# Radiomic features

## First-Order Statistics Features

### Mean

The average intensity value of all voxels in the region of interest (ROI).

*xi* = Intensity of the *ith* voxel.

*N* = Total number of voxels.

### Median

The middle value when intensity values are sorted.

*x =* Set of voxel intensities.

### Mode

The most frequently occ

*x =* Set of voxel intensities.

### Minimum

The lowest intensity value in the ROI.

### Maximum

The highest intensity value in the ROI.

### Range

The spread of intensity values.

### Interquartile Range (IQR)

The range between the 75th and 25th percentiles.

*Q1 =* 25th percentile

*Q2* = 75th percentile

### Variance

The average squared deviation from the mean.

*xi* = Intensity of the *ith* voxel.

*N* = Total number of voxels.

### Standard Deviation

The square root of the variance.

*xi* = Intensity of the *ith* voxel.

*N* = Total number of voxels.

### Skewness

Measure of asymmetry of the intensity distribution.

*xi* = Intensity of the *ith* voxel.

*N* = Total number of voxels.

σ = Standard Deviation

### Kurtosis

Measure of peaked Ness or flatness of the distribution.

Subtracting 3 gives the excess kurtosis.

*xi* = Intensity of the *ith* voxel.

*N* = Total number of voxels.

σ = Standard Deviation

### Energy

Sum of squared intensity values.

*xi* = Intensity of the *ith* voxel.

*N* = Total number of voxels.

### Entropy

Measure of randomness in the intensity distribution.

*Pj*: Probability of intensity in bin *j* (from histogram)

*M*: Number of histogram bins

### Uniformity (Angular Second Moment)

Sum of squared probabilities (higher means more uniform).

*Pj*: Probability of intensity in bin *j* (from histogram)

*M*: Number of histogram bins

### ****Root Mean Square (RMS)****

Square root of the mean of squared values.

*xi* = Intensity of the *ith* voxel.

*N* = Total number of voxels.

### Mean Absolute Deviation (MAD)

Average absolute difference from the mean.

*xi* = Intensity of the *ith* voxel.

*N* = Total number of voxels.

µ = Mean

### Robust MAD

The mean distance of all intensity values from the Mean Value calculated on the subset of image array with gray levels in between, or equal to the 10th and 90th percentile.

*xi* = Intensity of the *ith* voxel.

*N* = Total number of voxels.

µ*trim* = Mean after trimming lower 10% and upper 10% of values

### Median Absolute Deviation

Median of the absolute deviations from the median.

### Coefficient of Variation (CoV)

Ratio of standard deviation to mean (normalized dispersion).

σ = Standard Deviation

µ = Mean

## GLCM (Gray Level Co-occurrence Matrix) Features

### Autocorrelation

*P(i,j)* = Normalized GLCM value at position (*i,j*)

*N* = Number of gray level

*i,j* = Gray level indices

Autocorrelation measures the linear dependency of gray levels in neighboring pixels and it provides insight into the texture’s repetitiveness or periodicity. High values indicate a strong spatial relationship between pixel pairs.

### Contrast

*P(i,j)* = Normalized GLCM value at position (*i,j*)

*N* = Number of gray level

*i,j* = Gray level indices

captures the intensity contrast between a pixel and its neighbor. High contrast values suggest large intensity differences while low values indicate smoother textures.

### Correlation

*P(i,j)* = Normalized GLCM value at position (*i,j*)

*N* = Number of gray level

*i,j* = Gray level indices

µi, µj = Means of row and column GLCM marginal distributions

σi, σj = Standard deviations

Correlation assesses the linear relationship between gray levels in pixel pairs.

### Cluster Prominence

*P(i,j)* = Normalized GLCM value at position (*i,j*)

*N* = Number of gray level

*i,j* = Gray level indices

µi, µj = Means of row and column GLCM marginal distributions

Cluster Prominence is a higher-order moment measuring asymmetry and peakedness in the joint probability distribution.

### Cluster Shade

*P(i,j)* = Normalized GLCM value at position (*i,j*)

*N* = Number of gray level

*i,j* = Gray level indices

µi, µj = Means of row and column GLCM marginal distributions

Cluster Shade measures skewness of the pixel pair distribution.

### Dissimilarity

*P(i,j)* = Normalized GLCM value at position (*i,j*)

*N* = Number of gray level

*i,j* = Gray level indices

Dissimilarity quantifies the variation in gray level intensity between pairs.

### ****Energy (Angular Second Moment)****

*P(i,j)* = Normalized GLCM value at position (*i,j*)

*N* = Number of gray level

Energy measures textural uniformity. High energy implies fewer gray-level transitions and more homogeneity.

### Entropy

*P(i,j)* = Normalized GLCM value at position (*i,j*)

*N* = Number of gray level

*ϵ* = Small constant to avoid log (0)

Entropy evaluates the disorder or randomness of the texture.

### Homogeneity 1 (Inverse Difference Moment)

*P(i,j)* = Normalized GLCM value at position (*i,j*)

*N* = Number of gray level

*i,j* = Gray level indices

Homogeneity measures the closeness of element distributions to the GLCM diagonal.

### Homogeneity 2 (Inverse Difference Normalized)

*P(i,j)* = Normalized GLCM value at position (*i,j*)

*N* = Number of gray level

*i,j* = Gray level indices

Variation of homogeneity accounts for normalization by gray levels.

### Maximum Probability

*P(i,j)* = Normalized GLCM value at position (*i,j*)

Maximum probability reflects the most dominant gray-level pair frequency.

### Sum Average

*i,j* = Gray level indices

*px+y(k)* = Probability of *i+j =k*

Sum average is the mean of the sum distribution *i+j*. It captures average brightness transitions and gives a coarse summary of joint pixel behavior.

### Sum Entropy

*i,j* = Gray level indices

*px+y(k)* = Probability of *i+j =k*

*ϵ* = Small constant to avoid log (0)

Sum entropy measures randomness in the *i+j* sum distribution.

### Sum Variance

*px+y(k)* = Probability of *i+j =k*

This feature quantifies the spread in the sum distribution *i+j* It complements sum average by capturing variation in co-occurrence brightness.

### Difference Entropy

*px+y(k)* = Probability of *i+j =k*

*ϵ* = Small constant to avoid log (0)

Difference entropy analyzes complexity in the intensity difference distribution.

### Difference Variance

*px+y(k)* = Probability of *i+j =k*

µ = Mean

Evaluates variance in the absolute difference *i − j* distribution.

### ****Information Measure of Correlation 1****

*HXY*​ = Joint entropy

*HX​, HY*​ = Entropies of marginal distributions

*HXY1= ∑ P(i,j)log2(Px(i)Py(j))*

This measures mutual information normalized by maximum entropy. It reflects how much information about one pixel gray level reduces uncertainty in its neighbor.

### Information Measure of Correlation 2

*HXY*​ = Joint entropy

*HXY2 ​= ∑ Px​(i)Py​(j)log2​(Px​(i)Py​(j))*

IMC2 is an exponential-based metric of information dependency between pixel intensities. It shows how correlated the texture is across gray levels in 2D space.