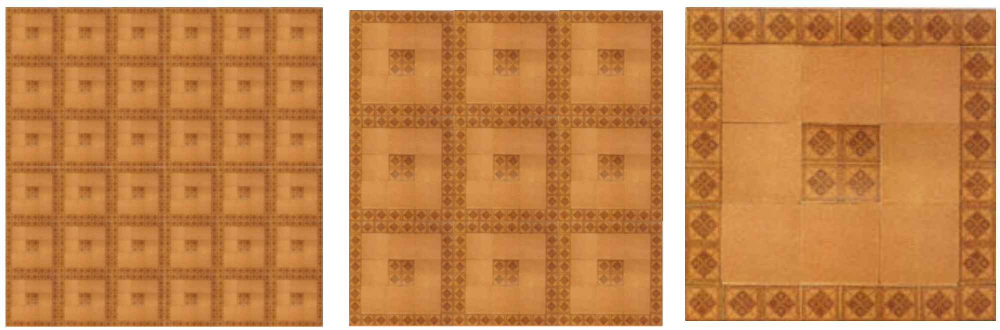
Texture

Texture

- Texture is an innate property of all surfaces (clouds, trees, bricks, hair etc…). It refers to visual patterns of homogeneity and does not result from the presence of a single color.

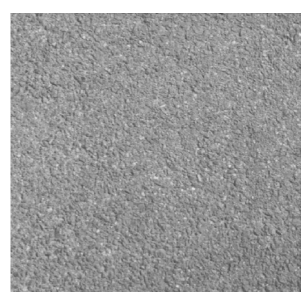
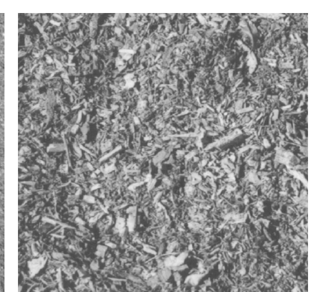
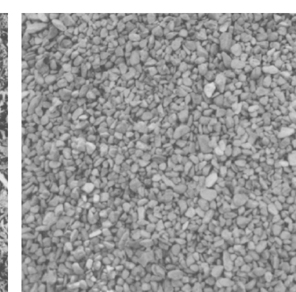
- Texturedness of a surface depends on the scale at which the surface is observed. Textures at a certain scale are not textures at a coarser scale. Differently from color, texture is a property associated with some pixel neighbourhood, not with a single pixel.



- Widely accepted classifications of textures are based on psychology studies, that consider how humans perceive and classify textures

- Textures can be detected and described according to *spatial, frequency* or *perceptual* properties. The most used approaches are:
  - Statistics: statistical measures are in relation with aspect properties like contrast, correlation, entropy
  - Stochastic models: stochastic models assume that a texture is the result of a stochastic process that has tunable parameters. Model parameters are therefore the texture descriptors
  - Structure: structure measures assume that texture is a repetition of some atomic texture

- For the purpose of matching any model can be used.
- For the purpose of clustering or categorization perceptual features are most significant:
  - Tamura's features (*coarseness, contrast, directionality, line-likeness, regularity and roughness*)
  - *Busyness, complexity* and *texture strength*
  - *Repetitiveness* and *orientation*

Space based models

- Co-occurrence matrix

  A basic measure for statistical model of textures is the gray level co-occurrence matrix. Given a texture, the image co-occurrence matrix measures the frequency of adjacent pixels. Each element *P (i,j)* in the matrix indicates the relative frequency at which two pixels of grey level i and j occur:

$$P(i\ j) = \frac{\neq \left[(p_1, p_2) \in I \mid (p_1 = i) \wedge (p_2 = j) \right]}{\neq I}$$

Original image

1	1	2	2	2
1	1	2	2	2
1	3	3	3	3
3	3	4	4	4
3	3	4	4	4

Co-occurrence matrix

	1	2	3	4
1	2	2	1	0
2	0	4	0	0
3	0	0	5	2
4	0	0	0	4

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- Statistics of co-occurrence probabilities can be computed and used to characterize properties of a textured region. Among them:

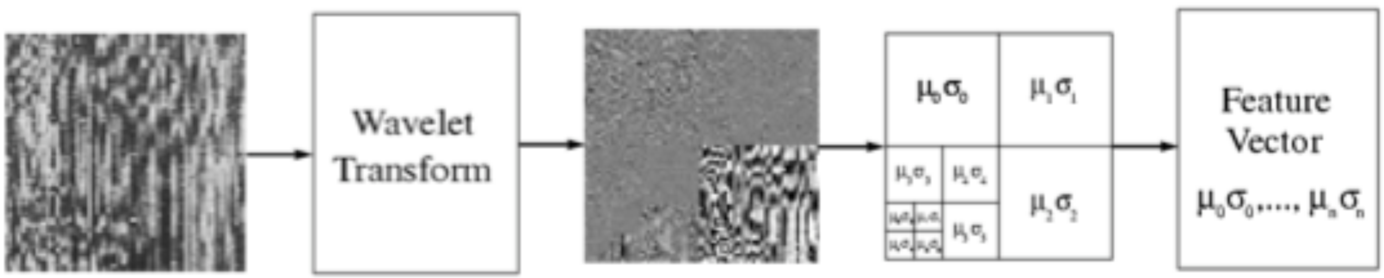
Entropy	$-\sum_i \sum_j P_d(i,j) \log P_d(i,j)$
Contrast	$\sum_i \sum_j (i-j)^2 P_d(i,j)$
Homogeneity	$\sum_i \sum_j \frac{P_d(i,j)}{1+\vert i-j\vert}$

	1	2	3	4
1	2	2	1	0
2	0	4	0	0
3	0	0	5	2
4	0	0	0	4

Contrast 2+4+2 = 8
Homogeneity 2+2/2+1/3+4+5+2/2+4 = 17,3

Frequency-based models

- Wavelet transform
  Coefficients of the wavelet transform can be used to represent frequency properties of a texture
  pattern. Gabor wavelet decomposition has been used in MPEG7



Perceptual models

- Tamura's features : Tamura's features are based on psychophysical studies of the characterizing elements that are perceived in textures by humans :
  - *Contrast*
  - *Directionality*
  - *Coarseness*
  - *Linelikeness*
  - *Regularity*
  - *Roughness*

- These features can be computed as in the following.

- Contrast

measures the way in which gray levels q vary in the image I and to what extent their distribution is biased to black or white.

$$contrast = \frac{\sigma}{(\alpha_4)^n}$$

where:

$n = 0.25$	recommended
$\sigma^2 = (q-m)^2 \Pr(q \mid I)$	*variance*
$\alpha_4 = \frac{1}{\sigma^4} \sum_{q=0}^{q_{\max}} (q-m)^4 \Pr(q \mid I)$	*kurtosis* (accounts for the shape of the distribution, i.e. the degree of flatness)

- Directionality

  takes into account the edge strenght and the directional angle. They are computed using pixelwise derivatives according to Prewitt's edge detector

$$\text{edge strenght} = 0.5(|\Delta_x(x,y)| + |\Delta_y(x,y)|)$$

$$\text{directionality angle} = \arctan\frac{\Delta x}{\Delta y} + \frac{\pi}{2}$$

Δx

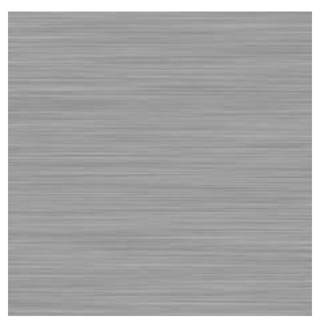
-1	**0**	**1**
-1	0	1
-1	0	1

Δy

1	**1**	**1**
0	0	0
-1	-1	-1

Δx, Δy are the pixel differences in the x and y directions

A histogram $H_{dir}(a)$ of quantised direction values is constructed by counting numbers of the edge pixels with the corresponding directional angles and the edge strength greater than a predefined threshold. The histogram is relatively uniform for images without strong orientation and exhibits peaks for highly directional images.

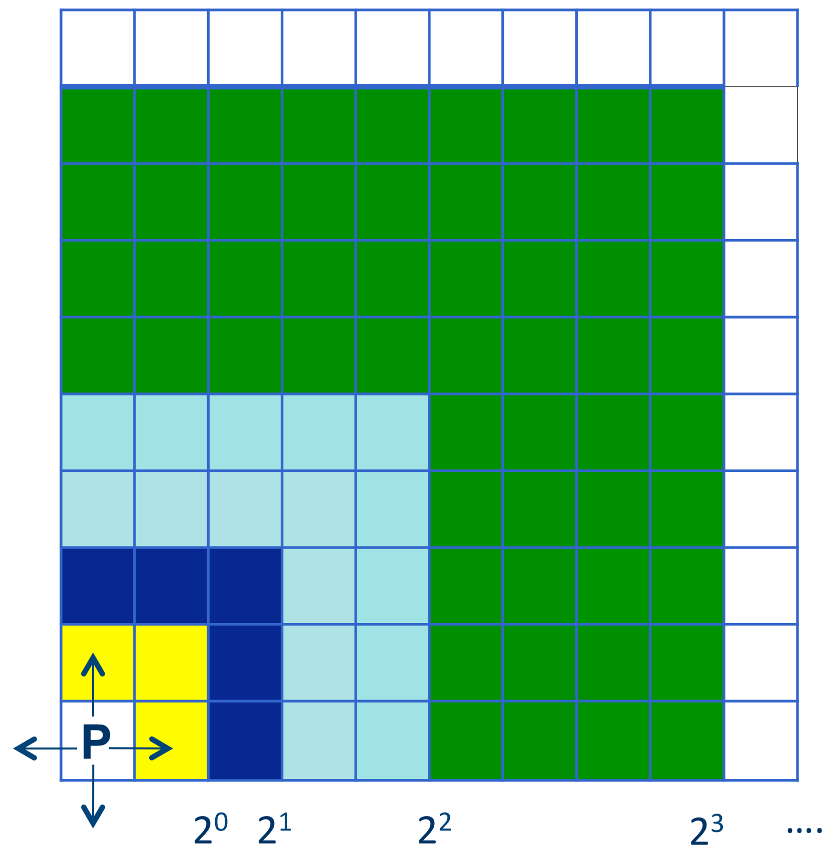


- Coarseness

  relates to distances of notable spatial variations of grey levels, that is, implicitly, to the size of the primitive elements (*texels*) forming the texture. Measures the scale of a texture.
  For a fixed window size a texture with a smaller number of texture elements is said more *coarse* than one with a larger number.

  A method to evaluate the coarseness of a texture is the following:

  1. At each pixel p(x,y) compute six averages for the windows of size k = 0,1,2,..5 around the pixel

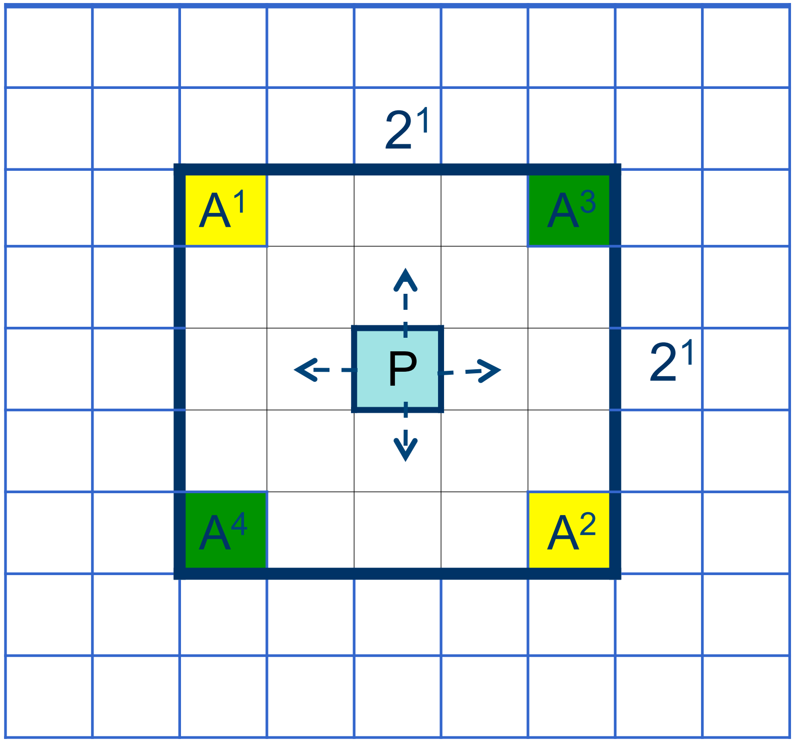


2. At each pixel
    - compute the absolute differences at each scale E_k (x,y) between pairs of nonoverlapping averages on opposite sides of different directions

$E_{k,a}(p) = | A_k^1 - A_k^2 |$

$E_{k,b}(p) = | A_k^3 - A_k^4 |$

$p(x,y) = \{ E_{1,a}, E_{1,b}, E_{2,a}, E_{2,b} \ldots \}$



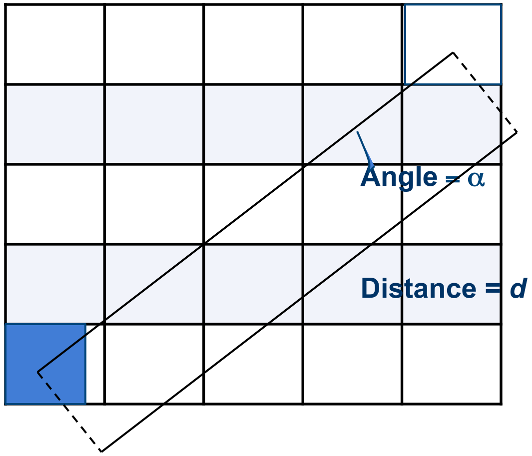
    - Find the value of k that maximizes E_k (x,y) in either direction.
    - Select the scale with the largest variation: $E_k = \max(E_1, E_2, E_3, ..)$. The best pixel window size S_{best} is 2^k
3. Compute coarseness by averaging S_{best} over the entire image

- Textures of multiple coarseness have a histogram of the distribution of the S_{best}

- Linelikeness

  it is defined as the average coincidence of edge directions that co-occur at pixels separated by a distance *d* along the direction α

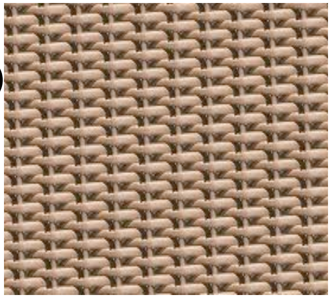




- Regularity

  it is defined as: $1 - r\,(\sigma_{coarseness} + \sigma_{contrast} + \sigma_{directionality} + \sigma_{linelikeness})$

  Being r a normalising factor and σ the standard deviation of the feature in each subimage of the texture




it is defined as: *Coarseness* + *Contrast*