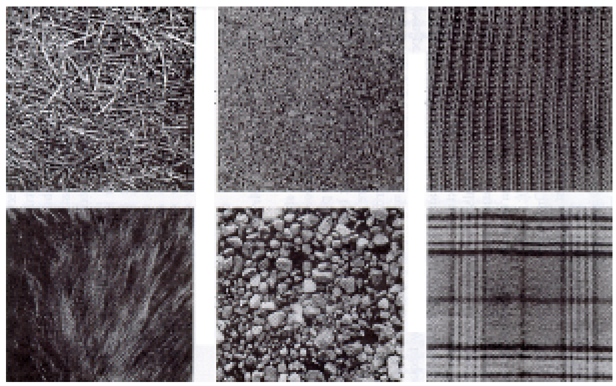
TEXTURE ANALYSIS

Texture represents regular and repeated structures in an image. The texture may be stochastic or deterministic.

Texture examples

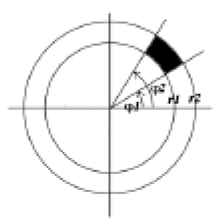


Texture analysis approaches

•Fourier analysis
•Gray-Level Cooccurence Matrices
•Autocorrelation
•Others...

Fourier-based texture features

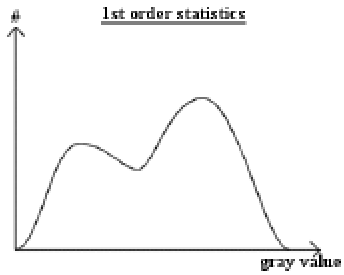
The main idea is to extract features based on the Fourier spectrum: $\int_{r_1}^{r_2} \int_{\varphi_1}^{\varphi_2} F(r, \varphi)drd\varphi$

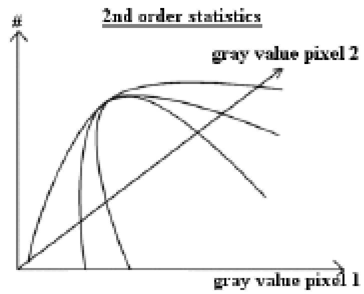


Basically, it means that you measure the energy in different wedges of the spectrum.

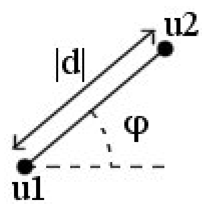
Gray level cooccurence matrices

In contrary to the histogram which is based on first order statistics of single gray scale values, the cooccurence matrices are based on second-order statistics of grayscale pairs at a certain separating distance and direction.





Pixel pair (u_1,u_2) defined by distance and angle:



Second order statistics

Second-order joint probabilities have been found useful in applications such as texture feature extraction. A second-order joint probability is defined as:

$$p_{u_1, u_2}(x_1, x_2) \triangleq \mathrm{Prob}\left[u_1 = x_1, u_2 = x_2\right], \quad x_1, x_2 = 0 \ldots L\text{-}1 \quad \approx$$

$$\frac{\text{number of pair of pixels } u_1 = x_1,\ u_2 = x_2}{\text{total number of such pairs of pixels in the region}}$$

where u_1 and u_2 are two pixels in the image region specified by a particular spatial relation (distance and direction). For example, u_2 could be specified as a pixel at distance *r* and angle q from u_1. The LxL array that contains the values of the joint probabilities is referred to as the cooccurence matrix.

A simple example

Image

$$\begin{array}{cccc} 1 & 2 & 0 & 3 \\ 1 & 2 & 0 & 3 \\ 1 & 3 & 0 & 2 \\ 1 & 3 & 0 & 2 \end{array}$$

Horizontal direction

$$d \rightarrow (\Delta x, \Delta y) = (1,0)$$

$$\begin{array}{c|cccc} & 0 & 1 & 2 & 3 \\ \hline 0 & 0 & 0 & 4 & 4 \\ 1 & 0 & 0 & 2 & 2 \\ 2 & 4 & 2 & 0 & 0 \\ 3 & 4 & 2 & 0 & 0 \end{array}$$

Vertical direction

$$d \rightarrow (\Delta x, \Delta y) = (0,1)$$

$$\begin{array}{c|cccc} & 0 & 1 & 2 & 3 \\ \hline 0 & 6 & 0 & 0 & 0 \\ 1 & 0 & 6 & 0 & 0 \\ 2 & 0 & 0 & 4 & 2 \\ 3 & 0 & 0 & 2 & 4 \end{array}$$

Based on the cooccurence matrices, a number of texture features can be computed such as Contrast and Angular Second Moment .

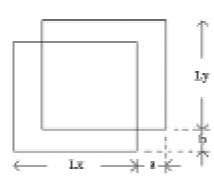
$$\text{Contrast} \equiv \sum_{i,j} (i-j)^2 p(i,j)$$

$$\text{Angular Second Moment} \equiv \sum_{i,j} p(i,j)^2$$

Texture analysis by autocorrelation

The discrete autocorrelation function (acf) is defined as:

$$r(a,b) = \frac{L_x L_y}{(L_x - |a|)(L_y - |b|)} \frac{\sum_x \sum_y f(x,y) f(x+a, y+b)}{\sum_x \sum_y f^2(x,y)}$$



Without going into details, the acf can be used for extracting texture features. Intuitively, an acf that falls off quickly (in a certain distance and for a specific lag) means the image contains high frequencies and the other way around.

Grayscale Difference Statistics

Grayscale difference statistics is a first order measure of grayscale differences that does not take into account in which range these differences are being found. The measure can be extracted from the cooccurence matrices, simply by adding the values in those matrix diagonals that parallels the main diagonal. Examples of features are Contrast and Angular Second moment:

$$\text{Contrast} \equiv \sum_i i^2 p_\delta(i)$$

$$\text{Angular second moment} \equiv \sum_i p_\delta(i)^2$$

Grayscale Run-Length statistics

A region can be represented by a sequence of strings holding a particular grayscale value. Examples of features are Long Runs Emphasis and Run percentage.

$$\text{Long Runs Emphasis} \equiv \sum_{i,j} j^2 p(i,j) \Big/ \sum_{i,j} p(i,j)$$

$$\text{Run Percentage} \equiv \sum_{i,j} p(i,j) \Big/ N^2$$

Textural edgeness

Textural edgeness (below denoted by g(d) where d is a distance) is a concept that can be represented in many different ways. One such possible way is the following:

$$\begin{aligned} g(d) \quad = \quad & \sum_{x,y} \quad [|f(x,y) - f(x+d,y)| + |f(x,y) - f(x-d,y)| \\ & + \quad |f(x,y) - f(x,y+d)| + |f(x,y) - f(x,y-d)|] \end{aligned}$$