# Computer Vision and Machine Learning

(Image features)

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## What is Texture ?

Some visual pattern on an infinite 2-D plane which , at some scale, has a stationary distribution.


## What is Texture? (contd.)

- A feature used to partition images into regions of interest and to classify those regions.
- Provides information in the spatial arrangement of colours or intensities in an image.
- Characterized by the spatial distribution of intensity levels in a neighbourhood.
- Repeating pattern of local variations in image intensity.
- Cannot be defined for a point.

## What is Texture? (contd.)

- For example, an image has a 50% black and 50% white distribution of pixels.

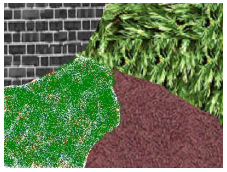
- Three different images with the same intensity distribution, but with different textures.
- Higher order statistics, which capture spatial arrangement of intensity, may help to quantify.

## Texture Analysis

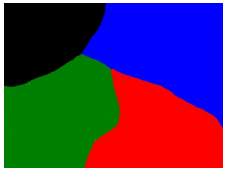
- Two main objectives of texture analysis:
  - texture classification
  - texture segmentation
- ***Texture classification*** is concerned with identifying a given textured region to be member of a texture class.
  - Each of these regions has unique texture characteristics.
  - Statistical methods are extensively used.

## Texture Analysis

- ***Texture segmentation*** is concerned with determining the boundaries between various texture regions in an image automatically.



Original texture regions



Segmented texture region

## Defining Texture

***Three approaches*** to define what texture is:

- ***Structural***: texture is a set of primitive texels in some regular or repeated relationship.
- ***Statistical*** : texture is a quantitative measure of the arrangement of intensities in a region.
  - This set of measurements is called a *feature vector*.
- ***Modeling*** : texture modeling techniques involve constructing models to specify textures.

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## Gray Level Co-occurrence

- A gray level co-occurrence matrix (*GLCM*) contains information about relative positions of pair of pixels having specific gray levels.
- A *GLCM* is a tabulation of how often different grey level pairs occur in an image.
- *GLCM* is a two-dimensional array, $C_d$, in which rows and columns represent possible gray levels.
- Element $C_d[i,j]$ is frequency of occurrence of all pairs of pixels having gray levels *i* and *j* separated by a displacement vector ***d*.**

## GLCM

**Graylevel cooccurrence matrix:**

$$C_{\theta,d}(m,n) = \sum_r \sum_c \Psi(f(r,c) = m \wedge f(r',c') = m)$$

where $r' = r + d * \cos\theta$ and $c' = c + d * \sin\theta$

If the argument is true $\Psi = 1$; otherwise $\Psi = 0$

$C_{\theta,d}(m,n)$ is a two-dimensional histogram of size $L \times L$

where $L$ is the number of graylevels.

## GLCM

- The *GLCM* is defined by:

$$C_d[i,j] = n_{ij}$$

– where $n_{ij}$ is the frequency of occurrences of the pixels values *i* and *j* lying at distance *d*.

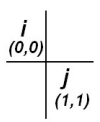
– The co-occurrence matrix $C_d$ has dimension *mxm*, where *m* is the number of possible gray levels.

## GLCM

For example, if displacement vector ***d*=*(1,1)***

| | | | | |
|---|---|---|---|---|
| 2 | 1 | 2 | 0 | 1 |
| 0 | 2 | 1 | 1 | 2 |
| 0 | 1 | 2 | 2 | 0 |
| 1 | 2 | 2 | 0 | 1 |
| 2 | 0 | 1 | 0 | 1 |

Graylevel image




| | | i | | |
|---|---|---|---|---|
| | | 0 | 1 | 2 |
| j | 0 | 0 | 2 | 2 |
| | 1 | 2 | 1 | 2 |
| | 2 | 2 | 3 | 3 |

GLCM $C_d$

there are 16 pairs of pixels in the image which satisfy this spatial separation. Since there are only three gray levels, $C_{(1,1)}[i,j]$ is a 3×3 matrix.

## GLCM

Algorithm:

- Count all pairs of pixels in which first pixel has value *i* and the other pixel displaced by *d* in the direction $\theta$ has value *j*.
- This count is entered in the **i$^{th}$** row and **j$^{th}$** column of the matrix $C_{\theta d}[i,j]$.
- Note that $C_{\theta d}[i,j]$ is not symmetric, since the number of pairs of pixels having gray levels *i* and *j* does not necessarily equal the number of pixel pairs having gray levels *j* and *i*.

## Normalized GLCM

- Conceptually, the measures require that each GLCM cell contain not a count, but rather a probability.
- The elements $C_{\theta d}[i,j]$ can be normalized by dividing by total number of entries in $C_d$.
- Normalized GLCM $C_{\theta d}[i,j]$ *is* defined by:

$$P[i,j] = \frac{C[i,j]}{\sum_i \sum_j C[i,j]}$$

which normalizes co-occurrence values to lie between 0 and 1, and allows them to be thought of as probabilities.

## Statistical Measures

- Numeric quantities or statistics that describe a texture can be calculated from the intensities (or colors) themselves.
- One problem with deriving texture measures from co-occurrence matrices is how to choose the displacement vector *d*.
- Choice of displacement vector is an important parameter in the definition of the GLCM.

## Statistical Measures (contd.)

- Occasionally the GLCM is computed from several values of *d* and the one which maximizes a statistical measure computed from *P(i,j)* is used.
- A $\chi^2$ measure may be used to select the values of *d* that have the most structural information; i.e., to maximize the value:

$$\chi^2(d) = \sum_i \sum_j \frac{P_d^2[i,j]}{P_d[i]P_d[j]} - 1$$

## Statistical Measures (contd.)

$$Energy = \sum_i \sum_j P_d^2\,(i,j)$$

$$Entropy = -\sum_i \sum_j P_d\,(i,j) \log_2 P_d\,(i,j)$$

$$Contrast = \sum_i \sum_j (i-j)^2 P_d\,(i,j)$$

$$Homogeneity = \sum_i \sum_j \frac{P_d(i,j)}{1+|i-j|}$$

$$Correlation = \frac{\sum_i \sum_j (i-\mu_i)(j-\mu_j) P_d(i,j)}{\sigma_i \sigma_j}$$

μ and σ are mean and st. deviation along rows (or columns).

## Local Binary Patterns

- Motivation
  - to develop methodology for 2-D texture analysis
  - to create basis for applications of machine vision
- Guiding Principles
  - computational simplicity for real time operation
  - invariance w.r.t. Illumination changes
  - invariance w.r.t. Spatial rotation of objects

## Local Binary Pattern

- Joint occurrences of LBP and contrast
- The operator works with eight-neighbors of a pixel and use the center pixel as threshold.

**An example in a 3×3 neighborhood:**

| example | | | thresholded | | | weights | | |
|---|---|---|---|---|---|---|---|---|
| 6 | 5 | 2 | 1 | 0 | 0 | 1 | 2 | 4 |
| 7 | 6 | 1 | 1 | | 0 | 128 | | 8 |
| 9 | 8 | 7 | 1 | 1 | 1 | 64 | 32 | 16 |

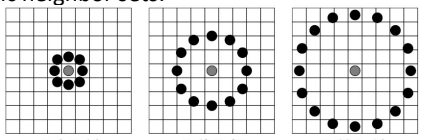
Pattern = **11110001**

**LBP** = 1 + 16 +32 + 64 + 128 = **241**

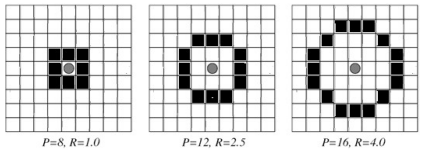
**C** = (6+7+8+9+7)/5 - (5+2+1)/3 = **4.7**

## Local Binary Pattern

- The neighborhood may be extended to multi-scale circularly symmetric neighbor sets.




- Circularly symmetric multi-scale LBP in discrete domain:



# Local Binary Pattern

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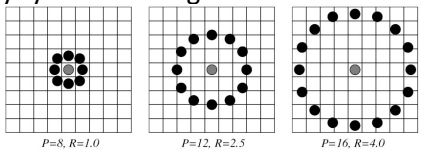
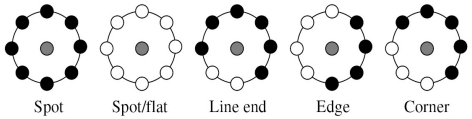


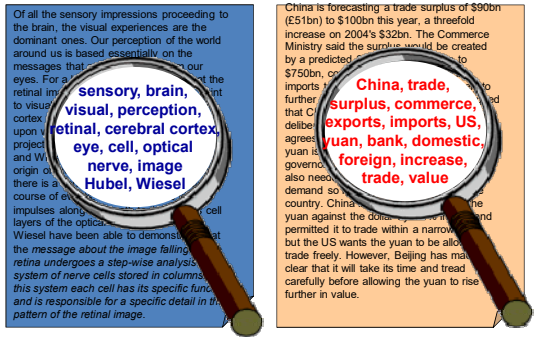

- Texture primitives detected by the LBP:



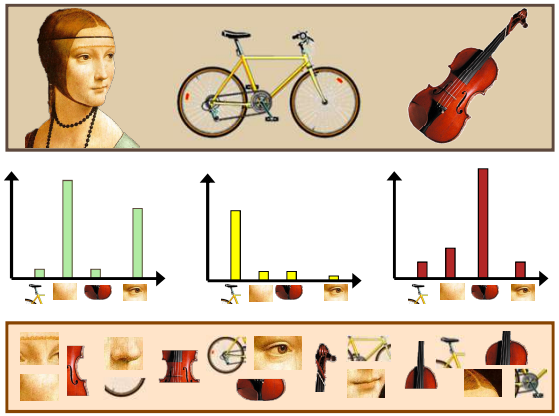

Bag of Visual Words Model (BoVW)



# Analogy to documents

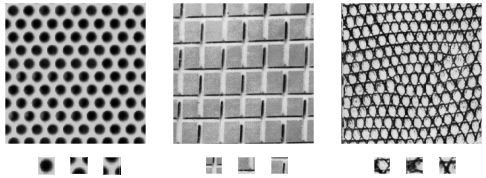




# Texture recognition

- Texture is characterized by the repetition of basic elements or *textons* or *texels.*
- For stochastic textures, it is the identity of the textons, not their spatial arrangement



Julesz, 1981; Cula & Dana, 2001; Leung & Malik 2001; Mori, Belongie & Malik, 2001; Schmid 2001; Varma & Zisserman, 2002, 2003; Lazebnik *et al.*, 2003

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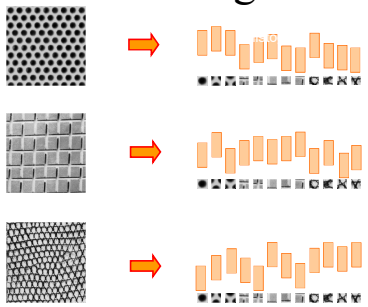
# Texture recognition



Julesz, 1981; Cula & Dana, 2001; Leung & Malik 2001; Mori, Belongie & Malik, 2001; Schmid 2001; Varma & Zisserman, 2002, 2003; Lazebnik *et al.*, 2003

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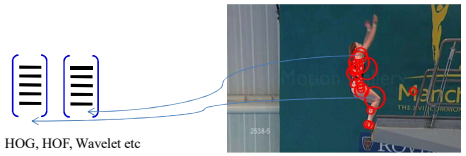
# Feature extraction

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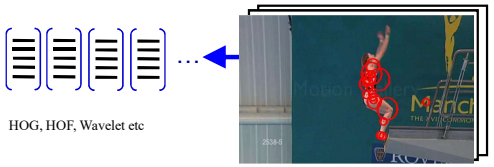
# Feature extraction

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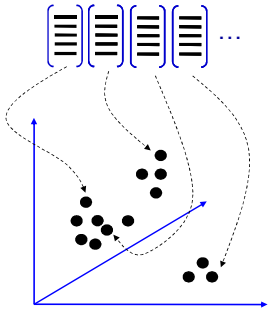
## Learning the visual vocabulary



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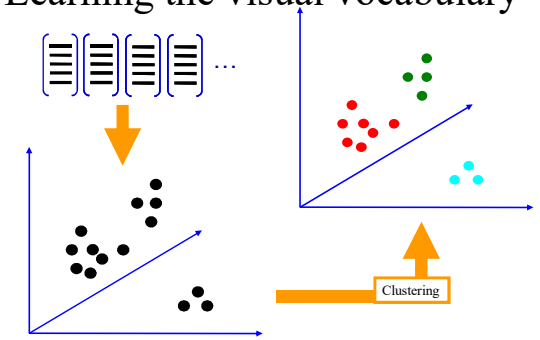
## Learning the visual vocabulary




Slide credit: Josef Sivic

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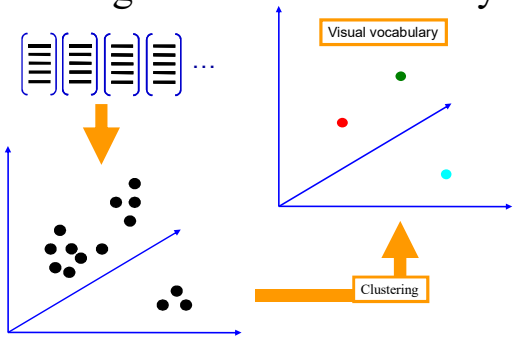
## Learning the visual vocabulary

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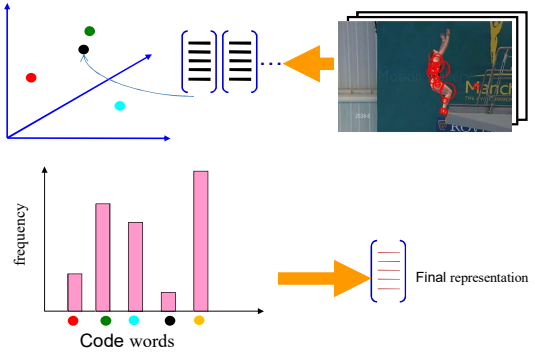
## Video Representation

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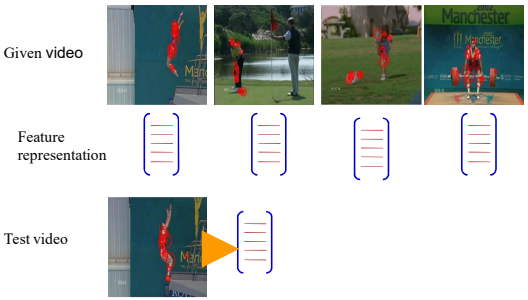
# Classification




• Classify using SVM or decision tree

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# Thank you !

## Any question?



# Square Grid