RADIOMICS FEATURES

For more in depth information regarding the way each feature is computed, refer to the IBSI documentation (https://arxiv.org/abs/1612.07003)

Abbreviations used in the MIRP package to name features

- Feature class

feature family	abbreviation
morphology	MORPH
local intensity	LI
intensity-based statistics	IS, STAT
intensity histogram	IH
intensity-volume histogram	IVH
grey level co-occurrence matrix	GLCM, CM
grey level run length matrix	GLRLM, RLM
grey level size zone matrix	GLSZM, SZM
grey level distance zone matrix	GLDZM, DZM
neighbourhood grey tone difference matrix	NGTDM
neighbouring grey level dependence matrix	NGLDM

- Feature aggregation method

morphology, LI	
–	features are 3D by definition
IS, IH, IVH	
2D	averaged over slices (rare)
–, 3D	calculated over the volume (default)
GLCM, GLRLM	
2D:avg	averaged over slices and directions
2D:mrg, 2D:smrg	merged directions per slice and averaged
2.5D:avg, 2.5D:dmrg	merged per direction and averaged
2.5D:mrg, 2.5D:vmrg	merged over all slices
3D:avg	averaged over 3D directions
3D:mrg	merged 3D directions
GLSZM, GLDZM, NGTDM, NGLDM	
2D	averaged over slices
2.5D	merged over all slices
3D	calculated from single 3D matrix

- Additional parameters

  d#: Chebyshev norm used with distance #

  a#: alpha parameter used to determine if there is a dependency between two voxels

RADIOMICS FEATURES

Feature class	Class description	Feature	Meaning
Local intensity features	Features computed from voxel intensities within a defined neighbourhood around a center voxel	Local intensity peak	Mean intensity in a $1cm^3$ spherical volume, centered on the voxel with the maximum intensity level in the ROI intensity mask
		Global intensity peak	Mean intensity in a $1cm^3$ spherical volume, centered on every voxel within the ROI. The highest value is then selected
Intensity-based statistical features	Description of the distribution of voxel intensities using common metrics	Mean intensity	Mean value of the grey levels of the image
		Intensity variance	Variance of the grey levels of the image
		Intensity skewness	Skewness of the intensity histogram of the image
		Intensity kurtosis	Kurtosis of the intensity histogram of the image
		Median intensity	Sample median
		Minimum intensity	Lowest grey level intensity
		10^{th} intensity percentile	10^{th} percentile of the intensity distribution
		90^{th} intensity percentile	90^{th} percentile of the intensity distribution
		Maximum intensity	Highest grey level intensity
		Intensity interquartile range	Difference between the 75^{th} and the 25^{th} percentile
		Intensity range	Difference between the minimum and maximum intensity

Feature class	Class description	Feature	Meaning
		Intensity-based mean absolute deviation	Measure of the dispersion from the mean grey level
		Intensity-based robust mean absolute deviation	Mean absolute deviation which does not take into account outliers outside of the 90^{th} and 10^{th} percentile
		Intensity-based median absolute deviation	Measure of the dispersion from the sample median
		Intensity-based coefficient of variation	Measure of the dispersion of the grey levels (μ/σ)
		Intensity-based quartile coefficient of dispersion	Measure of the dispersion of the grey levels (more robust index computed from quartiles)
		Intensity energy	Energy of the grey levels
		Root mean square intensity	Square root of the intensity energy divided by the number of voxels
Intensity-volume histogram features	Features computed from an intensity histogram which describes the relationship between a discretised intensity and the fraction of the total volume of the ROI which presents that intensity value or a higher one NOTE: while IBSI defines reference values only at 10% and 90%, MIRP and many other packages also compute these features at 50% and 75%	Volume at intensity fraction	Largest volume fraction that contains a grey level which has an intensity of at least x% of the total grey range present in the image
		Intensity at volume fraction	Minimum discretised intensty present in at most x% of the volume
		Volume fraction difference between intensity fractions	Difference between two volumes at intensity fraction
		Intensity fraction difference between volume fractions	Difference between two intensities at volume fraction

Feature class	Class description	Feature	Meaning
Morphological features	Description of geometric aspects of the ROI	Volume (mesh)	Volume of the ROI mesh
		Volume (voxel counting)	Volume of the ROI determined by counting its voxels
		Surface area (mesh)	Surface area obtained by summing the triangular surfaces areas of the ROI mesh
		Surface to volume ratio	Ratio between the surface area and volume of the ROI
		Compactness 1	Measure of how compact, or sphere-like, the ROI is. These features all compute the same thing using a different formula, and may therefore be redundant
		Compactness 2	
		Spherical disproportion	
		Sphericity	
		Asphericity	Quantification of the ROI deviation from a perfect sphere (perfect spheres have an asphericity of 0)
		Centre of mass shift	Computed as the distance between the ROI volume centroid and the intensity-weighted ROI volume, it is an abstraction of the spatial distribution of low/high intensity regions within the ROI
		Maximum 3D diameter	Distance between the two most distant vertices in the ROI
		Major axis length	Length of the major axis, associated with the highest eigenvalue after computing PCA
		Minor axis length	Length the second larger axis, associated with the second highest eigenvalue after computing PCA

Feature class	Class description	Feature	Meaning
		Least axis length	Lenght of the axis along which the ROI is less extended, associated with the lowest eigenvalue after computing PCA
		PCA elongation	Ratio of the major and minor principal axis lengths (eccentricity of the ROI)
		PCA flatness	Ratio of the major and least axis lengths (flatness of the volume relative to its length)
		Volume density (axis-aligned bounding box)	Fraction of the ROI volume and a comparison volume obtained frim an axis-aligned bounding box which encloses the ROI mesh vertex set
		Area density (axis-aligned bounding box)	Ratio of the ROI surface area and the surface area of a comparison volume obtained by an axis-aligned bounding box which encloses the ROI mesh vertex set
		Volume density (approximate enclosing ellipsoid)	Ratio of the ROI volume and a comparison enclosing ellipsoid obtained from the PCA eigenvalues
		Area density (approximate enclosing ellipsoid)	Ratio of the ROI surface area and the surface of a comparison enclosing ellipsoid obtained from the PCA eigenvalues
		Volume density (convex hull)	Ratio of the ROI volume and a comparison volume obtained from a convex hull which encloses the ROI mesh vertex set
		Area density (convex hull)	Ratio of the ROI surface area and the surface of a comparison volume obtained from a convex hull which encloses the ROI mesh vertex set
		Integrated intensity	Average intensity in the ROI multiplied by the volume
		Moran's I index	Indicator of spatial autocorrelation (values close to 1 and -1 indicate high autocorrelation)

Feature class	Class description	Feature	Meaning
		Geary's C measure	Indicator of spatial autocorrelation which is more sensitive to local spatial autocorrelation
Intensity histogram features	Description of how intensities within the ROI are distributed using features obtained from an intensity histogram generated by discretising the original intensity distribution into intensity bins	Mean discretised intensity	Mean value of the grey levels of the discretised image
		Discretised intensity variance	Variance of the grey levels of the discretised image
		Discretised intensity skewness	Skewness of the intensity histogram of the discretised image
		(Excess) discretised intensity kurtosis	Kurtosis of the intensity histogram of the discretised image
		Median discretised intensity	Sample median of the discretised image
		Minimum discretised intensity	Lowest discretised intensity in the image
		10^{th} discretised intensity percentile	10^{th} percentile of the discretised intensity distribution
		90^{th} discretised intensity percentile	90^{th} percentile of the discretised intensity distribution
		Maximum discretised intensity	Highest discretised intensity in the image
		Intensity histogram mode	Most common discretised intensity present in the histogram
		Discretised intensity interquartile range	Difference between the 75^{th} and the 25^{th} percentile
		Discretised intensity range	Difference between the discretised minimum and maximum intensity

Feature class	Class description	Feature	Meaning
		Intensity histogram mean absolute deviation	Measure of the dispersion from the discretised mean grey level
		Intensity histogram robust mean absolute deviation	Mean absolute deviation which does not take into account outliers outside of the $90t^h$ and 10^{th} percentile
		Intensity histogram median absolute deviation	Measure of the dispersion from the discretised sample median
		Intensity histogram coefficient of variation	Measure of the dispersion of the discretised grey levels (μ/σ)
		Intensity histogram quartile coefficient of disperison	Measure of the dispersion of the discretised grey levels (more robust index computed from quartiles)
		Discretised intensity entropy	Metric for the information contained within the discretised grey levels
		Discretised intensity uniformity	Quantification of uniformity of the discretised intensity histogram (approaches 1 when most intensities are contained in a single bin)
		Maximum histogram gradient	Maximum value of the histogram gradient (computed by analyzing the difference between the number of voxels present in two adjacent bins)
		Maximum histogram gradient intensity	Discretised intensity corresponding to the maximum histogram gradient
		Minimum histogram gradients	Minimum value of the histogram gradient
		Minimum histogram gradient intensity	Discretised intensity corresponding to the minimum histogram gradient

Feature class	Class description	Feature	Meaning
Grey level co-occurrence based features (CM)	Expression of how combinations of grey levels are distributed along one of the image directions It is expressed through a matrix where the element s_{ij} = frequency at which combinations of discretised grey levels *i* and *j* occur in neighbouring voxels along a direction	Joint maximum	Probability corresponding to the most common grey level co-occurrence
		Joint average	Grey level weighted sum of probabilities
		Joint variance	Measure of the distribution of neigboring intensity level pairs relative to the mean intensity level of the matrix
		Joint entropy	Quantity of information contained in the co-occurence matrix
		Difference average	Measure of the relationship between occurrences of pairs with similar intensity values and occurrences of pairs with differing intensity values
		Difference variance	Measure of heterogeneity that places higher weights on differing intensity level pairs that deviate more from the mean
		Difference entropy	Measure of the randomness/variability in neighborhood intensity value differences
		Sum average	Measure of the relationship between occurrences of pairs with lower intensity values and occurrences of pairs with higher intensity values
		Sum variance	Measure relative to the presence of group of voxels with similar grey levels
		Sum entropy	Sum of neighborhood intensity value differences
		Angular second moment (also called energy or uniformity)	Energy of the probability distribution of the grey level co-occurences

Feature class	Class description	Feature	Meaning
		Contrast	Assession of grey level variations (weighting of elements of the matrix with large grey levels differences)
		Dissimilarity	Conceptually similar to *contrast* and mathematically equivalent to the *difference average* feature
		Inverse difference	Measure of homogeneity where co-occurences with a large difference in grey levels are weighted less (the score is maximal if all grey levels are the same)
		Normalised inverse difference	Inverse difference normalised by the total number of voxels
		Inverse difference moment (also called homogeneity)	Similar concept of the *inverse difference* feature, but with lower weights for elements that are further from the matrix diagonal
		Normalised inverse difference moment	Inverse difference moment normalised by the total number of grey levels
		Inverse variance	Variance of the grey level co-occurences where elements further from the diagonal are weighted less
		Correlation	Correlation between the grey level co-occurences, which shows the linear dependency of grey level values to their respective voxels
		Autocorrelation	Autocorrelation of the matrix, measure of the magnitude of the fineness and coarseness of texture
		Cluster tendency	Measure of groupings of voxels with similar grey-levels (mathematically equivalent to the *sum variance* feature)
		Cluster shade	Measure of the skewness and uniformity of the matrix. A higher value implies greater asymmetry about the mean.
		Cluster prominence	

Feature class	Class description	Feature	Meaning
		Information correlation 1	Correlation between the probability distributions of *i* and *j*, quantifying the complexity of the texture
		Information correlation 2	
Grey level run length based features (RLM)	Quantification of the runs of consecutive voxels with the same grey level value. It is expressed through a matrix where the element s_{ij} = occurrence of the grey level *i* with a run of length *j*	Short run emphasis	Emphasis on short run lenghts
		Lon rung emphasis	Emphasis on long run lengths
		Low grey level run emphasis	Emphasis on runs of low grey level voxels
		High grey level run emphasis	Emphasis on runs of high grey level voxels
		Short run low grey level emphasis	Emphasis on short runs of low grey level voxels
		Short run high grey level emphasis	Emphasis on short runs of high grey level voxels
		Long run low grey level emphasis	Emphasis on long runs of low grey level voxels
		Long run high grey level emphasis	Emphasis on long runs of high grey level voxels
		Grey level non-uniformity	Distributions of runs over the grey values (it is low when runs are equally distributed along grey levels)
		Normalised grey level non-uniformity	Grey level non-uniformity normalised by the total number of runs
		Run length non-uniformity	Distribution of runs over the run lengths (it is low when runs are equally distributed along run lengths)
		Normalised run lenght non-uniformity	Run lenght non-uniformity normalised by the total number of runs

Feature class	Class description	Feature	Meaning
		Run percentage	Fraction of the number of realised runs and the maximum number of potential runs. Strongly linear or highly uniform ROI volumes produce a low value
		Grey level variance	Variance in runs over the grey levels
		Run length variance	Variance in runs over the run lengths
		Run entropy	Quantity of information contained in the matrix
Grey level size zone based features (SZM)	Quantification of the number of connected voxels that share the same grey level intensity. It is expressed through a matrix where the element s_{ij} = number of zones with grey level *i* and size *j*	Small zone emphasis	Emphasis on the number of small zones
		Large zone emphasis	Emphasis on the number of large zones
		Low grey level zone emphasis	Emphasis on the number of zones with low grey levels
		High grey level zone emphasis	Emphasis on the number of zones with high grey levels
		Small zone low grey level emphasis	Emphasis on the number of small zones with low grey level
		Small zone high grey level emphasis	Emphasis on the number of small zones with high grey level
		Large zone low grey level emphasis	Emphasis on the number of large zones with low grey level
		Large zone high grey level emphasis	Emphasis on the number of large zones with high grey level
		Grey level non-uniformity	Distribution of the number of zones over grey levels (it is low when the number of zones is equally distributed along grey levels)
		Normalised grey level non-uniformity	Grey level non-uniformity normalised by the total number of zones

Feature class	Class description	Feature	Meaning
		Zone size non-uniformity	Distribution of the number of zones over the zone sizes (it is low when the number of zones is equally distributed along zone sizes)
		Normalised zone size non-uniformity	Zone size non-uniformity normalised by the total number of zones
		Zone percentage	Fraction of the number of realised zones and the maximum number of potential zones. Highly uniform ROIs produce a low value
		Grey level variance	Variance in zone counts over the grey levels
		Zone size variance	Variance in zone counts over the different zone sizes
		Zone size entropy	Quantity of information contained in the matrix
Grey level distance zone based features (DZM)	Quantification of the number of zones of linked voxels which share a specific grey level value and possess the same distance to ROI edge It is expressed through a matrix where the element s_{ij} = number of zones with grey level *i* and distance *j*	Small distance emphasis	Emphasis on the number of zones with small distances
		Large distance emphasis	Emphasis on the number of zones with large distances
		Low grey level zone emphasis	Emphasis on the number of zones with low grey levels
		High grey level zone emphasis	Emphasis on the number of zones with high grey levels
		Small distance low grey level emphasis	Emphasis on the number of zones with small distances with low grey level
		Small distance high grey level emphasis	Emphasis on the number of zones with small distances with high grey level
		Large distance low grey level emphasis	Emphasis on the number of zones with large distances with low grey level
		Large distance high grey level emphasis	Emphasis on the number of zones with large distances with high grey level

Feature class	Class description	Feature	Meaning
		Grey level non-uniformity	Distribution of the number of zones over grey levels (it is low when the number of zones is equally distributed along grey levels)
		Normalised grey level non-uniformity	Grey level non-uniformity normalised by the total number of zones
		Zone distance non-uniformity	Distribution of the number of zones over different zone distances (it is low when the number of zones is equally distributed along zone distances)
		Normalised zone size non-uniformity	Zone size non-uniformity normalised by the total number of zones
		Zone percentage	Fraction of the number of realised zones and the maximum number of potential zones. Highly uniform ROIs produce a low value
		Grey level variance	Variance in zone counts over the grey levels
		Zone distance variance	Variance in zone counts over the different zone distances
		Zone distance entropy	Quantity of information contained in the matrix
Neighbourhood grey tone difference based features (NGT)	Quantification of the difference between a grey level value and the average value of its neighbours within a given distance	Coarseness	Measure of the average difference between the center voxel and its neighbourhood, which is an indication of the spatial rate of change
		Contrast	Measure of the spatial intensity change. It is high when both the dynamic range and the spatial change rate are high, i.e. an image with a large range of gray levels, with large changes between voxels and their neighbourhood
		Busyness	Indicator of the presence of large changes in grey levels between neighbouring voxels
		Complexity	Quantification of the non-uniformity and rapid changes in grey levels

Feature class	Class description	Feature	Meaning
		Strength	Quantification of the presence of well-defined zones in the image, reflecting slow intensity changes but more large coarse differences in the grey levels
Neighbouring grey level dependence based features (NGL)	Measure of the number of voxels in an area that have a grey level close to the central one (those voxels are called ″dependent″) It is expressed through a matrix where the element s_{ij} = number of neighbourhoods with a center voxel with grey level *i* and *j* neighbouring voxel that are dependent on it	Low dependece emphasis	Emphasis on the number of neighbourhoods with low dependece
		High dependece emphasis	Emphasis on the number of neighbourhoods with high dependece
		Low grey level count emphasis	Emphasis on the number of neighbourhoods with low grey levels
		High grey level count emphasis	Emphasis on the number of neighbourhoods with high grey levels
		Low dependence low grey level emphasis	Emphasis on the number of neighbourhoods with low dependences with low grey level
		Low dependence high grey level emphasis	Emphasis on the number of neighbourhoods with low dependences with high grey level
		High dependence low grey level emphasis	Emphasis on the number of neighbourhoods with high dependences with low grey level
		High dependence high grey level emphasis	Emphasis on the number of neighbourhoods with high dependences with high grey level
		Grey level non-uniformity	Distribution of the number of neighbourhoods over grey levels (it is low when the number of neighbourhoods is equally distributed along grey levels)
		Normalised grey level non-uniformity	Grey level non-uniformity normalised by the total number of neighbourhoods

Feature class	Class description	Feature	Meaning
		Dependence count non-uniformity	Distribution of the number of neighbourhoods over different dependence counts (it is low when the number of neighbourhoods is equally distributed along dependence counts)
		Normalised dependence count non-uniformity	Dependence count non-uniformity normalised by the total number of neighbourhoods
		Dependence count percentage	Fraction of the number of realised neighbourhoods and the maximum number of potential neighbourhoods. This value is usually equal to 1
		Grey level variance	Variance in dependence counts over the grey levels
		Dependence counts variance	Variance in dependence counts over the different dependence counts
		Dependence count entropy	Quantity of information contained in the matrix
		Dependence count energy	Energy of the probability distribution of the grey level dependences