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CBIR: Texture Features - 1

COMPSCI.708.S1.C

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QBE Using Texture Features

- "**Texture** - ...(*in extended use*) the constitution, structure, or substance of anything with regard to its constituents or formative elements."
  (*The Oxford Dictionary*, 1971; 1989)
- "**Texture** - ...a basic scheme or structure; the overall structure of something incorporating all of most of parts."
  (*Webster's Dictionary*, 1959; 1986)

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Texture - What Is It?

- A very general notion that can be attributed to almost everything in nature
- For a human, the texture relates mostly to a specific, spatially repetitive (micro)-structure formed by repeating a particular element or several elements
- The repetition involves local variations of scale, orientation, or other features of the elements

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Image Textures

- Image textures → images of natural textured surfaces and artificially created visual patterns, which approach, within certain limits, these natural objects
- Image sensors yield additional geometric and optical transformations of the perceived surfaces that should not affect a class of textures the surface belongs

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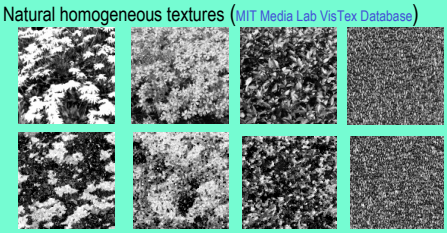
Natural Vs. Synthetic Textures

- Natural homogeneous textures (MIT Media Lab VisTex Database)



- Synthetic textures (Univ.of Auckland: Generic Gibbs random field model)

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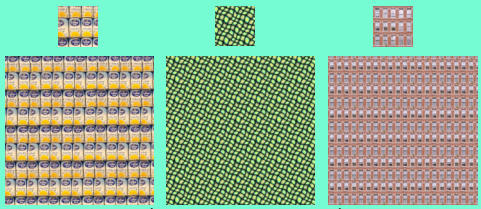
Natural Vs. Synthetic Textures

- Natural homogeneous textures



- Synthetic textures (Univ.of Auckland: Bunch sampling)

How to Describe a Texture?

- It is hardly possible to describe textures in words
- Each human definition involves informal qualitative features: **fineness - coarseness**, **smoothness**, **granularity**, **lineation**, **directionality**, **roughness**, **regularity - randomness**, *etc*
- The features define a spatial arrangement of texture constituents and single out the desired texture types, e.g. *fine* or *coarse*, *close* or *loose*, *plain* or *twilled* or *ribbed* textile fabrics, and so on

How to Describe a Texture?

- Human classifications cannot be used as a basis for formal definitions because there is no obvious ways of associating image features, easily perceived by human vision, with computational models
- Nonetheless, a variety of computational characteristics and properties for indexing and retrieving textures have been found
  - Local arrangements of image signals in the spatial or spectral (Fourier, etc) domains
  - Features of a particular random field model of textures

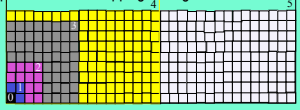
Tamura's Texture Features

One of most popular sets; contains six features selected by psychological experiments:

- ***coarseness***
- ***contrast***
- ***directionality***
- ***linelikeness***
- ***regularity***
- ***roughness***

Coarseness Feature

- Relates to distances of notable variations of grey levels
- Differences between the average signals for the non-overlapping windows of different size:
  - At each pixel (x,y), compute six averages in the windows of size $2^k \times 2^k$, $k=0,1,...,5$, around the pixel
  - At each pixel (x,y), compute absolute differences $E_k(x,y)$ between the pairs of non-overlapping averages in the horizontal and vertical directions



Coarseness Feature

  - At each pixel (x,y), find the value of k that maximises the difference $E_k(x,y)$ in either direction, and
  - At each pixel (x,y), set the best size $S_{best}(x,y)=2^k$
- **Coarseness feature** F_{crs} :
  - the average best size $S_{best}(x,y)$ over the entire image
- **Improved coarseness feature** to deal with textures of multiple coarseness properties:
  - a histogram characterising the whole distribution of the best sizes $S_{best}(x,y)$ over the image

Contrast Feature

- Measures how grey levels vary in the image $\mathbf{g}$ and to what extent their distribution is biased to black or white:

$$F_{con} = \frac{\sigma}{(\alpha_4)^n} \text{ where } \sigma^2 = \sum_{q=0}^{q_{max}} (q-m)^2 \Pr(q \mid \mathbf{g}) \text{ is the variance}$$

Mean grey level

$$\text{and } \alpha_4 = \frac{1}{\sigma^4} \sum_{q=0}^{q_{max}} (q-m)^4 \Pr(q \mid \mathbf{g}) \text{ is the kurtosis}$$

$n=0.25$ is recommended as the best for discriminating the textures

Directionality Feature

- Frequency distribution of oriented local edges against their directional angles
  - The edge strength $e(x,y)$ and the directional angle $a(x,y)$ are computed using approximate pixel-wise derivatives computed by the Sobel edge detector in the 3 x 3 moving window:

$$\begin{matrix}-1 & 0 & 1\\ -1 & \mathbf{0} & 1\\ -1 & 0 & 1\end{matrix}\ \Delta_x(x,y) \qquad \begin{matrix}1 & 1 & 1\\ 0 & \mathbf{0} & 0\\ -1 & -1 & -1\end{matrix}\ \Delta_y(x,y)$$

$$e(x,y)=0.5\left(|\Delta_x(x,y)|+|\Delta_y(x,y)|\right);\quad a(x,y)=\tan^{-1}\left(\Delta_y(x,y)/\Delta_x(x,y)\right)$$

Directionality Feature

- Histogram $H_{\text{dir}}(a)$ of quantised directional values a → the numbers of the edge pixels (x,y) with the directional angle $a(x,y)$ and the edge strength $e(x,y)$ greater than a predefined threshold
  - The histogram $H_{\text{dir}}(a)$ is relatively uniform for images without strong orientation
  - The histogram $H_{\text{dir}}(a)$ exhibits peaks for highly directional images

Directionality Feature

- The degree of directionality relates to the sharpness of peaks:

$$F_{\text{dir}}=1-r\cdot n_p\sum_{p=1}^{n_p}\sum_{a\in w_p}\left(a-a_p\right)^2 H_{\text{dir}}(a)$$

n_p - the number of peaks
a_p - the position of the pth peak
w_p - the range of the angles around the pth peak
r - a normalising factor related to quantising levels of a
a - the quantised directional angle (modulo 180º)

Three Other Features

- Highly correlated with the first three features
- **Linelikeness** F_{lin}: an average coincidence of the coded directional angles in the pairs of pixels separated by a distance d along the edge direction in every pixel
- **Regularity** $F_{\text{reg}}=1-r(s_{\text{crs}}+s_{\text{con}}+s_{\text{dir}}+s_{\text{lin}})$ where r is a normalising factor and each $s_{\cdots}$ is the standard deviation of the corresponding feature $F_{\cdots}$ in each subimage the texture is partitioned into
- **Roughness** $F_{\text{rgh}}=F_{\text{crs}}+F_{\text{con}}$

Tamura's Features and CBIR

- In the most cases, only the first three Tamura's features are used for the CBIR
- The features capture the high-level perceptual attributes of a texture well and are useful for image browsing
- However, they are not very effective for finer texture discrimination
- **Finer discrimination**: more intricate texture features, e.g. based on second-order signal statistics (matrices of signal co-occurrences)

Co-occurrence Matrices

Co-occurrence matrix shows how frequent is every particular pair of grey levels or colours in pixel pairs separated by a certain distance d along a direction a