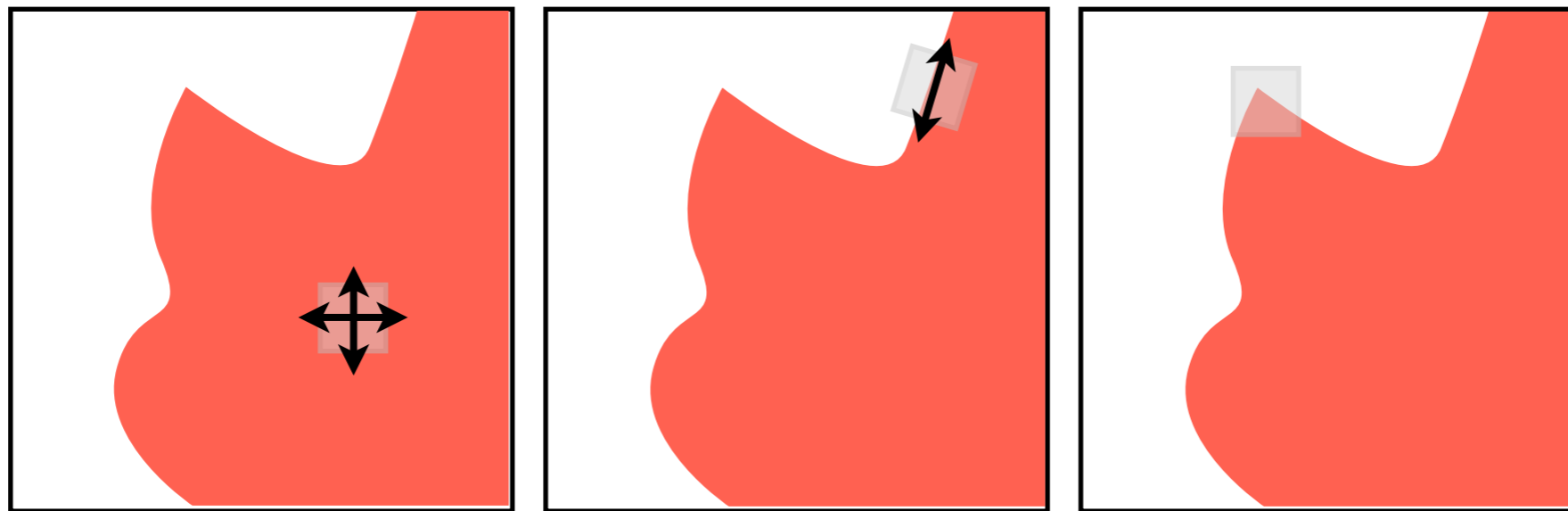# 15-381

ARTIFICIAL INTELLIGENCE

LECTURE 16:
VISION IV: RECOGNITION

FALL 2010

Several slides taken from: Fei-Fei Li, Josef Sivic, Kristen Grauman

CORNERNESS

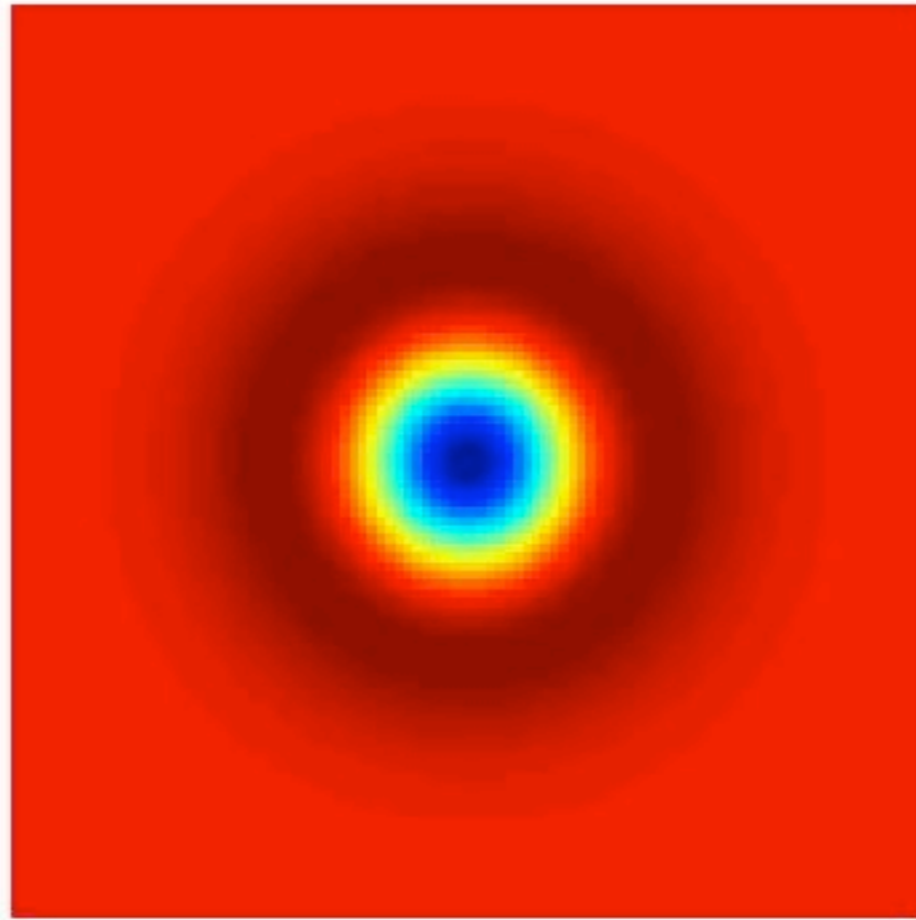- **IDEA**: SHIFTING PATCH IN ANY DIRECTION SHOULD PRODUCE LARGE CHANGE

Flat areas
No change in
all directions

Edges
No change
along edge

Corners
Change in
all direction

DIFFERENCE OF GAUSSIAN

$$D(x, y, \sigma) = (G(x, y, k\sigma) - G(x, y, \sigma)) * I(x, y)$$

$$D(x, y, \sigma) = L(x, y, k\sigma) - L(x, y, \sigma)$$
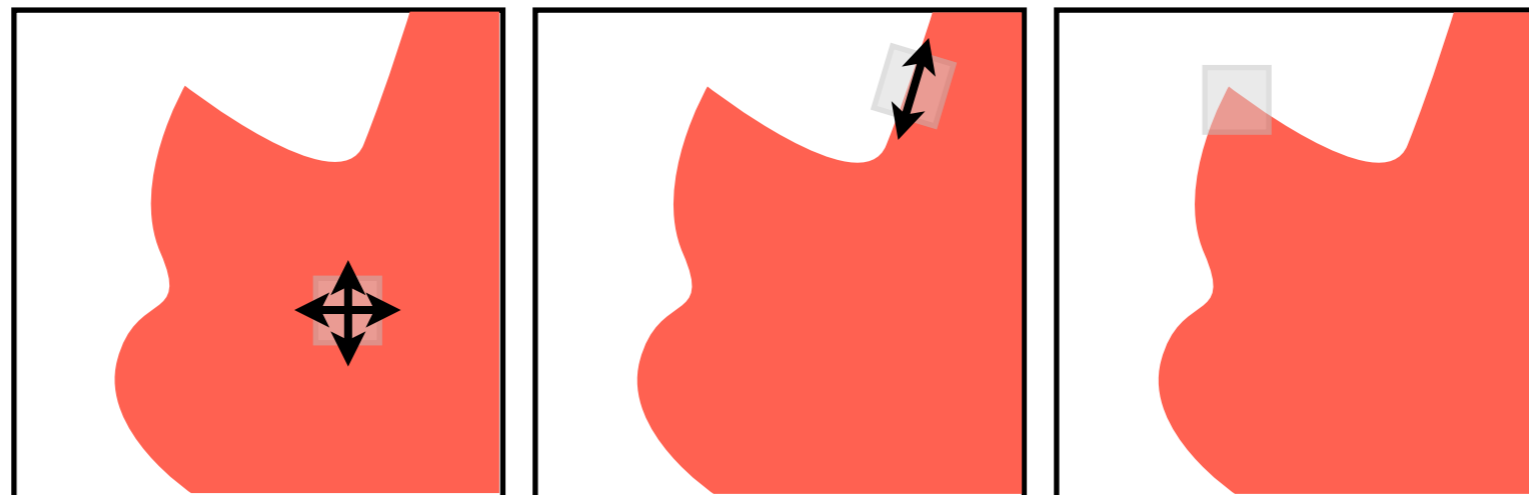
FAST APPROXIMATION TO THE LAPLACIAN OF GAUSSIAN

EDGE ELIMINATION

Change in *D*
(computer by taking adjacent pixel differences)

Hessian Matrix

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

The eigenvalues of H are proportional to the principal curvature of D

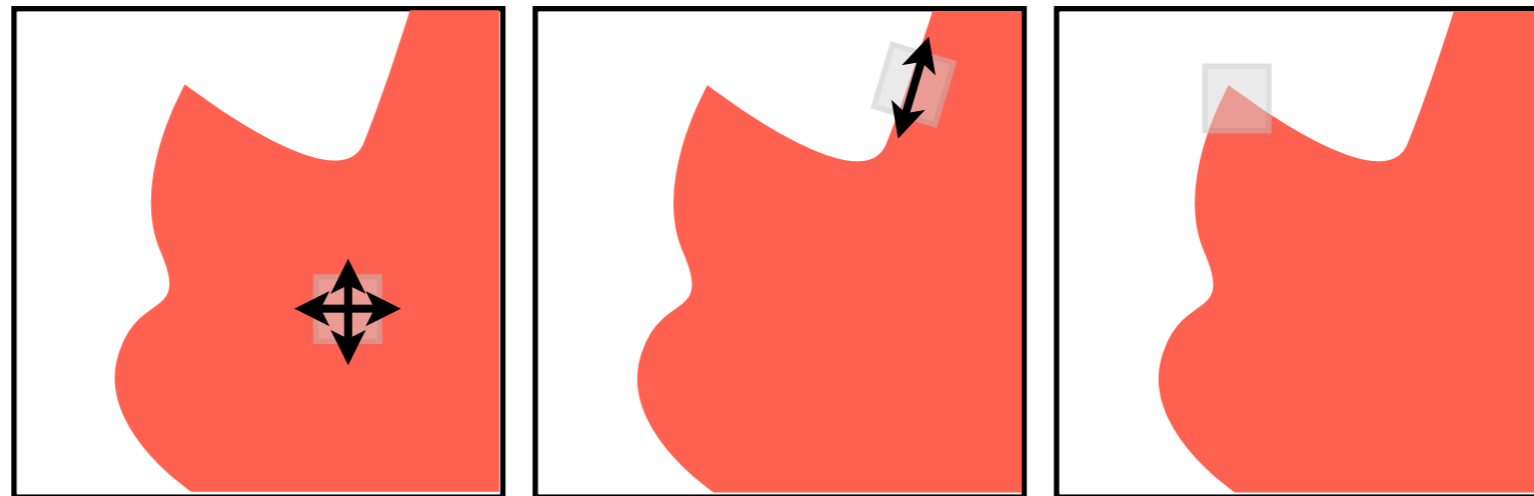**Flat areas**   **Edges**   **Corners**

CORNERNESS
HARRIS-STEPHENS CORNER

Hessian Matrix

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

Eigenvalues of **H**: α, β
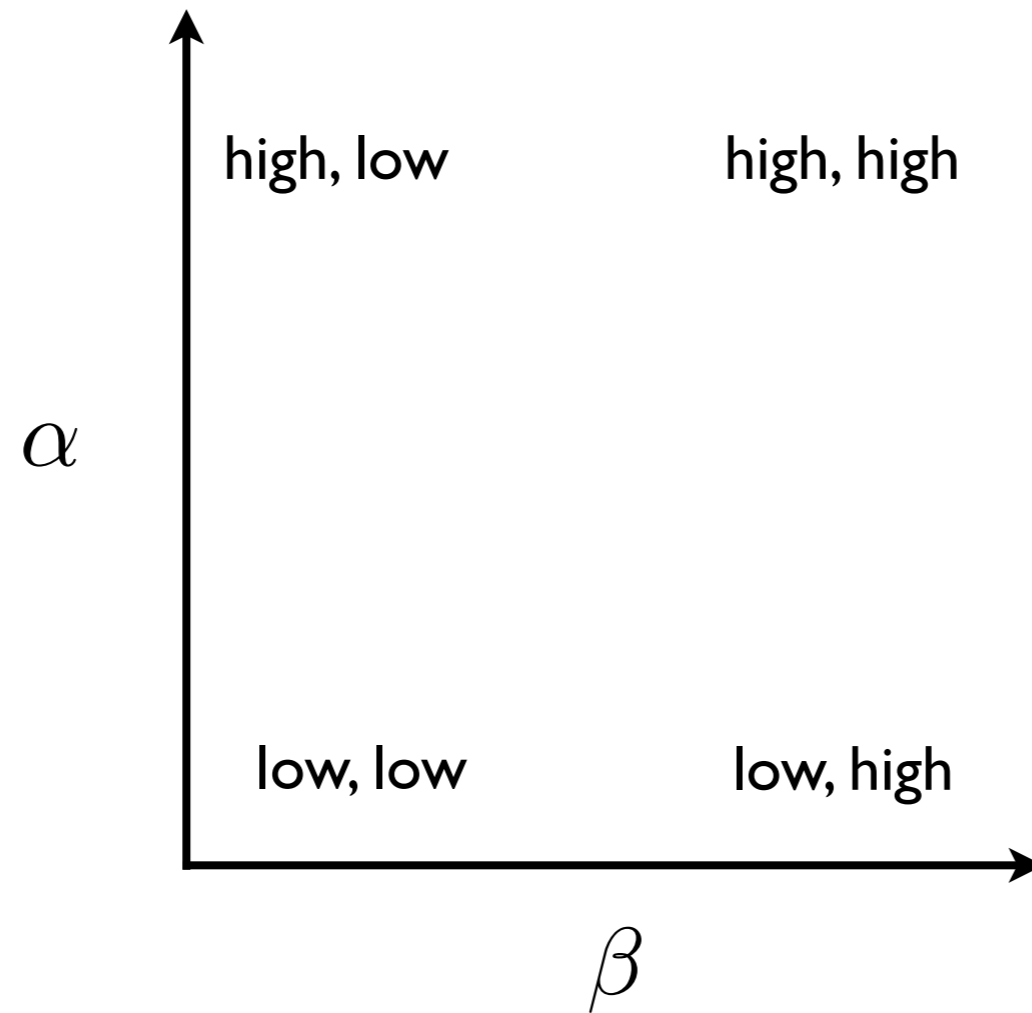

| two small eigenvalues | one large one small eigenvalues | two large eigenvalues |

SELECTING CORNERS

high, low   high, high

α

low, low   low, high

β

"A COMBINED CORNER AND EDGE DETECTOR"

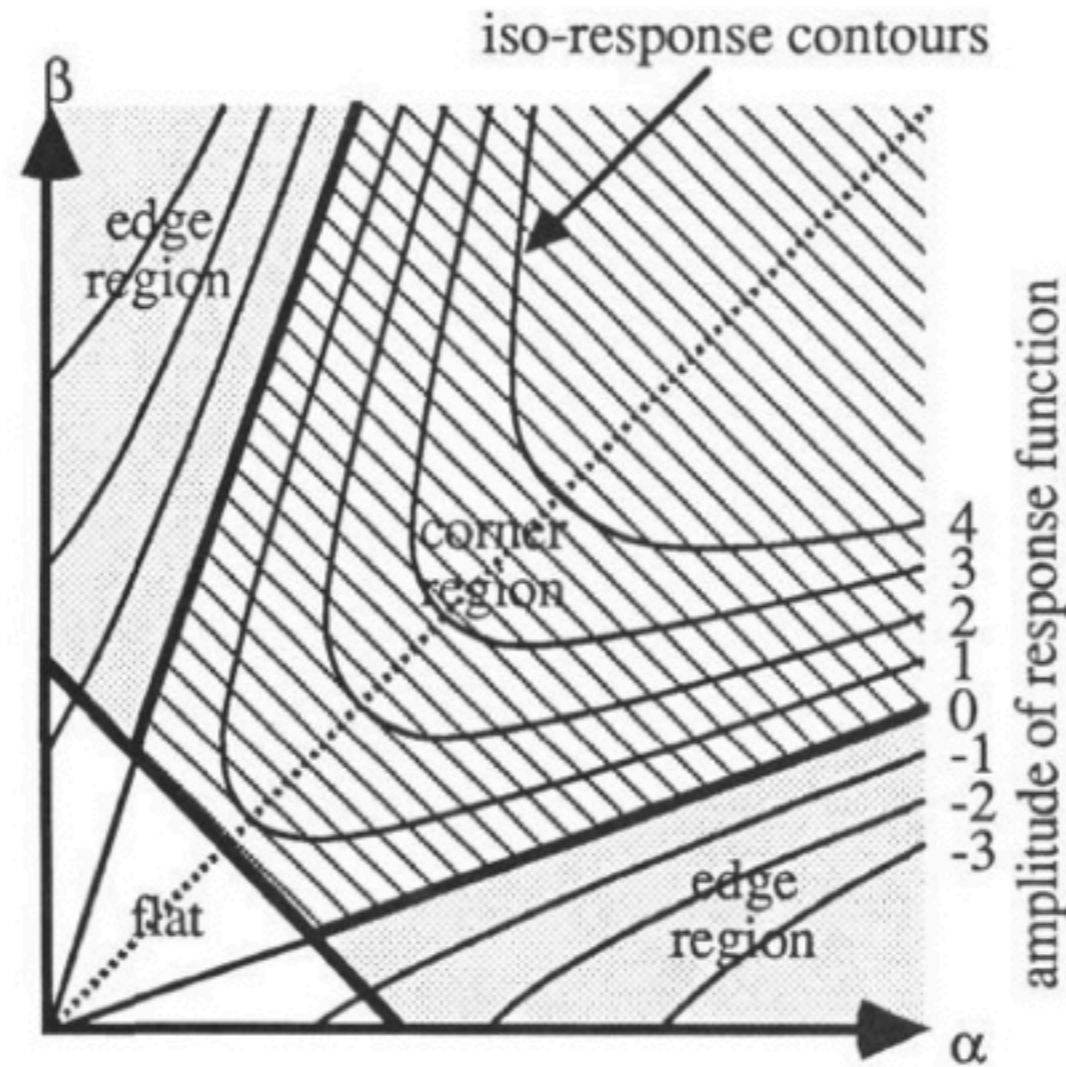
Figure 5. Auto-correlation principal curvature space-heavy lines give corner/edge/flat classification, fine lines are equi-response contours.
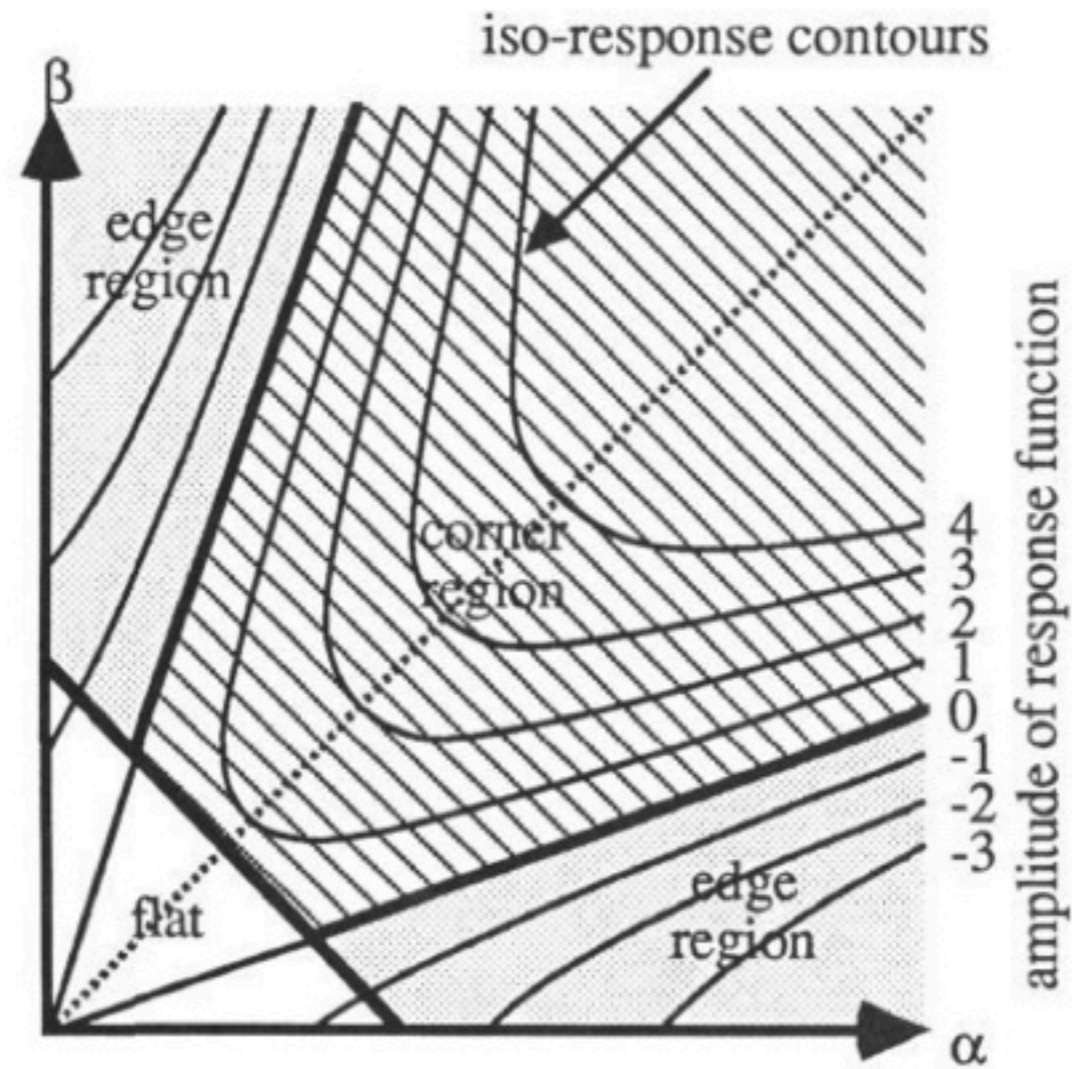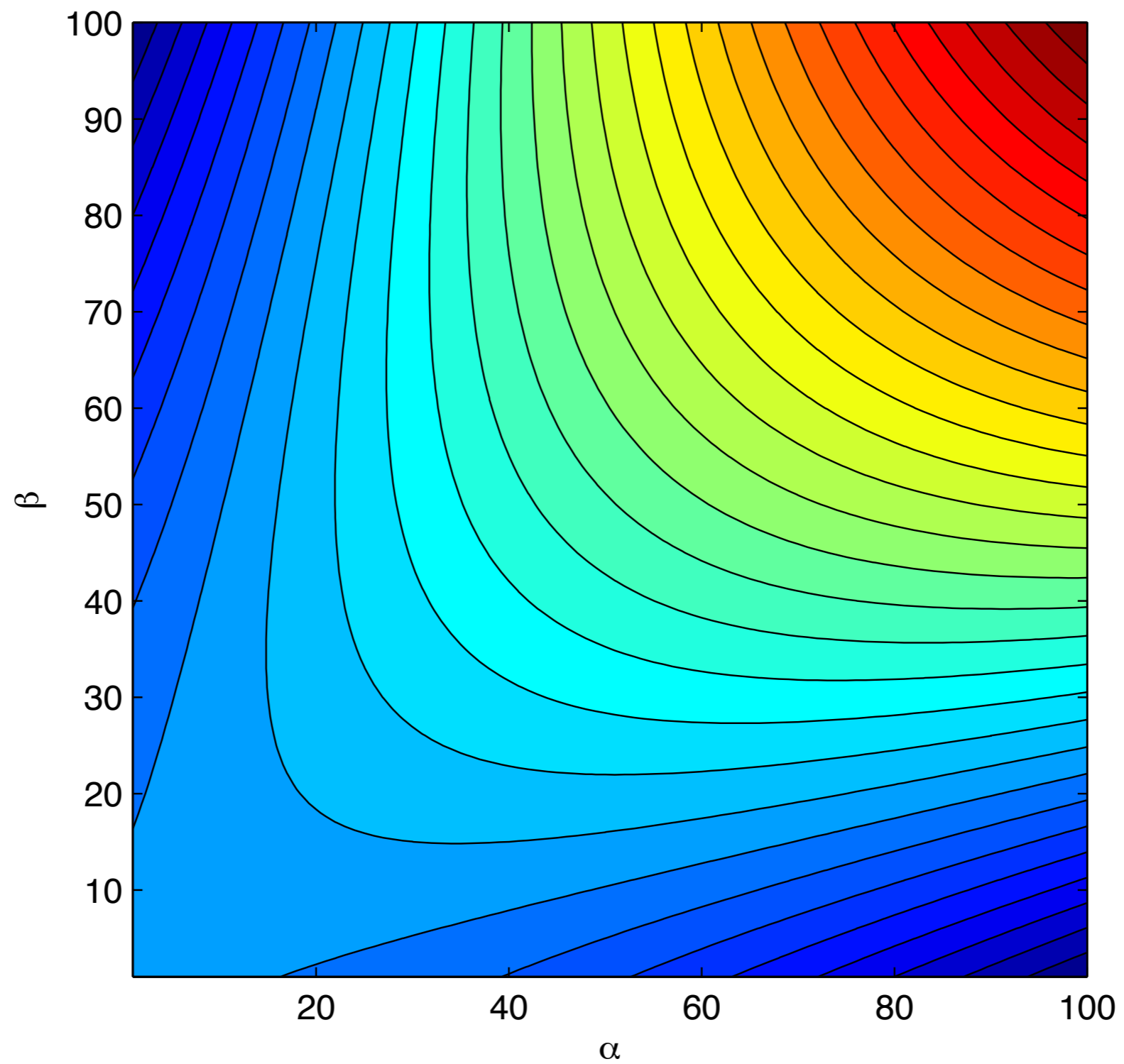
Figure 5. Auto-correlation principal curvature space-heavy lines give corner/edge/flat classification, fine lines are equi-response contours.

How do we get a response surface like that?

$$\alpha\beta - (\alpha + \beta)^2$$

CORNERNESS
HARRIS-STEPHENS CORNER

Hessian Matrix

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

Eigen values of **H**: α, β

$$\mathrm{Tr}(\mathbf{H}) = D_{xx} + D_{yy} = \alpha + \beta$$

$$\mathrm{Det}(\mathbf{H}) = D_{xx}D_{yy} - D_{xy}^2 = \alpha\beta$$

$$M_c = \alpha\beta - \kappa(\alpha + \beta)^2 = \det(\mathbf{H}) - \kappa\,\mathrm{trace}^2(\mathbf{H})$$

$$M_c > \mathrm{threshold}$$

$$\kappa = 0.04 \qquad\qquad \kappa = 0.15$$

HARRIS CORNERS

- ESTIMATE DIFFERENCE OF GAUSSIAN AT APPROPRIATE SCALE

- CONSTRUCT HESSIAN MATRIX FOR EACH PIXEL

- ESTIMATE M FOR EACH PIXEL

- CHOOSE LOCAL MAXIMA AS CORNERS

RECOGNITION:
IDENTIFICATION OF SOMETHING
PREVIOUSLY SEEN

BAG OF WORDS MODEL

Of all the sensory impressions proceeding to the brain, the visual experiences are the dominant ones. Our perception of the world around us is based essentially on the messages that reach the brain from our eyes. For a long time it was thought that the retinal image was transmitted point to point to visual centers in the brain; the cerebral cortex was a movie screen, so to speak, upon which the image in the eye was projected. Through the discoveries of Hubel and Wiesel we now know that behind the origin of the visual perception in the brain there is a considerably more complicated course of events. By following the visual impulses along their path to the various cell layers of the optical cortex, Hubel and Wiesel have been able to demonstrate that the *message about the image falling on the retina undergoes a step-wise analysis in a system of nerve cells stored in columns. In this system each cell has its specific function and is responsible for a specific detail in the pattern of the retinal image.*

sensory, brain, visual, perception, retinal, cerebral cortex, eye, cell, optical nerve, image Hubel, Wiesel

China is forecasting a trade surplus of $90bn (£51bn) to $100bn this year, a threefold increase on 2004's $32bn. The Commerce Ministry said the surplus would be created by a predicted 30% jump in exports to $750bn, compared with a 18% rise in imports to $660bn. The figures are likely to further annoy the US, which has long argued that China's exports are unfairly helped by a deliberately undervalued yuan. Beijing agrees the surplus is too high, but says the yuan is only one factor. Bank of China governor Zhou Xiaochuan said the country also needed to do more to boost domestic demand so more goods stayed within the country. China increased the value of the yuan against the dollar by 2.1% in July and permitted it to trade within a narrow band, but the US wants the yuan to be allowed to trade freely. However, Beijing has made it clear that it will take its time and tread carefully before allowing the yuan to rise further in value.

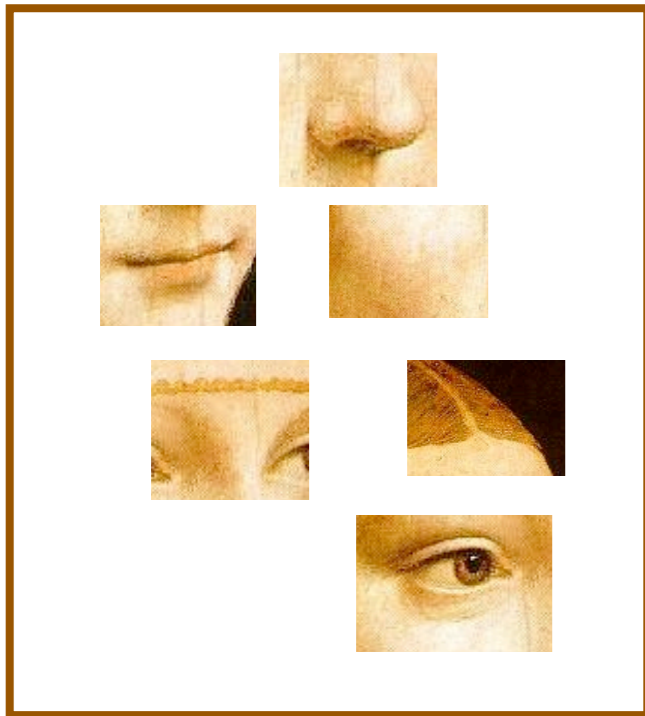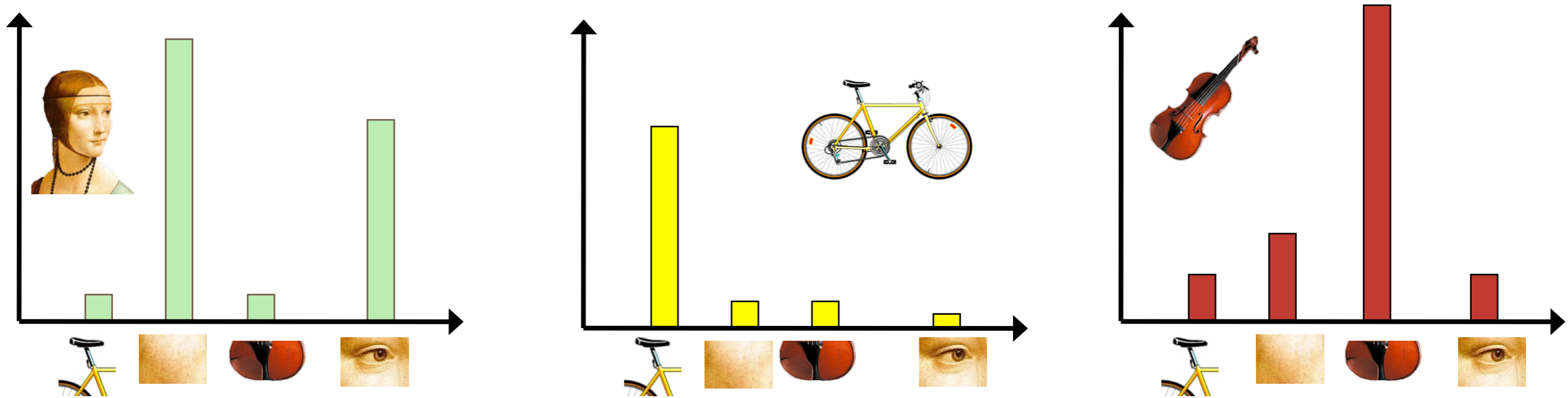**China, trade, surplus, commerce, exports, imports, US, yuan, bank, domestic, foreign, increase, trade, value**

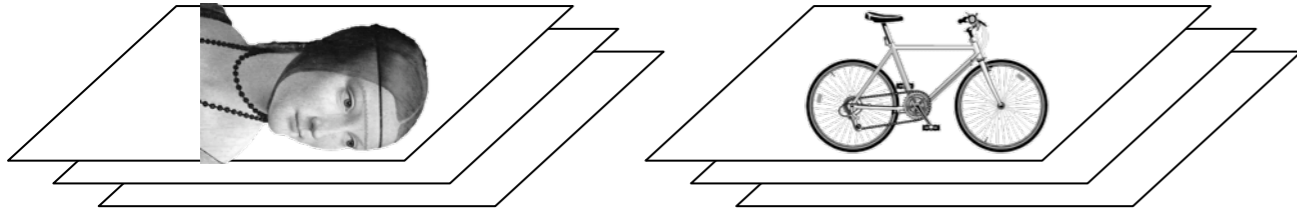**OBJECT**

BAG OF WORDS

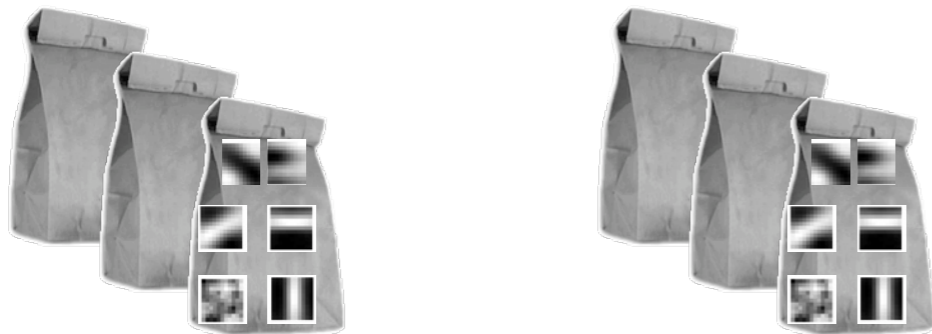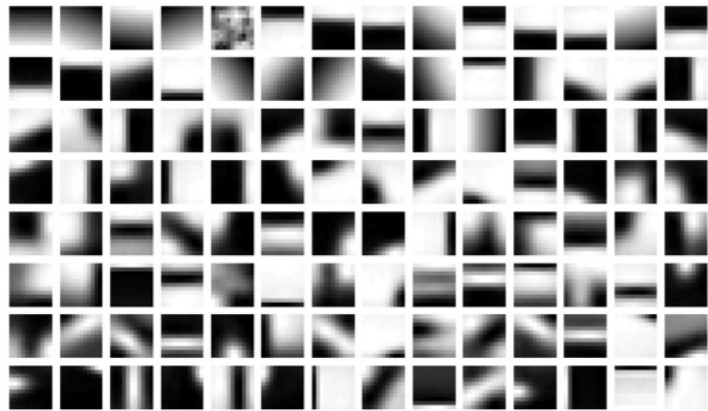# BoW: INDEPENDENT FEATURES

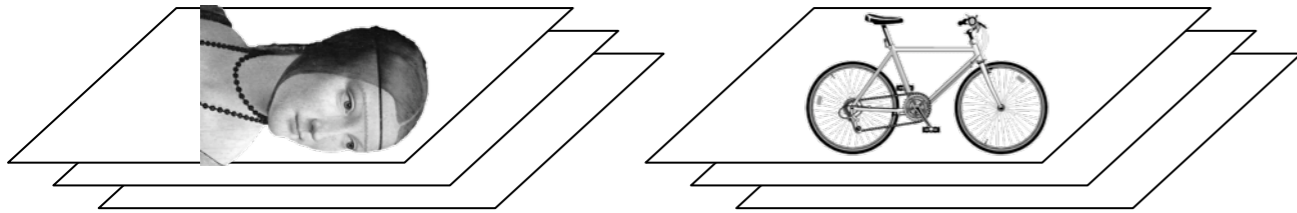- Independent features

HISTOGRAM OF FEATURES
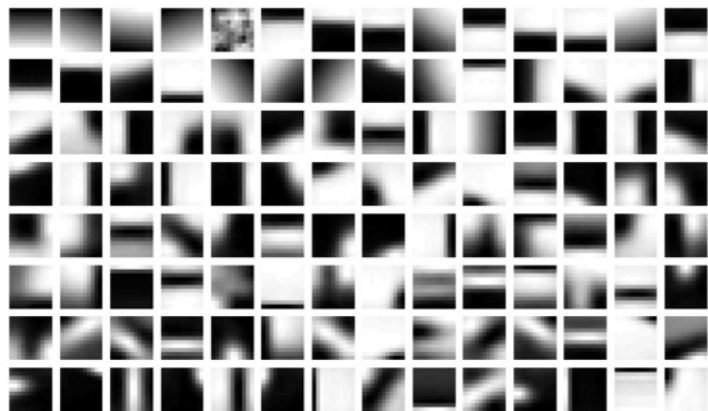
learning

codewords dictionary

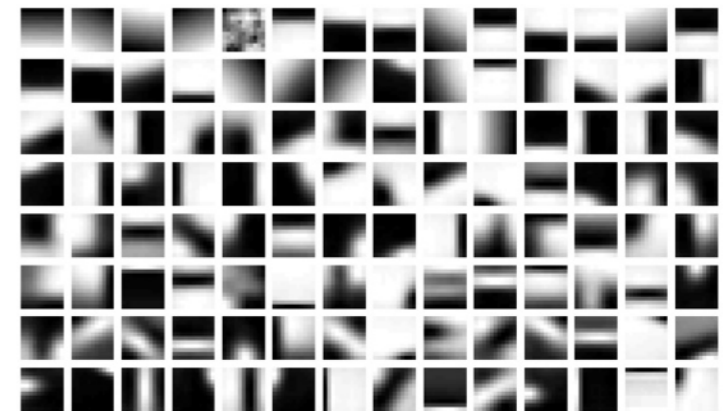corpus representation

learning

recognition

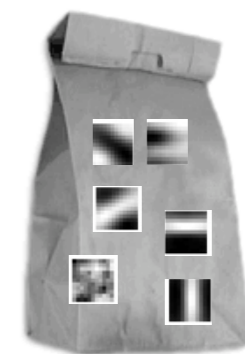## codewords dictionary

codewords dictionary
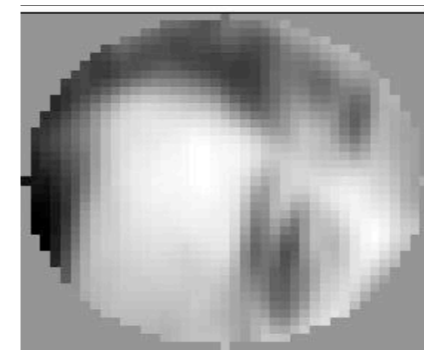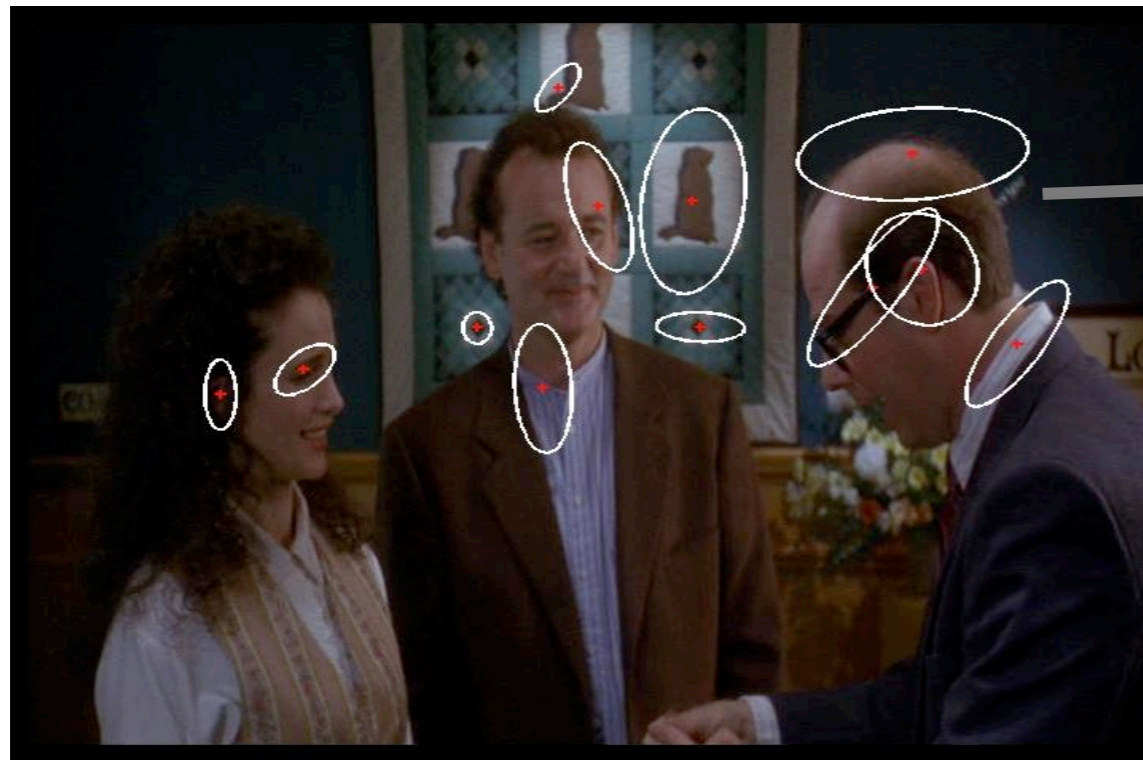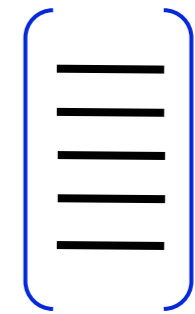
corpus representation

image representation

BUILDING A CODEBOOK
FEATURE DETECTION & REPRESENTATION

Normalize patch

Compute SIFT descriptor

Detect patches

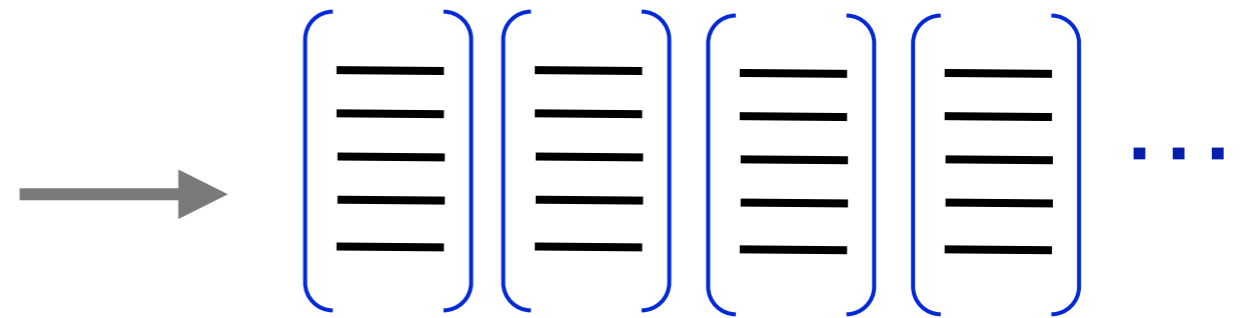[Mikojaczyk and Schmid '02]

[Mata, Chum, Urban & Pajdla, '02]

[Sivic & Zisserman, '03]

SIFT DESCRIPTOR
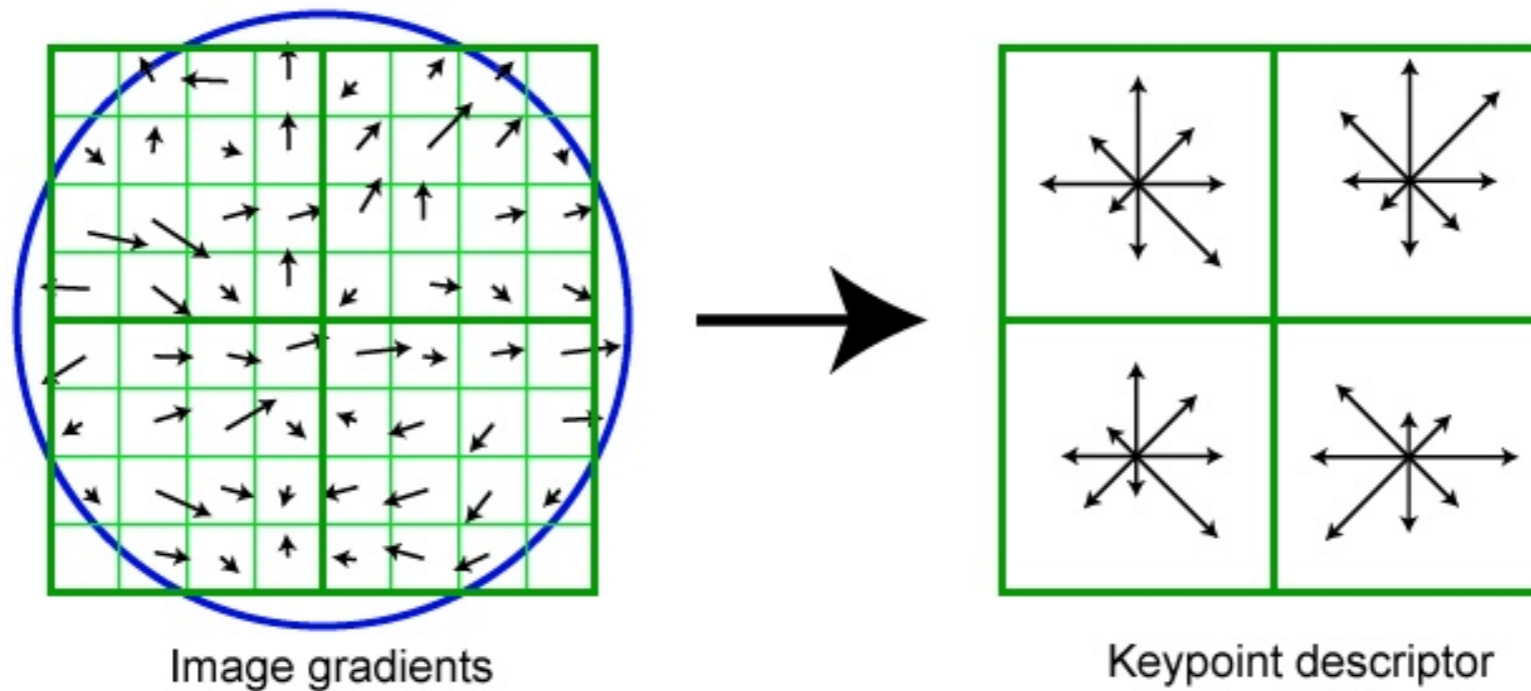
Image gradients

Keypoint descriptor

8x8

2x2

In practice: 16x16   4x4

(4 x 4) cells x 8 orientations = 128 length descriptor

SIFT
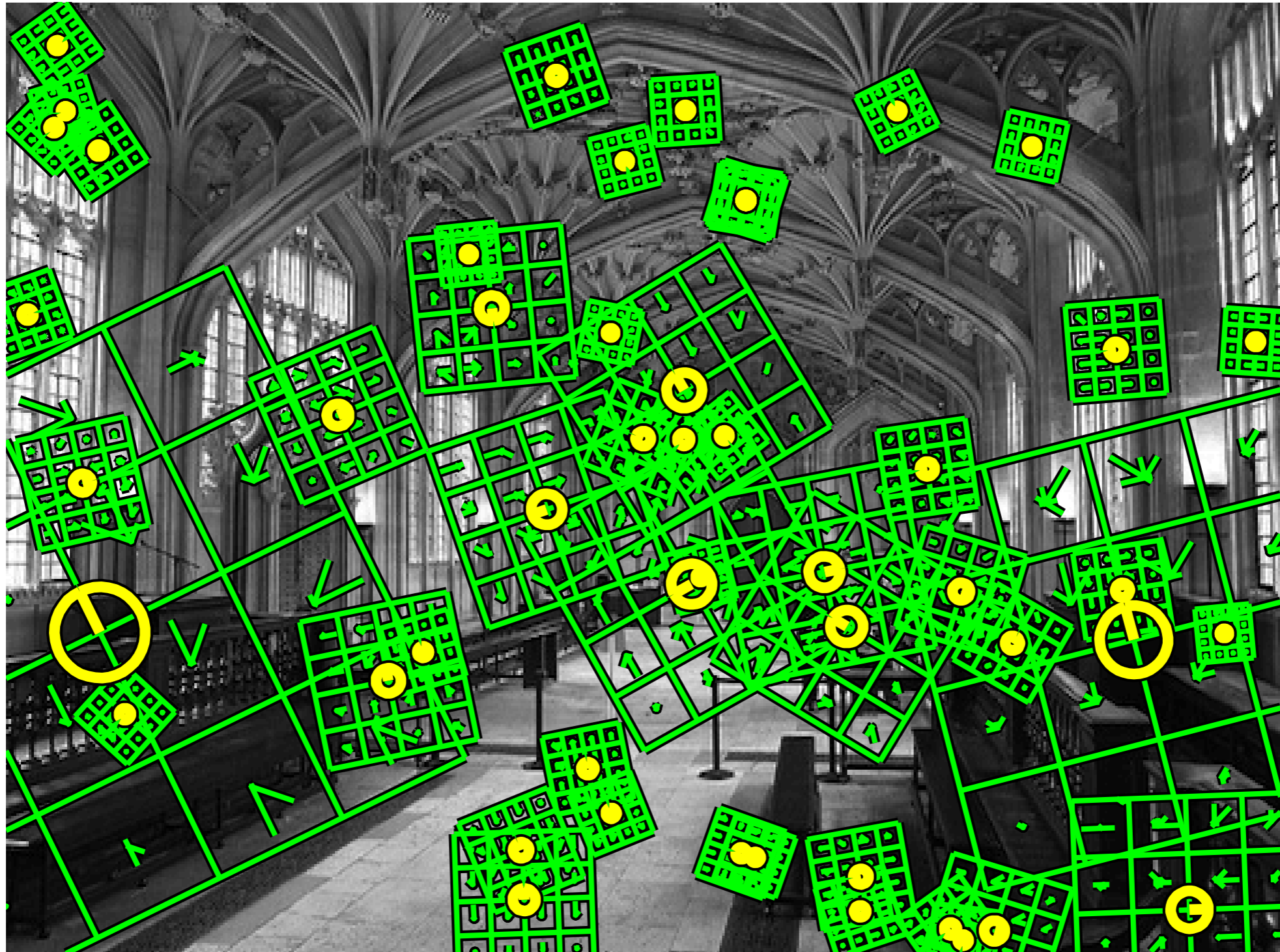
SIFT

BUILDING A CODEBOOK
FEATURE DETECTION & REPRESENTATION
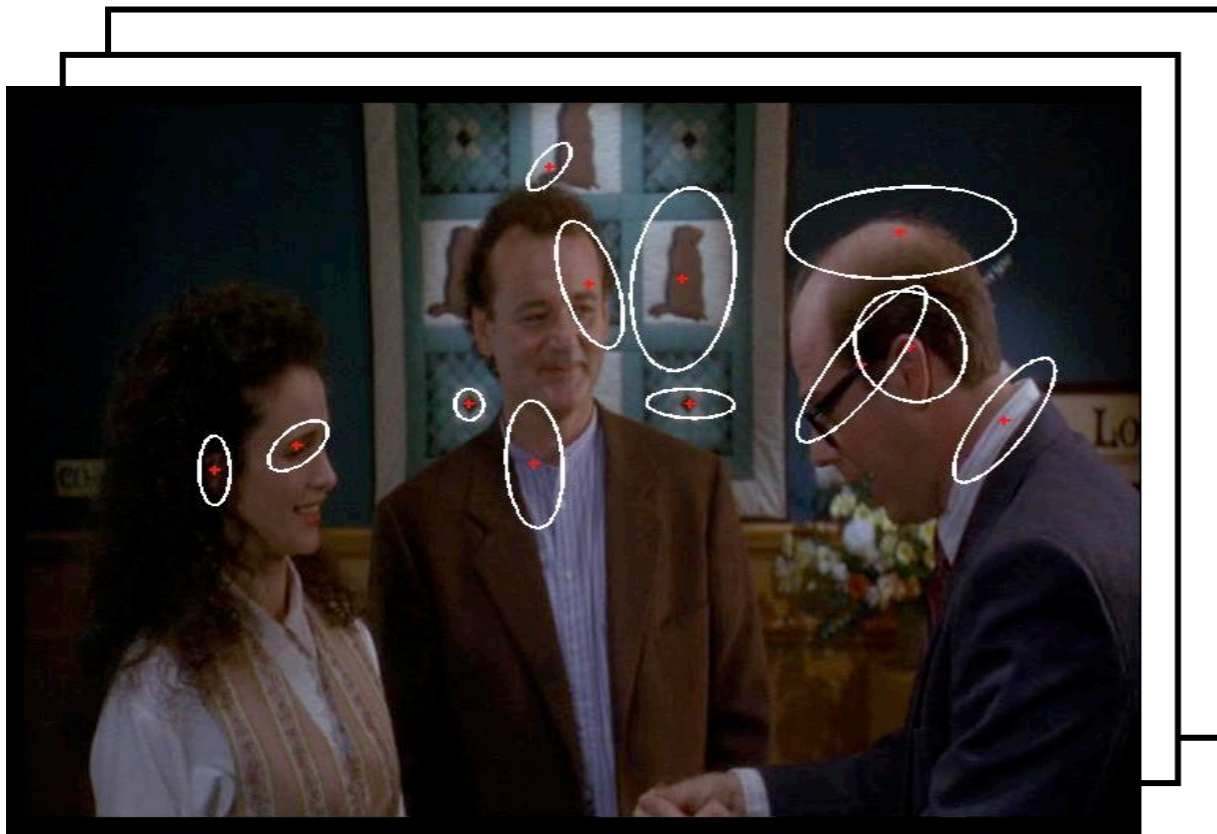
BUILDING A CODEBOOK
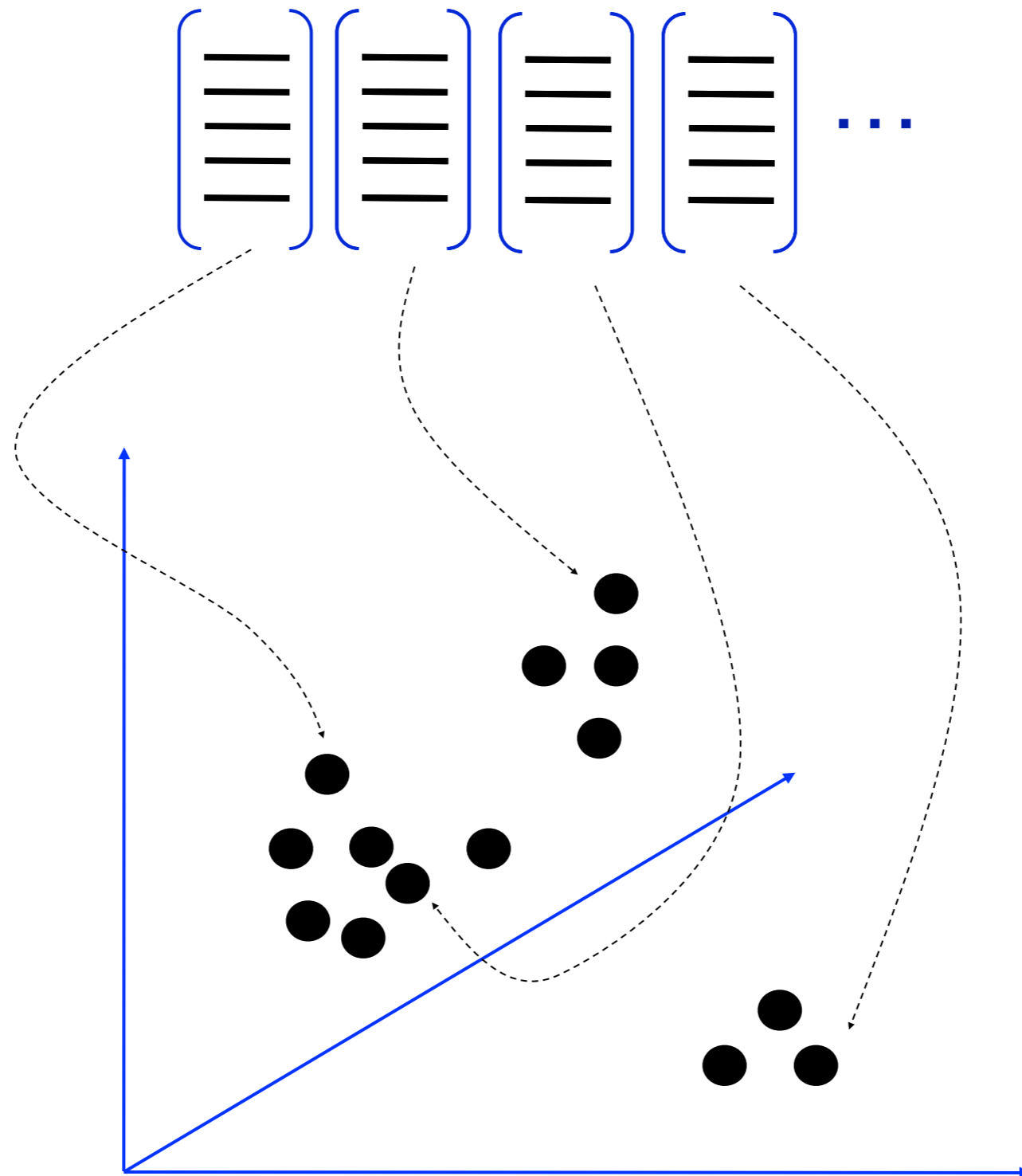
DICTIONARY FORMATION

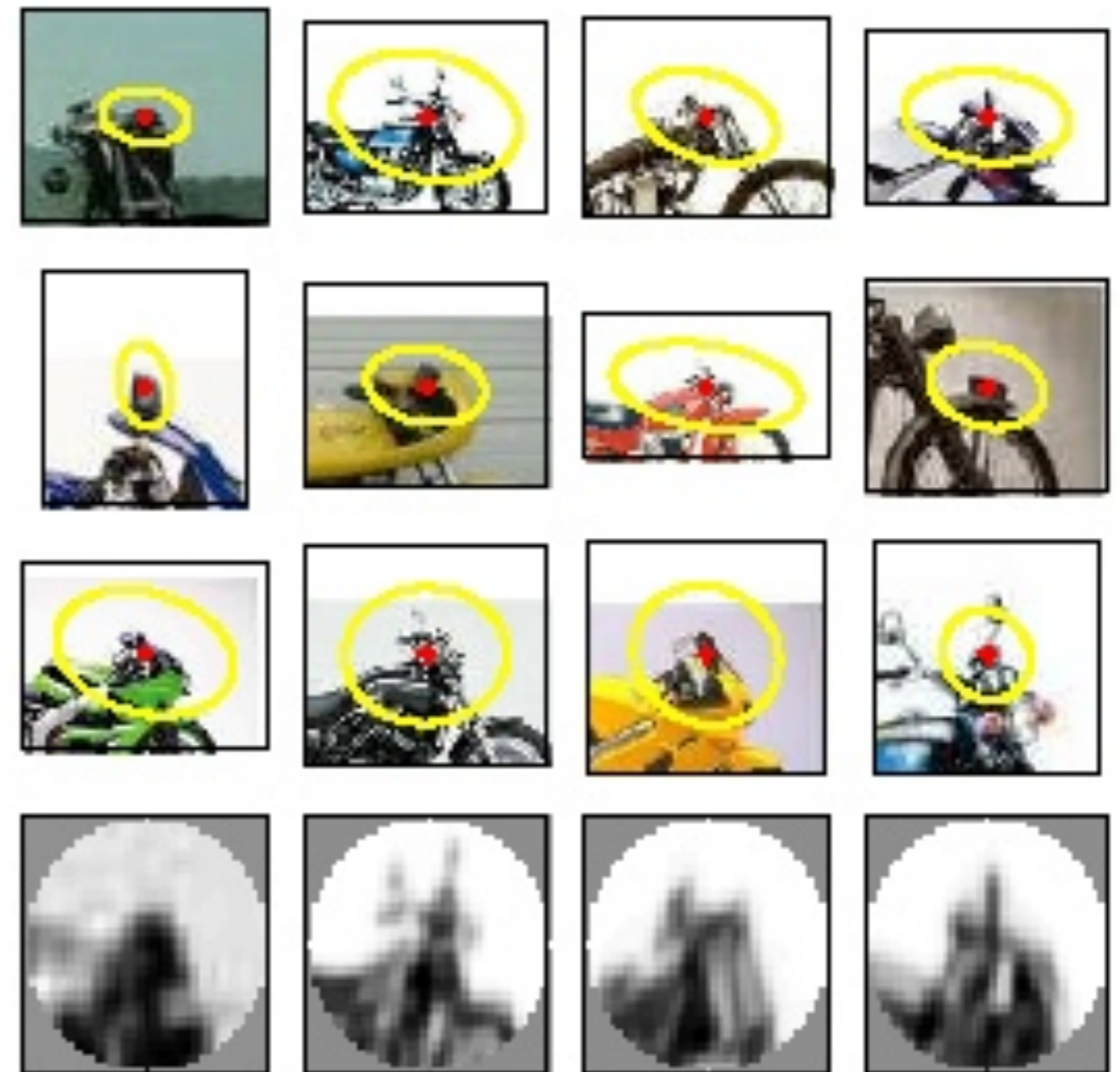# BUILDING A CODEBOOK
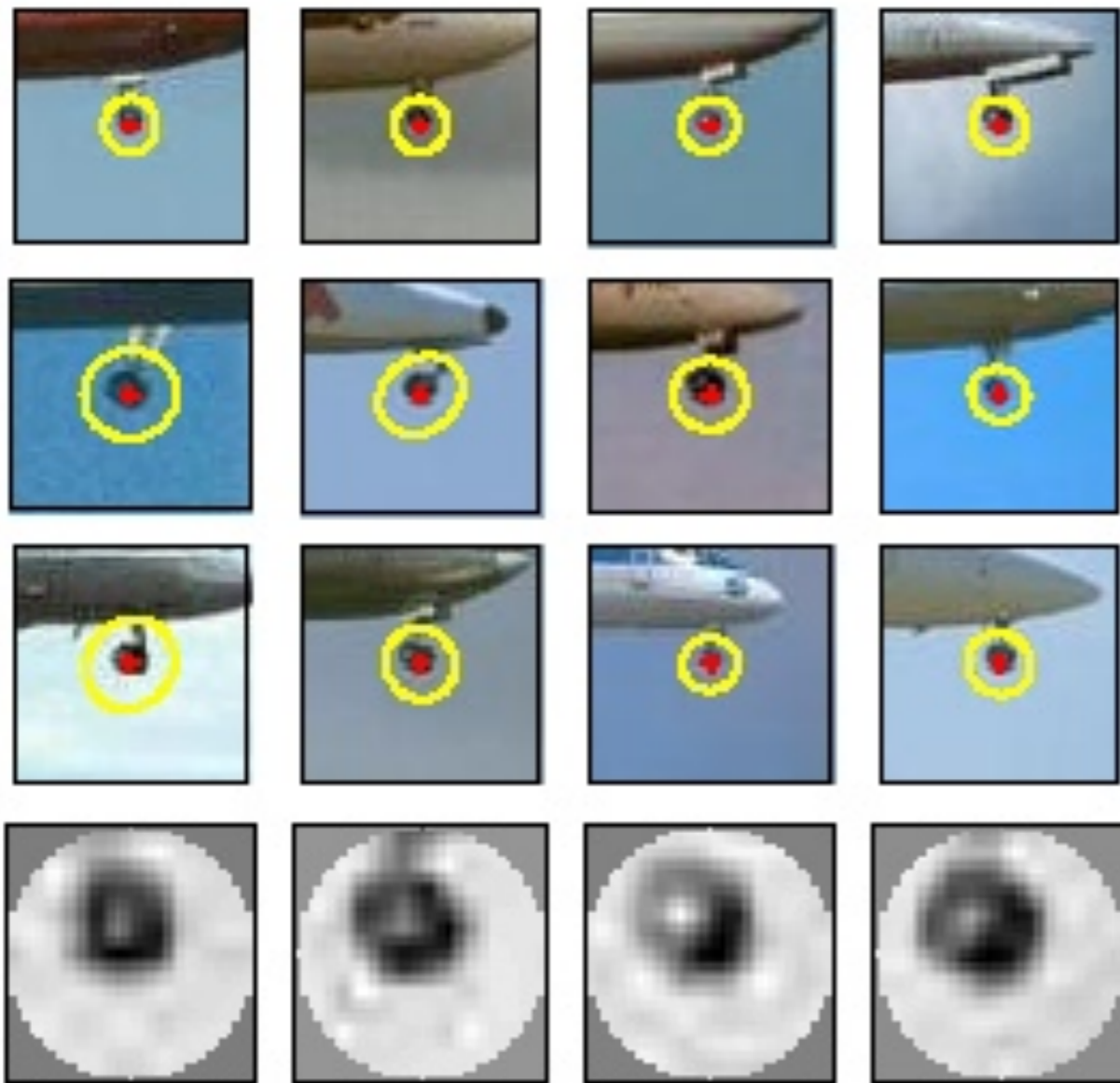
DICTIONARY FORMATION

Clustering
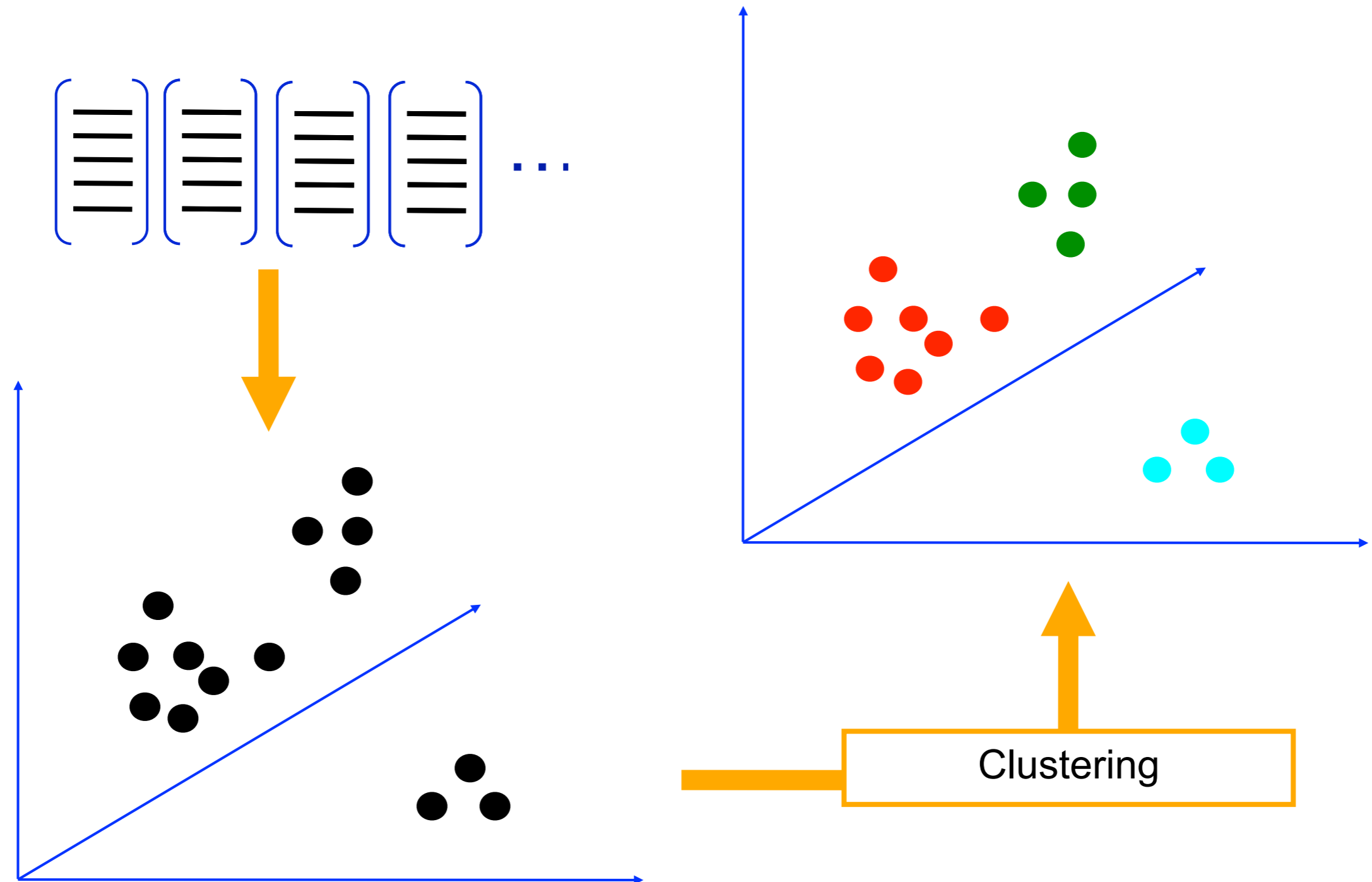
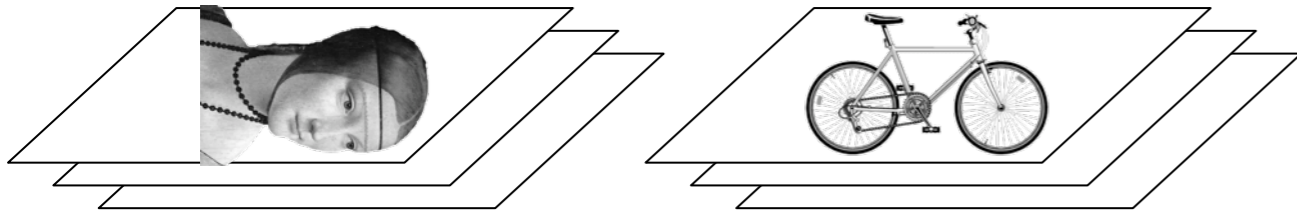# BUILDING A CODEBOOK
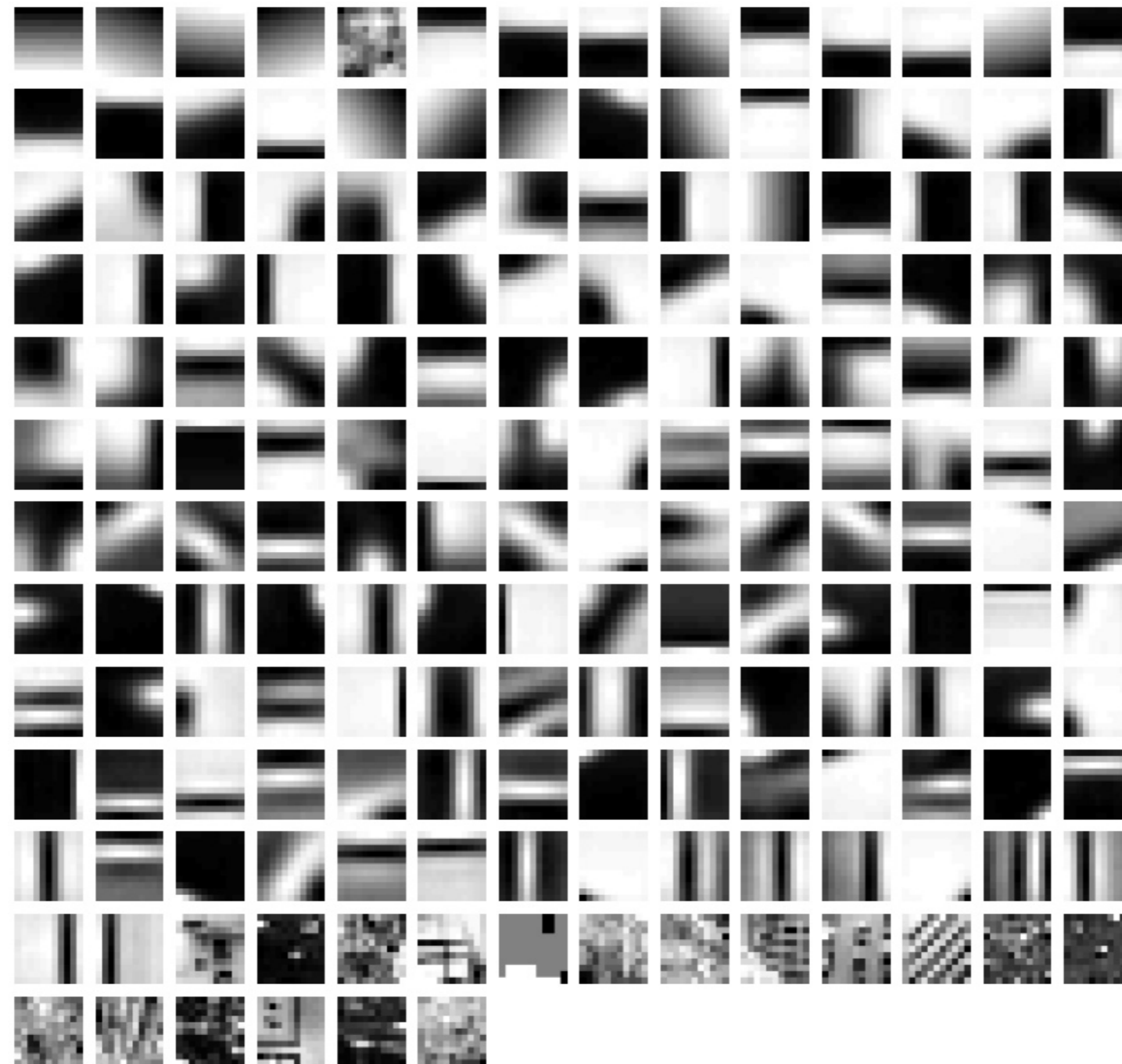
EXAMPLE CODEBOOK

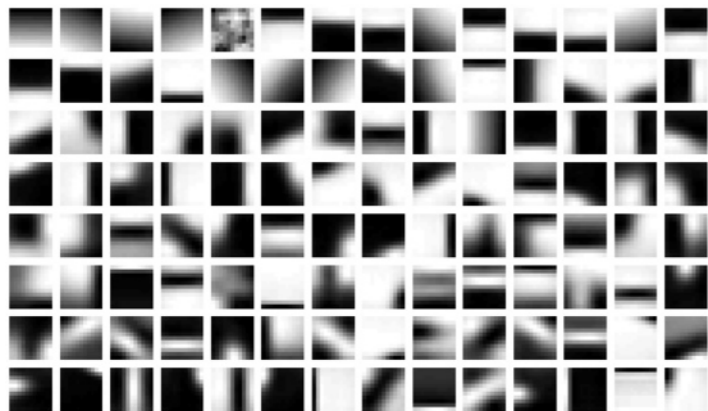# BUILDING A CODEBOOK
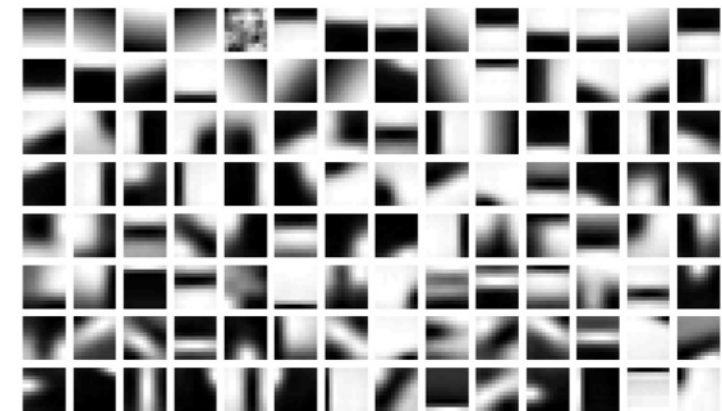
EXAMPLE CODEBOOK

learning

recognition

codewords dictionary

codewords dictionary

corpus representation

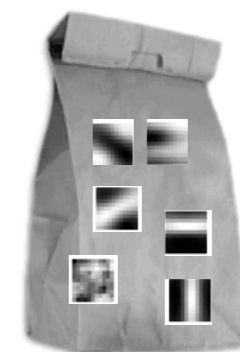image representation

IMAGE REPRESENTATION

CODEWORDS

codewords

CLASSIFICATION

unknown image

- NEURAL NETWORKS
- DECISION TREES
- K-MEANS
- NEAREST NEIGHBOR
- SUPPORT VECTOR MACHINES
  ...
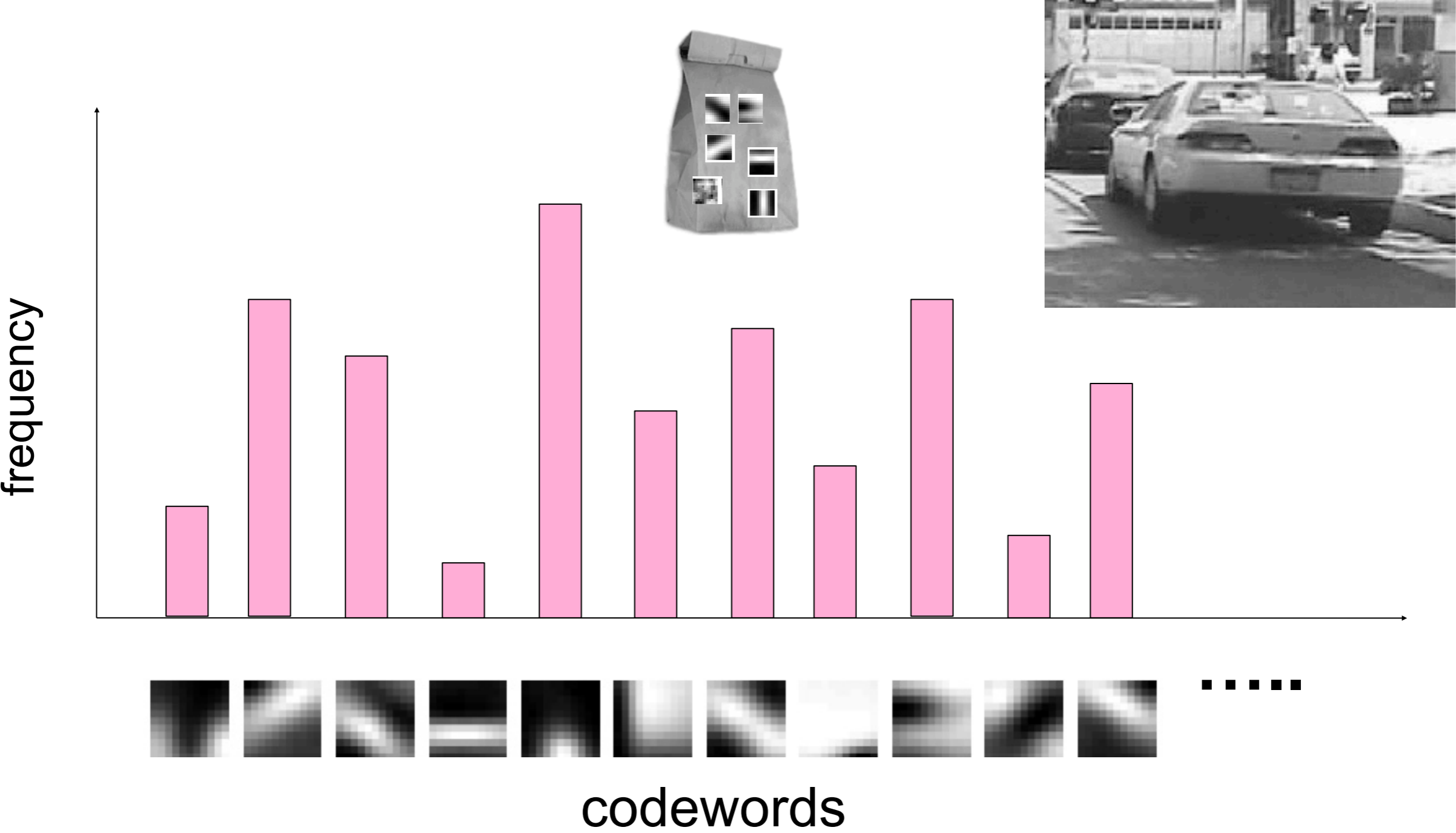
Lady with Ermine   Cycle   Sedan
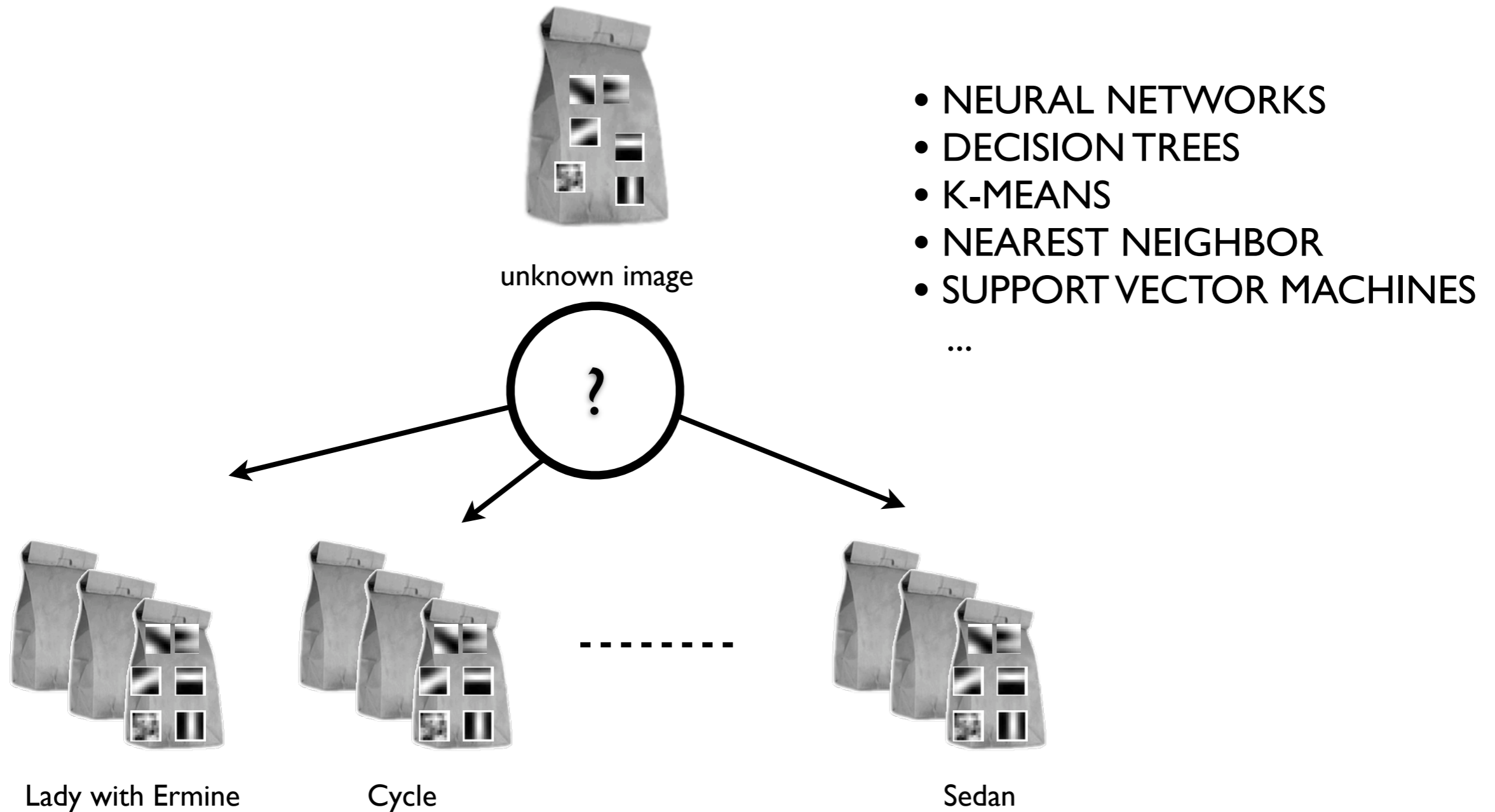
CODE

- SIFT implementation in MATLAB: http://www.vlfeat.org/

- Bag of words: http://people.csail.mit.edu/fergus/iccv2005/bagwords.html

- **Data**:

  - Image-net: http://www.image-net.org/