## Supplementary. Definition of Features

### 1st Order Statistic Features

Let $X$ denote the three dimensional image matrixes with $N$ voxels and $P$ the first order histogram with $N_l$ discrete intensity levels. The following first order statistics were extracted:

***1. Energy***

$$\text{Energy} = \sum_{i}^{N} X(i)^2$$

***2. Entropy***

A measure of randomness. Image entropy is a quantity, i.e., the amount of information. Low entropy images have very little contrast and large runs of pixels with the same or similar values. An image that is perfectly flat will have entropy of zero.

$$\text{Entropy} = \sum_{i=1}^{N_l} P(i) log_2 P(i)$$

***3. Kurtosis***

$$\text{Kurtosis} = \frac{\frac{1}{N}\sum_{i=1}^{N}\left(X(i)-\overline{X}\right)^4}{\left(\sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(X(i)-\overline{X}\right)^2}\right)^2}$$

where $\overline{X}$ is the mean of $X$.

***4. Maximum***

Max intensity from segmented tumor on T1 post/necrosis/edema, respectively.

***5. Mean***

$$\text{Mean} = \frac{1}{N}\sum_{i=1}^{N} X(i)$$

***6. Mean Absolute Deviation***

Mean of the absolute deviations of all voxel intensities around the mean intensity value.

***7. Median***

Median intensity from segmented tumor on T1 post/necrosis/edema, respectively.

***8. Minimum***

Min intensity from segmented tumor on T1 post/necrosis/edema, respectively.

***9. Range***

The range of intensity values of $X$.

***10. Root Mean Square (RMS)***

$$\text{RMS} = \sqrt{\frac{\sum_{i}^{N} X(i)^2}{N}}$$

### *11. Skewness*

$$\text{Skewness} = \frac{\frac{1}{N}\sum_{i=1}^{N}(X(i)-\bar{X})^3}{\left(\sqrt{\frac{1}{N}\sum_{i=1}^{N}(X(i)-\bar{X})^2}\right)^3}$$

where $\bar{X}$ is the mean of $X$.

### *12. Standard Deviation*

$$\text{Standard deviation} = \left(\frac{1}{N-1}\sum_{i=1}^{n}(X(i)-\bar{X})^2\right)^{1/2}$$

where $\bar{X}$ is the mean of $X$.

### *13. Uniformity*

A degree of pixel intensities having similar probability.

$$Uniformity = \sum_{i=0}^{L-1} p^2(i),$$

where $i$ is an intensity value, $p(i)$ is the probability of intensity $i$, $L$ is total number of intensity values within segmented tumor.

### *14. Variance*

$$Variance = \frac{1}{N-1}\sum_{i=1}^{N}(X(i)-\bar{X})^2$$

where $\bar{X}$ is the mean of $X$.

## Texture Features (3)

### *Gray Level Co-Occurrence Matrix (GLCM) Based Features*

A GLCM is a matrix where the number of rows and columns is equal to the number of quantized gray levels.

1. Autocorrelation
2. Cluster prominence
3. Cluster shade
4. Cluster Tendency
5. Contrast
6. Correlation
7. Difference entropy
8. Dissimilarity
9. Energy
10. Entropy
11. Homogeneity 1
12. Homogeneity 2
13. Informational measure of correlation 1 (IMC1)
14. Informational measure of correlation 2 (IMC2)
15. Inverse difference moment normalized (IDMN)
16. Inverse difference normalized (IDN)
17. Inverse variance
18. Maximum probability
19. Sum average

20. Sum entropy
21. Sum variance
22. Variance

***Gray Level Run-Length Matrix (GLRLM) Based Features***

1. Short run emphasis (SRE)
2. Long run emphasis (LRE)
3. Gray level non-uniformity (GLN)
4. Run length non-uniformity (RLN)
5. Run percentage (RP)
6. Low gray level run emphasis (LGLRE)
7. High gray level run emphasis (HGLRE)
8. Short run low gray level emphasis (SRLGLE)
9. Short run high gray level emphasis (SRHGLE)
10. Long run low gray level emphasis (LRLGLE)
11. Long run high gray level emphasis (LRHGLE)

## Morphometric Features

Let in the following definitions *V* denote the volume and *A* the surface area of the volume of interest. We determined the following morphometric features:

***1. Area***

Area of the segmented region in $cm^2$ calculated on largest tumor size.

***2. Compactness 1***

$$compactness\ 1 = \frac{V}{\sqrt{\pi} A^{\frac{2}{3}}}$$

***3. Compactness 2***

$$compactness\ 2 = 36\pi \frac{V^2}{A^3}$$

***4. Edge Sharpness***

The edge sharpness is defined the segmented boundary using the gradient magnitude,

$$S = \frac{1}{M \times N} \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} \sqrt{{Gx_{i,j}}^2 + {Gy_{i,j}}^2}$$

where *M* and *N* is total number of pixels, *Gx* and *Gy* is a gradient of *G* for *x* axis and *y* axis.

***5. Longest Axis***

Largest perpendicular cross-sectional diameter of segmented region in cm.

***6. Maximum 3D Diameter***

The maximum three-dimensional tumor diameter is measured as the largest pairwise Euclidean distance, between voxels on the surface of the tumor volume.

***7. Proportion***

Proportion of the entire tumor (the entire abnormality may be comprised of an enhancing component, a non-enhancing component, a necrotic component and an edema component).

***8. Slope***

The slope is defined as the change for enhancement for each slice. It is averaged across the entire volume.

***9. Spherical Disproportion***

$$spherical\ disproportion = \frac{A}{4\pi R^2}$$

where *R* is the radius of a sphere with the same volume as the tumor.

***10. Sphericity***

$$sphericity = \frac{\pi^{\frac{1}{3}}(6V)^{\frac{2}{3}}}{A}$$

***11. Surface Area***

The surface area is calculated by triangulation (i.e., dividing the surface into connected triangles) and is defined as:

$$A = \sum_{i=1}^{N} \frac{1}{2} \left| a_i b_i \times a_i c_i \right|$$

where *N* is the total number of triangles covering the surface and *a*, *b,* and *c* are edge vectors of the trangles.

***12. Surface to Volume Ratio***

$$surface\ to\ volume\ ratio = \frac{A}{V}$$

***13. Volume***

The volume of the segmented region is determined by counting the number of pixels in the tumor region and multiplying this value by the voxel size.