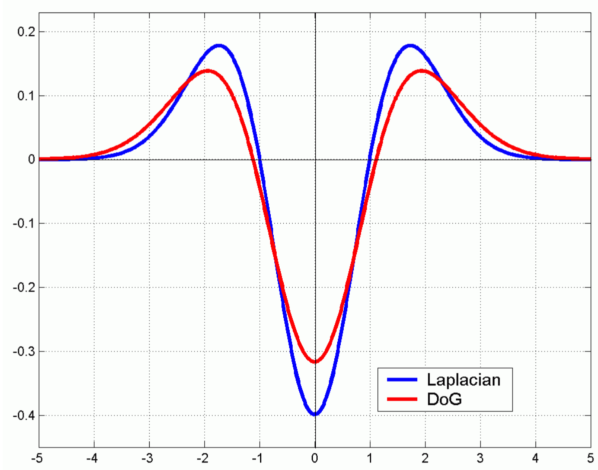
2D Recognition Using SIFT (cont.)

- Recognize **2D objects** in real-world cluttered scenes using the **Scale Invariant Feature Transform (SIFT)**.
  - The SIFT interest point detector
  - Matching and Results
  - Histogram-of-Oriented Gradients (HoG)
  - Shape Contexts

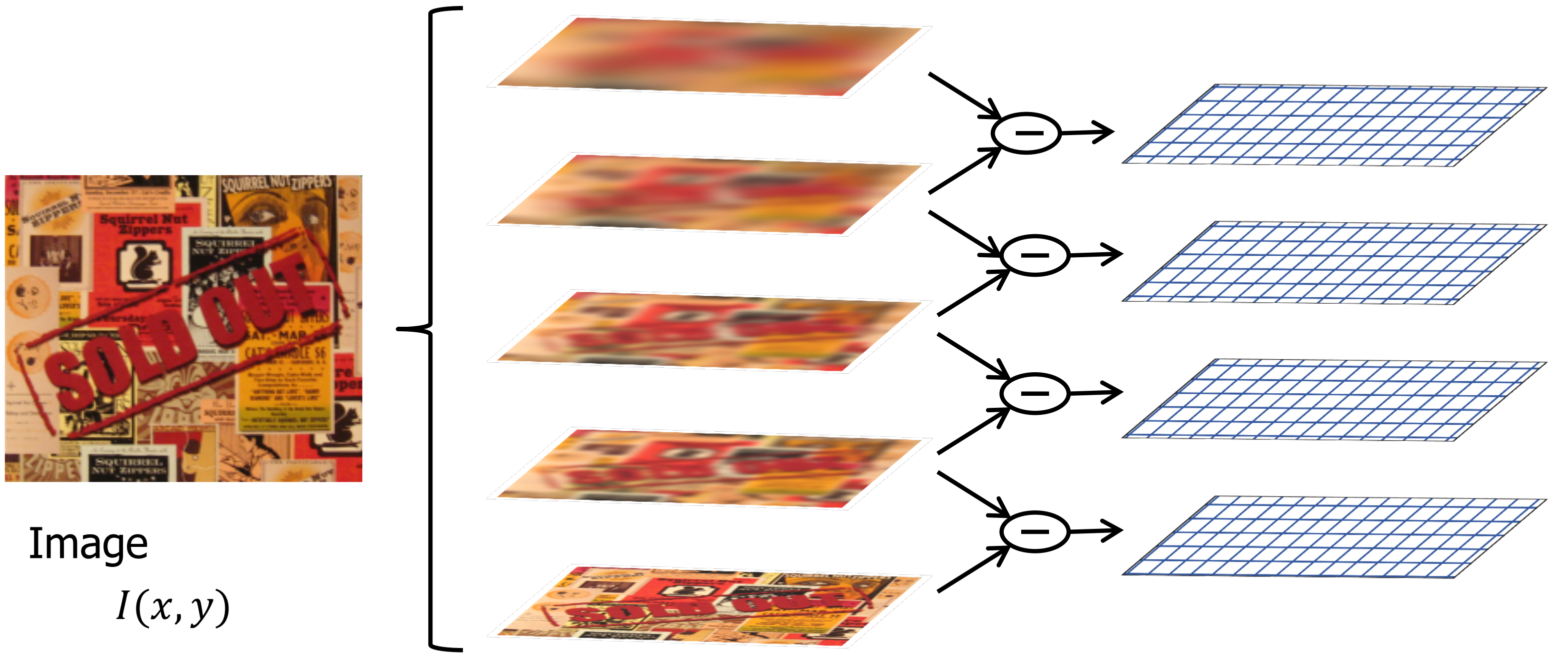
The SIFT Detector

- An Efficient Implementation of Blob Detector
- Uses **Difference of Gaussian** (DoG) as an approximation of NLoG
- Difference of Gaussian(DoG) $= (n_{s\sigma} - n_{\sigma}) \approx (s-1)\sigma^2 \nabla^2 n_{\sigma}$



DoG ≈ NLoG

Extracting SIFT Interest Points (1)



Image

$I(x, y)$

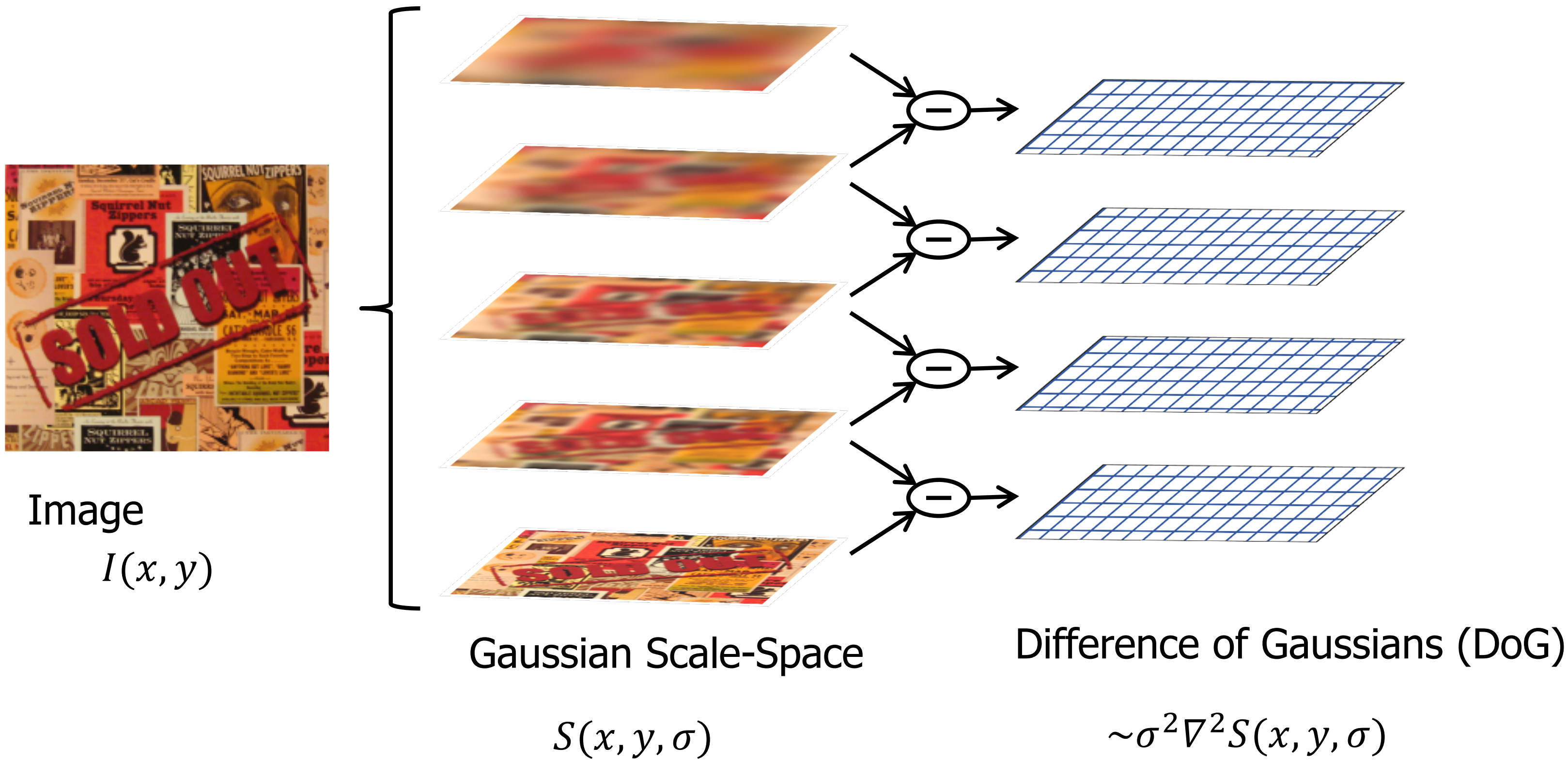
Gaussian Scale-Space

$S(x, y, \sigma)$

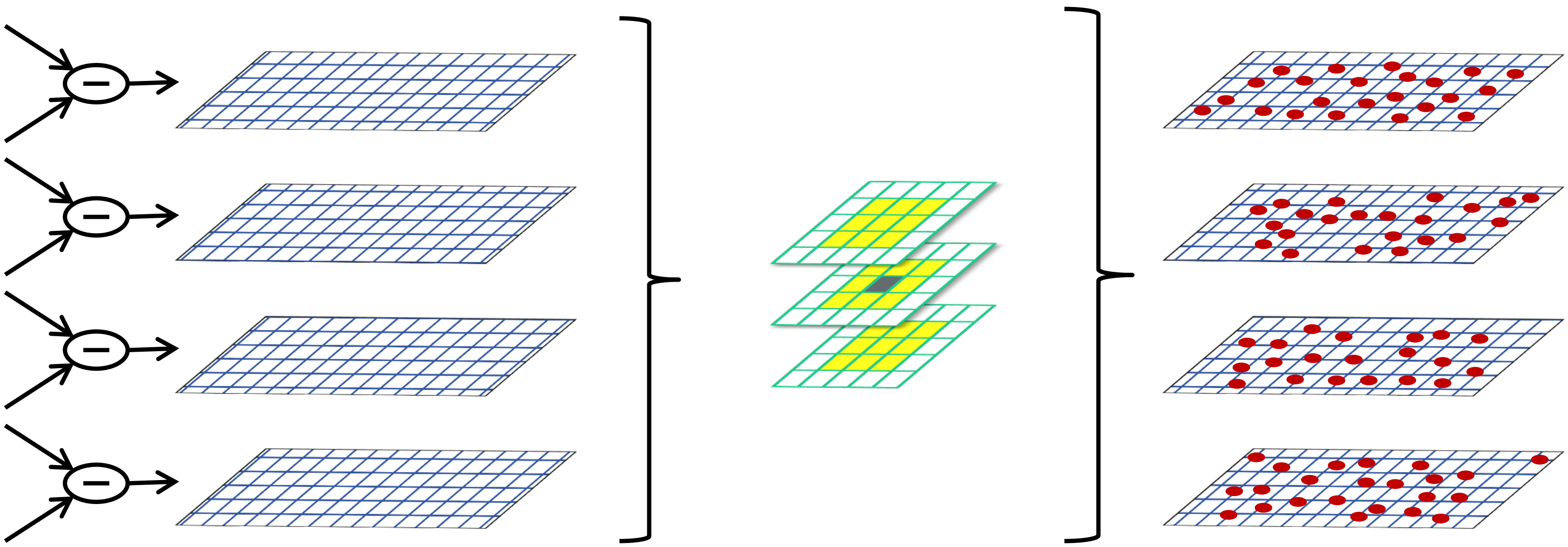
Difference of Gaussians (DoG)

$\approx \sigma^2 \nabla^2 S(x, y, \sigma)$

Extracting SIFT Interest Points (2)



Extracting SIFT Interest Points (3)



Difference of Gaussians (DoG)

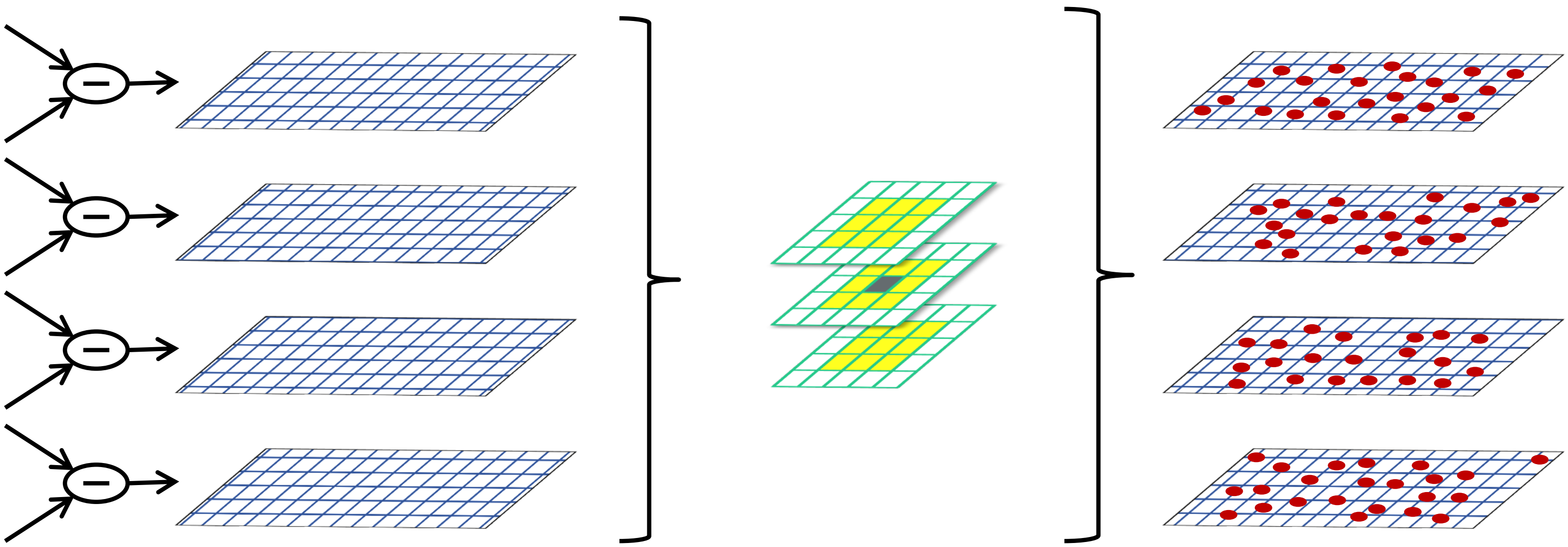
$\sim \sigma^2 \nabla^2 S(x, y, \sigma)$

Find Extrema in every 3x3x3 grid

Interest Point Candidates

(includes weak extrema, bad contrast, …)

Extracting SIFT Interest Points (4)



Difference of Gaussians (DoG)

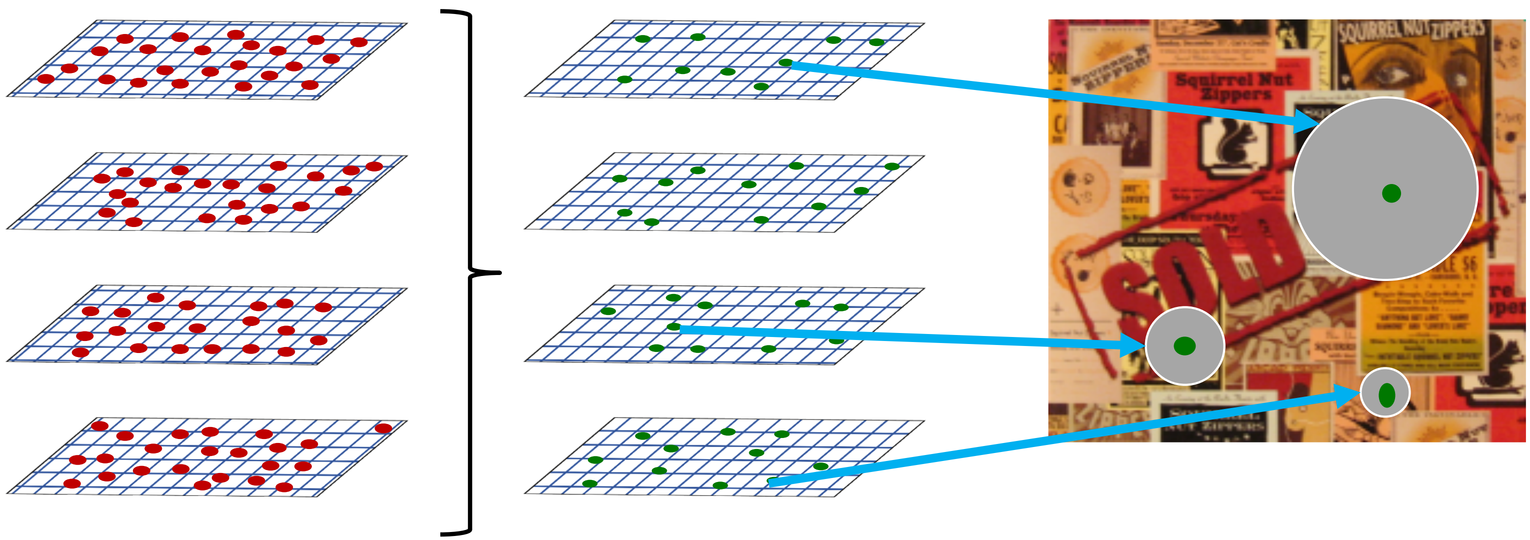
$\sim\sigma^2\nabla^2 S(x, y, \sigma)$

Find Extrema in every 3x3x3 grid

Interest Point Candidates

(includes weak extrema, bad contrast, …)

Extracting SIFT Interest Points (5)

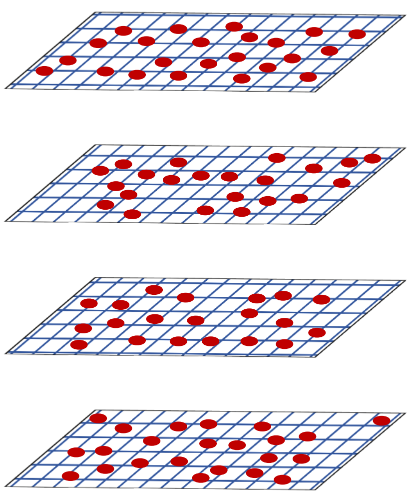


Interest Point
Candidates

(includes weak extrema, bad contrast, …)

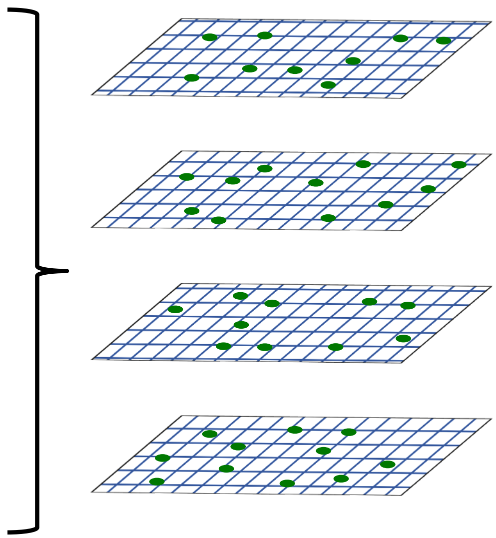
SIFT
Interest Points
(after removing weak points)

Extracting SIFT Interest Points (6)



Interest Point
Candidates

(includes weak extrema, bad contrast, …)



SIFT
Interest Points
(after removing weak points)

Interest Point Depiction

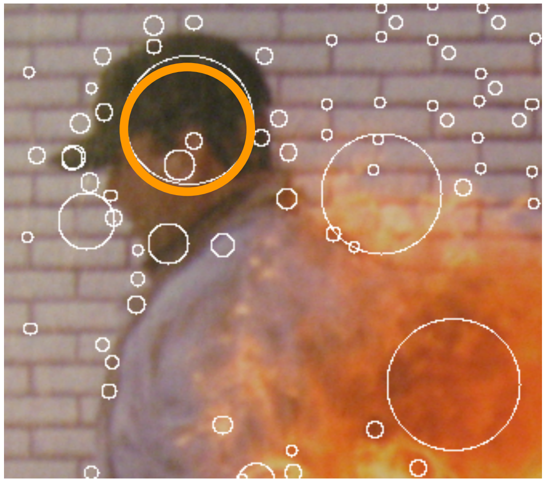
SIFT Detection Examples (1)

SIFT Detection Examples (2)

SIFT Detection Examples (3)

SIFT Scale Invariance

- Use the characteristic scales to match sizes



Computing the Principal Orientation

- Use the histogram of gradient directions

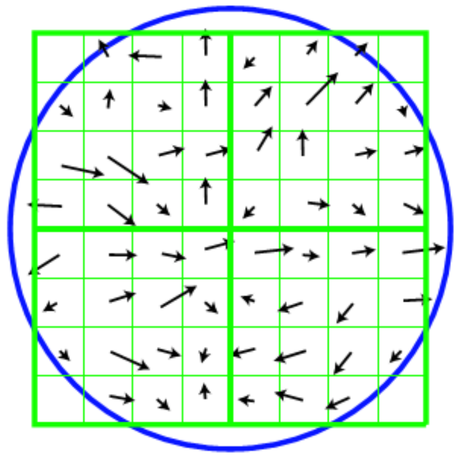
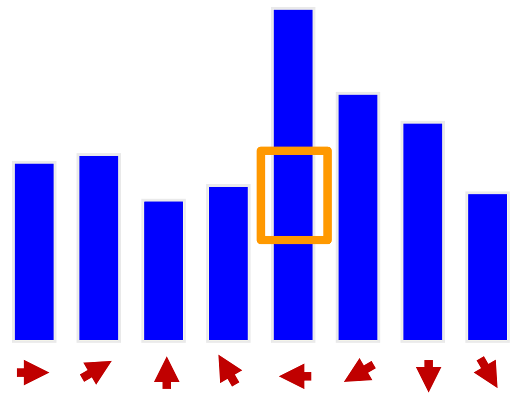


Image gradient directions

$$\theta = \tan^{-1}\left(\frac{\partial I}{\partial y} / \frac{\partial I}{\partial x}\right)$$

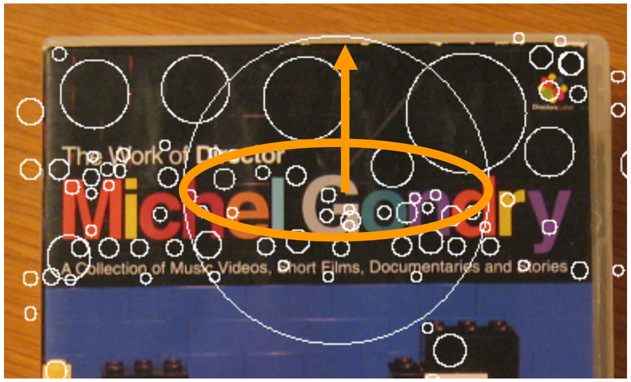
Principal Orientation

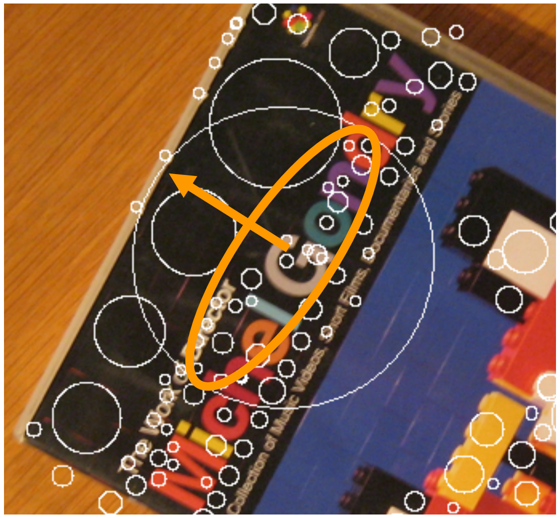


Choose the most prominent gradient direction

SIFT Rotation Invariance

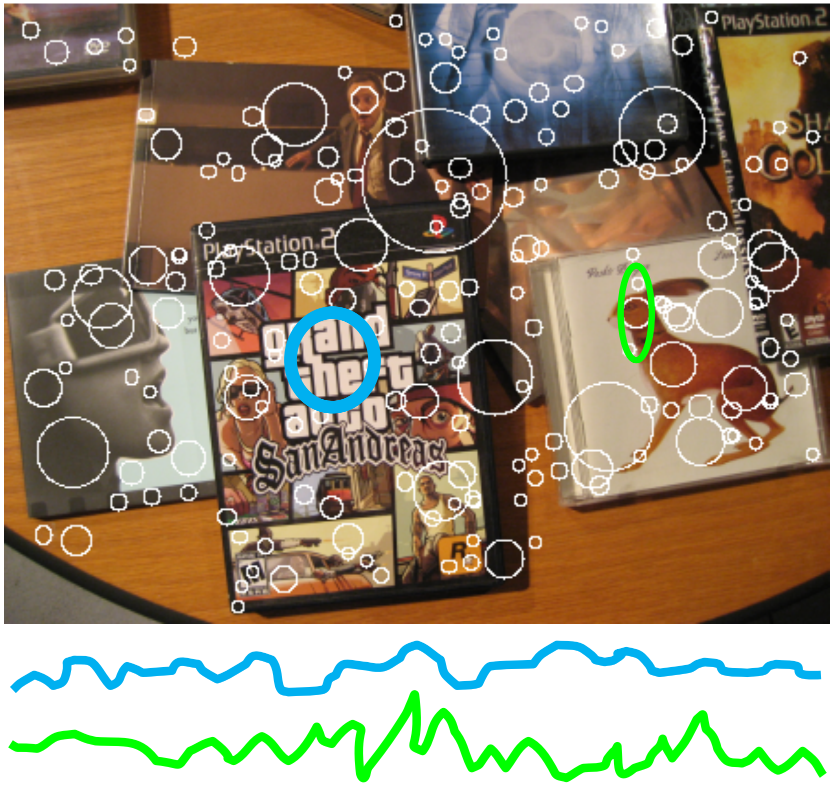
- Use the principal orientations to match rotation





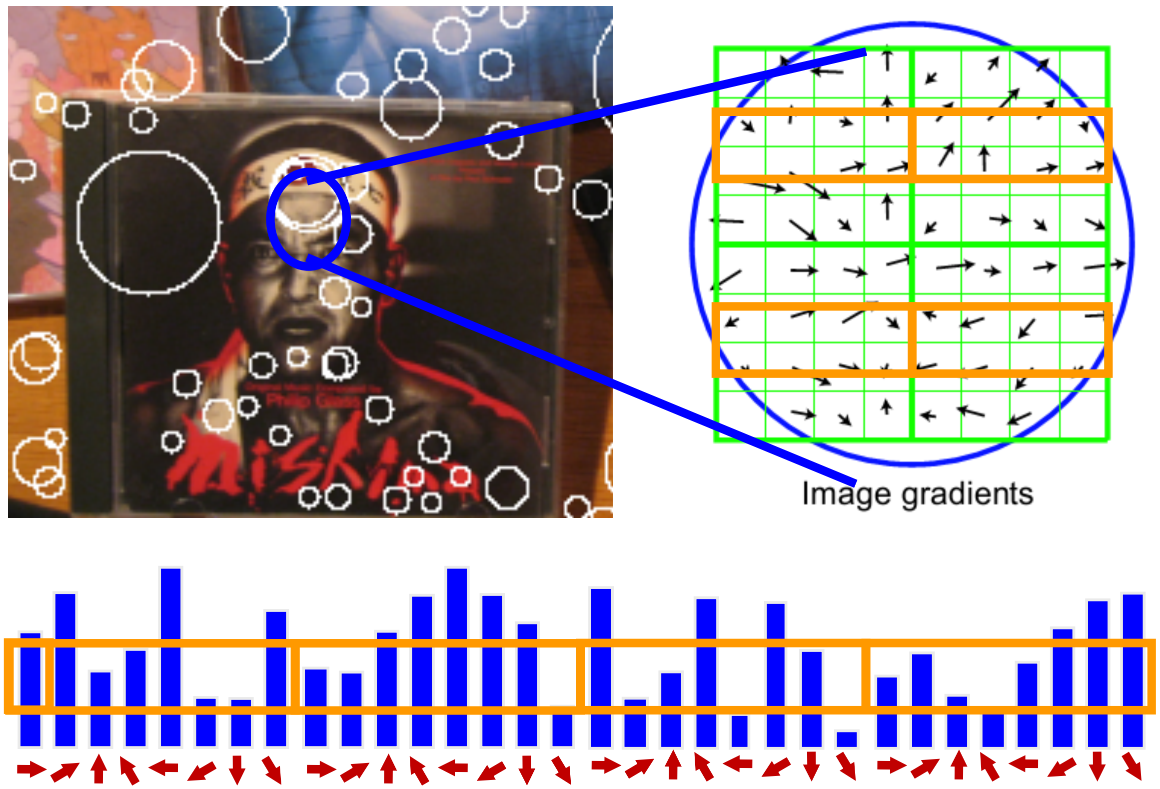
The SIFT Descriptor

- "**Describe**" points so they can be compared



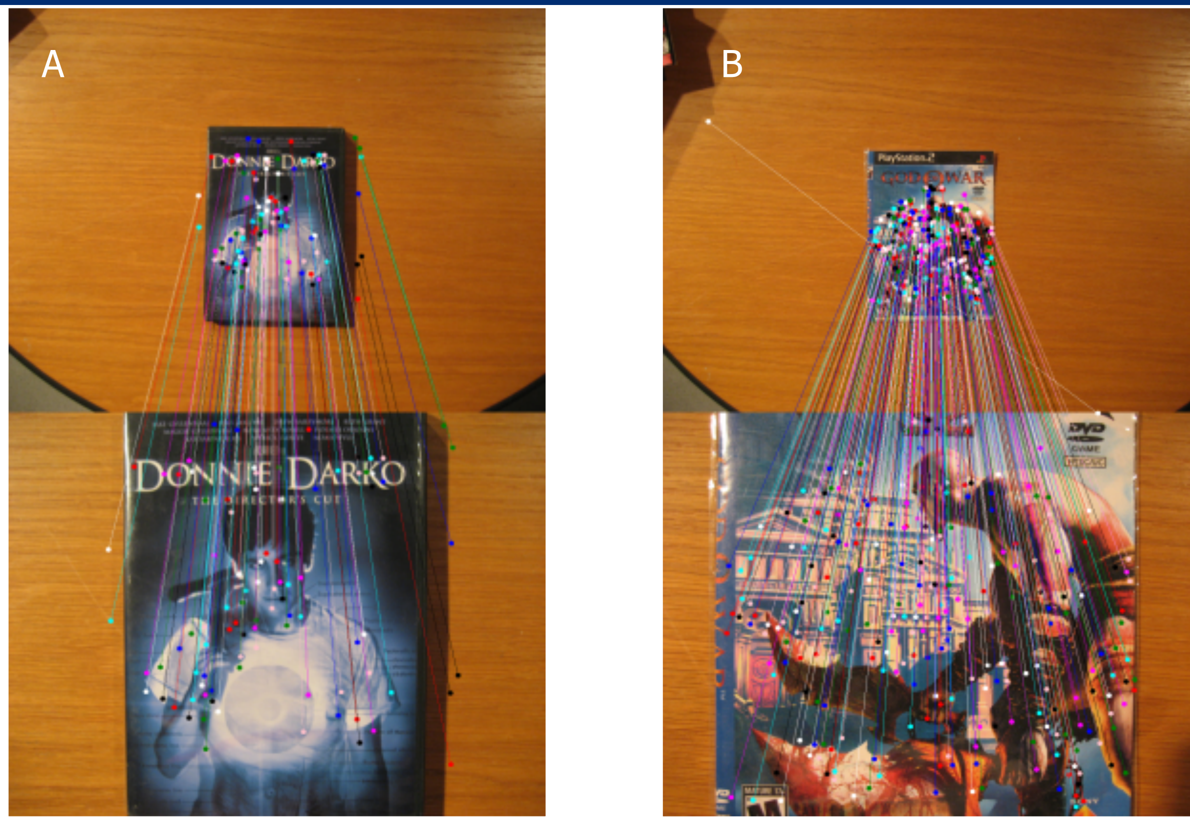
Computing the SIFT Descriptor

- Histograms of gradient directions over spatial regions



Invariant to Scale, Lighting, Brightness

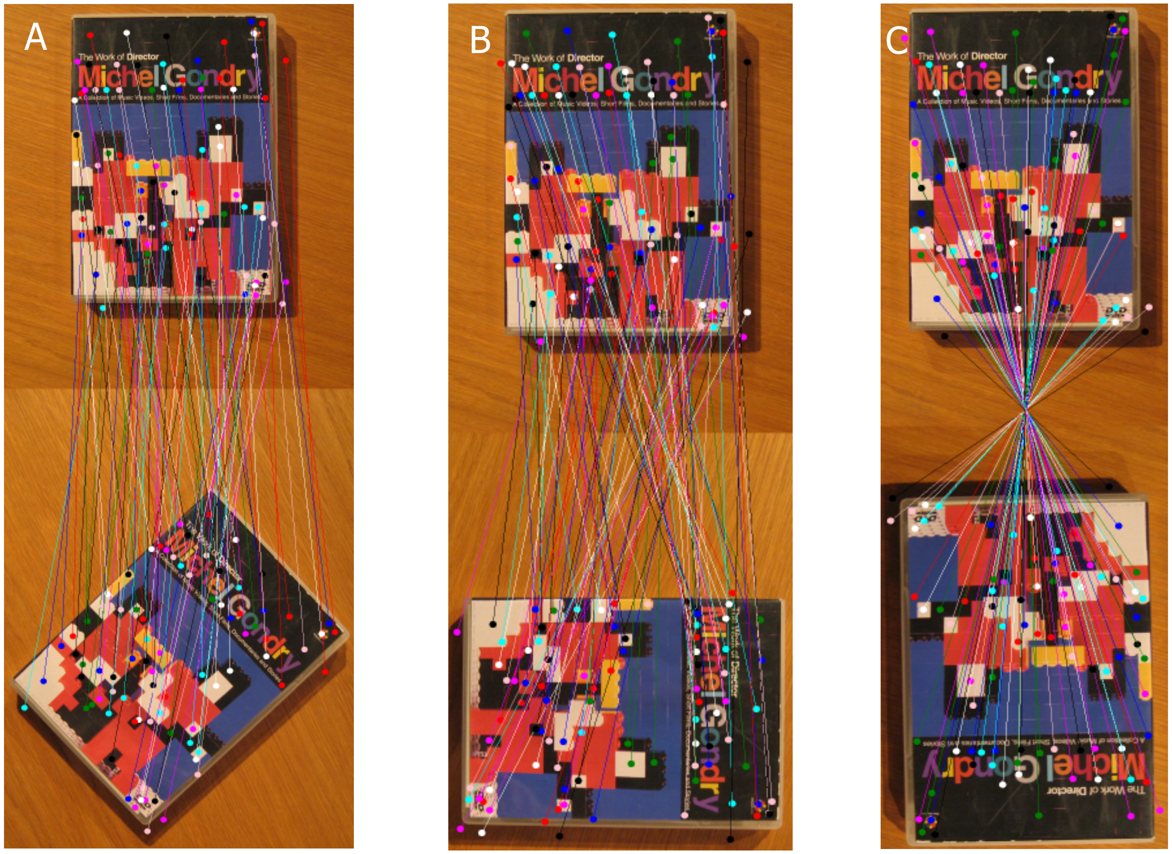
SIFT Results: Scale Invariance



SIFT detects corresponding features in images at different resolutions

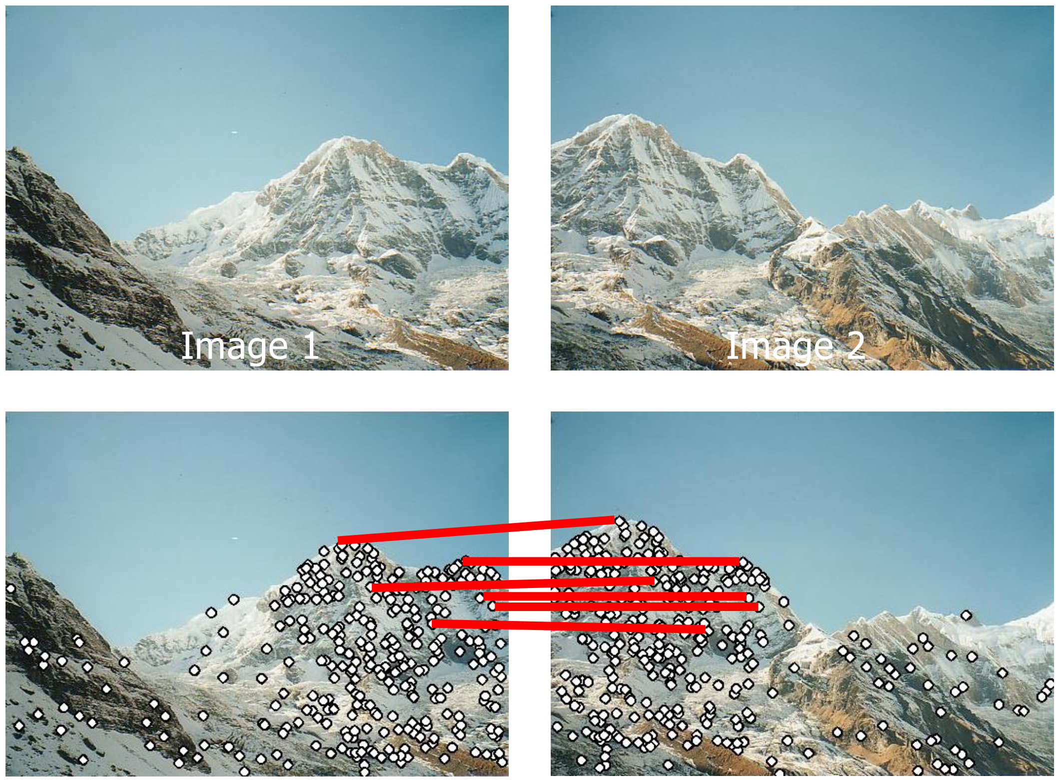
SIFT Results: Rotation Invariance

SIFT detects corresponding features in rotated images.



SIFT Robustness to Clutter

Panorama Stitching using SIFT (1)



Match SIFT Interest Points

[Autopano]

Panorama Stitching using SIFT (2)

- Transform/Warp one or both images so that corresponding SIFT points in images are aligned.

[Autopano]

Panorama Stitching using SIFT (3)

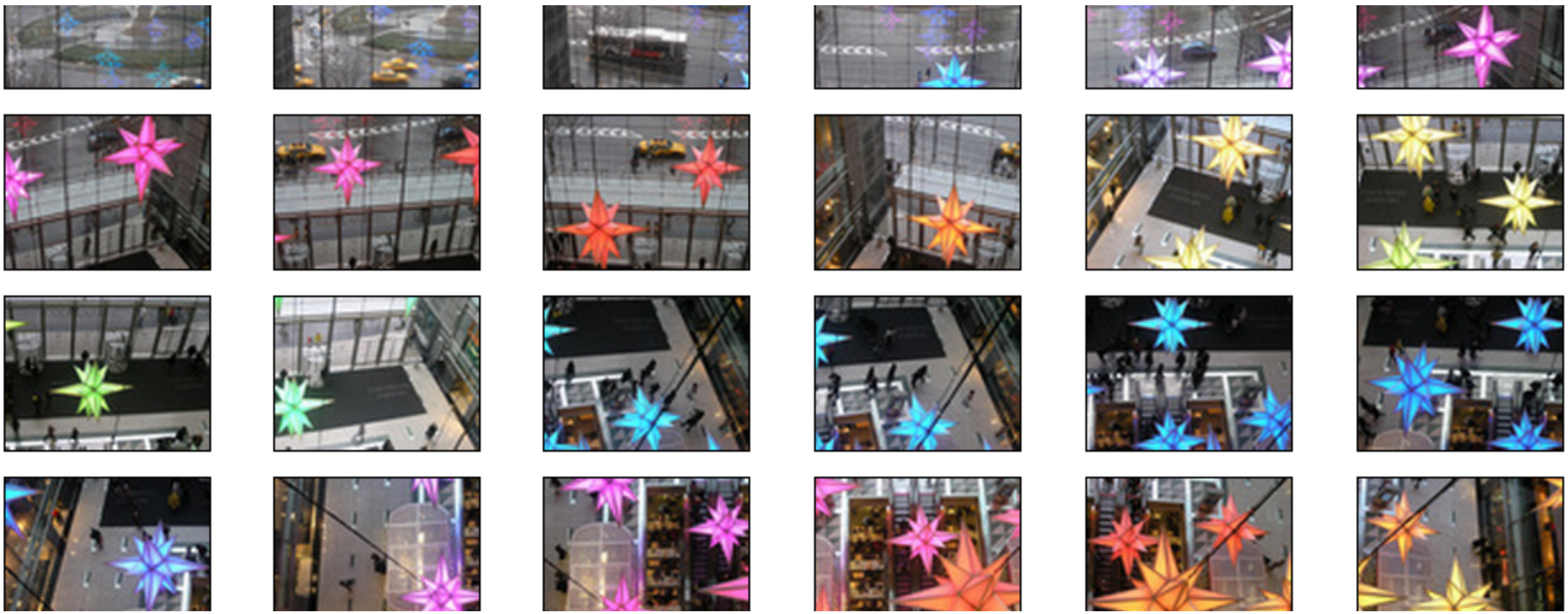
AutoStitch:

http://www.cs.bath.ac.uk/brown/autostitch/autostitch.html

(More on this in Image Stitching Lecture)

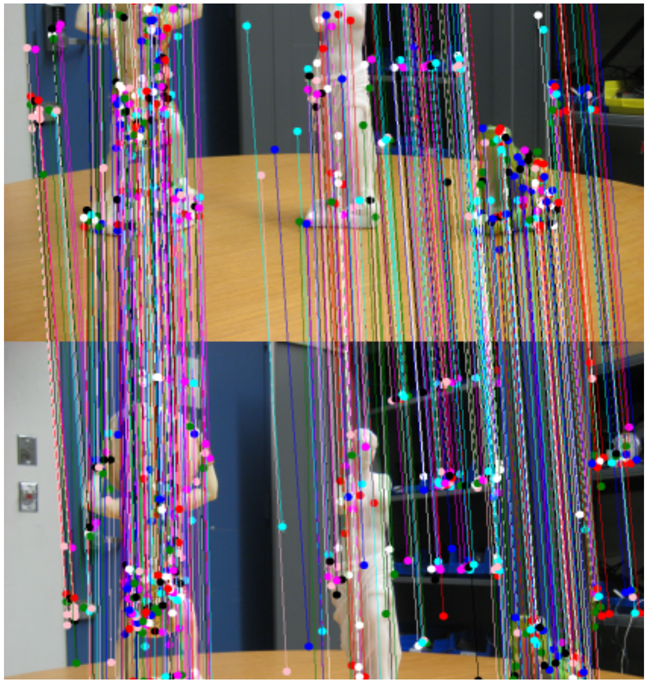
[Autopano]

Auto Collage using SIFT

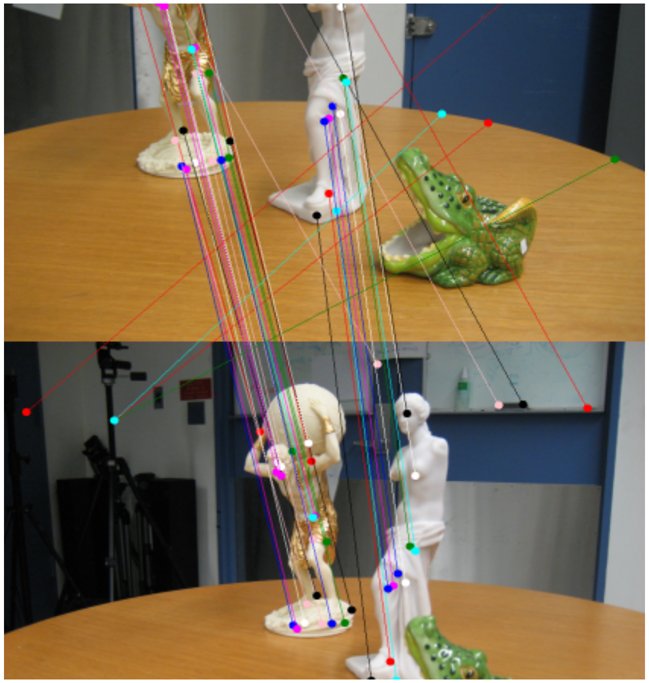


Auto Collage using SIFT (cont.)

SIFT for 3D Objects?



No Change in Viewpoint

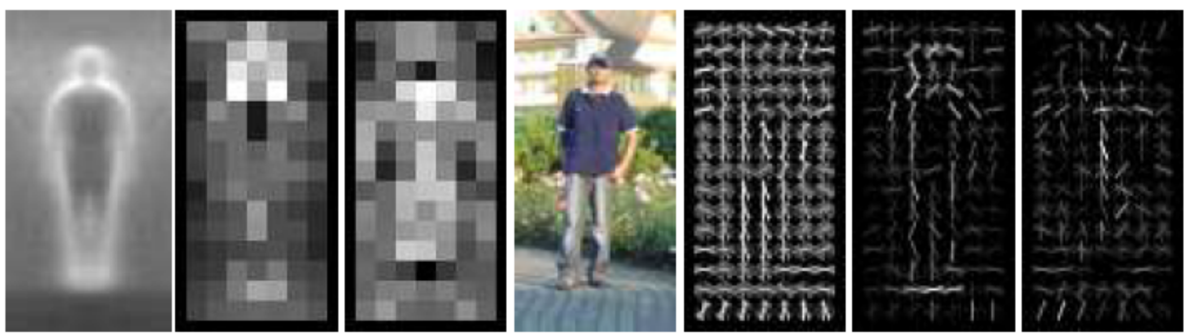


30° Change in Viewpoint

90° Change in Viewpoint

Histogram-of-Oriented-Gradients

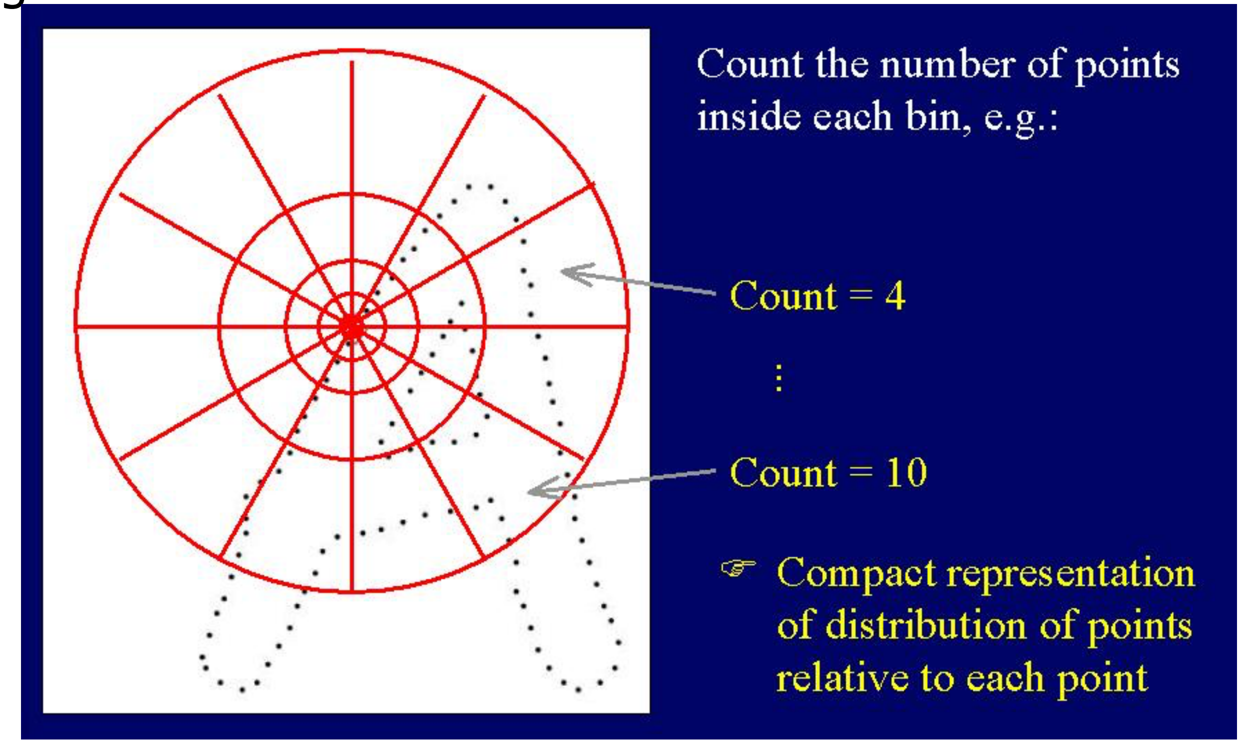
- HoG (Dalal, et. al., CVPR 2005) another similar approach: made popular to detect pedestrians in images



Shape Contexts

Shape Contexts (Belongie, et. al. 2002): descriptor to match shapes. Demonstrated on handwriting recognition

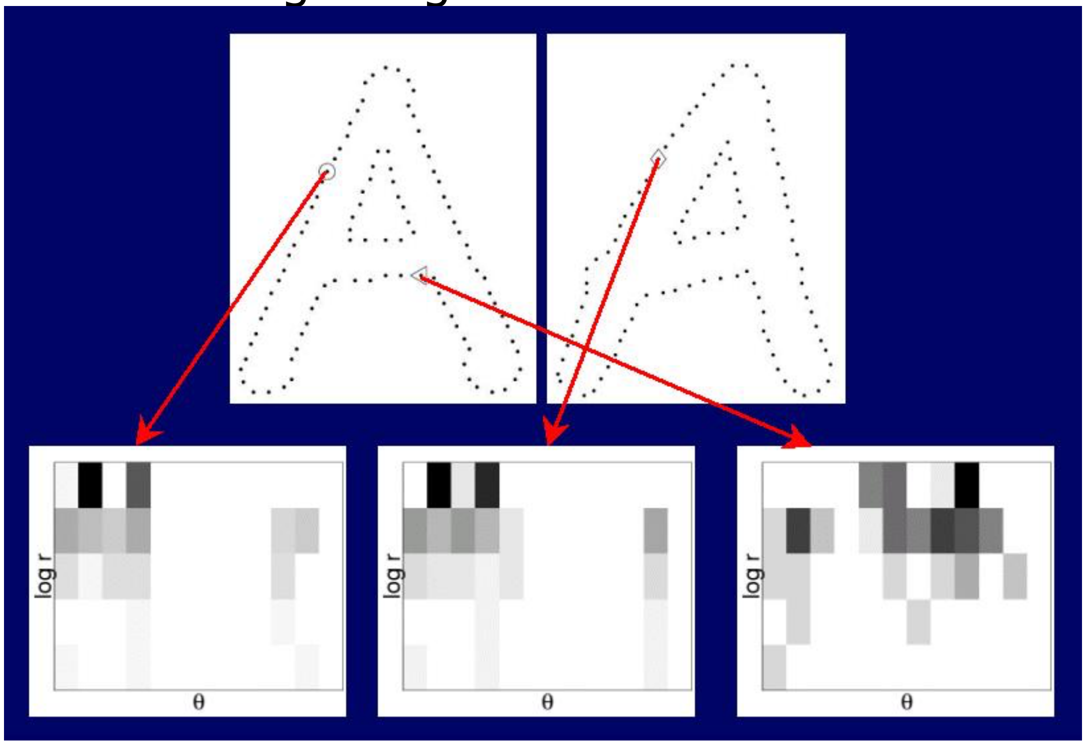
Log Polar
Distribution
(edge points)



Shape Contexts (cont.)

- Shape Contexts (Belongie, et. al. 2002): descriptor to match shapes. Demonstrated on handwriting recognition

Log Polar Distribution (edge points)



Summary

- SIFT feature detector: Robust matching
- Essential concepts in this lecture:
  - Building descriptors from detection
  - Histogram of gradients
  - Many other detectors possible

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- [Autopano] Software to make panaromas using SIFT. http://user.cs.tu-berlin.de/~nowozin/autopano-sift/
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