

Computer Science Department

University of Verona

A.A. 2015-16

Pattern Recognition

Feature extraction:

Bag of Words



Part 1: Bag-of-words models

by Li Fei-Fei (Princeton)

Related works

- Early “bag of words” models: mostly texture recognition
 - Cula & Dana, 2001; Leung & Malik 2001; Mori, Belongie & Malik, 2001; Schmid 2001; Varma & Zisserman, 2002, 2003; Lazebnik, Schmid & Ponce, 2003;
- Hierarchical Bayesian models for documents (pLSA, LDA, etc.)
 - Hoffman 1999; Blei, Ng & Jordan, 2004; Teh, Jordan, Beal & Blei, 2004
- Object categorization
 - Csurka, Bray, Dance & Fan, 2004; Sivic, Russell, Efros, Freeman & Zisserman, 2005; Sudderth, Torralba, Freeman & Willsky, 2005;
- Natural scene categorization
 - Vogel & Schiele, 2004; Fei-Fei & Perona, 2005; Bosch, Zisserman & Munoz, 2006

Object



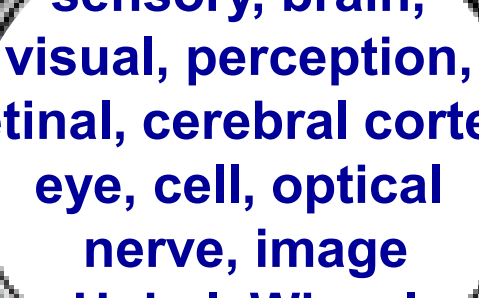
Bag of 'words'



Analogy to documents

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

For a large image centered in the movie image, discovery of known perceptual features is more complex following the Hubel demonstration that *image-wise analysis of stored images has its own specific image*.



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

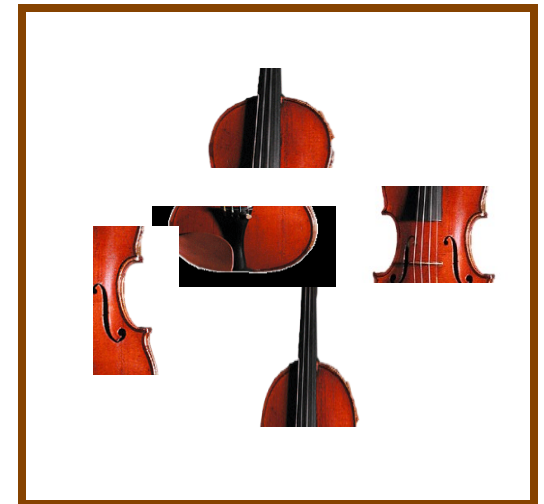
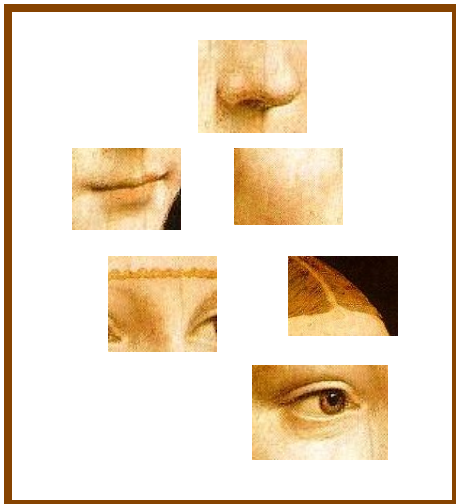
China is forecasting a trade surplus of \$90bn (£51bn) to \$100bn this year, a threefold increase on 2004's \$32bn. The Commerce Ministry said the surplus would be created by

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it will t
allowin

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

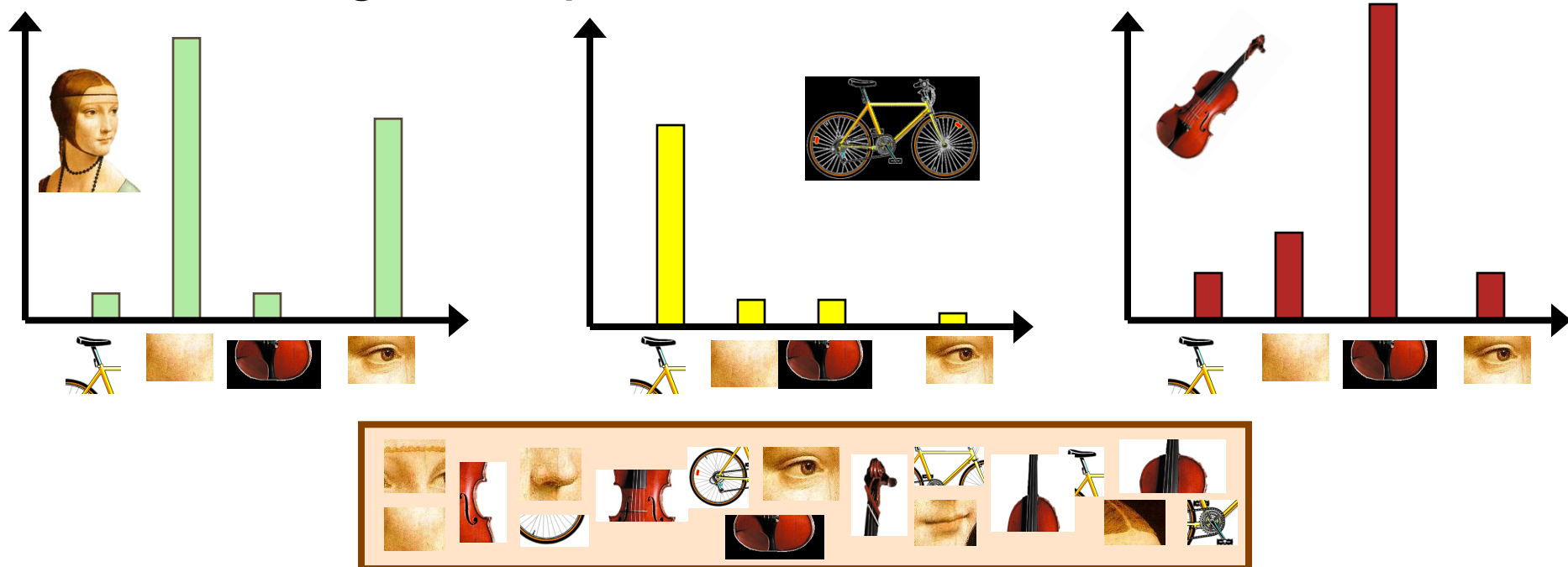
A clarification: definition of “BoW”

- Looser definition
 - Independent features

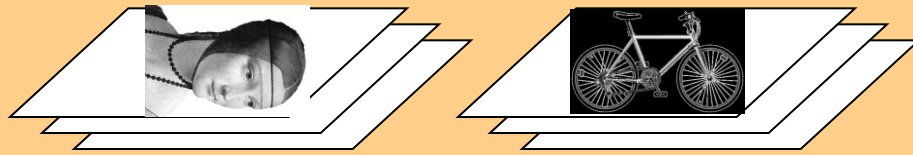


A clarification: definition of “BoW”

- Looser definition
 - Independent features
- Stricter definition
 - Independent features
 - histogram representation



learning



feature detection
& representation

codewords dictionary

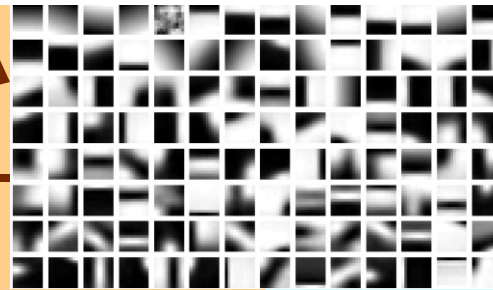
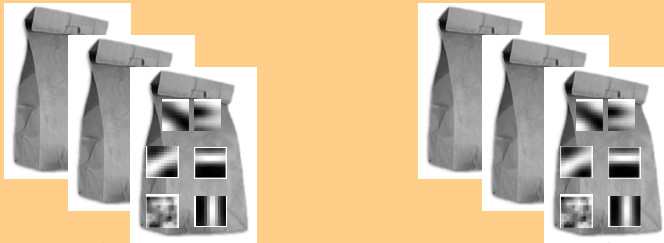
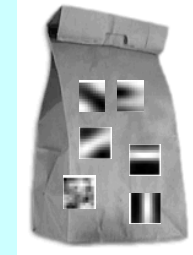
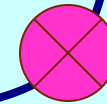


image representation



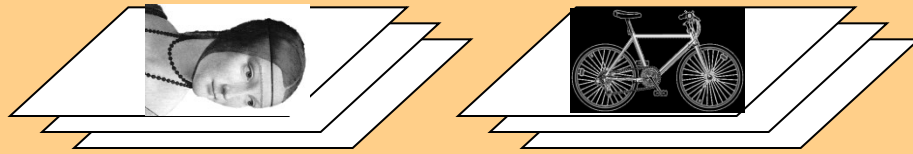
**category models
(and/or) classifiers**

recognition

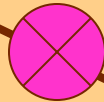


**category
decision**

Representation



1. feature detection
& representation



2. **codewords dictionary**

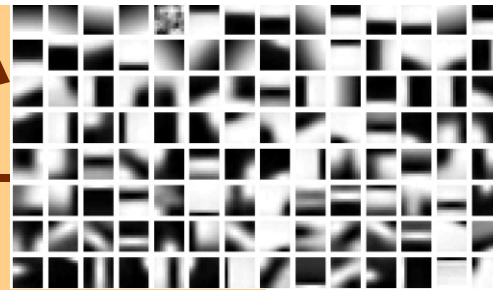
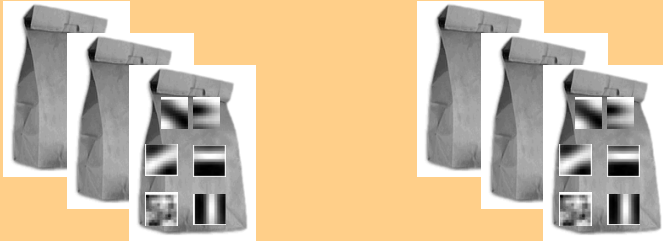
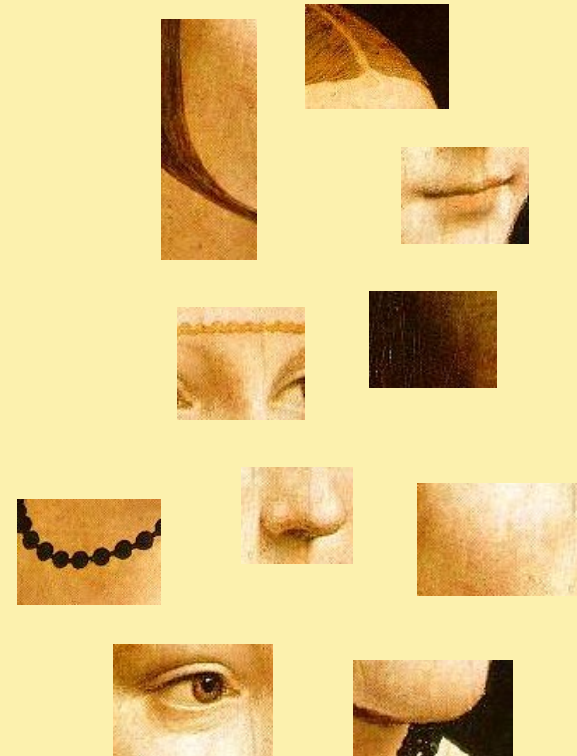


image representation

3.

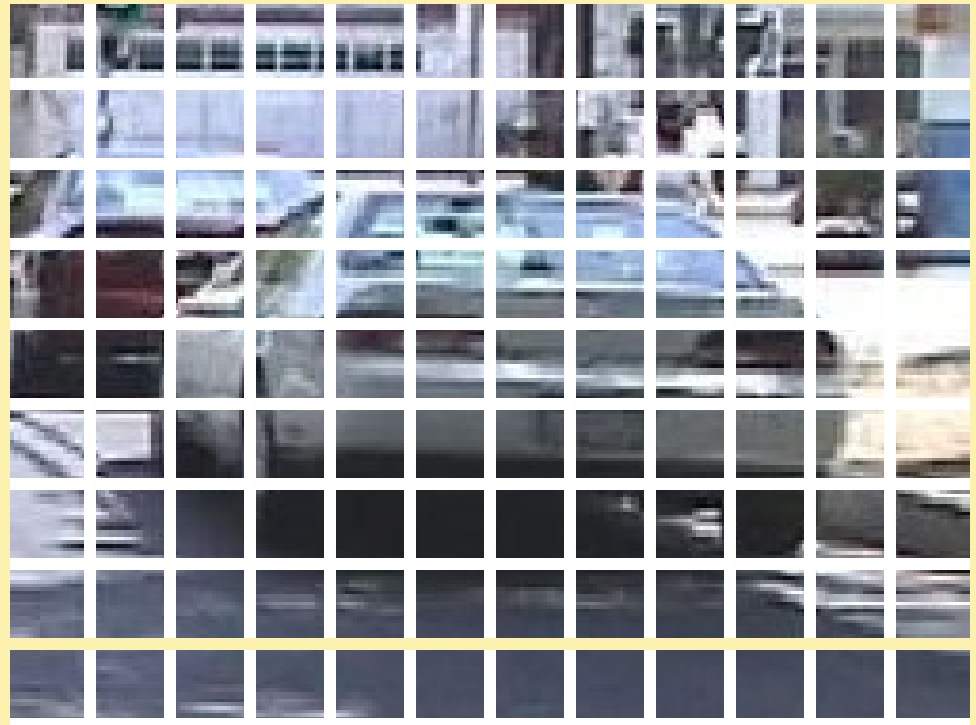


1.Feature detection and representation



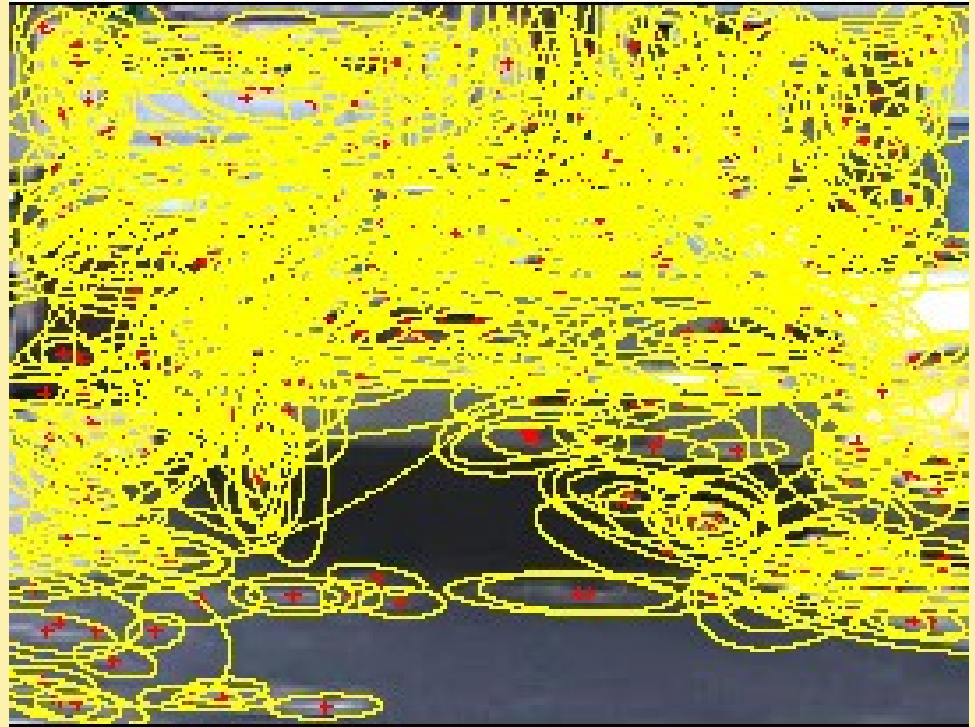
1.Feature detection and representation

- Regular grid
 - Vogel & Schiele, 2003
 - Fei-Fei & Perona, 2005



1. Feature detection and representation

- Regular grid
 - Vogel & Schiele, 2003
 - Fei-Fei & Perona, 2005
- Interest point detector
 - Csurka, et al. 2004
 - Fei-Fei & Perona, 2005
 - Sivic, et al. 2005

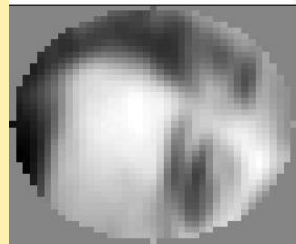


1.Feature detection and representation

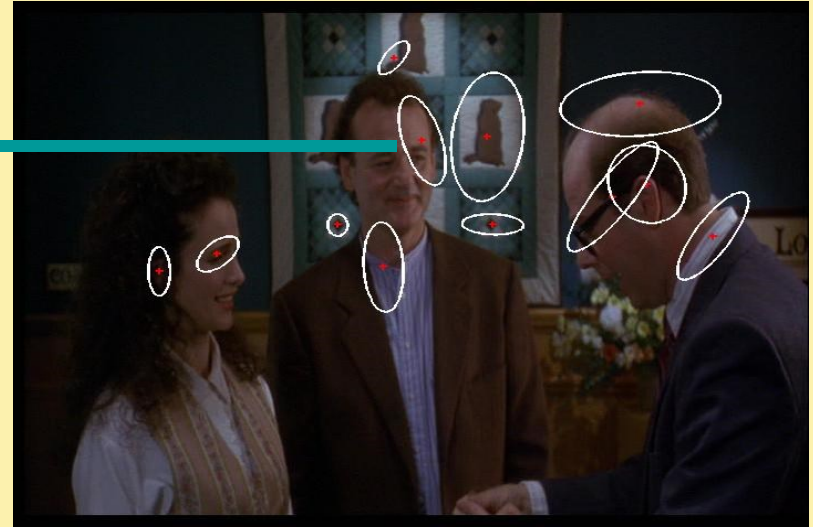
- Regular grid
 - Vogel & Schiele, 2003
 - Fei-Fei & Perona, 2005
- Interest point detector
 - Csurka, Bray, Dance & Fan, 2004
 - Fei-Fei & Perona, 2005
 - Sivic, Russell, Efros, Freeman & Zisserman, 2005
- Other methods
 - Random sampling (Vidal-Naquet & Ullman, 2002)
 - Segmentation based patches (Barnard, Duygulu, Forsyth, de Freitas, Blei, Jordan, 2003)

1. Feature detection and representation


**Compute
SIFT
descriptor**
[Lowe'99]



**Normalize
patch**



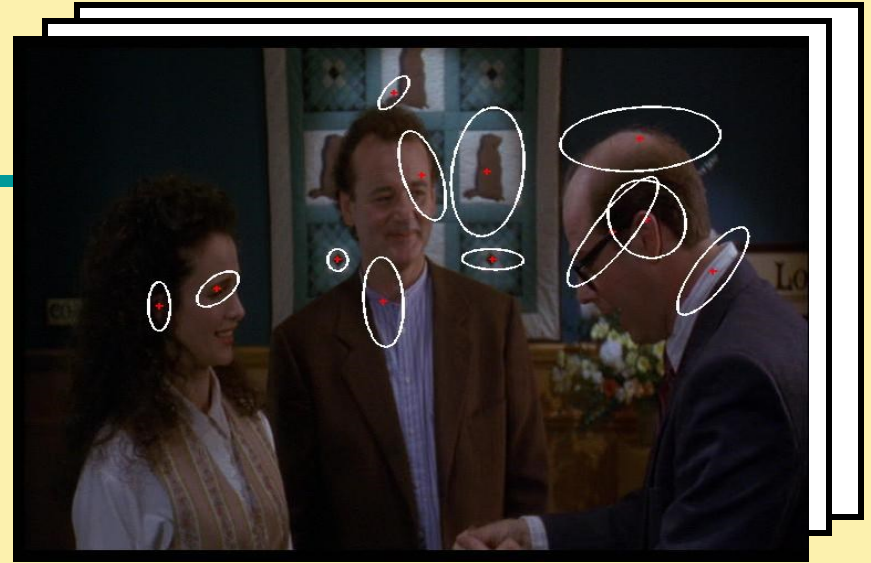
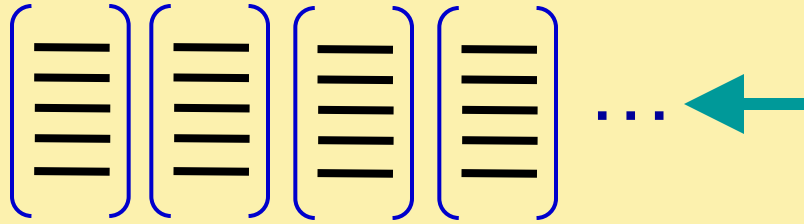
Detect patches

[Mikojaczyk and Schmid '02]

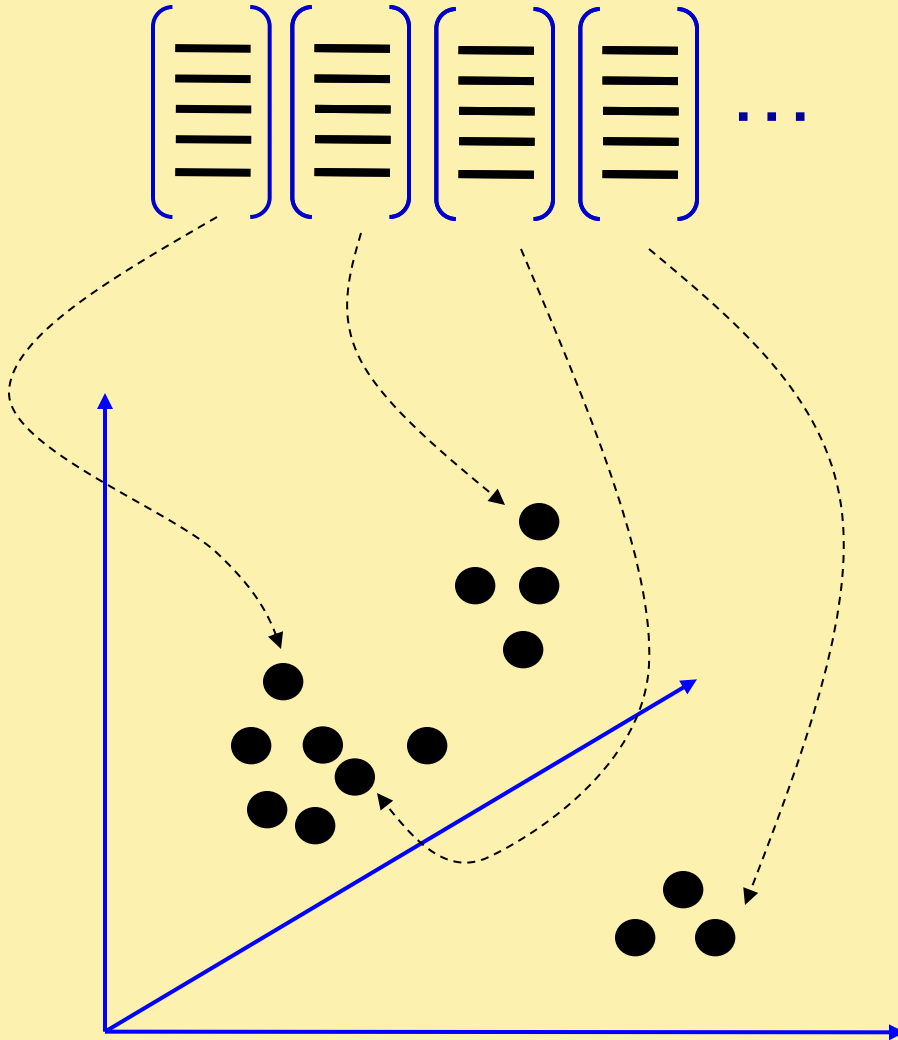
[Mata, Chum, Urban & Pajdla, '02]

[Sivic & Zisserman, '03]

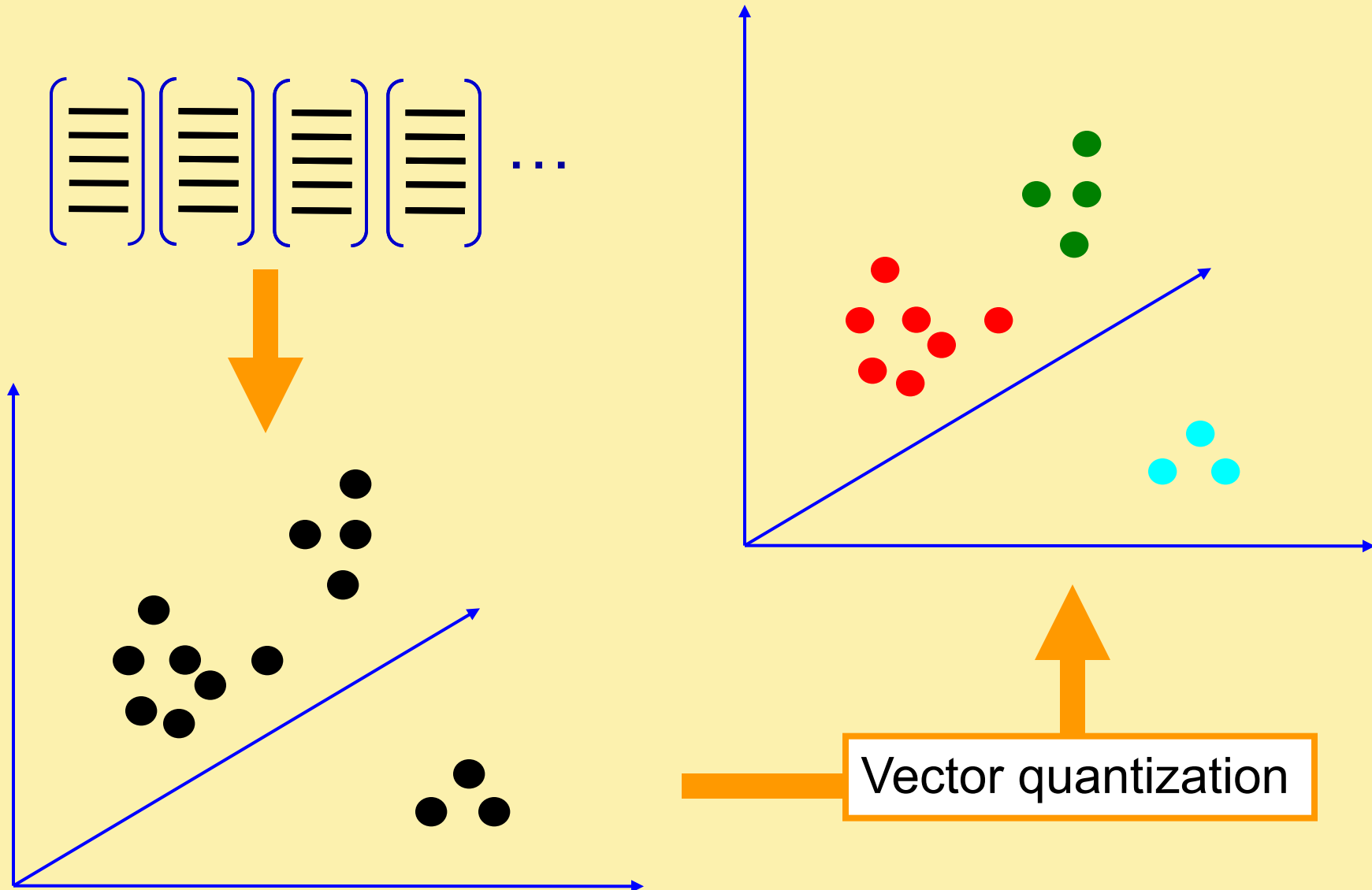
1. Feature detection and representation



2. Codewords dictionary formation



2. Codewords dictionary formation



2. Codewords dictionary formation

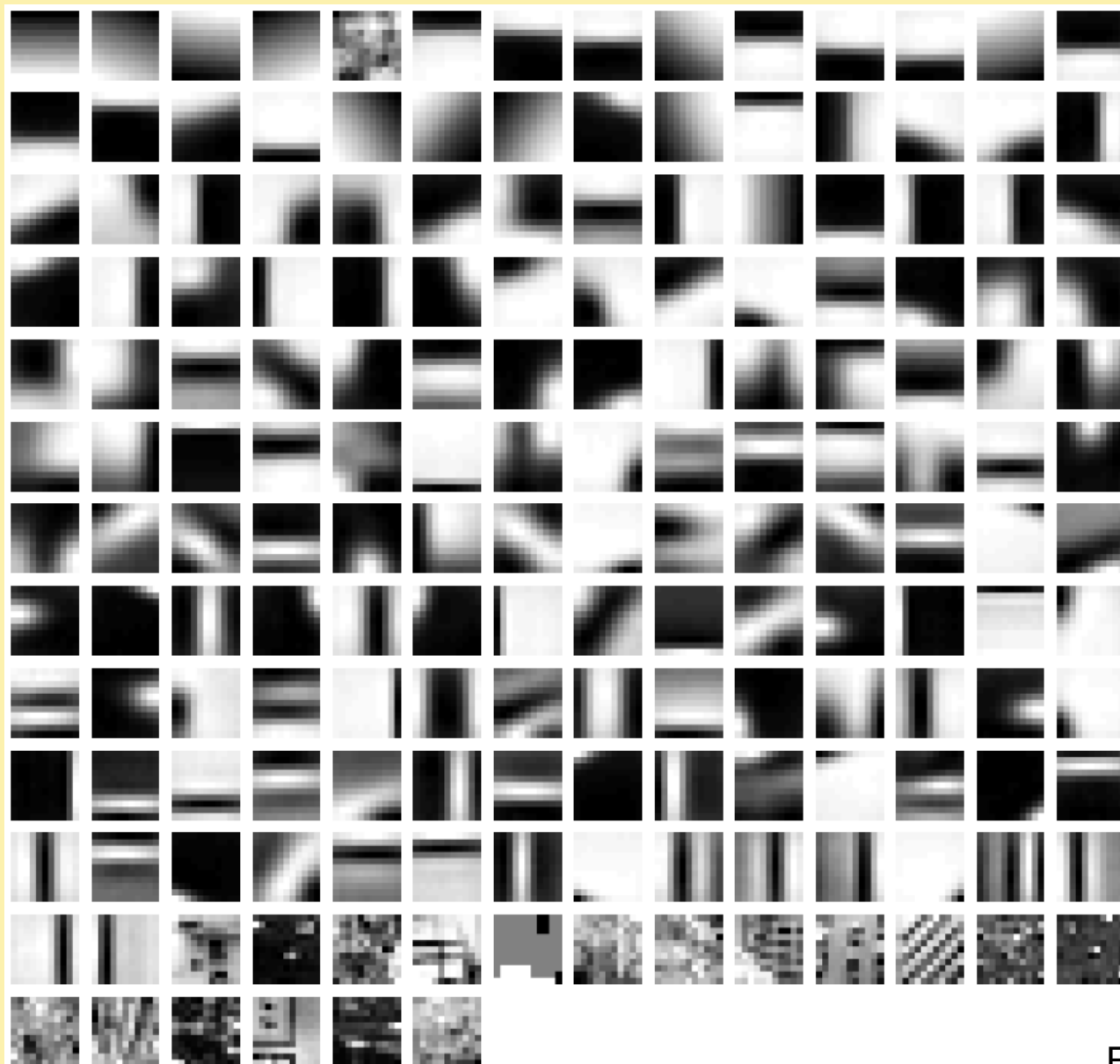
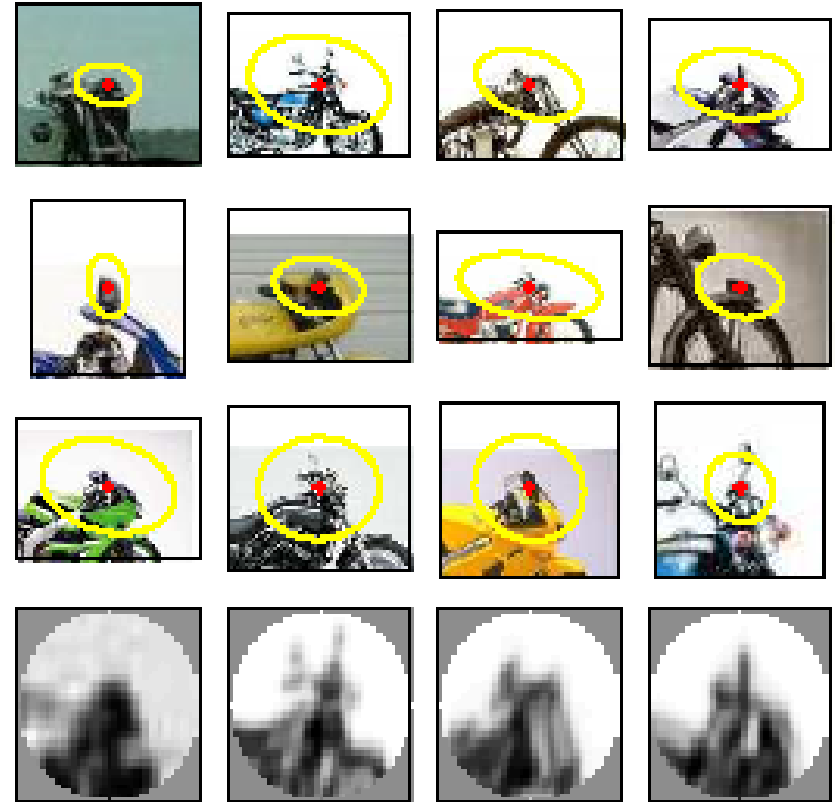
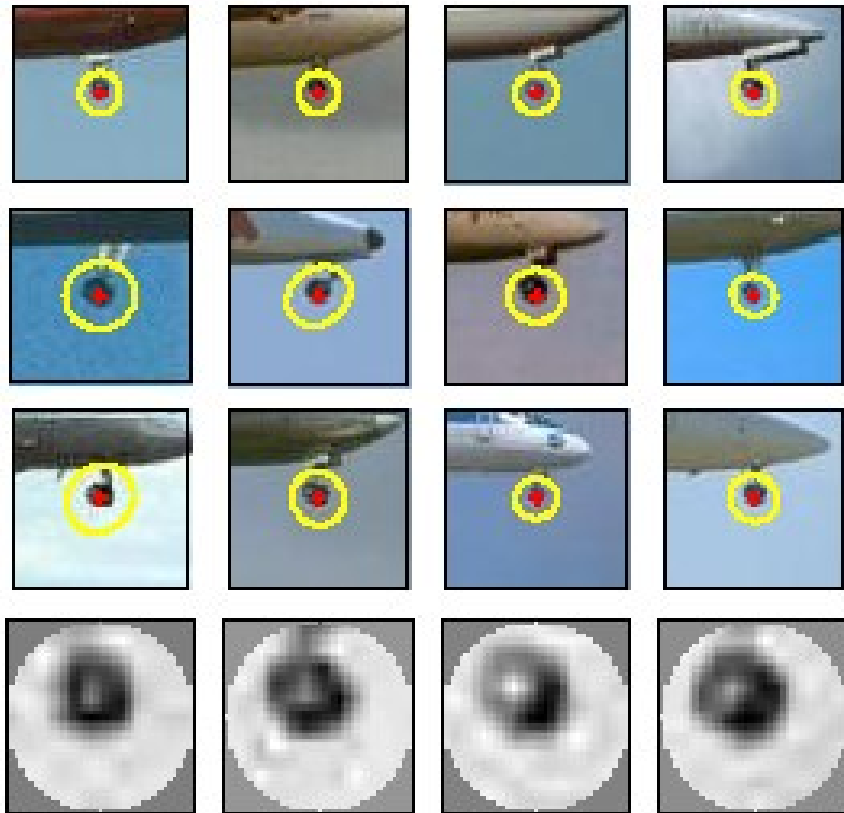


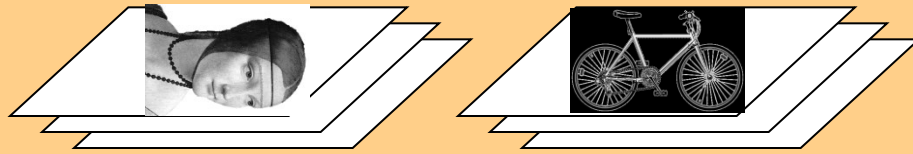
Image patch examples of codewords



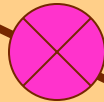
3. Image representation



Representation



1. feature detection
& representation



2. **codewords dictionary**

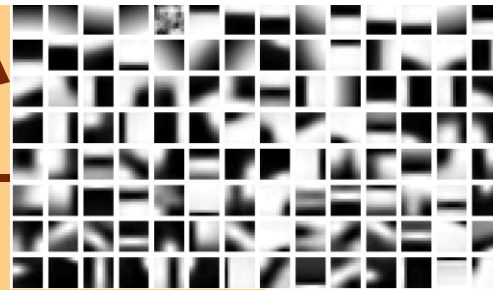
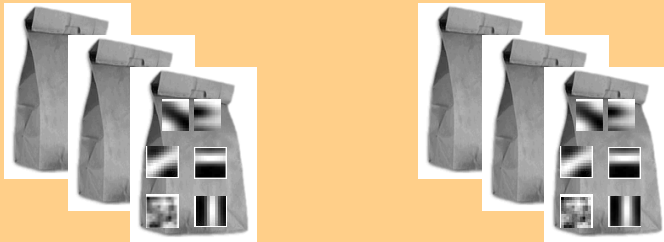


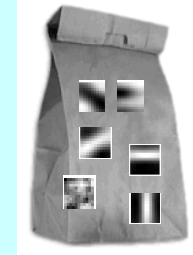
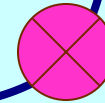
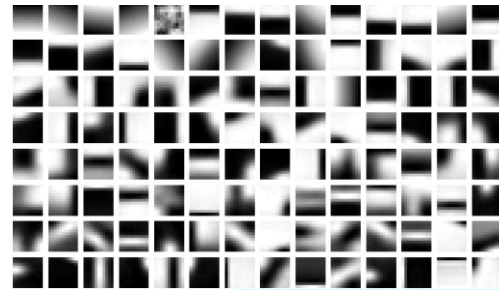
image representation

3.



Learning and Recognition

codewords dictionary

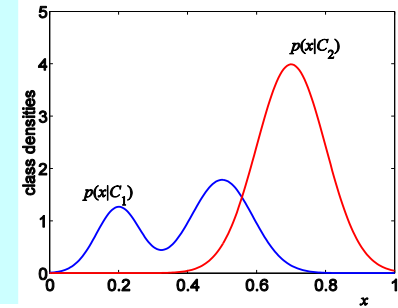


category models
(and/or) classifiers

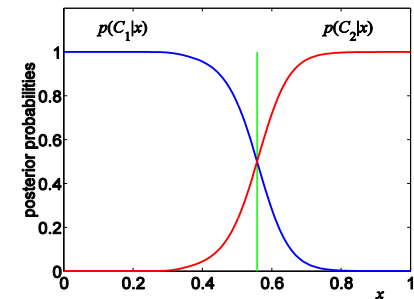
category
decision

Learning and Recognition

1. Generative method:
- graphical models



2. Discriminative method:
- SVM



**category models
(and/or) classifiers**