Automated Multi-Parametric MRI Segmentation of Post-Treatment Glioma Sub-regions

using Classical Machine Learning and Active Contours

Project Report Week 2

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1. Objective of Week 2

The objective of Week 2 was to design the preprocessing pipeline and feature engineering strategy required for implementing a classical machine learning based segmentation framework.

This week focused on methodological planning and mathematical formulation prior to implementation.

2. Proposed Preprocessing Strategy

2.1 Intensity Normalization

Due to inter-patient intensity variation in MRI, Z-score normalization will be applied independently to each modality:

$$I_{norm} = \frac{I - \mu}{\sigma}$$

where μ and σ represent the mean and standard deviation of non-zero voxels.

2.2 Brain Masking

To address severe class imbalance:

- Background voxels will be excluded.
- Only brain-region voxels will be considered for training.
- Class-balanced sampling will be implemented.

3. Voxel-wise Learning Formulation

The segmentation task is formulated as a multi-class voxel-wise classification problem.

For each voxel v_i:

$$v_i \rightarrow \mathbf{x}_i \in R^F, \quad y_i \in \{0, 1, 2, 3\}$$

where:

- $\mathbf{x}_i$ = feature vector
- y_i = class label

4. Planned Feature Engineering

4.1 Intensity Features

- T1
- T1Gd
- T2
- FLAIR

4.2 Texture Features (GLCM)

Planned features:

- Contrast
- Correlation
- Energy
- Homogeneity

4.3 Gradient Features

Gradient magnitude will be computed to capture boundary transitions.

Total planned features per voxel: **9**

5. Planned Baseline Models

The following classifiers will be implemented:

5.1 Logistic Regression

- Multi-class (One-vs-Rest)
- L2 regularization

5.2 Random Forest

- Ensemble of decision trees
- Non-linear decision boundaries

6. Evaluation Strategy

Segmentation performance will be evaluated using:

$$Dice = \frac{2|A \cap B|}{|A| + |B|}$$

Additional metrics:

- Hausdorff Distance
- Sensitivity
- Specificity

7. Experimental Plan for Week 3

- Implement preprocessing pipeline
- Extract handcrafted features
- Train baseline classifiers
- Evaluate Dice scores
- Perform qualitative visualization

8. Conclusion

Week 2 focused on designing the complete methodological framework required for classical machine learning based tumor segmentation. The preprocessing steps, feature engineering strategy, classification models, and evaluation metrics have been mathematically formulated.

Implementation and empirical evaluation will be carried out in Week 3.