!}$$

$$f(\mathbf{x}) = f + \frac{\partial f}{\partial \mathbf{x}}^T \mathbf{x} + \frac{1}{2}\mathbf{x}^T \frac{\partial^2 f}{\partial \mathbf{x}^2}\mathbf{x}$$

Take the derivative and solve for extrema

$$\mathbf{x}_m = -\frac{\partial^2 f}{\partial \mathbf{x}^2}^{-1} \frac{\partial f}{\partial \mathbf{x}}$$

Additional tests to retain only strong features

3. Orientation assignment

For a keypoint, **L** is the **Gaussian-smoothed** image with the closest scale,

$$m(x,y) = \sqrt{\underbrace{(L(x+1,y) - L(x-1,y))^2}_{\text{x-derivative}} + \underbrace{(L(x,y+1) - L(x,y-1))^2}_{\text{y-derivative}}}$$

$$\theta(x,y) = \tan^{-1}((L(x,y+1) - L(x,y-1))/(L(x+1,y) - L(x-1,y)))$$

Detection process returns

$$\{x, y, \sigma, \theta\} \longleftarrow \text{4D Keypoint!}$$

location scale orientation

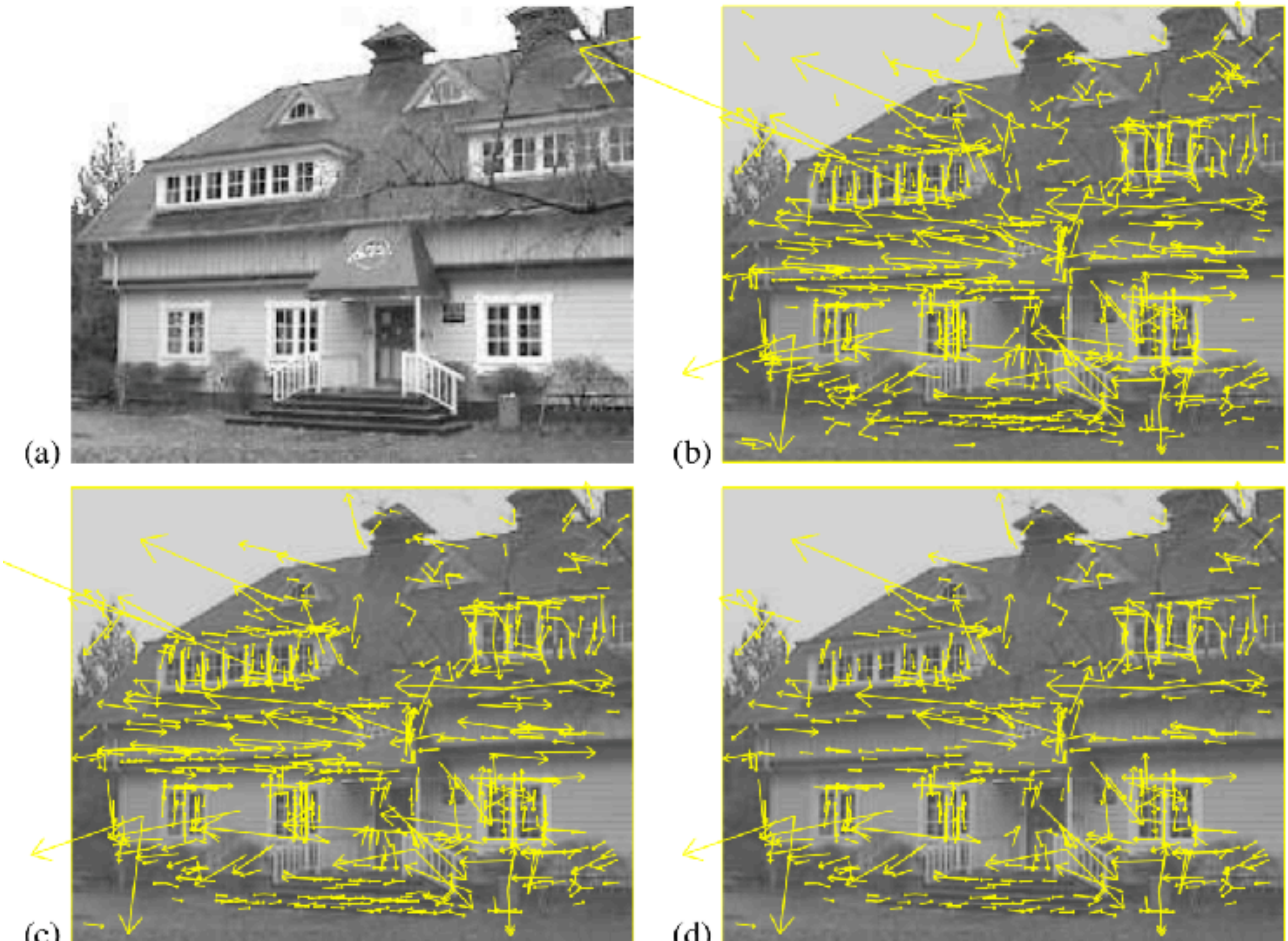
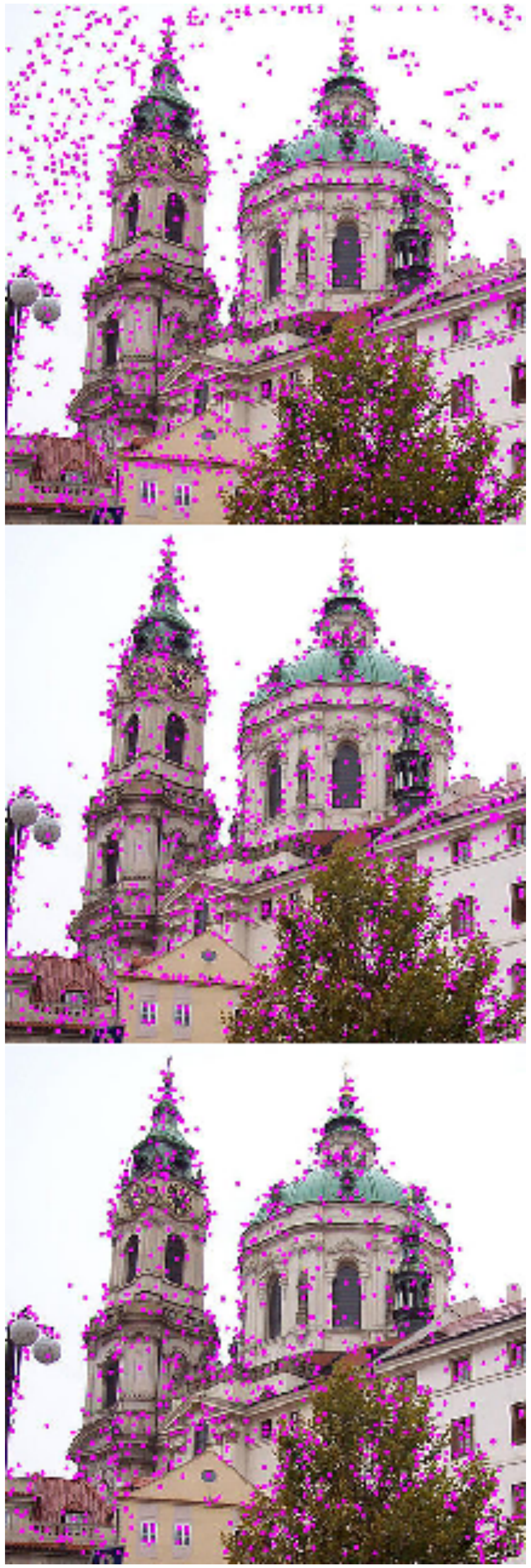


Figure 5: This figure shows the stages of keypoint selection. (a) The 233x189 pixel original image. (b) The initial 832 keypoints locations at maxima and minima of the difference-of-Gaussian function. Keypoints are displayed as vectors indicating scale, orientation, and location. (c) After applying a threshold on minimum contrast, 729 keypoints remain. (d) The final 536 keypoints that remain following an additional threshold on ratio of principal curvatures.



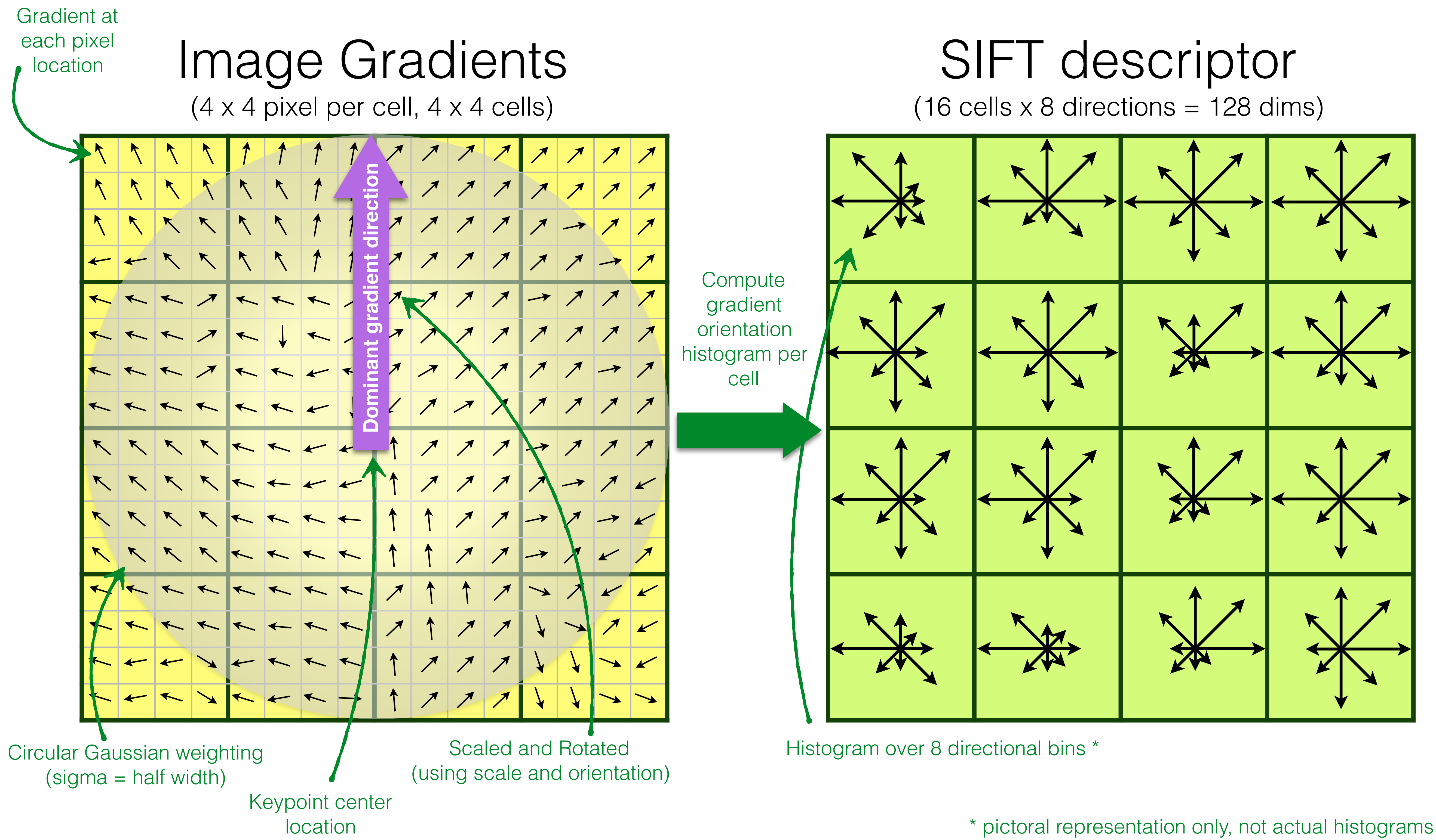
SIFT

(Scale Invariant Feature Transform)

SIFT describes both a **detector** and **descriptor**

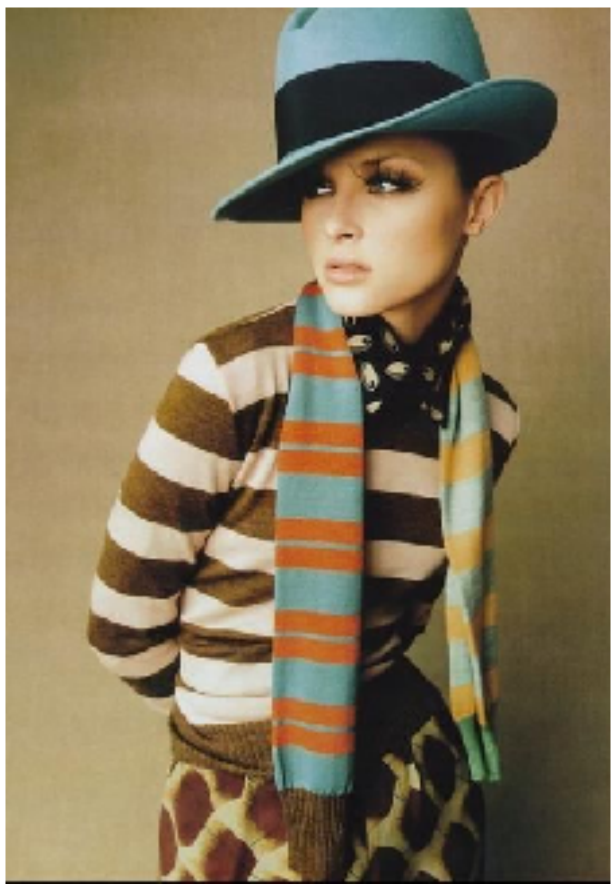
1. Multi-scale extrema detection
2. Keypoint localization
3. Orientation assignment
4. **Keypoint descriptor**

4. Keypoint descriptor

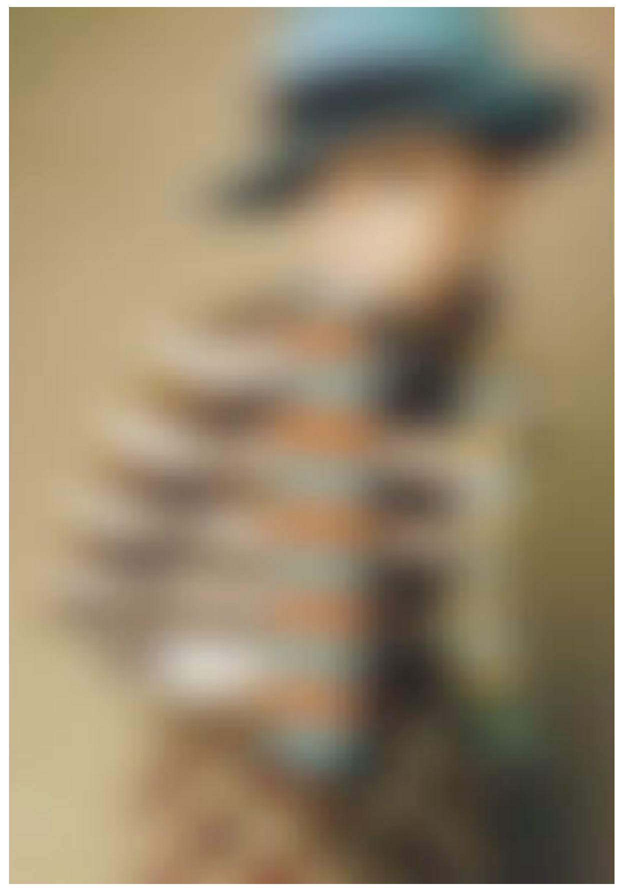


* pictoral representation only, not actual histograms!

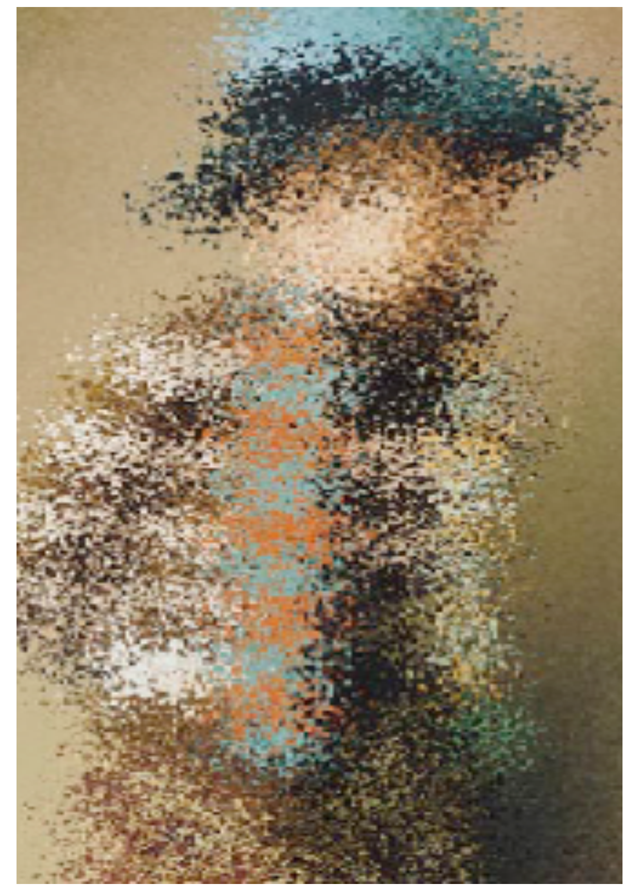
Discriminative power



Raw pixels



Sampled



Locally orderless

Global histogram

Generalization power