COMPUTER VISION
Describing Interesting Points

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-Scale and Rotation selection

- SIFT descriptor

- Texture descriptor

THIS CLASS

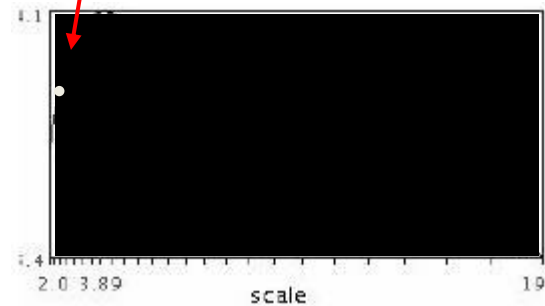# Automatic Scale Selection

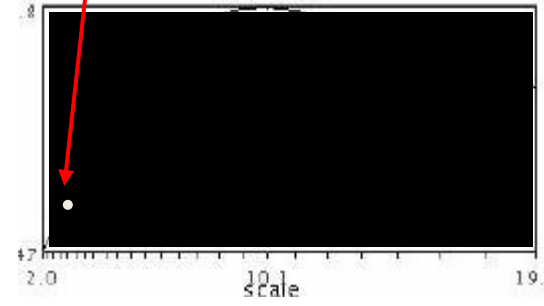$$f(I_{i_1 \dots i_m}(x, \sigma)) = f(I_{i_1 \dots i_m}(x', \sigma'))$$

How to find corresponding patch sizes?

Automatic Scale Selection

- Function res... ...f ... ... (scale signature)

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

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

Automatic Scale Selection

- Function res...... of ...... (scale signature)

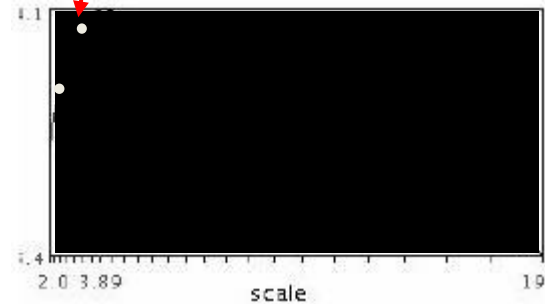$$f(I_{i_1 \ldots i_m}(x, \sigma))$$

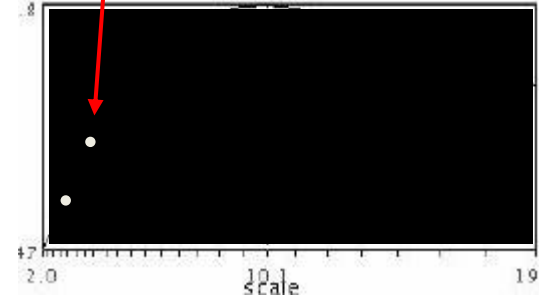$$f(I_{i_1 \ldots i_m}(x', \sigma))$$

Automatic Scale Selection

- Function res...   (scale signature)

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

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

Automatic Scale Selection
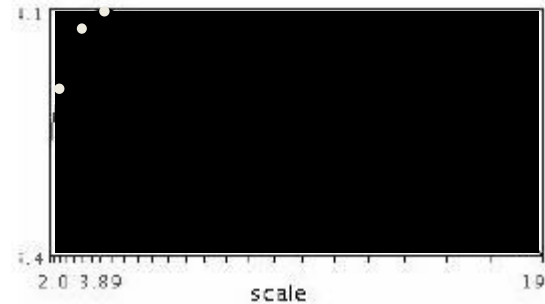
- Function res   (scale signature)

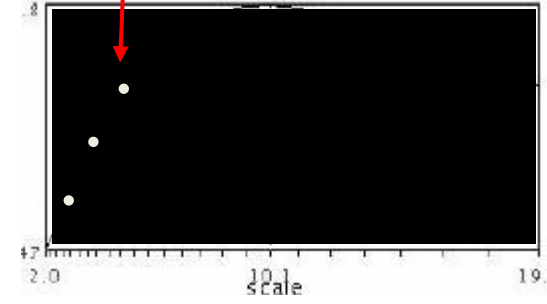$$f(I_{i_1 \ldots i_m}(x, \sigma))$$

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

K. Grauman, B. Leibe
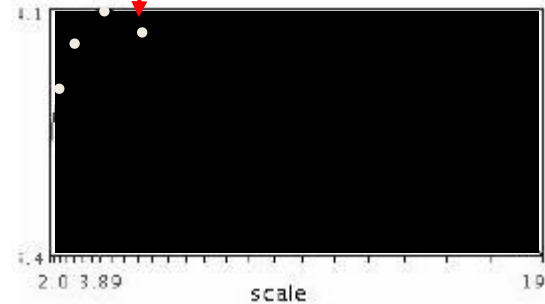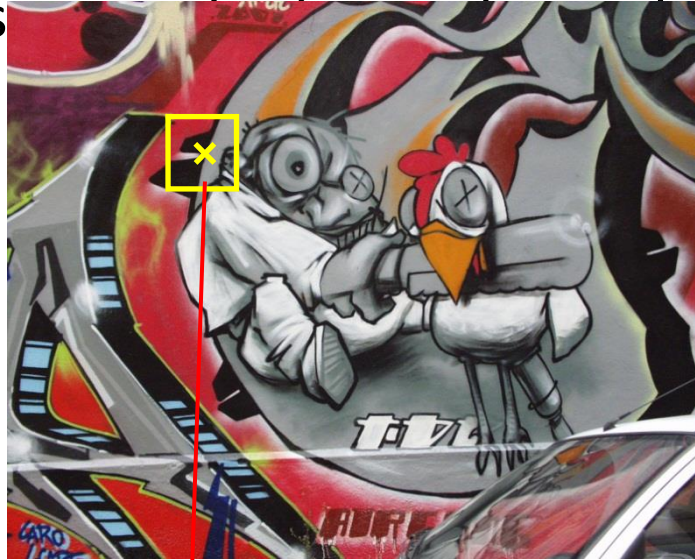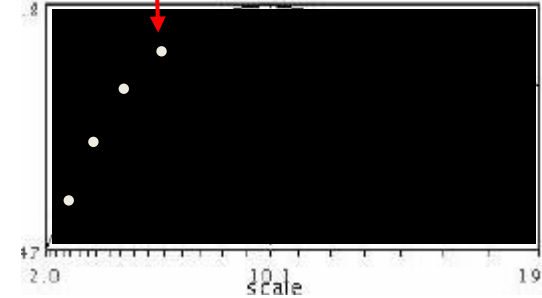
Automatic Scale Selection

- Function res_____ f_____ (scale si_____)

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

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

Automatic Scale Selection

- Function res... f ... ... (scale signature)
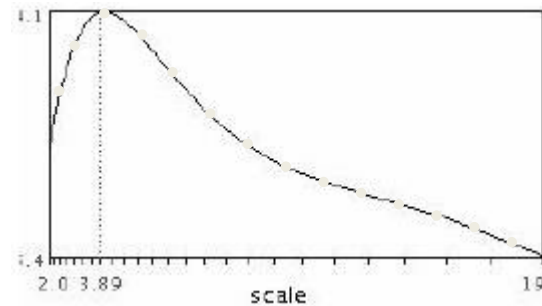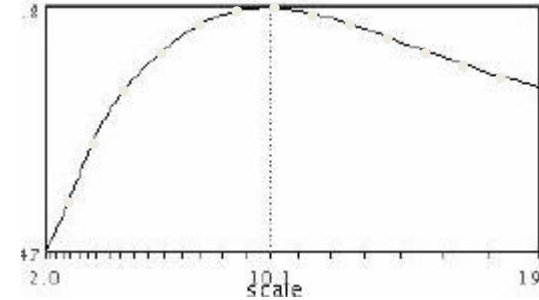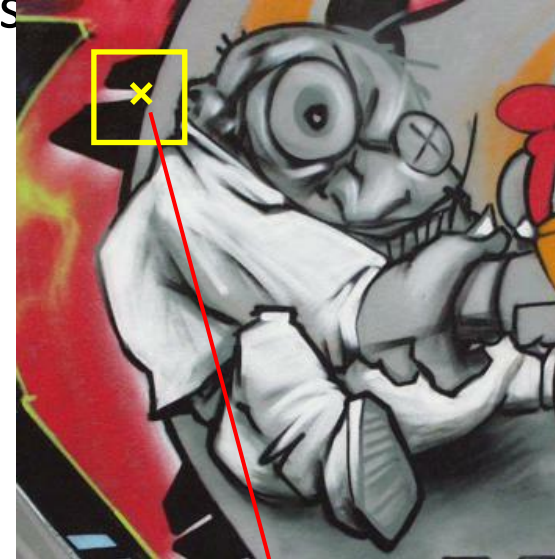
$$f(I_{i_1 \dots i_m}(x, \sigma))$$

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

What Is A Useful Signature Function?

- Difference of Gaussian = "blob" detector
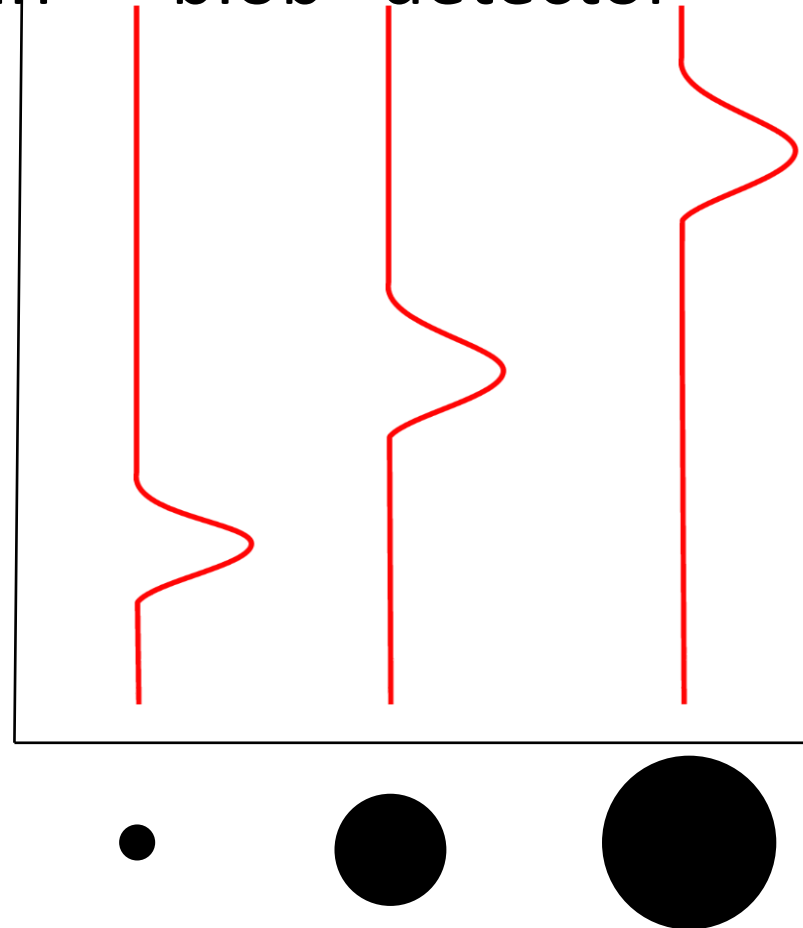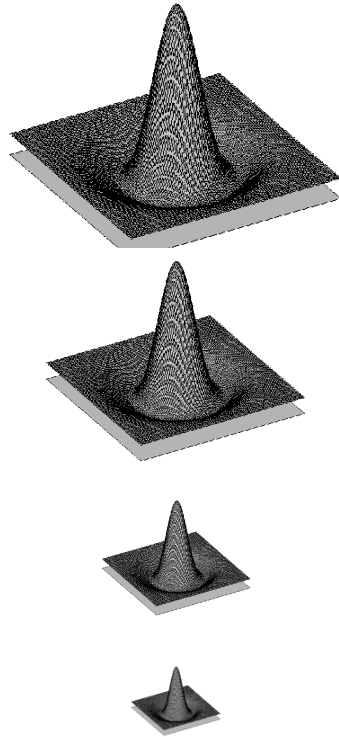
Difference-of-Gaussian (DoG)
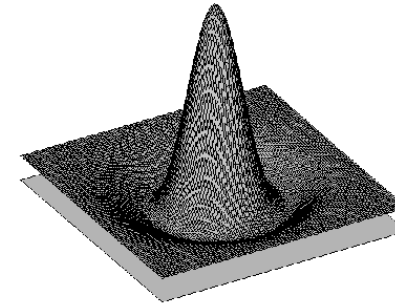
DoG – Efficient Computation

- Computation in Gau

Sampling with step $\sigma^4 = 2$

Original image

$\sigma = 2^{\frac{1}{4}}$

Scale (next octave)

Scale (first octave)

σ

Gaussian

Difference of Gaussian (DOG)
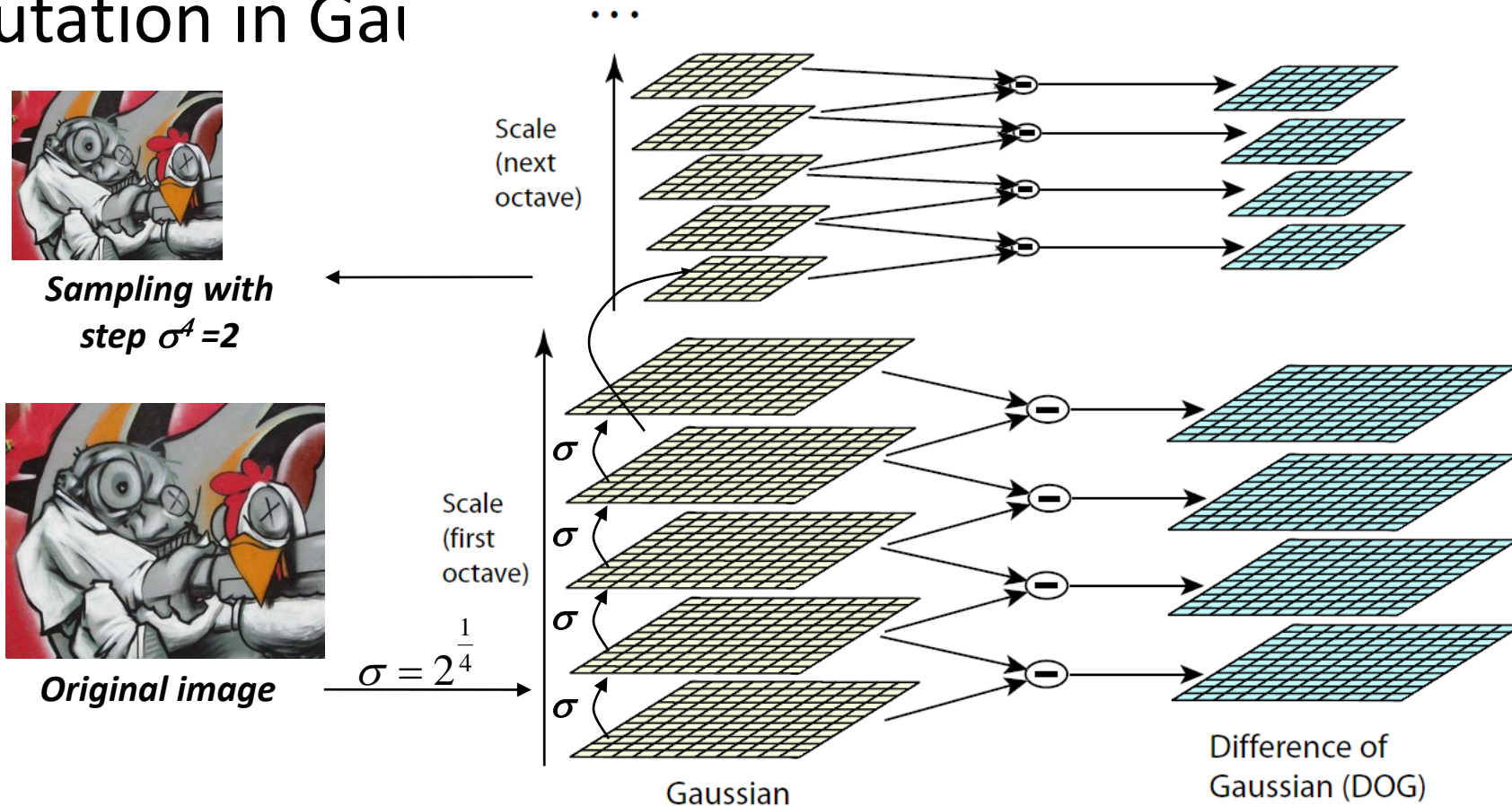
Find local maxima in position-scale space of Difference-of-Gaussian

$$L_{xx}(\sigma) + L_{yy}(\sigma)$$

σ^5

σ^4

σ^3

σ^2

σ

Scale

$\Rightarrow$ **List of (x, y, s)**

K. Grauman, B. Leibe
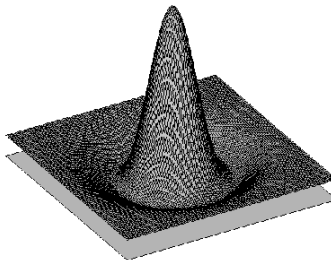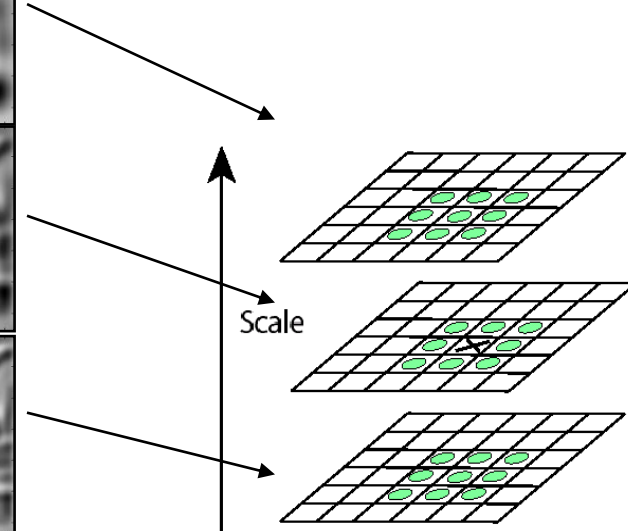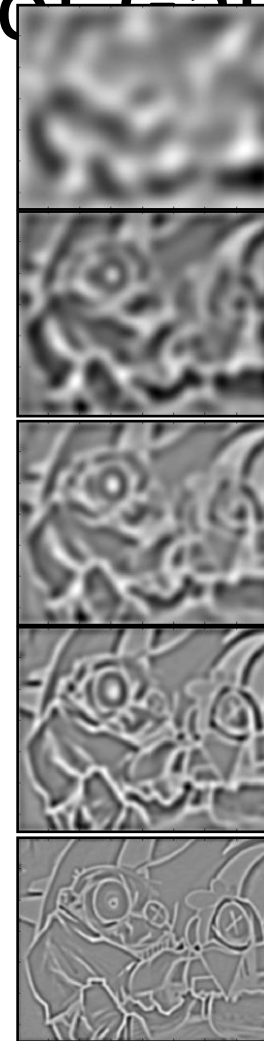
Results: Difference-of-Gaussian
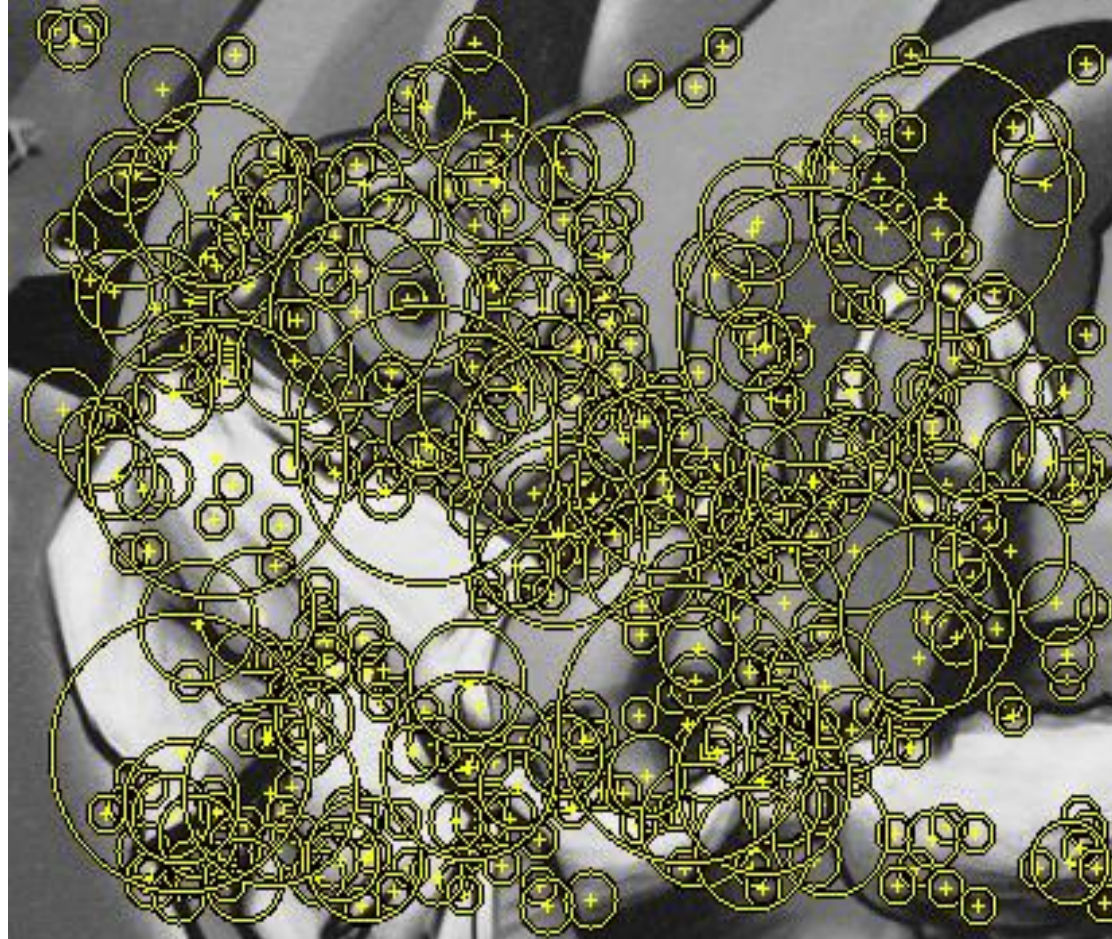
Orientation Normalization

[Lowe, SIFT, 1999]

- Compute orientation histogram

- Select dominant orientation

- Normalize: rotate to fixed orientation
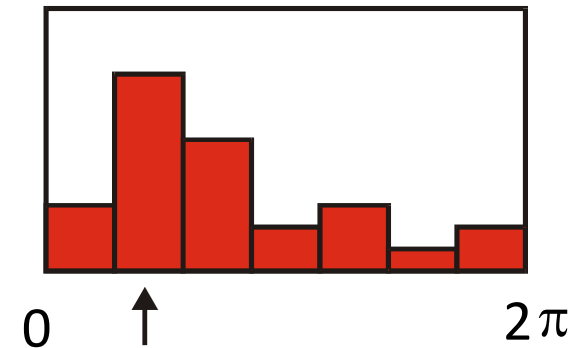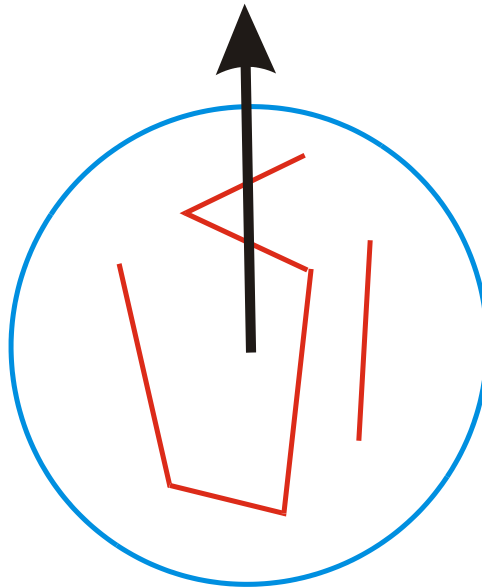
Local Descriptors

- The ideal descriptor should be
  - Robust
  - Distinctive
  - Compact
  - Efficient

- Most available descriptors focus on edge/gradient information
  - Capture texture information
  - Color rarely used

Local Descriptors: SIFT Descriptor

Image gradients

Keypoint descriptor
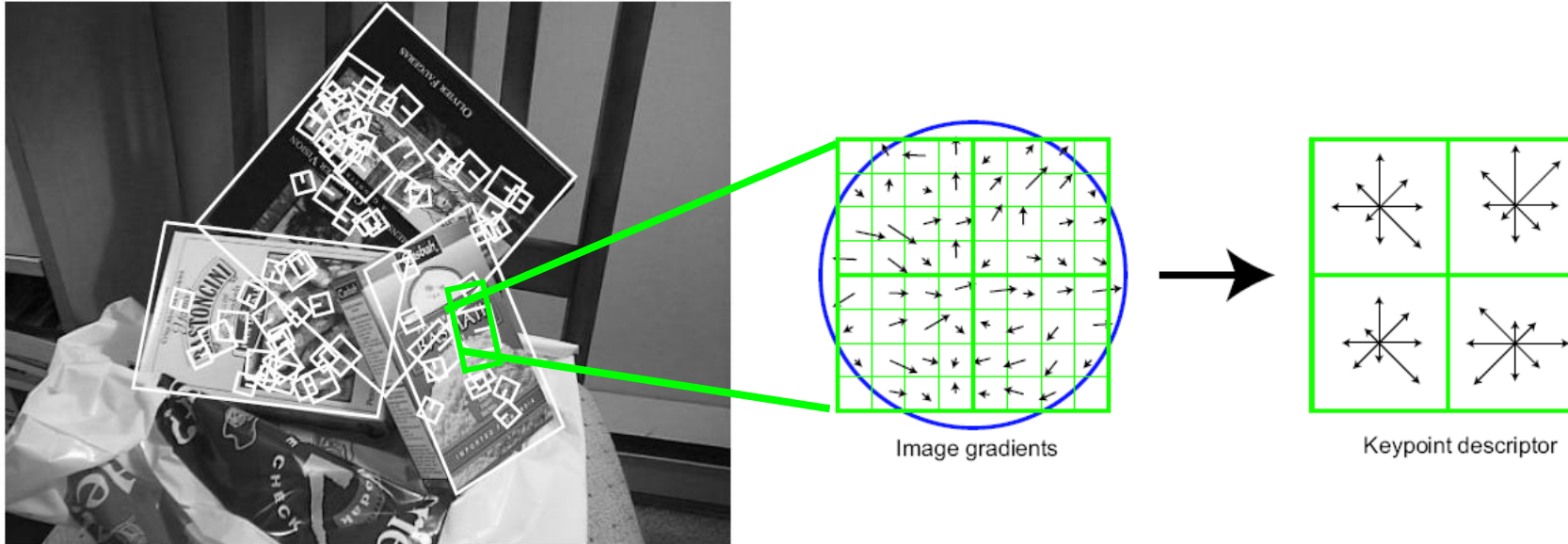
Histogram of oriented gradients

- **Captures important texture information**

- **Robust to small translations / affine deformations**

[Lowe, ICCV 1999]

Details of Lowe's SIFT algorithm

$$\mathbf{H} = \begin{bmatrix} D_{xx} & D_{xy} \\ D_{xy} & D_{yy} \end{bmatrix}$$

$$\frac{\mathrm{Tr}(\mathbf{H})^2}{\mathrm{Det}(\mathbf{H})} < \frac{(r+1)^2}{r}$$

- Run DoG detector
  - Find maxima in location/scale space
  - Remove edge points
- Find all major orientations
  - Bin orientations into 36 bin histogram
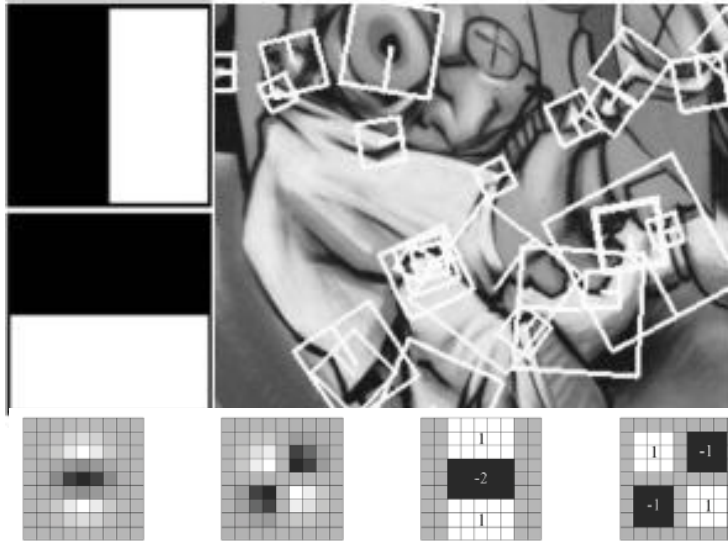   - Weight by gradient magnitude
    - Weight by distance to center (Gaussian-weighted mean)
  - Return orientations within 0.8 of peak
    - Use parabola for better orientation fit
- For each (x,y,scale,orientation), create descriptor:
  - Sample 16x16 gradient mag. and rel. orientation
  - Bin 4x4 samples into 4x4 histograms
  - Threshold values to max of 0.2, divide by L2 norm
  - Final descriptor: 4x4x8 normalized histograms

Local Descriptors: SURF

Fast approximation of SIFT idea

Efficient computation by 2D box filters & integral images
$\Rightarrow$ 6 times faster than SIFT

Equivalent quality for object identification

GPU implementation available

Feature extraction @ 200Hz
(detector + descriptor, 640×480 img)

http://www.vision.ee.ethz.ch/~surf

[Bay, ECCV'06], [Cornelis, CVGPU'08]

Things to remember

- Keypoint detection: repeatable and distinctive
  - Corners, blobs, stable regions
  - Harris, DoG

- Descriptors: robust and selective
  - spatial histograms of orientation
  - SIFT

Image gradients   Keypoint descriptor