Texture Calculation using GLCM Features

Grey–level Co-occurrence matrix is very famous technique for texture measurements in field of image processing. This method of texture measurements was firstly introduced by Harlick in 1970. He proposed a mathematical technique of calculation texture of images and since then it is being widely used in different field of Image processing application.

Let's start from the texture. So, What is texture?

They are most easily understood in relation to a topographical surface with high and low points, and a scale compatible with a finger or other.

GLCM basically calculates how often a pixel with grey level value i occurs either horizontally or vertically or diagonally to adjacent pixels with value j. GLCM provides a second order texture calculation. GLCM method as per it name it generates a Grey-level Co-occurrence matrix and apply different formulas and calculations on it to compute 14 textural features based on grey-tone spatial dependencies.

Let's see how GLCM do it's calculations. It defines how often different combination of pixels occurs in an image with same gray level value for a given distance d and a particular angle. Consider one pixel as reference pixel and other pixel which is d distance away from reference pixel in particular given angle. So each pixel in image becomes a reference pixel for any neighboring pixel. For GLCM calculation a symmetric matrix is required. If any image has x number of grey tones then the matrix created by that image will be the size of x*x and to make it symmetric alter the rows and columns of GLCM matrix (This process is called transposing of matrix) and then add the transposed matrix into original matrix. Resultant matrix will be symmetric. Before going for further calculation it is also required to normalize the matrix. To apply normalization first get the sum of all elements of symmetric matrix and then divide the matrix the answer of sum. Now our matrix is all set to apply different calculation on it and calculate GLCM features.

14 GLCM features are grouped into 3 different subgroups.

1)Contrast Group
2)Measure Related or Orderliness.
3)Stats Group

<u>Contrast Group</u>

It contains 3 GLCM features.

1. Contrast (this is also called "sum of squares variance" and occasionally "inertia"):

Contrast equation

$$\sum_{i,j=0}^{N-1} P_{i,j}(i-j)^2$$

Explanation:

When i and j are equal, the cell is on the diagonal and (i-j)=0. These values represent pixels entirely similar to their neighbor , so they are given a weight of 0 (no contrast).
If i and j differ by 1, there is a small contrast, and the weight is 1.
If i and j differ by 2, contrast is increasing and the weight is 4.
The weights continue to increase exponentially as (i-j) increases.

1. B. Dissimilarity (Contrast Group)

Instead of weights increasing exponentially (0, 1, 4, 9, etc.) as one moves away from the diagonal as Contrast did, the dissimilarity weights increase linearly (0,1,2,3 etc.).

Dissimilarity equation

This is a first degree measure.

$$\sum_{i,j=0}^{N-1} P_{i,j}|i-j|$$

1. C. Homogeneity (Inverse Difference Moment) (Contrast group)

Dissimilarity and Contrast result in larger numbers for more windows showing more contrast. If weights decrease away from the diagonal, the calculated texture measure will be larger for windows with little contrast. Homogeneity weights values by the inverse of the Contrast weight, with weights decreasing exponentially away from the diagonal:

$$\sum_{i,j=0}^{N-1} \frac{P_{i,j}}{1+(i-j)^2}$$

2) Measure Related Group.

Orderliness means how regular ("orderly") the pixel value differences are within the window.

2. A. Angular Second Moment (ASM), Energy and MAX

ASM equation

The square root of the ASM is sometimes used as a texture measure, and is called **Energy**.

$$\sum_{i,j=0}^{N-1} P_{i,j}^{\;2}$$

Energy equation

$$Energy = \sqrt{ASM}$$

The terms ASM and Energy

The name for ASM comes from Physics, and reflects the similar form of Physics equations used to calculate the angular second moment, a measure of rotational acceleration. If you are interested, look up "moment of inertia" in a Physics textbook. The meaning of "energy" is explained below. window is very orderly.

2. B. Entropy

Since ln(0) is undefined, assume that 0 * ln(0) = 0:

Entropy equation

$$\sum_{i,j=0}^{N-1} P_{i,j}\left(-\ln P_{i,j}\right)$$

Entropy is usually classified as a first degree measure, but should properly be a "zeroth" degree!

3. Descriptive Statistics of the GLCM texture measures

The third group of texture measures uses equations similar to those for common descriptive statistics, such as mean or standard deviation (or variance). However, all are calculated using the entries in the GLCM, not the original pixel values. Details below. The important thing is to be clear when using software that you are calculating the GLCM, not the first-order statistic. Many programs contain algorithms to calculate the first-order statistic as well. Also, be clear when writing a report that your terminology is always clear so that the reader will understand that you are using the GLCM statistic.

3. A. GLCM Mean
How GLCM mean differs from the mean of the pixel values in the window:

The GLCM Mean is not simply the average of all the original pixel values in the image window. It is expressed i*n terms of the GLCM*. The pixel value is weighted not by its frequency of occurrence by itself (as in a "regular" or familiar mean equation) but by its frequency of its occurrence *in combination with* a certain neighbour pixel value.

GLCM Mean Equation

hand equation. **For the symmetrical GLCM**, where each pixel in the window is counted once as a reference and once as a neighbor , **the two values are identical**. The two equations are included for mathematical and theoretical clarity, just in case a symmetrical GLCM is not being used.

$$\mu_i = \sum_{i,j=0}^{N-1} i\left(P_{i,j}\right) \quad \mu_j = \sum_{i,j=0}^{N-1} j\left(P_{i,j}\right)$$

3.B GLCM Variance and Standard Deviation

Variance equation

$$\sigma_i^2 = \sum_{i,j=0}^{N-1} P_{i,j}\left(i-\mu_i\right)^2 \quad \sigma_j^2 = \sum_{i,j=0}^{N-1} P_{i,j}\left(j-\mu_j\right)^2$$

Standard deviation equation

$$\sigma_i = \sqrt{\sigma_i^2} \qquad \sigma_j = \sqrt{\sigma_j^2}$$

Calculation details:
GLCM Variance in texture measures performs the same task as does the common descriptive statistic called variance. It relies on the mean, and the dispersion around the mean, of cell values within the GLCM. However, GLCM variance uses the GLCM, therefore it deals specifically with the dispersion around the mean of combinations of reference and neighbour pixels, so it is not the same as the simple variance of grey levels in the original image.
Variance calculated using i or j gives the same result, since the GLCM is symmetrical.
There is no particular advantage to using Standard Deviation over Variance, other than a different range of values.

Properties of Variance

Variance is a measure of the dispersion of the values around the mean. It is similar to entropy. It answers the question "What is the dispersion of the difference between the reference and the neighbour pixels in this window?"

3.C GLCM Correlation

The Correlation texture measures the linear dependency of grey levels on those of neighbouring pixels.

Correlation equation:

$$\sum_{i,j=0}^{N-1} P_{i,j} \left[\frac{(i-\mu_i)(j-\mu_j)}{\sqrt{(\sigma_i^2)(\sigma_j^2)}} \right]$$

By using the above features of GLCM we can calculate some more advances features of GLCM which are as below.

1) Maximum Probability (MAX): It measures texture uniformity solely on the basis of the highest probability of the pixel combinations.

2) Sum Average or GLCM Mean (SA): It weighs the pixel value by frequency of its occurrence in combination with a certain neighbor pixel value.

3) Sum Entropy (SENT): It measures the entropy from the GLSH (Gray Level Sum Histrogram) matrix.

4) Sum Variance (SVAR): It measure the Variance from the GLSH (Gray Level Sum Histrogram) matrix.

5) Difference Variance (DVAR): It measure the Variance from the GLDH(Gray level Difference Histogram).

6) Difference Entropy (DENT): It measures the Entropy from the GLDH(Gray level Difference Histogram).

7) Auto Correlation (AC): It measures the amount of regularity as well as fineness/ coarseness of the texture present in the image.