Content Based Image Retrieval of Glioblastoma Multiforme

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Introduction

- Glioblastoma multiforme brain tumors have a variety of MR image presentations
- Mean time to survival of patients diagnosed with GBM who have undergone standard treatment protocols is 18 months
- Time to survival, within the GBM subgroup of malignant brain tumors, is highly variable

Background

- Several studies have been done to find relationship between imaging variables and prognosis
- Imaging variables that negatively correlated with survival were: presence of edema, necrosis, satellites, and multifocality
- Previous literature uses qualitative descriptors of imaging findings or simple quantitative indices, such as bi-linear measurements

Methodology

- T1 post-contrast SPGR sequences, prior to surgery, from 40 patients diagnosed in GBM made up the data set.
- All patients underwent gross total resection and subsequent radiation and chemotherapy regimen.
- Quantitative features extracted from T1 post contrast study, but the T2 sequence was used to accurately delineate the edema region (Figure 1)

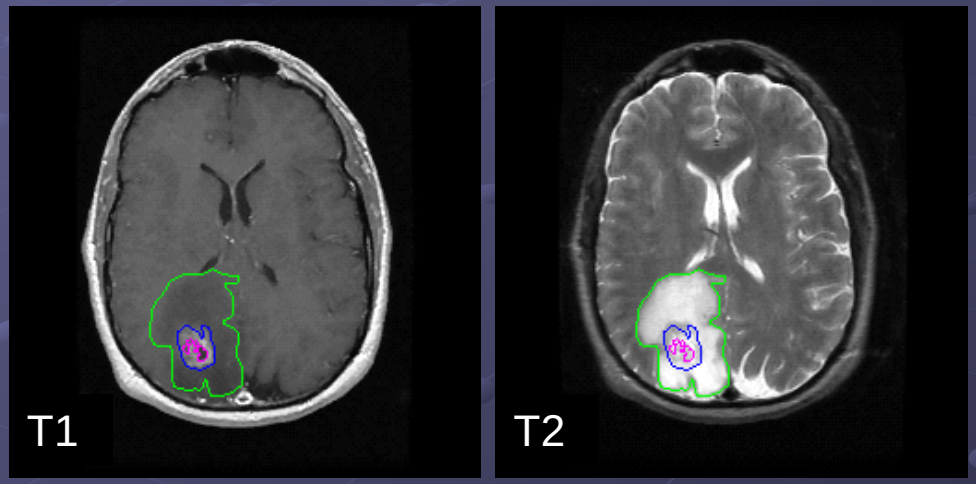


Figure 1. The left and right images are the T1 post contrast and respective T2 with the labeled regions that were segmented for quantitative analysis. The edema boundary is outlined by green, contrast enhancement by blue, and necrosis by magenta.

Image Conditioning

- Images were pre-processed to improve image quality
- The steps consisted of:
  1. Denoising (FSL)
  2. Brain Extraction (FSL)
  3. Image Alignment (FSL)
  4. Image Intensity Standardization via Normal Hemisphere Histogram Matching

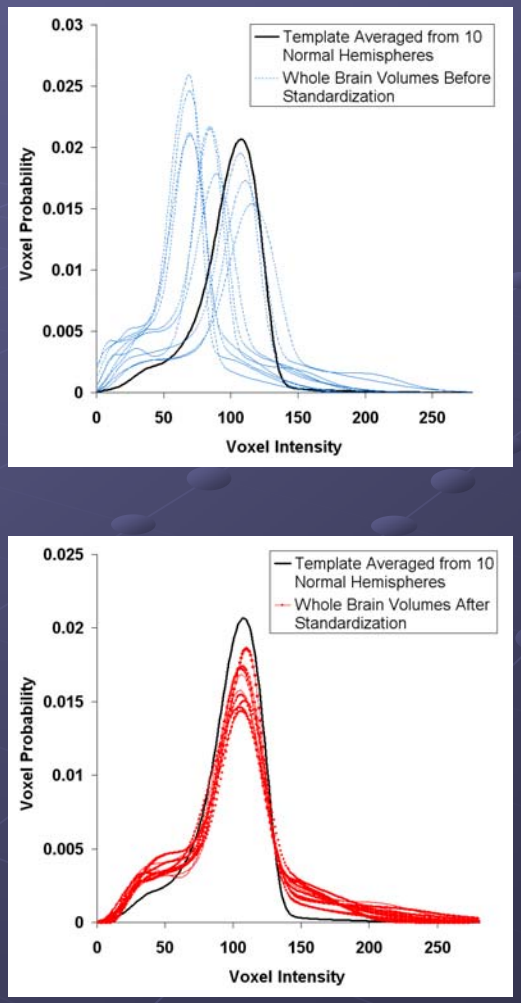


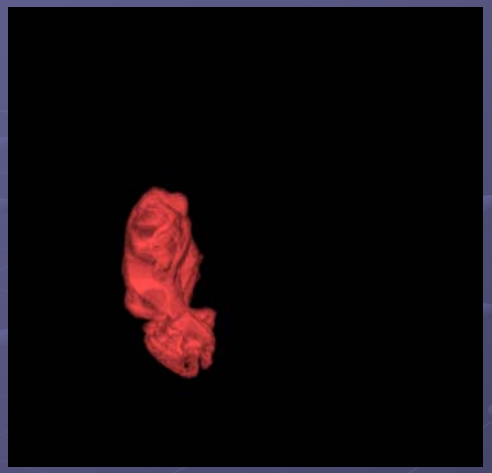
Figure 2. a) Histogram plots of $h_{template}$ and patient data before standardization
b) Histogram plots of $h_{template}$ and patient data after standardization

Features

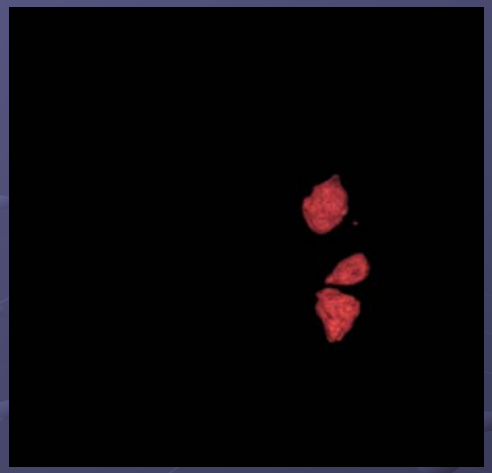
Category	Features
3D Texture via Co-occurrence Matrix	Correlation Contrast Homogeneity Energy
3D Shape Moments	Order 0 Invariant Moment (Volume) Order 1 Invariant Moments Order 2 Invariant Moments Order 3 Invariant Moments
Histogram	Mean Variance Skewness Kurtosis

Table 1: List of the different features extracted for each sub-region. The features consisted of texture parameters derived from 3D co-occurrence matrices, 3D shape moments, and histogram parameters.

Example 1 (Age = 68 years, TTS = 80 days)

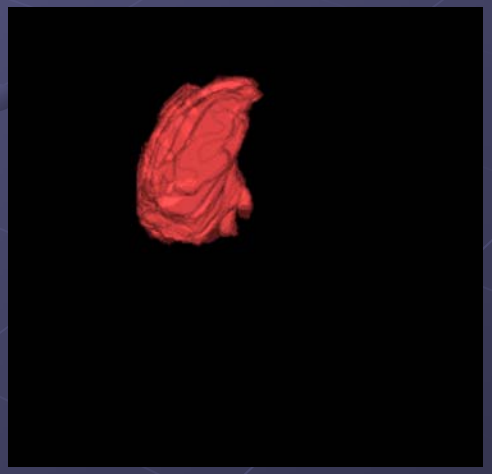


Edema Volume

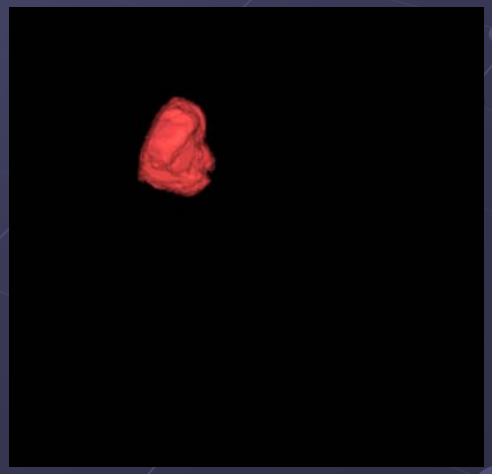


Contrast Enhancing Tumor Volume

Example 2 (Age = 64 years, TTS = 721 days)

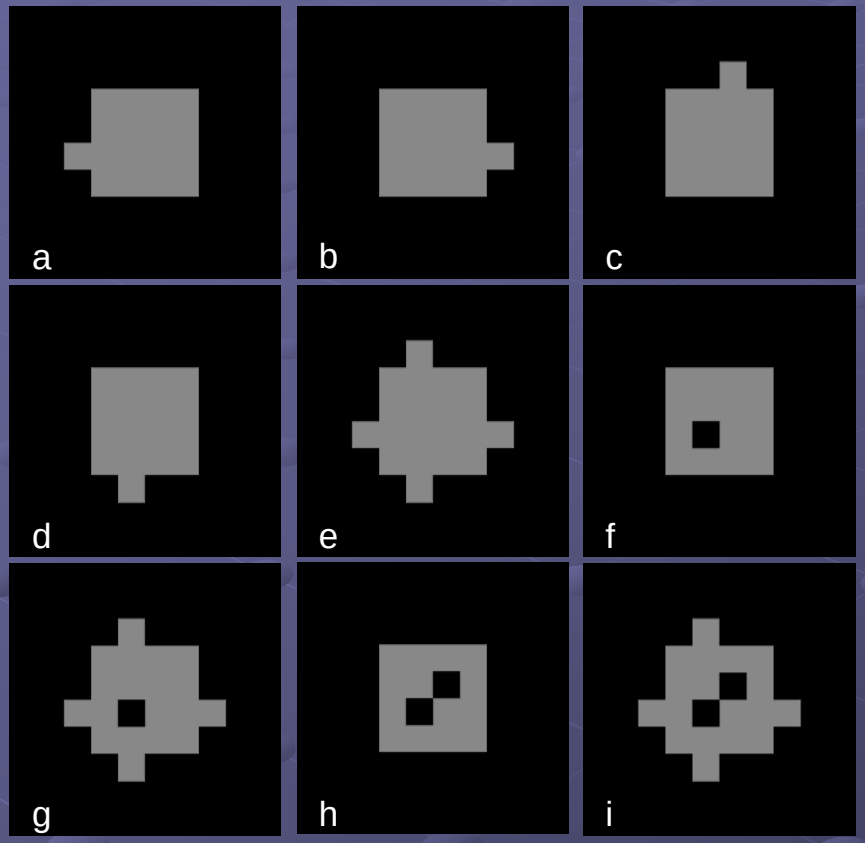


Edema Volume



Contrast Enhancing Tumor Volume

Invariant Shape Features

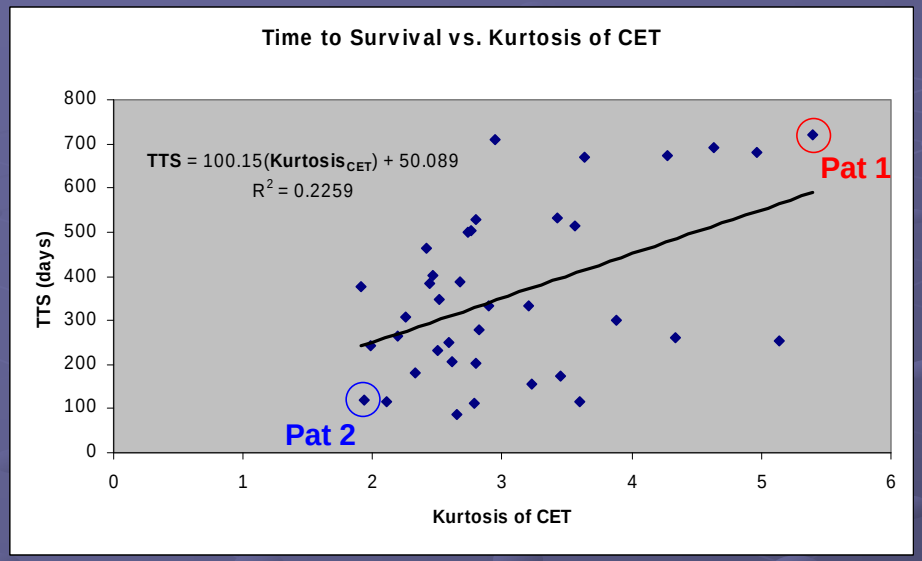


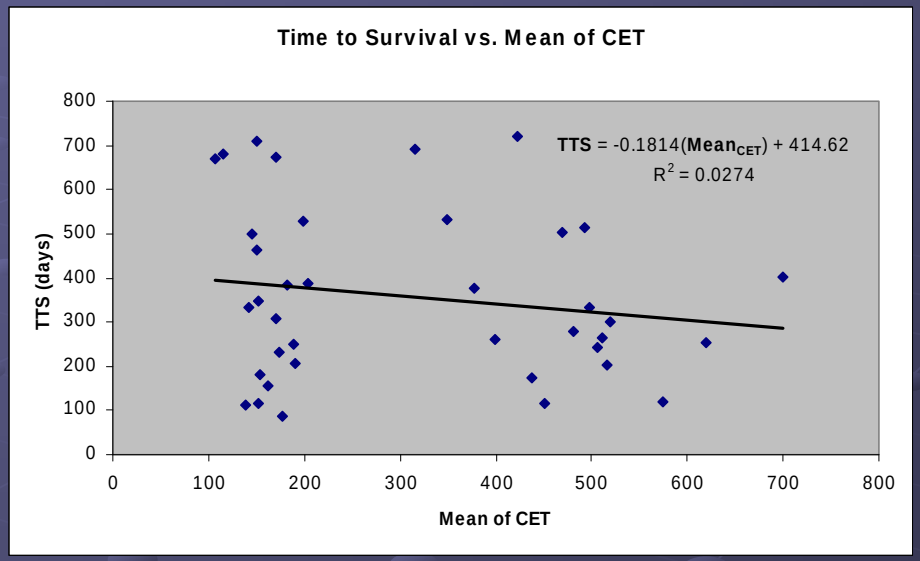
Synthetic shapes based on a cube

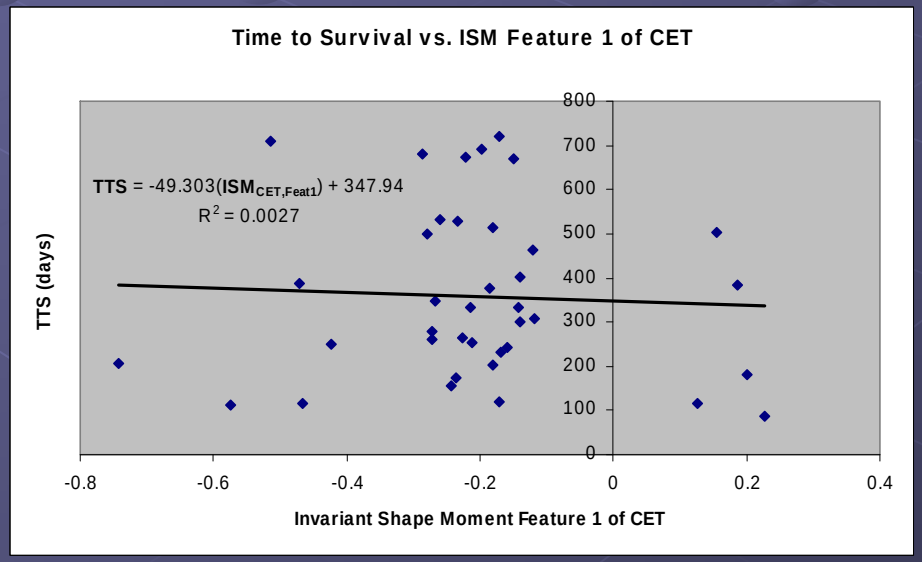
	Cube	A	B	C	D	E	F	G	H	I
I^2_00	**0.526**	**0.529**	**0.529**	**0.529**	**0.529**	**0.533**	**0.543**	**0.548**	**0.56**	**0.56**
I^2_22	**0**	**0.108**	**0.108**	**0.108**	**0.108**	**0.121**	**0.048**	**0.129**	**0.06**	**0.139**
I^2_222	0	-0.104	-0.104	-0.104	-0.104	0.117	0.044	0.124	-0.04	0.132
I^3_11	0	-0.1008	-0.1008	-0.1008	-0.1008	-0.124	-0.144	-0.155	-0.14	-0.16
I^3_33	0	-0.144	-0.144	-0.144	-0.144	-0.161	-0.077	-0.167	-0.08	-0.17
I^3_1113	0	-0.106	-0.106	-0.106	-0.106	0.124	0.1038	0.127	0.125	0.156
I^3_1133	0	0.118	0.118	0.118	0.118	0.126	0.102	0.149	0.11	0.152
I^3_1333	**0**	**-0.126**	**-0.126**	**-0.126**	**-0.126**	**-0.134**	**0.086**	**-0.145**	**0.08**	**-0.149**
I^3_3333	0	0.14	0.14	0.14	0.14	0.143	0.074	0.144	0.08	0.147
I^2,3_112	0	0.099	0.099	0.099	0.099	-0.123	-0.102	-0.134	-0.116	-0.156
I^2,3_123	**0**	**-0.115**	**-0.115**	**-0.115**	**-0.115**	**-0.124**	**-0.083**	**-0.139**	**-0.09**	**-0.148**
I^2,3_233	0	0.128	0.128	0.128	0.128	0.14	-0.066	0.139	-0.055	0.144

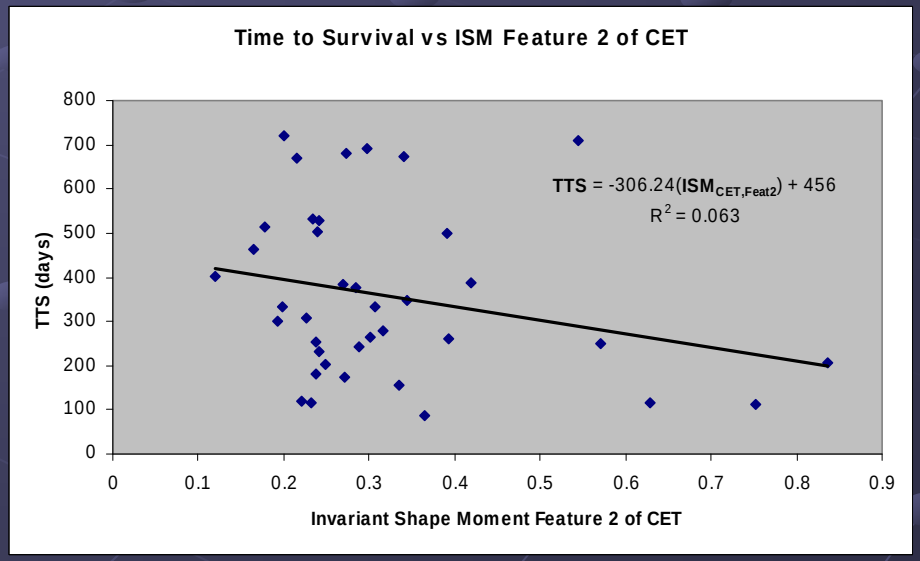
Invariant Shape Feature Values for Synthetic Shapes

Results

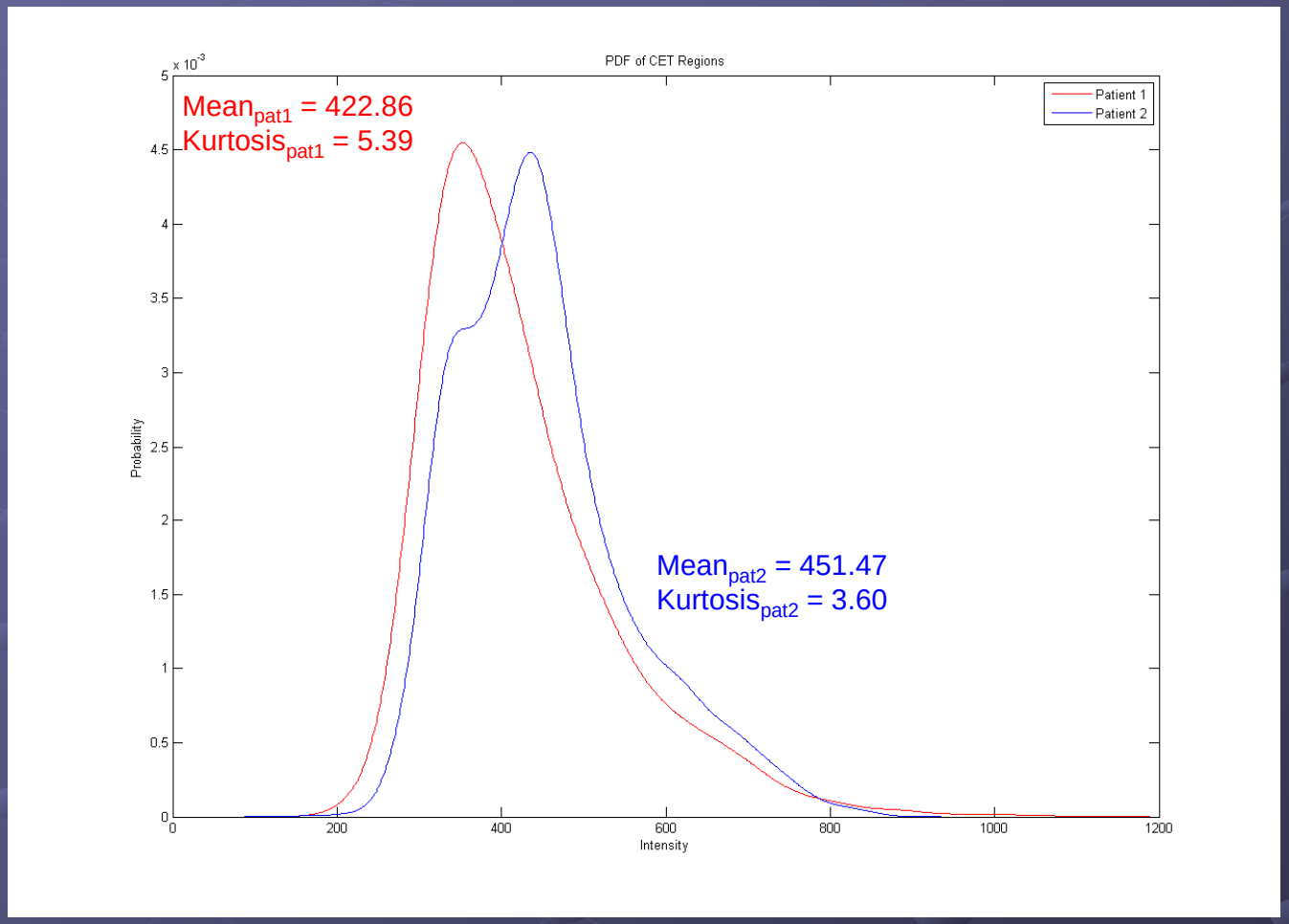

Time to Survival vs. Kurtosis of CET
TTS = 100.15(Kurtosis$_{CET}$) + 50.089
R^2 = 0.2259
Pat 1
Pat 2
TTS (days)
Kurtosis of CET
0
100
200
300
400
500
600
700
800
0
1
2
3
4
5
6


Time to Survival vs. Mean of CET
TTS = -0.1814(Mean$_{CET}$) + 414.62
R^2 = 0.0274
TTS (days)
Mean of CET
0
100
200
300
400
500
600
700
800
0
100
200
300
400
500
600
700
800

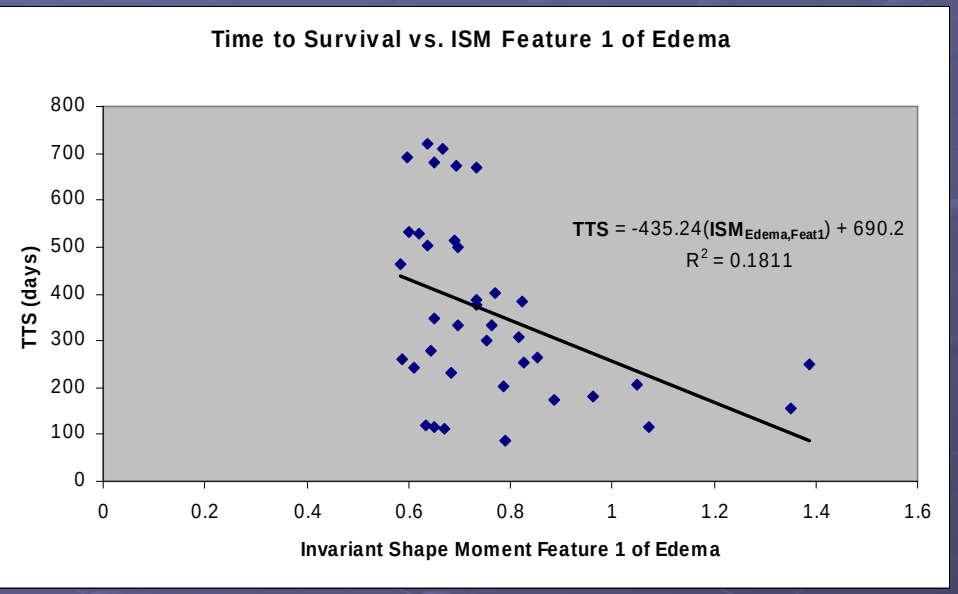

Time to Survival vs. ISM Feature 1 of CET
TTS = -49.303(ISM$_{CET,Feat1}$) + 347.94
R^2 = 0.0027
TTS (days)
Invariant Shape Moment Feature 1 of CET
0
100
200
300
400
500
600
700
800
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4

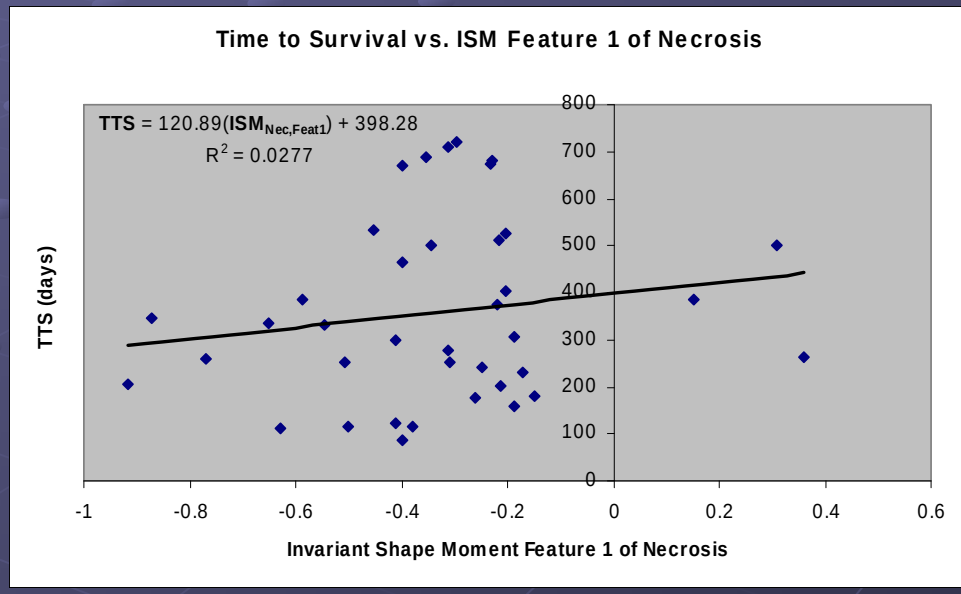

Time to Survival vs ISM Feature 2 of CET
TTS = -306.24(ISM$_{CET,Feat2}$) + 456
R^2 = 0.063
TTS (days)
Invariant Shape Moment Feature 2 of CET
0
100
200
300
400
500
600
700
800
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9

Results


PDF of CET Regions
x 10^-3
Mean_pat1 = 422.86
Kurtosis_pat1 = 5.39
Patient 1
Patient 2
Mean_pat2 = 451.47
Kurtosis_pat2 = 3.60
Probability
Intensity
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
200
400
600
800
1000
1200

Results


Time to Survival vs. ISM Feature 1 of Edema
TTS = -435.24(ISM$_{Edema,Feat1}$) + 690.2
R^2 = 0.1811
TTS (days)
800
700
600
500
400
300
200
100
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
Invariant Shape Moment Feature 1 of Edema


Time to Survival vs. ISM Feature 1 of Necrosis
TTS = 120.89(ISM$_{Nec,Feat1}$) + 398.28
R^2 = 0.0277
TTS (days)
800
700
600
500
400
300
200
100
0
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
Invariant Shape Moment Feature 1 of Necrosis

Feature Correlation

Model	Variables	Coefficients	Adjusted R Squared
1	Constant Kurtosis of CET	50.09 100.15	0.204
2	Constant Kurtosis of CET 2nd order ISM of Edema	363.15 85.46 -351.03	0.301
3	Constant Kurtosis of CET 2nd order ISM of Edema Mean of CET	501.80 89.67 -414.70 -0.33	0.374
4	Constant Kurtosis of CET 2nd order ISM of Edema Mean of CET 3rd order ISM of Necrosis	588.17 100.76 -438.04 -0.41 238.23	0.468
5	Constant Kurtosis of CET 2nd order ISM of Edema Mean of CET 3rd order ISM of Necrosis 2nd order ISM of CET	613.02 101.66 -510.09 -0.39 365.13 -315.30	0.539
6	***Constant*** ***Kurtosis of CET*** ***2nd order ISM of Edema*** ***Mean of CET*** ***3rd order ISM of Necrosis*** ***2nd order ISM of CET*** ***2nd order ISM of CET***	***713.84*** ***89.25*** ***-428.44*** ***-0.48*** ***325.91*** ***-518.02*** ***-469.59***	***0.585***

Table 2: Results of the stepwise multivariate linear regression model applied to the quantitative imaging data. Each model shows the variables involved, their weighting coefficients, and the resulting correlation coefficient to describe how well the model fits the data.

Edema Features:

- **The value of the invariant shape descriptor chosen for edema has a trend to increase the more irregular a shape becomes and in the presence of holes (i.e. tumor/necrotic regions)**

Necrotic Features:

- **For the necrotic shape descriptor, higher irregularity also leads to an overall lower estimate of survival, indicating the malignant nature in the morphology of the necrotic region**

Contrast Enhancing Tumor Features:

- **Kurtosis of CET reflects the peakedness of the intensity histogram, which is narrower for CET regions that had high TTS**
- **Mean intensity of the CET regions corresponds to average voxel uptake of the tumor. Thus, a higher uptake could indicate a higher degree of infiltration**
- **The two invariant shape parameters indicate that CET regions with a higher irregular structure accompanied with larger presence of necrosis yield an overall lower survival time estimate**

Future Work

- Expansion to a larger patient population
- Inclusion of more quantitative and qualitative (i.e. age, multifocality presence) features
- Correlations to other outcomes (i.e. time to tumor progression)
- Glioma molecular subtype characterization
- Application of an AdaBoost cascade methodology